

86

Assessing the Opportunities and Risks of Different Short-Range Wireless Strategies for an Automotive Manufacturer

by

Paul Andrew Mingardi

Bachelor of Science in Computer Science, Ottawa University (1997)

Submitted to the Sloan School of Management
and to the Department of Electrical Engineering and Computer Science
in Partial Fulfillment of the Requirements for the Degrees of

Master of Business Administration and
Masters of Science in Electrical Engineering and Computer Science

In conjunction with the Leaders for Manufacturing Program at
the Massachusetts Institute of Technology
June 2005

© 2005 Massachusetts Institute of Technology. All rights reserved.

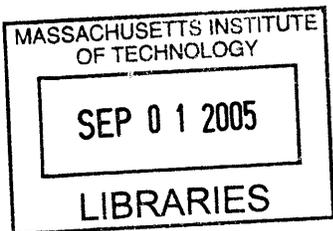
Signature of Author _____
Sloan School of Management
Department of Electrical Engineering and Computer Science
May 6, 2005

Certified by _____
Professor Alvin Drake
Professor Emeritus of Electrical Engineering and Computer Science
Thesis Advisor

Certified by _____
Professor John Carroll
Professor of Behavioral and Policy Sciences, Sloan School of Management
Thesis Advisor

Accepted by _____
Margaret Andrews
Executive Director of Masters Program
Sloan School of Management

Accepted by _____
Arthur C. Smith
Chairman, Department Committee on Graduate Theses
Department of Electrical Engineering and Computer Science



BARKER

Assessing the Opportunities and Risks of Different Short-Range Wireless Strategies for an Automotive Manufacturer

by

Paul A. Mingardi

Submitted to the Department of Electrical Engineering and Computer Science and the Sloan School of Management, in Partial Fulfillment of the Requirements for the Degrees of Master of Business Administration and Master of Science in Electrical Engineering and Computer Science

Abstract

Recent innovations in wireless technology enable devices that were once stand-alone to be “connected”. Today, connected products are changing the way people access information, communicate with others and live their lives. In the automotive industry, the notion of a connected automobile is now commonplace because of widespread adoption of pioneering telematics products. As wireless technology advances, automobile manufacturers must recognize new applications for their products and implications for their customers in order to maintain a competitive advantage. Now that cellular technology is established as the medium through which vehicles are connected, the next frontier is to understand the opportunities for an automotive manufacturer in broadband wireless.

This thesis focuses on a subset of wireless technologies referred to as short-range wireless, also often referred to as broadband wireless. It studies the opportunities and risks a large automotive OEM faces when committing to a broadband wireless strategy. First, it delineates the technology alternatives, identifying strengths, weaknesses and industry trends. Then, it analyzes several applications, taking a customer-centric viewpoint of the players along the automotive value-chain. It studies each player in terms of the overall value short-range wireless creates, the value an automotive OEM may capture, the differentiation or strategic control that can be sustained and the required product scope. After clarifying these strategically relevant unknowns, it describes alternatives through which a large automotive manufacturer can maximize its value.

The analysis confirms that suitable strategies exist for a large cost-conscious automotive manufacturer. These strategies differentiate between applications with known demand and those with high-risk latent demand, using business design to mitigate risks and to address the target market’s cost structure and size. In the case of low risk applications, forecasts are sufficiently narrow to point toward a single strategic direction. In the case of higher-risk applications, the outcomes may lie anywhere along a bounded range.

Thesis Supervisor: Alvin Drake
Professor Emeritus of Electrical Engineering and Computer Science

Thesis Supervisor: John Carroll
Professor of Behavioral and Policy Sciences, Sloan School of Management

(This page is left intentionally blank)

Acknowledgements

In writing this document, I am grateful for the helpful and support provided by the Leaders for Manufacturing (LFM) Program and General Motors Corporation. This opportunity has allowed me to grow professionally and intellectually. My Classmates and the faculty in the LFM program have been essential to my success and have given me helpful advice throughout my two years.

I would like to thank General Motors Strategic Initiatives (GMSI) for facilitating my work and offering valuable guidance along the way. The tools and lessons I have learned from their experience and expertise will be valuable throughout my career. I would especially like to thank Julius Reeves for project guidance and showing me the value of a patient leadership style. I would also like to thank Kevin Fruchey, for without his help I would never have been able to access the information and people needed to have an impact with my project. His help was critical throughout my project.

I am grateful for the help of my thesis advisors, Al Drake and John Carroll. Al's energy and knowledge of the processes at MIT and LFM have been valuable to LFM student for many years. He is always present and available, even in midst of many demands. I am also indebted to John, who gave me his time and patient counsel over the course of this project.

Table of Contents

ABSTRACT	3
CHAPTER 1 – INTRODUCTION	9
THESIS OBJECTIVE	9
STATEMENT OF PROBLEM	9
MOTIVATION	10
APPROACH	10
CHAPTER 2 – UNDERSTANDING AUTOMOBILE MANUFACTURERS	13
STRATEGIC DESIGN LENS	13
CULTURAL LENS	14
POLITICAL LENS	14
ORGANIZATIONAL IMPACT ON WIRELESS STRATEGY	15
CHAPTER 3 - WIRELESS TECHNOLOGY LANDSCAPE	17
RADIO FREQUENCY TECHNOLOGY	17
Radio Frequency (RF) Tradeoffs.....	18
Radio Frequency Regulation	19
COMMUNICATION	20
Modulation Fundamentals.....	20
Digital Signals	21
Access Techniques	22
STANDARDS	23
WAN – Cellular Providers	26
MAN – Telecom and Cable Providers	28
LAN / PAN – Computer Network Manufacturers and Device Manufacturers	30
THE TRENDS	33
TECHNOLOGY IMPACT ON WIRELESS STRATEGY	34
CHAPTER 4 – APPLICATION LANDSCAPE	37
AUTOMOTIVE WIRELESS VALUE PROPOSITION	37
Automotive OEM.....	38
Logistics Service Provider.....	39
Dealer	39
Fleet Customer	40
Retail Customer.....	40
APPLICATION ANALYSIS	41
Approach	42
Low-Uncertainty Short Range Wireless Applications	44
High-Uncertainty Short Range Wireless Applications.....	46

CHAPTER 5 – WIRELESS STRATEGY	57
STRATEGIC POSTURES AND MOVES.....	57
STRUCTURE	58
STRATEGIC ALTERNATIVES	59
Proprietary Strategy – “Closed”	60
Platform Strategy – “Marginally Open”	60
Leasing Strategy – “Open”	61
CHAPTER 6 – CONCLUSION	63
REFERENCES.....	65

List of Figures

<i>Figure 1 - Issues diagram Identifying Uncertainties</i>	11
<i>Figure 2 - The Electromagnetic Spectrum [4]</i>	18
<i>Figure 3 - Power Density of a Radio Frequency Signal</i>	19
<i>Figure 4 - Digital Modulation Techniques</i>	22
<i>Figure 5 - FDMS, TDAM and CDMA Access [8]</i>	23
<i>Figure 6 - Wireless Standards Compared by Bandwidth and Range [10]</i>	24
<i>Figure 7 - WAN, MAN, LAN, and Pan Overview [10]</i>	25
<i>Figure 8 - Comparison of Current 802.X Mobile Standards</i>	30
<i>Figure 9 - Differences Between 802.X Mobile Standards</i>	31
<i>Figure 10 - Bluetooth Power Classes</i>	31
<i>Figure 11 - Wi-Fi and Bluetooth Intended Uses</i>	32
<i>Figure 13 - Standards Trends for 2005 [14]</i>	34
<i>Figure 14 - Wireless Customers and Technology Alternatives</i>	42
<i>Figure 15 - Short-Range Wireless Customers, Risk and Benefit Potential</i>	44
<i>Figure 16 - DCF Analysis Result of Application with a “Clear Enough Future”</i>	45
<i>Figure 17 - Benefit to Variable Costs Delay</i>	46
<i>Figure 18 - Automotive Retail Customer Services Studied in Detail</i>	47
<i>Figure 19 - Service Analysis Using Qualitative Framework</i>	53
<i>Figure 20 – Strategic Control Points [23]</i>	54
<i>Figure 21 – Example Strategic Postures and Moves for a Large Automotive OEM</i>	58
<i>Figure 22 - Business Model Strategic Design</i>	59
<i>Figure 23 - Platform Strategy Alternative</i>	61

Chapter 1 – Introduction

Thesis Objective

Recent innovations in wireless technology enable devices that were once stand-alone to now be “connected”. Today, connected products are changing the way people access information, communicate with others and live their lives. In the automotive industry, the notion of a connected automobile is now commonplace because of widespread adoption of pioneering telematics products. As wireless technology innovation continues, automobile manufacturers must recognize new applications to their products and implications for their customers in order to maintain a competitive advantage. Now that cellular technology is established as the medium through which vehicles are connected, the next frontier is to understand the opportunities for an automotive manufacturer in broadband wireless.

This thesis primarily focuses on a subset of wireless technologies referred to as short-range wireless, which for the purpose of this thesis can be equated to broadband wireless. It studies the opportunities and risks a large automotive OEM faces when committing to a strategy that integrates short-range wireless technologies into its vehicles. First, it delineates the technology landscape and identifies the strengths and weaknesses of alternative wireless technologies, as well as the industry trends. Then, it analyzes several applications of wireless technology, taking a customer-centric viewpoint of potential users in the automotive value-chain. Next, it studies these players in terms of the overall value short-range wireless creates, the value an automotive OEM may capture, the differentiation or strategic control that can be sustained and the resulting product scope. After clarifying strategically relevant unknowns and analyzing the technology’s uses, this thesis compares alternatives through which a large automotive manufacturer can maximize its value.

Statement of Problem

In the day and age of rapid technology innovation, it is important that traditional product manufacturers identify applications of new technology into their products in order to establish a competitive advantage. Unfortunately, traditional product manufactures are often challenged by decisions involving new technologies because these organizations are optimized to operate in a world of incremental change, extreme cost pressures, and little uncertainty; a world where capital

outlays are made only after lengthy and cost focused planning. Therefore, the potential benefits of new technologies often elude traditional manufacturers and are instead captured by organizations with a higher tolerance for risk and an ability to move much more quickly to capture these growth opportunities. This thesis analyzes an instance of such a problem, studying the key opportunities and risks a large automotive OEM faces when committing to a strategy of integrating short-range wireless technologies into its vehicles.

Motivation

It is difficult for large automotive organizations to plan around the integration of broadband wireless technology into their vehicles. These organizations are challenged to address the needs of a diverse set of stakeholders who favor dissimilar wireless applications, where each application is often better served by a different wireless technology. Given the proliferation of wireless standards that are quickly evolving, decision makers are challenged to commit to a wireless strategy. For every potential broadband application, there are several feasible wireless technologies that offer connectivity, so technical experts often choose the one they are most familiar with as oppose to taking a global view of the entire problem and choosing the one best suited to a long-term strategy. The motivation of this thesis is to take such a global view. We provide a map of the stakeholders and an explanation of the alternative technologies and applications that could meet customers' needs. Then, considering an automotive manufacturer's overall strategy and core competencies, we develop reasonable strategic alternatives.

Approach

The approach used to solve this problem is to develop a framework by first identifying the key drivers of uncertainty for an automaker trying to develop a wireless strategy. An issues diagram helps in identify these drivers of uncertainty amongst many sources of uncertainty, shown in Figure 1 - Issues diagram Identifying Uncertainties. This diagram, created with the help of project stakeholders, identifies the relevant uncertainties used to focus our study. The key uncertainties are identified as the organizational barriers that hinder decision making, the availability of many rapidly changing wireless standards, as well as the complexity of having dozens of potential applications, each better suited to a particular variant of wireless technology and serving a different set of stakeholders in the automotive value-chain.

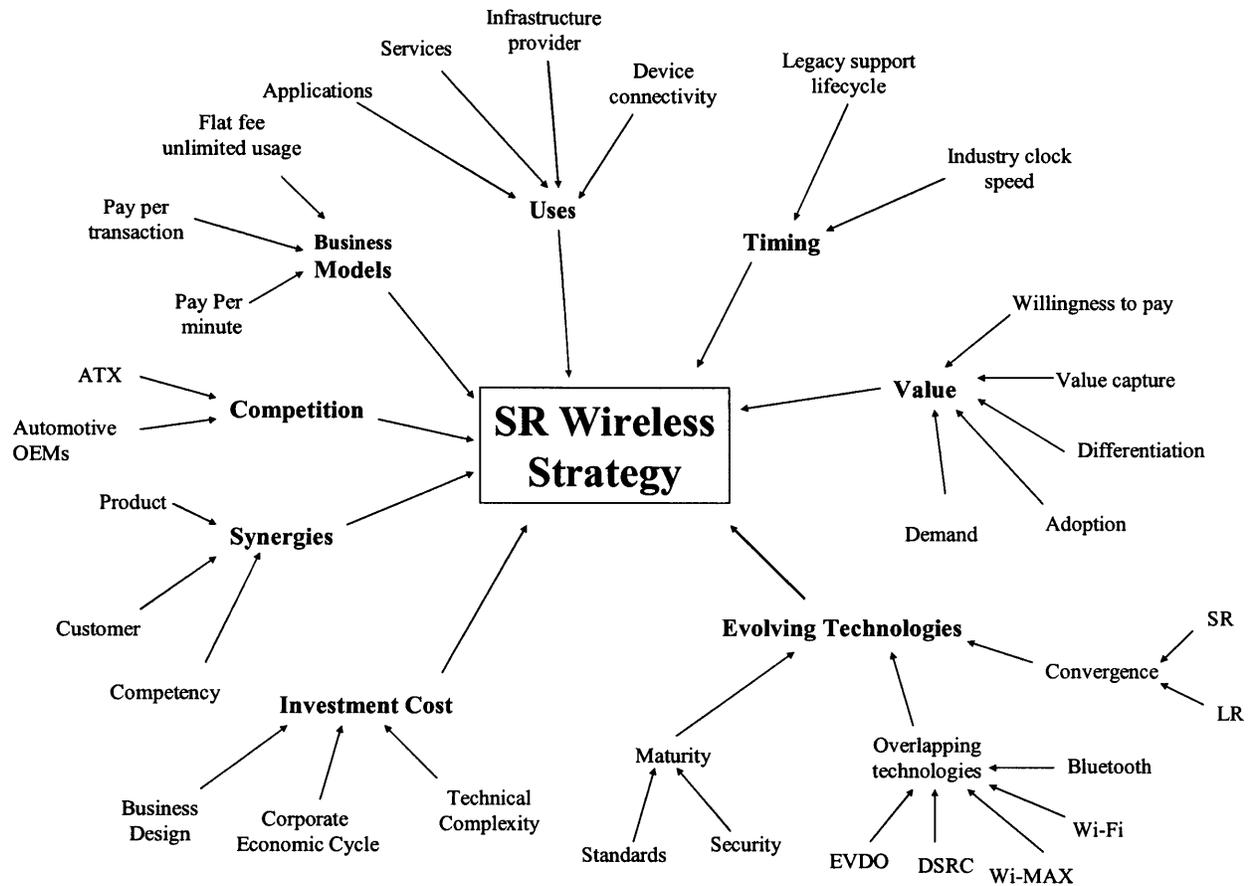


Figure 1 - Issues diagram Identifying Uncertainties

For each of these areas of uncertainty, different risk mitigation and analysis techniques are used. To study the organizational barriers that hinder decision making, three different perspectives are used to view organizational behavior and processes: strategic design, cultural, and political. To study wireless technologies, relevant standards are discussed and selection criteria are identified along with risk mitigation strategies. To study wireless applications, stakeholders are identified and applications categorized by risk. Then, distinctive analysis tools are applied to each risk category. A cash flow analysis (DCF) is used for low risk applications where projections are fairly well known, and a qualitative strategic framework is used for higher risk applications where cash flow projections are very uncertain. Finally, our learnings are used to lay out several alternatives for an automotive manufacturer to maximize its value.

Chapter 2 – Understanding Automobile Manufacturers

This chapter describes the internal challenges a large automotive manufacturer faces when confronted with the decision to incorporate rapidly evolving wireless technologies in its products. It looks at the automotive organization through three lenses: cultural, political and strategic design [1]. This helps clarify the organizational strengths and weaknesses that a typical automotive manufacturer must consider before it develops a robust short-range wireless strategy. These issues are summarized in the paragraphs that follow.

The automotive industry has gone through several significant shifts throughout the last century. In the first-half of the century, this industry was primarily dominated by American manufacturers with a focus on mass production to meet a demand that far outstripped supply. By the nineteen eighties, industry focus shifted to an emphasis on reliability and product differentiation. This shift was led by Japanese automakers employing lean production techniques. Consequently, in the last thirty years, American automotive manufacturers have experienced eroding profits and market share, and increasing competitive pressure. This history has resulted in American automotive organizations having a unique organizational structure, culture and political environment when compared to other industries. Moving from an era of dominance to decades of cost cutting, these organizations are optimized to carry out slow moving, capital intensive and cost sensitive decisions. When asked to solve problems and make decisions around fast moving technologies, automotive manufacturers find it difficult to compete with organizations from other industries.

Strategic Design Lens

Automotive manufacturers represent some of the longest standing organizations in North America. As such, they are typically hierarchical and structured by product. This lends itself well to mass production, error reduction and quality control, yet does not lend itself well to quick decision making. It is not uncommon for decisions in these organizations to require months of analysis, as well as multiple presentations to each stakeholder in the organizational hierarchy before a decision is made at the highest levels. This structure is optimal for building automobiles, something these companies do very well, but is less than optimal for building more rapidly-changing, innovative products. In contrast, the structure of high-tech companies tends to

push integration and coordination of tasks within the organization to a lower level, so that decision can be made more quickly.

Cultural Lens

The culture at large American automotive manufacturers has emerged from years of operating in a cost prohibitive environment with a focus on quality. In this environment it is important to minimize errors, effectively use assets and avoid excessive risk-taking. These companies tend to invest a lot in employees, historically offering career stability through near lifetime employment. There are many benefits to companies who maintaining a long-term focus through such employment agreements. One such benefit is employees are less likely to take risks because their careers are more invested in the company. Historically, these companies have managed through a Theory X style of management, as did most manufacturing organizations formed in first-half of the century. With this management culture, there is an emphasis on 'face-time' and early attendance. These companies have now changed much of their prevailing management style to promote a culture that values the input of lower-level employees. Although lower-level employees are valued, the culture is still different than that of a high-tech company where risk taking and creativity are key core competencies. As high-tech companies mature and the markets they address become more cost focused, their culture will most likely migrate to be closer to that of an automotive manufacturer. For now, the margins that high-tech companies receive allow them to profit by taking risks and innovating, as oppose to focusing on cost optimizations and lower defect rates. Therefore, when developing a wireless strategy, an automotive manufacturer should consider its culture and how well suited it is to execute a given strategy.

Political Lens

As with most longstanding manufacturing companies, power in a typical automotive manufacturer is very hierarchical. Once again, this enables automotive manufacturers to focus on cost and quality control. Consequently, somewhat less autonomy is given to lower-level employees than in a high-tech organization. Looking at an extreme case, Enron is an example of a large and more mature organization that shifted its culture to empower employees with more autonomy. This enabled to company to operate as a high-tech organization, taking large risks and leading the way into new markets. Without going into further analysis, the results were

obviously quite disastrous. Therefore, we must recognize that giving employees less autonomy than a typical high-tech organization also has benefits, but this difference should be considered in a short-range wireless strategy.

Organizational Impact on Wireless Strategy

This high-level analysis of a typical American automotive manufacturer reveals some of the differences between organizations that build automobiles and newer organizations that build rapidly changing hi-tech products. These differences must be considered when looking at the types of products or services from which automotive organization can effectively profit.

Attempting to compete with pure plays that are optimally structured for a given industry may be a tall order for a large automotive manufacturer. Companies often use creative strategies (partnering, joint-ventures, sub-contracting) to gain the competencies required to compete in a new market. As long as an automotive organization can bring unique value to such a partnership and exercise control, they stand to profit in a new market while leveraging their existing core competencies, instead of compromising them. In later chapters, we will study the unique value automotive manufacturer provide to short-range wireless enabled vehicles (Chapter 4) and how an automotive manufacturer's competencies should be considered vis-à-vis the types of wireless services being offered (Chapter 5).



Chapter 3 - Wireless Technology Landscape

This chapter focuses on the changing state of wireless technology - our primary driver of uncertainty. We describe the fundamentals of wireless technology, the predominant wireless standards and the current industry trends. By understanding the fundamentals of wireless technology, we gain a better understanding of the key factors traded-off when making a decision and choosing a particular technology variant. This includes the regulatory environment and other influences that have shaped the wireless landscape as we know it today. Next, predominant Wide Area Network (WAN), Local Area Network (LAN) and Personal Area Network (PAN) standards are discussed. The evolution of each standard is explained from the perspective of its segment of origin: cellular provider, cable provider and network provider. Finally, the industry trends are analyzed with an eye towards which standards are currently dominant and which ones are expected to be dominant in the future. We conclude by distilling our learning into current technology considerations relating to short-range wireless decisions.

Radio Frequency Technology

The basis of most wireless communication today is RF (Radio Frequency) technology. Although widespread adoption of wireless networking is fairly recent, the development of RF based communication has been taking place over the last century. It is important that decision makers understand the fundamentals of RF communication to gauge the ramifications of their wireless technology choices.

An RF signal is essentially an electromagnetic field generated by inputting an alternating current to an antenna, and is one of many types of electromagnetic radiation [2]. Electromagnetic radiation can be described as a stream of photons traveling in a wave pattern and moving at the speed of light. The difference between various types of electromagnetic radiation is the amount of energy found in each photon. A photon's energy is mathematically related to its wavelength and frequency, as described through the works of several well-known physicists: Max Planck, Albert Einstein, and Louis de Broglie [3]. It is common to use energy, wavelength, or frequency interchangeably to describe the various forms of electromagnetic energy. The diagram below shows these forms of electromagnetic energy, along with the range of spectrum they occupy.

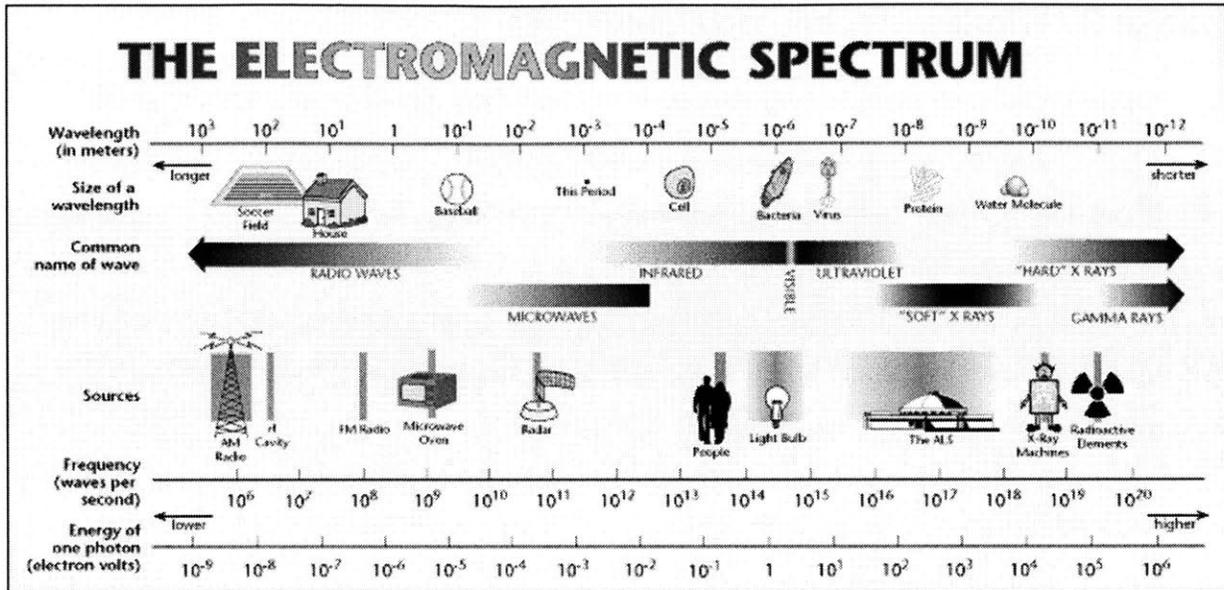


Figure 2 - The Electromagnetic Spectrum [4]

Of the various types of electromagnetic radiation, radio wave photons have the lowest energy level with a generated field frequency (the number of times a signal goes through a complete up and down cycle in one second) of approximately 9 kilohertz to 300 gigahertz – this range is referred to as the radio spectrum. Microwave and infrared have more photon energy than radio waves, and then visible light, ultraviolet light, X-rays and gamma rays have increasingly more photon energy. It is common for radio waves to be described by frequency, for optical and infrared light to be described by wavelength and for gamma rays and X-rays to be described by energy level. The reason is that low-energy photons (radio waves) tend to behave more like waves, whereas higher energy photons (X-rays) behave more like particles. Most wireless communication technology takes place in the radio or microwave end of the electromagnetic spectrum.

Radio Frequency (RF) Tradeoffs

Next, we study the characteristics of RF signals. Several characteristics of an RF signal make it more or less applicable to a specific communication scenario. For example, the received field strength depends on the distance of transmission, the signal frequency and the antenna design. Higher frequencies produce weaker signals that are less likely to travel through obstructions, and higher power and gain antennas produce stronger signals that will travel farther. It is the

responsibility of wireless system designers to select the appropriate operating parameters for a particular wireless application, within the boundaries of governmental regulation.

To better understand these tradeoffs, the relationships between characteristics of an RF field and the predicted radiating field strength are presented below. Given a single radiating antenna, we can calculate the power density of the generated radio frequency field using the following equation:

$$S = \frac{PG}{4\pi R^2}$$

S = power density
P = power input to the antenna
G = power gain of antenna in the direction of interest
R = distance to the center of the radiation of the antenna

Figure 3 - Power Density of a Radio Frequency Signal

The numerator of this equation includes of antenna gain and required input power. Gain is measured in decibels (dB) and is expressed as $10 \cdot \log(Power/Power_{ref})$. It represents the ratio of power required of a loss-free reference antenna to the power supplied to an antenna under study to produce similar field strength at the same distance. Therefore, an antenna with radiated power twice that of the input power would have a gain of $10 \cdot \log(2/1)=3\text{dB}$. When this is the case, the antenna itself does not create more power; instead, it focuses the radiated energy into a narrower coverage pattern appearing to be more powerful when measured in the direction of focus. Thus, the more focused the signal, the higher the gain.

The denominator of the equation varies with the square of the distance between the center of the radiating source and the point of measurement. This relationship implies that an antenna must use significantly more power (increasing exponentially) to radiate a signal greater distances. Technological and regulatory barriers inhibit the arbitrary use of power to increase signal strength.

Radio Frequency Regulation

Many of the wireless technologies today communicate over small bands of the RF spectrum. Examples of these technologies are analog and digital cell phone, wireless LAN, TV and radio broadcast, and id tags (RFID). Several consortiums handle the regulatory responsibility of

spectrum allocation. The International Telecommunications Union (ITU) allocates RF spectrum into various classes of service for each region of the world. Then, in the US, the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA) further allocate RF spectrum. The FCC is responsible for regulating commercial use and the NTIA government use [5].

In the mid 80's, the FCC allocated the Industrial, Scientific, and Medicine (ISM) frequency band as an unlicensed band that requires devices meet special regulations, such as stringent power requirements. Many of these requirements are imposed for health and safety reasons. The ISM bands include the frequency ranges 902-928 Mhz, 2400-2483.5 Mhz, and 5725-5850 Mhz. Commercial products using the ISM bands have become increasingly popular, as manufacturers are no longer required to pay licensing fees, allowing them offer products at a lower price point. Many of the technologies we discuss use the ISM band because manufacturers can offer consumers less costly products in the absence of licensing fees.

Communication

Along with the characteristics of an RF signal, the way information is sent over a signal is a principal element that needs to be determined before two or more parties can communicate wirelessly. Conventional radio signals operate through what is referred to as narrow-band communication. The FCC has historically favored narrow band because it uses less of the available radio spectrum, allowing the FCC to finely allocate bandwidth. Unfortunately, this technique is prone to interference, so recent spread spectrum techniques over the ISM band are becoming increasingly popular [6]. With spread spectrum, the signal is spread across a broader range in a predefined method, and the receiver de-spreads the signal on reception. Two of the commonly used spread spectrum techniques are Frequency Hopping Spread Spectrum (FHSS), which spreads a signal by hopping a narrow band signal as a function of time, and Direct Sequence Spread Spectrum (DSSS), which expands a signal over a broader portion of the radio band.

Modulation Fundamentals

Given the limits imposed on RF designers through regulation, much of the divergence in wireless technologies today stems from how information is sent over an indirect carrier wave. This

process is referred to as modulation. An indirect carrier wave is a wave whose properties are altered to send a message or a signal. In the case of wireless technology, this wave is typically an electromagnetic signal with a frequency in the RF spectrum. Any wave can be described by the formula $S(t) = A \sin(2\pi ft + \phi)$, where A , f and ϕ represent amplitude, frequency, and phase respectively [7]. Each of these variables can be manipulated to send information to a recipient. Amplitude modulation (AM) is well known for its use in public AM radio. With this form of modulation, the amplitude of a carrier wave is modulated with the amplitude of the signal we wish to send. Alternatively, in frequency modulation (FM), known for its use in public FM radio, the frequency of a carrier wave is changed over time to convey a signal. Finally, in phase modulation (PM), the phase of a carrier wave is modulated over time to send information.

Digital Signals

A signal can either be analog or digital. Digital signals are created by sampling analog signals at regular intervals, as defined by Nyquist’s theorem. These samplings are then represented as binary valued integers. The numbers of bits per sample determines the resolution of the digitized signal. As with analog signals, the amplitude, frequency, and phase of a carrier wave can be adjusted to send information to a recipient. This is referred to as amplitude, frequency and phase shift keying. The diagram below provides a summary of the more significant digital modulation techniques used in wireless technologies.

Linear Modulation Techniques	
Binary Phase Shift Keying (BPSK)	In this techniques the period of the carrier wave so that we can represent 4 different waves, where each wave represents the 0 and 1 bits respectively.
Differential Phase Shift Keying (DPSK)	DPSK is similar to BPSK, except differential encoding is used to map the information bits into the phase difference between two consecutive symbols, and thus is not susceptible to random phase changes in the carrier wave.
Quadrature Phase Shift Keying (QPSK)	In this technique the period of the carrier wave so that we can represent 4 different waves, where each wave represents the 00, 01, 10, and 11 bits respectively.
Constant Envelop Modulation Techniques	
Binary Frequency Shift Keying (BFSK)	With BFSK, two binary digits are two different frequencies near the carrier frequency

Minimum Shift Keying (MSK)	This technique is similar to BFSK but uses the minimum frequency spacing that allows two FSK signals to be orthogonal. In addition, the pulse sent to represent a 0 or a 1, not only depends on the information being sent but what was previously sent.
Gaussian Minimum Shift Keying (GMSK)	GMSK is the modulation technique used by GSM cellular networks. GMSK is similar to MSK but passes the binary signal through a Gaussian shaped filter before modulations, minimizing interference between adjacent signals in the frequency band.
Combined Linear and Constant Envelope Modulation Techniques	
M-ary Phase Shift Keying (MPSK)	In the technique, the M points are in a constellation on a circle representing the phases of the carrier wave. Each point represents a sequence of binary bits
M-ary Quadrature Amplitude Modulation (MQAM)	In this technique, both the phase and amplitude are varied by the symbols of the message. By doing so it achieved high spectral efficiencies.
M-ary Frequency Shift Keying (MFSK)	This technique is similar to BFSK, but M is the number of frequencies in the modulated signal.
Spread Spectrum Modulation Techniques	
Direct Sequence Spread Spectrum (DSSS)	A technique that spread the signal over a broader range of the spectrum using a specific encoding scheme, known as a Pseudo-noise sequence
Frequency Hopped Spread Spectrum (FHSS)	A technique that spreads the signal by hopping a narrow band signal as a function of time

Figure 4 - Digital Modulation Techniques

Access Techniques

Access to a wireless communication channels can be either random or coordinated. With random access collisions occur, and with coordinated access they do not. Standards, such as the well known network card standard Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), are used to manage random access and collisions. Collision-free access uses multiplexing techniques to coordinate access, which allows multiple signals to share a channel or available spectrum. There are various multiplexing techniques, and the more commonly known techniques are Frequency Division Multiplexing (FDM), Time Division Multiplexing (TDM) and Code Division Multiplexing (CDM). FDM operates by dividing the available frequency spectrum and sending different signals at different frequencies. In comparison, TDM interleaves bits from different slower streams into one faster stream. Another technique, statistical time division multiplexing, is similar to TDM but takes advantage of idle time on the channel to run more TDM streams. Time division multiple access (TDMA), which is used with radio and

satellite, allows the various transmitters to take turns sending information in closely spaced slots. With CDMA every communicator is allocated the entire spectrum all of the time. A unique spreading code is used to spread data before transmission, and the signal is then transmitted in a channel below noise level. The receiver uses a correlator to de-spread the signal and then passes it through a narrow bandpass filter. Through this process, the unwanted signals are not de-spread and are not passed through the filter. The diagram below visually represents the FDM, TDM and CDM access techniques.

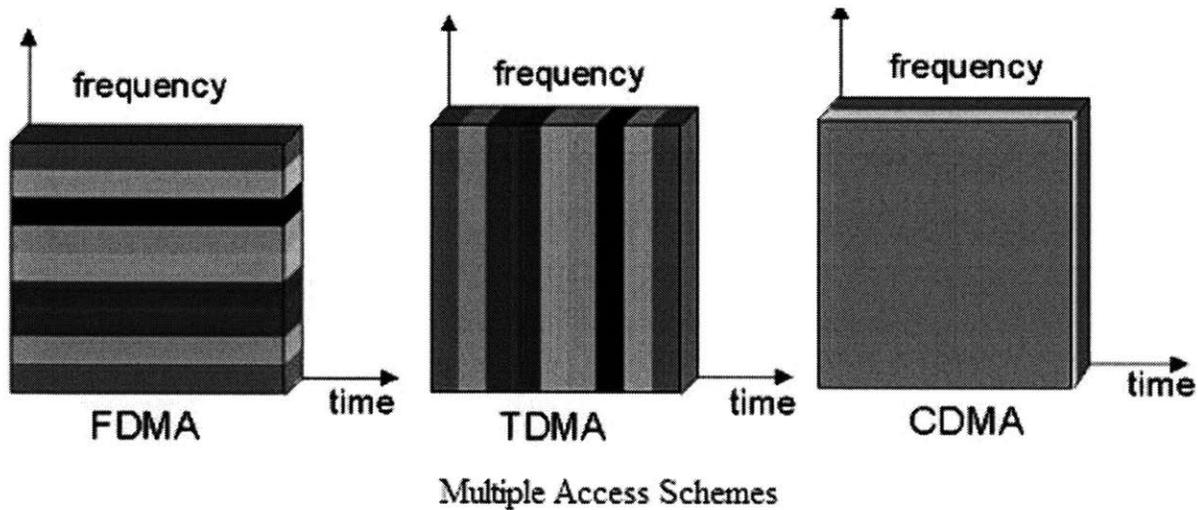


Figure 5 - FDMS, TDAM and CDMA Access [8]

Standards

With an understanding of the fundamentals of RF technology, we see that a multitude of factors (power, range, gain, modulation, and access) must be agreed upon before two parties can communicate wirelessly. Given the number of combinations of these factors possible, it is no surprise that an abundance of wireless standards exist. Each of these standards is designed by a unique group of stakeholders with a specific set of needs. Unfortunately, the needs of these stakeholders often overlap, forcing technologists to choose a standard for any given application. The diagram below shows many of the more prominent standards and compares them by range and transmission speed. From this diagram, it becomes clear that the number of wireless technology choices is overwhelming. Many of these standards are further detailed in this section.

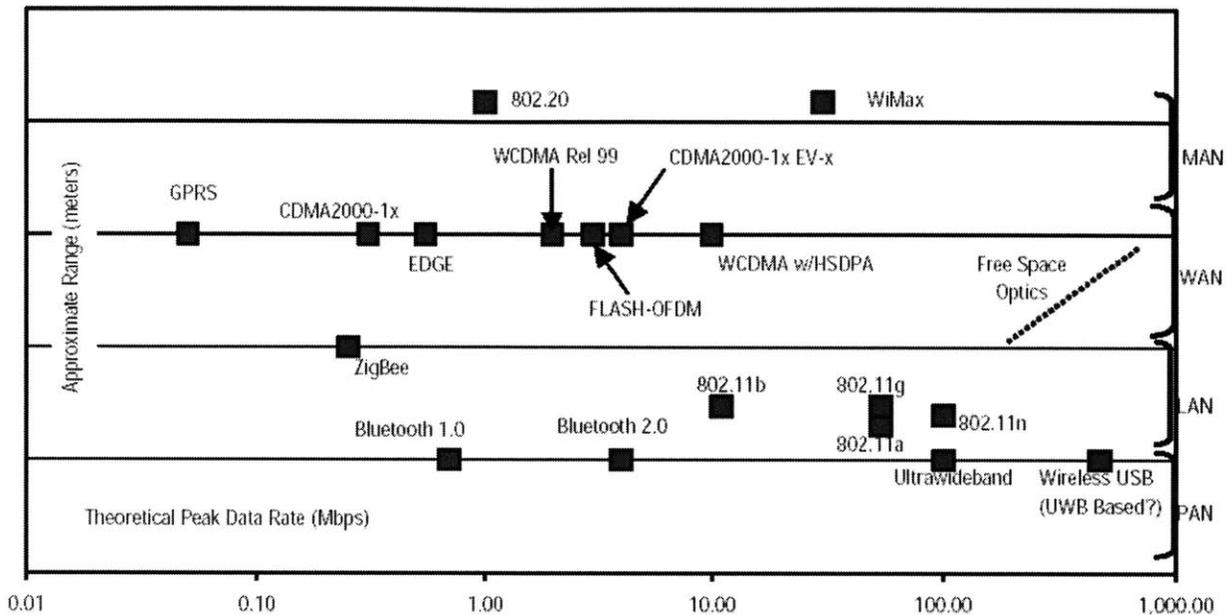


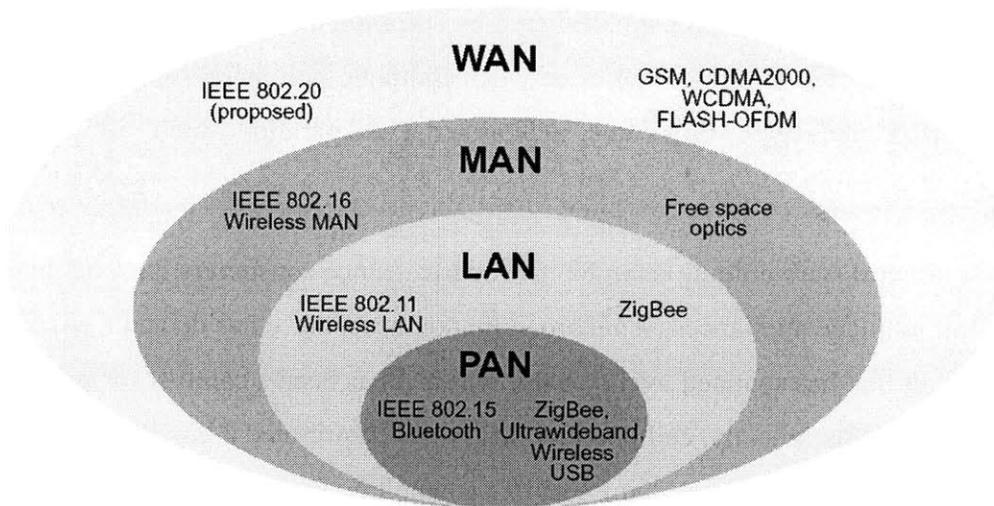
Figure 6 - Wireless Standards Compared by Bandwidth and Range [10]

Both the existence of standards with overlapping functionality and the rate at which new standards are introduced contribute to the uncertainty a technology manufacturer faces when committing to a wireless standard. Unfortunately, a chosen standard can quickly become outdated when another one becomes dominant in the market place. In this case, the product based on the older standard often becomes outdated as well.

In the high-tech industry, this problem is solved by rapidly introducing next generation products based on the current dominant wireless standard. This solution has the benefit of persuading existing customers to upgrade to the latest product, allowing companies to further profit. Unfortunately, in the automotive industry this solution is not appropriate, as the lifetime of a vehicle is significantly longer than that of a given wireless standard. Automotive customers reject such solutions because they are conditioned to expect more from their vehicles, also representing a much larger investment than a typical consumer electronics product. More feasible solutions are to allow customers to paying for added wireless flexibility or for manufacturers to disassociate the perceived link between broadband wireless connectivity and the automobile itself (perhaps by offering connectivity through an enabled device, such as a PDA). By doing so, customer expectations would be more in line with those of the consumer

electronics' industry [9]. Regardless of the chosen solution, a thorough analysis of existing wireless standards is essential in developing a long-term wireless strategy.

Industry analysts classify wireless standards by range and bandwidth. When comparing standards by these characteristics, we also naturally tend to aggregate by industry of origin, since each industry tends to have unique range and bandwidth needs. Although there are exceptions – primarily due to recent industry convergence - it is helpful to analyze the various categories and their related industries to gain a better understand of why each standard was originally created, where they are believed to be used today and how they should be incorporated into future plans. The diagram below shows the common classifications of network standards by range: Wide Area Network (WAN), Metropolitan Area network (MAN), Local Area Network (LAN) and Personal Areas Network (PAN). It also shows several of the standards we will discuss in each of these categories.



Network	Range	Examples
WAN	National	Mobile voice and data service, rural internet access
MAN	< 30 miles	Cell site back-haul, campus network, rural internet access
LAN	< 300 ft.	Internet access, device-to-device communication
PAN	< 30 ft.	Cable / wire replacement

Figure 7 - WAN, MAN, LAN, and Pan Overview [10]

Each category along with the industry sectors that have been most influential in developing standards in that category and their rationale for development are described below. This is followed by a more detailed history of standards in each category.

- ▶ WAN wireless standards are primarily designed by cellular providers to displace traditional land line telephone connectivity. Most automotive customer in North Americans are already familiar with cellular technology, as over 60% of the US population currently use cell phones in their automobiles[11]. Today, the telecommunications industry is shifting its focus from voice to data communication, and this represents a general trend in the wireless industry.
- ▶ MAN wireless standards are primarily developed by telecom and cable providers in an effort the replace existing metropolitan fiber and copper lines. These standards are more recent and designed as a last mile solution for wireless broadband connectivity.
- ▶ LAN wireless standards are designed by computer manufacturers and network providers. They are created as a substitute for office and home networks cables, and significantly simplify the physical requirements of deploying office computer networks.
- ▶ PAN wireless network standards are designed by stakeholders in the consumer electronics industry in an effort to eliminate cables between computer peripherals and portable devices. These standards replace existing wires, such as serial and parallel cables.

WAN – Cellular Providers

Today, WAN networks are ubiquitous in North America, since consumers have adopted cell phones as commonplace appliances. This broad market acceptance has driven a wireless network build out that has spanned over two decades and has been a catalyst for wireless innovation. During this time, the cell phone industry has contributed a handful of standards based on cellular technology. The premise of this technology is that network providers operate a network of distributed cell sites, each containing a radio transceiver and a base station controller. These sites send, receive and manage information between local mobile phones and a cellular telephone switch. This network of cell sites, referred to as a cellular system, allows spectrum frequency reuse because non-adjacent cells can operate over the same frequency. Over the years, various cellular systems have been developed using the aforementioned access schemes, FDMA, TDMA and CDMA.

Cellular standards were proposed to the FCC as early as 1968, but it was not until 1983 that the FCC allocated cellular channels for the analog FM based Advanced Mobile Phone Systems

(AMPS). This first generation (1G) analog phone system was commercially developed by AT&T in North America and operates over the 800 MHz frequency band. There were other 1G systems developed in different parts of the world, such as the Nordic Mobile Telephone (NMT) system and the Total Access Communication System (TACS). The similarities among these 1G systems are they are analog and based on the FDM access scheme. Rapid adoption of mobile phones led to a need for more efficient use of existing cellular channels. Therefore digital cellular systems were developed in the early 90's, as the second generation (2G) digital phone systems. In North America, TDMA and then CDMA digital systems were developed to work alongside AMPS. These systems operate in the same 800 frequency range as AMPS and use a third channel in the PCS frequency band (1800 – 2200 MHz). As in the analog world, several digital cellular systems were developed simultaneously. In Europe, the dominant telecommunications companies collaborated to develop the Global System for Mobile communications (GSM). It operates over the 850MHz, 900MHz and PCS frequency bands and is based on the TDMA access scheme, allowing up to eight users to share a single channel. Networks in the US today are either CDMA networks, originating from the extensions of AMPS, or GSM networks, based on the GSM standards developed in Europe.

As an increasing percentage of the information passed over digital cellular systems was data as oppose to voice, it became apparent that the usefulness of existing 2G networks was limited by a lack of data capabilities. While waiting for third-generation cellular systems supporting high-bandwidth data communications to meet these needs, extensions were added to current 2G networks to support their limited data capabilities. GSM and CDMA networks including these enhancements are referred to as 2.5G cellular networks. GSM's extensions are the General Packet Radio Service (GPRS), which enabled packet switched data transfer, and the Enhanced Data for GSM Evolution (EDGE), which improved data transfer rates. Alternatively, CDMA networks are updated with cdmaOne and CDMA2000 1x to enhance data capabilities.

The latest phase of cellular standards is what is referred to as the 3G cellular systems. These networks promise significantly increased data transmission rates of more than 2 Mbps in a fixed or in-building environments, 384 kbps in pedestrian or urban environments, and 144 kbps in wide area mobile environments [12]. Three different technologies are being used by different players in the wireless industry. In Europe, there is the Universal Mobile Telecommunications

Systems (UMTS), which is based on a wideband CDMA (W-CDMA) access scheme. Then CDMA2000 was evolved with CDMA2000 1xEV-DO, standing for EVolution Data Only. EV-DO uses a combination of CDMA and TDMA for voice and data respectively. Then CDMA2000 was further evolved with CDMA2000 1xEV-DV, a standard distinct from EV-DO and providing full voice and data at a rate of 3.1 Mbps. Finally, there is another 3G system being developed in China known as TD-SCDMA and is expected to be prominent in China and the surrounding countries. These 3G networks are significantly more expensive to operate, so provider adoption has been considerably slower than with the previous generations. In addition to cost barriers, a focus on bandwidth and data transmission puts these 3G cellular standards in direct competition with the current MAN and LAN standards. Some network providers are going as far as diversifying their holdings to include public wireless LAN networks to position themselves to offer ubiquitous broadband wireless with either of these technologies.

MAN – Telecom and Cable Providers

Telecom and cable companies compete fiercely in providing broadband internet connectivity to homes and businesses with their Digital Subscriber Line (DSL) and Broadband Cable services. In an effort to reach more customers, these companies are developing standards that will allow them to offer broadband wireless connectivity. The predominant standards are IEEE 802.16 and 802.20. The 802.16 standard is designed to provide an interface between a subscriber transceiver station and a base station transceiver at a range of up to 30 miles and a transmission speed of up to 70 Mbps. Specifically designed for fixed line-of-sight wireless communication, it is ideal for providing service to wirelessly enabled office buildings and homes with a cost-effective last-mile solution which connects 802.11 hotspots to the Internet. Several variants of this standard are under development. One variant, 802.16a is being designed for non-line-of-sight wireless communication, operating over the less expensive, unlicensed ISM frequency band. It will be ideal as a last mile solution where obstacles (trees or buildings) are present and is a focus of the WiMAX Forum (further discussed below). Yet another standard, 802.16e, is an amendment that enables broadband mobile communication. Finally, the 802.20 standard has a similar mandate to 802.16e, but is being designed specifically for high-speed broadband mobile communication. Both these mobile standards are well suited as broadband communication standards for vehicles.

The WiMAX forum is a non-profit organization formed in 2003 by more than 110 equipment suppliers to provide interoperability certification for broadband wireless products. The organization is currently working to support industry-wide acceptance of the IEEE 802.16 standard, in the same way that the Wi-Fi Alliance did for IEEE 802.11. The organization's goal is to promote interoperable and create industry momentum that will fuel 802.16 broadband wireless adoption. WiMAX compliant technology will support the IEEE 802.16 variants, and the ETSI HyperMAN wireless standards.

The 802.16e extension will allow laptops equipped with a 16e enabled chip to directly connect to a WiMAX antenna and roam across a city. The standard is to support movement at vehicular speeds up to 75 mph and includes functions to support handoffs between base stations, similar to cellular technology. It is designed for operation in licensed bands of 2-11 GHz and is designed with less latency than 802.16a. The 802.16e working group was formed in November of 2004, and there has been some confusion in the press as to the amount of functional overlap between this extension and the 802.20 standard already under development.

While 802.16e is designed for a mobile user walking around with a PDA or laptop, 802.20 addresses high-speed (155mph) mobility issues, such as providing connectivity in a high-speed train. The primary difference between these two standards is the manner in which they are deployed. 802.16e is designed to be deployed in the existing 802.16a footprint. Conversely, 802.20 will be deploying with a more widespread footprint, similar to a cellular network and providing more ubiquitous coverage. In addition, 802.20 will operate in the licensed band below 3.5 GHz and will allow for better quality of service and less latency than current mobile technologies. 802.20 will also enable seamless handover between other heterogeneous networks (802.11a/b/c or Bluetooth) by providing a virtual interface layer that enables transparent IP services over different mobile wireless interfaces. The implication is that vehicles could accommodate more than one network interface and seamlessly roam from one network to another. That is a compelling vision for automakers concerned with the obsolescence of wireless technologies in their vehicles. The table below provides a brief summary comparing the 802.16e and 802.20 technologies.

	802.16e	802.20
Spectrum	▶ Licensed	▶ Unlicensed
Freq. Bands	▶ 2-11GHz	▶ Below 3.5 GHz
Roaming Speed	▶ 75 mph	▶ 155 mph
Cell Size	▶ Metropolitan (30 miles)	▶ Metropolitan
Group Charter	▶ Extend the existing 802.16 standard's physical and medium access control layers, facilitating mobility and roaming	▶ Define physical and medium access control layers to support data rates and a number of user significantly higher than other mobile systems

Figure 8 - Comparison of Current 802.X Mobile Standards

Technologists argue that 802.20 is a direct competitor to third-generation (3G) wireless cellular technologies. Since mobile operators are spending millions to upgrade their networks to offer 3G services, some believe it is a tough sell to invest in yet another network.

LAN / PAN – Computer Network Manufacturers and Device Manufacturers

LAN / PAN standards are often referred to as short-range wireless standards. They are typically designed for higher bandwidth applications delivered through devices that have restrictive power requirements. The current predominant standards are Bluetooth and Wi-Fi (802.11). They are the only true broadband wireless standards that are successfully adopted into the marketplace today. As such, they are also the only standards mature enough for use in an automobile and are thus studied in more detail.

- ▶ **Wi-Fi:** 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 reference the entire class of 802.11x specifications designed as a wireless alternative to the wired networks, allowing computers in businesses, schools, and homes to communicate with each other. The Wi-Fi standards operate over the unlicensed ISM bands, enabling the availability of lower cost equipment. Today, these standards provide up to 54 mbps (802.11g) connectivity at ranges of up to 300 feet. A notebook or PDA that has a Wi-Fi networking card or built-in Wi-Fi chip can access the Internet wirelessly at broadband speeds. Wi-Fi technology has already proliferated globally; many retail stores and airports offer access to Wi-Fi hot spots for a fee and thousands of broadband users have installed Wi-Fi in their homes.

- ▶ **Bluetooth:** First developed in 1994, Bluetooth is a low-power, short-range (30 feet) networking specification promoting transmission speeds of up to 800 kilobits per second (barely qualifying as broadband at 70x slower than 802.11g). The standard was designed for smaller consumer electronics devices to communicate in a Personal Areas Network (PAN). For example, a Bluetooth-enabled cellular phone can connect directly to an enabled PC without the need for a cable. It can then perform operations such as synchronizing contacts between a contact manager on a PC and one on the phone.

The technical differences between these two standards are summaries in the diagram below.

Characteristics	Bluetooth	Wi-Fi
Frequency	2.4GH	2.4GH
Range	10m	100m
Primary Application	Device cable replacement	Internet Connectivity
Data Transfer Rate	0.8Mbs	11 to 54 Mbs
Power Consumption	Low	Medium

Figure 9 - Differences Between 802.X Mobile Standards

There is often some confusion because a varying array of capabilities is reported for the power and range facilities of Bluetooth. This is because three power classes are defined in the standard, each with its own characteristics. Most Bluetooth devices are ‘Class 2’, as this achieves an optimal tradeoff between the battery usage and transmission range required in portable devices. As far as most literature is concerned, the ‘Class2’ characteristics are taken as ‘the’ Bluetooth capabilities, as it represents the bulk of what industry has adopted. Although some devices - for example, some USB2 and PCMCIA adapters added to laptop computers - are ‘Class 1’, these are uncommon. The following table shows the differences between each of the classes.

Device Power Class	Max Output Power (mW)	Max Output Power (dBm)	Expected Range*
Class 1	100mW	20dBm	100m
Class 2	2.5mW	4dBm	10m
Class 3	1mW	0dBm	10cm

Figure 10 - Bluetooth Power Classes

The press originally positioned these two technologies as competing because of a general lack of understanding of their capabilities and a concern that they would interfere while operating in close proximity. Interference is not an obstacle to using these technologies together, as they use different spread spectrum communication techniques. They both operate over the ISM band, but

Bluetooth uses frequency hopping while Wi-Fi uses spread spectrum communication. As seen in figure Figure 11 - Wi-Fi and Bluetooth Intended Uses, the uses of these technologies differ significantly, as they were designed for two completely different purposes. The most common uses for these technologies are described below. It is not difficult to envision that both these technologies could be useful in the vehicle.

BLUETOOTH	Wi-Fi
<ul style="list-style-type: none"> ▶ Installation of low-power devices ▶ Installation into devices cheaper than \$300 ▶ Applications where high-bandwidth (>700K) isn't necessary (E-mail without attachments) ▶ Synchronization of multiple devices in a PAN ▶ Eliminating any wires and cables on handheld devices (Hands-free units for phones) 	<ul style="list-style-type: none"> ▶ Installation on medium-power devices ▶ Installation on devices more than \$300 ▶ Applications where high bandwidth (>1MB) is necessary (E-mail with attachments) ▶ Applications where reliability is needed (File sharing) ▶ Applications where greater range is desirable

Figure 11 - Wi-Fi and Bluetooth Intended Uses

Next, by examining an implementation where both Bluetooth and Wi-Fi are used together, one can appreciate how these two technologies (and even others) can be complementary. The following press release presents a case of a company who used the strengths of these technologies synergistically to improve their operations.

UPS Starts European Deployment Of Its Latest Wireless Technology

Press Release

FRANKFURT, Germany, June 22, 2004 – UPS (NYSE:UPS) today announced it will begin deploying wireless technologies, including Bluetooth and Wi-Fi, to package facilities and drivers in Europe to ensure customers continue to have the most up-to-the-minute tracking information available at all times.

The first part of the deployment will occur inside UPS sorting centers and hubs. It involves pager-sized Bluetooth scanners, worn on the middle finger, which send package tracking data to small Wi-Fi (802.11b) terminals worn on the waist by package sorters. The Wi-Fi devices then send the tracking data to UPS's computer network, where it can be accessed by customers.

"Our ultimate aim is to treat each UPS customer as if it is the only UPS customer," said Ken Lacy, UPS's chief information officer. "The wireless technology UPS is deploying today is laying the groundwork for the company to develop better operational software applications, which will allow us to offer new customized solutions to our customers while reducing our operational costs."

The new global scanning system is one of the freshest technologies in UPS's worldwide operation. When the enterprise-wide deployment is completed in 2007, UPS will have streamlined and standardized more than 55,000 ring scanners in 118 countries; integrated a number of UPS scanning applications into one, improved information flow, and decreased the cost of ownership.

By eliminating the cables that connect the ring scanners to the wearable terminals, UPS expects a 30 percent reduction in equipment and repair costs, as well as a 35 percent reduction in downtime and a 35 percent reduction in the amount of spare

equipment needed.

As part of the global deployment, UPS will install as many as 12,000 Wi-Fi access points in more than 2,000 facilities. The resulting Wi-Fi network is expected to be one of the largest in the world.

The deployment of the wireless scanning systems will be further boosted by the rollout of the newest hand-held computer to UPS's delivery drivers. The DIAD IV (Delivery Information Acquisition Device), currently in field trials in the United States, is the first handheld computer to include wireless connectivity options for personal (Bluetooth), local (Wi-Fi) and wide-area networks (GPRS or CDMA). Other innovative features include:

- ▶ A Global Positioning System (GPS) capability that will give drivers more detailed directions to customer pick-up or delivery points.
- ▶ A color screen that accommodates color coding of messages to drivers and displays information in a more attractive fashion for customers.
- ▶ An acoustical radio modem to facilitate dial-up access if necessary.
- ▶ An optical modem to enable transmission within a UPS center.

UPS began pilot testing the Bluetooth ring scanner and Wi-Fi terminal application in Europe earlier this month in Munich, Germany. The company now is launching another pilot test in Hamburg. UPS anticipates deploying the application at 73 sites in Europe by the end of 2005 and also will start deploying the DIAD IV in Germany next year. The company anticipates having 10,000 DIAD IVs deployed in Europe in 2005 and more than 70,000 worldwide by the end of 2007.

Figure 12 - Wi-Fi and Bluetooth Sample Case Study [13]

The Trends

With the multitude of broadband standards currently being used and developed, it is understandable that future looking companies wishing to incorporate a wireless technology into their products find themselves in a challenging position. Looking to the industry experts, we get a clearer picture of how far along these wireless technologies really are and whether they are likely to be adopted. Unfortunately, the information we typically hear is delivered through either a standard committee's marketing arms or the media, and therefore does not represent an unbiased opinion. To obtain an unbiased opinion of which standards are truly being adopted into the market place today, we look to a comprehensive research report from ChangeWaveInsight, an independent Information and Technology & Telecom research firm. They conducted an unbiased survey to discover key wireless broadband trends for 2005 – including Wi-Fi, WiMax, and 3G. Unfortunately, Bluetooth was excluded from the survey, as it was not designed to offer public broadband access. The study involved 78 influential wireless decision makers, and the results add color to our wireless decision making process. Several relevant qualitative trends are summarized in Figure 13 - Standards Trends for 2005.

Main Study Trends

- ▶ Of the Wireless broadband technologies, 3G Wireless (UMTS/WCDMA/GSM) and Wi-Fi are the current leaders, gaining momentum in the fight for broader market acceptance.
- ▶ Wi-Fi is best positioned to lead in the market over the next two years, while WiMax is seen as a very likely player in the long term.

Wi-Fi and WiMax Wireless Trends

- ▶ A significant majority (54%) of respondents believe that "Within the next two years, Wi-Fi Networks will become so widely available that Wi-Fi will be the market leader among wireless broadband"; 26% disagree with this assertion.
- ▶ A majority of respondents believed carriers and data networking companies will be buying WiMax equipment within the next two years.
- ▶ A majority of respondents believed that the market will support both Wi-Fi and WiMax, with 49% indicating that Wi-Fi and WiMax would continue to increase their market share.

"3G" Wireless Trends

- ▶ A majority of respondents (41%) believe that the UMTS/WCDMA/GSM family of standards will take more market share in the US than in the EV-DO / CDMA2000 family.

Figure 13 - Standards Trends for 2005 [14]

Technology Impact on Wireless Strategy

With a better understanding of wireless standards, we can appreciate the risks automotive manufacturers face when choosing among wireless technologies. Without knowing which standards will be dominant in years to come, it is difficult to integrate a chosen wireless technology into production vehicles. Adding to this challenge, vehicle design takes three or more years from initial planning to production, and then a chosen wireless technology is expected to be useful throughout the lifetime of the vehicle (often another ten years or longer). Since automobiles are already equipped with GPS and cellular technology, the question we must ask ourselves is what wireless capabilities are missing today and which technologies can get us there profitably? The answer to the first question is generally known in the telematics industry. The missing wireless functionality is 1) ubiquitous broadband connectivity, and 2) device connectivity. Unfortunately, determining which technology will get us there is more difficult and is the focus of the next paragraphs as we study various factors that influence our decision.

Although it is helpful to analyze industry trends in order to predict which technologies will emerge to be dominant, choosing such a technology in this manner is similar to picking a winning stock in an effort to achieve above market returns. In fact, it is quite similar because

investors often bet on companies that develop technologies based on potential emerging standards. An alternative consideration is to choose a technology that is dominant today by studying wireless standards from a historical perspective. This reveals which standards have remained dominant for an extended period of time and are likely to remain dominant in the future due to market dynamics, such as network externalities. It is also helpful to choose a wireless technology that can meet both our wireless requirements of ubiquitous broadband connectivity and device connectivity. Of the wireless technologies that are highly adopted in the marketplace today, Bluetooth has installations in over 1.4 billion nodes [15] and Wi-Fi has over 530,000 deployed hotspots in the US [16]. Comparing these two, Bluetooth is not capable of broadband connectivity because of its inherent design characteristics (low power consumption and short range), yet it is ideal for device connectivity. Conversely, Wi-Fi offers broadband access but not ubiquitously. Wi-Fi offers device connectivity for some newer and larger devices, but Wi-Fi enabled devices are nowhere near as dominant in the marketplace as Bluetooth enabled ones.

Next we consider how our technology choice may limit future potential. In the technology industry, it is common for large established companies to be surpassed by younger, smaller ones because they are often slower to adopt new technologies and limited by their past technology choices. This is a dangerous combination for deciding on a wireless technology when standards are rapidly changing. We refer to these limiting past decisions as legacy decisions. Fortunately, we can hedge against this through design flexibility. Flexible designs, otherwise referred to as modular designs, are ones that have the properties of low coupling and high cohesiveness. A design with low coupling is essential when integrating a technology that evolves on a two-year cycle (such as wireless technology) with one that evolves on a ten-year cycle (such as the automobile), allowing for more seamless upgrades. In the absence of flexibility, we must more seriously consider the future ramifications of our technology choice. For example, by coupling Bluetooth to vehicles we may have achieved more seamless device connectivity in the short-term but this advantage may not be as relevant in the long-term with an increasing percentage of Wi-Fi enabled devices, and we exclude the development of applications that require broadband connectivity. Since only Wi-Fi offers both broadband connectivity and device connectivity, we map out strategies assuming vehicles are equipped with Wi-Fi technology.

We may ask, why invest in Wi-Fi technology when we can simply wait for either 3G or WiMAX to be deployed, guaranteeing ubiquitous access? A strong counter argument is that many analysts believe Wi-Fi will be the catalyst for fixed wireless broadband WiMAX adoption anyway, where WiMAX provides trunk connectivity to Wi-Fi enabled infrastructure [17]. Regardless of whether this occurs or not, Wi-Fi is still the only standard that can offer broadband connectivity to wireless home networks and wireless business networks today. Given that there are a suitable number of applications that can be deployed over such an environment, it is worthwhile to study these opportunities. This is particularly important since there is no guarantee that 3G or WiMAX will be predominantly adopted into the marketplace. We should still consider designing in wireless interface flexibility to allow for future modification in the event that 3G and WiMAX do become dominant. This vision is described in the 802.20 standard, where a virtual interface is used to provide flexible wireless communication, and is something automotive manufacturers should continue to monitor. Such a modular architecture has been used in the computer industry for decades (as seen in the PC industry) [18], yet has not made its way into current automotive telematics solutions. To the credit of automotive manufacturers, moving vehicles are much more complex than stationary PCs due to vibration and safety concerns, yet as vehicles become increasingly computerized, investing in such capabilities will serve automotive manufacturers well in the future.

Chapter 4 – Application Landscape

In this chapter, we study the possible applications of wireless technology in vehicles. First, the value proposition of a large automobile manufacturer is discussed. Although we previously concluded in our organizational analysis that these organizations are not optimally structured for the quick decision making required to be successful with wireless technologies (Chapter 2), automotive OEMs do provide unique value because of their understanding and access to automotive markets and customers. Similarly, the value propositions of other potential users of short-range wireless in the automotive value-chain are discussed. These customers of wireless technology are identified as the automotive OEMs themselves, logistics providers, dealers, fleet owners and retail customers. The complexity of the problem is again addressed, that is, each customer wishes to use wireless technology for a different purpose and thus may be optimally served by a different technology standard. Each customer is then compared in terms of the overall market opportunity they present and the uncertainty of offering applications that address their needs. Through this analysis we focus on the most relevant uses of wireless technology and the appropriate analysis techniques to further explore them. Then, the result of this analysis is presented along with discussion of potential products/services.

Automotive Wireless Value Proposition

Before investing in wireless technology, automotive manufacturers require an understanding of the value that wireless connectivity offers customers. Many of the uses of wireless on vehicles are difficult to quantify because of latent demand. It is first useful to take a descriptive approach to understand how each user in the automotive value-chain can benefit from the technology. Therefore, each stakeholder is analyzed independently to further understand their needs. In reality, the uses for a technology enabler, such as wireless broadband connectivity on vehicles, is often undiscovered until it is made broadly available. Keeping this in mind, it is still valuable to justify such an investment with what is known and could be reasonably executed today. Thus, in this section we discuss the basic needs and drivers of value for relevant stakeholders who use wireless technology in the automotive value-chain.

Automotive OEM

The automotive OEM should be studied from two perspectives. First, we should establish why a manufacturer should pursue automotive wireless growth opportunities over a more focused wireless technology pure-play. Second, we should identify whether an automotive OEM can benefit from wireless enabled vehicles as a user of the technology.

Although we previously concluded that these organizations are not optimally structured for the quick decision making required when using wireless technologies (Chapter 2), an automotive OEM does provide value. There is no arguing that consumers are in a distinctive and captive state while driving their vehicles. It stands to reason that no other organization could better identify the needs of automotive customers while in this state than an automotive OEM. Thus, automotive manufacturers are uniquely positioned to deliver value to their customers and then to capture it. In addition, automotive manufacturers, along with their dealer networks and financing arms, own the customer relationship throughout the lifetime of the vehicle. An automotive OEM may choose to offer applications themselves or to facilitate a relationship through which a technology pure-play provides technology for a royalty. Regardless, a manufacturer would be foolish not to leverage their relationship and understanding of customers and explore the opportunities in broadband wireless.

Next, assuming the existence of ubiquitous broadband connectivity on the vehicles, how can automotive OEMs benefit? As automobiles become more sophisticated, they increasingly become dependent on software. This fact is already known by manufacturers and is reflected in their efforts to expand electrical engineering and software divisions to further innovation. The primary catalyst for this trend is a customer need for personalization, adaptation and flexibility. The run-time information available on the average vehicle is also increasing along with the level of software sophistication. The combination of increasing amounts of information on the vehicle along with a ubiquitous broadband connection could provide a platform of tremendous value to the automotive OEM. Although there are several barriers to realizing this value, such as data policies and information security, it requires little imagination to envision how this platform could be used on the factory floor, in the design room and in marketing departments to benefit a manufacturer. In addition, other non-automotive organizations could benefit from this information (insurance companies, marketing companies, land development organization etc.).

Logistics Service Provider

Once an automobile has left the factory floor, it is shipped to various dealers and fleet customers. This activity is outsourced to one or more logistics service providers. It would stand to reason that not unlike UPS, Fedex, and other shipping companies, who use technology as a competitive weapon, logistics service providers could use the wireless capabilities on vehicles to aid in shipping and tracking. A significant technological barrier to this benefit is the associated power consumption that Wi-Fi would impose on vehicles that are stationary for an extended period.

Dealer

Dealers have an ongoing relationship with customers from point of sale, servicing, trade-in and vehicle upgrade. This ongoing relationship provides a recurring touch point for dealers to benefit from broadband wireless connectivity. First, from a customer service standpoint, dealers can use the vehicle information and connectivity to make servicing interactions with their customer more seamless. In this case, any value delivered through improved efficiencies would most likely be shared with the customer through a less costly repair bill and the automotive OEM through reduced warranty costs. The dealer may see little benefit unless they are operating near capacity. Even though one may argue that much of the value is difficult for dealers to capture, anyone who has purchased a new vehicle is aware of the importance of the dealership Consumer Service Index (CSI) rating. The CSI rating is an index the manufacturers use to re-distribute profit back to the dealer. After purchasing a vehicle, a customer will typically get a call from the salesperson who sold them the vehicle – whether this is the intention of the automotive OEM or not - trying to convince them to provide a perfect service rating when later surveyed by the manufacturer's customer service representative. This rating is implemented as a performance incentive to motivate dealers in improving their overall customer experience. Automotive manufacturers understand that by doing so they will in turn produce an increase in market share and profitability. Thus, in the long run, dealers do capture some of the value back from the manufacturer, as manufacturers will redistribute their gains through existing incentive plans. In addition, the benefits of broadband connectivity could also promote dealer business growth.

Wireless technology also enables dealers to perform software repairs and upgrades wirelessly. Once again, the value bestowed to customers may be difficult to capture unless the dealer is running at full capacity, but reducing servicing time improves a customer's experience and

lowers their effort in owning a vehicle. The automotive quality revolution of the 1980's indicates how important a "hassle-free" vehicle is to customers.

Fleet Customer

As much as twenty five percent of a manufacturer's vehicle production is sold to fleet customers (Auto Rental Agencies, Car Services, Government Vehicles, etc.). The existence of a healthy fleet telematics market is an indicator that opportunities to deliver value to these customers exist. The current offerings in this market are primarily costly, customized fleet management hardware and software solutions. In addition, several fleet owners have developed telematics solutions themselves, as they feel it gives them an operational advantage. The number of companies providing solutions in this segment seems to indicate an automotive manufacturer could provide and capture value through broadband wireless enabled vehicles. Unfortunately, there are barriers that limit potential value capture in this market. First, fleet customers have significantly more market power than their retail counterparts because of the number of vehicles they purchase. As such, these fleet customers are known to be extremely price sensitive. In addition, the telematics applications in this segment are often highly customized, so it may prove to be difficult for an automotive OEM to address this market in a cost-effective manner with any scale.

Retail Customer

The largest percentages of production vehicles are sold to retail customers. The potential value of broadband wireless applications to these customers is difficult to quantify because a majority of the applications are radically new services for which consumers exhibit latent demand – customers cannot envision their needs for such services until they have experienced them first hand. For this reason, we see that retail oriented telematics services are typically given away for free in a trial period, allowing customers to use the service before imposing fees. Another factor that contributes uncertainty in determining the value of these applications is the pervasiveness of the automobile in our society. The variance in customer preferences is as widespread as the variance in the American population itself. Fortunately, automotive manufacturers have conducted extensive market research, identifying various types of retail customers in an effort to offer an optimal product portfolio of automobiles that meet their needs. It is most likely that automotive manufacturers have already mapped these customer needs to potential broadband wireless applications. If not, such a task would be a good fit for an automotive manufacturer's

capabilities. To illustrate this process, it is not difficult to identify various customer types. For example, there is a significant percentage of customers who are tech savvy. There is also a large percentage of customers who are afraid of technology and a large percentage of customers who are at-home moms. Each of these customer segments would have a unique set of needs and be inclined to use a different set of broadband wireless application. Automotive marketing professionals can then identify which of these customer segments will value a given application. Such analysis is beyond the scope of this document, as most automotive OEM's already have a good feel of their customer's needs and such information is proprietary to each manufacturer.

Application Analysis

We now focus our analysis on applications by using our insights on how various users in the automotive value-chain can benefit from broadband wireless. Because of the large scope of this problem, we again focus on the key drivers as we originally did with our uncertainty issues diagram (Chapter 1); this time, the key drivers of value. Before presenting the results, it is useful to revisit why automotive OEMs struggle to solidify plans to integrate a given wireless technology onto their vehicles. In the table below, we give examples of broadband wireless uses for each user in the automotive value-chain, along with suitable technology alternatives that could enable them. This table was generated with the help of telematics subject matter experts. The criteria used to identify suitable technologies were range, bandwidth, directionality and others. Economic factors such as cost were not considered. One could imagine holding a meeting with all these stakeholders in one room and having to coordinate an agenda that satisfies all their needs. From our analysis of various standards in the technology section (Chapter 3), we now understand why Wi-Fi is best suited as the baseline technology in our application analysis. It is the only technology that is here today and could potentially accommodate most stakeholder needs in some fashion, while also taking into consideration where this standard will likely be positioned among emerging standards of the future. As previously concluded, this should not preclude automotive manufacturers from planning for future wireless flexibility.

Customer	Technology Use	Suitable Technologies
Automotive OEM	Manufacturing and product development process improvements	Wi-Fi Bluetooth
Logistics	Vehicle tracking and defect management	WiMax, Satellite, Wi-Fi
Dealer	Customer check-in and software updates	WiMax, Bluetooth, Wi-Fi
Fleet	Rental car check-in and fleet management	Wi-Fi, Bluetooth
Retail	Digital entertainment, advertising, mobile commerce, personalization,...	Wi-Fi WiMax, WCDMA

Figure 14 - Wireless Customers and Technology Alternatives

Approach

In our study of short-range wireless applications, each customer is compared in terms of the overall market opportunity they present and the uncertainty in offering applications that address their needs. The level of market opportunity is used to identify the customers for whom we believe we can capture more value, and therefore the customers whom we should study in more detail. Then, the level of uncertainty is used to identify effective analysis techniques to study the remaining customer applications of the technology. Although we make a generalization in associating a given risk level to all applications targeted to a particular customer, we find it holds for the applications under study. In analyzing our customers, two categories of applications emerge: those where analysis points in a given direction, referred to as “clear enough future” applications, and those where analysis points to a range of alternatives due to latent demand, referred to as “range of futures” applications [19]. Based on interviews with subject matter experts, three of the five customers (automotive OEM, dealer, and retail customer) hold greatest market opportunity and thus are further studied in detail. The two remaining customers (logistics and fleet) provide weaker value propositions and thus are not analyzed. Of the three promising customers, automotive OEMs and dealers are the technology users who predominantly have “clear enough future” applications, whereas retail customers are the technology users who predominantly have “range of futures” applications due to latent demand. The diagram below summarizes the findings, showing the thresholds used to eliminate fleet and logistics customers based on interviews with subject matter experts, as well as the various classification of application/project risk. The classifications of risk are used to determine the analytic tools to study the applications. This technique is taken from Courtney, Kirkland and Viguerie’s 1997 article, “Strategy Under Uncertainty”, where they develop a framework for identifying the level of uncertainty surrounding strategic decisions and for tailoring strategy to that uncertainty. The

authors categorize the residual uncertainty facing a strategic decision into one of four broad levels:

Level 1: A Clear-Enough future. At level 1, managers can develop a single forecast of the future that is precise enough for strategy development. Although it will be inexact to the degree that all business environments are inherently uncertain, the forecast will be sufficiently narrow to point to a single strategic decision.

Level 2: Alternative Futures. At Level 2, the future can be described as one of a few alternate outcomes, or discrete scenarios. Analysis cannot identify which outcome will occur, although it may help establish probabilities. Most important, some, if not all, elements of the strategy would change if the outcome were predictable.

Level 3: Range of Futures. At level 3, a range of potential futures can be identified. This range is identified by a limited number of key variables, but the actual outcome may lie anywhere along a continuum bounded by that range. Companies in emerging industries or entering new geographic markets often face level 3 uncertainty.

Level 4: True Ambiguity. At level 4, multiple dimensions of uncertainty interact to create an environment that is virtually impossible to predict. Unlike in level 3 situations, the range of potential outcomes cannot be identified, let alone scenarios within that range. It might not even be possible to identify, much less predict, all the relevant variables that will define the future.

Examining our findings, it is not surprising that the technology applications used by the automotive OEM and its extended supply chain (logistics and dealers) represent significantly lower risk investments because of the manufacturer's ability to control application acceptance and demand. Conversely, fleet and retail customers, both end customers with largely unknown demand for broadband wireless applications, present a much higher risk to the automotive manufacturer who chooses to address their needs.

Customer	Technology Uses	Findings	
		Risk	Potential \$
Automotive OEM	Manufacturing and product development process improvements	●	✓
Logistics	Vehicle tracking and defect management	●	✗
Dealer	Customer check-in and software updates	●	✓
Fleet	Rental car check-in and fleet management	●	✗
Retail	Digital entertainment, advertising, mobile commerce, personalization,...	● ●	✓

Risk	Description	Analysis Technique
●	Clear Enough Future	Use standard strategy tool kit: market research, value-chain analysis, DCF analysis
●	Situational Analysis	Develop a set of discrete scenarios and the path to get there; each may require a different valuation model
● ●	Range of Futures	Develop a set of scenarios that collectively account for the probably range of outcomes and identify the risks
● ●	True Ambiguity	Systematically study and catalog the risks

Potential	Description	Yearly Benefit Estimate
✓	High Potential	> 50M
✗	Low Potential	< 50M

Figure 15 - Short-Range Wireless Customers, Risk and Benefit Potential

Applying the Courtney et al. framework, the analysis tools best suited to study applications of short-range wireless depend on an application’s level of uncertainty. This is an important finding because an analyst can fruitlessly attempt to analyze a project with level 2 to level 4 uncertainty using traditional analysis techniques (DCF, break event, etc...). For example, we choose to study only “clear enough future” applications using a traditional Discount Cash Flow (DCF) model. Alternatively, we chose to study the “range of futures” applications using a qualitative strategic framework developed by Adrian Slowatsky, which evaluates applications by looking at customer selection, value capture, differentiation and strategic control and the resulting service scope [20]. If we had chosen to study an application with Level 3 risk using a traditional DCF, our analysis would be in vain because the results would be dependent on several key variables – market acceptance being the dominant one - and for an embryonic service the values of these variables are unknown.

Low-Uncertainty Short Range Wireless Applications

The “clear enough futures” applications are studied by performing a traditional DCF analysis. The applications studied include those that provide value to automotive OEMs and dealers. The analysis is performed over a five and ten year period, with high, medium and low estimates for cash flows, representing an aggregate of all automotive OEM and dealer applications. The costs are calculated and compared for several wireless standards (although, since Wi-Fi is currently the

benchmark wireless technology, the results assuming 802.11b costs are shown below). Projections for cash flows are obtained from literature searches and interviews with subject matter experts and then incorporated into the DCF model. For each application, an automotive division agrees to the revenue and cost projections, thus becoming accountable for the initial capital expenditure to implement the application and the benefits later accrued. In the result graphs shown below, Figure 16 - DCF Analysis Result of Application with a “Clear Enough Future”, we see the aggregate DCF results of approximately a dozen “clear enough future” Applications. Both expected five and ten year NPVs are estimated to be positive and the cash flows are expected to be positive by the 8th project year. The results show that the mid-range projections track much more closely with the low estimate than the high. Although this could be interpreted as a belief that the probable cash flow outcome is skewed towards the low estimate, it instead represents the fact that managers in the automotive industry are very cost driven and business units are expected to over perform their objectives. Therefore, managers tend to underestimate as opposed to overestimate.

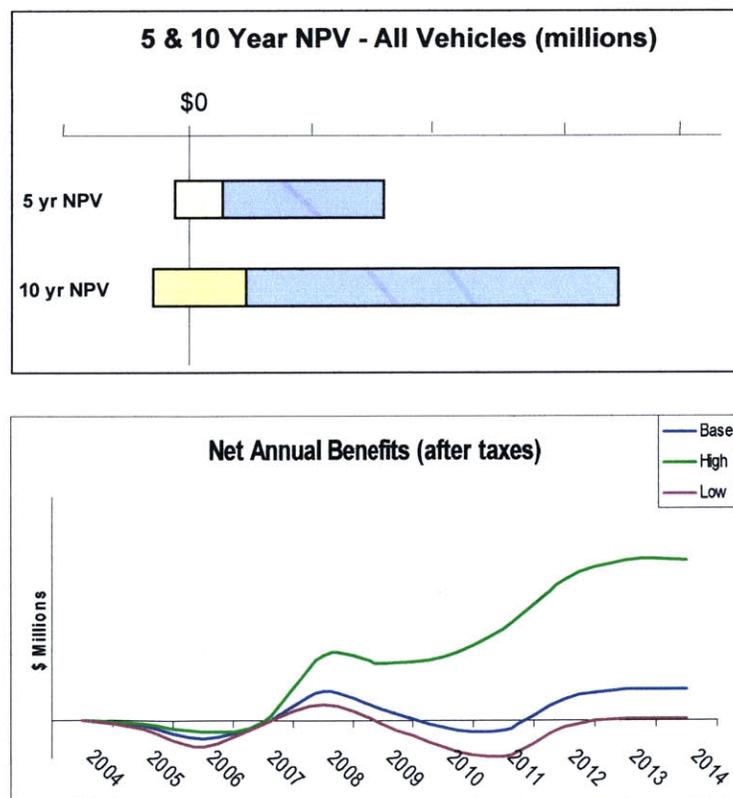


Figure 16 - DCF Analysis Result of Application with a “Clear Enough Future”

In studying the cash flows more closely, we see there is a decrease in between the 4th and 7th year. This decrease occurs because the cost of integrating wireless technology into vehicles increases proportionally to production, reaching full production in the 7th year. Yet, the benefits accrued from the technology platform are proportional to the number of outstanding vehicles with Wi-Fi on the roads at a given time. Depending on the type of benefit, this lifetime could be anywhere from four to ten years. A four year benefit is common with warranty related benefits and a ten year benefit is common with lifetime benefits. This relationship is shown in Figure 17 - Benefit to Variable Costs Delay. As the percentage of outstanding broadband wireless enabled vehicles on the road approaches 100%, the benefit reaches its full potential, around the 9th year. In reality, this increase would most likely be more dramatic because the ubiquity of Wi-Fi would drive the development of new applications. Yet, this analysis is only performed for low risk “Clear Future Applications” and does not take riskier revenue streams into consideration in an effort to put forth a highly conservative baseline estimate.

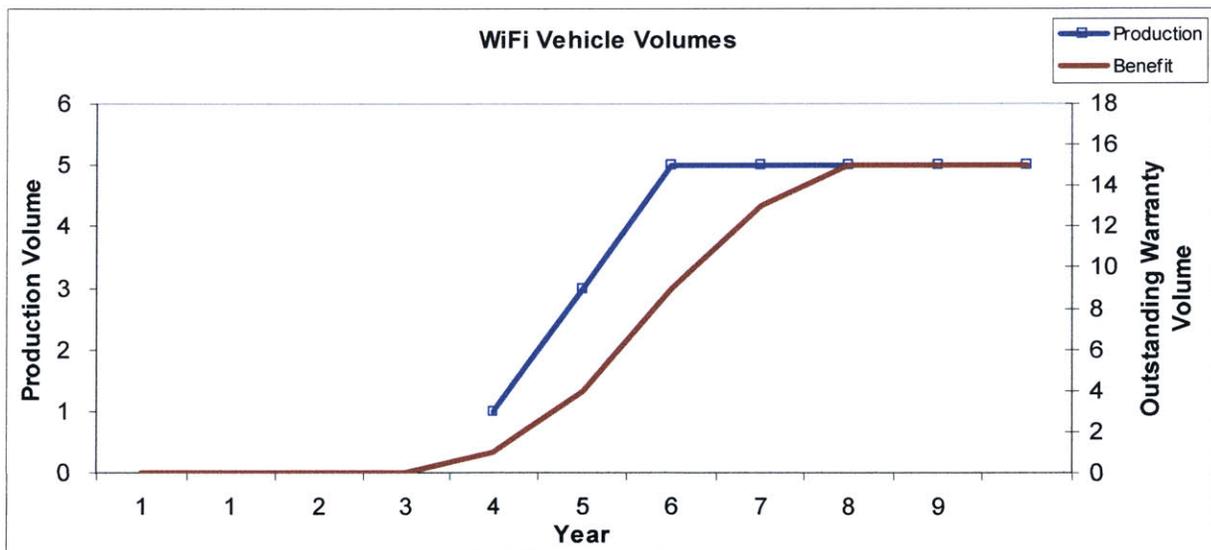


Figure 17 - Benefit to Variable Costs Delay

High-Uncertainty Short Range Wireless Applications

The analysis tool used to study “range of futures” applications – those servicing retail customers and exhibiting latent demand – is based on a strategic framework of customer selection, value capture, differentiation and strategic control, and product scope [21]. Customer selection focuses on customers to whom we can add real value. This part of the framework (customer selection) was also applied to differentiate the various technology users in the automotive value-chain by

and potential benefit. Now, customer selection is again applied, but this time solely to retail customers and at a finer level of granularity, distinguishing various types of retail customers and their needs. In the next step of the framework, value capture focuses on how and whether we can capture a portion of the value delivered to these customers. If no capture is possible, the firm should focus on another customer segment. Next, we study differentiation and strategic control to determine the sustainability of value capture. No business model or product advantage is permanent, and it is important that strategic control points are known so that a business design can be sustainable in the long-run. If this is not possible, we must at least know how to quickly innovate around our business design in order to remain competitive. Then based on this analysis, we determine the product or service scope that would satisfy our particular segment's needs. This includes not only an understanding of the actual product or service but also an understanding of how we build and deliver the service (e.g. in-house, subcontractors, partners).

The retail application categories studied are shown below. Four of the services/products cleared all the hurdles, but others were dropped because of a lack of value capture, strategic control, or simply a lack of reliable research information (a form of project uncertainty). In the exhibit below, the various types of services studied, the high-level selection criteria, and the chosen services (mobile commerce, digital entertainment, personalization and advertising) are shown. Although the names of these telematics applications categories vary somewhat from one analyst to another, these areas of interest are fairly well known in the telematics industry and are separately discussed below. The discussion also gives the high-level rationale around certain categories being more promising than others.

• **Seven application categories were studied - three were chosen for further detailed analysis**

<ul style="list-style-type: none"> ✓ 1. Mobile Commerce <ul style="list-style-type: none"> ▪ Payments (garage, tolls, drive-through) ✓ 2. Digital Entertainment <ul style="list-style-type: none"> ▪ Watch a movie ▪ Browse the Internet ▪ Listen to music, a magazine, or the Wall Street Journal X 3. Remote Office <ul style="list-style-type: none"> ▪ Read, write, and send email ▪ Dictate meeting notes, emails, appointments, and contacts ✓ 4. Advertising / CRM <ul style="list-style-type: none"> ▪ Location Based Advertising ▪ Vehicle triggered Advertising 	<ul style="list-style-type: none"> ✓ 5. Personalization <ul style="list-style-type: none"> ▪ Vehicle settings ▪ Telematics service preferences X 6. Connectivity <ul style="list-style-type: none"> ▪ Hands free access to PDA ▪ Hands free phone X 7. Data <ul style="list-style-type: none"> ▪ Government use: infrastructure planning ▪ Business use: Insurance, planning ▪ Third-party party applications 		<div style="border: 1px solid black; border-radius: 15px; padding: 10px; width: fit-content;"> <p><u>Selection Criteria</u></p> <p>Customer selection / needs</p> <p>Profit potential</p> <p>Technology alternatives</p> <p>Implementable now</p> <p>Growth opportunity</p> <p>Meets long-term objectives</p> <p><small>* More details on next slide</small></p> </div>
---	---	--	--

Figure 18 - Automotive Retail Customer Services Studied in Detail

- ▶ **Mobile Commerce:** The vision of seamlessly executing wireless payments from vehicles has recently become reality through the introduction of RFID toll road systems. Although RFID is not a broadband wireless technology, it is conceivable that a similar payment system could be implemented using Wi-Fi or another suitable broadband wireless technology. The customer need that mobile commerce would satisfy is convenience through an overall improvement of purchasing system economics. To infrastructure investors, this technology stands to improve transaction throughput and reduce labor costs. Once the penetration of broadband enabled vehicles reaches a reasonable threshold, smaller vehicle oriented infrastructure providers may also benefit, such as parking garages, car washes, and retail operations with drive-through windows. The drive through industry has historically been an early adopter of technologies that enable gains in efficiency or throughput.

Unfortunately, several obstacles stand in the way of making this vision a reality. One is an adequate human computer interface, allowing customers to interact during a given transaction. Unlike toll roads, where payments are mandatory, mobile commerce transactions are more complex; a price must be agreed upon and the purchase is optional. Installing the necessary complementary assets to address this obstacle could be prohibitively more expensive than the wireless technology itself. Another obstacle is that viable substitutes (credit cards, cash, etc.) exist that are not only useful to customer in their vehicles but also outside their vehicles. A final obstacle is that merchants will be hesitant to adopt this technology unless it is ubiquitously available on vehicles. Even with all these obstacles, we chose to further study this category of application because these capabilities could be an essential part of a broadband application platform.

- ▶ **Digital Entertainment:** Digital entertainment is thought to be one of the categories of greater profit potential, while at the same time presenting significant risk due to latent demand. Examples of digital entertainment services include digital movies, music, books or the Wall Street Journal. Several of these services have already been offered by telematics service providers in the past, but they have not been broadly adopted by the marketplace because of prohibitively high prices. Being offered over a standard, non-broadband connection and priced on per minute usage, these services are currently priced out of the

market. The basic enabler for many of these services will be the broadband wireless enabled vehicle, which would drastically reduce cost and the price of these services.

Implementation of digital entertainment services is even feasible when vehicles are equipped with non-ubiquitous broadband connectivity (such as that currently offered through Wi-Fi).

In such an environment, these applications could simply be implemented by synchronizing between the customer's vehicle and their PC connected through a Wi-Fi home network.

There are some limitations to this solution, for example, customers who live in apartments would not have access to their vehicles, nonetheless, there exists a market today that could be addressed in preparation for truly ubiquitous broadband connectivity. By simply partnering with a public hotspot provider, many of the obstacles could be overcome. A deterrent to building businesses around these services is the existence of substitutes. For example, customers could bring digital media players (e.g. iPod) in the vehicle and receive many of the same benefits. In counterargument, we should also consider there is nothing stopping customers from bringing their radios into the vehicle as well, yet for years radios have been offered in automobiles at a price premium. This is an indication that customers are willing to pay for the convenience of proper integration of these services.

- ▶ **Remote Office:** Remote office applications allow drivers to perform routine office functions safely while driving their vehicles. These services include reading emails, checking their schedules, or making conference calls. Despite how appealing these applications initially appear, there is little benefit brought to them through broadband wireless connectivity, and thus they are not studied in detail.
- ▶ **Advertising / CRM:** Along with digital entertainment, advertising and customer relationship management are application types with great potential. After the fallout of the high-tech industry, business analysts became skeptical of businesses that derive their revenue from advertising. However, with the recent IPO of Google, a successful high-tech company that derives a majority of its revenue from advertising, these concerns have been somewhat put to rest. In addition, even before the advent of the internet, radio and public television companies have been successful for years with advertising-based business models. Unlike public radio, which broadcasts generic advertising messages to every listener, broadband wireless advertising promises to be more effective in targeting the appropriate customer base

and then delivering a message specific to their interests. The success of such an advertising business is dependent on the usefulness of the entire platform. This includes a sophisticated set of applications and appealing content. The technologies used to deliver preference-enabled advertising are already making their way into digital television. In these systems, customer preferences are obtained either through user input or observation. In automobiles, digital advertising promises to be even more effective because drivers are much more captive and have fewer alternatives competing for their attention. In addition, we stand to learn much more from customers through their interaction with other applications and content, as well as through their vehicle location and speed.

One significant barrier to automotive manufacturers pursuing opportunities in personalized advertising is access to and use of information. An appropriate data policy is required for customers to feel comfortable with the service, defining which information is “off limits” to advertisers. A portion of these data policy issues can be resolved through application flexibility – something that is easily facilitated through software technology. This same flexibility could also allow customers to pay for services instead of being subjected to advertising, allowing them to keep their information confidential. Though some drivers prefer not to listen to advertising, many are conditioned to radio and television programming and are willing to accept services and content under this business model. This is a notable point in delivering broadband wireless applications, as many analysts struggle with how willing customers are to pay for these services because of latent demand. By focusing value capture on a different set of customers (advertisers and businesses wishing to target customers), the cash flows derived from our applications with Level 3 uncertainty become more realistic and less risky.

Customer relationship management (CRM) services would also access the same customer preference information to strengthen relationships. These applications could be the enabler that would allow automotive manufacturers to bridge the relationship gap between their customers, dealers and their financing arm.

- **Personalization:** Personalization applications have the ability to tailor themselves to a given customer’s needs. As opposed to customization, which allows users to directly control or adjust a service, personalization includes an added layer of sophistication, using a preference

model to adjust the application in question. As with advertising, customer needs or preferences are obtained through observation and user input. Given applications can be delivered through a common platform; there exists a compelling possibility of an aggregate service with demand side increasing returns (network externalities). With this platform, the more applications customers use, the more useful it becomes. Then, overall platform growth creates an incentive to build even more applications because of a larger customer base and a greater amount of personalization information. This is not different than any computer platform. Personalization applications can even be developed with today's existing wireless infrastructure. For example, more sophisticated automobiles have personalization information (radio settings, seat positions, etc.), which are reset when the battery is disconnected. If automobiles had the ability to synchronize with a PC through a home wireless network, it would be possible to retain these settings so a dealer could service a customer's car and return it with preferences intact. This is one of many ways in which personalization can be useful to customers today. Unfortunately, quantifying the value capture of personalization is difficult, as it primarily serves as a differentiator versus competitors.

- ▶ **Device Connectivity:** Device connectivity applications provide the lower-level functionality of communicating information between devices and the automobile. Similar to remote office services, which are often built using connectivity services, several barriers make them less appealing to an automotive OEM. First, the device market is highly fragmented, so building a complete set of synchronization services would be difficult. Second, it is challenging for an automotive OEM to capture value from such a service. At most, this service would be a differentiator, but most likely not as significant as satisfying a basic need, such as offering superior automobile styling or the ability to customize services according to preferences. The one connectivity service that is compelling is hands-free phone. This is currently being offered by several automotive manufacturers as an option enabled through Bluetooth technology. Given Bluetooth will never offer ubiquitous broadband access, offering it as an option for hands free phone is the appropriate way to package this technology onto the vehicle. In addition, experience integrating a wireless technology into vehicles provides valuable learnings to an automotive organization.

- ▶ **Data:** The data obtained by combining a global positioning system and ubiquitous broadband connectivity in vehicles is useful to many applications, both on vehicle and off. One such application commonly discussed among telematics experts is real-time traffic navigation, a service already broadly available in Japan. Even though a broadband connection could be useful for a large data set, in general it is not an enabler to this application.

A data oriented business model that telematics experts discuss is providing an open telematics platform where the automotive OEM captures value by charging for vehicle data. The drawback to this model is that it would be fairly easy for competitors to mimic, and the OEM's ability to charge for information would be drastically reduced. If the manufacturer could somehow lock the vendor into its telematics platform, either through contracts or technology, this risk could be mitigated, but realistically this would prove to be difficult.

Throughout our overview of the various retail application categories, additional technology enablers were needed to deliver many of the services. Examples of such enablers are storage capacity, a service processing platform and truly ubiquitous broadband connectivity. Although many of these core assets are required for an idealized version of the service, the sophistication of these assets would likely evolve over a period of time, along with the availability of ubiquitous broadband wireless connectivity. For now, many of the services can be offered with reduced functionality through a customer's home network with marginal impact to customer experience.

Next, we present three of the four promising services in more detail, applying Slowatsky's framework [22] to further define a possible business design for the services, shown in Figure 19 - Service Analysis Using Qualitative Framework.

	Mobile Commerce	Digital Entertainment	Personalization
Customer Selection	<ul style="list-style-type: none"> Entertainment seekers* They want it all Productivity friends 	Entertainment seekers They want it all	Tech savvy seniors They want it all Kids come before mom
	④ ③	① ②	⑤ ⑥
Value Capture	<ul style="list-style-type: none"> Transaction fee (1.4%) Share fee with TP partners 	•Music Sales Commissions	<ul style="list-style-type: none"> Additional Car Sales CRM capabilities
Differentiation / Strategic Control	<ul style="list-style-type: none"> Own customer relationship Integration of TP hardware and control over software 	<ul style="list-style-type: none"> Own customer relationship Own the standard First mover <ul style="list-style-type: none"> - Largest WiFi install base - Partnering power 	<ul style="list-style-type: none"> Own customer relationship First mover <ul style="list-style-type: none"> - WiFi install base lead
Scope	<ul style="list-style-type: none"> Hardware / software B TP C 	<ul style="list-style-type: none"> Sync / Interface (API) A Hardware B Software C 	Hardware / software C
Risks	<ul style="list-style-type: none"> Technology <ul style="list-style-type: none"> - Human comp interface - Security Customer acquisition costs higher than PV of micro-transactions revenue 	<ul style="list-style-type: none"> Regulatory change in industry Many new and competent industry entrants 	<ul style="list-style-type: none"> Not all drivers have wireless networks at home Not all drivers park near their home

Requirements/needs

- Entertained ①
- Informed ②
- Time Savings ③
- Productivity ④
- Simplicity ⑤
- Convenience ⑥

Scope

- In-house **A**
- Sub-Contracted **B**
- Partner **C**

Figure 19 - Service Analysis Using Qualitative Framework

First we study customer selection and find that entertainment seekers and productivity oriented customer segments are the ones from whom we can profit. These customer types are identified by mapping customer needs from the Requirement/needs column to the type of application. Although mobile commerce is not appealing on its own, it was included in this analysis because it can be a necessary part of billing for other broadband enabled applications.

Next, we study value capture. Here, we look to industry comparables to validate our beliefs. With mobile commerce, we look to the business models of the transaction processing industry, a healthy industry that continues to grow based on deriving micro-payments for transaction. As for digital entertainment, there are many examples in traditional radio, digital radio, television, and the music industry to validate capture through various business models (advertising based, transaction based, subscription based, etc.). It is important to note that the digital revolution is currently disrupting many of the traditional business models of these comparable companies, so we should use good judgment and reasoning in our business designs, as opposed to blindly copying what has been done. Capturing value through personalization is more difficult. As with mobile commerce, this service enables other services and is more of a competitive differentiator. An example of a service that uses personalization to achieve competitive advantage is TiVo.

Next, we look at differentiation and strategic control. Here, we study possible strategic control points that will allow services to be unique versus those of the competition and to capture value in a sustainable manner. Below we present a chart of typical control points used to sustain competitive advantage and their index of power protection, as shown in the work of Slywotzky and Morrison.

Profit-Protecting Power	Index	Strategic Control Point	Examples
High ↑ ↓ Medium ↑ ↓ Low ↑ ↓ None ◇	10	Own the standard	Microsoft, Oracle
	9	Manage the value-chain	Intel, Coke
	8	String of super dominant positions	Coke, Internationally
	7	Own the customer relationship	GE, EDS
	6	Brand, copyright	P&G
	5	Two-year product development lead	Intel
	4	One-year product development lead	(any innovator)
	3	Commodity with 10 to 20 percent cost advantage	Nucor, Southwest Airlines
	2	Commodity with cost parity	(many)
	1	Commodity with cost disadvantage	(many)

Figure 20 – Strategic Control Points [23]

In pursuing these services, an automotive manufacturer could easily implement several of these control points; in fact, several of them are already inherent and the reason we suggest an OEM pursue broadband wireless opportunities (discussed in Chapter 4, Automotive Wireless Value Proposition). For example, manufactures already own the customer relationship; pursuing CRM services could increase the strength of these relationships. This would be a re-enforcing control point, as the services were originally cross-sold through these relationships in the first place. In addition, all services would be differentiated by being the first to market. This advantage could be used to enforce several other control points. It could be used to maintain a competitive advantage through value-chain management, or by owning the standards, or a combination of the two. Many of the control points are dependent on the manufacturer’s overall wireless strategy. If an automotive manufacturer creates and delivers services itself, it would have the advantage of owning a proprietary technology. Conversely, if the automotive OEM chose to open up the development of these services to other qualified organizations, they would want to create and own the standards over which these services would operate. This would insure switching costs

to those service providers wishing to port to another platform. In addition, the manufacturer could possibly charge royalties to other manufacturers who use the standard, producing additional revenue streams.

Finally, based on our analysis we determine the scope of the product or service that would satisfy our particular segment's needs. In this step, the analysis from the first three parts of the framework are brought together to describe the product or service. This includes not only an understanding of the actual product or service but also an understanding of how we build and deliver the service (e.g. in-house, subcontractors, partners). Here we have to reflect back on our organizational analysis (Chapter 1). We assume a typical automotive manufacturer and allocate components of the product/service to the party best suited from a capabilities standpoint. We will see the results of this process in more detail in the next chapter. Although analyzing these services independently and in absence of an overall broadband wireless strategy is difficult, doing so reveals that much of what needs to be done to offer these applications does not fall within the capabilities of a typical automotive manufacturer, thus a partnering strategy where the manufacturer could exert some control would be preferable. At this point, it is also clear that we need to study services in the aggregate to determine the best overall broadband wireless strategy and to leverage the common assets between these services, increasing the likelihood of a profitable business.

Chapter 5 – Wireless Strategy

In the previous chapter, the potential applications of short-range wireless in vehicles were studied independently. Applications were analyzed by first studying the value they could provide to each user in the automotive value-chain, identifying the users who are more promising. Then, the remaining applications were divided into two categories by their level of project risk. The applications that served OEMs and dealers were found to be lower risk applications, labeled as Level 1 – “clear enough future” applications. The applications that served the retail customer were found to be higher risk applications due to latent demand, labeled as Level 3 – “range of futures application”, where the range is defined primarily by market demand. Following the framework described in Courtney et al. 1997 article, “Strategy Under Uncertainty”, appropriate analysis tools were applied to each risk category. A DCF analysis was performed for the “clear enough future” applications, revealing that these applications alone resulted in a positive NPV investment. Then, the additional “range of futures” applications, which would leverage many of the same core assets, were studied through a strategic framework.

Studying these services in isolation provides for useful strategic information, but successful companies often choose to service unprofitable customers in order to align to an overall firm strategy that allows them to profit across their customer base. In this chapter we take such a global view of short-range wireless strategies, mapping alternate strategies that could combine “clear enough futures” and “range of futures” applications. It is important that firms resist the temptation to optimize locally – for example, focusing solely on refining the costs of “clear enough future” applications, something automotive OEMs are comfortable with and do well (Chapter 1) - and instead focus equal attention on future growth opportunities provided through the “range of futures” applications.

Strategic Postures and Moves

We begin this analysis taking into consideration the typical vision and the capabilities of a large automotive OEM and translating them into a set of reasonable strategic postures and moves [24]. This process is summarized in the diagram below.

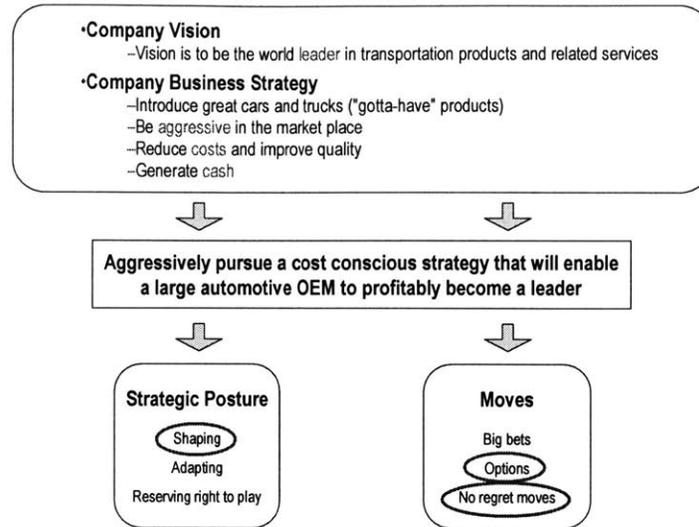


Figure 21 – Example Strategic Postures and Moves for a Large Automotive OEM

The organizational strengths and weaknesses discussed in the first chapter are applied to define boundaries to our strategic alternatives. Given the typical OEM’s organizational vision, shown above, and its strengths and weaknesses, we chose a posture of shaping. A posture of adopting or reserving the right to play would not meet our corporate objective of being a “world leader” and “aggressive in the marketplace”. Then, strategic moves could either be options or no regret moves. A big bet would not be aligned with a corporate objective of generating cash and a culture of cost cutting. We consider only strategies that satisfy our criteria – for example, we would eliminate a strategy that is both risky and capital intensive. Mapping our current analysis to the range of opportunities available, we find that pursuing “clear enough future” applications correspond to no-regret moves, since they represent low-risk, slower moving applications that match our core competencies and could be executed in-house. On the other hand, the “range of futures” applications of retail customers carry with them a significant amount of risk. They match a large automotive OEM’s strategic posture of shaping but not the available moves of options or no-regret moves, if executed in-house. Thus, delivering these applications is in line with our vision only when delivered through a partnership that promotes risk-sharing, making the move an option by offloading the initial business risk.

Structure

Given the discussed postures and moves, a joint venture or partnership with a high-tech organization would allow an automotive OEM to profit from these retail customers through an

organization better suited to capture the value. If the automotive OEM were to attempt to service these customers alone, it would most likely choose the wrong technology standard because of its aversion to risk, fail to capitalize on the opportunity in time because of slow decision making, or become unprofitable because of its organizational size and related interface costs (its inherent strategic design). An example of size and interface costs defining a firm's target market is seen in the financial industry where larger banks are forced to go after bigger deals that cover the costs of a more expensive and sophisticated deal team. This correlation between strategic design and type of application is shown in the diagram below.

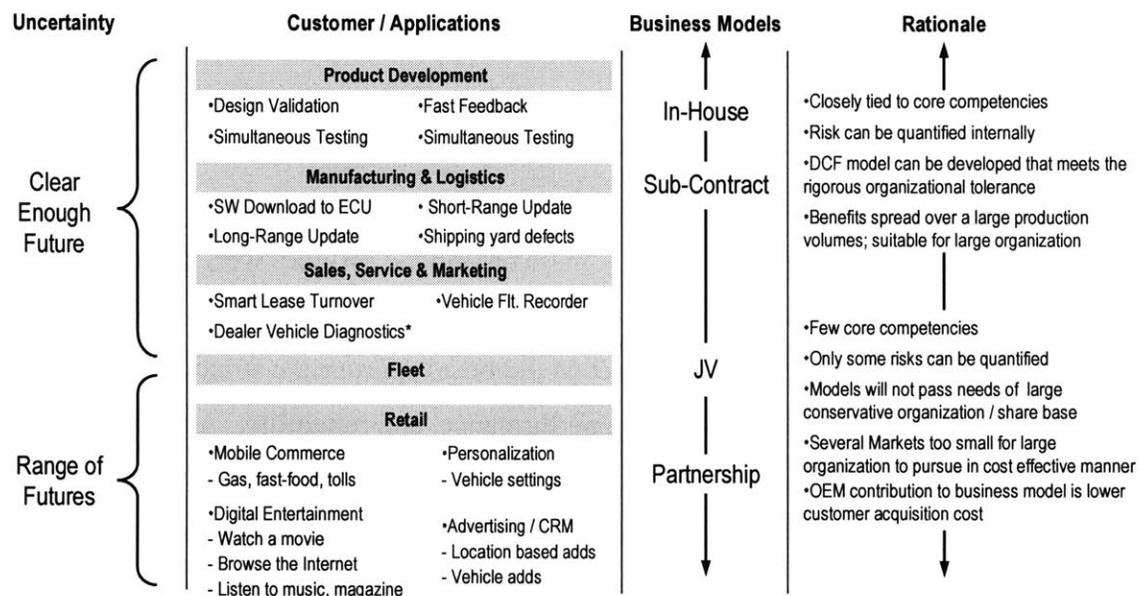


Figure 22 - Business Model Strategic Design

In this diagram, we give further detail on the applications categorized by their level of uncertainty. Then, based on this level of uncertainty, the applications are mapped to a suitable business design (In-House, Sub-Contract, JV, Partnership). Much of the rationale already discussed is presented in the right column.

Strategic Alternatives

Finally, given the bounds placed around our solution space, several platform strategies are explored. These alternatives rationalize the decisions that should be made in the short-term, mid-term, and long-term. A temporal focus is necessary when developing strategies around a rapidly changing technology because it is difficult to maintain strategic control long-term with a static business design. What works today will most likely not work three or six years from now.

Although we discovered it is a challenge for traditional automotive manufacturers to operate in a less static world, once again, by using the appropriate business design, automotive OEMs can use their strengths and partner to overcome any weaknesses and profit from broadband wireless technologies. Based on the preceding paragraphs, for all strategies, the appropriate path is to execute on “no regret moves”. In our case this is to capitalize on “clear enough future” opportunities. Then, the OEM should use its momentum to build the core assets required to execute the remaining platform strategy. We identify three strategic alternatives along a bounded range, ranging from a closed strategy to an open strategies.

Proprietary Strategy – “Closed”

Following a proprietary strategy, the automotive manufacturer attempts to offer services primarily through its own capabilities. Given the disparity between the capabilities needed to offer many of the services compared to those needed in traditional automotive manufacturing, we should question the feasibility of this strategy. If these broadband services were to define what customers primarily valued in future automobiles, then a strategic refocus of automotive manufactures to operate effectively in this market would be an appropriate strategy. Fortunately, consumers are primarily concerned with styling, performance, and reliability. Another alternative is to follow a proprietary strategy executed in partnership with a software company that already possesses the necessary capabilities, but even in this case, the risks associated with exposing existing customer relationships to an aggressive, well-run and much faster moving technology company may not be a wise choice for an automotive manufacturer.

Platform Strategy – “Marginally Open”

This strategy gives the automotive OEM control over platform assets (operating system, hardware, etc), yet only expects the manufacturer to provide a minority of the necessary capabilities – only those necessary to lock in strategic control points and ownership of the service platform. In studying this example (Figure 23 - Platform Strategy Alternative), it is apparent that the number of paths and strategic ambiguity becomes greater and greater the further out into the future we plan, yet it is important to consider how the strategy will evolve over time. The diagram below presents one such temporal path. It shows how far along an automotive manufacturer could be within one year, three years, and in six or more years (long-term). In this strategy, we see the OEM migrating to offer a telematics platform. The OEM would have

control of services offered through its platform and charge royalty fees for the services that it did not offer. The control points could be many of the ones discussed in the previous chapter (Figure 20 – Strategic Control Points).

	Today	3+ Years	6+ Years
Customer Selection	<ul style="list-style-type: none"> •Retail Customers <ul style="list-style-type: none"> - Safety conscious •Automotive OEM – low bandwidth 	<ul style="list-style-type: none"> •Retail Customers <ul style="list-style-type: none"> - Safety conscious - Entertainment seekers - They want it all - Productivity friends •Automotive OEM – all bandwidth 	<ul style="list-style-type: none"> •All Retail Customers •Automotive OEM – all bandwidth •Independent software/service providers
Value Capture	<ul style="list-style-type: none"> •Monthly service fee 	<ul style="list-style-type: none"> •Monthly service fee •Productivity savings •Music Sales Commission 	<ul style="list-style-type: none"> •Monthly service fee •Productivity Savings •Platform royalty fees •Independent service provider investments
Differentiation / Strategic Control	<ul style="list-style-type: none"> •Own customer relationship •Vehicle integration •Product development lead 	<ul style="list-style-type: none"> •Own customer relationship •Vehicle Integration •First move advantage <ul style="list-style-type: none"> - WiFi market leader - Partnering power 	<ul style="list-style-type: none"> •Own customer relationship •Vehicle Integration •First move adv / network effect <ul style="list-style-type: none"> - WiFi market leader (share / first) - Partnering power (first choice) •Cost advantage <ul style="list-style-type: none"> - Asset sharing - Light footprint partners
Scope	<ul style="list-style-type: none"> •Telematics service centers •Telematics hardware / software 	<ul style="list-style-type: none"> •Telematics service centers •Telematics platform developer •Partnership driven digital entertainment provider 	<ul style="list-style-type: none"> •Telematics service centers •Telematics platform provider •Bundled partner service provider

Figure 23 - Platform Strategy Alternative

Leasing Strategy – “Open”

This strategy is one where the automotive OEM leverages its customer base and knowledge of cars but chooses to be minimally involved in building and offering services. Instead, the manufacturer seeks out appropriate partnerships to offer these services, developing a leasing agreement to integrate these partner products into the vehicle. One of the concerns with this strategy is there is little stopping competitors from employing a similar strategy. If the manufacturer could somehow own the standards through which the components are integrated, then this strategy could be viable. Even in this case, unless the interfaces are exceedingly complex, there is little standing in the way of the service and platform provider from modifying the integration point for another manufacturer. In the extreme case, the automotive manufacturer could simply provide a socket and software hooks to access information. In this model the manufacturer could charge for the information or alternatively just pass over the market

opportunity and offer everything for free, positioning themselves with a competitive differentiator in hopes that the market develops.

Chapter 6 – Conclusion

The conclusion is that suitable strategies exist for a large cost-conscious automotive manufacturer to profit from integrating short-range wireless technology into vehicles. These strategies differentiate between applications with known demand and those with high-risk latent demand, using business design to mitigate the risk and to address the target market's cost structure and size. In the case of low risk applications, forecasts are adequately confined to point toward a single positive strategic direction in the short-term. These applications are also better suited to the core competencies of an automotive OEM, and thus can be pursued either internally or through sub-contracting. In the case of higher-risk applications, the outcomes may lie anywhere along a bounded range. An automotive OEM is not as well suited to deliver these applications unless it partners to gain the necessary core competencies and to offload some of the risk.

By following a platform strategy, an OEM can execute on the known profitable applications today to build the core assets for the future. This platform is one of several strategic control points that should be used to insure profits are sustainable. Regardless of how effective are the control points, in a faster moving industry the strategy should be mapped out over the short-term, mid-term and long-term, and the business design should be dynamic enough to evolve and remain competitive.

The general approach used to analyze this problem can be used to help any organization in a slower moving industry to profit with faster moving technologies. By focusing on the organizations strengths and weaknesses, the residual risk in the technology itself and the potential uses of the technology from a customer-centric viewpoint, we can determine which customers to serve and whether we can serve them profitably ourselves or with the assistance of a partner. Then, analyzing the technology uses by risk, we can value the more certain uses and use our analysis to map out our longer-term, evolving strategy.

References

1. Ancona D, Kochan T, Scully M, et al: *Managing for the future: organizational behavior and processes, Third Edition*: Boston: South West, 2005
2. Spread Spectrum Scene: *Radio Frequency Basics*
http://www.aerocomm.com/rf/rf_basics.htm
3. Ryament, David: *Planck, A Radically Modern Approach to Introductory Physics; Einstein, and deBroglie*: New Mexico Tech: December 4th, 2004
<http://www.physics.nmt.edu/~raymond/classes/ph13xbook/node73.html>
4. *Electromagnetic Spectrum*: Berkley Lab's Advanced Light Source:
<http://www.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html>
5. Communications Office of Engineering & Technology: *Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields*, Federal, OET Bulletin 65, Edition 97-01, August 1997
6. Spectrum Scene Online: *The RF Spectrum*: October 12th, 2004
<http://www.sss-mag.com/spectrum.html>
7. Pullen, Mark: *Computer Networks, Class 3*: Dec 10th 2003
http://cs.gmu.edu/~csnow/cs455/2002A/lectures/10sep/03_new_2up.pdf
8. UMTS World: *CMA Overview*
<http://www.umtsworld.com/technology/cdmabasics.htm>
9. Bue, Erik: *Leveraging Viral Growth Inherent in Mobile Peer-to-Peer Telematics to Strategic Advantage*: Massachusetts Institute of Technology, June 2004
10. Gregory J. Teets, Matt Lybarger: *Wilress Technology: WiFi & WiMax*: A.G. Edwards, August 6th, 2004
11. Leslie Miller & Associated Press: *More Americans than ever use cell phones while driving, report says*: The Detroit News, Autos Insider, March 2nd, 2005
12. Wexler, Joanie: *802.20, 802.16e throw curveballs at 3G*; Network World Fusion; Network World Inc.: April 21st, 2003;
<http://www.nwfusion.com/newsletters/wireless/2003/0421wireless1.html>
13. UPS release: *UPS Starts European Deployment Of its Latest Wireless Technology*: Frankfurt, Germany: June 22, 2004
14. ChangeWaveInsights: *Wireless Broadband Trends for 2005, 3G & Wi-Fi Show Most Growth – WiMax Hold Big Promise*: Oct 13th, 2004
15. Legard, David: *Bluetooth Devices: Ubiquitous by 2005, Technology to be common in cell phones, PCs, and PDAs by 2005*: PC WORLD, IDG Networks: September 7th 2005
<http://www.pcworld.com/news/article/0,aid,18362,00.asp>

16. MobileInfo.com: *Infrastructure, Products & Services*: June 2003
http://www.mobileinfo.com/News_2003/Issue18/wifi_news.htm
17. TOLLROADSnews: *ABI Research things 802.11p 5.9GHz toll standard will eventually displace Cellular*: July 14th 2004
<http://www.tollroadsnews.com/cgi-bin/a.cgi/j5xsWNXDEdiRW6r2jfFwDw>
18. Fine Charles H.: *Clockspeed Based Strategies for Supply Chain Design*: Product Development & Management Association, 2005
19. Courtney, Kirkland, Viguerie: *Strategy Under Uncertainty*: Harvard Business Review
November – December 1997
20. Slywotzky, Adrian J; Morrison, David J: *The Profit Zone, how strategic business design will lead you to tomorrow's profits*: Three Rivers Press, New York, Copyright 2001,
Mercer Management Consulting Inc.
21. Ibit.
22. Ibit.
23. Ibit.

Other:

- Ewalt, David M: *Pick A Standard: Wireless Standards Proliferate*: InformationWeek: TechWeb: CMP Media LLC: May 3rd, 2004
<http://www.informationweek.com/story/showArticle.jhtml?articleID=19205552>
- Lipset, Vikki: *802.16e vs. 802.20*, Wi-Fi Planet: Jupitermedia Corporation: September 4th 2003
<http://www.wi-fiplanet.com/columns/article.php/3072471>

Interviews:

- Donna: General Motors Corp.
Personal Communication, June 2004, Warren, MI
- Jeff Flood: General Motors Corp.
Personal Communication, Sept. – Dec 2004, Warren, MI
- Kevin Fruchey: Global Telematics Portfolio Planning: General Motors Corp.
Personal Communication, June – Dec 2004, Warren, MI
- Mathiew, Roy: Global Telematics Portfolio Planning: General Motors Corp.
Personal Communication, August-December 2004, Troy, MI.
- Anapom Malholtra: Global Telematics Portfolio Planning: General Motors Corp.
Personal Communication, August-December 2004, Troy, MI.

Julius Reeves: General Motors Strategic Initiatives: General Motors Corp.
Personal Communication, June – Dec 2004, Detroit, MI

Marc Brofeurer: General Motors Strategic Initiatives: General Motors Corp.
Personal Communication, June – Dec 2004, Detroit, MI

Mark Robinson: General Motors Strategic Initiatives: General Motors Corp.
Personal Communication, June – Dec 2004, Detroit, MI

Nick Pudar: General Motors Corp.
Personal Communication, June 2004, Warren, MI

Patric Popp: General Motors Corp.
Personal Communication, June 2004, Warren, MI

Rob Farmer: General Motors Corp.
Personal Communication, August 2004, Warren, MI

Peterson, Michael L.: OnStar Inc.
Personal Communication, June-Dec 2004, Troy, MI.