Leveraging Viral Growth Inherent in Mobile Peer-to-Peer Telematics to Strategic Advantage

by

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Submitted to the Sloan School of Management
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Abstract

Telematics, defined as the vehicle features and services made available through a wireless connection to data or other resources not onboard the vehicle, provides one of the most promising areas of innovation and value creation in the automobile market today. However, up to now the US market has only experienced successful telematics businesses in the quazi-insurance field of Safety and Security. In contrast, Consumer Telematics, defined as the confluence of consumer electronics and vehicle telematics, presents a much more exciting market opportunity. In spite of this, inadequate bandwidth, poor usability, fragmented standards and excessive cost have together created sufficient barriers so as to deter any automakers from entering the market.

In this thesis, we argue that the viral growth inherent in Wi-Fi class mobile peer-to-peer (mP2P) telematics presents an opportunity for an automotive OEM with significant marketshare to transcend these barriers, and thus capture significant value from this up-to-now elusive market. To do so, we analyze the proposed business through the filters of technology, value chain, applications and market dynamics in order to craft a comprehensive strategy for entering the market and insuring sustained return through its maturation.

The technology analysis both presents the potential benefits and limitations of mP2P as well as likely competitors and substitutes. It suggests that mP2P has a sustainable cost and bandwidth advantage over other architectures. Our examination of the Telematics value chain indicates that the wireless connectivity and IP backhaul segments of the chain are predisposed towards commodization and thus should be outsourced in a manner that retains flexibility to switch carriers and even technologies as the market evolves. By segmenting the most promising applications according to their connectivity demands, we plot out how service offerings should evolve in concert with the quality of wireless connectivity and market adoption. Finally, analyzing the market dynamics indicates the critical mass threshold where customer willingness-to-pay exceeds the cost, and thus the trade-offs between investment and strategy necessary for success. We conclude that this critical mass where viral growth ensues exists at only 3-5% market penetration, a target easily achieved by an Automotive OEM with dominant marketshare such as General Motors.

The proposed strategy resulting from this analysis endeavors to ensure sustained return by embracing an evolving business model. While initial value is captured through vehicle differentiation, it then shifts to primarily service revenue. Eventually, if the business is successful in garnering widespread adoption, value would eventually be principally derived through hardware licensing and operating system revenue. In the end, the key to success for the OEM is to set aside its traditional ways of doing business in order to leverage the complementary market forces that drive viral growth. Without this, this business is daunting and risky. With viral growth, it presents an opportunity that could eventually rival the profits derived from selling cars today.

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Chapter 1 Introduction

The introduction of a new product, and especially an entirely new class of products based on new technology, is obviously risky. When the infrastructure required for launching this new product is substantial, companies are (rightly) even more wary of committing. However, the greatest risk but also the greatest potential reward comes from products where the addition of each new unit in the marketplace, makes every other unit of the same product more valuable to its user. A classic case of this "positive network externality" behavior is the fax machine: each time a new user plugs in a new fax machine, it provides every other fax machine in the world one more potential destination. More recently, the same can be said of email. An outgrowth of this condition is that once a product reaches a critical threshold of market penetration, sales can explode. Naturally this is the ideal outcome from the company's perspective, however only a tiny fraction ever succeed.

The goal of this thesis is to explore how the potential of a technology for "viral growth" changes the economic viability and business strategy for entering this new market. In its most theoretical abstraction, devices that employ viral communication "work with no central backbone and scale almost without bound."[1] This changes the strategic calculus of both building out an infrastructure as well as controlling market and product growth. Specifically, the focus of this paper is to investigate how the viral growth inherent in mobile peer-to-peer (mP2P) networking technology can be leveraged to craft a comprehensive business strategy to successfully enter the "Consumer Telematics" market.

1.1 The Motivation

To begin, we must first define the three markets in which intersect to form Consumer Telematics: light-duty automobiles, wireless networking and consumer electronics. The following sections define these business and provide an overview of their state today. Finally, we discuss their intersection in the field of Telematics which we define as the vehicle features and services made available to a driver or passenger through a wireless connection to data sources or other resources not onboard the vehicle.

[1] Lippman & Reed, p. 2.

As much as 30% of the value in automobiles on sale today is in the form of electronic hardware and software, the majority of it invisible to the end user. Only when a computing component onboard the vehicle connects wirelessly with a stationary or another mobile device would we call it telematics. From a consumer electronics product perspective, companies are interested in this market because it facilitates the possibility of having a relatively inexpensive device and connection provide access to a limitless source of data and range of services. From a strategic perspective, it is interesting because it requires the merging the interaction of two very different clockspeed industries (automotive with consumer electronics and wireless networking.)

1.1.1 The State of the Vehicle

Culturally, physically and financially, the automobile plays a central role in the life of the average inhabitant of the United States. Consider the following statistics:

- Vehicle-related expenditures consume an average of 19% of annual household income.[2]
- The typical US citizen spends 541 hours a year driving in vehicles (or 1.5 hours/day.)[3]
- 97 million people in the US spend at least 37 minutes commuting in their cars every workday.[4]

For the last hundred years, automakers have been honing their products. As a result, they are very mature. With the exception of the inevitable stylistic evolutions, the typical "driving experience" has practically ceased to evolve. Only a revolutionary change, such as shift to an electric drivetrain or "by-wire" control, is likely to change this. However to maintain differentiation, automakers must continue to invent new features. Many in the industry contend that the area of innovation likely to have the most noticeable impact on a driver's daily experience will come from integrating more consumer electronics into the vehicle. While this is not new, the market is particularly ripe considering that 50%-70%[5] of cell phone minutes are consumed from within a vehicle. The Automotive industry lost a significant opportunity to control and benefit from this relatively new and now substantial revenue stream when they failed to embrace cell phones while they were still "car phones" and aggressively integrate them into their vehicles. The current migration to "smart phones" and connected PDAs (Personal Digital Assistants) is sure to only widen the range of consumer applications available to consumers from within the vehicle. As a result, the dispassionate observer can argue that the sooner car companies choose to aggressively participate in this evolution, the more likely they are to benefit.

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[2] *Transportation Energy Data Book*; Center for Transportation Analysis, Oak Ridge National Lab, 23 Ed, © 2003.
[3] NPTS via McKinsey's *Telematics Quo Vatis*
[4] Speering, Audible.com.
[5] Aldo Morri, Strategis Group, ITS 2013 Vision, PBSI, 2003

However automotive OEMs are unsurprisingly wary of entering such a different business. To do so, there must be a significant opportunity and they must be uniquely positioned to take advantage of it. We will present the argument that Telematics fits this criteria.

1.1.2 The State of Wireless Networking

In contrast to the automotive business, the wireless networking industry has only really come of age in the last decade and remains in a constant state of flux today. This is largely as result of the advent of inexpensive computing power and airwave deregulation. After all, wireless networking is simply the process of moving packets of digital data through the same radio waves we have been broadcasting analog AM and FM radio and television signals for decades. In a state of perpetual motion, at any given time there are a myriad of competing technologies and standards fighting for the same or overlapping market. In addition, successful technologies tend to expand into neighboring markets.

The best example of this is the cellular phone. The original analog cell phones were heavy, expensive to operate, had poor battery life and were only suited to transmit a scratchy voice signal. The latest generation of third generation ("3G") digital phones currently being rolled out into the market can transmit as much as 144 kbps (kilobits per second or baud), more than any modem over a traditional land line. At the other end of the bandwidth spectrum, a standard known as Wi-Fi® (or IEEE[6] standard 802.11b) was created to allow for wireless local area networks. The intension was to free companies from having to run new cable each time they moved the furniture. However the products turned out to be so convenient that they now appear in schools, homes and publicly available networks. The tremendous volume has pushed Wi-Fi prices down to $4 a chipset, making it competitive with inferior technologies designed for less expensive products.

In the end, however, the physics insures there is always the same tradeoff: higher bandwidth causes shorter range and thus a generally higher infrastructure cost to cover the same physical area. Related to this relationship and ever looming in the distance is the risk that a technology will become so successful that it will absorb all the available bandwidth in a given area. For sections of the electromagnetic spectrum that are regulated by the Federal Government, each licensee is responsible for managing their own allocated section of bandwidth. However for technologies using unlicensed bands, such as Wi-Fi, there is the potential for a "tragedy of the

[6] IEEE stands for the "Institute of Electrical and Electronics Engineers." It serves as the dominant, international body for creating open standards so competing companies can create devices that interoperate.

commons" phenomenon. Especially since it is these unregulated regions of the spectrum that have inspired the most innovation and product proliferation.

On the horizon are dozens more wireless communications technologies and standards, each with their advocates and entrepreneurs. It is this which engenders such a frenetic and unpredictable market. This is also the behavior which terrifies the auto industry. Although they would love to add wireless networking features to their vehicles, they are paranoid of getting left in the dust by companies used to operating in a market that evolves at 10 or 100 times the speed.

1.1.3 The State of Consumer Electronics

Overlapping with the wireless industry in both content and behavior is Consumer Electronics. Any product with the majority of its consumer value provided through electronic chips and the software that runs on them applies: everything from TVs and microwave ovens to cell phones, PDAs and personal computers. For our study, we are only interested in the functionality that could potentially be incorporated into vehicle features that one might use on a regular basis. Today, this list principally includes cell phones, PDAs and personal computers but also encompasses digital music players, satellite radio tuners and mobile navigation devices.

Like wireless networking, consumer electronics is rife with standards battles and product innovation. Generally, there are two phases of competition: innovation and commoditization.[7]

- First, companies innovate and then place product bets, speculating on what technology, product or feature will be the "next big thing." Sometimes a company is betting on a proprietary technology as Sony as done repeatedly over the years with such well-know failures as the Betamax video cassette, and more recently the minidisk and the memory stick. Perhaps its most successful new product is the Walkman. Most often, companies are merely coming up with evolutionary improvements in the form or new features for existing products. Cell phones are a good example today. Motorola got an early lead with its StarTAC® flip phone that reminded consumers of the old StarTrek TV series. Most recently Samsung surged ahead by being the first to introduce color screens and integrated cameras.
- What follows is commoditization. As soon as any company experiences success with any particular technology, product or feature, all its competitors race to bring their own

[7] Cell phone technology market behavior.

versions to market.[8] As a result, prices plummet and margins evaporate. In the brutally competitive cell phone business, the successful innovator or "first-mover" has 3-9 months [confirm] of excess profits before its competitors catch up and compete away any margins.

The behavior begets a few conclusions. Unless your particular market niche is having the absolute lowest manufacturing cost, a fast follower strategy will rarely succeed in consumer electronics. There are companies like this and (typically based in low cost region of the far east) they often end up serving as contract manufacturers for the customer-facing companies with the product development and branding expertise. As a result, one must continually innovate, or fail. To use the language of MIT Sloan Professor Charles Fine, the "Clockspeed" of this industry is very fast. In the cell phone business, companies introduce new products every few months, and rarely leave them on the market for more than a year.[9] Customers are expected to buy a new phone every one to three years. In contrast, automobile models are typically refreshed every 4-6 years, and drivetrains upon which they are based only 10-15 years.[10] Carmakers have good reason to believe that they would be left in the dust if they tried to compete head-to-head in consumer electronics.

A characteristic of new products in general, but one particularly true in consumer electronics, is that it is essentially impossible to predict which will win. In addition, consumers are historically unwilling to pay for entirely new applications until their value to them is proven thus making market surveys of limited use in predicting the success or failure of a new technology. To use the language of marketers, the consumer does not yet know that they will soon "need" from this product. The internet provides a good example. Despite all the hype, both through the media as well in the investing community, home broadband services took-off several years later then many industry experts predicted. The problem: the average consumer just couldn't convince themselves why they really NEEDED to pay an extra $30-50 a month for a service they were doing fine without, or through a modem service costing only $15 a month. As a result, many "dot.com" companies with products intended for the consumer broadband market failed waiting for people to subscribe to DSL or cable modem services.

However, while predicting when products will hit the threshold where they take or what specific product will be the one that makes it happen is unpredictable, technology soothsayers were correct about the potential of having a high bandwidth, always on connection in their homes.

[8] Ibid.
[9] Cell phone industry article
[10] Fine, p. 239.

A key lesson from the last ten years of innovation and entrepreneurialism in the internet space is that generally, consumers are extremely price sensitive when it comes to paying for additional services (they have a very high price elasticity.) After online advertising dried up in 2001, many companies tried selling their content over the internet. Few succeeded. Today, many more are selling their content, but only after years of experimenting.

For example, Vindigo provides a wide variety of useful information to the urban denizen. Restaurants, bars, movies, shops, museums and even dry cleaners, ATMs and the nearest publicly available bathrooms are all listed by location as well as type (with brief reviews as appropriate.) The service, available by synchronizing your PalmOS or PocketPC PDAs over an internet connection, has a fantastic user interface and a devoted user base. Today, the company is able to convince users to pay $25 a year (or $2.08 a month.) Why is this important? To gain marketshare and demonstrate the value to the consumer, the service is initially offered free and ideally bundled with new PDAs customers are already willing to pay for. However, once the consumer is convinced of the service's value, it may eventually spur them to upgrade their internet connection (so Vindigo updates download faster) or their PDA (so the cools maps appear in color) or load the service on their cell phone (so its always up to date.) While a consumer may not appear to place much value (especially initially) on a specific service, it is part of an ecosystem surrounding a technology where innovation in the technology (PDAs or broadband internet connections) enables value provided by related services (like Vindigo) to eventually feed back on the original technology, thus spurring upgrades or other forms of continued financial commitment. These dynamics become important when we consider the adoption of mobile peer-to-peer in the context of a vehicle in Chapter 5.

1.1.4 The State of Telematics

Telematics is loosely defined as the vehicle features and services made available to a driver or passenger through a wireless connection to data sources or other resources not onboard the vehicle. It is the merging of cars, wireless networking and consumer electronics encompassing just about any service or software available to you over the internet. In fact, another way to consider it is as a PC and an internet connection for your car. Now you may ask why one would want an internet connection in their car (as many did about broadband connections at home not too long ago) or why any government would allow the potential distraction (a valid issue, but one we are not going to discuss here[11]). There are a myriad of potential applications, the most important in which will be discussed in Chapter 4 (Applications.) For the sake of this introduction, we break the field up into three distinct and separate markets. They are outlined in the table below.

Table 1.1: The Three Telematics Markets

	CONNECTIVITY	APPLICATIONS	COMPETITION
"Safety & Security" Telematics **e.g. OnStar**	• extremely high availability • low bandwidth such as is available through cell or satellite phone connections today	• Emergency road-side services • Voice-based directions	• AAA roadside assistance • Self-help via personal cell phone
"Active Safety" Telematics	• vehicle-to-vehicle broadcast or • vehicle-to-infrastructure communications via • extremely low latency, • low bandwidth • high data integrity	• Driver warning of a specific hazard in order to make better decisions • Vehicle intervention to avoid specific hazard	• Adaptive cruise control & other radar-based systems • Driver skill & awareness
"Consumer" Telematics	• high bandwidth • inexpensive bandwidth • but tolerance for low or variable reliability	• Infotainment • Dynamic Navigation • Real-time traffic • Mobile Office • VoIP Telephony	• "Smart" Cell Phones • Wireless-enabled PDAs • Japanese Telematics services: G-Book, Carwings & InterNavi

1.2 The Context

1.2.1 Safety & Security Telematics Market

Market research as well as industry experience has shown that generally, but especially in the US, the telematics services consumers are most willing to pay for today come under the heading of "Safety and Security." The value proposition and sales psychology for safety & Security Telematics is more comparable to insurance than to convenience and entertainment, the factors that drive typical consumer electronics adoption, even though the DNA of the device that

[11] The issue of "driver distraction," be it by: a telematics device, a cell phone, a crying baby, a whining passenger, a yelling radio commentator, a rude neighboring driver or your Big Mac rolling across the floor, is a concern for all involved (drivers, automakers and regulators.) That being said, it is the opinion of this author that it is not a valid reason to dismiss feature-rich telematics technologies outright as it is no more remarkable then any other potential distraction, only different. Furthermore, the vehicle OEMs have decades of experience in designing human-machine interfaces in vehicles and we have no doubt their ingenuity will not fail them at this calling.

enables the service is essentially a cellular phone and a bare bones computer. On par with its "insurance" market, consumers care most about low cost and ubiquitous availability.

Through its OnStar division, General Motors Corp. is currently the US market leader in Safety & Security(S&S) Telematics with roughly three-quarters of the market. OnStar has proven the viability (through operational profitability) of a Safety & Security Telematics business model. Automobile owners pay $17 a month (or $199/year)[12] for access to a constellation of services centered around solving problems one hopes one never needs. Table 1.2 outlines the OnStar service offerings.

Table 1.2	"Safety & Security" Service	"Directions & Connections" Service
OnStar **Services**	• Automatic Notification of Air Bag Deployment • Stolen-Vehicle Tracking • Emergency Services • Roadside Assistance • Remote Door Unlock • Remote Horn & Lights • GM® Goodwrench® Remote Diagnostics • AccidentAssist • Online Concierge Services	• All "Safety & Security" services plus... • Driving Directions • Information/Convenience Services • RideAssist
Price	$17/month	$35/month

For $35 a month, OnStar also provides a navigation service where a human operator will verbally direct you to your destination. OnStar's technology is based on a verbal interface through a low-bandwidth cell phone connection. The most critical aspect of their business is that when a user activates the system and asks for help, it is available. As a result, they have continued to use analog cell phone service (more expensive per minute, but longer range and wider coverage) with a higher power transmitter (the legal limit of 3 watts vs. 0.6 watts as is typical in a hand-held phone) while most cell phone users have migrated to digital. Like any subscription-based model, the business works best with as many users as possible, each who only occasionally uses the service but remains a member for several years.

[12] OnStar web site; Personal communication w OnStar employees.

In recent years, GM has decided that OnStar provides a key differentiating factor to new vehicle buyers and has made an internal commitment to sell a large portion of its vehicles with OnStar; currently, 30% of new GM vehicles come equipped with the service (or ~1.5 million new vehicles per year.) Compared to OnStar's current base of only 2.5 million subscribers, this constitutes tremendous growth.[13] For the vehicles sold with OnStar as a standard option, we can deduce that a portion of the vehicle purchase price is used to cover the cost of the hardware as well as the first year of free service. Considering that OnStar is able to convince greater than 50% of customers reaching the end of their initial year of free service to renew at their own cost,[14] we can infer that while most customers find that the service is worth the cost, they are nonetheless very sensitive to price. Since OnStar must logically recoup their investment in hardware and the first year of service from this remaining group that elects to pay for the service, we can posit that there is intense pressure to bring these costs down.

Based on the logic presented above, we can posit that central to OnStar's rapid growth and emergent profitability[15] has been its ability to continually decrease the cost to GM of factory-installing its hardware thus making the service an attractive value proposition to more and more new car buyers. It follows that the side-effect of this single-minded drive towards low cost is product homogeneity, inflexibility and a lack of upgradeability. Considering the long 3-5 year vehicle development cycle, for the next several years, OnStar will likely be largely limited to its current set of human-operator interface, insurance-type services. The remaining quarter of the US Safety & Security Telematics market not supplied by OnStar is provided by ATX Technologies Inc. which provides largely the same services, only as an outsourced service to Auto OEMs[16] which brand it under their own names. However, OnStar's (and ATX's) biggest competition will remain the American Automotive Association (AAA) and the roadside assistance service they provide to their 41 million of members[17] and accessed through the individuals' personal cell phones (which they already own and maintain a plan for.)

[13] Peterson, Personal Communication.
[14] Public statement by GM CFO John Devine as related by Michael L. Peterson, Program Manager – Strategy, OnStar (Personal Communication, Dec. 2003)
[15] "GM CFO John Devine announced in the second half of 2002 that OnStar was making a profit." Quoted from *Going for Growth: Finding new sources of revenue is harder than ever* by Joseph McCafferty, CFO Magazine, March 01, 2004 This was also reported in CBS MarketWatch on February 28, 2003.
[16] Currently, ATX claims to provide the branded telematics services onboard Ford, Mercedes-Benz, Infiniti, Jaguar and BMW. Besides GM vehicle brands (Buick, Cadillac, Chevrolet, GMC, Hummer, Pontiac, Saab & Saturn), OnStar provides the telematics services in Acura and Audi and on a very limited basis to Volkswagen, Isuzu and Subaru. OnStar also provides Toyota's services under the "Lexus Link" brand.
[17] American Automobile Association web site.

1.2.2 Active Safety Telematics Market

Active Safety is defined as the vehicle features which act proactively to decrease the likelihood or severity of an accident. The first active safety systems (as opposed to passive safety systems such as crumple zones or side-impact reinforcement) were arguably airbags and anti-lock brakes. Today, some premium automobiles are being sold with "adaptive cruise control" whereby the vehicle uses a rudimentary radar technology to sense when one is closing in on a vehicle ahead in one's lane too quickly, and then acts to slow the car down until it is traveling at the same speed. While well designed for signal-less highway travel, today this technology is expensive and not able to react adequately to avoid all obstacles that appear suddenly from the side such as when a vehicle in an adjacent lane suddenly moved into yours or the proverbial "child chasing a ball across the street." The risk of all active safety systems is that increased protection from a prevalent class of risks will erode vigilance for the highly unpredictable and extremely rare events that a human can respond to, but a machine will likely be confused by.

Philosophy aside, a perennial goal of automakers is to engineer the risk out of automobiles, an endeavor validated by market research which indicates consumer's willingness to pay for these services. As a result, the potential of Telematics to contribute to active safety is impossible to ignore. In its extreme, cars that have complete awareness all other vehicles around them as well as the roads on which they travel and confidence that all those neighboring vehicles have a similar and predictable awareness, could drive themselves. This "Auto-Pilot" capability is the holy grail of active safety. In the mean time, we have the long road of incremental improvement.

Mobile Peer-to-Peer technology holds out the potential for a revolutionary leap in Active Safety functionality. In the contemplated implementation, mP2P-enabled vehicles use GPS[18] and detailed mapping technology to maintain a continual awareness of their location along a network of roads and lanes. Through mP2P connections, enabled vehicles are able to communicate their location, vector and any noteworthy information such as if: the vehicle has rapidly changed speed or the operator has suddenly applied their brakes or the all-wheel drive system has just engaged indicating a loss of traction due to an unsafe road condition such as ice or flooded pavement. Initially, the vehicle might only pay attention (and then notify the driver) of these sudden events. Eventually, once enough vehicles are enabled, the car could use its awareness of the vehicles around it to make recommendations based in this indirect data as well. The "DSRC"

[18] Geo-Positioning Satellites send out signals that allow consumers with the proper receivers to calculate their location on the earth (in longitude, latitude and altitude) to an accuracy of roughly 30 feet (10 meters.)

communications standard has been developed by an industry-government consortium to define a protocol and frequency for this purpose; it is discussed further in Chapter 3 (Technology.)

Once sufficiently mature, the active safety system could theoretically intervene, causing the vehicle to act. A popular example is that if the car senses that it is drifting into a neighboring lane or even off the road, the vehicle could self-correct and return to the center of its lane while "nudging" the driver to pay attention. Naturally, there are many questions. How would the vehicle know that the vehicle is drifting rather than the driver is consciously changing lanes or pulling off the road? If a driver were used to operating in regions where all or nearly all vehicles on the roads were Active Safety compliant, how would they react if when they went on vacation to an area where such technology had yet to become prevalent? Would this simply contribute to less-skilled drivers that were then used to not paying attention, and thus less prepared to react to the completely unforeseen event? Many concepts are based on outfitting roads and highways with special hardware to communicate key location and alignment data to the vehicle. Would all communities be able to afford such systems, and if not, how would drivers react from out of town?

Obviously there are a great many issues to consider. No doubt, many bright and creative engineers will be kept busy for decades to come figuring out solutions to each of these "what ifs?" There are, however, a few conclusions affecting the near term ideas to be considered. First, driver notification features can start to operate with a very small percentage of enabled vehicles. For these drivers, these features may be perceived as helpful and therefore valuable. From a business strategy perspective, it is difficult to argue convincingly that Active Safety features based on peer-to-peer technology will ever provide significant or sustained competitive advantage to any OEM. For these systems to be reliable and effective, they must appear on all vehicles thus eliminating the vehicle differentiation that creates competitive advantage. This becomes obvious when reversed: if 80% of vehicles have P2P Active Safety transponders, a disproportionate risk will come from the 20% that "don't show up on the radar" since drivers will start to grow dependent on the systems. This will undoubtedly spur governments to mandate the technology thus minimizing any competitive advantage. Of course, there will always be opportunity for better software and user interfaces, but we would argue that it reduces the differentiation back down essentially a cosmetic level, no different from a vehicle's interior finishes or the organization of the buttons on the radio.

1.2.3 Consumer Telematics Market

At the intersection of mobile consumer electronics and Telematics is "Consumer Telematics." While technically characterized here by tolerance for low or variable reliability connections and applications facilitated by high or inexpensive bandwidth, this market encompasses (for now) anything that is not covered by the Safety & Security or Active Safety markets. The term "Infotainment" has been coined to describe many applications that would be well suited for Consumer Telematics. Typical examples involve rich, web-like content on color screens delivered through inexpensive, high-bandwidth connections. Some representative examples include:

- Mobile Office features (phone, email, fax)
- Web access
- News, weather
- Music, video & interactive games on demand
- Real-time traffic updates & dynamic navigation services
- Online concierge services
- Location-based commerce; sight-seeing tours

A detailed discussion of potential applications and their technical requirements appears in Chapter 4.

In the US today, these types of services are currently being most aggressively pursued through PCS-enabled cell phones and PDAs. In Japan, Toyota, Nissan and Honda have all launched Telematics services. They include varying mixes of Consumer and Safety & Security type Telematics applications. OnStar has experimented with Consumer Telematics through its "Virtual Advisor" service. However, we can infer from the fact that the existence of this service is not actively promoted that the Company does not feel it provides a compelling value proposition to existing or potential customers.[19] Further expansion is limited by their hardware platform and their high cost per byte of data through expensive low-bandwidth analog connectivity. We can thus posit that while GM likely continues to ponder options for expanding into Consumer Telematics, it seems that its primary focus today is its OnStar strategy for providing inexpensive Safety & Security. In the broader wireless industry, there are interesting market dynamics on the horizon.

[19] If one examines the OnStar web site, the only mention of the Virtual Advisor service is buried deep within the site and even there, there is only a cursory mention of the available services. [See www.OnStar.com] In addition, despite a current, aggressive marketing effort in print and television, the author is not aware of any ads highlighting its Virtual Advisor service.

In a February 2004 front-page article, The Wall Street Journal reported current developments in marketing dual-mode cell phones that also used Voice over Internet Protocol (VoIP) and Wi-Fi to place voice calls[20]. Cisco Systems Inc., the telecommunications equipment giant has equipped 1,000 corporate customers with Wi-Fi phones in the last year. The attraction of Wi-Fi phones is cost and the potential for higher quality service indoors where Wi-Fi networks already exist. If nothing else, this reinforces that to discount Wi-Fi as a force to consider for Telematics would be naïve and short-sighted. As will be discussed in Chapter 7, the idealized near-term Telematics offering would incorporate a hybrid system: high-bandwidth, low cost connectivity (through Wi-Fi or its ilk) for areas of high population density where it is available, and a low-bandwidth, higher-cost cell phone or satellite connections for the areas where it is not.

1.2.4 Barriers to Consumer Telematics

Consumer Telematics services has for several years been touted as the future of the automobile. However, a profitable business model for these Consumer Telematics services has remained elusive up until now. Before we explore this market in detail, it is important to understand what has limited its growth to date. The reasons are is well summarized by the 2003 McKinsey report "Telematics: Quo Vadis?" as:[21]

- Unattractive "value for money" packages from an end user perspective
- Lacking technology maturity and standards
- Immature human-machine interface (HMI)
- Insufficient Bandwidth

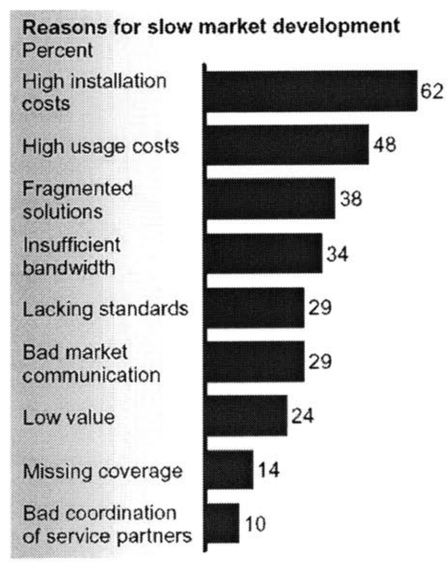

Figure 1.1: Reasons for Slow Consumer Telematics Market Development

Each class of barrier is discussed below. The top individual issues cited in the report are shown in Figure 1.1.[22]

1.2.4.1 VALUE FOR MONEY

For any new technology to be adopted, the prospective consumer needs to perceive a value. This is much more difficult for "disruptive innovations" than for incremental ones. With

[20] Drucker
[21] Von Bülow et al, *Telematics – Quo Vadis?*, McKinsey & Company, Presented at the A&A Extranet Confrence, Kitzbühel, Germany, January 31, 2003. *Quo Vadis* is a latin loosely translated as "where do we go from here?"
[22] Ibid; Detecon Research.

incremental improvements, the customer already understands the service. They are simply buying a better/faster/smaller/lighter/cheaper one. With completely new services, it is much more difficult to convince the user that they "need" this new product. As a result, the barrier to entry is much higher. A good example is broadband service at home. When such services were first offered to consumers in the late 1990's, few jumped on board despite the tremendous improvement over traditional modem connectivity. The question was: "why should I spend $35-60 a month for something I get right now for $20 through America Online?"

Today, cable modems and digital subscriber lines (DSL) have entered mainstream acceptance for millions of Americans. For those that have now grown accustomed to checking the weather, printing boarding passes, reading the news, downloading music files or recipes, shopping and sending email online, its difficult to imagine how we operated before there was the internet. If a market researcher asked five years ago whether one would pay for these services, the typical answer was "no." We operated just fine without them. Telematics and its substitute wireless services is probably where internet access was ten years ago: there are few available applications and the customer willingness to pay is very low. This is complicated by the fact that Automotive OEM's control what gets included in a vehicle. They perceive that it will require an enormous investment for them to offer Consumer Telematics services. With current market research indicating that few customers would be willing to pay for these types of services (as was the case with the internet ten years ago), they are disinclined to place any big bets.

1.2.4.2 TECHNOLOGY STANDARDS

This issue of standards is a perennial one with many technologies, but especially with wireless connectivity. As we know from Sony's Betamax standard for VCRs, the best technology does not necessarily win out in the market. Companies, mindful of preserving their competitive advantage are slow to team together. Automakers are used to using their own proprietary software and hardware inside their vehicles. The idea of giving up control over this is terrifying. In the wireless market, companies are always battling over whose flavor of a technology will win. This is particularly stark since traditional wireless systems require large infrastructure investments in order to achieve nominal performance. With lifespans exceeding fifteen years, Automakers are reticent to commit to a particular technology, especially when the wireless technology evolves every 3-5 years. In Chapter 2, we address this technical options more fully.

1.2.4.3 HUMAN-MACHINE INTERFACE

In *Crossing the Chasm,* Geoffrey Moore discusses how the primary barrier that inhibits a technology or product from progressing from Early Adopters to the Early Majority of consumers is usability. While the Early Adopters are tolerant of new and quirky technology that requires a high degree of technical savvy to use, the Early Majority are not. PDAs are a terrific example. For years, companies marketed electronic organizers with marginal success. However, Palm Computing's eventual success in bringing PDA to the mass consumers was in a large part driven on its simple, intuitive human-machine interface (HMI). Apple has kept itself alive by continually coming out with new products with powerful interfaces. The user demands for auto components are particularly strident since they should allow a driver to operate them while remaining focused on their primary job of operating their vehicle. OnStar chose to address this through a purely voice-driven interface.

1.2.4.4 INSUFFICIENT BANDWIDTH

The issue of sufficient bandwidth is related to both the value for money as well as the HMI issue. Today's Telematics connectivity medium of choice is the cell phone. While the available data rate for new PCS-enabled phones is an order of magnitude greater than those available just two years ago, they are theoretically limited to 144 kbps while traveling at highway speeds.[23] Compared to cable modems (20x faster) or Wi-Fi (500x), they limit a large proportion of potential applications. Higher bandwidth also implies cheaper bandwidth per byte transmitted which in turn enables even more applications.

1.3 The Approach

Understanding how to succeed in Consumer Telematics is complicated. It is complicated because there are so many different forces limiting its success. As a result, critical to crafting a compelling strategy is to understand each force, and then incorporate them together into a single, unified strategy. These factors are each addressed in a separate chapter (2-7). The conclusions and lessons for a company of GM's scale are then summarized in Chapter 8. Thus, this paper is organized as follows:

- Chapter 2: Wireless Broadband Technology
- Chapter 3: The Telematics Value Chain
- Chapter 4: Consumer Telematics Applications

[23] Malhotra, Personal Communication.

- Chapter 5: Market Dynamics & Network Externalities of Telematics Services
- Chapter 6: Assessing the Critical Mass for Viral Growth
- Chapter 7: Business Strategies for mP2P Telematics
- Chapter 8: Conclusions (Leveraging GM's Scale)

1.3.1 Structure of Thesis

The current landscape of wireless networking technologies is dizzying, and it is unlikely to become any less so in the future. In Chapter 2, we provide an overview of the current landscape. Of all the information in this thesis, this is the one that is likely to have the shortest half-life. As a result, we attempt to consider the competing standards and protocols in a way that will remain useful as some standards fall out of favor, and new ones evolve. Mobile wireless broadband connectivity including peer-to-peer technology remains an exciting area since while there are many commercialized products on the market today, new ones still appear monthly. This implies that in the time a large company take to decide to move forward, there will surely be several additional options to consider. The critical lesson, however, is that any Telematics system will have to be upgradeable in order to weather the consumer demand and technology evolutions throughout the 15 year lifetime of the vehicle. We conclude Chapter 2 with a notional product architecture that permits this flexibility.

To understand the market as well as the range of technologies required to serve it, it is important to fully understand the Telematics Value Chain. As a result, Chapter 3 pulls heavily from Chapter 2's discussion of the technology. This is important because understanding the value chain provides insights into which segments of it are currently (or will likely soon become) commodities. From a business strategy perspective, it is best to structure one's technical architecture and business strategy so these commoditized services may be outsourced to other companies that do it better or cheaper. Inherent in this is the premise that the consumer electronics and wireless networking industries move so quickly that a single company will not have the resources, expertise nor agility to remain the market leader in all components of the Telematics value chain. Thus, it is critical to make the best assessment of which functions are ideal to serve in-house and which are best to serve through partnering with dedicated organizations.

This first question that we would almost always encounter during our many interviews with experts in the Telematics field was what was the "killer app." While this term has fallen considerably out of favor since dot.com boom years of the late 1990's, the notion remains that for any new technology-based product to succeed, it must have a single "must-have" application. In Chapter 4, we provide a survey of Consumer Telematics applications. They are organized in terms of the technical foundation most likely to make them economic. Two conclusions arise: first, there is no "killer app" that we can predict today, and it is unlikely that one will surface during the market's gestation and early adoption. Instead wireless broadband will serve as the "killer enabler" for a constellation of applications, any one of which would not provide sufficient value but the portfolio of which does. The driver is economics: Wi-Fi type wireless broadband technology is inherently less expensive per byte of data. Advanced cell phone service looms perpetually at the horizon, but the preponderance of input received suggests that it will continue to lag wireless broadband networking standards for the foreseeable future. In addition, as long as broadband pricing remains decoupled from traffic and the cell phone company business models remain pegged to minutes or bytes of traffic, there will be many applications that remain outside the cost structure provided by cell phone services. Like the internet has done at home and at work, a mobile broadband connection has the potential become indispensable.

Having developed the "idealized state" of a future Consumer Telematics system, it is appropriate to investigate the mechanisms for getting there. Chapter 5 indulges us in brief foray into the theories of the market dynamics of positive network externalities. Leveraging the tools of System Dynamics theory, we create a notional model of the consumer Telematics market based on mobile peer-to-peer wireless broadband technology. Three separate market forces combine together to cause a powerful reinforcing structure whereby the first entrant in this market, if properly structured, can enjoy enormous advantage over all who try to follow. The lessons of this chapter, combined with allegorical business cases and conclusions from the investigation into the value chain result in strong suggestions as to the best cocktail of potential business strategies. The most poignant is that an automotive OEM with large market-share that moves first and boldly can achieve a sizable market advantage over any followers.

While Chapter 5 provides notional conclusions as to the best business strategies, it highlights the need for a quantitative estimate of the market penetration required to achieve various strategies. Chapter 6 attempts to answer question: what is the critical mass for market penetration. In other words, how much network seeding is required and at what point will the business become self-sustained. A mix of market dynamics and technological performance, we were unsuccessful in finding literature sources or experts able to adequately answer this question. Inspired by some modeling and empirical research done by GM research and development on the topic of using telematics-enabled vehicles as sensors for real-time traffic monitoring, we present a first order probabilistic analysis to answer the question on our own. Using detailed traffic data for the Detroit metropolitan area from the Michigan Department of Transportation, we construct a curve relating system performance to market penetration. Then, using benchmarking data from analogous services, we correlate performance to a customer's wiliness to pay. Finally, we conclude the tradeoff between investment and future revenue streams, and the benefits of having a large marketshare.

In Chapter 7, we put first brainstorm a range of promising business models, and then using the conclusions from the previous five chapters, recommend a strategy. The strategic options come from existing business cases spanning: traditional automobile marketing, consumer electronics product design, PDA hardware and software, cell phones and other wireless services, and finally computer operating systems. In doing so, we highlight the argument for controlling key "chokepoints" in the system interfaces while otherwise maintaining open systems as the best strategy for an Automotive OEM to move forward. In addition, we consider the threat of competitors and substitutes.

Finally, in Chapter 8 we attempt to broaden the lessons from using mobile peer-to-peer technology to pursue the Consumer Telematics market into more general conclusions about the impact of viral growth technologies on business strategy. We highlight the overwhelming market advantage that a player with leading market share (such as General Motors), or a coalition of smaller players, can achieve. Through corporate policy alone, they can create a high likelihood of success simply due to the market dynamics and a properly crafted strategy.

1.3.2 Methodology & Tools

As mentioned above, we gain insight into how to bring Consumer Telematics to market by first analyzing the business through four filters: technology(Ch.2), value chain(Ch.3), potential applications(Ch. 4) and market dynamics (Ch. 5 & 6.) As illustrated at right, business strategy then serves as the lens in which to focus this information into a cohesive go-to-market strategy(Ch. 7.)

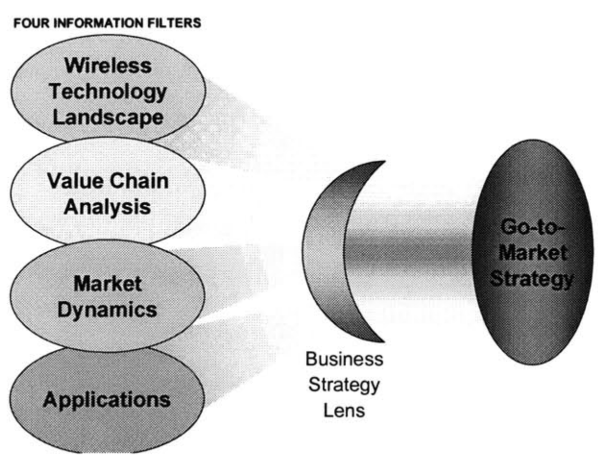

Figure 1.2: Thesis Analysis Methodology

Input data for this thesis was collected principally through open literature sources and interviews with industry experts. Since the research and analysis it was performed in the context of a 6-month internship within the corporate strategy group of General Motors Corp., the majority of these experts came from within GM and its OnStar subsidiary. In order to publish this thesis, no GM proprietary and confidential information was included. However since we employed the strategy of hypothesizing the ideal final state and then plotting backwards how best to reach this state, this was not a major issue. Nonetheless, the experience and opinions of the many very knowledgeable individuals we spoke with provided invaluable insight into the complexity and challenges of implementing a telematics system.

The market dynamics section relies heavily on the System Dynamics theory as espoused in John Sterman's text on this topic.[24] Expressions for the various loops in the model are relegated to the appendix. The discussion of the three network effects in play for this market comes from a number of papers on this topic and especially from the business cases described in Jeffrey Rohlfs's comprehensive book *Bandwagon Effects.*[25] The analysis of the Michigan traffic data in order to assess market penetration thresholds is based on elementary probability theory. Finally, presentations of the eventual business strategy recommendation as well as the underlying analysis and assumptions to key stakeholders within GM provided us with critical feedback. At this point, we note that for the remainder of this thesis, we will simply use the term "Telematics" term to imply Consumer Telematics since we will focusing exclusively on those opportunities not currently served by the proven OnStar and ATX business models.

[24] Sterman, John D., *Business Dynamics: Systems Thinking and Modeling for a Complex World;* McGraw Hill; ©2000; 982p.
[25] Rohlfs.

Chapter 2 Wireless Broadband Technology

From a wireless networking perspective, Telematics is simply a connected vehicle: some computing capability onboard the vehicle communicating with another mobile source or, more often, to a stationary, terrestrial computing system. The content is some form of packetized data. The number technologies available to accomplish this is overwhelming and continually in flux. To efficiently parse through this information, we start off with an overview of Telematics connectivity today. Following is a discussion of both the current state as well as the future potential of mobile Peer-to-Peer (mP2P) technology. The third section delves into how mP2P can enable Telematics. We conclude this chapter with a final technology platform recommendation as well as come additional factors to consider. The goal of this chapter is to provide a high-level overview of the propsed technology solution and its potential competitors and subsitutes within the context of the overall market dynamics and business strategy. Detailed technical issues are only mentioned if they are relevant to the overall strategy as there are many more in-depth and well-written sources that deal specifically with the detailed technical issues. Those that the author found particularly helpful in understanding the technical considerations are included by reference.

2.1 Telematics Connectivity Today: Licensed Infrastructure

Today, all Telematics systems on the market make use of cell phone or other "point-to-multipoint" infrastructure type system. In this type of system, central towers or access points service all users in a given geographic area. If there are more users then the cell tower has capacity, service quality or availability drops dramatically. Most cell phone users have encountered this at some time or another; the most typical example is probably in an airport when weather or some other *force major* has grounded or delayed passengers. Suddenly everyone is trying to make a phone call; the results is that no one can get through. As we will discuss later in this chapter, this is relevant since peer-to-peer systems have a potential edge in this capacity issue.

Figure 2.1[26] illustrates the general wireless landscape today on the scale of data rate or bandwidth versus range or coverage area. As we can see, cell phone systems provide greater range but lower bandwidth. In contrast, wireless local area networks (LANs) using spread spectrum technology achieve higher data rates at the cost of lower range. This is always the case with radio frequency technology. If one wants to increase both, this can only be done through higher power transmitters or more focused antennas. However, since the FCC (Federal Communication Commission) regulates the maximum allowable power so for any given platform, power is generally taken as a given.

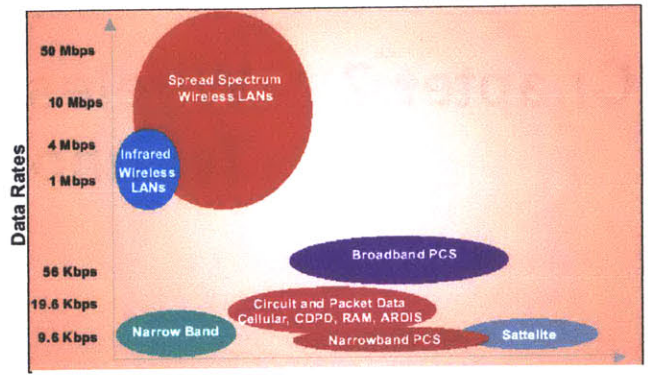

Figure 2.1: Wireless technologies data rate vs. coverage area or range.

For licensed infrastructure type systems such as cellular service, slices of spectrum are licensed to individual companies for their use with their proprietary systems. In Japan, some telematics services are provided by pure broadcast systems (analogous to traditional AM and FM radio and VHF and UHF television signals in the US); these are discussed under the subheading "Broadcast" below. In the US, both OnStar and ATX systems rely purely on cell phone service. In Europe, the few Telematics services that exist on the market make use of pager messaging or cellular service. The theme that ties them all together is that each wireless service company owns the exclusive license to market services on their allocated band of spectrum. For the sake of simplicity, we will generally limit our discussion to the US market.

Figure 2.2 illustrates the basic system architecture used in by OnStar and ATX. The central computing unit onboard the vehicle connects via a cell phone connection to the network of towers. From there it travels along the telecommunications backbone (typically fiber optic cable) to an OnStar call center where it interfaces with a proprietary information technology application management system and human operators. In the case of OnStar, the hardware is factory installed into each vehicle and is designed to only work with a specific cellular provider, in this case, Verizon Wireless.

[26] Knapp.

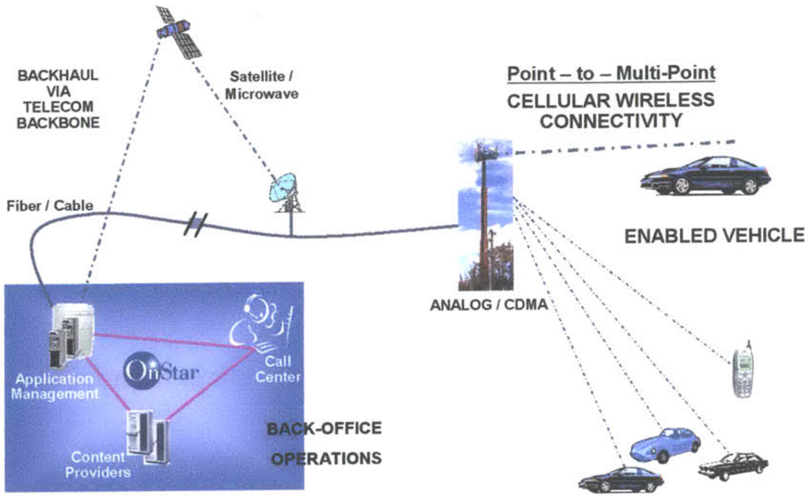

Figure 2.2: OnStar's Cellular-Based System Architecture

Up until Spring 2004, all OnStar systems used the old analog cell network (AMPS.) The benefit of analog is that it still has the best geographic coverage of any cellular technology thus maximizing ubiquity. The downside is that it that at 9,600 kbps, it is very low bandwidth, comparable to PC modems of the early 1990's. While this is adequate for voice communication, it is very limiting for data. Currently, the hardware is very costly and difficult to upgrade since it requires replacing components buried deep within the vehicle that are highly integrated with other vehicle control components. This is not by accident: central to OnStar's "insurance" type business model is high reliability. For example, if your car is stolen, one would not want it to be too easy for the thief to remove or disable the OnStar tracking system that facilitates vehicle recovery.

2.1.1 Cellular Phones & Pagers

Cellular and paging networks provide the foundation of wireless communications in the US today. Cell phone technology has evolved considerably from the brick-sized, analog phones that first gained acceptance in the mid-1980's. Today's digital phones have longer battery life, greater signal clarity and can even take and transmit color pictures. The market dynamics, however, remain largely constant. Competition among carriers is fierce and consolidation has just begun with the auction of AT&T Wireless in February 2004. More mergers are predicted as a way to combat the largely commodity pricing that exists in the industry. While the dominant players all have nationwide networks, the Cellular companies (CellCo's) nonetheless continue to invest heavily in new technology and additional towers to expand coverage.

Each CellCo's network of towers allow one to roam at up to highway speeds while maintaining a connection voice or data. The important dynamics of this "infrastructure" type service is that each carrier must site, erect and service their own proprietary networks of towers. This results in a considerable fixed cost and high infrastructure redundancy between carriers that cover the same markets. From a theoretical perspective, a CellCo must completely outfit a region before it begins to sell service. In reality, they start in the most high-density (and affluent) regions and build out from there. Even in area of complete coverage, Cellular service generally achieves 98% reliability. The remaining 2% result in dropped calls or other failed connections.

The growth in the US cellular phone industry provides some interesting background for contemplating future, alternative wireless systems. Figures 2.3 and 2.4 below present data from the Cellular Telecommunications & Internet Association on the total, industry-wide growth of cell towers, revenue, subscribers as well as the average monthly bill. Although this infrastructure type system suggests that there would have to be a heavy build-out in the beginning, followed by a period of technology maturation where the system becomes more mature and efficient, the data indicated otherwise. Throughout its twenty-year history, the industry has maintained a largely constant ratio of 1025 subscribers per cell site. After a long period of slow decline, the revenue per subscriber has recently leveled off at $50 per month.

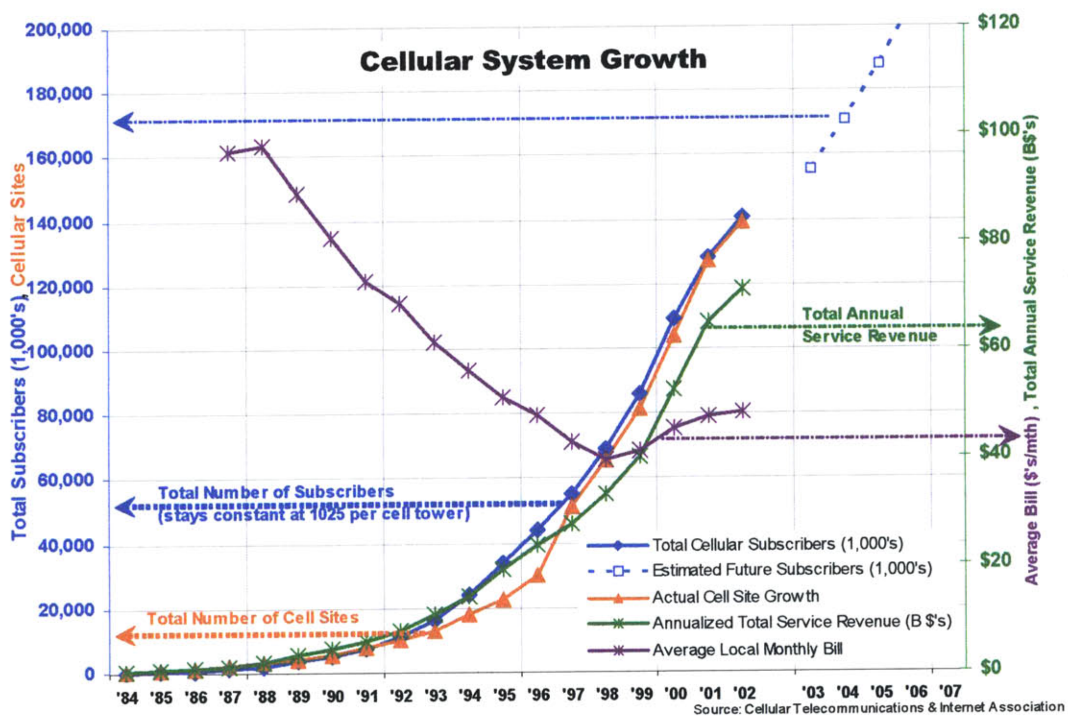

Figure 2.3: US Cellular system growth since inception.

These trends suggest a few conclusions. First, as the total market grew, existing CellCo's added greater coverage and thus more potential customers. This created more economies of scale for these companies, allowing them to decrease prices. For these existing companies, the subscribers per cell should have increased. However, as the total market matured, new entrants arrived which initially had lower utilization thus dropping the average tower utilization. In order to gain market share, they offered lower prices, further accelerating the downwards pressure on price.

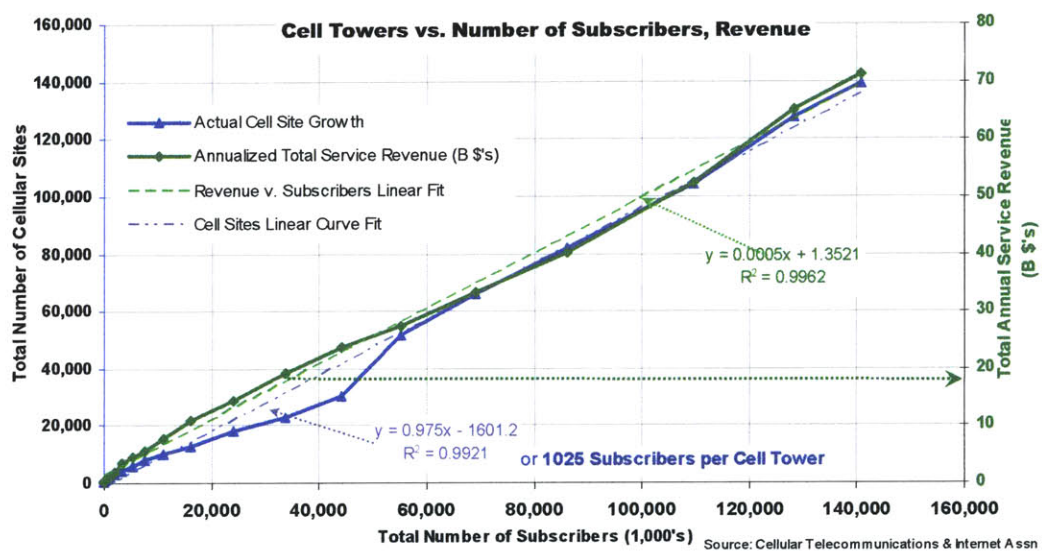

Figure 2.4: US Cell Towers & CellCo Gross Revenue versus Total Number of Subscribers

Two other factors are worth noting: in 1996, digital service, and in 1998, the first nationwide plans become widely available. These two facts are apparent in the graphs. In 1996, there was a sudden increase in the rate of new towers. While digital systems have a lower cost structure per minute, better quality and lower power usage (and thus longer battery life), they have shorter range. To maintain their coverage, they had to build more towers. The advent of single-rate nationwide plans made making long distance calls more attractive. Thus, the increase in the average subscriber's bill likely represents a similar shift in revenue away from the long-distance telecom companies. We will refer back to these trends when we discuss the market dynamics in Chapter 5.

2.1.1.1 CELLULAR TECHNOLOGY

The precise protocols and radio frequency algorithms used by CellCo's varies by country. In the US, we have experienced standard proliferation. While the AMPS[27] standard was used relatively uniformly for analog phones ("1G" or First Generation), four different major standards were used when it came time to build out the digital (Second Generation or "2G") tower network. The earliest standards were FDMA (Frequency-Division, Multiple Access) where each user was allocated a dedicated piece of spectrum to use. The next evolution was TDMA (Time-Division, Multiple Access), which services several users over a single band by alternating the signal between users over time. CDMA (code-division, multiple access) provided the highest capacity for a given band of frequency by distributing a subscriber's signal over both time and different frequency bands. The down side is that CDMA is the most difficult to implement and as a result originally tended to have lower quality than TDMA. GSM (Global System for Mobile Communications), a flavor of TDMA, is the standard in 162 countries, but only one of the four options in the US. Niche player Nextel uses its proprietary IDEN system for its walkie-talkie system. The table in Appendix A lists details of all the major wireless spectrums considered including the five discussed above.

Today most systems are considered "2.5G" systems since they transmit both voice communications through the 2G system, and data through 3G hardware. The migration to 3G from 2G will be similar to that from 1G to 2G in that it will provide higher bandwidth (as high as 120kbpts today and up to 2mbps in the future) and thus more services, but lower range. It will take five times the number of towers as 2G just to cover the same geographic area. 3G has been slow to appear due to the high investment in both towers as well as the fact that many carriers overpaid for their spectrum and are now burdened with high debt. Also, while 3G phones will theoretically be able to transmit up to 2mbps while stationary, they are theoretically limited to 144kbps when the user is moving at highway speeds.[28] In the end, this is the most important detail with regards to Telematics. The other major point, is that the cell networks are designed, and the CellCos' business models are organized around intermittent voice traffic. If users started to regularly use high data rates, the CellCos' would be challenged since their primary constraint would shift to capacity from geographic coverage as it is today.[29] We will refer back regularly to these points as they drive many of the issues that make other wireless broadband standards attractive.

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[27] AMPS – Advanced Mobile Phone System
[28] Malhotra, Personal Communication.
[29] Ibid.

2.1.2 Broadcast

If Telematics included unidirectional communication from stationary sources to the vehicle, then the first Telematics device would have been the AM radio. Fundamentally, all wireless communications uses radio technology. Figure 2.5 below shows the range of spectrum, and where FM, television and Cellular signals reside.

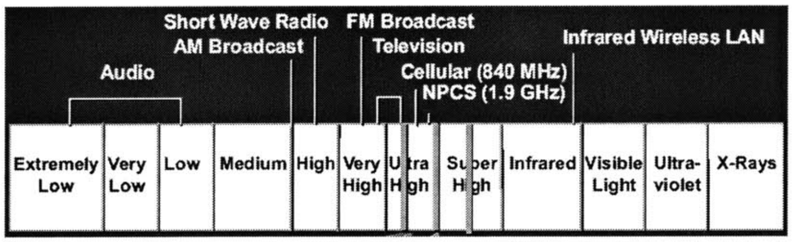

Figure 2.5: Wireless Radio Spectrum

Like all radio communication, the longer the wave (the thus the shorter the frequency), the greater the range but at the cost of bandwidth. Thus, FM radio provides higher fidelity than AM, but with shorter range. Broadcast type systems provide the greatest economies of scale since a single signal can be received by an essentially infinite number of users in within range of the source antenna. A radio or TV broadcast station is not even aware of how many users are receiving and decoding their signal let along experience any additional cost as a result. Thus, this is the ideal medium for transmitting information that may users will use without any need to communicate back with the transmitting party. In Telematics today, there are two principle architectures used in broadcast mode: satellite and FM.

2.1.2.1 SATELLITE: BI-DIRECTIONAL AND UNIDIRECTIONAL

Although satellites can be used in bi-directional applications such as satellite phones, the cost of installing and operating these systems has inhibited widespread adoption but for the few applications where users are willing to pay a large premium for world-wide ubiquity. The failures of the high profile satellite phone ventures Iridium and Teledesic has not lessened the prevailing wisdom on these technologies. The one exception is satellite-based credit card authentication. In these applications, retailers are outfitted with a small satellite dish (on the order of a foot in diameter) on the roof of their establishment. Success in this market is attributed to: the extreme importance of reliability and geographic ubiquity along with the very low bandwidth requirements of these transactions. This infrastructure may, in the future provide a convenient upgrade path towards higher bandwidth services, should the demand and the economics warrant. OnStar, due to is similar need for very high reliability and geographic ubiquity while employing a low-bandwidth system, would be well suited towards these types of systems. If the costs come down sufficiently, it is likely that the first appearance of bi-directional satellite-enabled Telematics will appear on Safety & Security Telematics systems such as OnStar or ATX. However, for the types of Consumer Telematics systems we contemplate in this thesis, it is unlikely to be economic for some time to come.

The consumer application where satellite technology has seen the most success is in satellite television such as DirectTV. By broadcasting the same signal to all its users in North America, it leverages the best characteristics of satellite broadcast. A newcomer with the same business dynamics is satellite radio. XM and Sirius, the two current competitors, license their receiver technology through partnerships with major consumer electronics companies. To use the receivers, users much pay XM or Sirius a monthly service fee. In exchange, they receive a 100+ channels of mostly commercial-free radio with an appreciable quality edge over regionally-broadcast FM stations. The only downside is that, like satellite TV, they have very limited local content since they broadcast the same signal across the entire US market. XM, partially owned by General Motors, benefits from strong promotion by the automaker. Since XM does not currently utilize all its available bandwidth, GM and XM are currently evaluating additional services (offered through the OnStar system or an onboard navigation system) that make use of information transmitted through these extra channels. Currently, the most likely type of information is continually-updated traffic information. The implications of these potential substitutes is discussed more in the "substitutes" section, in Chapter 7 (Business Strategy.)

2.1.2.2 FM BROADCAST

Besides being the low-cost, incumbent competitor to satellite radio and real time traffic updates (currently providing by tuning to your local traffic-radio station and listening for the regular broadcasts), FM broadcast is well suited to provide geographically-targeted, low-bandwidth data. Today, a government run FM broadcast system is widely used in Japan to send real-time traffic updates to transceivers installed within vehicles. This very low-tech system has been in effect for over a decade. Its success is attributed to the role the national government played in setting the standard and subsidizing the infrastructure. As one of the more promising Consumer Telematics applications, this potential substitute technology for real time traffic data transmission is also considered further in Chapter 7.

2.2 *Unlicensed Infrastructure*

2.2.1 Wi-Fi Wireless Broadband Technology

Wi-Fi®, or Wireless Fidelity represents the hottest area of growth in networking today. Although the Wi-Fi trademark refers specifically to the IEEE 802.11b standard, it is generally used to refer to the entire class of specifications designed as an alternative to the wired networks such as Ethernet that currently allow computers in businesses, schools and homes to communicate with one another. The various flavors are all variants of the 802.11 standard enacted in 1987[ref]. The key enabler to these technologies was the creation of several unlicensed bands of spectrum with wireless networking equipment manufacturers could use. Wi-Fi, and its more recent, higher bandwidth brother 802.11g, use the 2.4GHz band.[30] The other principle unlicensed band exists at 5.8GHz where the 802.11a standard operates. Today, these standards provide up to 56 mbps of connectivity at ranges of up to 300 feet. In practice, the actual bandwidths and ranges are considerably less due to building structures and other sources of interference. In addition, the existence of multiple concurrent access points in the same area decreases the effective data rate and range each user experiences to a fraction of the theoretical limit. For example, an 802.11b users would expect closer to 2 mbps and a range of 100 feet in a typical corporate office building instead of the 11mbps and 300 feet that could only occur with a single user in an open field with no interference.

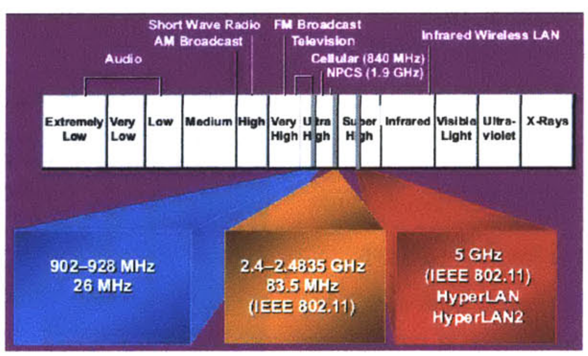

Figure 2.6: ISM Unlicensed Frequency Bands [Knapp]

[30] The reader is directed to Jordan & Abdallah who provide a good overview of the history and technical issues surrounding wireless communications such as Wi-Fi and Bluetooth.

Figure 2.6 shows the three unlicensed bands with the spectrum of radio frequencies. The limitation in these unlicensed bands is that there is no one regulating whether there are too many such devices in a single area. There is the potential for a "tragedy of the commons" phenomenon with bandwidth as there are thousands of different devices that make use of the ISM bands[31]. Many have experienced this early with cordless phones, where they would suddenly become privy to their neighbors' conversations. The only limitation is signal power, which is regulated as a part of the specification. Thus, in high-density urban environments, as the technology becomes more prevalent, performance and range degrades as the signal-to-noise ratio rises. To a Wi-Fi access point in one apartment, the signals of the Wi-Fi units in all adjacent apartments are noise. In large corporate, installations, engineers design their systems to minimize these effects. In residential environments, there is no such coordination. This behavior is important to note for any uncoordinated wireless communication system such as those using the ISM band since successful widespread adoption inherently causes service degradation.

2.2.2 The Growth of the Wi-Fi Market

Despite all the limitations, Wi-Fi has been an unqualified success. Its use today far exceeds the original expectations of a technology to free corporations from having to run miles of new Ethernet cable every time they reorganized their organizations. Figure 2.7 shows the growth of world-wide public Wi-Fi over three years. Most major hotel chains and airports in the US, have at least one provider of Wi-Fi services. The business models for the Wireless Internet Service Providers (WISPs) that provides these access points varies. Typically, they offer both single-use connections and monthly access fee contracts. Although the business traveler is a limited market, access points in high traffic zones can be profitable. Some retailers such as Starbucks and even McDonalds have experimented with

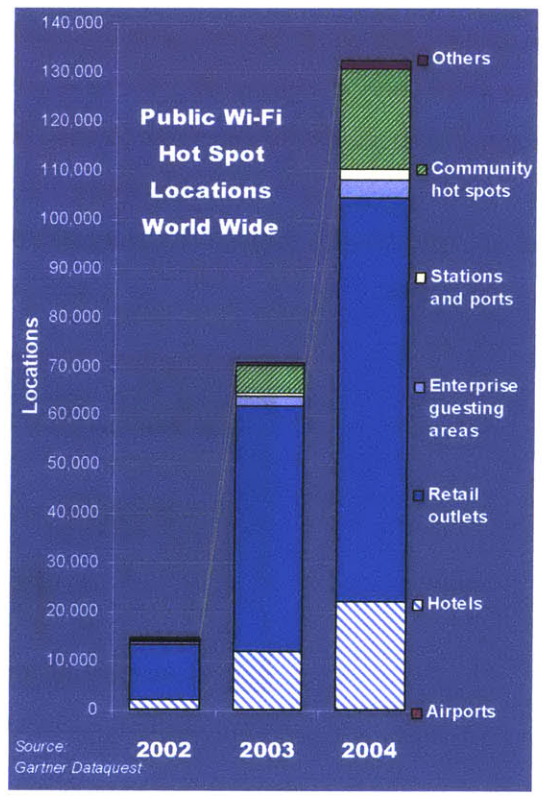

Figure 2.7: Growth in Public World Wide Access Points

[31] The *Industrial, Scientific and Medical* or ISM bands are the unlicensed sections of spectrum created by the FCC. Located at 915 MHz, 2.4GHz and 5.8GHz, they have enabled a enormous proliferation of wireless consumer products from cordless phones to Wi-Fi.

installing public access hot spots as a way to attract customers to their establishment. The strength of this model is yet to be proven, although this provides an opportunity for the satellite operator to enter a new market if the retailers already has the basic credit-card authentication equipment since this infrastructure can be used in install Wi-Fi access points. Finally, it is important for examining Telematics opportunities to note that the public hot spots available today are designed for a user with a laptop that enters their establishment. The antennas are not focused towards the parking lot, although this would take little effort to change.

While 30% of corporation (and growing at 110% per year)[32] are estimated to have Wi-Fi installations, the most explosive has been in the home. Gartner estimates that public Wi-Fi access points will grow 86% per year after 2004 with the total market reaching $1.4 billion by 2009.[33] Today, 4.5 million households are estimated to use Wi-Fi access points[34] to connect their PC to the internet. Interestingly, it is estimated that 25% of households with broadband internet service have invested in Wi-Fi connectivity. This implies that for these consumers, the role and usefulness of the internet has extended beyond the home office. For vehicles, these home hot spots may provide the first access points of convenience as users savvy enough to install Wi-Fi in their homes, will likely be the first to see value and feel comfort in configuring their vehicles to access applications through their home internet connections. The most interesting aspect in the growth of Wi-Fi hot spots is that many home users have left their nodes open for anyone within range to use. While it is unclear how long this will continue and how much it is simply due to ignorant users, it has resulted in an extensive network of uncoordinated but free access points. It is arguable that this behavior has accelerated adoption since one only needs a $50 client Wi-Fi card to begin to experience the benefits. Once the value of Wi-Fi has been demonstrated, it is an easier decision to the consumer to invest in an access point. Finally, with all this demand, the price of a Wi-Fi chipset has dropped to $4. This places it in direct competition with other, similar technologies, such as the Bluetooth standard, that was originally designed to have lower performance but at a lower cost.

2.3 mP2P: Mobile Peer-to-Peer Networking

Wi-Fi type wireless broadband technology can operate in one of two modes. In infrastructure mode, clients access a wired network through stationary access points or "hot spots." When installed in an institutional environment, network engineers locate the access

[32] Park Associates
[33] Frost & Sullivan
[34] Drucker, 13-Feb-04.

points so as to insure consistent coverage throughout the targeted area while minimizing overlap and thus interference. Like cell phones, this requires an upfront investment. The other mode is peer-to-peer. (P2P) In this configuration, client computers can connect to each other, regardless of the existence of access points. With PC's this Wi-Fi functionality has shown limited utility. However, peer-to-peer communication has been found useful in other contexts.

2.3.1 Bluetooth

Bluetooth[35], which operates exclusively as a P2P technology, represents the most promising pure P2P networking standard today. Although it has yet to become widespread, the promise remains compelling as a cable-replacement technology. Designed as the lightweight, low cost, range and power P2P cousin to Wi-Fi, Bluetooth allows consumer electronics devices to communicate between them. For example, a Bluetooth-enabled cellular phone can connect directly to an enabled PC, without the need for a cable. This allows, for example, the synchronization of contacts between one's contact manager on their PC and their phone. An enabled PC can print directly to an enabled printer without having to attach the traditional bulky printer cable to the LPT port. The lack of widespread adoption has been generally attributed to the proliferation of several flavors of Bluetooth, thus countermanding the benefit of a standard.

In telematics, Bluetooth has the potential to allow one's cell phone to connect with a compatible vehicle's audio system so the user could experience a hands-free conversation while driving, without having to purchase a separate phone and service plan for each vehicle. It could similarly provide connectivity for an onboard telematics system. Since OnStar currently has its own built-in cell phone, a Bluetooth option would present competition to this existing service thus making it less attractive to GM. However, several other OEMs have publicly stated an intention of adding this feature to their cars in the next year.[36] For a vehicle, peer-to-peer networking would involve cars communicating directly with other automobiles. Wi-Fi, or a variant thereof is a good starting point for considering vehicle P2P since at ranges of up to 300 meters, it would allow vehicles to connect while allowing safe traveling distances. For these moving applications, we refer to this as *mobile* peer-to-peer or *mP2P*.

[35] BlueTooth 1.1 is listed as standard IEEE 802.15.1. Like Wi-Fi, it uses the 2.4GHz ISM band, but it limited to 1 mbps of bandwidth, 10 feet in range and eight, simultaneously connected nodes. While it does not support the TCP internet protocol, its simpler interface permits easier connections. [Davies]

[36] Specifically, the following OEM's have publicly announced precise future vehicle models to include Bluetooth: Acura (branded as HandsFreeLink in the 2004 TL); BMW (standard or as an option in all vehicles starting in 2004); Chrysler (branded as Uconnect, as an option in 2004 models); Ford (branded as Mobile-ease in all 2004 Lincolns); Lexus (standard in the 2004 LS430 & LX470); Mercedes (standard in the 2005 S-class); SAAB (2004 9-3); Toyota (integrated with navigation system in the 2004 Prius).

2.3.2 Mobile Ad Hoc Networking: $mP2P^N$

A natural extension of peer-to-peer communications is to use those peers as repeaters to, in effect, connect to their peers, and so on. One way to think of this is as mobile peer-to-peer to the N^{th} power or $mP2P^N$. In practice, this is called *mobile ad hoc networking* or MANet. Mobile ad hoc networks are self-forming and self-healing. That means that one is continually updating the path to get from you to your destination. Figure 2.8 illustrates how multiple individuals with mP2P devices might connect to each other and thus connect to an access point that is out of range of their individual device. For the sake of simplicity, going forward we will assume that mP2P encompasses both direct connection (no hops) as well as ad hoc networking were peers serve as repeaters (1 to N hops.)

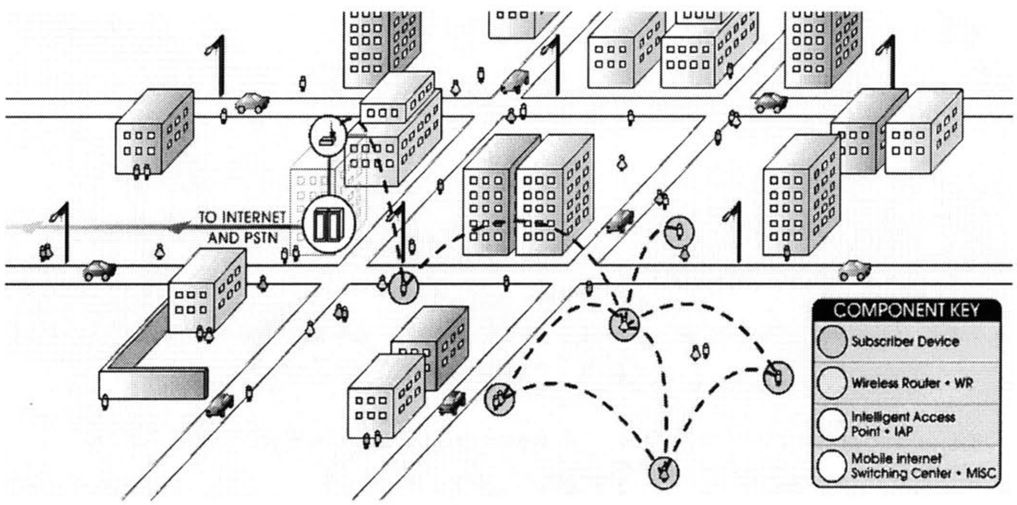

Figure 2.8: Illustration of mobile ad hoc system with connectivity to internet [MeshNetworks]

2.3.3 Viral Communications

The theoretical potential of mP2P is in its strength as a *viral communications system* and thus its ability to leverage the dynamics of *viral growth*. Lippman and Reed describe viral adoption as "a system architecture that can be adopted incrementally, and gains momentum as it scales."[37] The characteristics that make mP2P viral are:

- "Intelligence at the leaves:" Self-forming, self-healing networks.
- Scalability: bandwidth, quality & reliability scales with number of nodes.
- Density benefit: mP2P service improves, relative to an infrastructure system, as user density increases.

[37] Lippman & Reed, p5.

- Geographically dynamic: capacity moves with users.

These benefits are discussed below. In addition, they describe the secondary requirements for viral systems to be *future proof and adaptable.* We will address these issues further in Section 7.2, Technology Strategy.

Intelligence at the Leaves

Traditional wireless systems, such as cell phones, have centralized control. Pure peer-to-peer systems have distributed intelligence which allows self-forming, self-healing networks. Each node only needs to be aware of their own neighborhood of nodes.

Scalability

In an infrastructure system, a cell tower or access point has a set capacity of bandwidth (often seen as a limit in the total number of users per site.) The first user has all the bandwidth to themselves; each additional user increases the denominator, thus dividing the same capacity by the larger number of users. In a peer-to-peer system, the number of direct connections and potential paths to a destination within a given range scales geometrically with the number of nodes. Assuming that each connection has a fixed bandwidth, the total system bandwidth then scales with the number of nodes. As mentioned below, in practice the administrative[38] overhead associated with maintaining the network also scales geometrically with the number of nodes, so the total growth is more modest. Since the number of connections scales with the number of nodes, and each alternate connection can be considered a backup for the primary, the service quality and reliability also increases with the number of users.

Density Benefit

Due to the two reasons mentioned above, mP2P systems work best where the density of users is high. This is in stark contrast to infrastructure systems where system performance degrades as density increases as more users compete for the same bandwidth. Since the range of a radio scales with the square of power, having a shorter hop to the nearest neighbor implies the need for lower power. This, in turn, decreases the level of interference for all its neighbors. The assumption here is that each node will decrease its transmitter power to the level now required for a closer user. Reed & Lippman continue:

> *In 1995, Tim Shepard demonstrated an ad hoc, edge-based scalable network architecture whose capacity increased as the number of user nodes increased.*

[38] Administrative overhead here includes both the load associated with updating routing tables as well as the bandwidth used to forward the packets of data from other users.

This counterintuitive result contradicted the conventional wisdom that the capacity of radio architectures must be fixed and limited... Shepard's packet repeater network design works because each node forwards packets of information on behalf of each other node. Since the power needed to reach an adjacent node is reduced by a factor equal or greater to the square of the distance, the total amount of energy used to carry a bit from source to destination is reduced. And since the energy radiates over a narrower region, the total amount of information that can be simultaneously traveling in the network increases as the nodes in the network get denser. In effect, each node is a "tower" for all of the nodes that are nearby; the "cells" are defined by who wishes to communicate with whom rather than the topography or zoning requirements of the place.

Capacity moves with users

The most interesting characteristic of a mobile peer-to-peer system is that the capacity moves with the users. This is an enormous potential benefit over infrastructure systems where the operator must predict system requirements and thus user behavior far in advance. This necessitates placing risky bets. To control their exposure, companies will naturally elect to build out less in advance, waiting instead for the usage demands to inform future decisions. Then, even for the most agile companies, securing the property and building out the access site delays the response time and thus the user's experience. In practice, most mP2P applications require access to the terrestrial, wired network, thus still necessitating some infrastructure build-out. However, the mobile peer-to-peer connectivity and moving capacity would reduce this substantially.

2.3.4 Limitations of mP2P

Mobile ad hoc peer-to-peer networking is an area that is currently experiencing considerable attention in both the academic as well as the commercial sector. The intensity and nature of work at universities such as MIT[39] and Carnegie Mellon University[40] suggest that many challenges remain in the commercial adoption of mP2P telematics. Besides the natural market limitations of not having enough users, the topic of Chapter 6, the technical issues to be aware of are summarized below:

[39] The work of Prof. Robert Morris, among others, at the MIT Laboratory for Computing Systems on peer-to-peer system architectures and protocols such as the Grid Ad Hoc Systems Project and the *Roofnets* project provide insight into the leading issues confronting this technology. More information can be located at: http://www.pdos.lcs.mit.edu/roofnet/.

[40] The work of Prof. Brad Karp at Carnegie Mellon, among others, on the scalability of mP2P systems suggest the challenges that remains to be solved. More information may be found at: http://www.cs.cmu.edu/~bkarp/

- Interference: The issue of interference, mentioned above, remains forever a concern, but is rather well understood. Much work has been done simulating and experimenting with ad hoc peer-to-peer type systems. The one factor that requires further investigation is the impact of dense concentrations of metal-clad automobiles on system performance. Morris has suggested that the sheet-metal exteriors could act as reflectors, thus increasing multi-path interference.
- Administrative overhead & network complexity: If P2P systems had no administrative overhead, they would a truly scale exponentially with number of nodes. This overhead is largely due to the communication that results from each node updating each other node of its location for the purpose of updating their routing table.
- Security & authentication: Many applications require users to authenticate themselves. While there are a great many ways to achieve this, they all include a role for some central organization to serve as the clearing house for information. This is particularly so if users wish to encrypt information so that other users cannot snoop.

2.3.5 Commercially-Available mP2P Technology

Several companies are currently offering mobile peer-to-peer technology; the most mature is likely MeshNetworks of Maitland, Florida. Focused principally today around providing mobile ad hoc networks to municipal law enforcement and emergency response entities such police and fire departments, Mesh's technology is designed around reliability and a guaranteed minimum data rate. Their proprietary "Mesh Scalable Routing" protocol tries to solve some of the limitations due to administrative overhead traffic that occur as the number of nodes increases past 100. Figure 2.9 below shows the administrative overhead due to routing as a percentage of total bandwidth for the commercially available mP2P technology available from MechNetworks Inc.[41] In this configuration, they are limited to about 1,000 concurrent nodes in a single "neighborhood."

Mesh's systems are "radio agnostic" meaning they can operate in the 2.4 or 5.8 ISM bands, or a licensed band in the same range. When used in conjunction with a 2.4 GHz Wi-Fi radio, they have demonstrated a range of a third of a mile and reliable 1 mbps of usable bandwidth per user. In this configuration, the balance of available bandwidth (up to 11 mbps for Wi-Fi) is saved for relaying traffic from other nodes and administrative overhead. While this is

[41] Stanforth & Suter, Personal Communication.

far from the ideal system, there are numerous ways proposed in the technical literature to increase scalability by allowing separate neighborhoods to communicate.

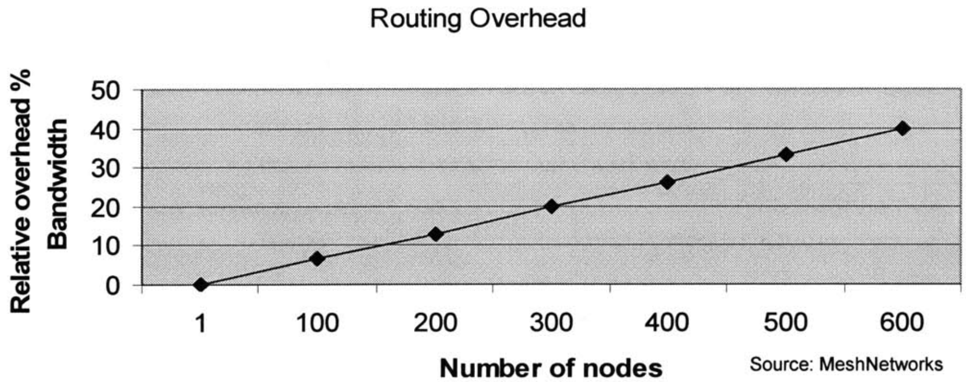

Figure 2.9: Routing Overhead vs. Number of Nodes in MeshNetworks' Technology

For municipal installations where the user density is low, they install inexpensive, regularly-spaced repeaters in the coverage area to allow the system to perform as if there were more users. In their proposal to outfit Miami Dade county, they bid $10,000-$12,000 per square mile to install the system, including all repeaters and network access points. From a strategic business perspective, MechNetworks has stated their willingness to license their technology for other companies (like automotive OEMs) to use in products they manufacture on their own, thus facilitating reduced unit cost and reduced business risk for applications with large potential markets. In the modeling in Chapter 6, we relay on the specifications of the MeshNetworks system is its performance is proven (as well as being demonstrated to the author.)

2.4 Other Competing or Complementary Standards

2.4.1 DSRC: Licensed Active Safety

As the software content in vehicles has risen over the years, the number of potential applications for Wi-Fi enabled vehicles has surged. Today, the consumer electronics company Kenwood is adapting their in-vehicle digital music player (the "Music Keg") to access music stored on a consumer's home PC over a Wi-Fi connection. Although we discuss these applications in detail in Chapter 4, Applications, one technology is worth mentioning here. A dedicated band of licensed spectrum immediately adjacent to the 5.8 GHz unlicensed band has been allocated to vehicular applications. The proposed DSRC (Dedicated Short Range Communications) standard has been designed to accommodate both vehicle-to-infrastructure and vehicle-to-vehicle communications with a focus around Active Safety Telematics. While the targeted applications are, like Safety & Security Telematics, characterized by low bandwidth and high reliability, they also require extremely low latency. Low latency implies a very short (measured in nanoseconds) delay between the time a message is broadcast, and the time the interested vehicle received and decodes the information into useful information. The motivation is that traditional infrastructure type systems such as cell phones cannot provide the required latency. Only direct, peer-to-peer type connections will suffice. The DSRC standard combines dedicated channels for high priority messages with lower priority channels for latency-tolerant, media-rich applications. It was positioned directly adjacent to the 5.8GHz unlicensed band so a single radio and chipset could easily be designed to use both bands.

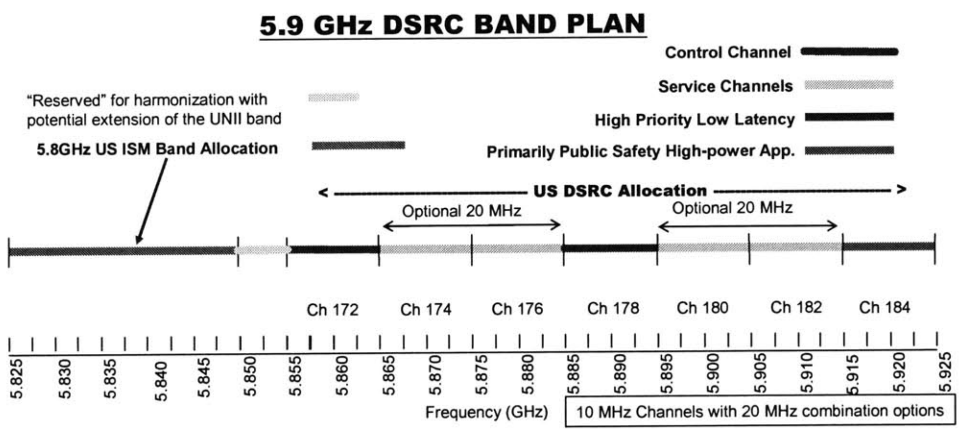

Figure 2.10: DSRC Band Allocation Plant (unratified)

The priority of the emerging DSRC standard (illustrated in Figure 2.10) is public safety and convenience. It is envisioned to include capability for applications such as: the notification of the proximity of emergency vehicles, automated toll collection as well as vehicle-to-vehicle active safety broadcasts. It would likely be supported by an infrastructure of transponders alongside the road to disseminate information. While it is an important development to keep apprised of, we consider it to be ancillary to the core strategies we are developing for this thesis.

2.4.2 MANs: Metropolitan Area Networks

Recently, a new category of wireless networking technology has come to the forefront. These metropolitan area networks or MANs provide 100+ mbps wireless broadband at distance up to tens of miles and were originally conceived as a potentially less expensive alternative to provide broadband services to offices in urban areas where pulling cable or fiber through old or tall building can be prohibitively expensive. The most mature is "WiMax" or IEEE standard 802.16.

A competing standard with capabilities to support for devices moving at up to 150 mph is IEEE standard 802.20 or "Mobile Broadband Wireless Access." (MBWA) According the IEEE, the MBWA scope is the "specification of physical and medium access control layers of an air interface for interoperable mobile broadband wireless access systems, operating in licensed bands below 3.5 GHz, optimized for IP-data transport, with peak data rates per user in excess of 1 Mbps. It supports various vehicular mobility classes up to 250 Km/h in a MAN environment and targets spectral efficiencies, sustained user data rates and numbers of active users that are all significantly higher than achieved by existing mobile systems."[42] While still in its infancy, this standard provides the most credible threat of a technology able to compete with mP2P directly on a bandwidth and cost per byte basis. However, it will be many years to see if any companies ever begin developing products for it.

2.5 Proposed Architecture & Technology Conclusions

While the final technology architecture proposed is detailed in Section 7.2, we will summarize the major conclusions of this chapter here. As one can see from Appendix A, there are a dizzying number of competing wireless technologies. Although they each have their specialty, there is much overlap. By far, the biggest concern of Automotive OEM's is that they install a system based on a particular technology in their vehicles, and three, five or seven years later it is superseded by a newer, better one. It is for this reason, that the market dynamics and corresponding business strategies are so important in validating the strength of mP2P.

Market dynamics aside, a successful Consumer Telematics system will require inexpensive, high bandwidth connectivity. Due to the natural physics of radio communications, there will always be the trade-off between bandwidth, range and spectral capacity. Based on the conclusions of the McKinsey report, and as will be discussed in Chapter 4, there are numerous consumer applications which will only become possible with high bandwidth and more importantly, low cost bandwidth. Thus, we posit that consumer telematics will only become possible through mobile wireless broadband. While 3G cellular phones promise capacity near the low end of a Wi-Fi system, their economics, latency and limited bandwidths for moving users make them less competitive for wireless applications than Wi-Fi and its brethren. Wi-Fi has brought low-cost wireless broadband to stationary applications in the home, office, hotel, airport and in retail establishments. Since vehicles spend most of their time parked, applications that do

[42] IEEE 802.20 Working Group web site: http://grouper.ieee.org/groups/802/20/

not require real-time data could benefit form Wi-Fi connectivity today. The 4.5 million consumers with Wi-Fi at home could take advantage of these applications today.

Automotive OEM's, like GM, are close to justifying the cost of putting Wi-Fi in cars simply due to the cost benefit it would engender from the internal warrantee servicing and order-to-delivery costs it would offset. The initial impetus behind this research was the question: "if GM started factory-installing mP2P-capable Wi-Fi in cars, what additional revenue opportunities might result?"

Pure mobile peer-to-peer applications would permit low-latency active safety vehicle features. If the mP2P-enabled vehicles also served as mobile routers, permitting mobile ad hoc networking, vehicles could then communicate with other vehicles outside the range of their transmitter alone. When combined with a sparse network of roadside repeaters and access points, as the MeshNetworks system does, mP2P acts to extend the range of those terrestrial nodes, thus allowing a lower initial infrastructure investment. In terrestrial broadband, this "last-mile" connectivity has historically been the biggest financial and logistical barrier to widespread adoption. MP2P could thus become the "last-mile" connection for inexpensive Wi-Fi type wireless broadband.'

While the 802.11b Wi-Fi protocol is not well suited for moving nodes, MeshNetworks has shown that my modifying the underlying system slightly, these 2.4 GHz ISM band protocols can handle connectivity for vehicles moving up to 80 mph. Current PC cards show that engineers can design inexpensive chipsets and antenna systems that can communicate using the original 802.11b Wi-Fi standard as well as the 54 mbps 802.11g and 5.8 GHz 802.11a standards. Thus, we conclude that, given sufficient volume, it would be possible to design a single, inexpensive system to be backwards compatible with the stationary Wi-Fi system as well as the additional enhancements necessary to provide moving connectivity through mobile ad hoc peer-to-peer. Several independent estimates suggest that adding mP2P networking capability to an existing vehicle telematics platform such a network card could cost less than $30 at volumes of less than one million units.[43]

Naturally, the rest of the automobile's telematics system necessary to take advantage of this connectivity would cost $150-$800 more depending on the features. However, consumers have shown a willingness to pay these types of prices for premium radios, smart phones and

[43] Hardt, Personal Communication.

PDAs. In fact, onboard navigation and DVD systems are priced today as $1000 to $2500 vehicle options.

In conclusion, the presumed system architecture would be based on an upgradeable card which includes backward compatibility for Wi-Fi as well as a mobile variant of the 802.11 class of standards that uses mobile as hoc P2P connectivity to communicate with other vehicles and terrestrial access points. Vehicle users would be managed and authenticated by a central service. Any user agreement would require that in order to access the extended range and terrestrial connectivity mP2P permits, they acknowledge that their receiver must also serve as a repeater for data from other users. If they did not, or in areas where there is no infrastructure, vehicles could still communicate in a pure peer-to-peer mode or directly with a Wi-Fi access point in their homes.

Chapter 3 The Telematics Value Chain

To understand the Telematics market as well as the interaction of the myriad players necessary to service it, requires us to fully understand the Value Chain. This is important because understanding the value chain provides insights into which segments of it are currently (or will likely soon become) commodities. From a business strategy perspective, it is best to structure one's technical architecture and business strategy so these commoditized services may be outsourced to other companies that do it better or cheaper. Inherent in this is the premise that the consumer electronics and wireless networking industries move so quickly that a single company will not have the resources, expertise nor agility to remain the market leader in all components of the telematics value chain. Thus, it is critical to make the best assessment of which functions are ideal to serve in-house and which are best to serve through partnering with dedicated organizations. In this chapter, we present the telematics value chain for all three markets, and then use the analysis to recommend the best potential business strategies for further consideration.

Plotting the value chain of an industry, we found, is an imprecise science. There are a number of potential frames in which use to present the information. We chose one that highlights competitive or substitute classes of technology as well as the key interfaces in which they interact. Much of the information referenced comes from Chapter 2 and its discussion of the platform architecture.

3.1 Value Chain Structure

In order to highlight these competitive issues, we broke the Telematics value chain up into two, parallel chains: infrastructure and services. Infrastructure includes functions that are based on physical hardware. Services include functions that that based on software, systems, labor pools or know-how. In many cases, the same firm may provide both services and infrastructure. However, since they can be provided by different firms, and the dynamics for replacing services is different from physical hardware or infrastructure, we felt it was instructive to keep them separate. Figure 3.1 illustrates our high-level telematics value chain.

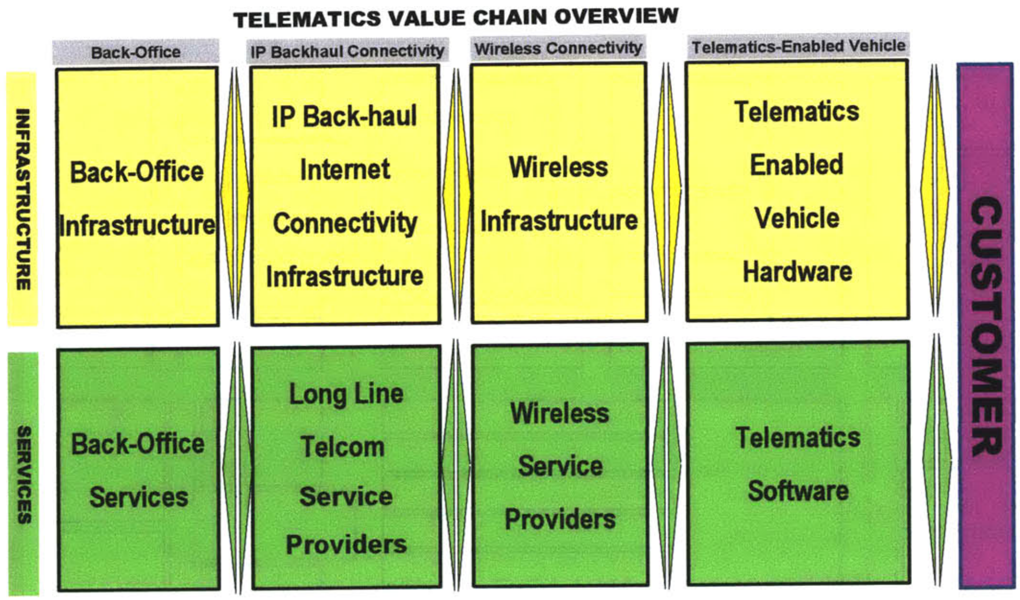

Figure 3.1: Telematics Value Chain

The telematics value chain consists of five components:

- The Customer,
- Telematics enabled vehicle hardware and software,
- Wireless connectivity infrastructure and service providers,
- IP backhaul internet connectivity infrastructure and services, and the
- Back-office infrastructure and services.

Each link in the chain only communicates with the adjacent links. While the infrastructure and service components cannot function without each other, they have different interfaces. This is largely due to the fact that individual firms have expanded across multiple markets in response the rapid evolution in technology and customer demands. For example, cable companies have expanded into broadband internet service and most recently into telephones services. Most recently "Voice over IP" (VoIP) firms have begun offering phone service to customers with broadband connections even though they have few if any traditional TelCo assets and certainly none physically connected to their customer who communicates with them over their existing internet connection. To better understand what is included in each link, Figure 3.2 presents a greater level of granularity in system architecture and technology substitute options.

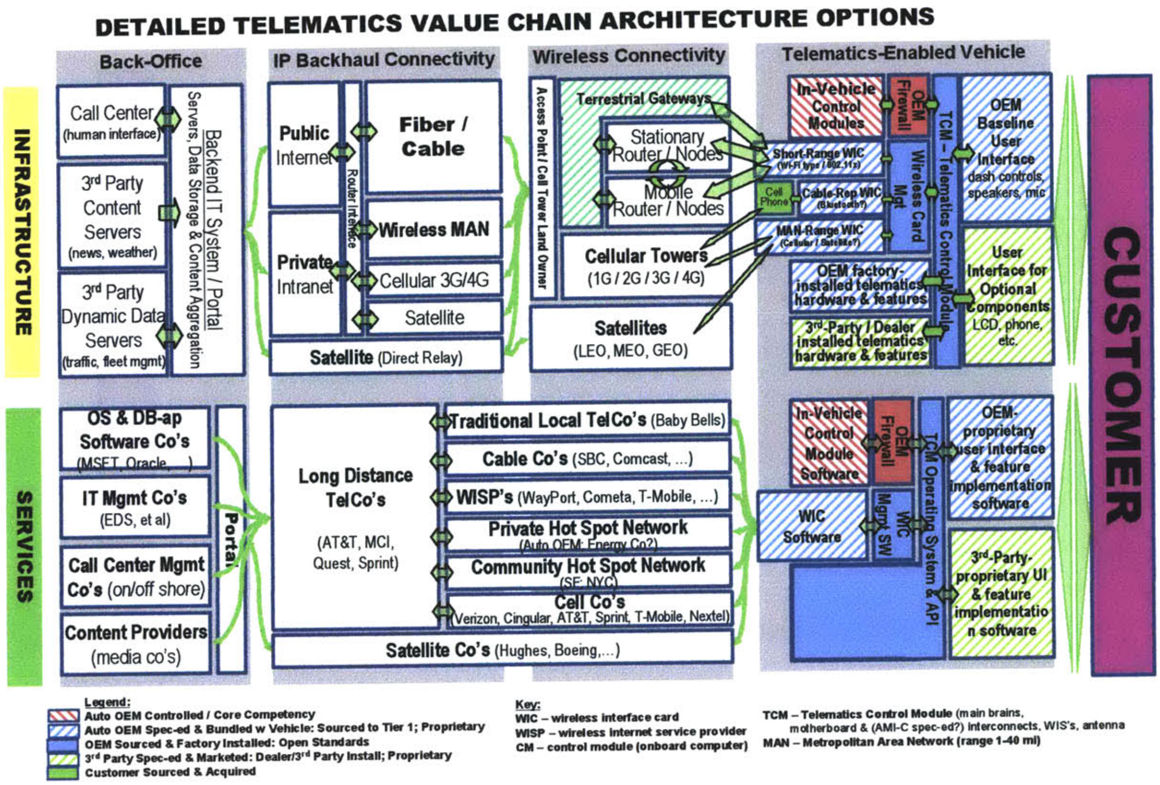

Figure 3.2: Telematics Value Chain Detailes Including Interfaces and Competors

3.2 *Telematics-Enabled Vehicle Hardware & Software*

The "telematics-enabled vehicle" link in the chain includes all the vehicle components involved in providing the services. The customer, however, interfaces only with the hardware and software that comprises the human-machine interface (or HMI.) This includes at a minimum some buttons on the dashboard or steering wheel but may also include: the audio system, a build-in microphone, a LCD monitor, a heads-up display or independent cell phone controls. Traditionally, Automotive OEMs only sell their vehicles with proprietary built-in audio, trip computer or navigation systems. This allows them to both have complete control over the customer experience as well as minimize costs through standardized factory installation. For audio systems, new car buyers typically have the chose of either a standard or a premium, branded radio system, but both are highly integrated.

In contrast, Figure 3.2 accommodates both proprietary built-in systems along with third-party HMI elements. While this would represent a major shift for OEMs, it is worth considering due to the strategic implications we discuss in greater later. In brief, it allows OEMs to leverage outside investment and innovation and allows customers to upgrade their vehicle telematics system with additional features once wireless service improves and they perceive it is worth the investment. In other words, its decouples the product evolution clockspeeds of the vehicle (5-15 years) from the consumer electronics (3 months to 5 years).[44] This argument also applies to the "brains" of a telematics system since processor and memory evolves on a 1-3 year cycle.[45] Everett discusses the importance of managing these clockspeed boundaries through standard interfaces in both hardware (through connectors) and software (through applications programming interfaces or API's).

The third component of the in-vehicle telematics system that would need to be segmented from the balance of the system that would remain unchanged for the life of the vehicle is the wireless connection hardware. Since wireless technology is destined to evolve several times over the fifteen-year life of a vehicle, it would also need to be upgradeable. In all likelihood, a comprehensive telematics system would have at least two wireless connectivity alternatives: one for short range, wireless broadband enabling mP2P Wi-Fi, and a second for long range, low bandwidth, "ubiquitous" connections such as a cell phone as the current OnStar and ATX systems use in the U.S. today.

The balance of the system would be highly integrated and remain for the lifetime of the vehicle. The criteria for deciding which elements are not upgradeable are: cost, clockspeed and OEM liability. For example, each OEM has their own proprietary systems that control build-in vehicle functionality. The engine, automatic door locks and airbag are each managed by a separate proprietary control module inside the vehicle. OEMs are very sensitive to who has access to these since they can impact vehicle safety and reliability. Thus, for an OEM to allow third party companies to interface with a vehicle telematics system, they would need to design the system so they are comfortable that these core modules are not compromised. In practice, this can be achieved by controlling the API and hardware interfaces, licensing and product approval procedures. A lighter option is the technique Microsoft employs where PCs are tested in order to receive "Designed for Microsoft Windows" certification. An OEM could stipulate that installing uncertified hardware or software voids the warrantee.

For software, upgrades are naturally easier as they could be performed by downloading new software (assuming there was sufficient memory and computing capacity) through the wireless connection and could even be transparent to the user. Like today's PDA's, the system

[44] Fine, p. 239.
[45] Ibid.

would only be compatible with a single brand of operating system, thus guaranteeing system control, stability and efficiency, but would allow users to install third party applications.

3.2.1 Benefits of Modular Architecture

This modular architecture is not unlike that of the PCs or many of the more powerful PDAs. In fact, we feel that early implementations could be based around today's PDAs which combine durability, flexible operating system platforms that permit new applications, color screens, Wi-Fi or cellular wireless connections and expansion slots for additional memory or accessories. Having replaceable wireless connection cards, would allow users to upgrade to the newest version of Wi-Fi, or switch cellular carriers thus alleviating risk of betting on any particular company or technology as OnStar has done with Verizon and analog. If a metropolitan area network (MAN) wireless broadband technology such as WiMax (MMDS or 802.16) or MBWA ever develop, users could add that connection option as well. Requiring that communications use standard TCP/IP packets would allow the telematics system to be agnostic to the wireless technology used. By permitting third party developers to create new applications and accessories, OEM's would both limit their initial investment and increase the value of such systems by creating an environment that encourages the development of a richer range of options of what one could do with such systems. Also, if developers were able to innovate in the HMI, there is a greatly increased likelihood that one would come up with a truly power interface, analogous to the PC's mouse-driven graphical user interfaces or the simplicity of Palm Computing's PDA operating system. We discuss the business strategy implications of these issues for the OEMs in Chapter 7.

3.3 Wireless Connectivity Infrastructure & Service Providers

The value chain implications of wireless connectivity is more straightforward. As we can see from Figure 3.2, there are a myriad of wireless technologies (and companies) that could provide the service. While one technology may be technically superior for a particular application, there are several others that could do. In fact, the driving factor in this area is not so much the technology as the level of infrastructure penetration. Cellular connections are the leading competitor in the US today due to the intense competition and extensive networks of towers, but are hobbled by the existence of no fewer than four major competing technologies. In Europe and much of the rest of the world, the GSM standard and its 3G successor prevails. In the US, there is a considerably greater infiltration of public Wi-Fi hotspots than in Europe. In developing countries, satellite connections may make more sense since cellular networks are more sparse and unreliable. Metropolitan area networks are nonexistent today, but may become a leading technology by the end of the decade.

The existence of so many competitors and potential substitutes implies that one probably does not want to get into the wireless services business. As the cellular phone service providers (CellCos) have discovered, there is a tendency to compete purely on price thus driving margins down to near-zero levels. In contrast, this creases a great environment for the consumer who experiences a wide range of options with each company working like crazy to win their business. To counteract this, CellCos try to get consumers to commit to long-term contracts. Since cell phones in the US are currently tied to a specific carrier, the consumer's investment in a phone provides the only other barrier to switch now that users can bring their numbers with them when they switch providers.

Even if individual technologies do not evolve (such as 802.11b to 802.11a and .11g), being able to switch carriers is critical for a system architecture to remain competitive. As mentioned, the business risk to an OEM rises if they hardwire a vehicle's telematics system to a specific provider and technology as OnStar has done with Verizon. To counteract the potential for "hold-up," OnStar presumably negotiated a long-term contract with Verizon. However, these types of contracts are necessarily very long and complicated, take years to negotiate, and are inherently inflexible. Individuals we interviewed within OnStar argue that providing an upgradeable phone module increases cost and decreases reliability. In addition, since OnStar uses a proprietary communication protocol, there would presumably be an added barrier to switching carriers. As a result of these issues, as well as its cultural focus on the vehicle design and validation cycle, OnStar's systems are likely planned far in advance. Considering that it is impossible to predict the state of wireless broadband technology and infrastructure three years hence, this structure begets the tendency of an OEM to design its hardware around old, proven systems. While this is fine for low bandwidth Safety & Security Telematics, its inherently uncompetitive where service quality and cost matter.

Since OnStar currently has no competition in GM vehicles, these issues should not currently pose a threat to its business. However, if another OEM started providing a dramatically superior service based on a nimble, modular architecture, OnStar would presumably have to completely reengineer its system to compete. Further evidence comes from the built-in OnStar phone. While driving, the built-in OnStar phone has superior ergonomics to the typical small handheld. However, it is analog, which implies lower quality sound and more expensive minutes.

We would then surmise that many users elect not to subscribe to the OnStar service (after the first free year) simply because they can perform the same functions, albeit with an inferior user experience, with a handheld digital phone for lower cost and higher quality. In the end, the driving question remains: is the added cost of this flexibility worthwhile to the business?

3.4 IP Backhaul Internet Connectivity Infrastructure & Services

While wireless connectivity experiences commodity pricing in it its most competitive areas, IP backhaul is a pure commodity nearly everywhere. Comprised predominately of long-distance fiber optic networks but also satellite and microwave tower systems, IP backhaul is capital-intensive, low margin and an even worse business to be in than wireless. The major providers (AT&T, MCI WorldCom, Sprint, Quest) differentiate themselves through bundled, service and connectivity packages to large businesses. In the late 1990's, the networks overbuilt, creating a glut of capacity.

When the Federal Government deregulated long-distance phone service in the late 1980's, consumers started choosing their own providers separate from their local phone company. Now that the local service is also being deregulated, end users are migrating in the opposite direction. They are increasingly migrating towards bundled packages which provide everything through a single monthly bill; it is clear that for many, simplicity and predictability are most important. In wireless connectivity, the IP backhaul is transparent to the user. If I have a Sprint cell phone, I don't know and don't care whether my voice travels over a Sprint network or that of some other carrier.

So why is this important to Telematics? This answer is standards. If, like OnStar, one chooses a proprietary protocol, it increases system cost, complexity and inflexibility as the data cannot be easily rerouted over large public IP (read: cheap) networks. This ties the consumer to a single provider. Thus, building one's system around an open and common protocol such as TCP/IP insures flexibility and market power.

3.5 Back-Office Infrastructure & Services

There are two models for back-office infrastructure and services: distributed and integrated. For Safety & Security Telematics services such as OnStar, where there is a limited feature set, slow product evolution and premium placed in service quality and reliability, integrated services make sense. In contrast, the world wide web is the ultimate distributed system.

Anyone with an Internet connection can offer services or content over the web. This model allows a lower initial capital investment and tremendous innovation and entrepreneurialism, but permits uncertain quality and reliability.

A hybrid architecture probably makes the most sense for Consumer Telematics. Initially, providers will want to guarantee a baseline of quality and reliability by hosting all their offerings within their own back-office operations. If an entrepreneur wants to sell a new service, they will need to have the integrated provider host their new content or application. However, in order to create incentives for innovation and outside investment, these providers will need to maintain a low cost and barrier to entry. Eventually, these would likely evolve into a constellation of approved back-office providers competing on price and performance.

3.6 Value Chain Conclusions

In conclusion, the Value Chain helps us understand that competencies required to provide Telematics services and the competitive forces therein. We see that a modular architecture for the in-vehicle system "future-proofs" the architecture by providing inexpensive and easy upgrade paths. It also allows the market leader to move faster, because they need less confidence around which wireless technologies will prevail in the future and can rely more on third parties to develop applications and thus supplant investment by the OEM. The Automaker will want minimize costs by factory-installing all components that can remain unchanged throughout the life of the vehicle (i.e. those with the same clockspeed as the vehicle.) In addition, they will need to control the interface standards so they can guarantee that core vehicle control modules are not compromised by components from outside vendors. The areas that will thus benefit most from outside innovation are the human-machine interface, wireless connectivity and the core "brains" of the unit which will also undoubtedly evolve quickly since it is technologically similar to a PDA.

Wireless connectivity and IP backhaul infrastructure and services are commodity or near-commodity services. As a result, the optimum system architecture will be staunchly protocol and carrier agnostic. By allowing changeable wireless connection cards, the vehicle owner can easily switch carriers, thus insuring healthy competition. As long as the communications protocol retains a standard, packetized format such as TCP/IP, the backhaul provider will be irrelevant and thus another commodity provider, likely bundled with the wireless provider. Back-office services are more important, but are modular in nature. The Telematics service provider will initially want to insure a consistent level of service quality and thus will probably want to host and serve as quality control agent for all offerings.

From the perspective of the Automotive OEM spearheading the launch of the new business, we want to structure our strategy along the following guidelines.

- For any commodity service (or one likely to become one soon) such as cell phones or IP backhaul, we should structure the system architecture so as to seamlessly outsource this component yet retain the ability to switch carriers by making the network card upgradeable. This insures the consumer of the wireless services, be it the end consumer or an application service provider, market power over their supplier and thus efficient markets and competitive pricing. In addition, structuring the system as such with low switching costs increases the ability of the Consumer Telematics service providers to compete head-to-head with very dynamic services such as cellular.
- For a new infrastructure-based service such as the broadband network of mP2P-compliant access points, it would be important to nurture the business until the market is established by guaranteeing it monopoly status. However, one would not want to spawn a monster which might later use its position to extract excess profits from all other members of the value chain. As a result, this network card should also be upgradeable, but only to approved providers, thus retaining some level of control to insure allocation of profits throughout the chain.
- For hardware components, the onboard the vehicle telematics system likely to evolve quickly and thus provide superior value to the consumer, we want to insure upgradeability. This inoculates the user against the concern that their system might become obsolete and inspires hardware makers to expand their offerings to take advantage of these new capabilities.
- In contrast, any hardware component that lacks a strong argument for upgradeability (such as the wiring harness connecting components, accessories and native vehicle control modules) should be integrated into the vehicle and factory-installed in order to minimize costs and maximize HMI and reliability. Where possible, individual components (such as memory & CPU) should be combined into a single, upgradeable component to again optimize cost, usability and reliability.
- To maximize innovation and investment in applications and services, the API and interface standards should be available to third-party developers. In order to insure the option to extract value from the this back-office segment in the future, the upgradeable

on-board telematics system components should include either a required license or a recommended certification.

In sum, we want to make sure every segment of the value chain can earn a profit, otherwise there is no incentive to remain in that business.

Chapter 4 Consumer Telematics Applications

4.1 How Does mP2P Enable Consumer Telematics?

The existence of mobile peer-to-peer technology in a car, by itself, provides no value to the end user. However, its capabilities has the potential to enable applications that up to now have either been infeasible or uneconomic. The types applications are broken up by the way in which the technology changes the market dynamics. Thus, we group them as:

- Low Bandwidth Cost Enabled Applications
- Location-Based Commerce Applications
- Low Latency, True P2P Applications
- Ubiquitous Wireless Network Applications

Figure 4.1 illustrates one way that mP2P can serve as the "killer enabler" for Consumer Telematics. Potential applications are organized along a scale of how mP2P changes their inherent business dynamics and makes them feasible. On the left of the scale are applications that are enabled simply by the lower cost per byte of data or the higher bandwidth that Wi-Fi capable mP2P would engender. On the far right are features that require the low latency that only mP2P could facilitate. In between are the applications that combine benefits of both. In general, all applications also leverage an awareness of their location that comes inherent in a mP2P system, and as a result system designers will likely include a GPS transceiver as well.

In addition, the scale shows a rough timeline for when each applications type would become available. For "burstable," non real-time applications, an infrastructure of hot spots is not required as initial users could connect through the 9% of American households that currently have Wi-Fi access points.[46] As we move to the right, real-time connectivity and the infrastructure to support it becomes more important.

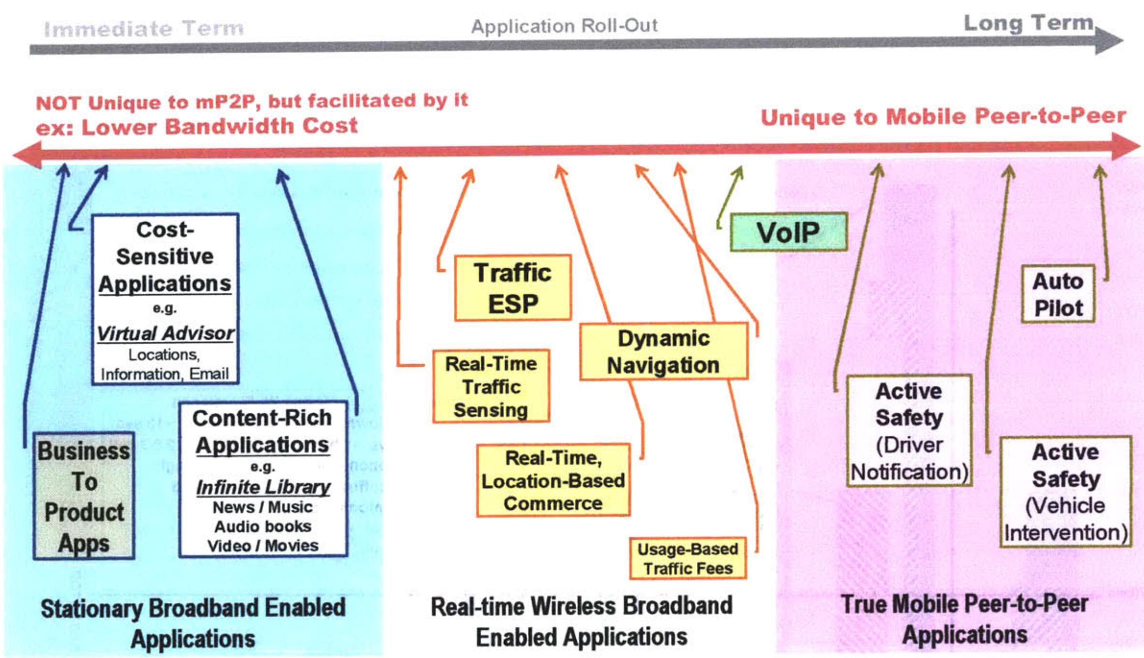

Figure 4.1: Range of potential telematics applications enabled by mP2P

Low bandwidth cost-enabled applications have a high data transfer rate relative to initial user value. The best example from the internet is peer-to-peer file sharing services such as the original Napster or KaaZa. If internet users had to pay for every byte of data they downloaded, few would consider this type of service worthwhile. However, since broadband internet services generally charge a fixed monthly rate for unlimited access (up to a fixed bandwidth), there is no marginal cost to the user for downloading an additional ten megabyte MP3 file. Another unfortunate beneficiary is unwanted email solicitations or "spam." If the senders had to pay for every email they sent, the volume of unwanted email would drop precipitously. It is for this reason that phone solicitators are barred from calling cell phones (because traditionally cell phones owners were charged for usage minutes regardless of whether they initiated, or welcomed, the call.)

4.2 Low Bandwidth Cost Enabled Applications

The first class of applications are those that are purely driven by cost. As raised by the McKinsey report, bandwidth and "value for money" are two of the major factors inhibiting

[46] Economist, 13-March-2004.

Telematics to date. Historically, the two are linked since higher bandwidth generally results in a lower cost per byte transmitted. To assess this quantitatively, we compared the impact of bandwidth on the performance of several wireless technologies. Figure 4.2 shows the time required to download a range of media-rich content. While the market for these examples may be modest, they do provide an instructive indication of how bandwidth can enable an application.

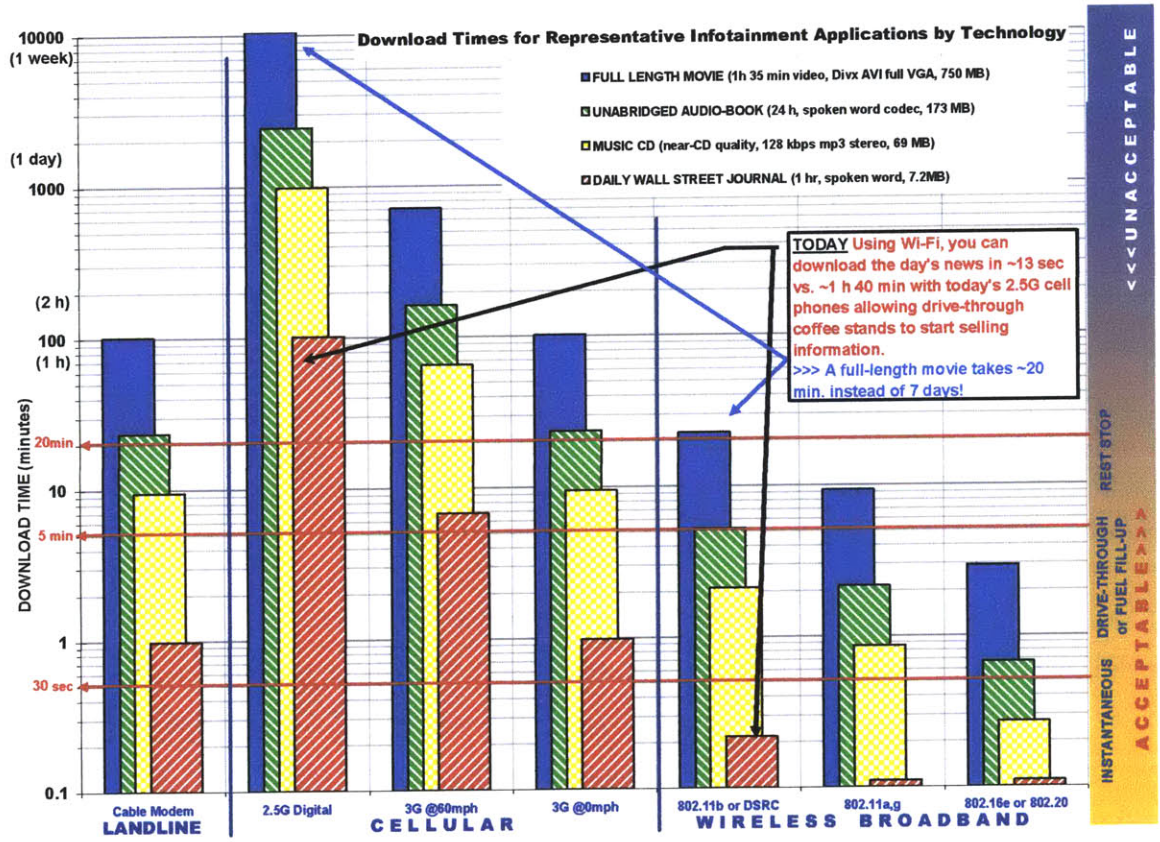

Figure 4.2: Application performance of bandwidth-intensive applications as measured by download times for six wireless and one wired technologies.

For example, using Wi-Fi, you can download the an hour-long program of someone reading the day's news from the New York Times or the Wall Street Journal (provided daily through Audible.com's service) in 13 seconds versus 1 hour 40 minutes with today's 2.5G cell phones. Intuition tells us that at an hour-plus, one would instead choose to listen to the radio. However, if the download only took 13 seconds, one could easily update from one's home Wi-Fi access point right after turning on the car, or alternatively update the data while passing through a drive-through coffee shop, filling up with gas, or even at a traffic light within range of an accessible hot spot. Obviously, the options are many, however it would present new business opportunities for local or national retailers to sell information access as well as their primary business. At the opposite extreme of the bandwidth range, one could download a 750 MB feature-length, full VGA resolution AVI-formatted movie in less than 20 minutes. In this scenario, one could conceive of a family stopping at a rest stop while on a long trip for lunch. In the time it takes to pick up some fast food and visit the restroom, one could have a new Disney movie ready for the kids to view. In comparison, a 2.5G cell phone today would require close to a week to download the same content. Table 4.1 outlines the detailed assumptions that underlie these calculations.

While these scenarios may seem overly narrow, they do provide compelling evidence of how increasing the bandwidth by one or two orders of magnitude, as wireless broadband does, can enable entire classes of previously infeasible or uneconomic applications. In Figure 4.2, we highlighted three time thresholds as symbolic of their ability to change the market dynamics. Twenty minutes is the outer threshold for burstable applications that one would realistically download from a home or during a short stop as for an errand or rest stop on a long trip. Five minutes represents the "gas station" scenario. Since most fueling stations with rapid credit card authentication already have both satellite dishes and business models that benefit from low-cost differentiation , they are a good target for early hot spot installations. Finally, the 30-second threshold is indicative of content that could be successfully downloaded during a "drive-through" transaction or even simply waiting at a traffic light.

Table 4.1: Detailed Applications and Assumptions Used in Figure 4.2 Along with Some Additional Scenarios and Technologies for Comparison

Content Download Time *(in minutes)*		Technology:	Landline			Cellular Phone				Stationary Wireless Broadband			Mobile Wireless Broadband		
		Carrier:	56k Modem	DSL	Cable Modem	Analog AMPS	2.5G Digital	3G Digital @60mph	3G Digital @0mph	802.11b nominal	802.11b average	802.11a,g average	DSRC average	DSRC Perform.	MMDS 802.16
Content / Quality	**Encoding**	(kbps)	52	384	1,000	0.300	9.6	144	1,000	1,500	4,500	11,000	4,500	13,500	*35,000*
Wall Street Journal Daily - 1 hr															
Low-Quality Spoken Word*	8 kbps, mono	3.7 MB	10	1.3	0.5	1,684	53	3.5	0.5	0.3	0.11	0.05	0.11	0.04	0.01
Good-Quality Spoken Word*	16 kpbs, mono	7.2 MB	19	3	1.0	3,280	103	7	1.0	0.7	0.22	0.09	0.22	0.07	0.03
Good S.W; Poor-Q Music**	mp3, 33 kbps, mono	14.4 MB	38	5	2.0	6,560	205	14	2.0	1.3	0.44	0.18	0.44	0.15	0.06
Music CD - 74 minutes															
Nominal Quality	96 kbps,stereo, mp3	52 MB	137	19	7	23,680	740	49	7	4.7	1.58	0.65	1.58	0.53	0.20
Good Quality	128 kbps,stereo, mp3	69 MB	182	25	9	31,573	987	66	9	6.3	2.10	0.86	2.10	0.70	0.27
Near-CD Quality	192 kbps,stereo, mp3	104 MB	273	37	14	47,360	1,480	99	14	9.5	3.16	1.29	3.16	1.05	0.41
Audio-Book															
Abridged Book, 6 hrs***	16 kpbs, mono	44 MB	114	16	6	19,844	620	41	6	4.0	1.3	0.54	1.32	0.44	0.17
Unabridged Book, 24 hrs****	16 kpbs, mono	173 MB	454	62	24	78,720	2,460	164	24	15.7	5.2	2.1	5.2	1.7	0.7
Video															
Full-length Movie: 1h 35 min	AVI, 1/4 screen	214 MB	563	76	29	97,524	3,048	203	29	20	6.5	2.7	6.5	2.2	0.8
Full-length Movie: 1h 35 min	AVI, Divx, Full VGA	750 MB	1,969	267	102	341,333	10,667	711	102	68	22.8	9.3	22.8	7.6	2.9
Full-length Movie: 1h 35 min	Full DVD Quality	3500 MB	9,190	1,244	478	1,592,889	49,778	3,319	478	319	106	43	106	35	14

Primary Source: Audible.com *(Personal communication, Foy Sperring, Senior VP Strategic Alliance, 26-Sept-2003)*

* Codec used for "Format 2 & 3" are optomized around spoken word as opposed to MP3 which is centerd around music; thus 16k SW & 33 k MP3 provide equivalent audio fidelity

** Audible MP3 format provides the same spoken word quality; Necessary for devices which don't support the "FM Radio" codec or include music.

*** Abridged / Short Audio-Book: ex: Tom Clancy, The Bear and the Dragon, 6h 3 min

**** Unabridged / Long Audio-Book: ex: Happy Potter & the Order of the Phoenix, 24 hrs

As the Web has shown, the range of potential applications enabled by bandwidth is limited only by imagination and the industriousness of a few entrepreneurial software engineers. If history is any indicator, it is nearly impossible to predict which types of applications will prove most compelling to consumers over the long term. However, representative examples of applications with burstable content include:

- "Infotainment" applications such as the "Infinite Library" of movies, music and spoken audio programs.
- Mobile-office applications that download and read email or other available content.
- Updated navigational maps or traffic data.

One example coming soon to market is Wi-Fi enabled digital music players for the vehicle. Kenwood's current Music Keg product consists of a cartridge-type hard disk that one removes periodically from the vehicle and connects with one's PC to download music. A future evolution would allow individuals to connect directly over Wi-Fi access points in their homes.[47]

Since betting on any single application is unwise, the value would come from insuring that the Telematics platform was sufficiently flexible and upgradeable so that it would accommodate new applications as they become available. We discuss the business model implications of these decisions in Chapter 7.

4.2.1 Business-to-Product & Business-to-Business Applications

There are a number of alternatives, taken together, which could generate sufficient value during this critical startup period. The first involves the class of business-to-product (B2P) applications. These would take advantage of the wireless broadband connectivity and powerful computing environment enabled by the mP2P telematics system. GM has performed extensive internal study of the potential applications and the value they would provide to the organization. Although the details are proprietary, it has determined that they are sufficient that they value they create could help, in effect, subsidize some of the cost and thus help justify their inclusion in future vehicles. One example that has been discussed openly is the cost savings that would result from being able to wirelessly provide software updates to new vehicles as they become available, rather then having to pay dealers to do it using the traditional wired connection and manual labor. Another area of interest is in the ability to gather data on the performance of these new vehicles, thus allowing engineers to spot problems months earlier than is currently the case. While many of these applications could also be achieved through the future generations of OnStar hardware, there is no reason an mP2P system could not provide these services instead.

Another customer for B2P applications would be fleet owners. An enabled vehicle could track data on vehicle usage and service level and wirelessly update the fleet manager's computer systems at the end of each day when they return to base. The more powerful consumer

[47] Speerling, Personal Communication.

telematics systems could also download updated data from the companies' servers in the morning on routes, customers or navigation for use by the driver during the day. While many applications of this type already exist as after-market, user-installed option, if the built-in consumer telematics system provided a superior or less expensive (or both) alternative, it would be attractive to these corporate customers.

4.3 Location-Based Commerce Applications

Location-based commerce (LBC) implies applications where geographic positioning is a key component. We break them down into two general groups: Business-to-Consumer (B2C) and Government-to-Consumer (G2C). Of the B2C applications, Real-time traffic is the most compelling and as a result, we discuss it separately. From a technological perspective, location-based commerce type applications differ from the previous burstable ones in that they require a nominal level of mobile connectivity. However, the service level may be very low. If one is uploading traffic data or advertisements for local merchants, these services could tolerate service levels as low as 10% as long as it was, say, 20 seconds every three minutes (and transparent to the user.) The benefit of this characteristic is that it would initially allow a sparse matrix of access points or enabled, repeater vehicles thus decreasing the initial infrastructure cost.

4.3.1 Real-time Traffic

Market research performed by General Motors and OnStar, as relayed through interviews[48] suggests that one of the most compelling applications would be one that used real-time traffic data to provide dynamic routing and navigation to the driver. As the story goes, right now the typical commuter runs into a traffic jam and only then turns on their local AM news radio station for the update. In addition, this information is delayed and only of marginal benefit. If a driver knows as soon as they start their vehicle the best path to work at that precise moment in time based on real-time status of congestion, accidents and construction, market research indicates that consumers would find substantial value in that application.

The application would function by combining static local mapping data with real-time traffic data and route-optimization algorithms to identify the best path. The application could have a log of previous or regular destinations so the driver would not have to input new coordinates. In burst-mode, the traffic data for a given region would be downloaded from a hot spot while the car is stationary. When mobile wireless connectivity is available, information can

[48] Malhotra & Mathiew, , Personal Communication.

be updated while driving. In a hybrid system, baseline data or new maps could be downloaded from a hot spot, but small bits of incremental traffic updates could easily be provide over a low-bandwidth cell phone connection.

While this application's most important functionality is based on location awareness, its functionality is enabled by low-cost bandwidth. The reason is that the best way to gather this real-time traffic data is by using the same enabled vehicles as data probes and have each upload their coordinates and speed to a central database where the information would be aggregated to provide the real-time downloads. Naturally, precautions would have to be made to protect a individual user's data so they need not worry about "big brother" issues. GM has performed extensive analysis as to the minimum threshold of vehicles necessary to provide reliable data. According to papers by Dai et al and Ferman et al, reliable data can be ascertained with only three percent of the vehicles enabled for non-signaled roads such as highways. The more challenging issue, is the vast sum of data uploaded on a continual basis by all the enabled vehicles. Initial assessments by the reports' authors[49] is that even with an innovative algorithms that only updated the system when a vehicle substantively changed vector, this would be prohibitively costly if done today over cell phone minutes. As a result, a less costly connection would be needed. Mobile peer-to-peer enabled Wi-Fi would be able to drop the cost down to an achievable level.

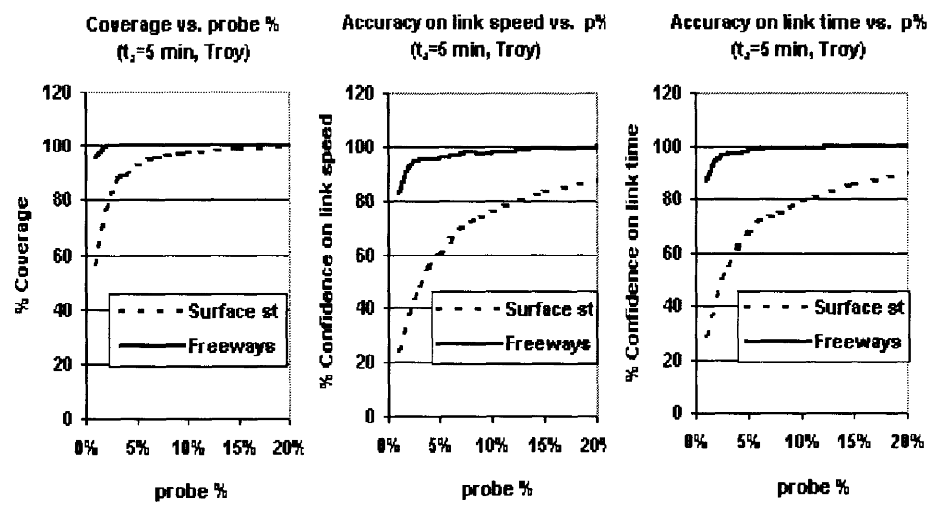

Figure 4.3: Geographic coverage & accuracy of traffic probe data versus percentage market penetration. For freeways, performance is greater than 95% above 3% penetration. [Dai et al][50]

[49] Xiaowen Dai, Martin A. Ferman and Jayandre Parick; Personal Communication.
[50] Ferman, M.A. (Gen. Motors Res. & Dev. Center, Warren, MI, USA); Blumenfeld, D.E.; Xiaowen Dai; "A simple analytical model of a probe-based traffic information system"; Proceedings of the 2003 IEEE International Conference on Intelligent Transportation Systems (Cat. No.03TH8708), 2003, pt. 1, p 263-8 vol.1)

4.3.2 Business-to-Consumer LBC

Besides real-time traffic, there are numerous other potential business-to-consumer location-based commerce applications. Many come under the heading of opportunistic marketing. Like banner adds on web sites, consumers may not appreciate them, but they may elect to endure these intrusions so that advertisers effectively subsidize access costs or content. In one example, a driver down an interstate is notified that at the upcoming rest stop, a fast food vendor or a roadside motel has a special deal. The consumer in the enabled vehicle could then order the food ahead of time, or reserve the room so that their transaction is faster and easier when they arrive. Circuit City has experienced some success experimenting with this merging of online and traditional bricks-and-mortar retail; one researches, selects, orders and pays for an item online, but then selects the option to pick up the item at their local store at a dedicated express counter rather than wait a few days (and pay the extra cost) to have it shipped. In the end, most Telematics services leverage geographic location information so here we use B2C applications to imply novel services such as sight-seeing tours, parking space locators, real-time car pooling or green-light on demand. Advertising services would require broadband-type business models where the amount of data transferred is independent of the cost, otherwise consumers would not endure advertisements using up the equivalent of their cell phone minutes.

4.3.3 Government-to-Consumer LBC

The most successful government-to-consumer application today is the "EZ-Pass" automated toll collection service (and its brethren.) Today one can drive from Washington DC to New Hampshire on Interstate 95 without every having to stop and pay a toll. The EZ-Pass RFID transponder instead identifies the user when one passes a toll and pays the toll from a registered account. Mobile peer-to-peer connectivity could eventually replace this system, and at the same time dramatically expand the range of potential services to include parking garage fee payment and even usage-based toll collection. While the average consumer may not be ecstatic about the capabilities this facilitates, the government might, and would thus be more inclined to subsidize infrastructure.

The DSRC initiative is structured along this model: a core of government services enabled by a government-funded infrastructure that could also be used for business-to-consumer commerce or communication. While the potential of these services are compelling, and the promise of government funding inspiring, we will not delve any deeper into government-funded DSRC services for three reasons: (1) public projects of this type take years if not decades to organize, fund and install, (2) the DSRC standard, by itself, will not be sufficient to enable all the market opportunities we discuss herein, and most importantly (3) any public project is necessarily available (for free) to all, thus obviating most competitive advantages for the leading firm.

4.4 Low Latency, True P2P Applications: Active Safety

To the far right of the spectrum of applications in Figure 4.1 are low-latency,[51] true peer-to-peer applications. These involve vehicle-to-vehicle communication, either through a direct P2P connection or over several hops via mobile ad hoc networking. Only these direct connections are fast enough to provide data used in vehicle safety[52]. As mentioned, the DSRC spectrum allocation initiative was created to enable this type of technology. The table below (4.2) lists active safety applications envisioned by the CAMP industry consortium.[53]

Table 4.2: Active Safety Applications as Envisioned by CAMP Consortium

COMMUNICATIONS BETWEEN VEHICLES	COMMUNICATIONS BETWEEN VEHICLES AND INFRASTRUCTURE
• Approaching Emergency Vehicle Warning • Blind Spot Warning • Cooperative Adaptive Cruise Control • Cooperative Collision Warning • Cooperative Forward Collision Warning • Cooperative Vehicle-Highway Automation System • Emergency Electronic Brake Lights • Highway Merge Assistant • Highway/Rail Collision Warning • Lane Change Warning • Post-Crash Warning • Pre-Crash Sensing • Vehicle-Based Road Condition Warning • Vehicle-to-Vehicle Road Feature Notification • Visibility Enhancer • Wrong Way Driver Warning	• Blind Merge Warning • Curve Speed Warning – Rollover Warning • Emergency Vehicle Signal Preemption • Highway/Rail Collision Warning • Intersection Collision Warning • In Vehicle Amber Alert • In-Vehicle Signage • Just-In-Time Repair Notification • Left Turn Assistant • Low Bridge Warning • Low Parking Structure Warning • Pedestrian Crossing Information at Intersection • Road Condition Warning • Safety Recall Notice • SOS Services • Stop Sign Movement Assistance • Stop Sign Violation Warning • Traffic Signal Violation Warning • Work Zone Warning

[51] CAMP defines the low-latency requirement as 100 milliseconds, however most data packets need only be 100-430 bytes (0.43 kb)
[52] Krishanna, Personal Communication.
[53] CAMP Task 3 Interim Report on Vehicle Safety Communications Consortium includes DaimlerChrysler, General Motors, Toyota, Volkswagen, Ford and BMW.

GM's Corporate Vice-President of Research & Development and Planning has espoused the goal of using active safety to engineer vehicles "that don't crash."[54] Since humans are inherently unreliable, this implies that the utopian end point of active safety is vehicles that drive themselves or auto-pilot. However for this to work, and in fact a core requirement of any vehicle-to-(government) infrastructure system, is that it is available to all. Even with near-term vehicle-to-vehicle active safety systems, they work best when there are open standards and all vehicles are enabled. As a result, it is unclear to the author how this type of system, while potentially benefiting society and providing good public relations for early proponents, will ever provide a good business. Furthermore, as we engineer systems to take over more and more of the driving responsibilities, we risk creating less competent drivers. As a result, we surmise that while any future system should be able to accommodate DSRC and active safety applications (either through built-in features or through an easy upgrade path), it is unlikely to provide a real business opportunity. Furthermore, government-funded DSRC-type active safety driven development would by necessity cater to these public safety applications, at the cost of other commerce-oriented functionality and thus presents a risk to the viability of these other applications.

4.5 Ubiquitous wireless network applications

The panacea of mobile broadband is a ubiquitous network: all or nearly all vehicles are enabled, and one can access a access point from anywhere on any major road. In an effort to better inform near-term decisions, we indulge in a little speculation of what possibilities this capability could enable.

One benefit of ubiquitous connectivity is that more of the computing and capacity and storage could be shifted off the vehicle telematics system to resources at the service or content provider. This "thin-client" model is well known in the information technology space, and is the basis for most web-based applications. The benefit is that it allows both lower cost hardware on-board the vehicle and more dynamic and upgradeable systems. GM's OnStar system is a version of this thin-client model, enabled by the near-ubiquitous, if low bandwidth and high cost, analog cell phone connection.

Another application that would become available with ubiquitous connectivity is internet-based telephone services or Voice over Internet Protocol (VoIP). As mentioned, these services have begun to be offered in the last year. For stationary connections, they permit essentially

[54] Stated at GM's Italian Summit as reported by TheCarConnection.com (*GM's Italian Summit: Sound bites from the General's open-doors conference*; Paul A. Eisenstein; 2000-07-03.

"free" phone calls as they leverage the broadband connectivity the user is already paying for. The historic challenge to VoIP has been latency. The TCP/IP protocol used over the internet is tolerant of high latency and even packets arriving through multiple paths and in a non-sequential order since data packets are agnostic to these issues. While a few second delay during a web page upload is tolerable, this makes for a disjointed and unpleasant phone conversation. Recent products have innovated in this area and largely addressed these issues. As a result, mP2P connectivity could also provide free phone calling and messaging vehicles. This is interesting from a business perspective since every application for which consumers currently already pay provides a potential area from which to poach away business.

Finally, the most distant, but most intriguing prospect of mP2P is that in its most basic sense, every vehicle becomes a mobile router. With 200 million vehicles on the road in the US today, we could see a point where we now have 200 million mobile routers, each ready to relay information. Since vehicle concentration tends to correlate with population density, from a macro perspective the network of all these connected vehicles could, in the end, form a second, mobile internet of connected routers. At this point in the conversation, the issue of vehicles consuming power while parked (and thus either running down their batteries or needing to run the engine) justly comes up. While the level of power consumption would be minuscule relative to that required to move the vehicle, over time, it could run down the battery.

One solution to this glimmer-in-the-eye future is that if vehicles were by then powered by fuel cells, this power consumption issues would be largely resolved since fuel cells generate electricity and are in fact most efficient at the points of lowest power usage. Thus, in this scenario the current concept of infrastructure is turned on its head. Instead of vehicles using mP2P to bridge the "last-mile" to connect to the wired infrastructure, instead we could provide broadband connectivity at home by connecting to the mobile infrastructure through our cars. Unrealistic? Perhaps, but it is just these disruptive innovations that changes the nature of how we do business.

4.6 Applications Strategy

In summary, a Wi-Fi capable mobile peer-to-peer telematics platform can serve as the "killer enabler" for a broad range of applications they range from near-term, burstable applications that take advantage of the low cost and high bandwidth of wireless broadband to medium-term mobile yet low-quality connectivity-tolerant location-based commerce applications to long-term services that require ubiquitous connectivity. Active safety applications also span this range: some, such as a driver warning of a traffic jam a few hundred yards ahead, would begin to function with only a few percent of the vehicles enabled. More sophisticated features that actually intervene in the driving of the vehicle, require near complete installation density.

By creating a flexible and upgradeable telematics platform, we enable all these classes of applications. This "constellation" strategy hedges risk by not "putting all one eggs in one basket" since predicting which applications that we know of today will win, let alone the ones of which we have not yet conceived, is a historically poor bet. As a result, being upgradeable is more important than being flexible. Since computing and wireless hardware tends to drop quickly in price for a given performance, investing too early is foolish. Also, trying to anticipate every possible future application will guarantee only the project will take too long and cost too much. The same is true for the wireless networking technology. By making it upgradeable, and allowing two or three different technologies, we accommodate future evolutions in technology as well as hybrid solutions to bridge us through the near term.

An example from PCs is the modem, the Ethernet card and now the wireless connection. The modem provides near-ubiquitous connectivity, albeit at a low bandwidth and relatively high incremental cost (phone minutes.) If one brings their PC to the office, or installs a cable modem at home, they how have broadband access at those locations. When on the road, the modem is still available. Finally, with the prevalence of Wi-Fi, this third option adds more flexibility. If metropolitan area networks such as WiMax succeed in the marketplace, we may soon see PC manufacturers replace their modems with WiMax cards as they have now done by replacing the old 3½ floppy drives with CDRW drives (although manufacturers are slow to drop previously default features since by that point, the incremental cost of adding these commodity features them is typically very low.)

Critical to success will be creating an application development platform that is powerful, efficient, easy to program and available to independent third-party developers. While the leading OEM may create an internal group to develop applications, they should be in competition with outside sources to maximize entrepreneurial innovation and outside investment. (This operating system strategy is discussed further in Chapter 7.) The most successful operating systems (Windows, Palm OS, MacOS, UNIX and now Linux) all effectively leveraged outside development (by coddling their software engineers and creating powerful development packages.)

Chapter 5 Market Dynamics & Network Externalities

System Dynamics, as expounded by Sterman, provides a useful tool for understanding the viral nature of mobile peer-to-peer networking and its impact on business strategy. The methodology makes use of stock and flows as well as the impacts of reinforcing and balancing feedback loops on dynamic systems. There are many options regarding how detailed a model is necessary or useful for understanding a problem. To comprehend the viral growth inherent in mP2P, we created two versions. First, we constructed a notional model which intuitively provides insight into the growth dynamics. Subsequently, we evolved this into a functional model which uses quantitative equations (rather than qualitative concepts) to approximate this behavior. There are several orders of magnitude of complexity and detail that separates them. The functional model succeeded in one important respect. It ratified the intuitive notion that to quantitatively assess the rate of viral growth, one must first deduce the relationship between market penetration of mP2P enabled vehicles and the resulting value this provides to the end consumer. Chapter 6 endeavors to answer this question with some specificity.

To describe and motivate the relationships, equations and coding that comprise the functional model could provide a thesis topic on its own. As a result, we content ourselves to explain the notional model and its conclusions in this chapter. However, since an initial working, quantitative (i.e. functional) model was created as a result of this research, we include the detailed documentation of its construction as Appendix D (labeled as mP2P model version 5.2).[55] Thus, we leave the functional model for future work.

5.1 Components of mP2P System Dynamics Model

The model breaks the driving forces behind viral growth of mP2P into three major components. Each is phrased in terms of the value it provides in terms of end consumer willingness-to-pay (WTP).

[55] The references that provide the basis for the functional model are listed under the Chapter 5 section of the References. It is important to note that the functional model could not have been brought to its current level of maturity without the generous guidance of Mark Paich, a very experienced practitioner of system dynamics and a consultant to General Motors on these matters.

- "Cell Phone:" The first driver articulates the value the infrastructure of access points provides to each user on the network as a result of the ability it provides vehicle nodes to access content and services providers connected to the wired network.
- "Windows:" The second addresses the value of the applications and services created to take advantage of this connectivity.
- "Fax:" The third driver is the value provided by the network of mP2P enabled vehicles and their ability to benefit from the volume and density of nodes.

We address each component in a separate section. The final section (5.5) discusses the interplay between the drivers and the resulting conclusions for understanding viral growth of mP2P.

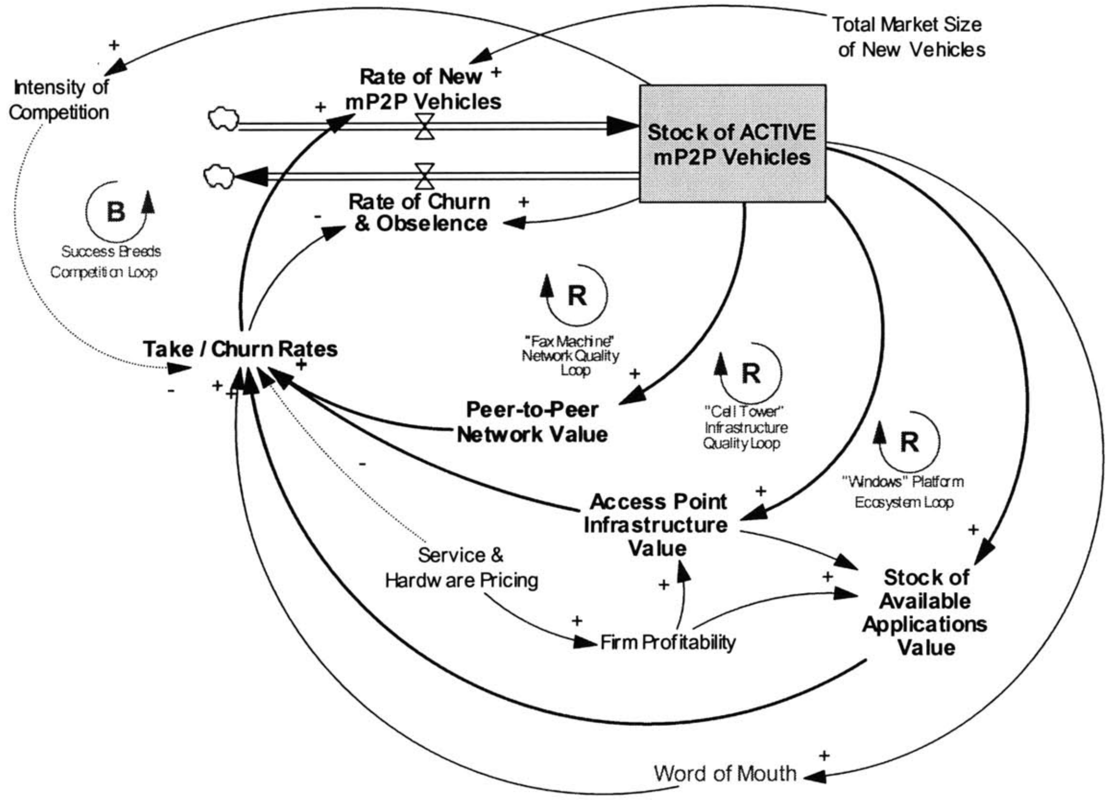

Figure 5.1: Top-Level view of the three forces that drive the system dynamics of mP2P viral growth (negative arrows are represented with dashed lines)

Figure 5.1 provides a simplified top-level view of the model's major components and how they influence the rate of new mP2P vehicles and thus the total stock of active users. In the end, we care most about the total stock of mP2P-enabled vehicles, so that value is at the center. While a gross simplification of the subtle issues of regional geographic concentration, desperate adoption rates between rural, suburban and urban areas, and the impact of local travel patterns, it provides a good metric from-which to meter consumer value. There are two principal flows that impact the stock of enabled vehicles: the rate of new vehicles with activated, compatible telematics systems and the rate of customer churn due to dissatisfaction with the cost to value proposition or obsolesce. An increase in the stock of active vehicles will tend to cause the value to the customer provided by each of the three driving factors to rise (in different ways). This, in turn, increases the "Take Rate" and decreases the "Churn Rate" which then impacts the flows of new and departing vehicles. The churn rate is also affected by the total existing stock of enabled vehicles. Each of these drivers thus functions as a reinforcing feedback loop, increasing the total stock of enabled vehicles thus engendering even greater rates of future adoption.

The simplified causal-loop diagram in Figure 5.1 also includes the balancing effect of competition whereby success (as measured by a large stock of active mP2P vehicles) convinces other firms that it's a good market to get into. This in turn provides competition and thus consumer choice. Also, we include the positive impact of marketing through public awareness or "word of mouth." This awareness can also be created through advertising. Since, the rate of new enabled vehicles is a percentage of the total market, we must include this information as well. Finally, pricing policies of both hardware and software play a critical role in the success or failure of a new service. If the price is too high, consumers will not buy the hardware or not renew the service (as represented by the negative, or dashed, arrow between Pricing and Take Rate.) However, if pricing is too low, firms will not be profitable and will thus not want to invest in the infrastructure, applications or vehicles required to create value to the user. The following three sections detail out each of the three major reinforcing feedback loops.

5.2 *Infrastructure: "Cell Tower" Effect*

The impact of infrastructure on consumer adoption is perhaps the easiest force to understand. Although we refer to this as the "cell phone" effect, it is relevant with any device which needs an infrastructure to make it useful. Infrastructure requires large capital investments that are worthless if consumers fail to sign up for the service. Thus, for companies to place the necessarily large bets, they demand a higher degree of certainty that demand will materialize. As a result, systems are rolled out incrementally, with the highest expected return areas first. Public Wi-Fi access point service providers (such as Wayport, Boingo, Comeda & iPass) have focused on business travelers, installing their systems predominantly in hotels and airports. These operators have thus been relatively slow to roll-out large networks, instead waiting to see how demand matures. For cell phone systems, operators initially focus on affluent urban areas and major highways, the areas with high concentrations of cell phone users. Geography and competition also play important roles: the densely populated northeast of the US has largely ubiquitous cellular coverage while in the sparsely settled sections of western US, coverage tends to be limited to highways and urban areas.

Taken in isolation, and illustrated in Figure 5.2, this reinforcing feedback loop presents a chicken-and-egg dilemma. We will posit for now that an automaker decides to produce mP2P-enabled vehicles thus creating an initial stock of vehicles. The existence of these vehicles then increases the attractiveness of putting in new access points as there is now a new market for mobile wireless broadband access. This, in turn causes access point operators to initiate expansion in their networks. However, there is a delay in the step since it takes months for operators to make the decision, secure the real estate and install the hardware. Once installed, this increases the total stock of mP2P-compatible access points which in turn increases the value this newly expanded network provides to the user. According to microeconomic theory, each potential customer has their own price in which a service is worth.[56] Thus, increasing the value of the network makes the service worthwhile to a larger set of potential customers and as a result, increases the aggregate rate new users elect to take the service. Finally, this increases the take rate of new vehicles with active service and thus the total stock of mP2P-enabled vehicles. The cycle then repeats itself.

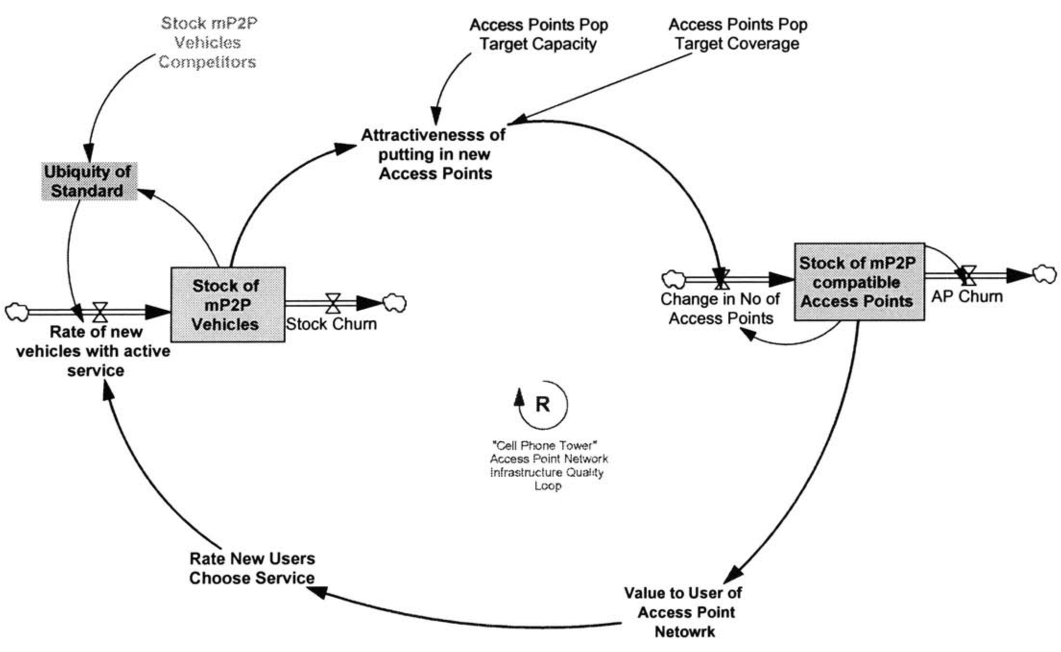

Figure 5.2: Cell phone infrastructure causal loop diagram

56 Rohlfs, p. 24.

A number of other factors also influence the adoption rate due to the quality of the infrastructure network. The most critical is the ubiquity of the standard. Competing standards obviously can attract away potential customers, but more importantly, they provide confusion in the marketplace as to which standard will eventually succeed (if any.) The are numerous examples of where competing standards have stymied adoption of a new technology. Removable PC storage media provide a good example. During the 1990's hundreds of different companies competed with dozens of technologies in the battle to replace the 3½ inch floppy disk as the standard of choice. They included the Zip Disks (4 different types), Superdisk, Rewritable CD's, PCMCIA memory cards, Jazz Drives, removable hard drives, memory sticks and most recently USB-port flash drives. The failure a single standard to surface as the dominant one to replace the floppy drive resulted in the fact that floppy drives continued to be installed in PC ten years beyond the point where they were really useful. Only very recently have rewritable CDs and USB drives become widespread enough that many PCs now finally no longer include a floppy drive as standard equipment.

In many cases, the government has defined the standard as occurred in Europe with the GSM cell phone standard. This resulted in a widespread, high quality network since there was no uncertainty as to which standard would win. In contrast, in the US there are four different cellular standards. While it has created intense competition among carriers, it has also resulted in lower coverage for each network as companies competed to win with their own standard by installing redundant systems in high-density areas while leaving lower density regions until their market position was more secure. In cell phones, this has not been a disaster since each carrier generally sells phones only compatible with their own systems and phones are sufficiently inexpensive that consumers are not deterred by the prospect of having to switch carriers (and thus purchase new phones) every few years. In these cases where the switching cost is low, it is less of an issue. It is for this reason that we conclude that the "network card" for the vehicle telematics system should be upgradeable, thus providing consumer choice and the carrier flexibility to evolve technology platforms as necessary.

Another factor shown in Figure 5.2 is the "access point" target coverage. This implies that there is a saturation point beyond which adding additional coverage creates less and less additional perceived service value to the customer, thus decreasing the incentive to the service operator to expand their system. In practice, this is a complicated issue and there are probably always new geographic markets that one could expand into, however the implication is that as the network size approaches the saturation point, returns will diminish.

5.3 Applications: "Windows Platform Ecosystem" Effect

The second effect that drives the adoption of mP2P-enabled vehicles is the indirect network externality resulting from the availability of applications and services. Nearly all computer and consumer electronics technologies are only useful if there is software applications to run on them. The piece of software that serves as interface between the hardware and the applications is the operating system (or "OS"). The OS's application programmers' interface or API both facilitates programming and the process of evolving the hardware while keeping existing body of applications still useable. One could argue that Microsoft Corporation's success to date is largely due to its success in managing its Windows Operating System product. Today, there are over 50,000 existing applications that run on Windows. Since a successful applications strategy is principally dependent on the operating system strategy, we name this effect the "Windows Platform Ecosystem Effect" since the ecosystem environment created by the OS strategy drives the growth in applications.

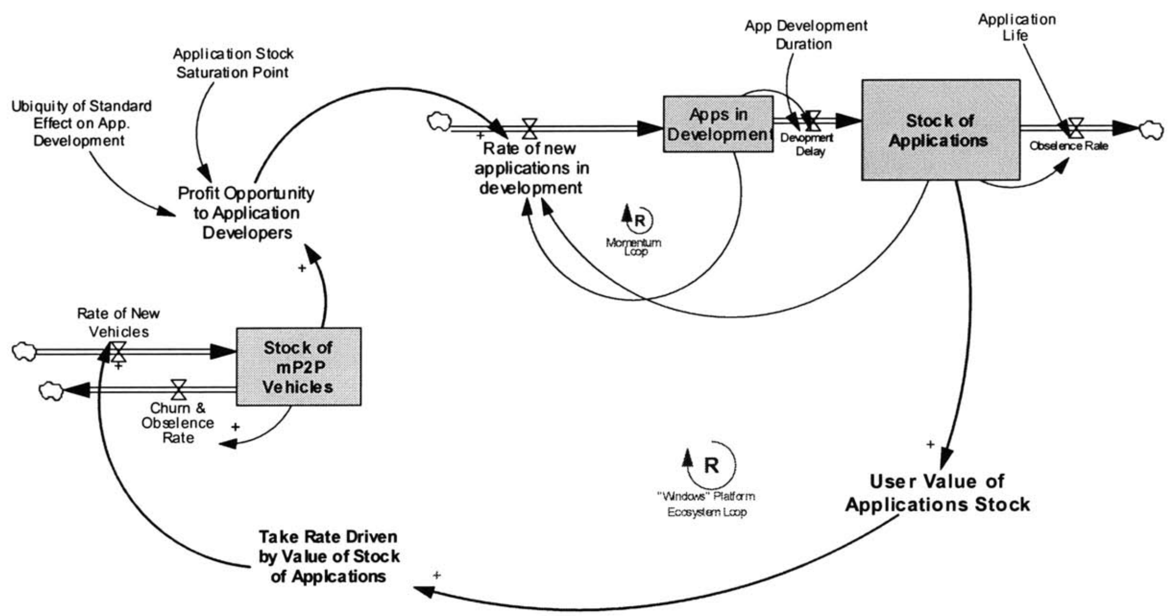

Figure 5.3: Causal Loop Diagram for "Windows" Platform Ecosystem Application Development Loop

Figure 5.3 illustrates the reinforcing impact of applications on the adoption of mP2P-enabled vehicles. An existing stock of enabled vehicles creates a profit opportunity for application developers. Initially, the automaker or a partner would likely create some base level of functionality into the operating system of the telematics device. In the case of OnStar, the system was closed so the applications that OnStar developed comprises all that are available. While this approach allows for a very tightly integrated, efficient and reliable application set, it does not leverage any outside innovation or investment in applications. In contrast, Apple, Microsoft and Palm have all chosen to build in only a basic level of functionality, and then facilitate the effort of outside developers to expand the functionality of the device through new applications. Today, the majority of applications are created by outsiders. For OnStar, the loop described in Figure 5.3 this loop has essentially zero effect. For Microsoft, it is tremendous and in fact the source of its monopolist position and the driving force behind the success of the PC. In the home video gaming system market, the most popular games are created by outside developers despite the very integrated nature of the product.

As discussed in Chapters 2 and 3, we assume that the mP2P platform is designed in a way that leverages outside application development and that the vehicle safety issues can be addressed through creating a firewall or read-only interface between the sensitive, OEM-proprietary vehicle control modules and the telematics system. Thus, the initial mP2P telematics systems will be seeded with a base level of applications (created by the OEM or a partner), but additional development would be driven by third-parties. The creation of new applications generates additional value to the user (or prospective user) of the system which in turn increases the rate at new vehicle buyers will elect to acquire mP2P-enabled vehicles. The larger stock of enabled vehicles then presents a greater profit opportunity for developers of new applications, sparking more application development projects to be initiated.

Since applications take several months to several years to be developed, there is a stock of in-progress applications (in the functional model, we assume 12 months.) Also, programs eventually become obsolete (on average, 5 years.) Besides the stock of potential customers, the key factors that impact the initiation rate are: the existing stock of applications, (once again) the ubiquity of the standard and the saturation point beyond which the creation of new applications has an increasingly marginal effect on the value it presents to potential users. Prior to the saturation point, having a large stock of existing applications actually provides an incentive to developers since no one wants to waste the time developing an application for a platform no one is certain will endure or succeed. Having other third-party developers working on a platform makes it seem less risky. Palm Computing is famous for their success in fostering their development community and their enduring success today remains largely attributed to the way they nurtured and managed outside programmers. The success of NTT DoCoMo's i-Mode cell phone platform in Japan is attributed to the way they allowed third parties to develop applications and services for their phones. I-mode provides a good model for telematics since DoCoMo approves applications, collects fees and, most importantly, controls access.

5.4 Network: "Fax Machine" Network Externality Effect

While the previous two effects exist widely in a number of different types of computing and consumer electronics products, this last one is unique to mP2P telematics. A direct network externality exists when each individual's demand is dependent on the purchases of other individuals. In telecommunications, "as the set of users expands, each user benefits from being able to communicate with more persons (who have become users of the product or service.)"[57] Examples abound of the impact of positive direct network externalities on the rate of adoption of new technologies. The classic one is the fax machine. A single fax machine has no value to the user. However, each additional user which installs a fax, provides another potential recipient for each existing owner thus increasing the usefulness and thus value of the fax to each existing user even though they have not expended any additional funds. Adoption driven by these forces takes the familiar "S" shape where the rate is initially slow, but increases dramatically once the installed base reaches a critical mass where the value presented by the device exceeds the cost for an ever increasing number of potential users. The adoption rate slows, illustrated by the top of the "S" curve," as the total population of users approaches the saturation point. In computer networking, Metcalf's law states that the value of the network goes up as the square of the number of users. In reality, the first users tend to benefit more than later users and, in general, the value of the network increases much less than proportionately to the square of the number of users.[58]

The value provided by the network of mP2P enabled vehicles provides a positive, direct network externality because the value to each user of the peer-to-peer network increases as the total number of users increases. In practice, a mP2P network is considerably more complex then that of the fax machine. If we had 1000 users all concentrated in a sufficiently small, geographic area so that they regularly benefited from the connectivity provided by other users, the value presented by the existence of the other users (i.e. the network) would be considerably more than if the same 1000 users were evenly distributed around the US. The implications of this is that any rollout would ideally occur geographically. In other words, the way to maximize the benefit resulting from each additional user would be to concentrate the initial roll-out in a single geographic region. Chapter 6 attempts to quantify the relationship between value and average vehicle density. For now, we assume that these effects can be averaged out as they do not impact the fundamental understanding of the system.

[57] Rohlfs, p.8.
[58] Rohlfs, p.29.

Referring back to Figure 5.1, we see that increasing the stock of mP2P-enabled vehicles increases the value of the peer-to-peer network to the user. This occurs as a result of the two classes of functionality mP2P provides: direct vehicle-to-vehicle communications that enables applications such as active safety and "last-mile" connectivity to the wired infrastructure of access points via mobile ad hoc networking. This increased value increases the adoption rate of new mP2P vehicles, thus increasing the total stock.

5.5 Summing the Effects

Summing the effects of the three primary drivers (Figure 5.1) results in an intense reinforcing feedback system with a high dependence on seeding infrastructure, applications and enabled vehicles. Qualitatively this implies an exaggerated "S" curve where the value to the users remains very small until a critical mass of enabled vehicles are on the road, after which adoption will grow exponentially. The major balancing factor would be the ubiquity of the standard or, in other words, competition.

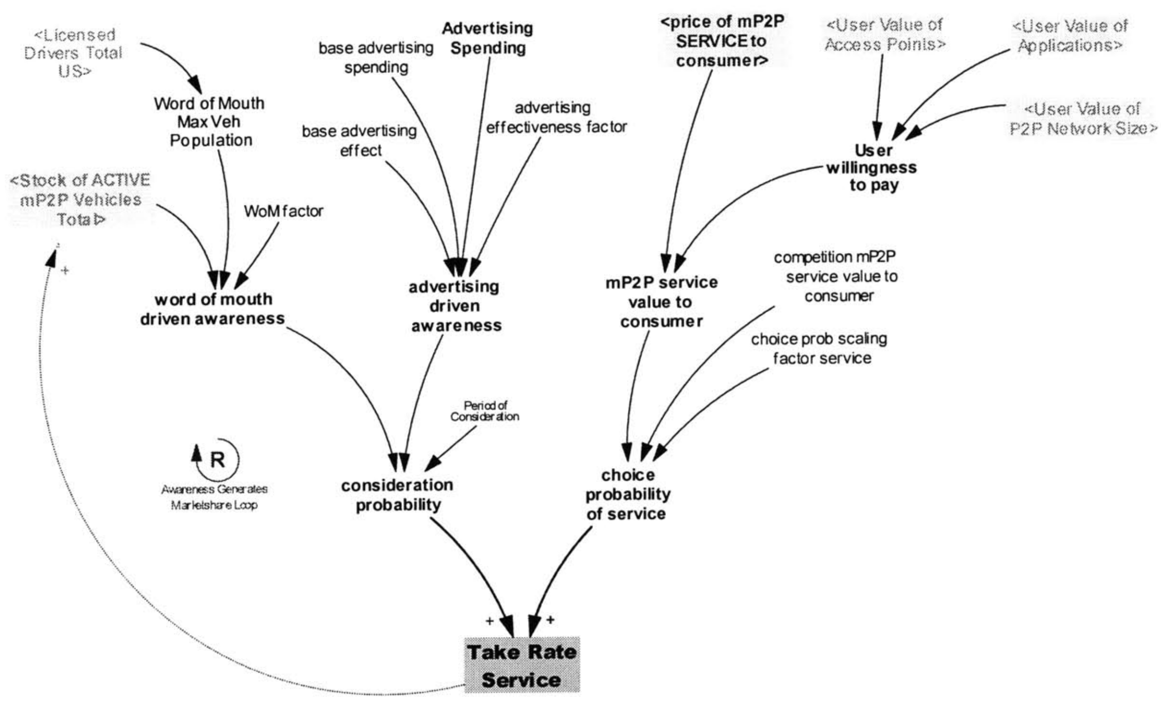

Figure 5.4: Final Adoption Rate as a result of infrasture, applications and mP2P network quality as well as marketing effects.

At this point, it is helpful to look a little deeper into what factors drive the take rate of new enabled vehicles. Figure 5.4 depicts how the functional model[59] actually calculates adoption (the "take rate.") We see on the right that the impacts of the stock of applications, access points and enabled vehicles on user value can be summed into a single user "willingness-to-pay." When this is compared against the price to the consumer, it results in the net value of the service to the consumer and thus the "choice probability" or the likelihood that a consumer, given the option, will elect to become an active member of the system. Since consumer demand for any good increase as the price decreases, we can conclude that initially the service price should be very low.

This tracks with many new services offered over the internet in recent years where most companies had to initially offer their services for free. While many elected to fund their services through online advertisements (for example: search engines and news magazines), some did succeed in migrating to user fees once they had established a large enough based of users willing to pay for the service. A good example of this with potential application to telematics is Vindigo, a provider of location-based information on local restaurants, movies, nightlife, stores, museums, music, weather and even bathrooms and ATMs along with maps and directions as to how to get there. Time-sensitive information such as what is playing at the local movie theatre tonight is updated via the internet for PDAs or over the cellular network for smart phones. For the first few years of operation, the service was free. Once they had a critical mass of dedicated users, Vindigo was able to start charging fees (initially $15/year but now up to $25/year.)[60]

The left-hand side of Figure 5.4 depicts traditional marketing forces to adoption resulting in a consideration probability. This is the likelihood that a user will be aware that a service exists. This is affected principally through advertising and word-of-mouth. The more users that exist (with positive experiences), the greater the impact of word-of-mouth. Multiplying the consideration probability with the choice probability results in the take rate. The actual adoption rate results by factoring in the total potential population, or in our case the number of new vehicles purchased in a given year.

5.6 Model Conclusions

In sum, by mapping out and understanding the business dynamics that drive market adoption of mP2P, we are left with two key conclusions. First, there is a significant barrier to entry to this technology driven by the reinforcing nature of three driving forces although, as we

[59] Model 5.2, see Appendix B for details.
[60] Company web site: www.Vindigo.com.

will show in Chapter 7, this barrier can be overcome through the proper business strategy. Second, once critical mass is reached, adoption will explode as all three reinforcing systems accelerate in value.

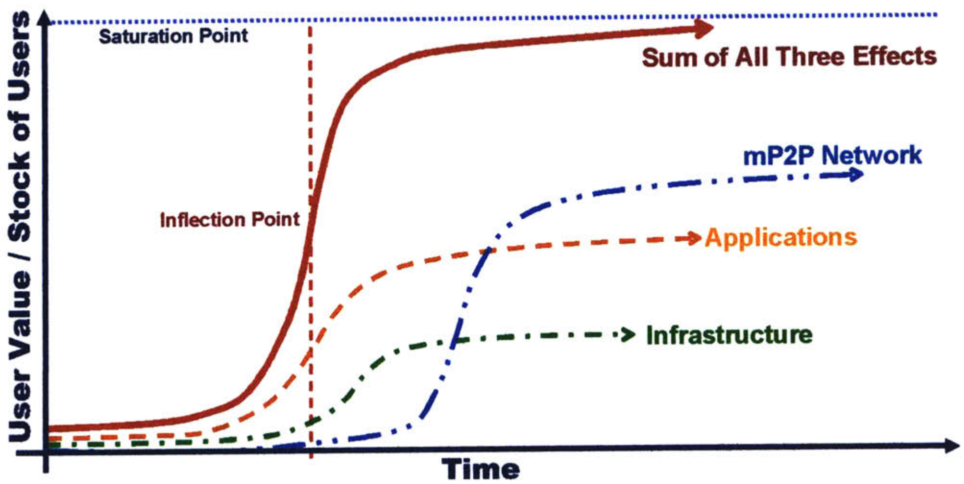

Figure 5.5: Notional Adoption Rate vs. Time for three primary mP2P driving forces.

Figure 5.5 depicts the notional adoption rate of each of the three market forces, and their cumulative impact, over time. The Y-axis tracks both the value provided to the user as well as the resulting increase in the total stock of active users. While they would actually rise at different rates, the relative shapes of the four curves (as we saw from the cell phone adoption data in Figures 2.3 and 2.4) would be basically the same.

Applications are likely to have the first impact, as any new product offering will not be offered without at least a base level of applications built in (thus starting at a low, but non-zero value.) Infrastructure will also start at a low, non-zero value because while they are only convenient for stationary connectivity, there is value in the existing access point infrastructure of 4.5 million US homes and fifty to eighty thousand retail outlets (Fig. 2.7). Based on the application strategy set forth in Section 4.6, consumer value would expand from stationary "sync-and-go" applications to mobile ones. The last force to have an impact would likely be the value of the mP2P network since for this capability to function, we require a critical mass of enabled vehicles. While initially zero, it enables a potentially higher eventual value than that created by applications or infrastructure. The shift from near-zero to high value would be very steep.

The three effects are summed in the solid (red) line. The inflection point represents the time when the growth in adoption starts to slow. It will continue to do so until it asymptotically reaches the market saturation point. The biggest uncertainty is what market penetration is required to reach the point where adoption takes off. Once that determination is reached, we can devise policies and strategies for achieving it. Chapter 6 endeavors to provide some quantitative answers to this question.

Chapter 6 Assessing the Critical Mass for Viral Growth

To provide a quantitative answer to the final question of Chapter 5, what is the market penetration required to reach critical mass where market adoption takes off, we studied a specific case with empirical data. By defining a scenario, we can better manage all the variables inherent in bringing a mP2P telematics system to market and thus provide an example from real world data of the tradeoff.

The end goal is to define the relationship between market penetration of mP2P enabled vehicles and a customer's willingness to pay. Since we already have a sense of the supply cost of how much a mP2P telematics system would cost (from Chapter 2), understanding the demand and thus where the two intersect should indicate the point of critical mass. To do this, we first investigate the relationship between market penetration and functionality. Second, we benchmark, from comparable existing services, customer willingness to pay versus functionality. Finally, we combine the two to plot market penetration versus customer willingness to pay. The section on infrastructure cost provides guidance as the investment required to support our assumptions based on specific technical requirements.

6.1 Assessing Market Penetration Versus mP2P Functionality

As we have discussed, there are three general classes of connectivity that enable applications of potential value to the consumer:

- stationary Wi-Fi connections for periodically updated data,
- mobile connections to the wired networks to access content and service providers, and
- pure mobile peer-to-peer (i.e. vehicle-to-vehicle) communications for applications such as active safety.

Since the user connects to an available access point, stationary connection functionality is independent of market penetration. If there is a ubiquitous network of available access points such that vehicles are always within range of one, then mobile connections to wired networks are also independent of market penetration. However, since there will be a considerable period of time before this extensive infrastructure is fully implemented (if ever), we consider the use of using the mobile ad hoc capability of mP2P for "last-mile" connectivity to distant access points that would otherwise be out of range. Since mobile ad hoc communication is simply an extension of mobile peer-to-peer, and so called "pure" mP2P applications such as active safety also benefit from using ad hoc connectivity to extend their range, we consider them together. In sum, since stationary connectivity is available today, and ubiquitous infrastructure exists in the *very* distant future, the viability of mP2P hinges on its ability to operate in ad hoc mode.

From a high-level perspective, mobile peer-to-peer functionality is dependent on three factors:

- the technological limitations of the system (such as transmitter range, packet delivery reliability within context of road environment and the maximum number of ad hoc networking hops the system can support),
- the service level required to be accepted by the customer (i.e.: reliability) and
- the probability that there are sufficient mP2P-enabled vehicles within range in order to deliver service.

Infrastructure investment is also critical, but we consider it to be a dependent variable, determined by the above three variables; the tradeoff is discussed in section 6.4 below. Thus, the focus of this and the next section is to get a quantitative sense of how functionality varies with market penetration, assuming a given technical capability and service level.

6.1.1 Derivation of Probabilistic Analysis

To assess the market penetration required for a given vehicle's mP2P system to operate at an acceptable level to the consumer, we use a simple probability calculation. First, let us define:

P = the market penetration of enabled vehicles, on average.

Incidentally, this is also the probability that a random vehicle is mP2P-enabled. It then follows:

$(1 - P)$ = the probability that a single vehicle is <u>NOT</u> mP2P-enabled

Also, let:

Y = the average number of vehicles within range of a given vehicle at any given point in time

It then follows that:

$(1 - P)^Y$ = the probability that <u>ALL</u> vehicles within range are <u>NOT</u> mP2P-enabled and thus,

$1 - (1 - P)^Y$ = the probability that at least one mP2P-enabled vehicle is within range

Let us now define:

N = maximum number of other mP2P-enabled vehicles needed to relay a packet to the nearest access point, thus implying that it also equals:

= (number of hops to the nearest access point) - 1

(since, by definition, the probability that the user's vehicle is mP2P-enabled is 1.)

Using ad hoc networking, one hop (N=0) implies that every enabled vehicle can connect directly to an access point and no vehicle is ever out of range. Two hops (N=1) implies that a vehicle may connect directly or may need to have packets relayed through up to one other enabled vehicle. Three hops (N=2) implies that a vehicle may connect directly or may need to have packets relayed through up to two other enabled vehicles. And so on. Thus, we can now state, that:

$\left[1 - (1 - P)^Y\right]^N$ = the probability that for each of N+1 hops required for a data packet to get to the nearest access point or to the destination vehicle, each vehicle will have at least one enabled vehicle within range

Now, let us define:

S = the service level, or the probability of having service at any given moment in time

Finally, we can stipulate that the service level, S, is equal to the probability that a given vehicle communications packet can reach its destination or symbolically:

$$S = \left[1 - (1 - P)^Y\right]^N \qquad \text{(Equation 6.1)}$$

If we rearrange the equation and solve for P, then:

$$P = \left[1 - (1 - S)^{1/N}\right]^{1/Y} \qquad \text{(Equation 6.2)}$$

Now, in order to determine the average number of vehicles within range (Y), let us define:

x = average number of vehicles passing a given point on the road per hour

v = average speed of the vehicles (in miles per hour)

r = maximum range of the mP2P transmitter given the minimum bandwidth specification (since bandwidth drops with distance)

In addition, let us assume the following:

- vehicles are uniformly distribution on the road,
- their speed is, on average, constant, and that
- for the sake of calculating range, the road is a one-dimensional system.

In other words, the range is always greater than the width of the road, and we will ignore vehicles and access points not on the road. Thus, dividing x by v gives us:

$$\frac{x}{v} = \text{average vehicle density (in vehicles per mile of road)}$$

Since Wi-Fi and mP2P system use multi-dimensional antennas, we can safely state that the length of road any given vehicle can communicate (the *reach*) is actually $2r$ since it can reach a distance of r both forward and backwards on the road. Then multiplying the equation above by the reach, provides the equation for the average number of vehicles within range of a given vehicle at any given point in time or Y.

$$Y = \frac{2rx}{v} \qquad \text{(Equation 6.3)}$$

Then, plugging equation 6.3 back into 6.2, provides an expression for the market penetration as a function of technical specifications and traffic density.

$$P = \left[1-(1-S)^{1/N}\right]^{2rx/v} \qquad \text{(Equation 6.5)}$$

We will now use this equation to reduce real traffic data into conclusions on the trade-off between market penetration and system functionality.

6.1.2 Technical Assumptions

It is now necessary to define the technical inputs to the analysis. As discussed in Chapter 2, the mP2P technology sold by MeshNetworks Inc. provides a good baseline of the state of the art available in the marketplace today. Thus, for the sake of this analysis we use their performance characteristics, acknowledging that there are other, potentially superior, implementations either commercially available or in development.

The Wi-Fi variant of the Mesh system, demonstrated to the author, can provide for the all the classes of applications we outlined in Chapter 4. It has a maximum range of a third of a mile with guaranteed throughput of 2 mbps at up to 80 mph available to the user.[61] While each node is actually capable of bandwidth several times this figure, Mesh only guarantees 2 mbps because it allows them to reserve the balance of the capacity for administrative overhead and relaying packets of data from other nodes on the system.

As discussed, the biggest technical challenge facing mP2P is scalability. Their particular implementation (*Mesh-Scalable Routing*™) uses a hybrid approach that allows scaling of the total number of nodes as long as each node only requires a relatively finite number of hops to reach its destination, be that an access point on a wired network or another vehicle. According to Mesh, performance only begins to degrade when each node maintains a routing table with more than a few hundred nodes. This tradeoff is consistent with research published on other implementations of mP2P networking.[62] As a result, in order to be conservative in our assumptions of the performance requirement, we assume that the initial infrastructure rollout for major traffic routes would be designed around no more than seven mP2P hops to the nearest access point.

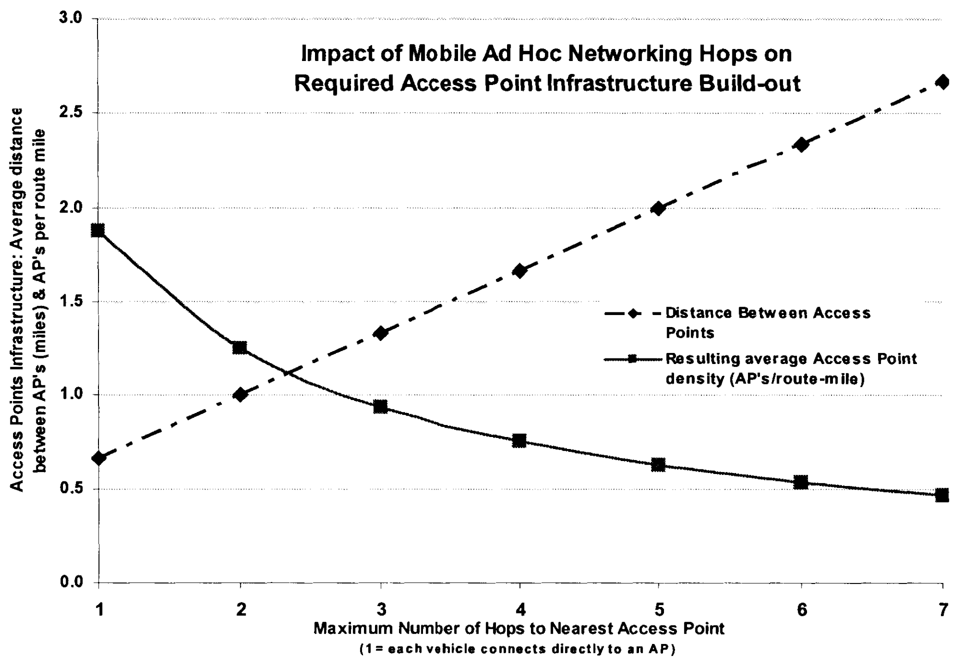

Figure 6.1: Access point density versus maximum number of mP2P hops

Figure 6.1 shows the tradeoff between the maximum number of allowable hops and the resulting required access point spacing (denoted as the dashed line.) The second (solid) line then indicates the resulting access point density, and thus also the necessary infrastructure investment,

[61] Stanforth & Sutter, Personal Communication.
[62] Karp et al.

per route-mile. As we can see from the chart, the return on using mP2P to decrease access point density diminishes as the number of hops goes up. The tradeoff that results from increasing the maximum number of hops, however, is that we require a greater market penetration of vehicles for a given level of functionality. We discuss this further in Section 6.2.

6.2 Infrastructure Costs Tradeoff

In order to better understand the tradeoff between infrastructure costs and technical specifications for the system, we examine a few scenarios. As previously stated, the there would be zero infrastructure cost for enabled vehicles to access wired resources while at home for the 4.5+ million households with Wi-Fi access today. If partnerships with gasoline retailers were made, 30% of the fueling stations in the US could be installed with an access point for $71 million. (Detailed assumptions and calculations for this assertion are included as Appendix B). Finally, the most informative metric with regard to the necessary infrastructure costs is to that which relates the tradeoff between maximum allowable hops and the resulting costs of the network of access points necessary to support it.

To do so, we first posit that the initial rollout of mP2P infrastructure would be targeted towards highways and principal arterial routes. From a strategic perspective, enabling highways first makes sense because it suggests that the initial target market are those traveling a long distance. In metropolitan areas, this group is dominated by commuters. As a demographic, they present an attractive market as they regularly spend a significant period of time in their cars (97 million people in the US spend at least 37 minutes commuting in their cars every workday[63].) This intuition is confirmed if one looks at the network roll-out patterns of cellular phone companies. Data from the US Department of Transportation states that there are 207,257 route-miles of highways and principal arterial routes in service today.[64] While in practice, any rollout would likely target a few metropolitan area first, then expand to other cities and only enable the long stretches of less-utilized interstates that connects cities one the market is proven, we assume that the entire network is enabled for the sakes of conservatism and clarity (one can always down-rate them later.) Also, it allows us to present the tradeoff between hops and capital cost.

In contracts MeshNetworks has bid on for implementing its technology across Miami-Dade County in Florida, it committed to installation costs of $10.000-12,000 per square mile. Adjusting these figures for a linear roadway system, we come up with a cost of $1,818 per access

[63] Speering, Personal Communication.
[64] US Dept of Transportation.

point. Assuming that a nationwide rollout would reduce costs due to economies of manufacturing scale, we assume a cost savings of 35% and thus a unit cost of $1,181. However, since all the US is not as flat or orthogonally laid out as south Florida, when calculating the total number of access points necessary, we assume only 80% of the idealized figure based on the number of route-miles of road to conservatively account for the inefficiencies that result from uneven geography, curving roads and man-made barriers (like buildings.) Finally, the product of the derated route-miles and the access point density results in a first order assessment of the infrastructure costs as well as the trade-off presented between by the maximum number of mP2P hops variable as shown in Figure 6.2 below.

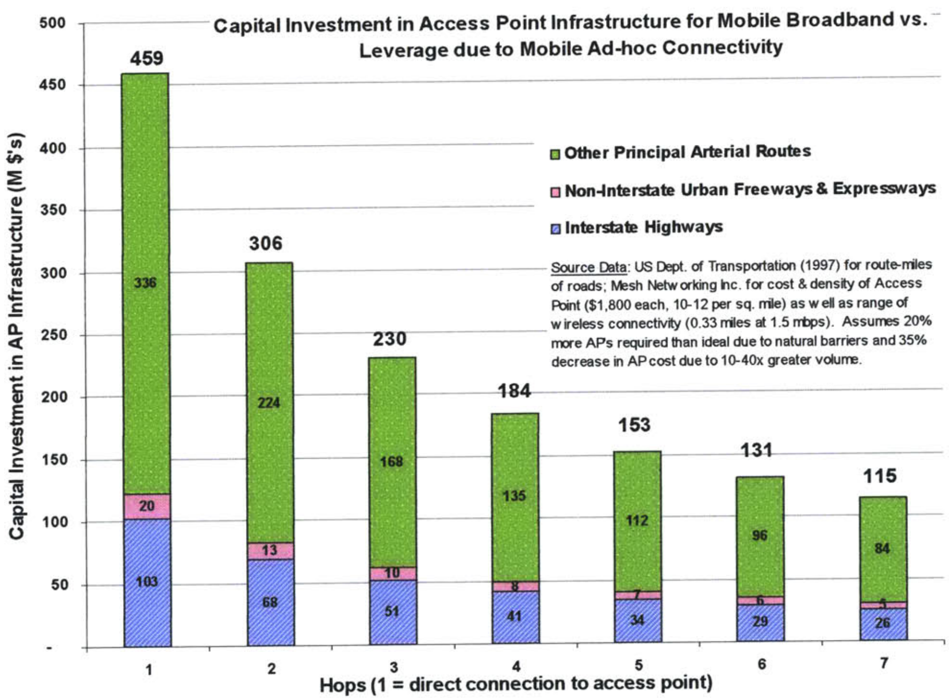

Figure 6.2: Access Point Infrastructure Investment vs. Maximum mP2P Hops Design Point

As we can see, for the four-hop threshold we use in the analysis going forward, outfitting all the highways in the U.S. could only cost $184 million. If one did not want to allow for the uncertainties of any mobile ad hoc connectivity (and thus enable wireless broadband even with zero market penetration), the cost would only be $459 million.[65] While these figures are large, it is important to note that they are small with respect how much the cellular industry expends annually in order to build out their networks (measured in billions) or the federal government spends on road infrastructure projects or automakers spend on capital investment investments for

[65] Calculations assumptions and details are included as Appendix B.

new business. As a point of comparison, according the Cellular Telecommunications and Internet Association (the cell phone industry's trade group), Cell Phone Companies collectively spent over $21 Billion dollars on capital investment in the US in 2002 alone. With the advent of 3G networks, and the resulting five-fold increase the tower density over 2G, this figure is only likely to grow. In this light, the $459M proposed above represents only 2.1% of 2002 CellCo investments.

6.3 Real-World Calibration Case Study: Metro Detroit

6.3.1 Traffic Data Assumptions

Given the technical and infrastructure assumptions outlined above, we now use the analysis methodology of Section 6.1.1 to access the market penetration versus functionality tradeoff using real-world traffic data. The data, provided by the Michigan Department of Transportation (MDOT) for the Detroit Metropolitan area throughout the month of September 2003, consists of average hourly vehicle traffic at various points throughout the region. The data was collected from loop detectors installed in the road that sense every time a vehicle passes. Based on our assumption of the initial rollout of a highway-based mP2P infrastructure, the MDOT data comes exclusively from sensors on highways (i.e. non-signaled roadways.)[66] The hourly figures were compiled from data that recorded the number of vehicles that passed every minute, as well as their average speed, for each available lane at that given point in the road. Examination of this considerably finer resolution data confirmed that the traffic density and speed did not vary sufficiently over the course of an hour for it to be a relevant factor in our analysis. Thus, our analysis relies on the aggregated hourly data.

In an attempt to insure the analysis is robust, we pulled out one key uncertainty: the impact of congestion. As any experienced driver can attest, vehicle density on the road has a nonlinear impact on average speed. The traffic can be moving at highway speeds one minute, and then be "stop-and-go" the next without any apparent change in the number of cars on the road. To highlight this point, we present Figure 6.3 which shows the relationship between road capacity and speed based on a study of the Atlanta Metropolitan area.

[66] Non-Signaled roadways are those without traffic lights, typically have two or more lanes and are designed for high-speed travel.

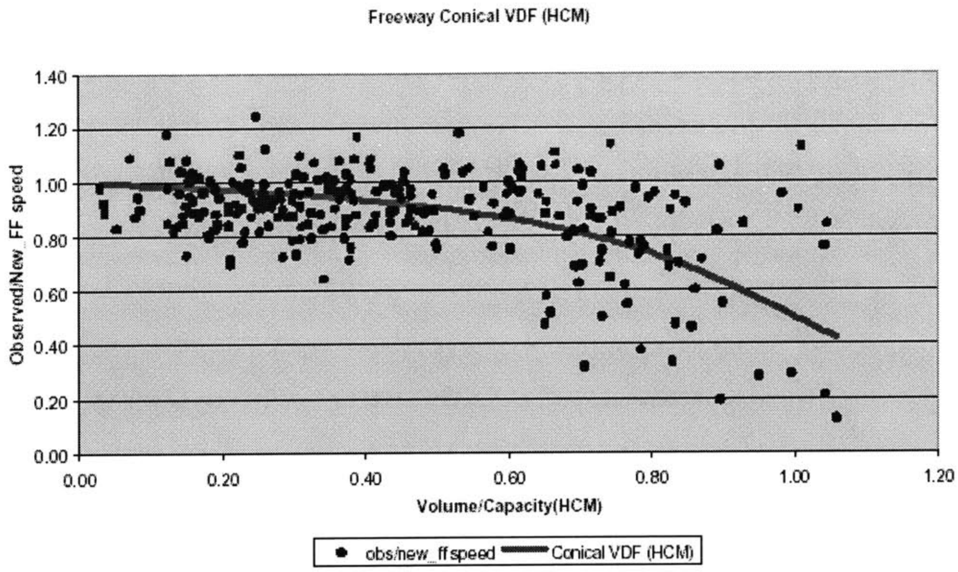

Figure 6.3: Observed Speed, as Percentage of Free-Flow Speed vs. Volume, as Percentage of Maximum Road Capacity for Highways in the Atlanta Metropolitan Area[67]

The key conclusions are: that average vehicle speed on the road decays as the road reaches its maximum capacity, and that there is a high degree of scatter (or variability) in the actual impact. As a result, our analysis assumes a constant average speed of 60 mph. The impact is that for periods of intense congestion, when average speed decreases well below the nominal free-flow rate of 60 mph, vehicles are actually considerably more packed together than if they were moving freely.

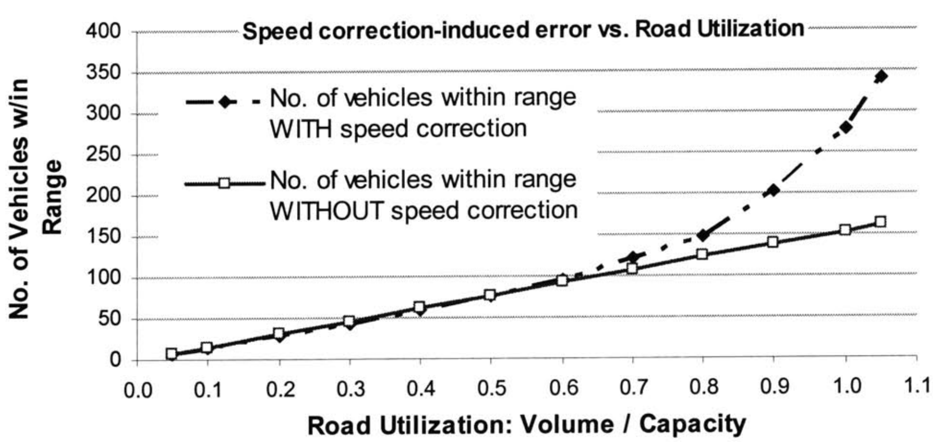

Figure 6.4: Speed Correction-Induced Error vs. Road Utilization[68]

[67] Wilbur Smith Associates

[68] The chart is based on the curve of Figure 6.3 which relates speed versus capacity based on an assumed speed of 60 mph, and the same mP2P range of ⅓ of a mile.

Since we are only concerned with a reliably figure of market penetration versus density, underestimating density only results in a lower service level at the highest density periods. As our results are driven by the minimum service level, underestimating the periods of maximum service had no real impact on the final result. To quantify the error, however unimportant, we include Figure 6.4 which plots the impact of congestion on the actual versus the assumed number of vehicles which would be in range at any given point in time.

6.3.2 Impact of mP2P Hops on Service Level

Before we present the results, it is relevant to delineate the trade-off between the maximum (or design-level) number of hops and the service level. Figure 6.5 shows how the service level varies with the number of hops and market penetration, based on Equation 6.1 and the assumption that 60 vehicles are within range. With only 1% of market penetration, increasing the number of hops causes the service level to drop precipitously. In contrast, with 8%, service remains above 95% beyond the seven hop threshold we stated for the current technology. For the sake of improving our intuition of the problem, we extend the chart out to 100 hops. Figure 6.6 uses the same inputs, but rearranged into Equation 6.5 to provide market penetration as a function of vehicle density and number of hops. The analysis of the Detroit data that follows takes this form.

In sum, increasing the number of hops, delays the point of market penetration where the system functions reliably but also decreases infrastructure investment cost. So, to assume a large number of hops, raises the bar. Going forward, we assume a design point of 4 hops (N=3). Thus, a vehicle would need to have its data packets relayed through up to three intermediate vehicles before reaching the access point. It is worth nothing that in calculating performance, we assume that all vehicles have to connect through the maximum number of intermediate nodes while in reality, this would only be the case for the roughly 30% of the time that the vehicle is farthest from the access point (i.e., equidistant from the one in front and the one in back.) The rest of the time, the effective number of hops (and thus N) would be 3, 2 or 1, thus increasing the probability of a connection. For now, we leave this subtlety for future work and chalk it up to conservatism. Another way to look at it is to say that when we base our analysis on the 4-hop assumption, in reality this more likely represents the reliability of a 5-hop system. In any case, our goal is to provide first-order results (+/- 30%) with the intended outcome of assessing the general viability of the business strategy and thus whether further, more rigorous research is warranted.

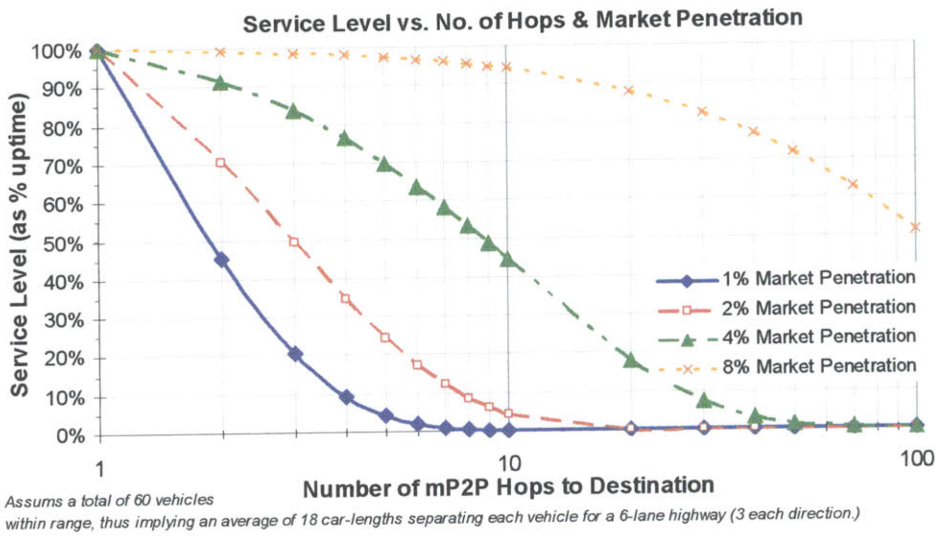

Figure 6.5: Service Level vs. Number of Hops & Market Penetration of mP2P Vehicles

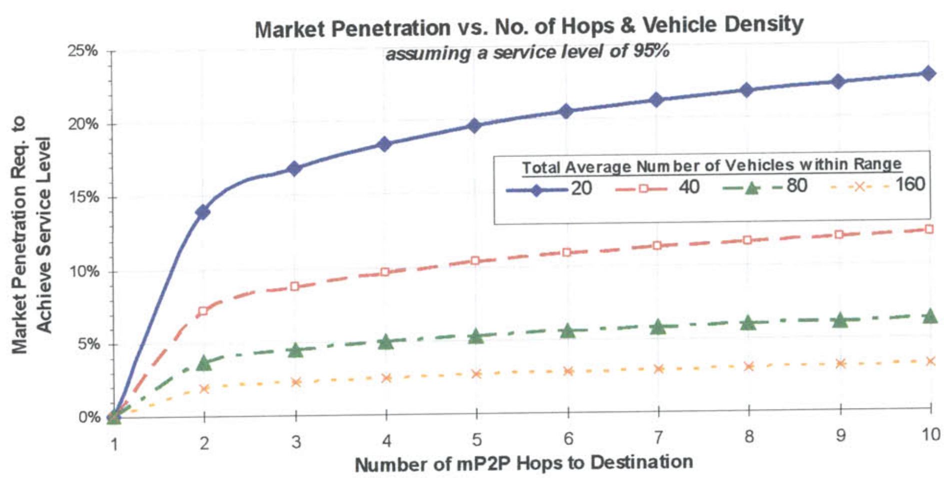

Figure 6.6: Required Market Penetration vs. No. of Hops & Vehicle Density

Figure 6.7 presents the results of the above analysis for the eastbound side of the road for one of the loop detector sites (#2: Woodward Av. & I-696). The data from the entire month is segregated into days of the week, thus each data point is an average of three of four different days. From the graph, we can clearly see the diurnal nature of the traffic. The reason that the afternoon commute is larger than the morning one suggests that most commuters travel west in the morning to go to work, and return home east in the afternoon. When we plot the results of both at the same time, the commuting "humps" will be of essentially the same magnitude. It is comforting to note that the weekday and weekend data are very consistent. Finally, the graph indicates that there is roughly an order of magnitude of variation between the peaks and troughs.

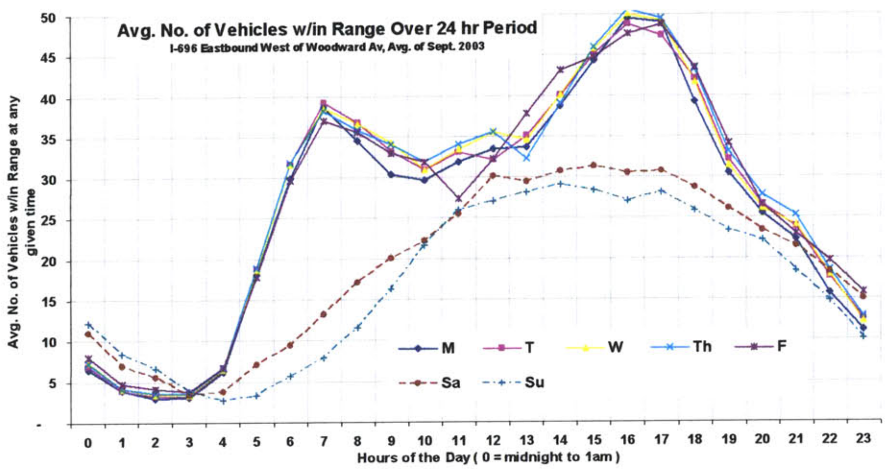

Figure 6.7: Number of Vehicles Within Range Over 24-hr Period for Site #2

6.3.2.1 MARKET PENETRATION VERSUS ACTIVE SAFETY FUNCTIONALITY

Since Active Safety applications are of such stated importance to OEM's like GM, we digress for a moment to show the impact of pure vehicle-to-vehicle mobile peer-to-peer hops on functionality. In this scenario, there is no requirement for infrastructure. The only goal of the system is for enabled vehicles that sense a hazard or other important information that might be relevant to other drivers in the area to broadcast that information. If the information can be relayed through several vehicles, than it provides additional warning time to drivers. Figure 6.9 at right shows how market penetration varies versus the number of hops for the three levels of service.

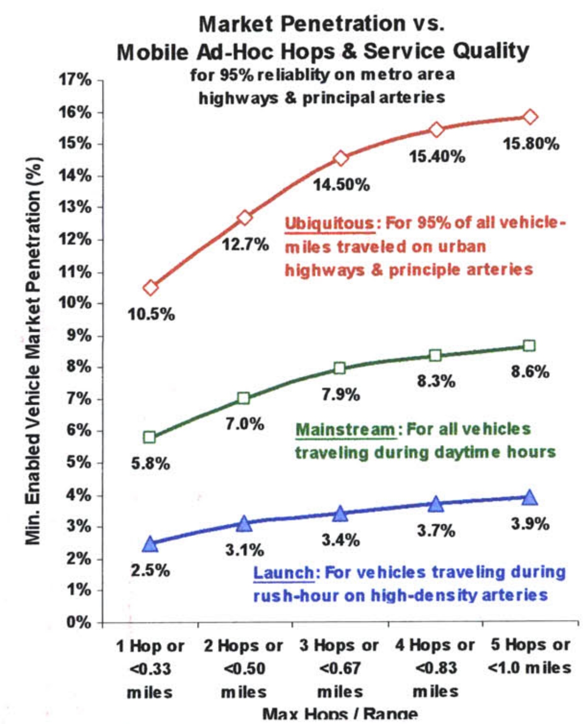

Figure 6.8: Active Safety Performance vs. Hops

6.3.3 Traffic Density Data Analysis

Since the traffic density is so critical to the results, we chose to analyze data from three regions in the Detroit Metro area, chosen to represent the range of potential inputs. Thus, scanning the entire data set of over 1,500 loop detector sites, we chose two among the highest density, two in near the median of density, and of one of the lowest. Figure 6.7 shows a map of the area. The highways classified by the US DOT as interstates or principal arteries (and thus part of the total infrastructure cost of Section 6.2) are in bold red and blue. The five sites chosen for analysis, circled (in dark orange) and numbered on the map, are identified in the table below.

Table 6.1: Loop Detector Sites Used for Analysis

No. on Map	Density Zone	MDOT rep_id	mile point	lanes	location	route	direction
1	High	1114352	14.06	4	EB I-696 W of Coolidge (W of	I-696	E
2	High	1114372	16.38	4	**EB I-696 W of Woodward**	I-696	E
3	Medium	458972		3	EB I-96 W of Novi	I-96	E
4	Medium	458952		3	EB I-96 E of Beck (at rest area)	I-96	E
5	Low	851998		3	EB I-94 E of Wayne	I-94	E
1	High	1179888	14.06	5	WB I-696 W of Coolidge (E of	I-696	W
2	High	1179868	16.38	4	**WB I-696 W of Woodward**	I-696	W
3	Medium	524628		3	WB I-96 W of Novi	I-96	W
4	Medium	524648		3	WB I-96 E of Beck (at rest area)	I-96	W
5	Low	851998		3	WB I-94 E of Wayne	I-94	W

Figure 6.9: Map of Detroit Metro Area Highways(blue) & Principal Arteries (red) with Five Loop Detector Sites Circled and Numbered 1-5

Performing the analysis on all three traffic zones resulted in largely the same pattern as Figure 6.7. Figures 6.10 shows the results from the full range of traffic density regions (high, medium and low). While there is some variability among the three zones (particularly visible in Fig. 6.11), it is small in comparison to the variability throughout the day (especially considering the first-order nature of this analysis.) This is consistent with the understanding that, within a Metro area, traffic quickly fills any available capacity and thus it makes sense that volumes are rather consistent. The most informative result of Figure 6.10 is its graphical depiction of the minimum thresholds for daytime and rush-hour operations assuming the stipulated 95% service level and 4-hop maximum. As one can see, users would start to see reliable service during rush hour in the high-density zones with as little as 3.2% market penetration. Figure 6.11 shows an expanded view of Fig. 6.10 along with a delineation of the penetration thresholds for each density and time of day. Once there is 7.8% penetration, all daytime users in even low-density zones should experience generally uninterrupted service. A more detailed depiction of the analysis is included as Appendix C.

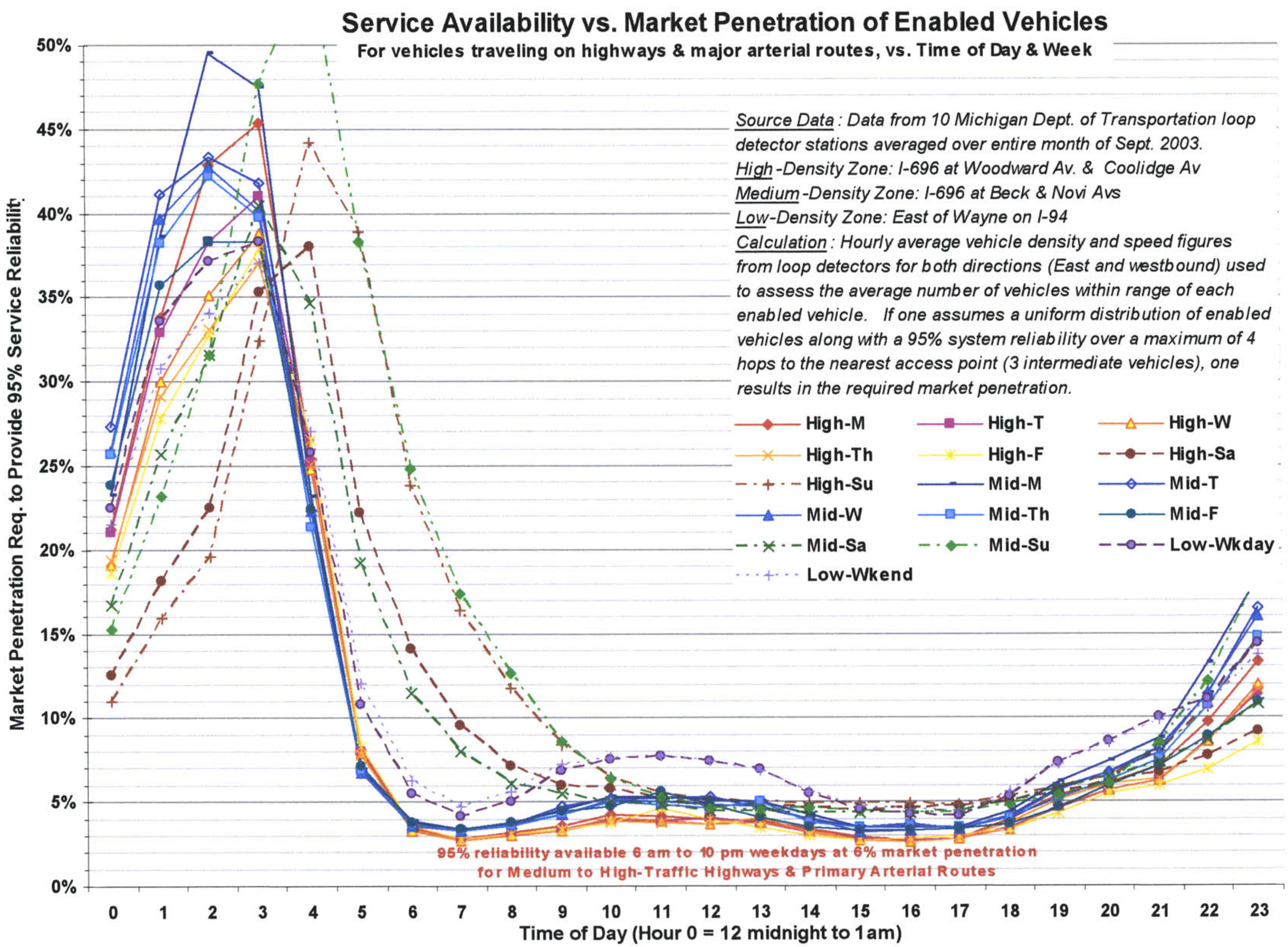

Figure 6.10: Market Penetration Required for 95% Service Level by Hour of Day & Day of Week for All Three Traffic Density Zones (high, medium & low)

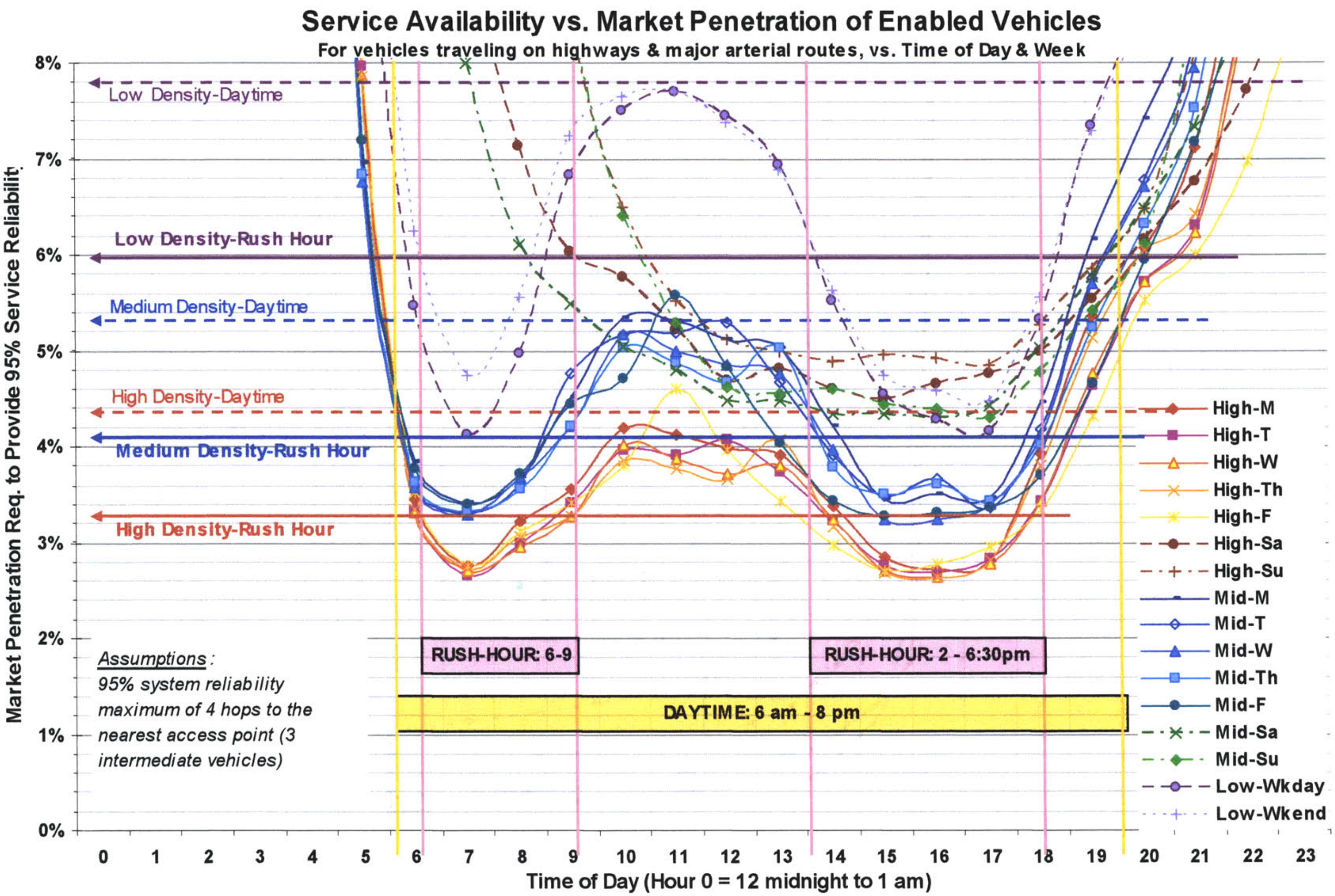

Figure 6.11: Detail of Figure 6.10 Showing Level the Market Penetration Thresholds for Key Daytime Hours for Each of the Three Traffic Density Zones

6.3.4 Market Penetration vs. Service Availability

Now that we have a sense of how performance would vary throughout the day for the three zones of density, it is informative to understand the impact on the customer experience. Here we see a compounding of the density effect. In short, most vehicle-miles traveled on the road occur during the periods of highest density. Thus, summing up all the vehicle-minutes of travel on the road and sorting them by the market penetration required for the assumed 95% service level (herein "service"), results in the plot of Figure 6.12.

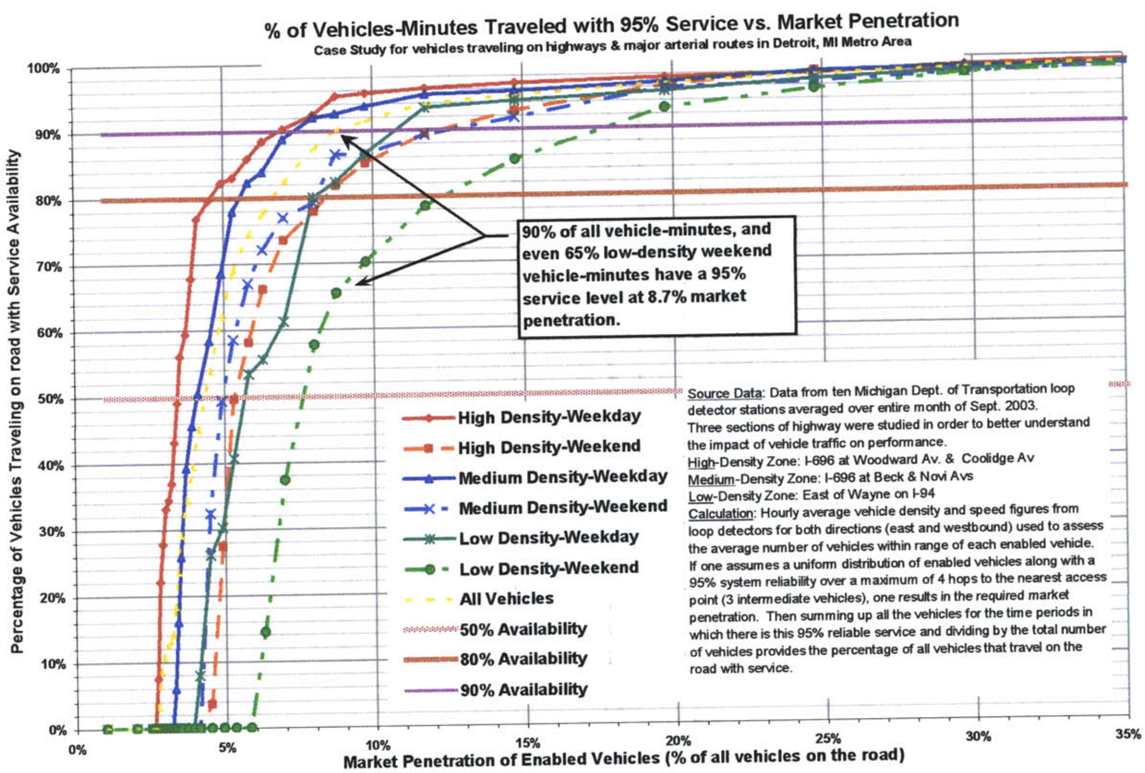

Figure 6.12: Percentage of Vehicles on Road with 95% Service Level vs. Market Penetration

Here we see the dramatic impact of this compounding effect. In sum, users experience no consistent service until market penetration reaches 2.6% in a given metropolitan area. At this point, the system "lights-up" as the percentage of vehicle-minutes on the road that experience the threshold service level explodes. By 4.5%, 80% of vehicles-minutes in high-density zones experience 95% service; by 8.5%, 80% of all but weekend drivers in low-density zones experience service and at 14.7%, the service threshold reaches 95% of all vehicles-minutes on the road.

To assess the sensitivity of these results to the assumed service level, we re-plotted the results with a 70% service level assumption instead. The results (figure 6.13) show that the curves steepened slightly, but shifted to the left significantly. The 3% "light-up" point for high-density weekdays is now only 1% and 90% of all vehicles-minutes traveled have service at only 4.8% (instead of 8.7%!) This implies that for applications were the user might be tolerant to a 70% service level, say where the user is willing to wait 30-90 seconds for a result (such as real-time traffic data for dynamic routing), the point where the consumer may begin experiencing reliable daytime service is tantalizingly low. To highlight the differences in the curves, Figure 6.14 plots the two service levels on the same chart for all the vehicle-minutes traveled. It is here we see that the asymptotic behavior of the relationship causes the gap to widen as the percentage of vehicle-minutes approaches 100%.

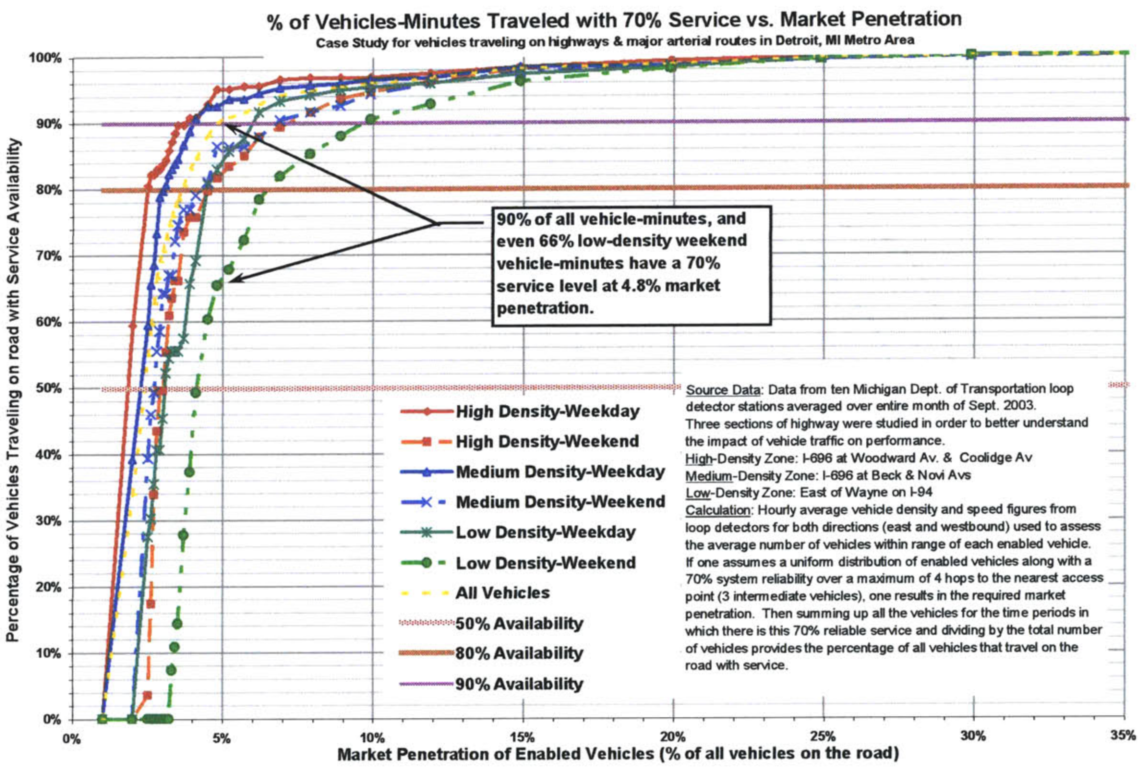

Figure 6.13: Percentage of Vehicles-Minutes Traveled vs. Market Penetration for 70% Service Level Threshold

With the above results, we have in effect determined the point of critical mass whereby the network of mP2P-enabled vehicles is providing value to the majority of users on the road. If we assume critical mass occurs when over 50% of vehicle-minutes achieve 70% service for even low density weekdays, we can state that critical mass for the Detroit Metro area occurs at only

3.9% market penetration (and 7.5% for the 95% service level necessary for low latency applications like VoIP and active safety.)

This conclusion should be of particular interest to Automotive OEMs with large domestic marketshare (such as General Motors) since they could reach this critical mass point completely on their own and within a relatively few years by making the policy decision to install mP2P system on most of their vehicles. In 2003, GM is factory-installed its OnStar system on roughly 28% of its total US light-duty vehicle sales. If GM were to make the commitment to factory install mP2P in 75% of its new vehicles, that would inject 3.6 million new vehicles every year. Assuming a net domestic population of 161 million vehicles on the road today, and a net annual increase of 3%, then at the rate of 3.6 million new mP2P vehicles each year, GM would reach the critical mass of 3.9% market penetration in only 1.8 years. At the 2004 OnStar production rate, the period only slips to 2.9 years. These factors have important strategic importance that we discuss further in the next chapter.

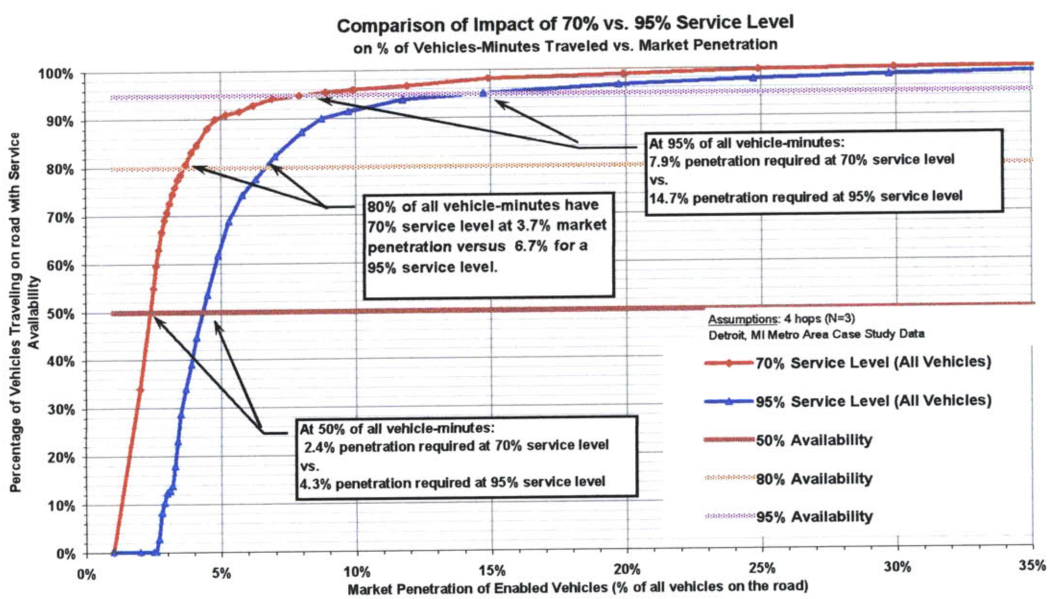

Figure 6.14: Comparison of 70% vs. 95% Service Level Impact Achieving Critical Mass

6.4 Benchmarking Customer Willing-to-Pay

Having quantified the relationship between market penetration and functionality and thus achieved a sense of where the critical mass threshold lies, we now move on to tie the functionality back to value. Expressed as a customer's willingness-to-pay (WTP), we benchmark analogous products and services to assess this value. Before doing so, however, we feel it is important to note that the process of correlating a broad basket of allegedly analogous services to a completely new service on is the academic equivalent of watching an interpretive dance. While the benchmark data is hard and quantifiable (as the movements in a dance are), what one takes away from these data is subject to considerable interpretation. As a result, while we suggest some conclusions, we also acknowledge that the reader may come to significantly different results based on the same inputs.

With our hedging complete, we now present a broad range of potentially analogous products and services and their respective pricing. Table 6.2 sorts the suggested benchmarks into the following categories: connectivity, purely content-based services, bundled connectivity and services and device hardware. The table includes the range of monthly fees, the maturity of the market, the companies involved as well as some clarifying notes. One of the challenges in this analysis is the tremendous variability in how companies elect to market and price their services. For example, some potential substitutes (such as onboard vehicle navigation and DVD systems) are bundled with new car sales and while automakers do not charge a monthly fee, they are able to charge significant premiums since consumers have no choice but to buy their proprietary system if they want the capability.

Other services (such as cell phone services) typically subsidize their products in order to lock in the monthly service fee. OnStar appears to use a combination of the two. Initially, all current OnStar-equipped vehicles (to our knowledge) come with the system factory installed. Whether the price of the hardware and first year's service (included free) are included in the new vehicle price or simply subsidized varies with the vehicle. In reality, even Automotive OEM's with their extensive market research capability have great difficulty assessing how much an additional feature is worth to a customer.

Since the consumer's willingness-to-pay for a unproven mP2P telematics system would likely remain considerably below cost until the market penetration reaches critical mass, we must include this assumption in our analysis. Finally, for the products would not likely have a monthly fee component, we use a 10% cost of capital and a postulated product lifetime (typically five years for vehicle systems) to convert this value back into a monthly value for comparison to the other services.

Table 6.2: Proposed Comparable Product and Serivce Benchmarks for mP2P Telematics

TELEMATICS COMPETITORS AND SUBSTITUTES SERVICE & HARDWARE PRICE BENCHMARKS

Delivery	Level	Monthly Fees (range)		Maturity (1-10)	Companies	Service Notes
CONNECTIVITY						
Land-line Phone	Basic	$15	$25	10	Local Util's	Unlimited local
"	Unlimited	$38	$43	8	Nat'l Long Dist.	Unlimited local & long distance et al
Cell Phone	Basic Voice	$15	& up	8	any	30 min
"	Semi-Unlimited	$40	& up	6	5 Major's	every variant you can think of
Smart Cell Phone	Unlimited Data	$15	$80	5	Sprint, Verizon, AT&T	PDA type services
Internet	Modem	$10	$20	8	NetZero, Earthlink	<56 kbps
"	DSL	$20	$35	7	Local TelCo's	<500 kbps
"	Cable	$35	$60	6	Local CableCo's	<3 mbps
WISP	Unlimited	$22		3	Boingo	5,000 AP's
"	"	$30	$50	3	Wayport	606+ Hotels, Airports & McDonad's monthly rate for annual contract and month to month
BUNDELED CONNECTIVITY & SERVICES						
Cell Info & Services	Fixed monthly fee	2.40		5	NTT DoCo Mo iMode	Subscription-based content & services over 2.5G cell phone (Japan)
"	Per site subscription	0.80	2.40	5		
Dynamic Traffic Info.	Basic-Sat Broadcast	5.00		2	XM Radio	Data & Pricing Source: NavTech
Consumer Telematics	Fixed monthly fee	10.53		3	G-Book	Unlimited data & services (Japan)
		17.82		3	BMW Online	Unlimited data & services (Germany & UK)
Safety & Security	Basic	16.95	15.26	5	OnStar	Operator-based Safety & Security
Telematics	Directions & Connections	35.00	31.50	4	OnStar	Operator-based S&S + Directions
	" + Consierge	60.00	54.00	3	OnStar	Above + Personal Consierge (operator)
Online Portal Services & ISP		21.00	25.00	7	AOL, MSN	Online portal services, email & dial-up access
SERVICES ONLY						
Portal Services		0.00	*Ads*	5	Yahoo!, Google	Paid through advertising
Personal Concierge Servi	Per Call Basis	0.89		4	inFone	89 cents per call: rest recc, res. Directions
Periodicals & Info.	Daily, Customized	0.00	1.25	4	AvantGo.com	Publications delivered to your PDA or 2.5G Phone; Suplemented w Ads
Urban "Directions & Connections"	Unlimited data, sync PDA over internet	2.08		4	Vindigo	Great UI; PDA platform; restaurant reviews, movies, etc, $25/yr, PC sync
"	Same but via 2.5G cell phone	2.99		4	Vindigo	i-Model biz. model, Monthly service fee, available through Verizon, ATT, Sprint et al
Consumer Telematics	Content Only	3.44	4.96	3	G-Book	Limited to Unlimited services (Japan)
Email Services		2.50	5.00	5	Yahoo!	Complete email services at extra charge
Digital Audio Media	Basic Membership	14.95	19.95	4	Audible.com	Download to MP3 player - Basic: Daily WSJ or NY Times + 1 audio book/month
DEVICE HARDWARE PRICES (independent of reoccuring expenses)						
Cell Phones		$30	$500	7	Verizon, ATT,...	2.0-2.5G services
PDAs		$80	$600	6	many	Palm & PocketPC OS based
Satelite Radio	Any Install type	$130	$600	4	XM, Sirius	100+ digital radio stations; data-capable
OnStar	Factory Installed	$399	$699	4	OnStar	Free on some high-tne GM models
OnBoard MP3	Aftermarket-Player	$200	$500	5	Apple et al	HD-based sytems w 10-40GB
	Aftermarket-Built-In	$500		3	Kenwood, ...	"Music Key" type systems
	Factory Installed	$500		1	OEMs	Not prevalent yet
Rear-Seat DVD System	Vehicle Option	$1,000	$1,400	5	OEMs	Often bundeled
Onboard Navigation	Aftermarket-PDA	$400	$550	4	Garmin iQue 3600	Palm OS 5 based dash-mounted, PDA driven, color screen, voice commands
	Aftermarket-Radio	$999		4	HarmonKardon TrafficPro	Icon & Voice command, 2-CD US atlas, integrated w CD & Radio (slick, ,fm europe)
	Aftermarket-Screen	$1,500	$3,000	4	Bose, Kenwood	DVD-based w 6-8" screen
	Built-In	$500	$2,500	5	OEMs	Typically bundeled with other entertainment options
Consumer Telematics	Factory Installed	$754	$989	4	BMW Online	Vehicle Option for 7 Series in Europe (920€)

MATURITY LEGEND		Code	Maturity
1	Never offered, hypothetical/guess	6	Slowing Growth: Still some significant service variance
2	New/Proposed, some independent price point	7	Mature: Slight service & more package/pricing differentiation
3	Nasient Growth: few/small players; market still unestablished	8	Very Mature: package/bunding/pricing innovation on otherwise mature product
4	Growing Growth: several players crossing the chiasm	9	Super Mature: very little differentiation, only by brand
5	High Growth: Intense competiton amond several players	10	Completely mature:commodity/no price-value movement

Table 6.3: Proposed Correlation Between Functionality, Customer Willingness-to-Pay, and thus Market Penetration

Table 6.3: Proposed Correlation Between Functionality, Customer Willingness-to-Pay, and thus Market Penetration

							Estimated Application Availability, Value & Willingness-To-Pay (WTP)												
								Service-Derrived Value				Hardware-Derrived Value				Hardware Cost Value			
									BW Enabled										
Mkt Penet*	GM Penet.	Connect Location	Connect Type	Service Quality	Benchmark Source	Min AP Invest. (M $'s)	Total WTP for each Service Level ($/mth)	Biz-2-Prod	Burstable Content	Real-Tiime Content	TOTAL	Biz-2-Prod	Burstable Content	mP2P	TOTAL	Biz-2-Prod	Burstable Content	mP2P	Payback Period
	(2)	Stationary, Burstable				(6)	(7)				($/mth)				($/mth)	($'s)	($'s)	($'s)	(yrs)
0%	0%	Dealer	Wi-Fi(1)	Broadband	Hardware cost is converted into a monthly "value" to the customer by assuming a 5-year payback with a 15% cost of capital.	$ -	$ 0.04			-	-	0.04	-	-	0.04	0.50	-	-	1
0%	0%	Home	"	Broadband		-	$ 1.47			-	-	0.18	1.29	-	1.47	2.00	40	-	3
1%	4%	Retail	"	Broadband: 5% of Gas Stations		12	$ 2.04			-	-	0.26	1.78	-	2.04	3.00	70	-	4
2%	7%	"	"	Broadband: 10% of Gas Stations		24	$ 2.89			-	-	0.35	2.54	-	2.89	4.00	100	-	4
3%	11%	"	"	Broadband: 30% of Gas Stations		71	$ 3.61			-	-	0.44	3.17	-	3.61	5.00	125	-	4
		True Peer-to-Peer Connectivity																	
0%	0%	Enab. Veh.	mP2P	Vehicle SMS / Person-to-Person	Hardware cost is converted into a monthly "value" (same method as above).	-	$ 0.53	-	-	-	-	-	-	0.53	0.53	-	-	25	5
3%	11%	"	"	"		-	$ 1.06	-	-	-	-	-	-	1.06	1.06	-	-	50	5
10%	35%	"	"	"		-	$ 1.59	-	-	-	-	-	-	1.59	1.59	-	-	75	5
30%	106%	"	"	"		-	$ 2.12	-	-	-	-	-	-	2.12	2.12	-	-	100	5
		Real-time Wireless Broadband																	
3.0%	11%	Hwy AP(6)	Mob AH(4)	Real-Time Traffic / Sensing Service	Critial Mass Threshold for Consumer Value	89	$ 0.50		-	0.50	0.50		-	-			-	-	
3.4%	12%	"	"	High Density Highway: Rush-hour		89	$ 1.00		-	1.00	1.00		-	-			-	-	
4.2%	15%	"	"	Medium Density Highway: Rush-	*Interpolated between values above and below*	178	$ 2.00		-	2.00	2.00		-	-			-	-	
4.5%	16%	"	"	High Density Highway: Daytime		89	$ 3.00		-	3.00	3.00		-	-			-	-	
5.4%	19%	"	"	Medium Density Highway:		178	$ 3.50		-	3.50	3.50		-	-			-	-	
6.0%	21%	"	"	Low Density Highway: Rush-hour		230	$ 4.00		-	4.00	4.00		-	-			-	-	
7.8%	28%	"	"	Low Density Highway: Daytime	NavTech/XM dynamic routing service	230	$ 5.00		-	5.00	5.00		-	-			-	-	
8.5%	30%	"	"	>90% of Enabled Vehicles on Urban Hwys	Toyota G-Book services & unlimited connection	230	$ 10.53		-	10.5	10.5		-	-			-	-	
14.5%	51%	"	"	>95% of Enabled Vehicles on Urban Hwys	OnStar Safety & Security service	230	$ 16.00		-	16.0	16.0		-	-			-	-	
37.0%	131%	"	"	>99% of Enabled Vehicles on Urban Hwys	Online portal services such as MSN dial-up & WISP services like Boingo	230	$ 21.00		-	21.0	21.0		-	-			-	-	
54.0%	191%	"	"	>99.99% of Enabled Vehicles on Urban Hwys	Online portal services such as AOL	230	$ 25.00		-	25.0	25.0		-	-			-	-	
80.0%	283%	"	"	Saturation	OnStar Directions & Connections Services; Home DSL/Cable broadband		$ 35.00		-	35.0	35.0		-	-			-	-	
100%	353%	"	"	All Standard Use Vehicles			$ 35.00		-	35.0	35.0		-	-			-	-	

LEGEND

* Penetration defined as fraction of total US vehicle population used for everyday consumer applications.
Thus, it would likely leave out: rental fleets, most corporate fleets & specialty cars such as antiques and "science projects"
=> the general assumption used thorgh this project is that the total market for enabled vehicles is equal to the total number of licensed drivers or 161M

** Of the target demographic with the new car with the free hardware a la OnStar

(1) 802.11x connection

(2) Required % of all GM vehicles on road to enable total US market penetration

(3) Daytime: 6am to 10 pm weekdays

(4) Mobile ad hoc networking: 95% reliability over a max. of 3 hops to nearest AP

(5) Rush-Hour: 6 - 10 am & 2 - 7 pm weekdays

(6) DOT definition: Interstates, freeways & principle arteries

(7) Maximum of value from Service and Hardware (not sum or average)

BW Enabled — Applications enabled by broandband services charged to consumer on an unlimited data basis (fixed rate per month)

Urban Hwys — Interstates, freeways and principle arteries in metropolitan areas and along highly trafficed interstae corridores

Using these techniques, Table 6.3 presents a proposed consumer willingness-to-pay for the entire range of functionality. The first group is for stationary applications, starting in the home and including access through retail establishments such as gas stations. For this class of application, we assume that the consumer would not be willing to pay a monthly service fee, but some percentage of new vehicle buyers would place value on this as a vehicle component. What then varies, as the number of available access points increase, is the acceptable price for hardware (independent of whether this is sold as a separate option, or bundled with other features.) The second group, assesses the value of active safety-type true peer-to-peer connectivity using the same technique.

Finally, the last group in Table 6.3 attempts to value real-time wireless broadband services. In some cases, we use other connectivity services as benchmarks. In others, we instead employ services that would be enabled by that quality of connectivity. The source of each is identified under the column "Benchmark Source" while "AP Investment" lists the nominal investment in access points (in millions of dollars) that would be required to facilitate each. In sum, we assume the maximum potential value of this service (in today's $s) is $35 per month.

6.5 Market Penetration vs. Customer Willingness-to-Pay

Taking the above results, we now plot market penetration versus customer willingness-to-pay ("WTP") in Figure 6.15. Starting at zero market penetration and lasting until 1-3% market penetration, depending on the aforementioned assumptions, the our analysis indicates that the customer WTP is around $2 per month. In reality, this is figure is a rough valuation of the monthly value that results from a product purchase price of about $70.[69] The service this hardware provides is Wi-Fi at home or other free stationary access points. We do not assume that the consumer actually commits to any additional services that incur a monthly fee. The $70 is taken, albeit arbitrarily, as the price of an individual Wi-Fi card when the demand for then started to really take off in the US several years ago.

What is missing is the number of people who would be willing to buy at this price. These Early Adopters tend to be technologically savvy and have significant disposable income to invest in speculative new technologies they are still unproved (and expensive.) To be fair, it probably is on the order of ten thousand new car buyers in the first year out of the 17 million total or 0.06% of the market for new vehicles. In any case, we are a long way from reaching the 1-3% critical

[69] Assuming a life of 4 years, a cost of money of 10%.

mass threshold. As a result, we assume that to get anywhere near to this penetration, the product will need to be bundled with existing vehicles and thus essentially given away for free. After critical mass is reached, the value begins to climb steeply.

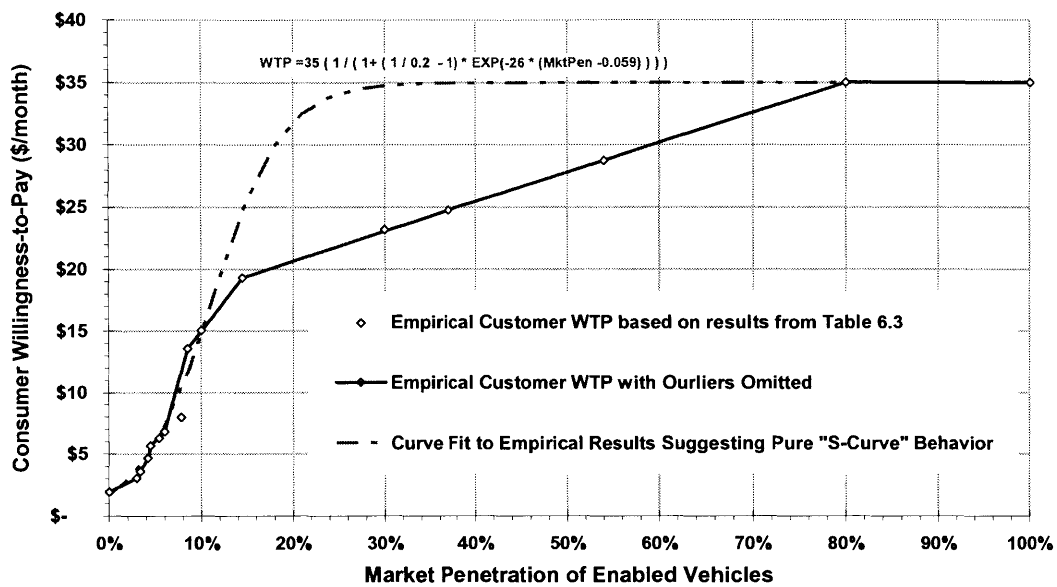

Figure 6.15: Customer willingness-to-Pay vs. Market Penetration

To see to what degree our empirically-derived curve agrees with theoretical adoption patterns, we fit a standard exponential "S" curve to the data points. This exercise highlights the fact that the benchmark curve switches from exponential to linear growth to at around $20 a month before eventually reaching the maximum WTP plateau at $35. Since this section of our analysis is so first-order in accuracy, who is to say. However, the intuition from Chapter 5 suggests that the value to the customer as a result of applications and infrastructure will have a more modest growth rate, so perhaps this is not so far off. Regardless, a conjoint or other marketing study of what consumers would be willing to pay for what level of service would make a terrific area for follow-on work. In the end, we postulate that the adoption does follow an S-curve behavior, as theory suggests.

6.5.1 The Impact of the Critical Mass Threshold on Viral Growth

Having assessed the critical mass threshold at 1-3% market penetration, we now have a good sense of when this market would become self-sustaining and thus begin to experience viral growth in market adoption. From this perspective, the key challenge in getting mP2P to "cross the chasm" is the near-zero level of customer willingness-to-pay value until the market reaches critical mass. Beyond that point, it should grow on its own. In Chapter 7, we propose a comprehensive business strategy that attempts to facilitate this transition as well as insuring positive returns in the long term.

Chapter 7 Business Strategy for mP2P Telematics

Having evaluated the technology, value chain, applications, market dynamics as well as the impact of viral growth and critical mass threshold on market adoption, we now have the inputs necessary to craft a comprehensive business strategy to bring mobile peer-to-peer telematics to market. To do so, we first list our the goals. In rough order of priority, the strategy should:

1. Address the four barriers to Consumer Telematics identified in Section 1.2.4: value for money, technology standards, human-machine interface and sufficient bandwidth.
2. Include a "future-proof" technology strategy.
3. Insure the development of compelling ("must-have") consumer applications.
4. Minimize up-front investment and financial risk.
5. Anticipate competition and substitutes if and when the product succeeds.
6. Be "bootstrap-enabled" or on other words, insure profitable revenue as the market and product matures.
7. Insure long-term profitability (based on our understanding of the value chain.)
8. Leverage partnerships and independent third-party investment (and thus contribute to goal number 4.)
9. Anticipate the challenges of rapid growth that would come when the market penetration reaches critical mass.
10. Finally, ideally anticipate distant opportunities and facilitate their coming to pass.

While this list may seem overly ambitious, considering all these issues will provide the best chances of long-term success.

To address all these points with a minimum of repetition, we break up this Chapter into the following sections:

- 7.1 Marketing & Consumer Value Strategy (addresses: 1a, 6),

- 7.2 Technology Strategy (addresses: 1b, 1d, 2, 8),
- 7.3 Applications Development Strategy (addresses: 1c, 3, 8),
- 7.4 Infrastructure Strategy (addresses: 4, 6, 8),
- 7.5 Competitive Strategy (addresses: 5), and
- 7.6 Business Model & Profit Strategy (addresses: 6, 7, 8, 9)

We address issue 10 in the Conclusion.

7.1 Marketing & Consumer Value Strategy

The first rule for a successful marketing and consumer value strategy is that the perceived value delivered to the customer (and thus their willingness-to-pay) must exceed the cost. While obvious, this is challenging with a new product and especially with a new technology. The critical mass analysis of Chapter 6 tells us that aggregate customer willingness-to-pay will initially be zero, or close to zero. In practice, every customer has their own price and marketing theory tells us that the group of early adopters will be willing to pay for a new "gizmo." The problem then becomes crossing the chasm to where the early and late majority are willing to pay.[70] Many new products never successfully weather the crossing for a number of reasons. One of the principal barriers cited by the McKinsey Report for telematics (of Section 1.2.4) being inadequate "value for money."

So if one wants to succeed, in crossing the chasm, one must either initially sell it substantially below cost (as is done with home gaming platforms) or bundle it with something the customer already knows they want (as Microsoft has done repeatedly with Windows.) With its Internet Explorer browser, Microsoft pursued both tactics, but they were competing against an entrenched rival (Netscape) with a overwhelming market-share. In our case, we assume this is the first product of this type to market. The best strategy is thus likely to be the one GM pursued with OnStar: bundle the new, unproven product with the car or as Acura currently does by bundling OnStar with their onboard navigation system option package.

There are many useful lessons from OnStar's experience. When first launched in 1996, the service was a $1400 (list) dealer-installed option. Of that, we estimate that GM's cost was over $1000, with installation likely comprising a significant fraction of that figure. During the first four years when this was the model, under 80,000 units were sold in total. However, in 2000

[70] Moore, p.17.

when GM committed to factory-installing the system and bundling it with the vehicle, costs dropped by over half (due to both the manufacturing economies of scale as well as a near ten-fold drop in installation cost) and annual sales jumped by a factor of over 40. Since then, it has continued to decrease costs and increase volume. On some products (such as GM's top-of-the line Cadillacs) it is currently a standard feature, on others it is a $300-700 option (list) The lesson: committing to a volume, and then factory-installing the system are critical to get the costs down. Volume then generates economies of scale on the backend. Today, OnStar is operationally in the black and GM is happy since it now has increasing evidence that OnStar helps sell cars.

The challenge is thus to craft a strategy that can weather the period of the initially flat section of consumer willingness-to-pay versus market penetration curve before critical mass is reached. While Figure 6.15 shows this section as small on a linear scale of market penetration, this is deceiving since 1-3% of the market actually represents 1.6-4.8 million vehicles. Figure 7.1 depicts this curve with a logarithmic x-axis instead to emphasize the fact that the challenges (and thus the necessary focus) are most difficult at the lowest market penetration, and get easier as installed base grows. Within this context, the points at which the most promising applications and capabilities that would be possible through an mP2P telematics system can take hold are labeled. The point of the diagram is how the earlier applications would allow us to bootstrap our way up to the later, higher value ones.

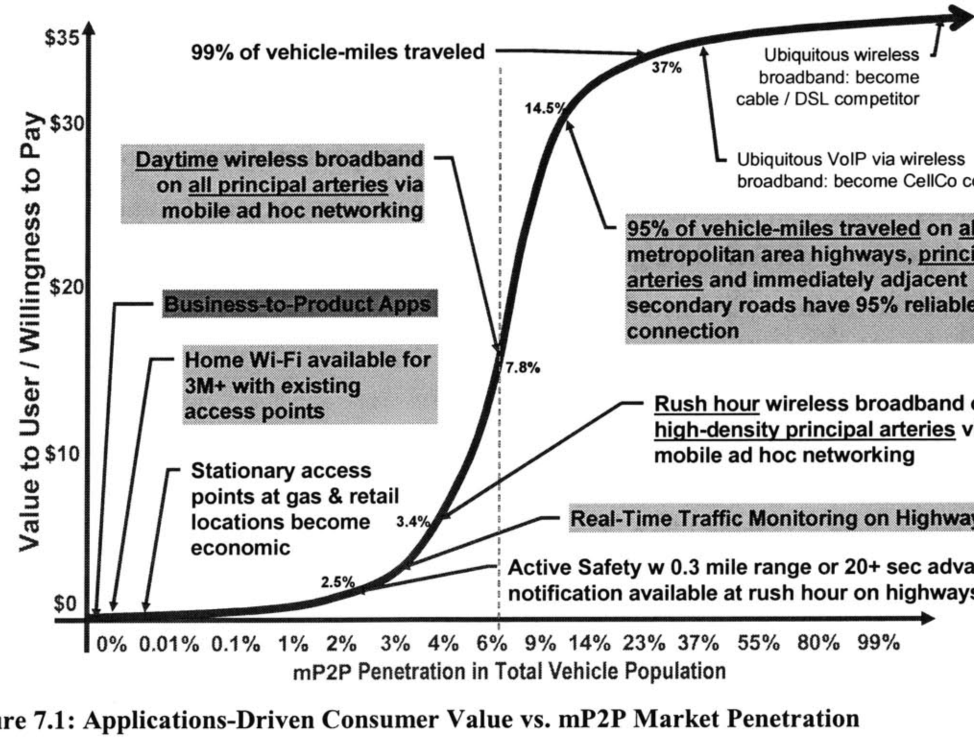

Figure 7.1: Applications-Driven Consumer Value vs. mP2P Market Penetration

It the installed cost were $300 per vehicle, a good ballpark figure based on our research, this represents a cost of $500 million to $1.5 billion. Even GM, with its dominant 28.3% US marketshare would likely consider this a hugely risky investment if it were to subsidize the expense purely on the bet that it could recoup its investment once critical mass was reached. As a result, we must find a way for the proposed consumer telematics system to generate a return prior to the critical mass necessary for mP2P functionality. To do so, the "burst-able" applications that function at destination access points while the vehicle is stationary must provide sufficient value so as to justify a slightly higher cost of the vehicle bundled with mP2P.

Once customers have been acquired, the challenge is to keep them and ideally wow them so much that they tell all their friends how great their new gizmo is. Once again, we come back to value for money. The best way to achieve this is to initially way over-deliver value relative to expectations. While perhaps counterintuitive to those entrenched in the "promise-the-world" advertising world-view of marketing, it is well documented in the newly coined field of viral marketing. High-end liquor companies have had success using this technique by hiring charismatic people to go to trendy bars and conspicuously order their drink. Many successful new electronic products or services (especially from small companies who don't have the resources for expensive advertising) have successfully launched products in this way, relying exclusively on word of mouth-driven growth sparked by hooking influential people (like journalists) and trend-setters. An extreme example would be to not promote the service at all, but instead introduce the new vehicle owner to the great new feature they have in their car once they have already signed the paperwork. While an exaggeration, the key point is not to initially over-market the product, and then fail because consumers had overly inflated expectations of what the product could deliver. (Also, advertising is expensive.) Since they expected nothing, whatever value they do perceive will feel like a gift and they are more likely to be wowed. Keeping them wowed depends on having a pipeline of compelling applications, which we address in Section 7.3

7.2 Technology Strategy

Executing an omnipotent technology strategy is the most complicated component of the strategy. The key here is to think like a PC-maker, not an Automaker. Car companies optimize every component for lowest manufactured cost, not upgradeability since they do not expect to see another dollar from you until (hopefully) the next time you upgrade your vehicle. The problem with this is vehicles have a 15-year life, while consumer electronics' lifetimes are closer to 3-5 years. Considering that wireless networking technology evolves so quickly, it is impossible to predict the future. Current Safety and Security Telematics platforms are optimized around low cost and are highly integrated into the vehicle. As a result, they are not easily upgraded. To accommodate potential future applications and services, the focus ends up being on them then "flexible." In effect, this implies staring into a crystal ball, hypothesizing the future customer demands and technology evolutions, and then designing an optimized system accordingly. However, this typically results in over-designed hardware and intransigent legacy issues down the road that end up compromising strategy. Instead, one needs to take a page from the PC world and make the system modular and thus upgradeable.

Now, to make a well-integrated, well-designed consumer telematics system completely upgradeable would be prohibitively expensive. Instead, we choose the key components most likely to need upgrading during the life of the vehicle and make them modular, leaving the balance of the system hard-wired into the vehicle. By defining the industry clockspeeds of the major components, we can sort them into two groups based on whether they should be upgradeable or not. Taking strategic lessons for the technology architecture from Chapters 2 (Technology) and 3 (Value Chain) drives one to identify the components or services mostly likely to be commoditized; in this case it is network services and over the long term, potentially the central computing unit and accessories.

For example, the CPU, memory and system bus (likely as a single unit) should be replaceable as should the network cards and potentially the antenna and display (potentially integrated with the CPU & memory). In addition, there should be a few ports (probably firewire[71]) for adding accessories. The rest, should be built in. After all, it is unlikely that there would be a serious need to upgrade the wiring that connects the system to the: antenna, speakers, mike, controllers on the steering wheel or the rest of the vehicle control modules (since these aren't gong to be replaced during the life of the vehicle either.) This way, the labor-intensive component of the installation (i.e. the wiring) remain fixed, while the brains and the wireless cards could be swapped out like PCMCIA cards on a laptop. While hardened automotive engineers will tell you that modularity increases the potential for failure, we have no doubt that they can devise an acceptable solution. After all, since today's CD and tape player can reliably accept "modular music" thousands of times over the life of the vehicle, there is no reason to believe a device that will only be replaced a few times cannot be engineered as equally reliable.

[71] The IEEE 1394 standard, capable of data rates of up to 400 mbps, has been identified by as the likely interface of choice for this type of telematics s system. [Salem]

Also, although it is unacceptable for the engine control module to fail, that is not the case for a device used to inform and entertain. As a case in point, when your cell phone or PDA breaks, you simply replace it.

The keys to modularity are standards and interfaces. For the upgradeable components, the trade-off is between integrating them all into a single replaceable module, thus minimizing manufacturing cost and many different, smaller components (as in a PC) thus maximizing flexibility and competition. Minimizing cost and complexity to the user and maximizing integration into the vehicle experience encourage fewer modular components and thus more of a PDA type architecture than that of a PC (many expansion and connectivity options, but a single, integrated CPU & display.) In the end, our research indicates that the optimum design is one where only those modules which are critical to be upgraded separately, are. The proposed architecture is depicted in Figure 7.2.

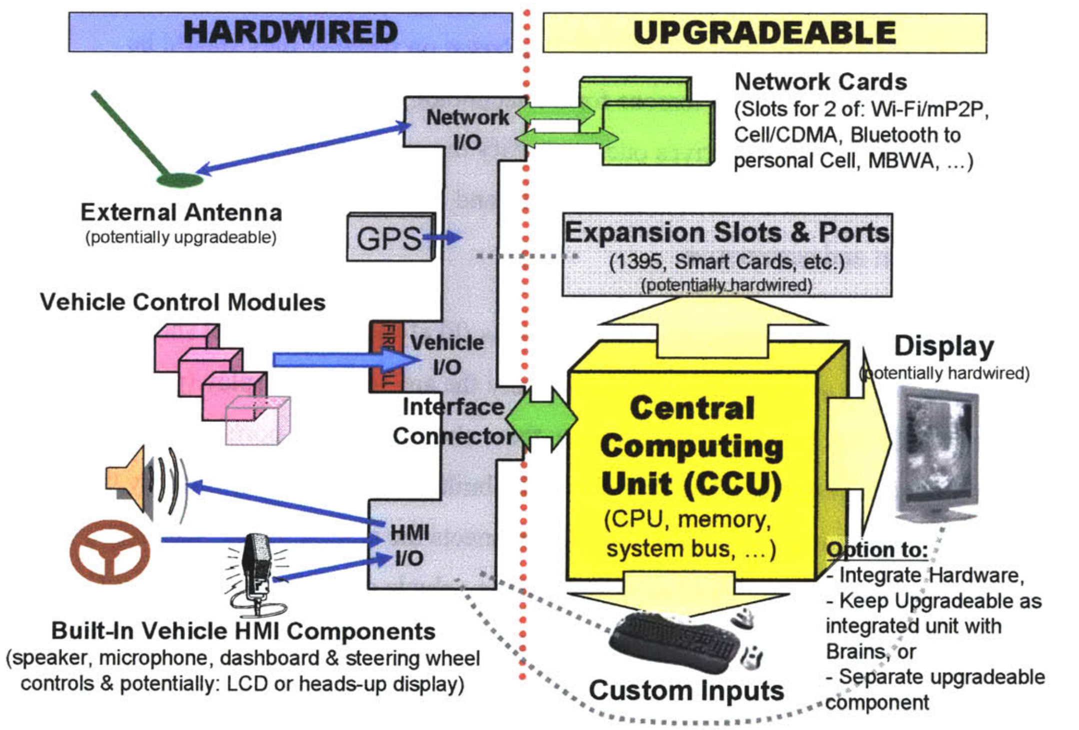

Figure 7.2: Proposed Technology Architecture Delineating Hardwired and Upgradeable Components

The central computing unit (CCU) is upgradeable as are up to two network cards (ideally one for a low-bandwidth, high availability connection such as cell phone and one for a low latency, wireless broadband connection such as mP2P-enabled Wi-Fi.) For the display, expansion ports and custom input components, there are three options. They could be: upgradeable, integrated with the upgradeable CCU, or hardwired. The hardwired (grey) standard connection can simply be a glorified wiring harness or could potentially have some computing power, although this will likely only increase complexity and cost while decreasing long-term flexibility.

One way to bootstrap the investment is to introduce the product using off-the shelf components as much as possible. While it would obviously not be optimal, using the Tungsten line of PDAs from Palm serves an interesting example of a potential initial test product. Each Palm has a standard interface through the cradle, an expansion slot for additional memory, devices (such as GPS), or communication (such as Cellular, Wi-Fi or Bluetooth) as well as a small touch-sensitive color screen (visible in a wide range of lighting conditions) and a mini keyboard for input. With 64 megabytes of RAM and built-in Wi-Fi, the Tungsten C™ is exactly the type of off-the-shelf device that would provide a terrific initial test-bed for development and even the foundation for a first generation of product. From a cost minimization perspective, the device already exists and is completely capable of handling most applications we have discussed. At they very least, it provides a cost and capability baseline: any specialized product must be better and cost less to make. From a marketing perspective, leaving it in a PDA mode might help with marketing since they would be simply be buying a PDA, only one that connects really well to their car and has some nifty features to boot.

To insure healthy development and minimize in-house investment, it makes sense to partner with a few other companies that make consumer electronics hardware. In the case of XM Radio, they partnered with Pioneer, Alpine, Sony and Delphi to manufacture and market their head units. Limiting this list to 3 or 4 manufacturers insures competition and creativity while making sure that they can each earn a profit on the products and thus have an incentive to invest in new products. Creating a completely open standard that anyone can design products for, increases the likelihood of brutal price competition. Also, by partnering, the OEM can have a hand in insuring standards of functionality and quality.

7.3 Applications Development Strategy

No matter how successful the technology or widespread the infrastructure, any mP2P consumer telematics system will inevitably fail without great applications to create value for the end consumer. In the end, mP2P is only the "killer enabler" of applications, not the "killer app" itself. Chapter 4 outlined the spectrum of applications that could leverage mP2P on the continuum of connectivity (and thus implicitly infrastructure and market penetration) ranging from stationary, burstable connections over Wi-Fi to ubiquitous mP2P. The key take away is that to maximize the chance for success, one needs a portfolio strategy: create a powerful operating system (OS) based on an upgradeable platform to support a wide array of features and services. Besides hedging risk, this strategy maximizes the ability of the platform to continue to provide value as the market matures. The burstable applications create value now while mP2P has zero market penetration. By the time the field begins to saturate, there will be sufficient mP2P presence for latency-tolerant, real-time mobile broadband applications to begin to take hold, and so on until the entire spectrum of applications is spanned. In our view, however, the most significant determinant of success in creating great applications is the ability to leverage outside help.

7.3.1.1 LEVERAGING THIRD-PARTY DEVELOPERS

The most successful platforms, be they Windows, MacOS, PalmOS, or any of the home video gaming platforms, all won out in the marketplace by leveraging the creativity, ingenuity and investment of independent third-party developers. A cautionary tale of the risks associated with relying purely on in-house development is that of the modern smart phone. Up to now, nearly all US Cellular Companies have developed their integrated phone applications in-house (or occasionally with contract developers for in-house customers.) While current technology severely limits the memory, CPU and power available to these devices thus making completely integrated systems seen necessary, their track record is nonetheless dubious. Besides the digital camera feature, we are not aware of any evidence that owners of these new, feature-laden phones perceive any real value in these applications. While one could argue that this is due to the emaciated screen or computing capability of these phones, there are two examples of phone platforms that have succeeded in this respect that suggest otherwise. The first are hybrid phone-PDAs based on the already successful PalmOS platform such as the Treo line of phones by Handspring (now part of Palm Computing.) The second, using a very different model yet nonetheless leveraging third-party development, is NTT DoCoMo's i-Mode phones in Japan (whose business model we discuss below, in Section 7.6.)

In sum, we believe that there is a strong case to suggest that to create a lastingly successful consumer telematics product, one must design the system around a power, flexible and efficient but also open operating system, and then court independent third-party developers to create applications for it. Developers should ideally *love* to program for it. Since we know from Section 5.3 (Application Development Market Dynamics) that getting outside developers on board will take time (as well as market penetration and momentum), the core OS shipped with the product should include a base level of applications that nearly everyone will want. This both insures a nominal level of functionality while other developers are brought on board and creates some expertise in-house. Taking a page from both Microsoft and the gaming platforms, the in-house group can then compete just as any outsider to build "must-have" applications. If this rational were not sufficient, exploiting outside development minimizes in-house investment, creates a network of firms invested in the platform's success, and also reduces risk of market failure.

7.3.1.2 HUMAN-MACHINE INTERFACE

Along with compelling applications, any successful consumer telematics system will have a multifaceted and intuitive human-machine interface. This area is historically, and will likely remain for some time, the domain of the Automakers. They have the experience of how best to design devices for interaction within the context of the vehicle. In addition, since the interface components (including: dash-board and steering wheel controls, speakers, microphones but also dash-board LCD and head's up displays) are tightly integrated into the surfaces and wiring of the vehicle, there is little sense in bringing this outside the sphere of the car designer. To get out of the traditional car mindset, we would recommend hiring away a few usability experts from Apple, Palm or IDEO to bring in some fresh perspectives to the design process.

7.4 Infrastructure Strategy

Since a hybrid Wi-Fi and cellular consumer telematics system could generate the required value to the early consumer to justify the cost of installing it in vehicles and there are several potential, competing wireless broadband technologies, the infrastructure component of this strategy provides the greatest risk to those who fund it. As a result, it is critical to minimize upfront investment as much as possible by taking an incremental or bootstrap approach to its build-out. To that end, we break up the infrastructure strategy into three separate steps: use existing home access, develop stationary retail points of presence and finally leverage pseudo-infrastructure of existing mP2P-enabled vehicles to catalyze development of roadside mobile access point network.

The first infrastructure is home Wi-Fi access points. Since this already exists and is anticipated to continue growing rapidly over the next several years, it provides a terrific jumping-off point. The automaker begins seeding the network by installing hybrid systems enabled for mP2P, but backwards compatible with existing Wi-Fi and capable of low-bandwidth updates over existing cellular networks. This creates sufficient value among Early Adopters and Early Majority to warrant the cost.

Second, create partnerships with big nationwide fueling stations, retailers or wireless internet service providers (WISPs) to install mP2P-compliant Wi-Fi access points for stationary access. The nascent but growing body of vehicles in the marketplace will serve as the target market, and thus the argument to potential partners that this is a good bet. For retailers, Starbucks' experience of offering Wi-Fi as a technique to get customers in the door (and thus sell more coffee) provides a good case study. The ideal retailers to target would be those that cater to customers who frequent regularly, arrive via vehicle and have disposable income so coffee shops like Starbucks or Dunkin' Donuts are actually a great target markets since many customers will stop every day on their way to work. The other obvious market of this type is gasoline retailers. Today they generate the majority of their profits not on selling gasoline, but on the food and other conveniences they sell in their accompanying shops. Since they all offer very similar products, a small differentiation could be viewed as a key strategic advantage. As a result, we would recommend approaching a company like Exxon with its 16,000 fueling stations nationwide. Other good targets would be: 7-Eleven (5,800 locations), Starbucks (5,600), McDonalds (14,000) and of course Allied Domecq Quick Service Restaurants (11,300) which owns Dunkin' Donuts and Baskin-Robbins along with several other quick-service eateries.[72] In the case of Exxon, outfitting all of its locations would only cost $19-48 million,[73] chump change to a company that earned $22 billion last year.

A follow-on activity would be to begin forging partnerships for smaller opportunities that would nonetheless create value for the consumer by either providing valuable services or further increase the base of compatible access points. An example would be B2C and G2C applications such as those provided by RFID[74] technologies like EZ-Pass. For example, an operators of parking garages might use this system to charge customers automatically increasing service and decreasing (labor) costs. Some businesses might use the opportunity for location-based commerce to justify the costs of an access point. In the end, increasing applications and access points (as we learned from the market dynamics analysis of Chapter 5) increases the value to the customer and thus the attractiveness of mP2P-enabled vehicles (which can then be captured through either higher prices or higher sales volumes.) For automakers like GM anything that

[72] All figures on the number of locations provided by Hoovers.com.
[73] The $19M figure is based on the volume-discounted, Mesh-quoted average access point cost of $1,182. $48M assumed a conservative $3,000 unit cost, installed.
[74] RFID or Radio Frequency Identification Devices identify the bearer to anyone with the proper transponder to decode the signal.

uniquely differentiates their vehicles in the marketplace is valuable, so it is possible that the value provided by these stationary applications could be sufficiently so as to have been worth the investment.

That being said, we know that the truly interesting opportunity lies with *mobile* broadband applications (not stationary.) In the last step, we use the existing presence of mP2P-enabled vehicles in the marketplace as proof that there is a sufficient market so as to justify investing in road-side access points. Once again, the automaker would partner with a national Telco, a WISP or some other major telecommunications carrier with the resources and know-how to engineer the systems and install the infrastructure. Initially, one would start with a pilot in metropolitan area with (ideally) the largest concentration of mP2P vehicles per road-mile. There they would work out the technical kinks in the system, gather finer resolution data on consumer preferences and behavior and address trade-offs such as the ideal ratio of access points to repeaters.[75]

Once the technology and market has been proved, the process of enabling the road network could ensue. As discussed in Section 6.2, outfitting all the highways and principal arteries in the US would cost between $150-500 million. In practice, operators would likely invest in major signaled (i.e. secondary) roads in high concentration urban areas before outfitting rural highways. There are many potential creative strategies. For example, Verizon announced last year that it was investigating putting an access point at many of its pay phones in New York City since its incremental infrastructure costs were low and with cell phones, pay phones don't have the demand or traffic they once had.

7.5 Competitive Strategy

Addressing potential competition requires a multifaceted approach since it varies both over time, as the market matures, and for both infrastructure and services for each of the four segments of the telematics value chain. For the sake of this discussion, we break out our strategy by phase of market development, generally following the structure of Chapter 4 (Applications.)

[75] To the vehicle, repeaters appear as access points, however in reality they are not connected to the terrestrial network (only to an AC outlet.) They instead relay their packets to an access point within range. Since they are typically positioned higher above the ground than vehicles and can have larger, more directional antennas, they can connect to access points (or other intermediary repeater) out of range of local vehicle. This results in greater service quality while avoiding the investment of pulling fiber to every access point. The Mesh implementation assumes a certain percentage of access points are actually repeaters.

7.5.1.1 CURRENT COMPETITION: SUBSTITUTES PRODUCTS & SERVICES

During the first phase, connectivity transpires via a "synchronizing" activity, akin to PDAs, through stationary home or retail access points. The primary competition comes from substitute products and services such as smart phones and PDAs. The market advantage of consumer telematics during this period comes from cost and most importantly ergonomics. Bundling the hardware with the vehicle engenders an easier buying decision for the consumer. Since connectivity is either free or quazi-free due to the fact that consumers are already paying for their internet service, we have an advantage over smart cell phone and wireless PDA services that require additional monthly charges for data services (as they currently do.) For PDAs without wireless services, this argument is more tenuous. As a result, only the truly unique differentiator is usability.

The author's anecdotal interviews with a few current and former OnStar customers suggests that many customers that subscribe to the integrated cell phone service available within their vehicles, despite the greater cost (relative to current hand-held digital cell phone plans) and inferior sound quality, because of the superior ergonomics that comes with built-in hands-free calling. Thus, having a compelling human-machine interface even for exactly the same applications available through a smart phone or PDA, is likely to provide an enduring competitive advantage relative to substitute products.

7.5.1.2 NEAR-TERM: COMPETING TELEMATICS BUSINESSES

Beyond the threat of hand-held substitutes, the biggest competition would come from existing domestic Safety and Security (S&S) Telematics services expanding into consumer telematics or existing Japanese integrated Telematics services entering the US market. If they follow the conventional strategy, their systems will be based around digital cellular connectivity. Domestically, the there is an indirect threat from OnStar and ATX systems. OnStar's next generation system, slated to go on sale this spring, includes a dual-band digital phone and have more features, including improved voice recognition.[76] If the trend continues, eventually these Safety & Security services would encroach into some of the potential applications for our mP2P Consumer Telematics business, however it would take a dramatic shift in strategy before they were able to address most of the mP2P applications. What holds them back is what makes them successful in S&S: systems that are completely integrated with the vehicle and that are: extremely reliable, low-cost but not upgradeable nor particularly powerful. Although we do not see a

[76] GM Press Release available at: http://www.gm.com/company/gmability/safety/security/onstar/onstar_voice_recog_022604.html

pathway for them to ever be: as inexpensive, have as wide a pipe nor able to provide peer-to-peer active safety services, any encroachment could erode the price consumers would be willing to pay.

The services now on the market in Japan, namely Toyota's G-Book and Nissan's Carwings, definitely count as Consumer Telematics systems and would thus give out system a run for its money. To our knowledge, that they don't have is the upgradeable, open OS strategy so it is likely that our strategy would be more nimble and eventually have considerably more applications. Assuming they remain based on cellular technology, mP2P retains the bandwidth advantage. They are also devoid of any peer-to-peer capability.

7.5.1.3 MEDIUM-TERM: COMPETING INFRASTRUCTURES

The most threatening medium-term threat is that of competing mP2P infrastructures. Since the real long-term strength of this model comes from having a large network of vehicles and the infrastructure to support them, the advent of competing systems will instill uncertainty in the market both to those investing in the infrastructure as well as to the end consumer. The answer to this is to insure the infrastructure is welcome to all by making the mP2P protocol available for others to license and permit the wireless telematics service providers (WTSP) to provide services to competing OEMs. The WTSP will be happy to go along as it would only bring in more business. To retain some level of control and insure a long-term return from this component of the value chain, we recommend that the leading OEM take a minority stake in the dedicated WTSP. Initially the license fee to the competing OEM should be zero or very close to zero in order to strongly encourage them to get on board. As the market penetration increases, this fee can be increased to a modest level. In general, the WTSP would derive its revenue from fees to the users and application service providers (for those that bundle connectivity and service.)

Potentially, the leading OEM could partner with several infrastructure providers, segmented by region to avoid initial competition. Several regional players means that as the market matures, they may elect to do head-to-head competition. The real check on the long-term power of the WTSP, however, is substitute connectivity facilitated by the consumer's ability to shop around for service and simply swap out their network card accordingly. To insure revenue in this area as well as keep out non-approved makers of the central computing unit (CCU), we take a page from the home video gaming business where console makers actually derive all their revenue from sales of games. As a result, we suggest the system be designed so that no CCU or network card could connect without being approved by the OEM. Again, this is a revenue opportunity where initially the license fee should be free but structured to rise to a nominal level once sales exceed a preset threshold. By insuring long-term revenue streams from connectivity and hardware upgrades, this encourages the leading OEM to also take a long-term view of the business, and thus be more likely to subsidize initial costs to increase the user base.

7.5.1.4 MEDIUM-TERM: SUBSTITUTE INFRASTRUCTURES

The most obvious infrastructure threat is from competing technologies getting to the point where they erode the bandwidth advantage of our proposed mP2P solution. In Chapter 2 (Technology), we make a strong case for the fact that the both 3G cellular and the more far off MBWA technologies will not be competitive on a cost per byte basis for a some time, if and when they arrive. In addition, in their current incarnation, they will never be capable of peer-to-peer connectivity. If 3G meets current predictions, within 2-5 years (depending on your location) it should have the bandwidth of Wi-Fi's predecessor, IEEE standard 802.11 had five year ago. It is already well on its way. Sprint PCS offers service it claims can provide up to 120 kbps (while stationary) and Verizon Wireless just launched a pilot wireless laptop modem service in Washington, DC & San Diego. Capable of up to 300-500kpbs, the CDMA EV-DO protocol service is nonetheless still 10x slower than Wi-Fi and at $80 a month, only within range of the high-end business traveler. [77]

The lesson: Wi-Fi will without a doubt experience intense competition from 3G cellular or eventually WiMax and MBWA for wireless broadband services (less that 2 mbps.) However, they are inherently limited by three forces: (1) 3G cellular's current restriction to 144 kbps at highway speeds, (2) higher cost per byte of data, and (3) their inability to operate in mobile peer-to-peer mode and hence enable the last-mile infrastructure leverage and active safety applications that result. Finally, if these other technologies end up being superior competitors, the upgradeable system architecture permits the consumer to switch anytime thus inoculating the OEM, telematics service provider or vehicle owner against the concern that they are betting on any particular technology.

7.5.1.5 FAR-OFF: MARKET SATURATION

If all the tactics are successful, then the infrastructure will get built, and mP2P will have a dominant marketshare. It is hard imagining there not existing at least one other competing platform. If there were not, there would certainly be antitrust issues to contend with. The longest term risk, however, is that the rest of the market so adopts this technology (or a competing

[77] Mossberg, 8-April-2004.

business based on a parallel model) that brutal price competition occurs for each component, driving the profit premium out of most sections of the value chain. To continue to thrive, one must simply continue to innovate both in technology and services as well as strategy.

7.6 Business Model & Profitability Strategy

Most of the components of the business model and thus the sources of revenue and profitability have been addressed above. Here we present a series of models along with existing examples of their use. We then identify which components we recommend using for our strategy. Finally, we conclude with a table summarizing the strategy.

In presenting existing, successful business models, we draw widely from multiple industries including: automotive, wireless networking, cellular phone services, personal computers, general consumer electronics and of course, telematics. Table 7.1 below lists each along with a leading example, how it works and the benefits it engenders.

Table 7.1: Successful Business Models with Applicability to mP2P Consumer Telematics

BUSINESS MODEL	EXAMPLE(S)	STRATEGY DESCRIPTION & LESSONS
Unique Vehicle Attribute Revenue Model	All Automotive OEMs	All OEMs differentiate their vehicles through unique vehicle attributes; this may be exclusively styling or may involve superior performance or quality, or even innovative features. Otherwise, the OEMs would have to compete exclusively on price, thus driving away whatever meager profits they may enjoy. While originally described to Analysts as a stand-along business, GM has realized that today OnStar provides unique vehicle differentiation valued by the customer and thus may be inclined to tighten integration with the subsidiary.
Subscription Revenue Model	Internet Service Provider (ISPs) AOL, Cable & DSL broadband and now home phone services. OnStar & ATX Safety & Security Telematics	ISPs, for both modem and broadband, charge a single, fixed monthly fee for unlimited access but with a capped maximum data rate, regardless of usage. This model encourages usage, thus creating an environment where users get "hooked" on the service. OnStar's current business model is similar: pay a fixed monthly fee for service, regardless of how much you use it. A challenge of this type of model is that typically a small percentage of subscribers consume the majority of total monthly resources expended.

BUSINESS MODEL	EXAMPLE(S)	STRATEGY DESCRIPTION & LESSONS
Data Traffic Flow Tax Revenue Model	Cellular Service Providers	With cell phones, you pay by the packet of data (or by the minute of voice, which is a surrogate for data.) Recently, plans have evolved into a hybrid of this and the ISP model (free nights and weekends) as CellCos have learned that it encourages billable usage thus allowing them to extract more consumer surplus.
Operating System Model	Microsoft Windows	Employ open API so anyone can develop applications for your product (on their own nickel). Drive wide distribution through initially inexpensive pricing. Use market penetration to encourage developers to code more applications. Leverage installed market of users and applications to insure hardware manufacturers continue to design for your OS. Finally, use dominant position to extract more value from user as they are now bound to your product due to the mass of applications, infrastructure and expertise tied to your product.
Hardware & Software License Fee Revenue Model	Sony Playstation; Microsoft X-Box Microsoft "Designed for Windows XP" Certification	Sell the base console at a highly subsidized rate, knowing that you will make it back through game sales since customers are unlikely to switch platforms after have invested in the console and several games. In addition, games can be sold at premium prices since they are highly differentiated. The trick is that the majority of games are designed by third parties, so for the games to work, developers must secure a license, thus agreeing to redirect a portion of revenue back to console developer.
Hardware Modularity	IBM PC	Modularity facilitates outsourcing of components to multiple competing suppliers, thus increasing pressures to cut costs (helping the OEM). Modularity also permits using commercial off-the-shelf (COTS) components and leverage outside supplier company investment.
Human-Machine Interface Design	Apple Macintosh & iPod, Palm Pilot	Create a really cool product that captures the imagination by designing a user interface so intuitive, previous non-consumers are willing to adopt.
Rapid Product Evolution	Cellular Phones from Ericson, Nokia et al	Launch a new product weekly to insure there is a product for everyone and that you are so nimble, you can quickly respond to any competitor.
Advertising Model	Newspapers, Magazines, Network TV, Search Engines	Sell service at marginal cost (typically printing cost), fund organization and generate profits through selling adds. For many internet services like search engines, marginal cost is considered to be zero.
Lifetime Subscription Model	TiVo	For services that customers resist paying ("a new") monthly bill but highly value the product, instead add the option to purchase a lifetime membership at point of sale
Aggregate Model	NTT DoCoMo i-Mode smart phone service	Combine Multiple Models: Subscription + Data Traffic + Access Fee + OS + HMI. i-Mode smart phones provide a unified user interface for accessing over 50,000 applications and services created by over 3,000

BUSINESS MODEL	EXAMPLE(S)	STRATEGY DESCRIPTION & LESSONS
		developers. DoCoMo charges $2.40 per month fee to have the service and then 0.2 cents per 128 byte packet of data transmitted. Users may subscribe to services for between $0.80-2.40/month /site, which goes to the third-party service operator less 15% cut for DoCoMo which handles all fee collection and must approve each service before going live. i-Mode has been hugely popular in Japan by combining subscription with pay-as-you-go and intuitive usability.

While obviously not comprehensive, each of these models provides lessons for our own business strategy. Vehicle differentiation creates value initially by helping defray the installed hardware cost. To the technologically-savvy consumer, the built-in services provide real value. To a larger audience of especially young buyers, the system could create a "halo" of perceived value. In-house application development could continue the differentiation as other OEMs license the system.

Monthly subscription fees would fund road access though the Wireless Telematics Service Provider (WTSP). Advertising for location-based commerce could be used as a way to offset subscription access fees and thus draw in a larger base of cost-sensitive buyers. The WTSP could then provide the option to pay more for an ad-free version of the service. The lifetime subscription model could be used as still another way to lure in tentative consumers wary of incurring yet another monthly fee. This would be particularly applicable to those electing for the base level of service: mP2P-only connectivity for applications such as active safety (as opposed to full internet access through the road-side access points for the full range of services.) Alternatively, services could be bundled with access for the users wondering if they really needed unlimited access.

Creating an intuitive and highly accessible user interface (i.e. HMI) would be key to insuring less tech-savvy buyers can take maximum advantage of the system's capabilities. Using rapid product development and regular online updates would insure product usability continued to improve and available applications to expand after the vehicle was purchased. As mentioned in Section 7.3, modularity of key components (the central computing unit, network cards, and accessories) allows capability to be upgraded as wireless technology evolves.

Finally, the operating system model, combined with hardware licensing, provides a mechanism for the leading OEM to open the system to other automotive OEMs to include in their vehicles while still insuring a long-term revenue stream. Basing the system around a single operating system and thus encouraging widespread adoption would insure greater application development, infrastructure investment and consumer adoption as discussed in Chapter 5 (Market Dynamics.) Since the leading OEM would want to leverage outside expertise in operating system design and development (and thus also facilitate outside investment), the negotiated terms with the OS partner would require a long view towards return. We would advocate a structure whereas the OEM committed to only using their software (and thus acting as the launch client) and in return gets preferential pricing and a nominal revenue sharing fee should the system be "wildly successful." The threshold should be calibrated to the point where market penetration is predicted to take off, or around 3% according to the results of Chapter 6. This way, the OS developer wins either way: if the system is a marginal or modest success, they get to sell software. If it's a hit, they still win, but the OEM gets something too for serving as the launch client.

The i-Mode model provides, at a minimum, a structure for the authenticating authority to insure that all applications are fully compliant with system specifications and free from bugs that may compromise system integrity. At the extreme, the i-Mode model could be adopted in its entirety and serve as the basis for the rest of the revenue strategy. The strength of i-Mode is that it insures quality, a consistent user experience and the ability to order and pay for services through a single interface thus facilitating buying.

In sum, we recommend that the following tactical partnering structure be established to insure all are properly incented towards long-term success but also committed to the necessary investment. Assuming we adopt a version of the i-Mode model, a separate operating company should be created that would own the OS, define hardware architecture, established partnerships (via licensing) with core system hardware manufacturers (and license any future third-party accessory manufacturers), provide user authentication and initially implement billing. We would probably want the initial WTSPs to participate as minority investors as they would be responsible for the network cards that interfaced with their systems. Since we envision an eventual structure where multiple WTSPs compete for customers' business, it would be important to keep them from being too integrated into the JV. As with all the application service providers, the WTSPs would bill through the JV. The OEM would be responsible for making sure their proprietary vehicle control modules could communicate with the mP2P system, selecting which hardware manufacture's to bundle with their vehicles and then factory-installing hardware.

7.7 *Summary: The Evolving Business Model*

As the reader will have noticed, the business model, including the primary sources of revenue, evolve as the business matures. Table 7.2 attempts to summarize this evolution, along the multiple dimensions of the strategy.

Table 7.2: Summary of Business Strategy by Component and Phase

	NEAR-TERM	MIDDLE-TERM	LONG-TERM
mP2P Market Penetration	MP < 3%	3% < MP < 15%	MP > 15%
Access Point Infrastructure	**4.5M Homes, Car Dealers, Retailers, Gas Stations & WISP alliances**	**Urban Highways & Principal Arteries Enabled for mP2P**	**Entire Metropolitan Areas & Rural Highways Enabled extended by mP2P penetration**
Wireless Networking Connectivity	**Stationary Wireless Broadband for Burstable Applications via Wi-Fi** **Hybrid cell phone provides low-bandwidth transition technology**	**Mobile Peer-to-Peer Mobile Broadband on Highways via mobile ad hoc networking**	**Near Ubiquitous Connectivity**
Applications & Sources of Consumer Value	• Businesses-to-Product applications provide value to OEM & fleet owners • Burstable, content-rich applications • Burstable, cost-sensitive applications previously uneconomic due to bandwidth capacity & cost • Moving infotainment services via hybrid cellular connection	• Mobile & content-rich applications • Real-time traffic monitoring • Dynamic routing applications • Location-based commerce • Active safety: driver notification • Thin-client applications	• Active safety: vehicle intervention • Voice over IP • Usage-based tolls • Eventually, Autopilot on principal arteries
Principal Business Models	• Vehicle differentiation • OnStar type factory installation • Open Operating System API permits independent 3rd Party Development (nurture developers) • Powerful, Intuitive Human-Machine Interface	• i-Mode: Subscription Model with single point of application access & billing • Advertising & location-based commerce subsidizes subscription price • TiVo: basic mP2P service cost through hardware price	• Operating system license revenue • Hardware & software certification revenue

	NEAR-TERM	MIDDLE-TERM	LONG-TERM
Technology Strategy	• Modular Central Computing Unit, network cards & accessories encourage competition thus providing consumer choice	• Modular architecture also facilitates rapid product evolution & market nimbleness as business matures	• "Last Mile" connectivity via mobile ad hoc networking
Target Market	• Early Adopters & Early Majority • 4.5 million households with Wi-Fi • Those willing to pay $200-500 for PDAs & MP3 players	• Remaining Early Majority and Late Majority • Mainstream commuters • The 100's of millions of individuals who own a PC or a cell phone	• All 17 million new vehicles sold in the US every year
Benefits to Automotive OEM	• Business-to-Product Apps • Vehicle Differentiation • Leadership in consumer telematics • Develop expertise in mP2P	• Service revenue streams • OS & hardware certification revenue from 3rd party manufacturers • Vehicle option revenue	• OS license revenue • Hardware certification revenue from other OEMs
Goals for Automotive OEM	• Validate market • Seed Network • Develop expertise in mP2P • Establish partnerships • Rollout basic services	• Populate network of mP2P vehicles • Establish OS & hardware standards as dominant • Build-out access point infrastructure • Expand services	• Maintain profit stream from services • Expand operating system and hardware certification revenue
Commo-ditized Offerings	• Cell phone services & phones	• Safety & Security; Static Navigation Systems; vehicle-cell Bluetooth connectivity	• mP2P connectivity

By anticipating an evolving business model, we enable a more bootstrap, lower initial investment model by leveraging the investment of partners and opening the field to competitors. However, this also engenders faster adoption and thus less time to critical mass. By using an operating system & hardware strategy for the long term, we can insure revenue once the technology has become widespread and vehicle is less of a competitive advantage. Thinking about these issues now is particularly important because the OEM would want to incorporate this strategy into how it negotiates its partnership or joint venture agreements. From a purely tactical point it view, it should be feasible to include these terms since: (a) it is a huge signaling force saying "I really believe this is going to succeed," and (b) it's a win-win for the partner: initially they get all the revenue and if the technology take off, they still make a lot of money, only the OEM gets a piece of the action. From a value chain perspective, we must look at every step, and make sure everyone can have a profitable business so it remains an attractive, but competitive business.

Chapter 8 Conclusions

This paper has endeavored to provide the background, analysis, rational and strategy for an OEM with substantial or dominant marketshare to enter the consumer telematics business using mobile peer-to-peer technology. In Chapter 1, we discussed the motivation, the market contexts and the approach for addressing the issue. Chapter 2 addressed both mP2P networking technology as well as the range of competing or substitute wireless broadband options. The telematics value chain of Chapter 3 investigated all the different industries and competencies necessary to provide consumer telematics with an eye towards which present attractive businesses and which will provide negligible profits due to commoditization or intense competition. Chapter 4 introduced the concept that the strategy, in this case for applications, will need to evolve as the penetration of mP2P vehicles and the infrastructure of compatible access points expands over time.

In Chapter 5, we mapped out the market dynamics of mP2P consumer telematics and most importantly, the dominant impact of the network externalities in the system. With four compounding and self-reinforcing systems: infrastructure, application development, mP2P network quality, and word-of-mouth promotion, we learned that qualitatively, the system is prone to strong S-curve type behavior. The challenge is that without a robust quantitative model, we have no scale for the adoption curve's X or Y axis. As a result, Chapter 6 tries to answer this question by analyzing real-world traffic data. Using assumptions accounting for the infrastructure trade-offs and benchmarks of other comparable services we generated a first-order result describing the relationship between consumer willingness to pay and market penetration. These results corroborated the intuition from Chapter 5 that the system would follow a very steep "S" curve encompassing a substantial "flat" period of before critical mass is reached and the customer value (and thus market growth) takes off. Finally, in Chapter 7, we outline a proposed business strategy for entering this market and most importantly, how important it is to embrace a multi-phased business and revenue model. This encourages growth and outside investment initially, when the consumers and partners are the most tenuous and future rapid growth the most uncertain, and pushes off harvesting profit until after critical mass has been attained and the opportunity becomes considerably more interesting.

8.1 Organizational Structure

As we have discussed throughout this paper, by partnering with the various companies in the value chain, the Automotive OEM spearheading the development of this new market in mP2P-enabled consumer telematics can leverage outside investment and thus long-term commitment to the market. This ecosystem of companies, centered around this new business, has secondary benefits as well. It inspires both the investment community to fund new projects and companies, and the government to affect any regulatory reform that may become necessary as the market develops. Throughout the entire analysis, we refer implicitly to a single agent guiding the process through partnerships, but controlling it through a very few critical "chokepoints" in the technical architecture. With too many partners, we risk stiffing innovation and market growth. With too few, we risk "hold-up" and the original investors (primarily the leading Automotive OEM) loosing the ability to extract their return once the market develops or a single company acting to maximize short-term profits over the long-term viability of the business.

Assuming that a single Automotive OEM (or several working in concert) launches the market, the chokepoints should exist onboard the vehicle where the OEM has complete control over the initial product. We recommend two: one on the hardware level, one on the software level. Through a licensing structure similar to the home video gaming business, only hardware licensed from the OEM (or its surrogate as we will get to below) may operate onboard the vehicle. For liability reasons, we recommend that this be a gate. In other words, OEM certification (and thus a license) is a requirement, not an option. Only in this way could the OEM insure that, however unlikely, no third-party markets products compromise the integrity of the vehicle system. While initially unadvisable, this also provides a mechanism for the OEM to extract revenue from future hardware sales as the market develops, thus motivating the OEM to keep a long-term perspective on the vehicle architecture (which is not necessarily always the case.) The first hardware manufactures to sign up as partners would get preferential terms, likely in the form of the ability to manufacture their first several million units license fee free in addition to sales guaranteed by the OEM.

The second chokepoint would be the Operating System. It would control which applications, services or even WTSPs the vehicle telematics system could access. By getting all the developers to design their products for this OS, they crease an enormous momentum around this platform. Here there are a range of options for controlling third-party access. On one extreme, we could adopt the same policy as the hardware and require every application to seek approval and receive a license to operate. On the other extreme, we could open up the OS for anyone to develop products and services for as with PCs. For our delicate business where there is a symbiotic relationship between the different members of the value chain, to have too heavy a hand in controlling access will stifle third-party development. The Microsoft model is that they will be happy to certify your product as "Designed for Microsoft Windows" (useful in branding and product promotion) for a "nominal" fee. The more controlling, but still potentially viable option is the aforementioned i-Mode model which retains control over access, but nonetheless essentially allows developer wide access to customers. While this strategy is obviously preferable from the OEM's perspective, the details of it must be delicately structured so as not to alienate notoriously independent developers.

Finally, we propose the structure of the entity which actually controls these chokepoints. Should it be the OEM directly? We suggest not. Having the OEM in command creates an agency problem and a cultural problem. Again, some decisions that insure the long-term viability of the market (and thus all involved) may not maximize the short term profits for any participant. While this may not be a problem for the benevolent leader, all one needs is a nasty downturn in the market or the company for behavior to change. From a cultural perspective, putting exclusively "car guys" in charge of what is essentially a consumer electronics product has a dubious track record. As a result, we recommend a joint venture(JV) between the selected operating system company, the wireless telematics service provider (WTSP) that would build-out and operate the mP2P-compliant network of access points and the Automotive OEM.

Historical experience indicates that the non-automotive partners should not be the dominant player in their industry (e.g. Microsoft) as they are unlikely to agree the kind of revenue-sharing terms we have described. This market must seem like a really exciting opportunity that they could not launch on their own (for example, Palm Computing.) Ideally, the JV would bring in investment from the public or private equity markets as well. The OS company would transfer the employees and IP used on the project (or at least an unlimited license to it) to the new JV which would own and control all future OS development as well as the key specifications for the hardware architecture and its interfaces. The WTSP would transfer the people and IP (or at least provide an unlimited, royalty-free license) for defining the network access specifications and managing the licensing of card manufacturers to the JV. However, the WTSP would still fund and manage the development of the mP2P access point infrastructure in-house. By creating a single entity, we link the futures of three most critical stakeholders.

The JV would then create non-equity partnerships with two to four hardware manufacturers, several applications developers or service providers and one or two nationwide cellular providers to provide the low-bandwidth, high reliability component of the hybrid service. Having most of the relationships at arm's length eases the burden of coordination and sets out the standard of healthy competition among parties. It is for this reason, that we are reticent to advocate partnering with another automotive OEM from the start since it slows everything down and thus makes the initial launch more costly. However, if the partner OEM was considerably smaller, and mostly complementary (as Honda is with GM), there would be a good opportunity to cost share the development and hasten the advent of market penetration critical mass. For the initial launch, much of the initial system design and functionality should be developed from within the JV. This would help with coordination, reliability and pre-launch confidentiality. While there are many potentially viable variations to this proposed organizational strategy, we feel that this general architecture has the highest chance of market and financial success.

8.2 Opportunity for GM: The Market Share Advantage

The most interesting outtake of our analysis is the disproportionate advantage afforded to an OEM with a dominant marketshare to enter and succeed in this completely new market. In the US, this benefit goes to General Motors with its 28% domestic marketshare. For number two Ford, it would take 40% longer assuming they devote the same percentage of sales to this endeavor. The only real competitor in terms of resources and wherewithal for this kind of strategy in the US is Toyota. However, with only 11% domestic marketshare, it would take 2.6 times as long; thus, if it took GM three years (as we show in Section 6.3.4), it would take Toyota almost eight. Along with its existing base of experience in Safety & Security Telematics, it is uniquely positioned to take advantage of this market. However, every year that its marketshare drops, its loses a bit of its inherent lead.

The biggest barriers for GM would be cultural. Outside the OnStar division or the small groups in research or planning investigating these topics, there is a strongly-held view that GM's core competencies lie in "bending metal or assembling vehicles." The biggest barrier for GM to enter this market is that it will be perceived by many within the organization that GM is creating a competitor to OnStar. However, since OnStar's insurance-oriented business model is so different from that that we propose here, we assert that GM should be able to work through these concerns. The lesson from OnStar seems to be that if the enterprise remains a wholly-owned division of the Automaker, it will never truly have the independence to develop its own culture or priorities.

While OnStar today definitely has a distinctive culture and way of operating, separate from GM as a whole, one could argue that it is considerably more similar to GM then to, say, to a cell phone or PDA service company. With GM beginning to recognize the value OnStar provides in helping to sell vehicles, OnStar will logically trend towards tighter operational integration with its parent in order to create better alignment between the two entities. However, this is precisely the opposite direction we feel would be necessary in order to be in a position to pursue the consumer telematics market. As a result, the joint venture framework described above would be a critical element of success.

While GM would still maintain tremendous sway over strategy as the only customer and a one-third shareholder, the WTSP and OS companies would have their say as well. Without their buy-in, the venture will fail. In addition, we would recommend shifting the initial HMI design to the JV. While there should definitely be some experienced auto designers on the team (contributed by GM), it should be lead by an individual from the consumer electronics business with tremendous talent in usability. Finally, to complete the cultural separation from the monolithic Detroit auto culture, the JV should be located in a city strong in product innovation and high-tech. The four leading cities that fit the bill are: San Francisco, Boston, New York and Washington DC. Since GM has an existing broadcast telematics strategic and equity partner (XM Radio) there as well as the fact that it is has the lowest living costs of the four cities, and it is in close proximity the regulatory authorities that will need some hand holding through the infrastructure definition and build-out process, Washington DC stands out as the best option for locating the JV.

8.3 Key Conclusions & Future Work

While we feel that the results of this analysis are robust, we acknowledge that it is very first-order in accuracy. As a result, there is a wealth of opportunity for future work. First, we would recommend designing a simulation model to gain further insight and precision beyond the probabilistic analysis of Chapter 6. Beyond that, one really requires a real world study to calibrate the analytic results; we recommend outfitting 100 or more cars each with a couple students, a laptop and a MeshNetworks mP2P card and have them drive around in close proximity in various levels of traffic to collect empirical data on performance (students are cheap, but employees would do.) We recognize that the least robust aspect of our analysis is the customer willingness-to-pay versus market penetration relationship derived by benchmarking comparable services. While market research could increase the understanding of the relationship, we propose an additional mechanism as well. There are no better subjects to query than existing customers. Thus, we suggest using the mP2P connectivity and the ease of software updates built in to our system to collect essentially real-time data from initial customers (with their permission, of course) on everything from usability and features to the value they perceive in the system. With this information in hand, one could refine the system dynamics model of Chapter 5 (and Appendix D) to better understand the market adoption dynamics.

Lastly, we recommend performing a detailed financial analysis to assess pricing and cost constraints on creating a venture with a positive net present value. In this endeavor, it would require getting quotes on the cost of both designing the onboard telematics system as well as manufacturing it in volume. We would also require detailed cash flow estimates from a prospective WTSP on the level and timing of the access point infrastructure build-out. While there are a great number of uncertainties, we feel that our analysis here has presented that there is at least one credible strategy with a good potential for success. Since the opportunity is so large, we feel that there is a strong case that this strategy should be investigated further in order to access more precisely where the figures end up and whether this business is as promising as it seems.

Finally, we feel that the most durable intellectual asset of this paper is how the positive network externalities inherent in this business drive non-linear dynamics in market adoption and in turn viral growth, and thus the potential for new business opportunities. Another key conclusion is that the critical mass threshold may, at 3-5%, be surprisingly low and thus quite accessible to a major Automotive OEM. We feel that the potential strength of bringing consumer electronics business models to the slow clockspeed automotive industry is also compelling. Furthermore, we found interesting the conclusion that, contrary to the typical behavior of either collaboratively setting standards setting across firms or using closely-held proprietary standards, in this case it may be advantageous to instead lead the charge and define the standards independently, but then open them up for licensing by partners and competitors. One meta-point that the reader may have noticed is that the business model we have described here is not reliant on using mP2P technology; we simply feel that today, mP2P provides the most promising platform but it is by no means the only way of implementing this strategy. In sum, we are convinced that this strategy presents a significant opportunity in an exciting new business with the potential to change the way we view our automobile experience in the future.

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Appendices

Appendix A: Wireless Technology Landscape

Trade-name or Description	Standard	Primary Use	App Focus	Bandwidth Avg.	Bandwidth Max.	Frequency Min	Frequency Max	Frequency Range	Rated Range	Max. # Nodes	Regulatory Status	Standards Ownership	Region	Path-Sharing Scheme	Modulation Encoding	TCP/IP Compliant
				(mbps)	(mbps)	(GHz)	(GHz)	(MHz)	meters		(licensed)					(y/n)
PEER-TO-PEER CAPABLE TERRESTRIAL																
ZigBee	IEEE 802.15.4 (868MHz)	SRLP	Monitor & control, low-power, low data-rate	0.02	0.02	0.87	0.87	1	< 30	255	No	Open	Europe	CSMA/CA	DSSS/BPSK	N
	IEEE 802.15.4 (915 MHz)	"		0.04	0.04	0.90	0.93	26	< 30	255	No	Open	USA	CSMA/CA	DSSS/BPSK	N
	IEEE 802.15.4 (2.4GHz)	"		0.25	0.25	2.40	2.48	83	< 30	255	No	Open	Global	CSMA/CA	DSSS/O-QPSK	N
802.15.1 Bluetooth 1.1	IEEE 802.15.1	SRLP	Cable Repl.	1	1	2.40	2.48	83	< 10	8	No	Open	Global	N/A	FHSS/GFSK	N
WiFi	IEEE 802.11b	MRHB	www, email, ethernet	4.5	11	2.4	2.5	83.5	30 - 90	30	No	Open	USA	CSMA/CA	DSSS/CCK	Y
WiFi extention	IEEE 802.11g	MRHB		11	54	2.4	2.5	83.5	< 90	30	No	Open		CSMA/CA	DSSS/PSCC	Y
WiFi5	IEEE 802.11a	MRHB	"	11	54	5.8	5.9	300	25 - 60	30	No	Open		CSMA/CA	OFDM	Y
WiFi w Security	IEEE 802.11i	MRHB	"	4.5	11	2.4	2.5	83.5	30 - 90	30	No	Open		CSMA/CA	N/A	Y
DSRC	IEEE 802.11p	MRMC	Traffic Mgmt	4.5	27	5.0	6.0	75.0	< 1000	N/A	Yes	Open	USA	CSMA/CA	OFDM	Y
ITS-RS		MRMC		4.5	11	5.9	6.0	75.0			Yes					Y
Mesh Networks	QDMA?	MRMC	Multi Fct.	0.5-2	6	2.4	*(multiple freq.)*		LOS< 1609	N/A	No	Mesh	flexible	N/A	N/A	Y
MBWA-Mobile Broadband '	IEEE 802.20	LRHB	BB up to 150mpł	1	TBD	TBD	3.5	TBD	1000+	TBD	TBD	Open	flexible	TBD	TBD	Y
WiMedia	IEEE 802.15.3	SRHB	Cable Repl.	?	55	*2.4?*	?		< 50		No	Open	flexible	ad hoc	QAM	Y
Ultra-Wide Band	IEEE 802.15.3a??	SRHB	Cable Repl.	?	100	3.1	10.6		< 10		in process	Open	flexible	TBD	TBD	TBD
"	"	"	"	?	200	"	"		4 - 6		in process		flexible	TBD	TBD	TBD
"	"	"	"	?	480	"	"		< 4		in process		flexible	TBD	TBD	TBD
INFRASTRUCTURE-DEPENDENT TERRESTRIAL																
MMDS / FWA (MANs)	IEEE 802.16 (r,a,e)	LRHB	hernet/last mile		120+	10	66		1000+	N/A	Yes	Open		DA/TDMA	OFDM/QAM	Y
RPR	IEEE 802.17									N/A		Open		N/A	N/A	Y
1G - Analog Cellular	AMPS	LRVT	Voice	9.6 kbps					*1000* +		Yes	Open	USA	FDMA		N
"	D-AMPS 800	LRVT	Voice	"		0.8	0.8		*1000* +		Yes	Open	USA	TDMA		N
"	D-AMPS 1900	LRVT	Voice	"		1.9	1.9		*1000* +		Yes	Open	USA	TDMA		N
2G - Digital Cellular	TDMA	LRVT	Voice	"		1.5			*1000* +		Yes		USA	TDMA		N
"	GSM 900	LRVT	Voice	"		0.9	0.9	25	"		Yes	Open	Europe	F/TDMA	GMSK	N
"	CDMAone (IS-95)	LRVT	Voice			1.9			"		Yes	Qualcom	USA	CDMA		N
2.5G - Digital Cellular	GPRS / EDGE	LRVD	Voice/Data	0.064	0.128				1000 +	1000	Yes	Open	Europe			N
3G - Digital Cellular	CDMA 1xRTT	LRVD	Voice/Data	0.115	0.38						?	?	USA			N
("wideband CDMA")	W-CDMA	LRMB	Data (VoIP)		2	1.71	1.86	145			Yes		Japan/Global			N
(an evolution of GSM)	W-CDMA	"	Data (VoIP)		2	2.52	2.67	150					Japan/Global			N
Hierarchal Cell Structure?	CDMA 2000 1x	LRMB	Voice/Data		0.144					100's/tower			USA			N
(data & voice separate)	CDMA 2000 1xEV-D(	LRMB	Data (VoIP)	0.45	2.4			1	1000		Yes		USA/Globa	CDMA	Adaptive	IP-based
(data & voice reintegrated)	CDMA 2000 1xEV-D\	LRMB	Data (VoIP)	up to	3.09			1	1000		Yes		USA/Globa	CDMA	Adaptive	IP-based
	UMTS	LRMB	Data (VoIP)		2						Yes		Europe			N
	3xRTT	LRMB	Data (VoIP)		2			5	1000		Yes		?	CDMA	QPSK	N
SATELLITE																
	Ka-band	ETHB	Data		>100				>10,000 km		Yes	*varies*	*Global*	*varies*	*varies*	*varies*
	Ku-band	ETHB	Data		>100				>10,000 km		Yes	*varies*	*Global*	*varies*	*varies*	*varies*
Low Earth Orbit	LEO	ETHB	Data		>100				>10,000 km		Yes	*varies*	*Global*	*varies*	*varies*	*varies*
Medium Earth Orbit	MEO	ETHB	Data		>100				>10,000 km		Yes	*varies*	*Global*	*varies*	*varies*	*varies*
Geosynchronous Orbit	GEO	ETHB	Data		>100				>10,000 km		Yes	*varies*	*Global*	*varies*	*varies*	*varies*

Appendix B: Access Point Investment Calculation Details

Access Point Investment Requirements for Initial Highway Roll-out

Assumptions

Highway Route Mile Data (1997 US DOT data)			
Interstate Highways	46,314	route-miles	
Non-Interstate Urban Freeways & Expressways	9,116	route-miles	
Other Principal Arterial Routes	151,827	route-miles	
Wireless Technology			
Wireless Packet Radio Maximum Transmit Range (to AP)	0.33	mile	*Source: Mesh Networks currently available product*
Wireless Packet Radio Average Transmit Range to anothei	0.17	mile	*Assuming uniform trafic and enabled vehicle distribution & thus, on average, a vehicle will be halfway between you and your maximum range.*
Average system efficiency (due to natural/man-made barrie	80%		
Nominal Access Point Installation Capital Cost	$ 1,818	/AP	*Ref: Mesh: 10-12 AP's required to cover a sq. mile @ a cost of ~$20k*
Volume Access Point Installation Capital Cost	$ 1,182	/AP	*Assume that at super high volume, price would go down at least 50%*

	Units	Total Avg. No. of hops to nearest Fixed Access Point						
		1	2	3	4	5	6	7
Access Point Installations		(aka directly to fixed access point)						
Maximum Allowable Distance to nearest Access Point	(miles)	0.33	0.50	0.67	0.83	1.00	1.17	1.33
Distance Between Access Points	(miles)	0.67	1.00	1.33	1.67	2.00	2.33	2.67
Resulting average Access Point density (AP's/route-mile)	APs/route-miles	1.9	1.3	0.9	0.8	0.6	0.5	0.5
Total Number of Access Points Needed for US Rollout								
Interstate Highways	AP's to cover	86,839	57,893	43,419	34,736	28,946	24,811	21,710
Non-Interstate Urban Freeways & Expressways	AP's	17,093	11,395	8,546	6,837	5,698	4,884	4,273
Total for all Highways only	AP's	**103,931**	**69,288**	**51,966**	**41,573**	**34,644**	**29,695**	**25,983**
Other Principal Arterial Routes	AP's	284,676	189,784	142,338	113,870	94,892	81,336	71,169
Total for all Highways & Principle Arterial Routes	AP's	**388,607**	**259,071**	**194,303**	**155,443**	**129,536**	**111,031**	**97,152**
Total Cost of US Highway Access Points Rollout								
Interstate Highways	M $'s	$ 102.6	$ 68.4	$ 51.3	$ 41.1	$ 34.2	$ 29.3	$ 25.7
Non-Interstate Urban Freeways & Expressways	M $'s	$ 20.2	$ 13.5	$ 10.1	$ 8.1	$ 6.7	$ 5.8	$ 5.1
Total for all Highways only	M $'s	**$ 122.8**	**$ 81.9**	**$ 61.4**	**$ 49.1**	**$ 40.9**	**$ 35.1**	**$ 30.7**
Other Principal Arterial Routes	M $'s	$ 336.4	$ 224.3	$ 168.2	$ 134.6	$ 112.1	$ 96.1	$ 84.1
Total for all Highways & Principle Arterial Routes	M $'s	**$ 459.3**	**$ 306.2**	**$ 229.6**	**$ 183.7**	**$ 153.1**	**$ 131.2**	**$ 114.8**

Stationary Access Point Roll-Out Costs	% of US Gas Stations	Total No. of APs	AP Inv. Cost (M$'s)	Max Users (M's)
Gas Stations, % of all US	0%	-	$ -	
Starbucks, all US	2.8%	5,600	$ 6.6	1,612,800
7-Eleven, all US & Canada	2.9%	5,800	$ 6.9	1,670,400
Gas Stations, % of all US	5%	10,000	$ 11.8	2,880,000
McDonald's, all US	7.0%	14,000	$ 16.5	4,032,000
ExxonMobile Gas Stations, all US	8.0%	16,000	$ 18.9	4,608,000
Gas Stations, % of all US	10%	20,000	$ 23.6	5,760,000
"	20%	40,000	$ 47.3	11,520,000
"	30%	60,000	$ 70.9	17,280,000
"	40%	80,000	$ 94.6	23,040,000
"	50%	100,000	$ 118.2	28,800,000
"	60%	120,000	$ 141.8	34,560,000
"	70%	140,000	$ 165.5	40,320,000
"	80%	160,000	$ 189.1	46,080,000
"	90%	180,000	$ 212.8	51,840,000
"	100%	200,000	$ 236.4	57,600,000

<u>Assumptions</u>:

Cost per Access Point (installation & hardware): $ 1,182

Maximum No. of Users per Node: 288

(takes into consideration capacity factor & design-for-peak limitations)

<u>Calculation of Access Points Capacity Per User</u>

12 users	Number of concurrent users per access point: design
30 users	Number of concurrent users per access point: max
	Max vs Design # of users made to accommodate variability across nodes.
40%	Effective Capacity Factor at Peak
2.5 x/day	Number of times per day the average user will connect
1 minutes	Duration of connection: Min (2 sigma)
20 minutes	Duration of connection: Max (2 sigma)
7 minutes	Duration of connection: Weighted Average
17.5 minutes	Total Average Connection Time
	Principal design Hours: dependent on peak times
3 hrs	Morning Rush Hour: 6-9am
4 hrs	Evening Rush Hour: 3-7am
7 hrs	Total
5040 minutes	Total number of user-minutes available during rush hour at design point
288 users	Maximum number of users per node

Appendix C: Traffic Density-Based Market Penetration Analysis Details

Volume of Vehicles (per hour) crossing given loop detector (across all lanes)

Station: 1114372 EB I-696 W of Woodward Site# 2 Weekday Daytime Weekend Daytime

Date	Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Average
1-Sep-2003	M*	927	624	423	245	213	277	437	566	778	990	1,264	1,839	2,313	2,538	2,662	2,760	2,590	2,481	2,415	2,373	2,127	1,891	1,532	1,121	1,474
2-Sep-2003	T	656	371	276	302	652	1,959	3,257	4,151	3,778	3,373	3,219	3,362	2,292			4,393	5,164	4,985	4,286	3,335	2,686	2,372	1,839	1,353	2,639
3-Sep-2003	W	718	412	346	374	701	1,961	3,337	4,160	3,871	3,710	3,345	3,496	3,730	3,765	4,191	4,766	5,131	5,322	4,469	3,283	2,762	2,545	1,856	1,293	2,898
4-Sep-2003	Th	743	422	374	382	704	1,966	3,343	4,029	3,839	3,411	3,519	3,547	3,745	1,942	4,208	4,986	5,154	5,221	4,391	3,495	2,864	2,523	1,882	1,314	2,834
5-Sep-2003	F	820	480	408	406	726	1,898	3,184	3,865	3,888	3,447	3,545	619	1,998	3,941	4,510	4,851	5,070	4,866	4,607	3,500	2,719	2,418	1,997	1,567	2,722
6-Sep-2003	Sa	927	624	423	245	213	277	437	566	778	990	1,264	1,839	2,313	2,538	2,662	2,760	2,590	2,481	2,415	2,373	2,127	1,891	1,532	1,121	1,474
7-Sep-2003	Su	1,185	757	666	389	299	352	604	808	1,224	1,689	2,405	2,736	2,746	2,851	2,999	2,852	2,914	3,187	2,788	2,491	2,108	1,806	1,614	1,096	1,774
8-Sep-2003	M	677	434	320	310	708	1,879	3,231	4,365	3,848	3,368	2,881	3,448	3,596	3,573	4,193	4,788	5,117	5,129	4,356	3,295	2,705	2,378	1,680	1,255	2,814
9-Sep-2003	T	752	418	340	344	722	1,954	3,288	4,204	3,832	3,536	3,311	3,549	3,662	3,736	4,177	4,749	5,141	5,026	4,573	3,359	2,811	2,638	1,833	1,318	2,886
10-Sep-2003	W	790	443	315	351	659	1,969	3,269	4,261	3,920	3,513	3,422	3,509	3,758	3,815	4,156	4,760	5,317	5,263	4,580	3,369	2,922	2,594	1,959	1,331	2,927
11-Sep-2003	Th	695	422	386	376	703	2,024	3,318	4,035	3,658	3,731	3,402	3,469	3,722	3,843	3,450	4,488	5,278	5,211	4,535	3,325	2,914	2,768	1,930	1,338	2,876
12-Sep-2003	F	827	474	448	435	728	1,912	3,165	3,892	3,984	3,538	3,509	3,732	3,854	4,028	4,530	4,341	4,512	5,048	4,600	3,796	2,924	2,389	2,103	1,737	2,938
13-Sep-2003	Sa	1,214	747	646	417	517	995	1,223	1,740	2,230	2,582	2,873	3,091	3,609	3,380	3,617	3,580	3,448	3,566	3,284	3,196	2,926	2,766	2,266	1,774	2,320
14-Sep-2003	Su	1,324	923	776	385	282	353	636	947	1,420	1,809	2,318	2,814	3,085	3,255	3,221	3,247	2,857	3,002	2,808	2,400	2,361	1,925	1,500	1,029	1,862
15-Sep-2003	M	664	384	307	327	636	1,890	3,163	4,171	3,447	3,326	3,200	3,488	3,604	3,610	4,136	4,801	5,140	5,224	4,032	3,189	2,781	2,414	1,734	1,209	2,787
16-Sep-2003	T	720	415	384	329	667	1,982	3,332	3,889	3,982	3,605	3,320	3,471	3,594	3,650	4,186	4,824	5,090	5,476	4,461	3,266	2,907	2,598	1,916	1,368	2,893
17-Sep-2003	W	828	432	395	386	706	1,992	3,350	3,970	3,931	3,524	2,965	3,498	3,697	3,249	4,294	4,832	5,192	5,210	4,426	3,443	2,826	2,589	1,972	1,328	2,876
18-Sep-2003	Th	788	436	394	344	673	1,942	3,318	3,979	3,862	3,657	3,365	3,590	3,710	3,812	4,335	4,923	5,475	5,295	4,797	3,648	2,944	2,638	2,003	1,394	2,972
19-Sep-2003	F	890	496	435	377	671	1,849	2,972	3,758	3,403	3,370	3,228	3,633	3,828	3,977	4,480	4,742	4,951	5,355	4,698	3,533	2,745	2,467	2,101	1,707	2,903
20-Sep-2003	Sa	1,225	729	645	384	379	869	1,244	1,722	2,100	2,363	2,612	2,943	3,406	3,222	3,284	3,290	3,106	3,160	2,955	2,626	2,364	2,116	1,953	1,713	2,100
21-Sep-2003	Su	1,283	846	688	425	317	360	632	833	1,141	1,715	2,249	2,754	2,800	2,800	2,933	2,737	2,621	2,678	2,536	2,297	2,322	2,004	1,554	1,052	1,732
22-Sep-2003	M	722	431	295	314	642	1,888	2,943	3,621	3,368	3,271	2,890	3,056	3,292	3,311	3,830	4,266	5,130	4,968	3,953	3,042	2,494	2,275	1,570	1,074	2,610
23-Sep-2003	T	695	432	341	333	658	1,991	3,390	4,124	3,783	3,449	3,191	3,541	3,629	3,680	4,174	4,841	4,891	4,030	4,522	3,447	2,844	2,492	1,909	1,348	2,822
24-Sep-2003	W	742	440	380	348	681	1,932	3,335	3,799	3,681	3,643	3,295	3,537	3,737	3,737	4,257	4,912	5,351	4,888	4,074	3,125	2,462	2,395	1,777	1,230	2,823
25-Sep-2003	Th	801	436	348	373	679	1,995	3,379	3,994	3,701	3,489	3,135	3,714	3,761	3,941	4,368	4,892	5,353	5,089	4,464	3,453	2,940	2,712	1,987	1,360	2,932
26-Sep-2003	F	830	551	442	381	685	1,820	3,127	4,002	3,680	3,488	3,128	3,529	3,849	3,952	4,621	4,887	5,485	5,225	4,368	3,524	2,786	2,416	2,070	1,642	2,937
27-Sep-2003	Sa	1,240	816	639	391	472	836	1,061	1,555	2,078	2,493	2,582	2,874	3,324	3,217	3,325	3,519	3,683	3,717	3,422	2,781	2,406	2,253	1,935	1,721	2,181
28-Sep-2003	Su	1,305	977	649	411	265	314	521	752	1,101	1,640	2,113	2,631	2,760	2,913	3,055	3,089	2,975	2,972	2,765	2,630	2,521	1,988	1,521	1,083	1,790
29-Sep-2003	M	645	414	307	317	620	1,946	3,236	4,096	3,809	2,816	3,509	3,408	3,542	3,644	4,145	4,775	5,413	5,265	4,156	3,283	2,729	2,317	1,631	1,186	2,800
30-Sep-2003	T	753	412	354	365	642	1,957	3,386	4,250	3,904	3,504	3,217	3,449	3,690	3,685	4,287	4,923	5,344	5,370	4,256	3,503	2,743	2,434	1,798	1,276	2,896
TOTAL:		880	540	438	359	574	1,511	2,504	3,137	3,067	2,968	2,943	3,139	3,355	3,435	3,872	4,252	4,516	4,490	3,933	3,146	2,659	2,367	1,832	1,345	**2,550**

** Monday Sept. 1, 2003 was Labor day, and thus was counted as a weekend rather than a weekday.*

	Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Average
Averages by Day	M	677	416	307	317	652	1,901	3,143	4,063	3,618	3,195	3,120	3,350	3,509	3,535	4,076	4,658	5,200	5,147	4,124	3,202	2,677	2,346	1,654	1,181	2,753
	T	715	410	339	335	668	1,969	3,331	4,124	3,856	3,493	3,252	3,474	3,373	3,688	4,206	4,746	5,126	4,977	4,420	3,382	2,798	2,507	1,859	1,333	2,849
	W	770	432	359	365	687	1,964	3,323	4,048	3,851	3,598	3,257	3,510	3,731	3,642	4,225	4,818	5,248	5,171	4,387	3,305	2,743	2,531	1,891	1,296	2,881
	Th	757	429	376	369	690	1,982	3,340	4,009	3,765	3,572	3,355	3,580	3,735	3,385	4,090	4,822	5,315	5,204	4,547	3,480	2,916	2,660	1,951	1,352	2,903
	F	842	500	433	400	703	1,870	3,112	3,879	3,739	3,461	3,353	2,878	3,382	3,975	4,535	4,705	5,005	5,124	4,568	3,588	2,794	2,423	2,068	1,663	2,875
	Sa	1,152	729	588	359	395	744	991	1,396	1,797	2,107	2,333	2,687	3,163	3,089	3,222	3,287	3,207	3,231	3,019	2,744	2,456	2,257	1,922	1,582	2,019
	Su	1,274	876	695	403	291	345	598	835	1,222	1,713	2,271	2,734	2,848	2,955	3,052	2,981	2,842	2,960	2,724	2,455	2,328	1,931	1,547	1,065	1,789
Standard Dev. by Day	M	33	23	10	7	39	31	138	316	246	256	299	199	147	152	166	261	142	132	176	117	126	62	70	77	134
	T	41	23	39	23	31	17	59	140	87	88	59	76	606	36	54	207	163	571	142	94	86	111	51	36	118
	W	49	14	36	18	21	25	36	205	116	95	201	19	25	264	62	71	104	194	219	137	199	93	92	47	98
	Th	48	8	20	17	16	36	29	27	101	148	161	102	23	963	432	226	135	85	177	133	37	106	55	34	130
	F	32	35	18	27	29	43	96	100	257	71	206	1,508	923	39	61	251	400	213	141	139	91	32	50	75	202
	Sa	150	79	110	77	134	319	378	559	682	750	724	572	579	375	402	373	475	553	448	345	337	371	301	309	392
	Su	62	96	56	19	22	21	53	82	142	71	123	76	160	205	123	230	155	211	127	141	170	90	50	30	105
Std Dev as % of Avg:	M	5%	6%	3%	2%	6%	2%	4%	8%	7%	8%	10%	6%	4%	4%	4%	6%	3%	3%	4%	4%	5%	3%	4%	7%	5%
	T	6%	6%	12%	7%	5%	1%	2%	3%	2%	3%	2%	2%	18%	1%	1%	4%	3%	11%	3%	3%	3%	4%	3%	3%	4%
	W	6%	3%	10%	5%	3%	1%	1%	5%	3%	3%	6%	1%	1%	7%	1%	1%	2%	4%	5%	4%	7%	4%	5%	4%	4%
	Th	6%	2%	5%	5%	2%	2%	1%	1%	3%	4%	5%	3%	1%	28%	11%	5%	3%	2%	4%	4%	1%	4%	3%	3%	4%
	F	4%	7%	4%	7%	4%	2%	3%	3%	7%	2%	6%	52%	27%	1%	1%	5%	8%	4%	3%	4%	3%	1%	2%	5%	7%
	Sa	13%	11%	19%	22%	34%	43%	38%	40%	38%	36%	31%	21%	18%	12%	12%	11%	15%	17%	15%	13%	14%	16%	16%	20%	22%
	Su	5%	11%	8%	5%	8%	6%	9%	10%	12%	4%	5%	3%	6%	7%	4%	8%	5%	7%	5%	6%	7%	5%	3%	3%	6%

Table C.1: Raw Traffic Data

The table at left shows the raw data inputs extracted from MDOT databases for the month of Sept. 2003 for the Eastbound side of loop detector sites number 2 (Woodward Av. & I-696.) Based on the aggregate results, we have defined daytime hours for weekday and weekend traffic (shaded in yellow and green, respectively.)

The table below shows the averages for each day of the week along with the standard deviation of the result variability among the days (which does not present an easily identifiable pattern.)

Table C.2: Market Penetration Required for 95% Service Level for High Density Zones by Hour of Day and Day of Month

Reducing the above average vehicle density data for all the high density loop detector sites, using the assumptions listed, provides the following detailed table of results. The cells are coded according the thresholds listed in the upper right-hand side of the table (under 5%, shaded in pink, etc.) We can see that

Market Penetration (P) required for Assumed Service Level for High Density Zones by day of month & hour of day.

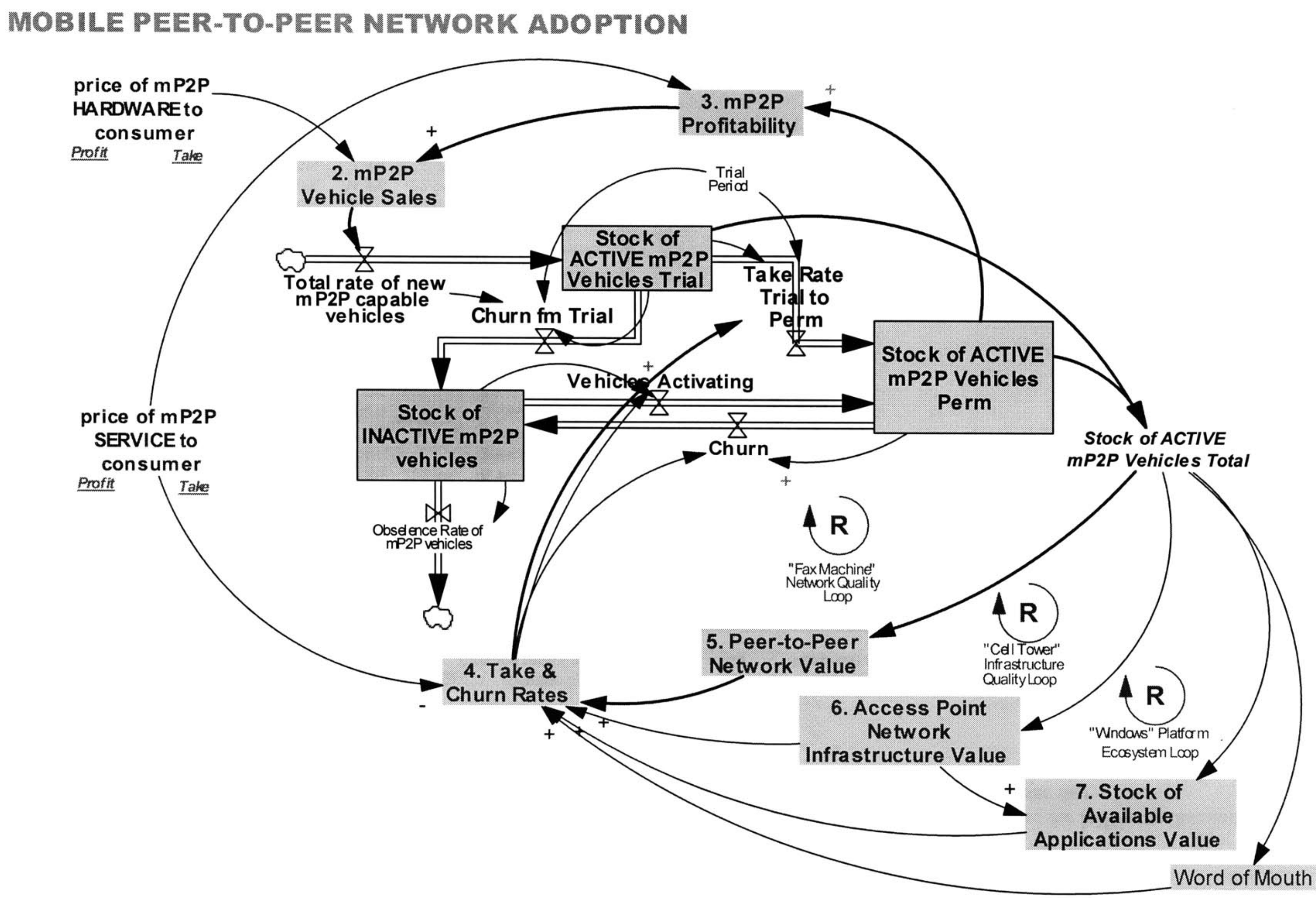
Assumptions: Average speed (v): 60 mph; Average range radius (r): 0.3 miles; Average Reliability (S): 95%; Maximum no. of Hops: 3 (N-1)

Color Coding: under 5%; 5% to 8%; 8% to 15%; 15% to 30%

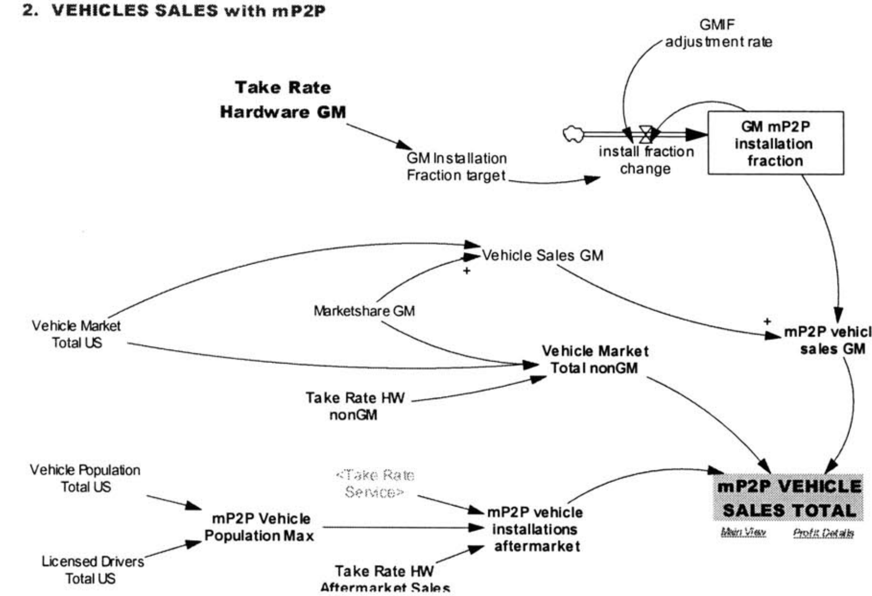
Date	Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1-Sep	M	18%	25%	35%	53%	58%	48.4%	34.3%	27.7%	21.0%	16.9%	13.5%	9.5%	7.6%	7.0%	6.7%	6.4%	6.8%	7.1%	7.3%	7.4%	8.3%	9.2%	11.3%
2-Sep	T	24%	39%	47%	48%	25%	7.9%	3.4%	2.6%	3.0%	3.4%	4.0%	3.9%	5.9%			2.9%	2.6%	2.7%	3.5%	4.6%	5.7%	6.3%	8.7%
3-Sep	W	19%	30%	34%	37%	24%	7.6%	3.2%	2.6%	2.9%	3.1%	3.8%	3.8%	3.6%	3.6%	3.1%	2.6%	2.6%	2.7%	3.3%	4.5%	5.6%	6.1%	8.5%
4-Sep	Th	19%	29%	33%	36%	24%	7.6%	3.2%	2.7%	3.0%	3.3%	3.6%	3.7%	3.6%	6.9%	3.1%	2.6%	2.6%	2.8%	6.3%	8.7%	10.0%	9.5%	13.3%
5-Sep	F	27%	39%	43%	49%	33%	8.0%	3.4%	2.8%	3.0%	3.3%	3.6%	18.9%	6.4%	3.4%	2.9%	2.6%	2.6%	2.9%	3.2%	4.1%	5.3%	5.7%	6.9%
6-Sep	Sa	15%	22%	29%	46%	55%	42.2%	28.8%	22.4%	18.3%	14.1%	10.2%	7.6%	6.3%	5.7%	5.3%	5.1%	5.4%	5.5%	5.5%	5.8%	6.7%	7.9%	9.9%
7-Sep	Su	11%	17%	19%	32%	45%	40.8%	22.6%	16.1%	11.4%	8.1%	6.0%	5.2%	4.9%	4.8%	4.7%	4.7%	4.6%	4.3%	4.8%	5.5%	6.3%	7.4%	9.6%
8-Sep	M	18%	31%	39%	45%	24%	7.9%	3.3%	2.5%	2.8%	3.5%	4.3%	4.0%	3.8%	3.8%	3.2%	2.7%	2.6%	2.7%	3.4%	4.7%	5.7%	6.5%	9.3%
9-Sep	T	20%	32%	36%	39%	23%	7.7%	3.2%	2.6%	3.0%	3.4%	3.7%	3.8%	3.7%	3.6%	3.1%	2.7%	2.6%	2.7%	3.3%	4.5%	5.5%	5.8%	8.4%
10-Sep	W	18%	30%	36%	39%	25%	7.7%	3.2%	2.6%	2.8%	3.2%	3.7%	3.8%	3.6%	3.6%	3.2%	2.7%	2.6%	2.6%	3.3%	4.6%	5.3%	5.8%	7.9%
11-Sep	Th	19%	29%	32%	36%	24%	7.6%	3.3%	2.6%	2.9%	3.2%	3.8%	3.7%	3.6%	3.5%	3.2%	2.8%	2.6%	2.7%	3.3%	4.5%	5.1%	5.5%	7.4%
12-Sep	F	16%	26%	29%	33%	24%	7.8%	3.4%	2.6%	2.9%	3.3%	3.6%	3.5%	3.4%	3.3%	2.9%	2.7%	2.9%	3.0%	3.3%	4.0%	5.2%	5.7%	6.3%
13-Sep	Sa	11%	17%	21%	31%	31%	17.0%	10.9%	7.3%	5.4%	4.6%	4.5%	4.1%	3.8%	4.0%	3.8%	3.8%	4.1%	4.2%	4.5%	4.9%	5.0%	5.5%	6.3%
14-Sep	Su	10%	15%	19%	32%	45%	38.4%	23.3%	15.1%	10.9%	7.7%	6.0%	5.0%	4.6%	4.5%	4.5%	4.6%	4.7%	4.7%	5.0%	5.7%	6.3%	8.0%	10.5%
15-Sep	M	23%	36%	44%	43%	25%	7.9%	3.4%	2.7%	3.6%	3.3%	4.0%	3.9%	3.8%	3.7%	3.2%	2.7%	2.7%	2.7%	5.0%	6.4%	5.8%	6.5%	9.2%
16-Sep	T	19%	30%	36%	39%	24%	7.6%	3.2%	2.7%	3.0%	3.1%	3.8%	3.8%	3.7%	3.6%	3.2%	2.6%	2.6%	2.7%	3.3%	4.5%	5.3%	5.9%	8.0%
17-Sep	W	17%	30%	33%	36%	23%	7.5%	3.2%	2.7%	3.0%	3.2%	4.3%	3.7%	3.6%	4.1%	3.3%	2.6%	2.6%	2.7%	3.3%	4.5%	5.2%	5.8%	7.9%
18-Sep	Th	18%	28%	33%	37%	25%	7.7%	3.3%	2.7%	3.0%	3.1%	3.8%	3.7%	3.6%	3.5%	3.1%	2.6%	2.5%	2.7%	3.2%	4.2%	5.1%	5.6%	7.6%
19-Sep	F	16%	25%	31%	34%	24%	8.1%	3.7%	2.8%	3.2%	3.4%	3.9%	3.6%	3.4%	3.4%	2.9%	2.7%	2.8%	2.9%	3.2%	4.3%	5.5%	6.1%	7.1%
20-Sep	Sa	12%	17%	21%	32%	36%	19.4%	12.0%	8.3%	6.5%	5.8%	5.6%	5.1%	4.7%	4.8%	4.7%	4.6%	4.8%	4.9%	5.2%	5.8%	6.5%	6.9%	7.5%
21-Sep	Su	11%	16%	19%	31%	40%	34.4%	22.2%	15.7%	11.4%	8.5%	6.6%	5.7%	5.4%	5.4%	5.2%	5.4%	5.3%	5.1%	5.6%	6.2%	6.5%	8.0%	10.5%
22-Sep	M	20%	33%	42%	45%	25%	7.8%	3.6%	3.0%	3.5%	3.4%	4.3%	4.3%	4.2%	4.0%	3.6%	3.0%	2.7%	2.8%	3.7%	5.3%	6.3%	8.1%	9.9%
23-Sep	T	21%	32%	34%	37%	24%	7.7%	3.2%	2.6%	2.9%	3.3%	3.9%	3.7%	3.7%	3.6%	3.2%	2.7%	2.7%	3.1%	3.3%	4.4%	5.5%	6.4%	8.6%
24-Sep	W	20%	28%	34%	39%	24%	7.7%	3.3%	2.7%	2.9%	3.3%	3.8%	3.8%	3.6%	3.6%	3.1%	2.6%	2.6%	2.8%	3.5%	4.9%	6.3%	6.6%	9.0%
25-Sep	Th	20%	29%	31%	36%	24%	7.6%	3.2%	2.6%	3.0%	3.2%	3.9%	3.7%	3.6%	3.4%	3.0%	2.6%	2.6%	2.8%	3.3%	4.3%	5.2%	5.6%	7.3%
26-Sep	F	17%	24%	28%	35%	23%	8.2%	3.4%	2.6%	3.1%	3.4%	3.7%	3.7%	3.4%	3.3%	2.9%	2.6%	2.6%	2.8%	3.3%	4.3%	5.5%	5.8%	6.8%
27-Sep	Sa	12%	16%	20%	32%	33%	19.3%	12.4%	7.8%	5.6%	4.6%	4.7%	4.6%	4.2%	4.5%	4.3%	4.1%	4.0%	4.1%	4.3%	5.2%	6.0%	6.5%	7.2%
28-Sep	Su	11%	15%	20%	31%	43%	38.7%	24.7%	17.1%	12.0%	8.6%	6.7%	5.6%	5.2%	4.8%	4.6%	4.6%	4.6%	4.8%	5.2%	5.5%	6.0%	7.8%	10.4%
29-Sep	M	22%	32%	42%	43%	25%	7.8%	3.3%	2.6%	2.9%	3.8%	3.9%	3.9%	3.8%	3.7%	3.2%	2.7%	2.6%	2.7%	3.5%	4.8%	5.8%	6.7%	9.4%
30-Sep	T	19%	30%	36%	38%	25%	7.8%	3.2%	2.6%	2.8%	3.5%	3.9%	3.8%	3.6%	3.7%	3.1%	2.6%	2.5%	2.6%	3.4%	4.4%	5.7%	6.2%	8.7%

Appendix D: Functional System Dynamics Model Documentation

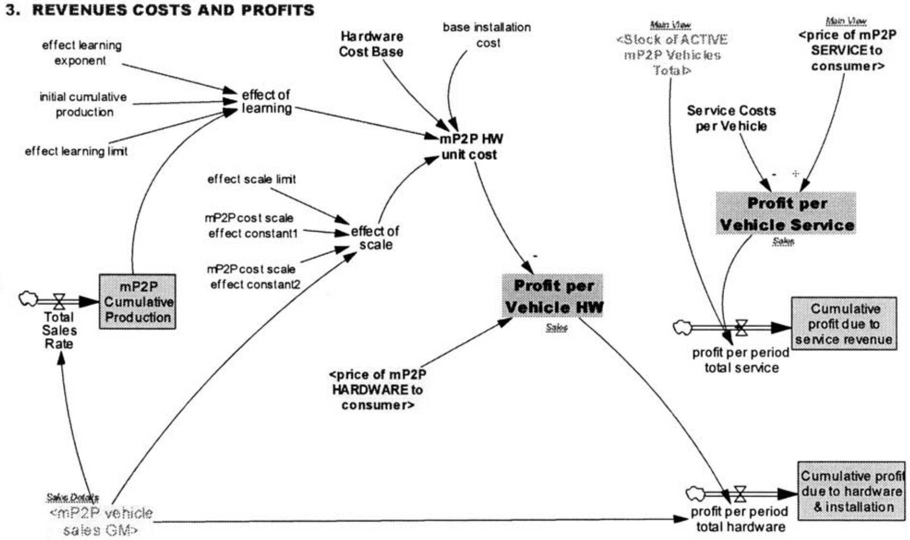
Coded in Vensim 5.0a, DSS build
mP2P Model version 5.2g



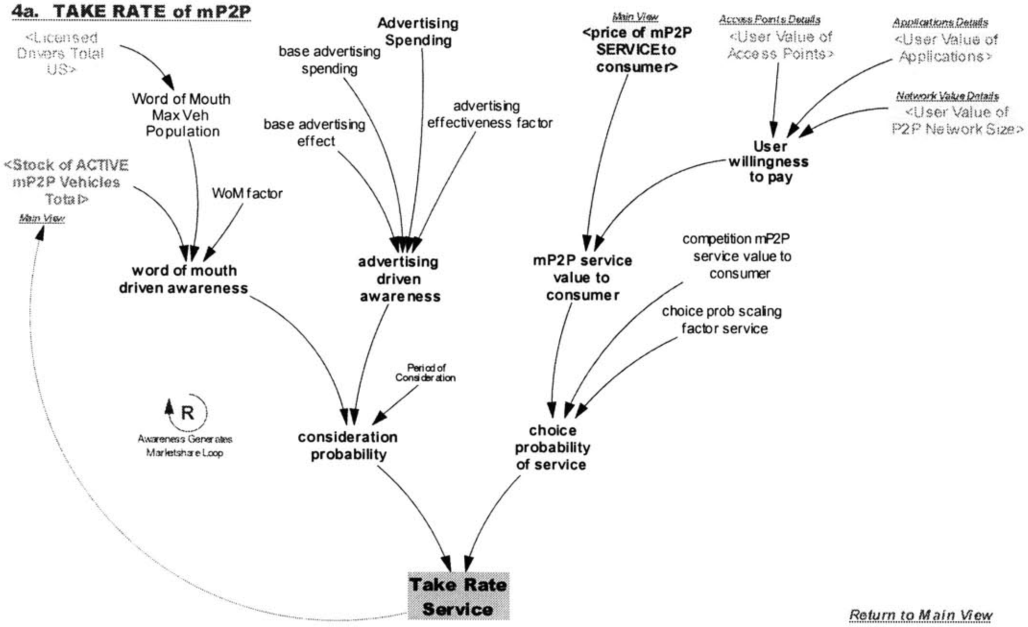
2. VEHICLES SALES with mP2P



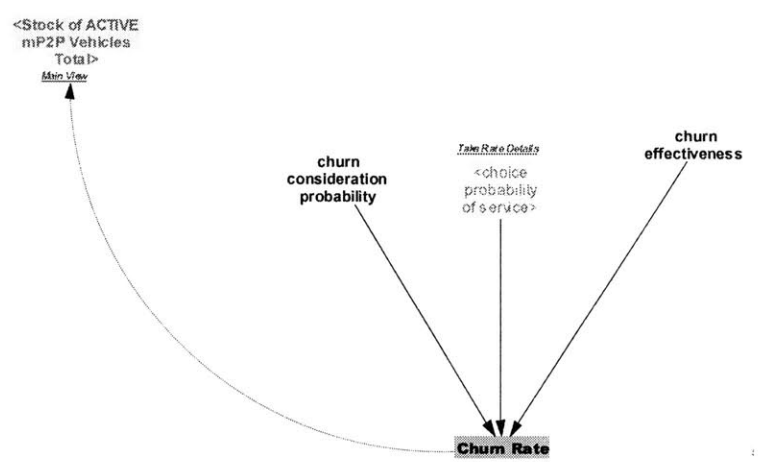
3. REVENUES COSTS AND PROFITS



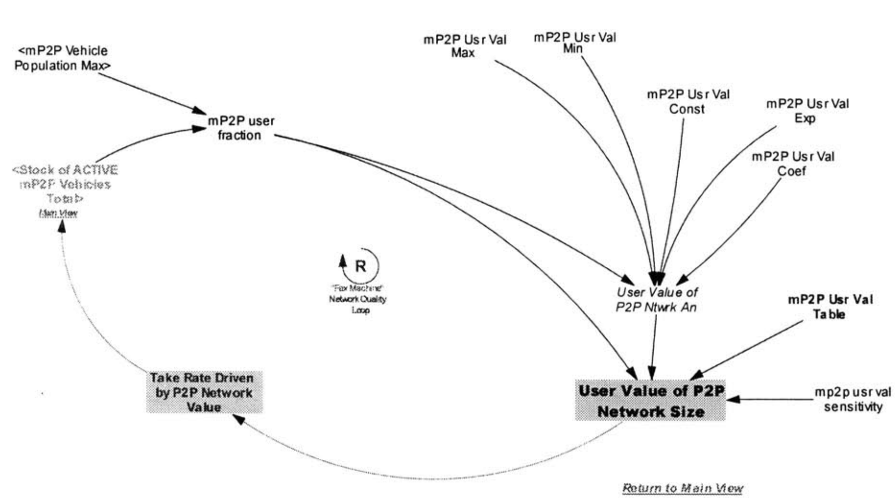
4a. TAKE RATE of mP2P



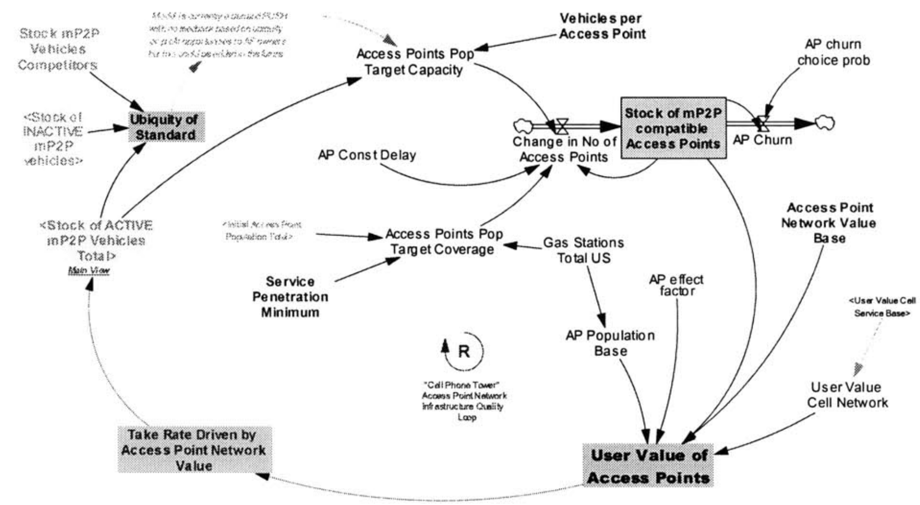
4b. CHURN RATE of ACTIVE mP2P CUSTOMERS



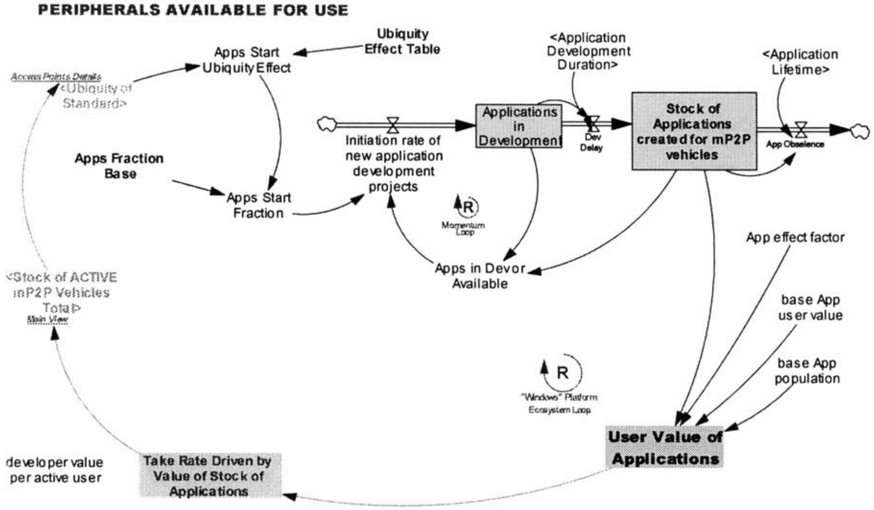
5. "FAX" LOOP: NETWORK VALUE TO P2P USER BASE



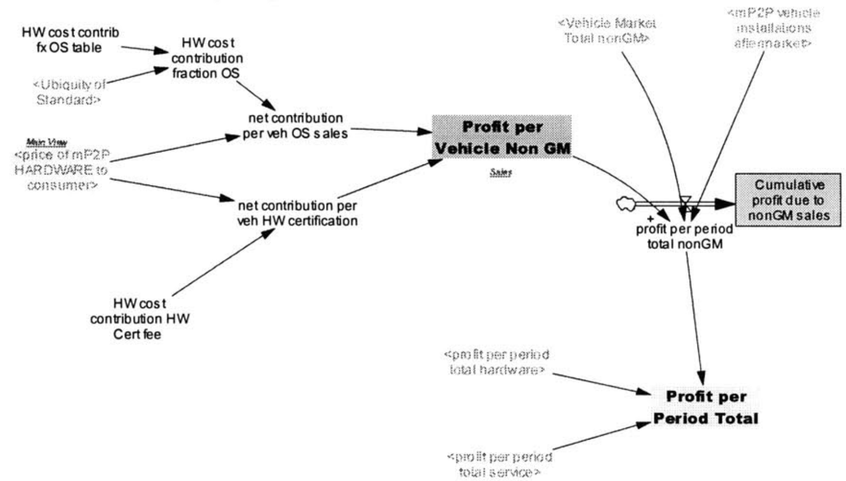
6. ACCESS POINT INFRASTRUCTURE NETWORK VALUE



7. VALUE OF STOCK OF APPLICATIONS AND PERIPHERALS AVAILABLE FOR USE



8. OTHER REVENUE OPPORTUNITIES



Functional System Dynamics Model Code

Coded in Vensim 5 DSS
By Erik Bue
Last revised 14-Dec-2003
mP2P Model version 5.2g (functional model)

```
mp2p usr val sensitivity = 1

User Value of P2P Network Size=
	mP2P Usr Val Table ( mP2P user fraction ) *mp2p usr val
sensitivity  +   ( 0 * User Value of P2P Ntwrk An\
		)
	~	dollars/(Month*vehicle)
	~	Value to mP2P vehicle user per vehicle per month
of having other mP2P \
		enabled users
	|

Churn fm Trial=
	( 1 - Take Rate New Sales ) * Total rate of new mP2P
capable vehicles
	     +  (1 - choice probability of service)  *  (Stock
of ACTIVE mP2P Vehicles Trial\
		  /  Trial Period)
	~	vehicles/Month
	~	Number of new vehicle purchasers that elect NOT
to sign up for the free \
		trial flow immediately to the stock of INACTIVE
vehicles, PLUS the number \
		that do not elect to make the service permenant
after the trial period.
	|

Take Rate Trial to Perm=
	choice probability of service  *  (Stock of ACTIVE mP2P
Vehicles Trial  /  Trial Period\
		)
	~	vehicles/Month
	~		|

Access Point Network Value Base=
	30
	~	dollars/(Month*vehicle)
	~	Value to mP2P vehicle user of having nominal
coverage of access points as \
		defined by base AP population. Value taken from
cell phone and internet \
		broadband service plans: assume $30/month for
perfect service.
	|

Access Points Pop Target Capacity=
	Stock of ACTIVE mP2P Vehicles Total   /   Vehicles per
Access Point
	~	access points
	~	Target number to total Access Points in service
	|

Access Points Pop Target Coverage=
	IF THEN ELSE( FLAG AP Coverage v Capacity=1 ,
	    Gas Stations Total US * Service Penetration Minimum
	, Initial Access Point Population Total )
	~	access points
	~	Target number to total Access Points in service
	|

advertising driven awareness=
	base advertising effect
	    * ( ( Advertising Spending  /  base advertising
spending ) ^ advertising effectiveness factor\
		)
	~	Fraction
	~	Advertising component of consideration factor;
presented as fraction.
	|

advertising effectiveness factor=
	0.35
	~	Dimensionless
	~	FIX INPUT: $'s required to make 1 potential user
aware of service.
	|

Advertising Spending=
	(5.7e+007 )
	~	dollars/Month
	~	KEY INPUT: Total $$'s/month spent on advertising
services.  ZERO FOR NOW.
	|

AP Churn=
	Stock of mP2P compatible Access Points  *  AP churn
choice prob
	~	access points/Month
	~	Rate as which providers decomission currently
active access points
	|

AP churn choice prob=
```

```
        0
        ~       Fraction/Month
        ~       AP Churn Rate.  currently Zero.
        |

AP Const Delay=
        3
        ~       months
        ~       Number monmths to construct new Access Point
        |

AP effect factor=
        0.4
        ~       Dimensionless
        ~       Exponential determing effect of diminishing
returns of additional access \
                points beyond base level. (0.2-0.5 for
advertising, Paich) Assume high \
                effect thus low power.
        |

AP Population Base=
        10  *  Gas Stations Total US
        ~       access points
        ~       Number of access points in the US to achieve
nominal ubiquity of service.  \
                Fro services we access only once a week, the
200,000 service stations in \
                the US provide good competition.  Wor wireless
connectivity, we will \
                assume 10x that number of stations.
        |

App effect factor=
        0.4
        ~       Dimensionless
        ~       Exponential effect of diminishing returns of
additional applications \
                beyond base level. (0.2-0.5 for advertising,
Paich) Assume high effect \
                thus low power.
        |

App Obselence=
        Stock of Applications created for mP2P vehicles   /
Application Lifetime
        ~       applications/Month
        ~               |

Application Development Duration  = 12
        ~       months
        ~       INPUT: Average time it takes to develop a new
application from initiation.
        |

Application Lifetime=
        5  * 12
        ~       months
        ~       Average lifetime of an application before
epiration, refreshing or \
                issueing a new version.
        |

Applications in Development  =
          INTEG( Initiation rate of new application development
projects
                     - Dev Delay ,
                0)
        ~       applications
        ~       Number of applications currently in development
        |

Apps Fraction Base=
        0.05  / 12
        ~       Fraction/Month
        ~       PLACEHOLDER:
        |

Apps in Dev or Available=
        Stock of Applications created for mP2P vehicles  +
Applications in Development
        ~       applications
        ~       Total number of apps in progress or available.
        |

Apps Start Fraction=
        Apps Fraction Base  *  Apps Start Ubiquity Effect
        ~       Fraction/Month
        ~               |

Apps Start Ubiquity Effect=
        Ubiquity Effect Table( Ubiquity of Standard ) *10
        ~       Fraction
        ~       REVISIT: SCALING AN ISSUE
        |

Avg Consumer Technology Lifetime=
        5 * 12
        ~       months
```

```
~       Cell-phone & PC technology has a generational
life of about 2-4; many \
        peripherals have a longer term of 5-7 years.
Assuming 5 years.
        |

Avg Vehicle Life=
        15 * 12
~       months
~       Media age of vehicles in operation (in 2002, RL
Polk & Co.) was 8.4 years \
        for cars & 6.6 for trucks.  Thus, nominal average
vehicle lifetime is 15 \
        years.
        |

base advertising effect=
        0.035
~       Fraction
~       Exponential determing effect of diminishing
returns of advertising \
        spending beyond base level. (0.2-0.5, Paich)
        |

base advertising spending=
        5.7e+007
~       dollars/Month
~       Level of advertising spending necessary to affect
base level effect \
        ($50-100M, based on $4B GM spends per year on 70
itemzations or an average \
        of $57M/annum each, Paich)
        |

base App population  = 100
~       applications
~       Number of applications to achieve nominal level
of service. It is assumed \
        (from PC operating system market) to be 100
applications.
        |

base App user value  = 15
~       dollars/(Month*vehicle)
~       INPUT: Value to mP2P vehicle user of having
nominal level of applications \
        available for use as defined by base App
population. Value taken from \
        Japaneese cell phone market: assume $15/month.
        |

base installation cost  = 10
~       dollars/vehicle
~       INPUT: currently based on factory installation at
1M+/year volumes. Dealer \
        installation causes a discontinunity in cost
curve.
        |

Change in No of Access Points=
        ( MAX( Access Points Pop Target Capacity, Access Points
Pop Target Coverage )  -
                Stock of mP2P compatible Access Points
                )  /  AP Const Delay
~       access points/Month
~       Change in the Stock of access points per monthy.
        |

choice prob scaling factor service=
        10
~       dollars/(Month*vehicle)
~       PLACEHOLDER: Must have same units as Value to
Consumer- scale based on \
        mP2P Service Value to Consumer actual value.  Its
going to be somewhere in \
        the range of $3-50/vehicle/month.
        |

choice probability of service=
        EXP ( mP2P service value to consumer   / choice prob
scaling factor service )
            / ( 1 +  EXP ( mP2P service value to consumer /
choice prob scaling factor service\
            )
            + EXP ( competition mP2P service value to
consumer  /  choice prob scaling factor service\
            ) )
~       Fraction
~       KEY INPUT: Fraction of those who consider the
product who actually take it
        |

Churn=
        Stock of ACTIVE mP2P Vehicles Perm * Churn Rate
~       vehicles/Month
~       Rate of current customers that elect to cancel
service.
        |

churn consideration probability=
```

```
        1 / 6
        ~       Fraction/Month
        ~       Assumption is that current customers reevaluate
their relationship every \
                six months; thus there is a 1 in 6 chance of
reconsidering.
        |

churn effectiveness  = 0.3
        ~       Fraction
        ~       KEY INPUT: The probability that customers who, if
asked, would elect to \
                cancel their service, will actually do so out of
laziness or hassel in any \
                given month. For now: 30%.
        |

Churn Rate=
        churn consideration probability   *   (1 - choice
probability of service)   *   churn effectiveness
        ~       1/months
        ~       Percentage of currently Active mP2P users per
month that will cancle \
                service (or allow it to lapse).
        |

competition mP2P service value to consumer  = 0
        ~       dollars/(Month*vehicle)
        ~       PLACEHOLDER: Compare against competitive options.
Eventually this would \
                likely be driven by the profit opportunities to a
potential entrant.  ZERO \
                FOR NOW SINCE NO COMPETITION.
        |

consideration probability=
        ( word of mouth driven awareness   +   advertising
driven awareness
                  - ( advertising driven awareness   *   word
of mouth driven awareness ) )\
                / Period of Consideration
        ~       Fraction/Month
        ~       Fraction of potential vehicle user base made that
considers adopting the \
                service each month.
        |

"Cumulative profit due to hardware & installation"  =
        INTEG( profit per period total hardware ,
                0)
        ~       dollars
        ~               |

Cumulative profit due to nonGM sales  =
        INTEG( profit per period total nonGM ,
                0)
        ~       dollars
        ~       Initial value should potentially be initial
investment for service.
        |

Cumulative profit due to service revenue  =
        INTEG( profit per period total service ,
                0)
        ~       dollars
        ~       Initial value should potentially be initial
investment for service.
        |

Dev Delay=
        Applications in Development  / Application Development
Duration
        ~       applications/Month
        ~       Rate that new applications become available for
commercial use.
        |

developer value per active user=
        0
        ~       dollars/(Month*vehicle)
        ~       Future Use?
        |

effect learning exponent  = 0.2
        ~       Dimensionless
        ~       INPUT: exponent determines learning curve; taken
from curve fitting to \
                OnStar cost reduction
        |

effect learning limit  = 0.4
        ~       Dimensionless
        ~       INPUT: Lower limit of learning effect fraction
(as fraction of base unit \
                cost); ie the lowest the cost can go.
        |

effect of learning  =
        MAX ( ( ( initial cumulative production
                / mP2P Cumulative Production )
```

```
                ^ effect learning exponent ) ,
           effect learning limit )
       ~       Dimensionless
       ~       Fraction of original base cost as a result of
production learnings
       |

effect of scale  =
        effect scale limit
             + ( mP2P cost scale effect constant1
                  / ( mP2P vehicle sales GM
                       + mP2P cost scale effect constant2 ) )
       ~       Dimensionless
       ~       Fraciton of original base cost that isa as a
result of production scale.
       |

effect scale limit  = 0.4
       ~       Dimensionless
       ~       INPUT: Lower limit of scale effect fraction (as
fraction of base unit \
               cost); ie the lowest the cost can go.
       |

FLAG AP Coverage v Capacity=
       1
       ~       Dimensionless
       ~       INPUT: Boolean flag.  0 = determin target # of
APs only from capacity \
               requirement;  1=determind target # of APs as the
max of capacity and \
               minimum coverage
       |

FLAG Usr Val Apps=
       1
       ~       Dimensionless
       ~       FLAG: Boolean.  1=Include User Value of
Applications; 0=Don't
       |

FLAG Usr Val APs=
       1
       ~       Dimensionless
       ~       FLAG: Boolean.  1=Include User Value of Acces
Points; 0=Don't
       |

FLAG Usr Val Cell Service  = 0
       ~       Dimensionless
       ~       Boolean flag (0 or 1) to indicate whether to
include additional value of \
               having long-range, low-bandwidth (i.e. cell
phone) network
       |

FLAG Usr Val mP2P network=
       1
       ~       Dimensionless
       ~       FLAG: Boolean.  1=Include User Value of
Applications; 0=Don't
       |

Gas Stations Total US=
       200000
       ~       access points
       ~       Total approximate number of gas statiosn in the
US.  Assuming that each is \
               potential access point of nominal geographic
dispersion, we use this a \
               surogate for nominal coverage.
       |

GM Installation Fraction target=
       Take Rate Hardware GM
       ~       Fraction
       ~       Target mP2P installation as percentage of all new
GM manufactured vehicles.
       |

GM mP2P installation fraction= INTEG (
       install fraction change,
             0)
       ~       Fraction
       ~       Percentage of new GM vehicles that are installed
with mP2P capability
       |

GMIF adjustment rate  = 1.5
       ~       months
       ~       INPUT: Rate change smoothing factor; initially
1.5 months
       |

Hardware Cost Base  = 292
       ~       dollars/vehicle
       ~       PLCAEHOLDER: Hardware cost currently based on
factory installation at \
               1M+/year volumes. Dealer installation causes a
discontinunity in cost \
```

```
            curve.
        |

HW cost contrib fx OS table(
        [(0,0)-(10,10)],(0,0),(1,0))
        ~       Fraction
        ~       OS licensing fee that is extractible from 3rd
party installations based on \
                ubiquity of service
        |

HW cost contribution fraction OS=
        HW cost contrib fx OS table(Ubiquity of Standard)
        ~       Fraction
        ~       FIX INPUT: Percentage of mP2P hardware system
price that represents \
                operating system revenue back to GM.  This is be
highly dependent on the \
                marketshare penetration or ubiquity of service.
Ranges non-linearly from \
                0% to 5%.
        |

HW cost contribution HW Cert fee=
        0.01
        ~       Fraction
        ~       INPUT: Percentage of hardware sales price
returned as certification fee or \
                royalty.  Currently 1%.
        |

Initial Access Point Population Total=
        71078 / 3 /3
        ~       access points
        ~       Gartner Dataquest 2003 est of worldwide Public
Wi-Fi Hotspots * 1/3 to \
                estimate the US percentage. Could include both
true access points as well \
                as wireless routers to extend range of existing
network of AP's.  This \
                total is then divided by 6 assuming 6 competing
major networks.
        |

initial cumulative production  = 534765
        ~       vehicles
        ~       INPUT: Total volume of production at time of
launch - normalizing factor \
                for base cost.
        |

Initial No of Apps Available at Launch  = 10
        ~       applications
        ~       Initial number of applications available at
service launch
        |

Initial stock of active mP2P vehicles=
        100
        ~       vehicles
        ~       Initial Seeding of Captured Vehicle Test Fleet.
        |

Initial Stock of Inactive mP2P vehicles=
        100
        ~       vehicles
        ~       Initial Value to Stock of Inactive Vehicles
        |

Initiation rate of new application development projects=
        Apps in Dev or Available * Apps Start Fraction
        ~       applications/Month
        ~       FIX: Rate at which new application development
projects are started
        |

install fraction change=
        ( GM Installation Fraction target - GM mP2P installation
fraction )
                        / GMIF adjustment rate
        ~       Fraction/Month
        ~       Determines increase or decrease in fraction of
new GM vehicles to be \
                installed with mP2P capability. Expression
smoothes transitions
        |

Licensed Drivers Total US=
        1.61267e+008
        ~       vehicles
        ~       Total number of licensed drivers in the US.
Includes thouse without a \
                vehicle.  The realistic market is probably pretty
close to this figure.  \
                Source: Alliance of Automotive Manufacturers,
2003
        |

Marketshare GM  = 0.3
        ~       Fraction
```

```
        ~       US marketshare.  Should be variable going
forward: fixed at 30% for now.
        |

mP2P cost scale effect constant1  = 850196
        ~       vehicles/Month
        ~       Constant #1 for calculating scale effects; taken
from curve fitting to \
                OnStar cost reduction
        |

mP2P cost scale effect constant2  = 696242
        ~       vehicles/Month
        ~       Constant #2 for calculating scale effects; taken
from curve fitting to \
                OnStar cost reduction
        |

mP2P Cumulative Production  =
         INTEG( Total Sales Rate ,
               initial cumulative production )
        ~       vehicles
        ~       Cumulative number of vehicles sold with the mP2P
hardware
        |

mP2P HW unit cost  =
         ( Hardware Cost Base
               + base installation cost )
               * effect of learning
               * effect of scale
        ~       dollars/vehicle
        ~       total cost of mP2P capability per vehicle
        |

mP2P service value to consumer  =
         User willingness to pay
               - price of mP2P SERVICE to consumer
        ~       dollars/(Month*vehicle)
        ~       Customer Willingness to Pay - Price (with some
variance to be incorporated \
                later)
        |

mP2P user fraction=
        Stock of ACTIVE mP2P Vehicles Total   /   mP2P Vehicle
Population Max
        ~       Fraction
        ~       Fraction of total vehicles on the road with
active mP2P services
        |

mP2P Usr Val Coef=
        20
        ~       Dimensionless
        ~       PLACEHOLDER: To Tune.  Coefficient for
calculating value to consumer of \
                P2P network size.
        |

mP2P Usr Val Const=
        0.8
        ~       Dimensionless
        ~       PLACEHOLDER: To tune. Fractional constant for
calculating value to \
                consumer of P2P network size
        |

mP2P Usr Val Exp=
        1.8
        ~       Dimensionless
        ~       PLACEHOLDER: To Tune.  Exponent for calculating
value to consumer of P2P \
                network size
        |

mP2P Usr Val Max=
        31.2
        ~       dollars/(Month*vehicle)
        ~       KEY INPUT: Upper limit of value to consumer of
P2P network size.  Assumed \
                to be $20 /month /user.
        |

mP2P Usr Val Min=
        0
        ~       dollars/(Month*vehicle)
        ~       Lower limit of value to consumer of P2P network
size. Assumed Zero.
        |

mP2P Usr Val Table(
        [(0,0)-
(1,30)],(0,0),(0.01,1),(0.03,3),(0.1,8),(0.192661,12.4561),(0.3
,18),(0.4,22),\

        (0.489297,24.9123),(0.584098,27.193),(0.688073,28.4211),
(0.8,29),(1,30))
        ~       dollars/(Month*vehicle)
        ~               |
```

```
mP2P vehicle installations aftermarket=
	mP2P Vehicle Population Max    *   Take Rate Service    *
Take Rate HW Aftermarket Sales
	~	vehicles/Month
	~	Rate of 3rd party mP2P vehicles installations:
initially stipulated as 1% \
		of non-Gm mP2P vehicles sales volume
	|

mP2P Vehicle Population Max=
	(0.9 * Licensed Drivers Total US + 0.1 * Vehicle
Population Total US)
	~	vehicles
	~	INPUT: Max. network size is calculated as the
average of: the total \
		population of registered vehicles in the US AND
the total number of \
		licensed drivers
	|

mP2P vehicle sales GM=
	Vehicle Sales GM   *   GM mP2P installation fraction
	~	vehicles/Month
	~	Rate of new GM vehicles sold which have the mP2P
hardware installed per \
		period
	|

mP2P VEHICLE SALES TOTAL=
	mP2P vehicle installations aftermarket  +  mP2P vehicle
sales GM  +   Vehicle Market Total nonGM
	~	vehicles/Month
	~	Dummy Variable; actual on mage page
	|

net contribution per veh HW certification=
	HW cost contribution HW Cert fee * price of mP2P
HARDWARE to consumer
	~	dollars/vehicle
	~		|

net contribution per veh OS sales=
	HW cost contribution fraction OS * price of mP2P
HARDWARE to consumer
	~	dollars/vehicle
	~		|

NVF ext indicator  = 1
	~	Dimensionless
	~	INPUT: "delta" Binary indicator: 1 if there are
network externalities, 0 \
		if there are not.
	|

"NVF val w/o ext"  = 0.5
	~	dollars/(Month*vehicle)
	~	INPUT "k" Value of the network per active
user/vehicle in the absence of \
		network effects
	|

Obselence Rate of mP2P vehicles=
	Stock of INACTIVE mP2P vehicles   *   Ubiquity of
Standard   /   Avg Vehicle Life
		+ Stock of INACTIVE mP2P vehicles  *  ( 1 -
Ubiquity of Standard )
		  /   Avg Consumer Technology Lifetime
	~	vehicles/Month
	~	With Ubiquitous Standards, technology lasts the
life of the vehicle. \
		Without, it expires at the same rate at other
consumer electronics \
		technology since there isn't enougth mass to
insure backwards campability.
	|

Period of Consideration=
	1
	~	Month
	~		|

price of mP2P HARDWARE to consumer  =
	 price table hardware ( Time )
	~	dollars/vehicle
	~	KEY LOOKUP INPUT: take from revenue or price
elasticity curve? Define as \
		relationship with current sales volume? The
higher the price, the lower \
		the take rate and the higher the churn.
	|

price of mP2P SERVICE to consumer  =
	 price table service ( Time )
	~	dollars/(Month*vehicle)
	~	KEY INPUT: take from revenue or price elasticity
curve? Define as \
		relationship with current sales volume? The
higher the price, the lower \
		the take rate and the higher the churn.
```

```
	|

price table hardware(
	[(2003,0)-
(2020,500)],(2003,0),(2004,0),(2005,0),(2006,0),(2008,0),(2010,
0),(2012,0)\
		,(2014,0),(2016,0))
	~	dollars/vehicle
	~	KEY LOOKUP INPUT: take from revenue or price
elasticity curve? Define as \
		relationship with current sales volume? The
higher the price, the lower \
		the take rate and the higher the churn.  ZERO FOR
NOW.
	|

price table service(
	[(2003,0)-(2016,50)],(2003,5),(2016,5))
	~	dollars/(Month*vehicle)
	~	KEY LOOKUP INPUT: take from revenue or price
elasticity curve? Define as \
		relationship with current sales volume? The
higher the price, the lower \
		the take rate and the higher the churn.Currently
$20/mth.\!\!
	|

Profit per Period Total=
	profit per period total hardware + profit per period
total service + profit per period total nonGM
	~	dollars/Month
	~	Total gross profit earned per month
	|

profit per period total hardware=
	Profit per Vehicle HW   *   mP2P vehicle sales GM
	~	dollars/Month
	~	Total profit due to hardware sales per period.
	|

profit per period total nonGM=
	Profit per Vehicle Non GM * (Vehicle Market Total nonGM
+ mP2P vehicle installations aftermarket\
		)
	~	dollars/Month
	~	Total profit from all active vehicles for given
period
	|

profit per period total service=
	Stock of ACTIVE mP2P Vehicles Total   *   Profit per
Vehicle Service
	~	dollars/Month
	~	Total profit from all active vehicles for given
period
	|

Profit per Vehicle HW=
	price of mP2P HARDWARE to consumer  -   mP2P HW unit
cost
	~	dollars/vehicle
	~	Net contribution (exclusive of G&A) per vehicle
sold
	|

Profit per Vehicle Non GM=
	net contribution per veh HW certification + net
contribution per veh OS sales
	~	dollars/vehicle
	~	Net Contribution per non-GM factory installation
due to Operating System \
		and Hardware Certification revenue.
	|

Profit per Vehicle Service=
	price of mP2P SERVICE to consumer   -   Service Costs
per Vehicle
	~	dollars/(Month*vehicle)
	~	Gross profit per vehicle due to services
	|

Service Costs per Vehicle  = 10
	~	dollars/(Month*vehicle)
	~	VARIABLE MAP based on volume
	|

Service Penetration Minimum=
	0.1
	~	Fraction
	~	INPUT: From diesel fuel, we know that consumers
need 10-30% of gas \
		stations to have diesel to feel comfortable that
they will be abl to \
		refuel.  Since this service is an optional one,
the lower bounds seems \
		appropriate.
	|

Stock mP2P Vehicles Competitors=
	0
```

```
	~	vehicles
	~	FIX: Currently Zero - To be connect to parallel,
competitor loop once \
		subscripting is engaged.
	|

Stock of ACTIVE mP2P Vehicles Total=
	Stock of ACTIVE mP2P Vehicles Perm	+	Stock of ACTIVE
mP2P Vehicles Trial
	~	vehicles
	~	Total number of active vehicles, both those on
temporary trial activation \
		as well as those that elected to stay as
permenant members.
	|

Stock of ACTIVE mP2P Vehicles Perm= INTEG (
	Take Rate Trial to Perm	+	Vehicles Activating	-
Churn,
		Initial stock of active mP2P vehicles)
	~	vehicles
	~	Stock of currently activated mP2P-enabled
vehicles.
	|

Stock of ACTIVE mP2P Vehicles Trial= INTEG (
	Total rate of new mP2P capable vehicles - Take Rate
Trial to Perm - Churn fm Trial,
		Initial stock of active mP2P vehicles)
	~	vehicles
	~	Stock of currently Trial-Period activated mP2P-
enabled vehicles.
	|

Stock of Applications created for mP2P vehicles= INTEG (
	Dev Delay	- App Obselence,

			Initial No of Apps Available at
Launch)
	~	applications
	~	Stock level of applications & peripherals
currently available for use on \
		mP2P systems.
	|

Stock of INACTIVE mP2P vehicles= INTEG (
	Churn	+	Churn fm Trial	-	Vehicles Activating	-
Obselence Rate of mP2P vehicles\
		,
		Initial Stock of Inactive mP2P vehicles)
	~	vehicles
	~	Vehicles with hardware capability installed but
not activated
	|

Stock of mP2P compatible Access Points= INTEG (
	Change in No of Access Points	-	AP Churn,
		Initial Access Point Population Total)
	~	access points
	~	Stock of access points compatible with mP2P
hardware.
	|

Take Rate Hardware GM=
	1
	~	Fraction
	~	INPUT: Corp. Policy Decision of what fraction of
vehicles on which to \
		install hardware: 0-100%.  Will likely not be
100% as the lowest price \
		vehicles will not have it for a while.  For now,
target of 80%
	|

Take Rate HW Aftermarket Sales=
	0
	~	Fraction
	~	Fraction of those that have the hardware in their
GM vehicles that would \
		actually perform an aftermmarket installation.  A
reasonable guess might \
		be 1% eventually.  For now, zero.
	|

Take Rate HW nonGM=
	1
	~	Fraction
	~	INPUT VARIABLE: Franction of non-GM new vehicle
market installed with mP2P \
		capable hardware.  Zero for now.  Eventually
could try low penetration \
		like 5% of market.
	|

Take Rate New Sales=
	0.95
	~	Fraction
	~	OnStar's experience is that 95% of new buyers of
vehicles with OnStar \
```

```
            hardware factory installed choose to have it
activated EVEN THOUGH its \
            free for the first year.
      |

Take Rate Service=
      consideration probability   *   choice probability of
service
      ~     Fraction/Month
      ~     Liklihood that users with mP2P-capable vehicles
will activate the service \
            each month. Actually units are: "vehicels that
will take service per month \
            / stock of vehicles that could take per month".
      |

Total rate of new mP2P capable vehicles  =
       mP2P VEHICLE SALES TOTAL
      ~     vehicles/Month
      ~     Total rate at which new mP2P capabile vehicles
are sold into the market
      |

Total Sales Rate  =
       mP2P vehicle sales GM
      ~     vehicles/Month
      ~     Total rate of new mP2P-enabled vehicle sales by
GM.
      |

Trial Period=
      6
      ~     months
      ~           |

Ubiquity Effect Table(
      [(0,0)-
(1,10)],(0,1),(0.12844,1.14035),(0.299694,1.66667),(0.46789,2.3
2456),(0.623853\

      ,3.20175),(0.785933,4.34211),(0.865443,4.73684),(1,5))
      ~     Dimensionless
      ~           |

Ubiquity of Standard=
      ( Stock of ACTIVE mP2P Vehicles Total   +   Stock of
INACTIVE mP2P vehicles )
                  / ( Stock of ACTIVE mP2P Vehicles Total   +
Stock of INACTIVE mP2P vehicles\
                  + Stock mP2P Vehicles Competitors )
      ~     Fraction
      ~     PLACEHOLDER: Fraction of all mP2P systems in
marketplace that are \
            compatible with GM standard.  Connected to Stock
of competirors loop.
      |

User Value Cell Network=
      IF THEN ELSE( FLAG Usr Val Cell Service=1 , User Value
Cell Service Base , 0 )
      ~     dollars/(Month*vehicle)
      ~     PLACEHOLDER: If turned on my Cell Phone Flag,
assumes a value to mP2P \
            users of having a "ubiquitous" long-range, low-
bandwidth connection (ie a \
            cell phone) in addition to the mP2P network.
      |

User Value Cell Service Base=
      10
      ~     dollars/(Month*vehicle)
      ~     PLACEHOLDER: If turned on my Cell Phone Flag,
assumes a value to mP2P \
            users of having a "ubiquitous" long-range, low-
bandwidth connection (ie a \
            cell phone) in addition to the mP2P network.
Initially, its $10. \
            (Eventually, we really need to add in the
additional hardware cost and \
            service cost to support the system to the model.)
      |

User Value of Access Points=
      Access Point Network Value Base
               * (Stock of mP2P compatible Access Points / AP
Population Base) ^AP effect factor\

               + User Value Cell Network
      ~     dollars/(Month*vehicle)
      ~     Value to mP2P vehicle user per vehicle per month
of having wide base of \
            access points available for use. Similar
diminishing returns expression as \
            advertising.
      |

User Value of Applications=
      base App user value
```

```
	* ( Stock of Applications created for mP2P vehicles /
base App population ) ^ App effect factor
	~	dollars/(Month*vehicle)
	~	Value to mP2P vehicle user per vehicle per month
of having wide range of \
		applications available.
	|

User Value of P2P Ntwrk An=
	mP2P Usr Val Min
	    + ( ( mP2P Usr Val Max   -   mP2P Usr Val Min )
	         *    ( mP2P Usr Val Coef   *   mP2P user
fraction ^ mP2P Usr Val Exp )
	         /    ( mP2P Usr Val Const  +   mP2P Usr Val
Coef  * mP2P user fraction ^ mP2P Usr Val Exp\
	       ) )
	~	dollars/(Month*vehicle)
	~	Value to mP2P vehicle user per vehicle per month
of having other mP2P \
		enabled users
	|

User willingness to pay=
	IF THEN ELSE( FLAG Usr Val mP2P network=1, User Value of
P2P Network Size, 0 )
	    +  IF THEN ELSE( FLAG Usr Val Apps=1, User Value of
Applications, 0 )
	    +  IF THEN ELSE( FLAG Usr Val APs=1, User Value of
Access Points, 0 )
	~	dollars/(Month*vehicle)
	~	Sum of value placed on: application base, number
of other users & number \
		of available access points
	|

Vehicle Market Total nonGM=
	Vehicle Market Total US  * ( 1  - Marketshare GM )  *
Take Rate HW nonGM
	~	vehicles/Month
	~	Rate of non-GM vehicles installed with GM-
compatible mP2P hardware
	|

Vehicle Market Total US=
	1.7e+007  / 12
	~	vehicles/Month
	~	INPUT: Based on total annual US volume of new
vehicles of 17M; total mP2P \
		capable vehicles per period
	|

Vehicle Population Total US=
	2.20883e+008
	~	vehicles
	~	Total number of registered light-duty vehicles
(cars & light trucks.)  \
		Includes governmental, commercial and collectors
vehicles.  Thus, \
		realistic market is quite a bit lower than this.
Source: Alliance of \
		Automotive Manufacturers, 2003
	|

Vehicle Sales GM=
	Vehicle Market Total US   *   Marketshare GM
	~	vehicles/Month
	~	Rate of new GM vehicle sales in mP2P-compatible
countries
	|

Vehicles Activating=
	Stock of INACTIVE mP2P vehicles   *   Take Rate Service
	~	vehicles/Month
	~	No. of vehicles/yr with required hardwre that
activate the mP2P service.
	|

Vehicles per Access Point=
	288
	~	vehicles/access point
	~      Average number of Access Pints per Active Vehicle.
The minimum geographic \
		availability issues would be achieved through a
gradual roll-out by \
		geography.
	|

WoM factor=
	0.6
	~	Fraction
	~	INPUT: Ratio non-users who become aware of
service based on hearing about \
		it from current users. 1.0 implies that each
person makes one new \
		(non-duplicative) person aware each period.
Typically this 0.2-0.8 with an \
		average of 0.5 /year or 0.042/mth.
	|

word of mouth driven awareness=
```

```
      WoM factor  *  ( Stock of ACTIVE mP2P Vehicles Total  /
Word of Mouth Max Veh Population\
             )
      ~      Fraction
      ~      Potnetial user vehicles per month that have been
made aware of (or \
             reminded of) service in given month due to word
of mouth; normalized as \
             fraction (0-1 scale)
      |

Word of Mouth Max Veh Population=
      Licensed Drivers Total US * 0.5
      ~      vehicles
      ~      Realistic population for adoption is a fraction
of the total number of \
             licensed drivers.  Downrating the number of total
livensed drivers by 50%.
      |

********************************************************
      .Control
********************************************************~
             Simulation Control Parameters
      |

FINAL TIME  = 2050
      ~      Month
      ~      The final time for the simulation.
      |

INITIAL TIME  = 2004
      ~      Month
      ~      The initial time for the simulation.
      |

SAVEPER  =
        TIME STEP
      ~      Month [0,?]
      ~      The frequency with which output is stored.
      |

TIME STEP  = 0.0833333
      ~      Month [0,?]
      ~      The time step for the simulation.
      |
```