The Evolution of the Wireless Equipment Value Chain

by

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Submitted to the Alfred P. Sloan School of Management
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Abstract

Mobile wireless telephone systems require enormous investments in land-based radio, transmission, and switching systems in order to provide the coverage and capacity to efficiently operate a regional or nationwide cellular phone network. This wireless equipment is manufactured by an oligopoly of Original Equipment Manufacturers (OEM). These "wireless OEMs," in turn, depend upon a growing number of "upstream" component and subsystem suppliers and "downstream" wireless operators. Together these firms compose the "Wireless Equipment Value Chain."

As in many industries where technology is changing rapidly, wireless telephony has seen waves of change in industry structure. This thesis surveys the forces currently driving change in the industry, outlines scenarios that describe potential directions for reorganization of the industry structure, and lists a set of warning signs that may provide clues to future trends within the industry. In addition, the thesis provides a model for the structure of the industry, which is used to construct the scenarios. Finally, it compares the strategies of two large OEMs using the models and scenarios.

Thesis Advisor:	Professor James M. Utterback David J. McGrath Jr. Professor of Management and Innovation
Thesis Reader:	Professor Henry Birdseye Weil Senior Lecturer, MIT Sloan School of Management

Acknowledgements

Finishing this thesis and the MOT program would not have been possible without the love and support of my wife, Mary, and my sons, Matthew and Andrew. The work behind this document is dedicated to the sacrifices they made to support my dream. Without my family support, I doubt that I could have completed the MOT program.

I would also like to acknowledge the unfettered support of Professor James M. Utterback. His guidance, brainstorming, patience, and advice were instrumental in providing me with the focus needed to complete this work. During our many lunches and discussions, I felt both encouraged by his feedback on my early work and challenged to push outside of my comfort zone.

In addition, I would like to acknowledge the kind support of Professor Henry Birdseye Weil and his dedication as a mentor and advisor. His advice on scenario planning and frameworks for modeling complex interactions within industries were invaluable to my learning.

Finally, I would like to acknowledge the support of three alumni of the MIT Sloan School and three of my classmates in the MOT program who supported my efforts through meetings and discussions over coffee, donuts, and many a beer: Mick Bass (MOT 2000), Wayne Boulais (MBA 1996), Bob Donahue (MOT 2000), Toshiro Kawahara (MOT 2002), Philip Lim (MOT 2002), and Arvind Venkateswaran (MOT 2002).

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1 Introduction

From an industry that began with fewer than a hundred thousand subscribers in 1984, by the end of 2001, wireless phone subscribers grew to over 125 million subscribers (see figure 1-1) in the United States. According to the Cellular Telecommunications and Internet Association, the Cumulative Annual Growth Rate (CAGR) for wireless subscribers has been 57% over the past 15 years.[1]

Figure 1-1 Cumulative Subscriber and Cell Site Growth in the US

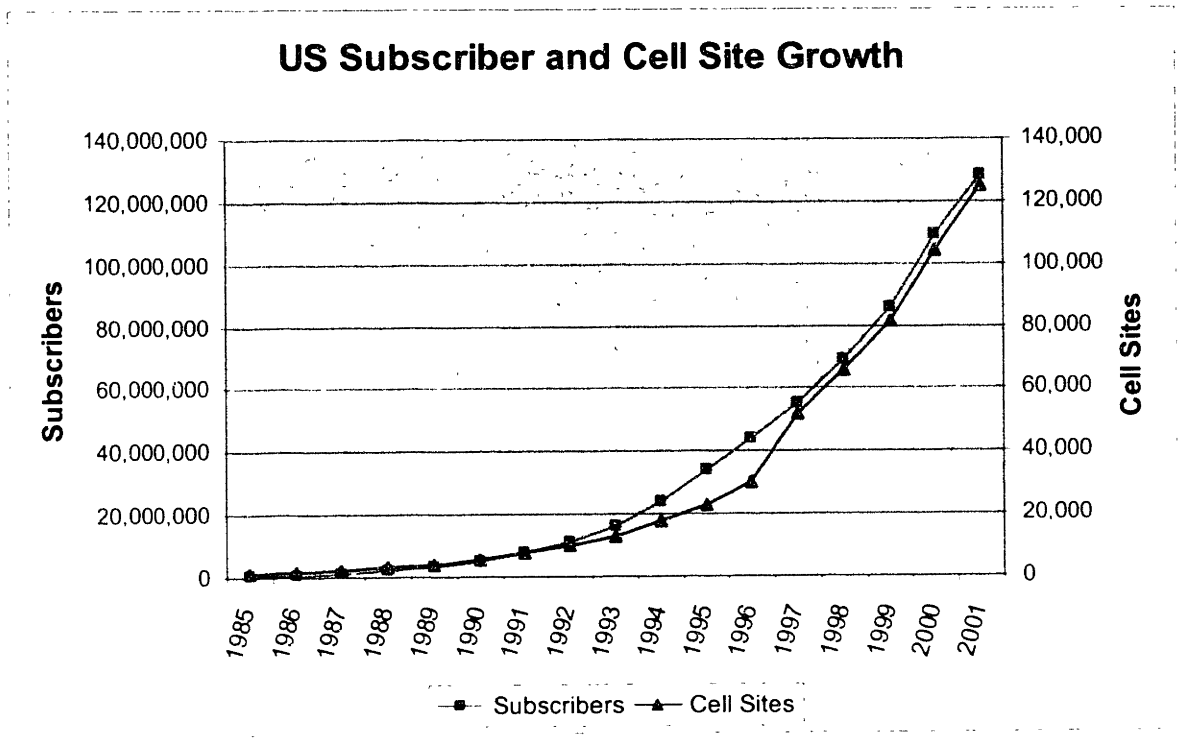
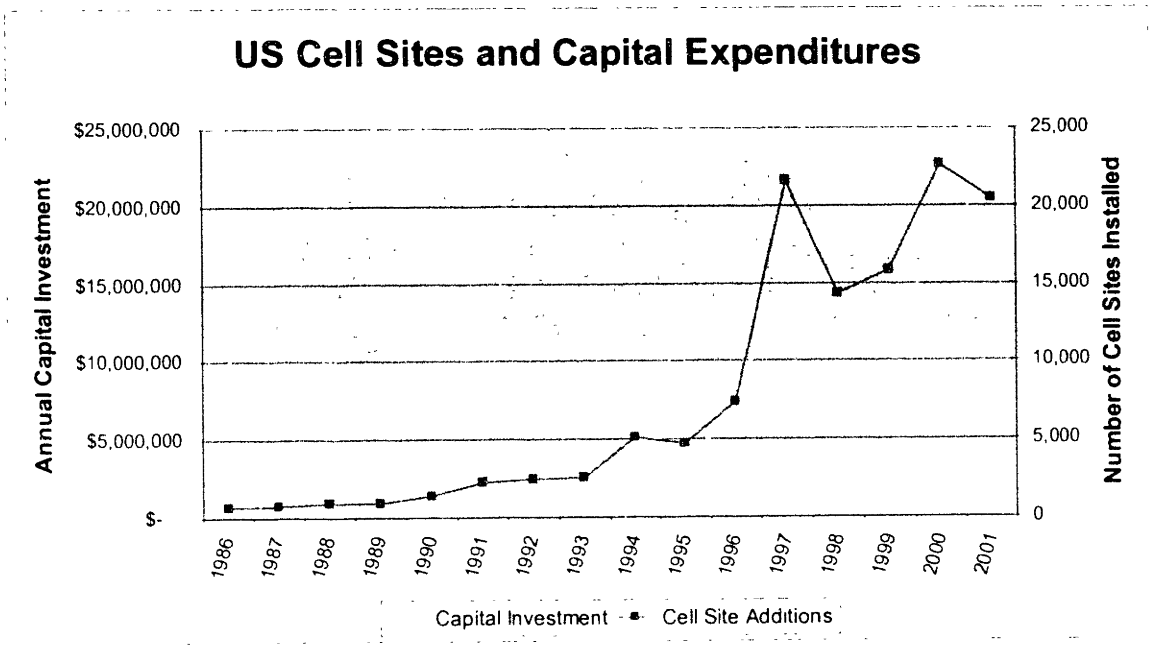


Figure 1-2 shows a comparable rise in the number of radio towers (cell sites) in the US relative to the number of subscribers. In order to provide the coverage and capacity to stay ahead of this phenomenal growth, wireless operators have made enormous investments in land-based radio, transmission, and switching systems. This wireless equipment is manufactured by an oligopoly of vertically integrated Original Equipment Manufacturers (OEM). These "wireless OEMs", in turn, depend upon a growing number

[1] Cellular Telecommunications and Internet Association, Semi-Annual Wireless Industry Survey, June 2001.

of "upstream" component and subsystem suppliers and together these firms compose the "Wireless Equipment Value Chain".

Figure 1-2 Annual Cell Site Additions and Capital Expenditures in the US



At the top level, the wireless service value chain contains four principle types of firms: Wireless Component Suppliers, Wireless Subsystem Manufacturers, Wireless OEMs, and Wireless Service Providers. Figure 1-3 shows the top firms in each of these categories and the following sections describe how these firms create value.

Figure 1-3 Wireless Equipment Value Chain

- **Wireless Component Suppliers** – Wireless component suppliers provide the semiconductors for a wireless network. These suppliers are either part of larger wireless equipment providers or independent component vendors supplying parts to the major equipment manufacturers. Some of these firms where created as wireless equipment manufactures divested themselves of their semiconductor electronics divisions, including the spin-off of Agere Systems by Lucent and Infineon Technologies by Siemens. Other firms have grown organically within the wireless marketplace, including major suppliers such as Qualcomm, Texas Instrument, and Analog Devices.

- **Wireless Subsystem Suppliers** – The internal R&D units within the wireless equipment manufacturer's organizations dominate this segment of the value chain. These units design the core subsystems for most wireless systems. Nevertheless, the segment is slowly evolving towards allowing more stand-alone firms to supply subsystems to the OEMs. Several of these firms are on the boundary of the manufacturer's core competencies: high-power amplifiers for radio basestations (Mitec, Powerwave, Spectrian), wireless messaging systems

(Glenayre), optical network interfaces (Tellabs), and microwave network interfaces (Harris).

- **Wireless Equipment Manufacturers** – Six large global firms control this segment of the wireless value chain (Ericsson, Motorola, Nokia, Lucent, Nortel, and Siemens). One competency of the manufacturers is to integrate, test, and deploy the various hardware and software components of these very complex systems. Integration requires knowledge of the subsystems and adamant adherence to discipline and quality that is usually associated with a production operation. OEMs stock labs with millions of dollars of equipment configured with every conceivable option. Also they invest in developing specialized test equipment that can exercise this variety of configurations. In addition, wireless equipment manufacturers develop specific skills around deploying wireless systems including: spectrum planning, project management, and network engineering.

- **Wireless Operators** – Wireless operators manage the day-to-day operations of the physical wireless network and market the service to particular customer segments. Operations staff is positioned at Network Operations Centers (NOC) throughout a geographic region and field service personnel are dispatched to radio tower sites to repair or correct problems with the network. The marketing organization controls the promotion and back-office operations including advertising the service, acquiring the customer accounts, and providing for billing, service provisioning, and customer service support.

The focus of this thesis is not whether, but how the Wireless Equipment Value Chain will evolve over the next three to five years. More specifically: What would the value chain of the wireless equipment manufacturers look like under the conditions of a new dominant architecture, open standards, and modular components? These trends will inevitably lead to the disintegration of incumbent wireless equipment manufacturers in a manner similar to the mainframe computer manufacturers circa 1980. Additionally, the adoption of improved components and architectures will cause the leading wireless infrastructure companies to fragment and specialize in a manner similar to the current

computer industry. Today firms along the value chain compete within an industry nurtured by massive growth. Nevertheless staying ahead of this growth, as opposed to quality of service, has been the industry's top priority.

US Wireless Industry Priority: Growth, Not Quality

The phenomenal growth in wireless telephony has come at the expense of the overall system quality and service. Current wireless services in the US are incredibly unreliable, especially outside of our urban centers. Consumers fundamentally accept this as either a fact of life or inherent to the technology. There is widespread user dissatisfaction with network coverage in terms of call reliability and quality[2]. Consumers look for better coverage and quality by switching wireless operators. Operators have responded to this "churn"[3] by marketing longer-term contract pricing plans that lock consumers into their offerings for up to two years. On average each wireless operator in the US loses over one third of its customers to churn each year[4].

The wireless operators seem to accept the status quo in that they are investing huge amounts into their networks without a corresponding increase in the overall level of quality. For example, April Sands, spokesperson for Verizon Wireless acknowledged:

> "We're spending $4 billion on our network this year - we're continuing to invest and improve." Pointing out that RF technology will always be fallible in places due to its very nature, Sands explained at the point of sale, "we talk to our customers about how they use the phone and guide them as to how it works," though not all Verizon resellers do this at present[5].

Thus the wireless operators have come to accept the limitations of wireless technologies because they are fundamentally dependent upon one or more of the infrastructure providers to maintain and grow their existing networks.

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[2] Calls For Poor Coverage to be Exposed, by Elizabeth Biddlecombe, Total Telecom, 23 August 2001.

[3] Churn is the term used in the industry to describe the percentage of existing customers lost to other service providers. In the first quarter of 2001, service providers lost more than 6 existing customers for every 10 new customers added (The Wireless Industry Scorecard, Legg Mason, 2Q 2001, p. 12).

[4] Ibid. At an average monthly churn rate of 2.5% in 2001, a operator loses 34.5% of its subscribers annually.

[5] Calls For Poor Coverage to be Exposed, by Elizabeth Biddlecombe, Total Telecom, 23 August 2001.

According the to Yankee Group:

> Coverage is always in great demand, and the facilitation of new base stations to provide the necessary coverage is becoming increasingly important. However, the tower paradox looms, in that we want the benefits of tower coverage without the towers. Even though the wireless/mobile industry enjoys reasonable market penetration, the most prevalent complaint among the mobile user community (particularly in the North American markets) is the unreliable nature of wireless coverage. To some extent, the public has learned to live with the inconvenience; however, as we move toward the implementation of advanced wireless data services, which potentially require the much promised "Always-Connected" functionality, the need for improved network coverage grows in importance. It is true that for the purposes of personal information management (PIM), synchronization techniques assist in filling gaps in coverage by providing a holding pattern for otherwise ready-to-send data, but these techniques cannot overcome the coverage limitations of many wireless/mobile networks[6].

Thus as the new types of data services proliferate, the demand for reliable coverage will likely grow. Intuitively, the status quo in the wireless industry is unstable. With literally hundreds of firms vying for profits within this growing industry, it should not be surprising that the industry structure is evolving. However, given the enormous range of factors driving the industry and the continuous technological changes impacting these firms, the nature of this evolution is virtually unpredictable.

Research Questions

This thesis does not attempt to make specific predictions about the future of the industry. Instead, it explores the structure of this complex industry and attempts to suggest how it could change given several scenarios that may transpire. This research should be used only as a basis for learning about the industry or for developing strategic plans for specific firms within this value chain.

Framing my research and subsequent writing are a number of questions that I will attempt to explore in depth, including:

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6 The Yankee Group, The Wireless/Mobile Tower Outsourcing Industry: Understanding the Market Dynamics, Wireless/Mobile Technologies Report Vol. 2, No. 8, July 2001.

- What are the dominant system architectures and business models prevalent within the wireless industry today?
- Is the basis for competition between the wireless operators about to change? If so, under what conditions would a new basis for competition emerge?
- Under what conditions would the wireless OEMs disintegrate into horizontally structured system integrators?
- What would the value chain of the wireless equipment manufacturers look like under the conditions of a new dominant architecture, open standards, and modular components?
- What role do the financial markets play in the structure of the wireless value chain?
- How will new business models impact the value chain?
- When will the market for wireless telephony saturate and transition to a slower growth trajectory?

This work will present data, models, and scenarios that suggest answers to these questions.

Document Structure and Research Frameworks

The research for this thesis is grounded in several important specializations of recent business and economic research relating to innovation in firms and industries. Each chapter draws on different frameworks as follows.

Chapter 2 introduces the current state of the wireless industry today from the point of view of the Wireless OEMs. This chapter draws on many of the core tools and frameworks provided during the Management of Technology program. Additionally, it also draws on Professor Utterback's model of the stages of industry evolution. It includes a description of the dominant architecture and business model present within the industry today.

Chapter 3 identifies, refines, and explains the key building blocks for the scenarios that follow. The primary framework for the research has been an amalgamation of the

Scenario Planning methods outlined by Russell Ackoff, Arie de Geus, Peter Schwartz, and Pierre Wack. The chapter focuses on both trends assumed to be "predetermined" for each subsequent scenario and also several "driving forces" which impact different actors in value chain through a complex dynamic. The chapter also uses the frameworks from Clayton Christensen's research to describe individual forces that may be moving the basis of competition within the industry. The chapter relies on the research into Modular Systems as described by Baldwin and Clark, and Langlois and Robertson, as a basis for the arguments made. Finally, the data for the chapter is based on numerous industry research reports and the book by John Burnham titled "The Essential Guide to the Business of US Mobile Wireless Communications."

Chapter 4 develops a causal loop model and the scenarios themselves. This research hinges upon research by Professor Henry B. Weil, and draws from the frameworks of System Dynamics best presented in John Sterman's book, to develop a causal loop model of the wireless industry value chain. This modeling technique provides a more explicit view of the interactions and dynamics between the various actors in the industry. Following the development of the model, the chapter introduces five likely future scenarios outlining a range of possible evolutionary paths for the industry. These scenarios provide a richer understanding for the reader than the static models alone can convey.

Chapter 5 presents an application of the model and scenarios to the strategic competitive environment between the two largest wireless OEMs: Nokia and Ericsson. This chapter relies on the frameworks introduced by Professor Rebecca Henderson in her Technology Strategies course. Specifically, it is based on her papers on Architectural Innovation and the Dynamics of Standards Driven markets. It also draws on some of the work by David J. Teece, especially his paper titled "Profiting From Technological Innovation."

Chapter 6 provides a list of warning signs and the possible strategic actions various members of the wireless equipment value chain should note given the previous analysis. In this chapter I return to Peter Schwartz' work to suggest a set of "signals" that should be monitored by those interested in the direction of the industry.

Chapter 7 concludes the thesis by returning to the questions outlined in this chapter and suggesting the most likely evolutionary direction for the wireless equipment value chain.

Background Information

For those with a particular interest in a more detailed understanding of the architectures and systems in modern wireless telephony and wireless LAN systems, please refer to the following books:

> Wireless and Mobile Network Architectures by Yi-Bang Lin and Imrich Chlamtac, Wiley, 2001.
>
> WLAN Systems and Wireless IP for Next Generation Communications by Neeli Prasad and Anand Prasad, Artech House, 2002.

2 Current State of the Wireless Industry

This chapter introduces the current state of the wireless industry today. First, it describes the current technology transition from second to third generation mobile systems throughout the world. Second, it explains the wireless industry value chain in more detail and examines the profit structure along the value chain. Next, it provides a Porter's analysis of the industry environment and describes the dominant design for wireless systems today. In addition, it describes the auxiliary role of mobile applications environments, alternative data networks, and capital equipment financing in relation to the value chain. Finally, it illustrates a vision for an idealized system design that should be considered as the target for further discussion.

2.1 Worldwide Technology Migration Plan

Figure 2-1 shows the current migration plans for the major wireless telephone markets in the world. By the end of 2003, every major market will have begun their transition to Third Generation (3G) technologies. Korea and Japan are the early adopters of the technologies and are about six months to a year ahead of the rest. North America is next, and Europe is a laggard in terms of the overall adoption schedule. Most consultant reports expect Wideband Code Division Multiple Access (W-CDMA) in its various forms will eventually occupy 75-85% of the total market by 2006, with CDMA2000 following with 15-20% of the world total.[7]

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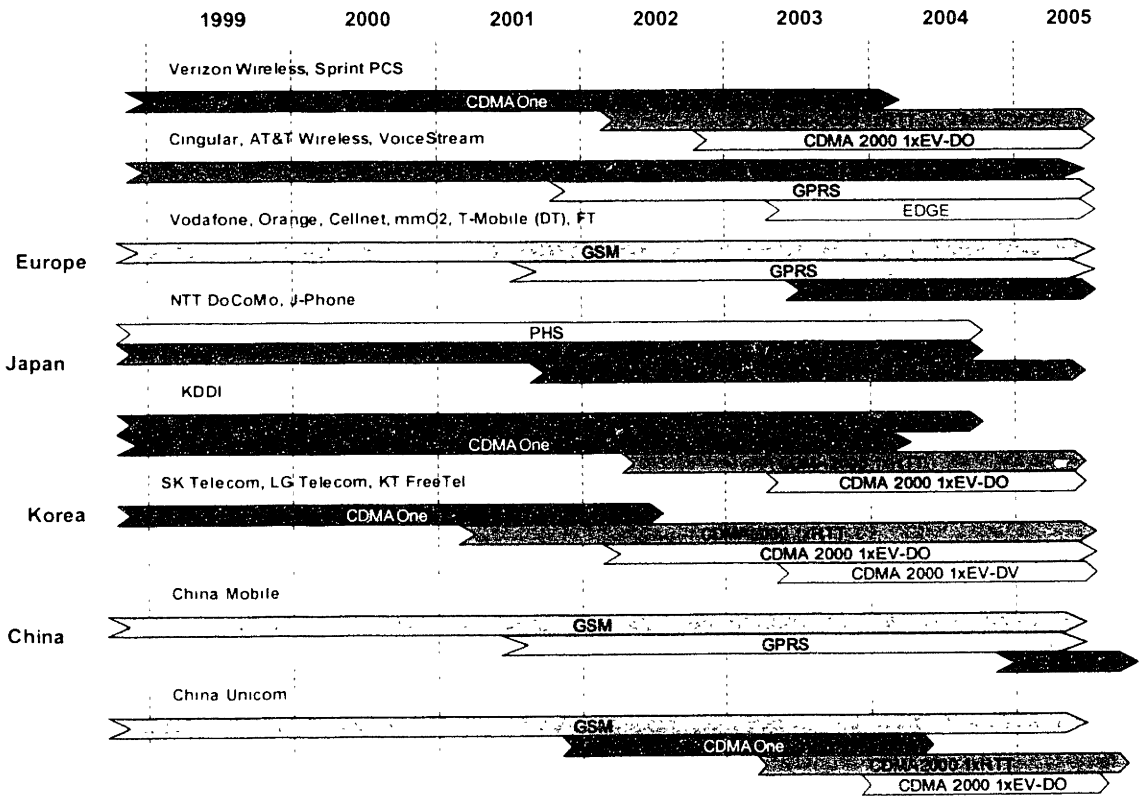
[7] W-CDMA is a European and Japanese supported standard for 3G. CDMA2000 is a US supported standard for 3G.

Figure 2-1 Worldwide Wireless Technology Migration Plans



North America shows two extremes in the migration path where two technology camps exist: Code Division Multiple Access (CDMA) and Time Division Multiple Access (TDMA). The CDMA operators (Verizon and Sprint PCS) will have a clear advantage due to the limited capital costs of upgrading from CDMAOne to CDMA2000. These firms have begun a process of upgrading at a cost of about $40,000 per basestation. The TDMA operators believe that they can survive for the next two years with Global System for Mobile communications (GSM) and extended data services from the General Packet Radio Service (GPRS), delaying the rollout of 3G until at least 2004. Thus they are upgrading to GSM/GPRS at a cost of $20,000 per basestation, and then upgrading to W-CDMA at an additional cost of $100,000 per basestation. However, the limited bandwidth and consequent increased latency of the GPRS system may allow CDMA operators to exploit a competitive advantage. Since costs are likely to drop at equivalent rates between the technologies, we conclude that the cost difference and the two-year delay will put the CDMA camp at a significant strategic advantage.

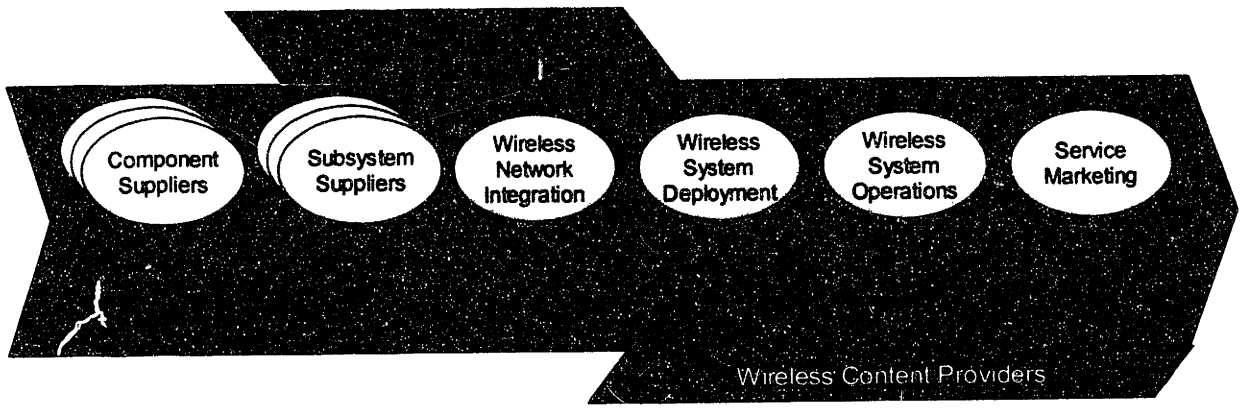
In Europe the transition to W-CDMA has just begun with installations expected by the end of 2002, and operational service expected by the middle of 2003 in Germany, the UK and France.

In Japan the transition to W-CDMA technologies is required out of necessity. In order to provide the capacity necessary to meet demand, new frequencies were allocated for 3G services and an accelerated program to develop W-CDMA for Japan was begun. NTT DoCoMo has agreed to cover all of Japan with their 3G service by the end of 2003.

2.2 Dominant Business Model for Wireless Operators in the US

This section outlines the dominant business model in place among US wireless service providers today. Figure 2-2 outlines the wireless service delivery value chain that dominates the current US market. This section reviews the current structure in more detail as it delineates each of the players in the value chain from the point of view of their functional contribution to the total value created in the industry. Some of the functions (ovals in the figure) may be accomplished by either a single firm or by multiple firms.

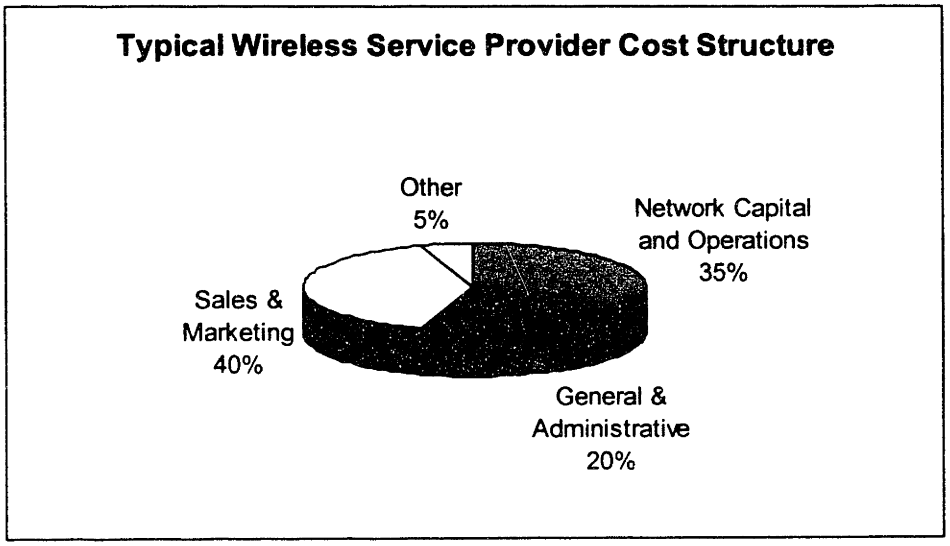
Figure 2-2 Layers in the Wireless Service Delivery Value Chain



- **Component Suppliers** - Component Suppliers provide the electronic components for subsystems in a wireless network. As mentioned earlier, these suppliers are either part of larger wireless equipment providers or independent component vendors that supply major equipment manufacturers.

- **Subsystem Suppliers** – As mentioned before, the internal R&D units within the wireless OEM's organization currently dominate this segment of the value chain. These units design core subsystems for most wireless systems.
- **Contract Electronics Manufacturers** - In recent years most of the large wireless equipment manufacturers have made concerted efforts to divest their subsystem manufacturing capabilities to outsourced contract manufactures such as Solectron Inc. and Flextronics International Ltd.
- **Wireless Network Integrators** - One of the primary core competencies of the wireless OEMs is their ability to integrate and test the various hardware and software components that make up these very complex systems.
- **Wireless System Deployment** - Deploying a metropolitan area cellular network requires many skill sets including: RF Planning, Real-Estate Acquisition, Project Management, Facilities Management, and Network Engineering. These multi-functional teams must provide disciplined adherence to the overall quality goals of the wireless equipment manufacturers. This is a critical core competency that is currently distributed between the major wireless OEMs and the operators.
- **Wireless Operator** - Historically the Wireless Operator controlled the marketing and back-office operations. The Marketing function includes marketing the service, acquiring the customer accounts, and providing for billing, service provisioning, and customer service support. The Wireless System Operations function manages the contracts and deployment of the networks, operates the existing network, and owns the spectrum licenses. Figure 2-3 shows the cost structure for a typical wireless service provider in the US and Europe. It is notable that close to 50% of the cost structure is dedicated to the network operations, while the remaining portion is devoted to marketing the service.

Figure 2-3 Wireless Service Provider Cost Structure

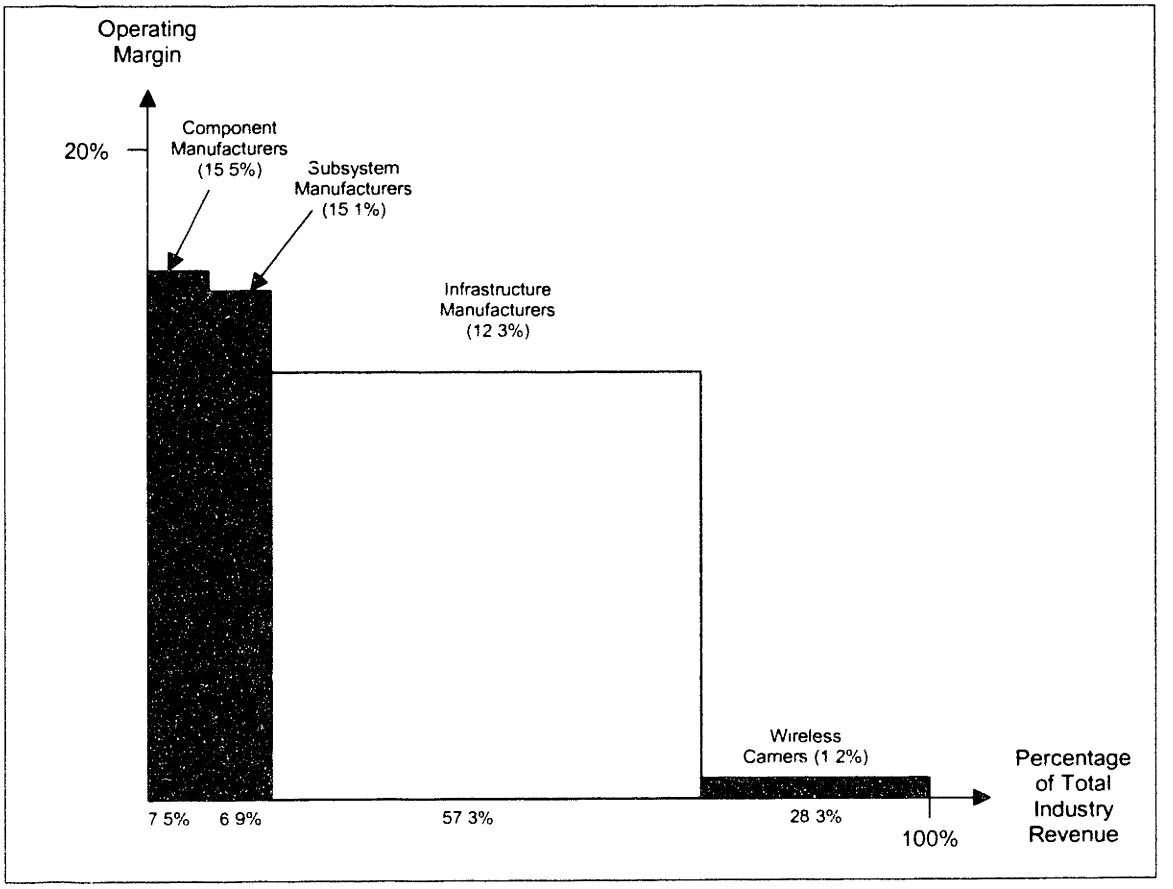


- **Network Operators** - Network Operators manage the day-to-day operations of the physical wireless network. Staff is positioned at the NOC and throughout the geographic region.
- **Service Marketing** - Wireless operators are constantly looking for an edge against their competition. However, since most of the providers are beholden to one or two wireless equipment manufacturers, they have little ability to differentiate their basic product (voice and data bandwidth) from their competitors. Thus marketers use service plans, wireless data content, and exclusive phone contracts to market their service to particular user segments.
- **Content Provider** - Typically several independent providers are licensed by a wireless operator to supply content to the wireless device. This content can include news, weather, shopping, animation, games, ringtones, music, and videos. Occasionally a "content aggregator" will supply a host of "channels" to a single operator. The content providers pay slotting charges to get prime positions in the channel lineup (similar to Cable TV).

2.3 Profit Structure with the Wireless Service Value Chain

Figure 2-4 shows the overall profitability for each segment on the value chain according to Profit Pool analysis. As can be seen from the diagram, while the component, subsystem, and infrastructure manufacturers have enjoyed reasonable operating margins, the wireless operators' margins continue to be low (or negative in many cases). This is a simple graphical explanation of where the profits flow in this market. The infrastructure manufacturers take advantage of their competitive position to produce high profit margins across a large revenue base.

Figure 2-4 Profit Pool Diagram for Wireless Value Chain[8]

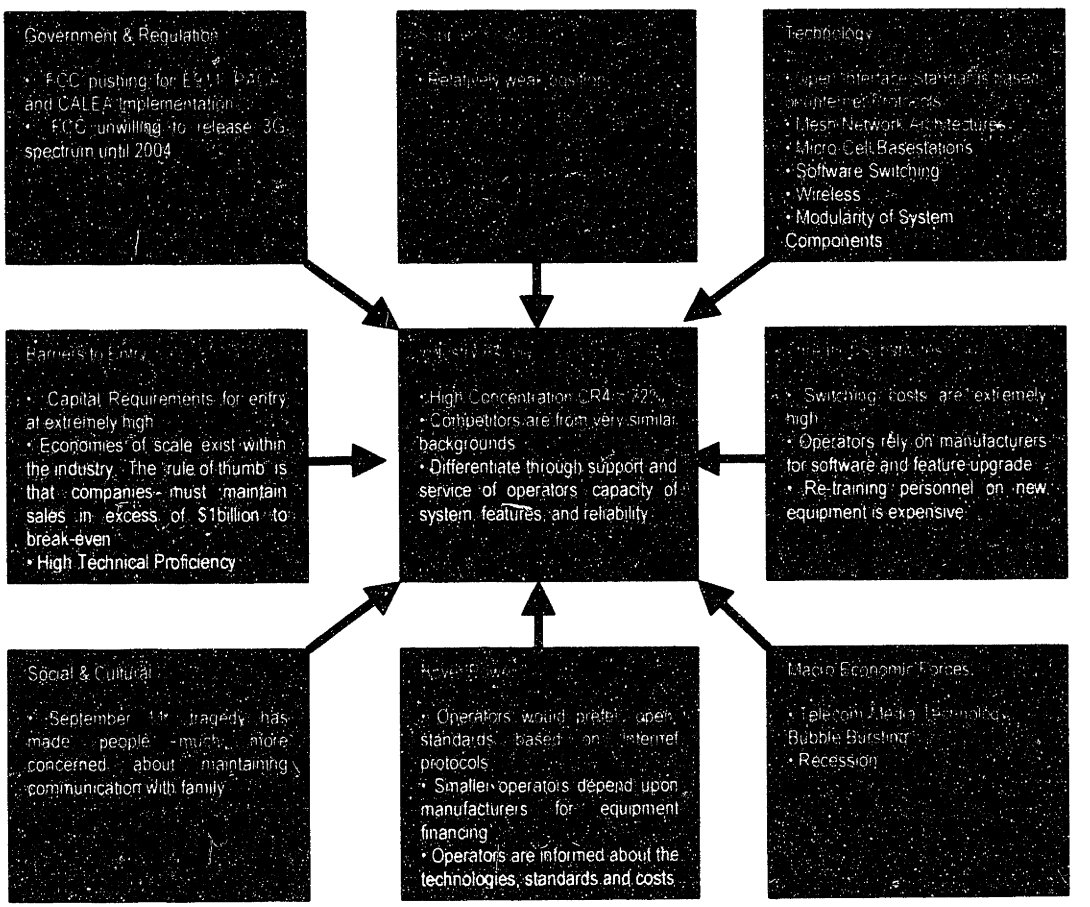


[8] Orit Gadiesh and James L. Gilbert, "Profit Pools: A Fresh Look at Strategy", Harvard Business Review, May-June 1998.

2.4 *Competitive Environment for Wireless OEMs*

Many of the aspects of the industry environment can be assembled via an analysis of the wireless infrastructure industry according to Michael Porter's Five Forces model, as shown in Figure 2-5. [9]

Figure 2-5 Porter's N-Forces Analysis for the Wireless Infrastructure Industry



[9] Extended in Prof. Starling Hunter's class to nine forces including: Technology, Social & Cultural, and Government & Regulation, and Macro-economic Forces.

Industry Rivalry

As mentioned before, there is a very high concentration of market share among the wireless infrastructure manufacturers. Since the major specifications for the systems are essentially the same, these big players tend to become affiliated with a given set of wireless operators based on long-term relationships.[10] Wireless operators do show a preference for certain manufacturers based on technology or familiarity with the system, yet the primary justification for any system purchase is the cost per subscriber that the system can carry.

Barriers to Entry

Barriers to entry include capital, competence in wireline switching, and large patent portfolios. The capital requirements to enter this industry are quite high. Developing a system from the ground up would take a minimum of $2 to $3 billion over a minimum of five years. Of today's major players, Ericsson, Nokia, Lucent, Nortel, and Siemens were all wireline telephone switch providers prior to 1980 and Motorola has provided mobile radios since the 1940's. Each of these companies has built portfolios of patents and strong technical competencies in switching, microprocessors, software, protocols, and radio design.

Buyer Power

Buyers have little power in the market because, while operators would prefer open standards between the wireless equipment providers, the current reality is that only a few major interfaces are open. In addition the smaller operators depend upon the wireless infrastructure manufacturers to finance their equipment purchases. Yet wireless operators do drive the standardization process to some extent by their presence at the meetings. In addition they retain technical teams who constantly scan the markets for component systems that can be adapted to their equipment in order to offer differentiated services.

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[10] In some cases these relationships are based on the heredity of both companies from the original AT&T prior to the 1984 divestiture. For example, many of the Regional Bell Operating Companies (RBOCs) still prefer Lucent Technologies equipment.

Power of Suppliers

The component suppliers in general have a relatively weak position in negotiations with the wireless infrastructure manufacturers unless they have some unique intellectual property or differentiated.

Substitutes

The costs of changing suppliers are extremely high for the wireless operator. Also the operators rely on their manufacturers for frequent software and feature upgrades. Finally, re-training personnel from one system to the next can be time consuming and expensive.

Technology

Perhaps one of the forces with the greatest potential to change the nature of the industry is the relentless march of technology. There are several areas of emerging technologies, which may impact the wireless landscape.

Government Regulation

Since the September 11th attacks on New York City and Washington, D.C., the FCC has stepped up the pressure on the wireless operators to begin implementation of several features long delayed due to their economic impact.[11] The FCC has additionally announced a compromise disallowing any additional spectrum auctions until 2004.[12]

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[11] There is now more urgency for wireless providers to upgrade their equipment in order to deploy the location-based E-911 features into the systems because they are now perceived as an essential lifesaving service. Pressure from the public and regulatory officials is going to make it difficult and expensive to delay E-911 service rollout beyond the Oct 1, 2001 deadline. In addition, wireless providers have to consider the cost and implication of implementing a system that accords priority on wireless networks to key government officials in times of emergency (the so called Priority Access and Channel Assignment or PACA feature). The wireless industry also has to address the wiretap requirements of the Communications Assistance for Law Enforcement Act (CALEA) of 1994, balancing customers' concern over privacy issues and the social responsibility for national security and public safety.

[12] Washington Internet Daily, October 9, 2001, *Bush Administration Unveils New 3G Plan, Removing Threat to DoD.*

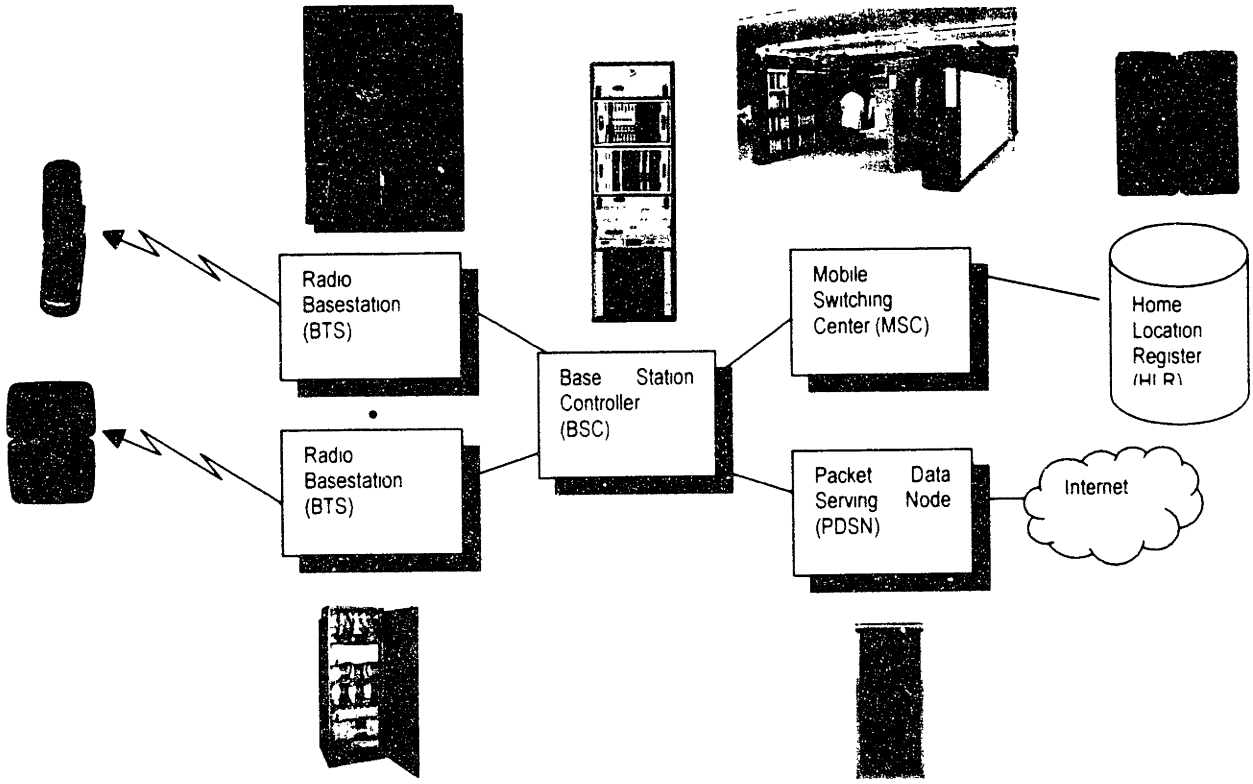
Social and Cultural

Also since the September 11th attacks, people have generally become more concerned with staying in touch with family and friends. Therefore, the demand for wireless communications due to security concerns has increased.

2.5 The Dominant Design of Wireless Infrastructure in 2001

This section outlines today's wireless system architectures and the characteristics of the dominant design present within the industry, as shown in figure 2-6 below.

Figure 2-6 Detailed Block Diagram of the Major Components of a Cellular Network[13]



A typical wireless phone system is made up of the following major components:

- **Radio Basestations (BTS)** – This equipment sits near the radio towers and transmits and receives signals from the cellular telephone. A typical system

includes hundreds of these basestations spaced from between a half mile up to five miles apart.

- **Base Station Controllers (BSC)** – This equipment controls hundreds of basestations and translates the digital information to voice and data formats compatible with today's networks. It is usually located in an air-conditioned environment (e.g., a computer room) near the switching systems. A system may have 1-4 BSCs.
- **Mobile Switching Center (MSC)** – This is a special version of a wireline telephone switch that is designed to handle cellular telephone calls. Usually only one MSC is deployed within a city per wireless operator.
- **Home Location Register (HLR)** – This system component is designed to hold relevant information about a given subscriber. It typically holds the current location, service plan, and encryption information for up to one million subscribers.
- **Packet Data Serving Node (PDSN)** – This is the local termination point for the Internet into the wireless network. The PDSN provides for allocation of IP addresses as well as routing and buffering of data for wireless data sessions to the mobile handsets.

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[13] Information for this figure was derived from Network Reference Model for CDMA2000 Spread Spectrum Systems, Revision A, Third Generation Partnership Project 2, December 13, 1999.

Table 2-1 shows some of the common specifications for the dominant design of these major subsystems.

Table 2-1 Wireless Infrastructure Dominant Design

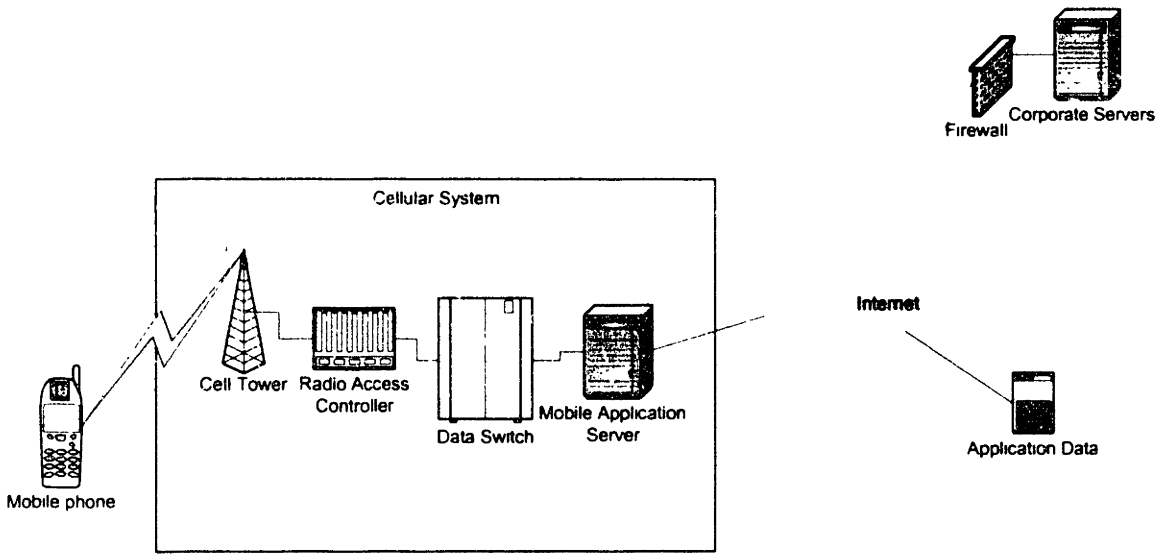
Subsystem	Dominant Characteristics
Basestation (BTS)	Output Power of 12 Watts/MHz/Sector
	Integrated Power Amplifiers
	Dual Rack (RF and Digital) Cabinets
	Proprietary Protocols to the BSC
	Packetized Backhaul over E1/T1
	Code Division Multiple Access Physical Layer (CDMA2000 or W-CDMA)
	Synchronization via GPS
	Uninterruptible Power Supplies from 8 min to 8 hours
	Capacity of 25 0 Erlangs/Carrier/Sector
	Outdoor Operating Temperature -35°C to 50°C
	Physical Footprint 12 ft^2
Base Station Controller (BSC)	Supports 50 to 150 Basestations per BSC
	Integrated Operations and Maintenance Function
	Total Call Throughput 3,000 – 7,000 Erlangs
	Inter-operable with multiple vendor MSCs
	Physical Footprint 60 ft^2
Mobile Switching Center (MSC)	Capacity scales from 500,000 to 1,000,000 Busy Hour Call Attempts (BHCA)
	Handles 80,000 to 160,000 simultaneous subscribers
	Open IS-41 over SS7 Interface to the HLR
	Open "A" Interface to the BSC
	ISUP over SS7 Interface to the wireline network
	Supports Adjunct System for Voice Mail and Short Messaging
	Physical Footprint 500 ft^2
Home Location Register (HLR)	Capacity scales up to 2,000,000 subscribers
	IS-41 Protocol Compliant
	1,200 to 3,000 Transactions per second
	99 996% Availability
Packet Data Service Node (PDSN)	Capacity scales to serve up to 64,000 simultaneous PPP sessions

2.6 Wireless Data Application Environments

Mobile Application Platforms are enabling an increasing level of customization of the user's mobile data experience. These platforms allow a level of personalization that is key to the overall adoption of wireless data for the average user. The Mobile Application Platforms examined here share a number of common characteristics. A generic architecture for these platforms is shown in figure 2-7 and described below. There are three major components of the platform: 1) Software on the Mobile Phone, 2)

Transmission Bandwidth supplied by the Cellular System, and 3) the Mobile Application Server that utilizes data from public and corporate content providers.

Figure 2-7 Generic Architecture for Mobile Application Platforms



- **Mobile Phone** - In order to support custom mobile applications, the mobile phone must be augmented with additional software. Typically this includes a micro-browser (a limited version of a PC Internet Browser), a Java Virtual Machine, a more advanced real-time operating system, Internet protocol stacks, and extra memory and processing resources (sometimes including a co-processor).

- **Wireless System** - The wireless data system supplies the "always on" Internet packet connection to the mobile phone. The speed of these connections is increasing from the 2G systems (Personal Digital Cellular or PDC in Japan and CDMAOne in the US) at 9.6 or 14.4 Kbps to the 3G system (CDMA2000 and W-CDMA) of 144Kpbs to 2.4Mbps. Typically the user pays by the packet transmitted over the network during application or data download.

- **Mobile Application Server** - A key component of these systems is the application server. Many important functions are implemented inside the server including: authentication of users, billing, application catalog

management, application download, and access to public and corporate data servers.

Table 2-2 examines the common characteristics of the four mobile application environments that are likely to dominate the market in the coming years. Each environment has a unique approach and some common characteristics that are typical of the fluid phase of this market's development.

Table 2-2 Summary of Mobile Application Development Environments

Mobile Application Development Environment	Real-time Operating System	Applications	Location Services	Java Support	Application Download	Wireless Systems Supported	Connectivity and Multi-Media Support
Qualcomm's BREW	Supplied by Handset Manufacturer	Email, PIM	gpsOne and SnapTracs	J2ME	MobileShop	CDMA2000	USB, Bluetooth, PureVoiceMail™, IP, WAP, cHTML, Qsynth™, CMX™, IP Voice Chat, MP3, QTV™, MPEG4
Nokia's Series 60 Platform	Symbian OS	Standard POP3/IMAP4 Email		Symbian's kJava	MIDLet standard (Sun and Nokia)	GSM/GPRS and W-CDMA	WAP, SyncML, Multimedia Messaging Service (MMS) Short Message Service (SMS), Bluetooth, IrDA, and Flash file devices.
NTT DoCoMo i-Mode						PDC, W-CDMA	cHTML (DoCoMo's defacto standard)
Microsoft Windows® Powered Smartphone 2002	WindowsCE	POP3 and SMTP		MIDP-compliant JVM (not supported by Microsoft)		GSM/GPRS and W-CDMA	USB, IrDA, Bluetooth, HTML, WAP, and cHTML

In order to "expand the pie" and offer compelling content, wireless operators need to provide a business model that provides incentives for the operator, the content providers, and the customer to obtain value. An example of the "virtuous cycle" created is NTT DoCoMo's attempt to open up their network to all comers. In February, DoCoMo opened its i-Mode local service to any content provider. Previously, DoCoMo had limited its portal to content providers that it had selected as partners.[14]

2.7 Alternative Data Networks

Competing networks are vying for transmission of wireless data between Internet-based servers and mobile devices, as well as, between the devices themselves.

- **Metropolitan Area Networks (MAN)** - These networks, traditionally known as "cellular" phone networks, include 2.5G (GPRS, EDGE) and 3G systems (W-CDMA, CDMA2000). They may also eventually include data-only wireless networks using so-called "4G" technologies. Data rates range from 14.4Kbps to 64Kbps for 2.5G systems and 150Kbps to 2Mbps for 3G systems. Access point coverage ranges from 500m to 8Km and beyond.
- **Wireless Local Area Networks (WLAN)** - WLAN networks include Enterprise, residential, and eventually "hot spot" access points using the IEEE 802.11b standard. Current technology operates up to 11Mbps in the 2.4GHz unlicensed band. An emerging standard IEEE 802.11a is designed to operate at data rates up to 54Mbps in the 5GHz unlicensed band. In addition, there is a competing ETSI Broadband Radio Access Network (BRAN) family of standards marketed as HIPERLAN 1/2 that support up to 25Mbps access, and HYPERLINK that supports up to 155Mbps data rates.[15] Another popular WLAN product is HomeRF. HomeRF 2.0 provides data rates up to 10Mbps and operates in 2.4GHz ISM band, but only up to range of 50 meters.[16]

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[14] February 25, 2002, "NTT DoCoMo Opens Access To Local Wireless Net Service", By Adam Creed, Newsbytes.

[15] Prasad, Neeli and Anand Prasad, WLAN Systems and Wireless IP for Next Generation Communications, Artech House, 2002, pp. 25-32.

[16] Chinitz, Leigh, HomeRF Technical Overview (www.homerf.org).

- **Personal Area Networks (PAN)** - Bluetooth is a true PAN standard for connections up to 721Kbps and ranges up to 10m. Bluetooth also operates in the 2.4GHz ISM band. In addition, IEEE 802.15 is working on a PAN standard to operate up to 55Mbps.

2.8 Capital Equipment Financing Options

This section will examine the current financing options open to wireless operators.

Equipment Vendor Financing and Debt Securitization

One of the most popular methods of competition among wireless equipment manufacturers is to use vendor-financed "bridge loans" to enhance their competitive position. Vendor's use their balance sheet and financial capacity to increase their debt leverage to provide lower-cost loans to service providers. In some cases, the provider's only alternative to vendor financing would be to scale back or eliminate their equipment purchases.

Typical vendor finance deals are structured with a single payment due at the end of the contract. This financing does not impact the vendor sales in that they are allowed to recognize the revenue as the equipment is installed even though the actual payments may be delayed far into the future. In a sense, the vendors are financing their equipment sales with future cash flows destined to be generated by the wireless operators. In another sense, they are stuffing the distribution channel with products that would not otherwise be purchased in order to maintain their revenue stream.

Vendor financing can be a double-edge sword because it can over-leverage a vendor's balance sheets and cause liquidity problems during economic downturns. In the late 1990's Lucent Technologies was a major victim of its own largess as some of their largest wireline customers Winstar and OneTel declared bankruptcy. More recently the Turkish wireless operator Telsim has refused to make payments on loans of $2 billion from Motorola and $719 million from Nokia.

One of the areas where the major vendors have pushed vendor financing is in the competition for 3G contracts in Europe. As table 2-3 shows, the total exposure for these vendors from just their European customers is substantial. Nokia has by far the

largest exposure relative to its contracted sales and is essentially buying its way into a higher 3G-market share using the cash flow from its mobile phone sales.

Table 2-3 Vendor Financing Exposures by Suppliers in the European W-CDMA Market[17]

Supplier	Amount (mEuro)	Mobile System Sales 2001E (mEuro)	% of existing revenues	Examples
Ericsson	1,000	16,500	6%	Mobilcom
Nokia	3,500	6,000	58%	Hutch; Orange
Siemens/NEC	1,200	8,500	14%	Hutchinson
Alcatel/Fujitsu	500	3,000	17%	Orange France
Nortel	1,500	5,000	30%	BT, Xfera,
Motorola	500	5,500	9%	Telsim
Lucent	1,800	4,500	40%	Group 3G
Total	10,000	49,000	20%	See list above

Another tactic used by vendors to remove debts from their balance sheets is to securitize or bundle a number of the "bridge loans" into a package and sell these to a combination of banks and insurance companies. During economic booms, this tactic recharges the vendor's ability to finance additional sales while not causing extraordinary impacts to their finances. Unfortunately the game of musical chairs has to stop at some point and the wireless equipment manufacturers are usually left with the most risky loans on their own books. Alternatively, they are forced to discount the securitized loan packages and write off the resulting loss. This cycle of vendor financing and debt securitization is summarized in the figure 2-8.

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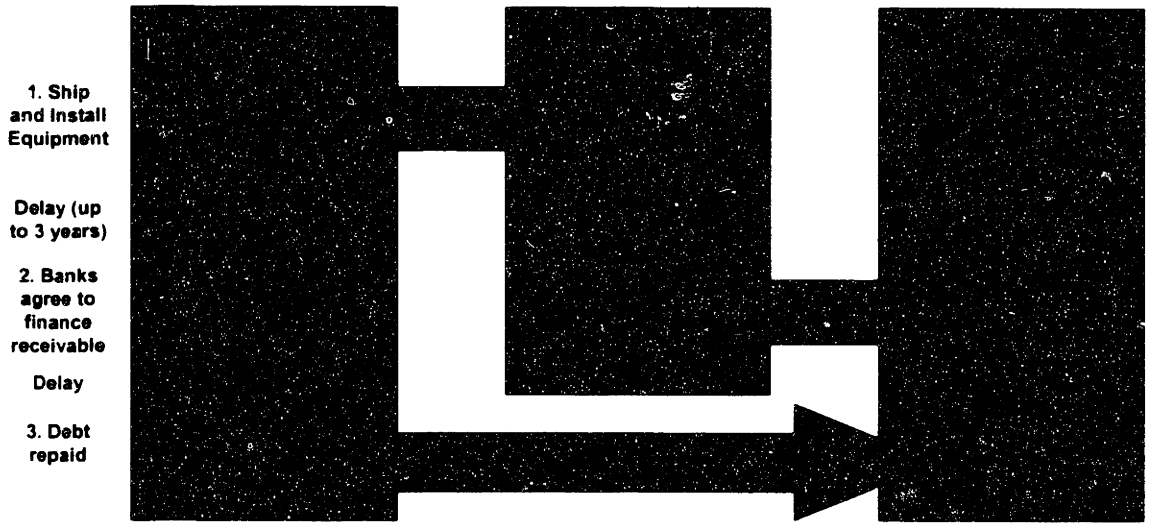
[17] Source: Dresdner Kleinwort Wasserstein Report. Mobile Infrastructure, January 9, 2002

Figure 2-8 Vendor Financing and Securitization Cycle[18]



One serious question that is being asked is: "If the markets will not finance the project, why should we be happy that the vendors will?" One reason that vendor investments are required is the sheer volume of financing required to deliver the 3G systems in Europe. Another reason is that the wireless operators want more flexibility in how they finance their capital expenditures. Banks are only willing to finance debt from established operators.[19]

Wireless Operators Self Financing

Established operators can also use some of their own cash flow (assuming it is positive) to finance the purchase of additional equipment. Table 2-4 summarizes the Capital Expenditures (capital equipment) vs. Profitability (EBITDA) for the "Big 6" operators in the US. While Cingular and Verizon appear to be close to the ability to self-financing, the remaining companies are not. Given a strong enough balance sheet and cash flows, the corporate bond market would be open to these players.

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[18] Source. Schroder Salomon Smith Barney: Vendor Financing: Bark Probably Worse than its Bite, May 4, 2001

[19] Schroder Salomon Smith Barney: Vendor Financing: Bark Probably Worse than its Bite, May 4th, 2001, p.5.

Table 2-4 Capital Expenditures vs. Profitability for the Big 6 US Wireless Operators[20]

Big 6 CAPEX	1Q00	2Q00	3Q00	4Q00	1Q01	2Q01	3Q01	Annualized
AT&T Wireless	$795	$1,215	$810	$894	$1,122	$978	$1,055	$3,925
Cingular Wireless	$290	$247	$582	$1,000	$406	$619	$500	$2,082
Nextel	$661	$686	$666	$963	$640	$616	$534	$2,723
Sprint PCS	$693	$742	$675	$937	$655	$1,060	$1,150	$3,378
Verizon Wireless	$473	$913	$992	$1,944	$988	$1,384	$970	$4,379
VoiceStream	$261	$331	$479	$511	$599	$471	$385	$1,735
							Total	$[illegible]

Big 6 EBITDA	1Q00	2Q00	3Q00	4Q00	1Q01	2Q01	3Q01	Annualized
AT&T Wireless	$ 431	$ 550	$ 472	$ 381	$ 788	$ 858	$ 803	$2,447
Cingular Wireless	$ 933	$ 1,052	$ 1,086	$ 853	$ 972	$ 1,252	$ 1,233	$4,218
Nextel	$ 262	$ 323	$ 392	$ 418	$ 352	$ 483	$ 526	$1,575
Sprint PCS	$ (181)	$ 11	$ 122	$ 21	$ 253	$ 491	$ 402	$639
Verizon Wireless	$ 1,171	$ 1,319	$ 1,453	$ 1,221	$ 1,409	$ 1,566	$ 1,631	$5,583
VoiceStream	$ (105)	$ (53)	$ (222)	$ (280)	$ (120)	$ (107)	$ (95)	($501)
							Total	$[illegible]

Asset-Backed Leasing

In addition to vendor financing, banks, and free cash flow, there are a number of financial service companies that provide lease financing (off balance sheet) for wireless operators, including GE Capital's Telecommunications Financial Services and the AmeriLease Corporation

Revenue Sharing Plans

This scheme allows the wireless operator to accept the equipment with little or no money down and keep a higher percentage of their cash This approach allows the wireless operator to put off payment for equipment until certain financial milestones have been met, for instance in terms of revenue intake or subscriber growth Should an operator fail to successfully launch its services, the supplier is liable to incur write-down costs for a substantial part of the whole amount of the receivables

Risk-revenue sharing

In exchange for direct payments, the wireless OEM receives a certain percentage of the wireless operator's future cash flows (limited to a time period of a few years) Compared with pay-as-you-grow, this arrangement increases the financial leverage of

Source: Legg Mason 3Q 2001 Wireless Industry Scorecard

the OEM and reduces that of the operator. However, as with options in general, the financial terms are typically defined so as to offset the risk-adjusted cost for the operator. Importantly, risk-revenue sharing ties the financial interests of a supplier to that of a given operator and may therefore make it more difficult to win competing customers.

Equity participation

As a final method, the supplier may take a minority interest in the wireless operator through equity participation schemes. Thus, the economic interests of the OEM and the operator are integrally linked.

2.9 Idealized Wireless Industry Structure Going Forward

Following the scenario-planning methodology outlined by Dr. Russell Ackoff, the first step involves imagining a "clean slate" and today's technology.[21] What characteristics would be desirable for in a wireless system? Asking users about what is wrong with today's cellular service is a good way to understand what an idealized service should be. First and foremost, it should solve today's problems:

- **Coverage** – a uniform expectation of assured coverage inside buildings, in subway tunnels, maybe even inside elevators. Calls would initiate (originate) within 5 seconds greater than 99.9% of the time. Calls ending due to a coverage or network problem would occur less than 0.1% of the time.
- **Voice Quality** – it should be easy to recognize the speaker and to hear what he is saying. There should not be any discernable echo. The volume of the call should be uniform and reasonable. An ideal system would have the voice quality of the current wireline system.
- **Costs** – a uniform per-minute charge and unlimited coverage on nights and weekends should be available. Minutes would be charged according to the actual time of usage down to the second. There should also be no unexpected charges accumulated against the account. Account information will be available both

[21] Russell L. Ackoff, Creating the Corporate Future, pp. 104-125.

through the Internet service page and through the phone's web browser. Special charges for roaming service will be built into the regular per-minute cost of normal service.

- **Service Selection** – the user would be able to select an operator that has the best service offering. There would no longer be any contracts or penalties for switching between service providers.
- **Service Flexibility** – the user would be able to change the parameters of their service offering through a web page without penalty. They could add features (e.g., Call Waiting, CallerID, etc.) on a per-call or per time-period basis.

In addition to the basic services outlined above, there are a number of potential services that should be provided as options at a higher cost

- **Wireless Data** – "always on" data services should be provided through the phone system. The incremental fixed cost of adding the service should be less than $100 (additional cost of upgraded phone or data card for PCs). Wireless data would be available at speeds that start at 64Kbps (superior to current dial-up services) and scale up to 1Mbps (superior to current broadband services).
- **Internet Content Availability** – There would be no restrictions on the content that users could obtain through their wireless provider. Each web page on the Internet would be given equal access from any device.
- **Worldwide Roaming** – the phone that you use in any country would have the ability to digest a signal within the populated areas of any other industrialized country. A user would be able to initiate a call without any credit verification. A user would be able to receive calls on his personal number anywhere in the world.
- **Personalization Services** – the network would understand your context including location, time-of-day, and interests. Applications could make use of these data to deliver context-specific offers, alerts, warnings, or news.

Idealized Suppliers

In addition to the service offering, equipment providers play an important role in innovation of new features and services. Ideally equipment providers would specialize in areas that reflect their core competencies.

- **Open Interfaces** – each major piece of equipment within the cellular system would be open to multiple competitors. Open standards would be applied to wireless systems in much the same way that the Internet has done with computer systems.
- **Performance Innovation** – suppliers would focus on differentiating themselves based on the performance of their component. Innovation would come faster within each system component.
- **Emerging System Integrators** – since the level of complexity involved with installing, tuning and operating a wireless system increases in relation to the number of companies involved, wireless systems integrators would take over this specialty function.

Idealized Regulation

Normally, when considering the question of Idealized Regulation, the answer is that no regulation is the ideal. In fact this is not necessarily the case. Regulation is required to insure that monopolies or oligopolies are not formed in any one area of the value chain. Typically this is done through regulations that attempt to divide the market into a dozen or more competitors.

- **Spectrum Allocation** – Spectrum should be allocated to those that can provide the greatest near-term benefit with it. Thus, an ideal system would allow spectrum to be shifted between operators on an unregulated and short-term basis. A real-time auction system should be put in place to assess the value of spectrum on an open market.
- **Access to Location** – In order to verify the whereabouts of a particular user in an emergency, the operators would be required to record the last known position of

a person and have the capability to provide these locations to rescue authorities in a timely manner.

Idealized System Architecture

Functionality of a wireless system can be broken down into the following very simplified areas:

- **Virtual Networks** - In today's circumstances a single equipment provider offers almost all of these functions. In an idealized system, the architecture would function as a connected mesh of nodes that could offer one or more of these services to a provider. If a node fails, then additional equipment would be able to take over the load of that node. If a node runs out of capacity, then some of its load would be automatically shifted to surrounding nodes.
- **Distributed Ownership of Elements** - Networks could be built in real-time from the best offering of resources. Individual nodes could be owned by anyone willing to "host" the equipment (e.g., similar to micro power generation relative to the grid). For example, a homeowner could install a wireless access point on his house and sell the access service back to the operator.
- **Wireless "Grid" Operator** – a "grid operator" who controls the allocation of spectrum and the regional installation of access points would service the access network. Individuals could apply to provide service through this system. If someone did not like the coverage of the cellular system in their area they could do something about it. Service providers would be required to purchase all of their system access through the grid. The grid operator would control the entire spectrum and would model access applications as a single unified service system. The grid operator would insure proper access and capacity by continuously monitoring call statistics vs. location and by testing the system on a continuous basis.
- **Automatic Capacity Balancing** – Operators will be able to use the correlation between drop call reasons (e.g., loss of signal vs. user termination of call) and caller location to automatically detect areas where calls are lost. Discovery of a

coverage hole could trigger a process allowing speedy installation of additional capacity at existing sites or a new cell site.

- **Stealth Cell Sites** – Companies will continue to invest in technology allowing cell towers to be built into church steeples, faux trees, and other objects that blend into the landscape.

3 Scenario Building Blocks

3.1 Predetermined Elements

Though the "driving forces" of any scenario are important, we must also discuss elements that are virtually predetermined (or assumed to be so) for the purposes of outlining the scenarios. In this thesis, I assume the following as predetermined elements:

3.1.1 Economic Conditions

Although the US economy is undergoing a recession, it is unlikely to impact the growth of wireless telephony and data services in the longer run since the productivity improvements and utility of wireless telephony outweigh the forces of any economic slump. It is important to note, however, that any recession may delay the demand for wireless data services at a critical juncture.

3.1.2 Consolidation of Wireless Operators

It is widely recognized by industry analysts that some type of consolidation is necessary in the US, and perhaps globally. One factor driving consolidation in the US was the recent schedule adopted by the FCC to completely lift caps on spectrum ownership by January 1, 2003. This restriction is seen as allowing the current "Big Six" operators to drop to the "Big Three." Current analysis assumes operators will consolidate around common technologies with some combination of AT&T Wireless, Cingular, and VoiceStream merging around the GSM standard, while Verizon, Sprint PCS, and Nextel merge around the CDMA standard. While economies of scale can be found in wireless operations, consolidation is more likely to be due to the weaker competitors' failure to continually respond to the pressure of upgrading their networks and services.

As the competition for wireless subscribers increases, marginal operators will either file for bankruptcy or merge with stronger players. This trend has already begun in Europe due to the heavy debt burdens incurred by the 3G operators for spectrum licenses. For example, Italian mobile operator Blu SpA has recently declared bankruptcy. Telecom Italia Mobile SpA, ENEL SpA's telecommunications unit Wind

Telecomunicazioni SpA, and Hutchison Whampoa, Ltd.'s unit H3G have presented offers to buy the assets.[22]

3.1.3 Adoption of 3G Standards

As systems using both competing 3G standards (CDMA2000 and W-CDMA) come online this year, the migration to the third generation of wireless digital standards will continue in fits and starts. For CDMA2000 systems, the economics of migration are clear since the transition will double the capacity of the systems for voice calls and allow data services at peak rates above 100Kbps. The economics for W-CDMA are less clear. The investment expenses for W-CDMA networks should be mitigated through network sharing and limited rollout until a clear need for data capabilities can be shown.

3.1.4 Emergence of a Dominant Design for Wireless Data Application Environments

Wireless application development environments are currently in a state of "foment" without a clear dominant design emerging. However, some of the common characteristics of a dominant design can be seen in the I-Mode and BREW systems. For the purpose of presenting the scenarios, we assume that a dominant application environment will emerge in a short period of time. This environment will allow Independent Software Vendors (ISV) to develop applications for these wireless systems.

3.1.5 Network Sharing by Wireless Operators

In Western Europe wireless operators are cutting deals to reduce their initial capital equipment expenditures. These agreements allow multiple operators to share network resources, which potentially reduces network construction costs by 20%. In addition, there have been agreements between operators in the US, India, Canada, and several European countries as shown in table 3-1.

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[22] Wireless Internet Daily, February 25, 2002.

Table 3-1 Network Sharing Agreements

Date	Country	Companies	Technology
January 2002	US	Cingular, AT&T Wireless	GSM, GPRS, EDGE
January 2002	India	AirTel, Escotel	GSM
December 2001	Italy	H3G, TIM	GSM
December 2001	Netherlands	Dutchtone, Ben	W-CDMA
October 2001	US	Cingular, VoiceStream	GSM, GPRS, EDGE
October 2001	Canada	Bell Mobility, Telus Aliant Telecom Wireleess	CDMAOne
October 2001	Netherlands	KPN Mobile, Mm02 (BT Wireless)	W-CDMA
September 2001	Spain	Telefonica Moviles, E-Plus	W-CDMA
June 2001	UK, Germany	Deutsche Telekom (T-Mobile) Mm02 (BT Wireless)	W-CDMA

3.2 Driving Forces

This section discusses the primary driving forces[23] that will guide the future of wireless operators and infrastructure manufacturers in the next few years. These forces will lay the foundation for the industry model and scenarios developed in the following chapter.

3.2.1 Value of Wireless Applications to Users

Data applications for 3G technologies are targeted at the Enterprise and Consumer marketplaces. Certain unique characteristics will allow these applications to emerge and then dominate their respective markets. The degree to which the emerging applications meet the following characteristics will determine the value of the wireless applications to the end user.

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[23] Peter Schwartz, The Art of the Long View, p. 101.

Successful Enterprise wireless data applications share all or some of the following primary characteristics:

- **Tied Into Advanced Business Processes and Increased Productivity**–they should integrate into overall improvements in organization and business processes. The primary motivation for adoption is to get positive and significant near-term payback in the investment. Successful applications provide productive use of otherwise "wasted" time. A good application should provide some level of productivity enhancement for the enterprise user.
- **Time-Sensitive Data**–they must deliver data to the worker with a certain element of time sensitivity. That is, the data must have value within a short time window after which the value falls literally to zero as the window passes.
- **Personalized Delivery of Enterprise Data Based on Time and Location**–they are enhanced by mobility or location identification. Thus, an application includes the location context when it delivers personalized information.
- **Utilize the Capabilities of More Advanced Devices**–they should be designed for the enhanced display capability and user interface of the worker's device. Features should be simplified so they are easy to use and intuitive to operate.

Successful consumer wireless data applications will share all or some of the following primary characteristics:

- **Build User Communities**–they must give the consumer some sense of being more attached to a community. These communities could allow private conversations to take place in situations where they otherwise would be taboo, or they could bring together people in disparate geographic locations and keep them connected to each other on a continuous real-time basis.
- **Short Attention Span**–they must deliver "micro experiences" that are easy to digest and compose over a short period of time.
- **Enhance Data with Mobility and/or Location**–they are enhanced by mobility or location identification. Thus, an application is aware of the location context and

delivers personalized information specific to this location (e.g., location specific advertising).

- **Occupy or Save Time**–they either "kill" time or provide productive use of otherwise "wasted" time.
- **Fully Utilize the Capabilities of the Limited Device**–they should be designed for the limited display capability and user interface of the devices. Features should be simplified such that they are easy to use and intuitive to operate.

The demand for data services is a critical element in determining the eventual usage patterns and required capacity for the 3G systems. While the overall push from the industry experts has been towards "bandwidth hungry" applications such as real-time video and music, most applications will be characterized by the relatively low bandwidth required and their reliance on the processing being performed at the handset by specialized application code. In addition, there is widespread recognition that the "killer application" does not exist. Instead, data usage will be distinguished by large fragmentation in the number of applications. User uptake of any given application is predicted to be less that 20% of the available market. Appendix A provides a more detailed analysis that maps the market segments and devices to the type of application and wireless network.

3.2.2 Competitive Position of Mobile Virtual Network Operators (MVNO) Service Offering

In recent years a business model called the Mobile Virtual Network Operator (MVNO) has emerged as a viable option to the traditional wireless operator. MVNOs sign contracts with existing network operators in a given region for wholesale minutes on the network. According the BWCS Mobile Metrix,[24] the characteristics of a successful MVNO are:

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[24] BWCS/Mobile Metrix, MVNOs: Their strategies and role in the mobile communications value chain, 2001.

- **Provide Economies of Scale** – they must attract at least 100,000 subscribers to break even. The more subscribers they attract, the more valuable they become to their wholesale minutes supplier.
- **Lower Cost Handsets and Subsidies** – the MVNO must find a way to reduce the costs associated with acquiring customers. The largest component of this cost is the handset subsidy, thus MVNOs must work to reduce or eliminate these subsidies.
- **Sell to an Existing Customer Base Through Established Channels** – After handset subsidies, advertising and marketing expenses are the largest cost for MVNOs. Ideally a successful MVNO will build upon an established brand and sell to its existing customers first. The most notable successful MVNO is Virgin Mobile in the UK, Australia, Hong Kong and the US. Virgin has built upon their "hip" brand image in the UK to build a successful customer base. According to the Yankee Group: "Not everyone is a suitable partner for an MVNO. For a wireless operator to put its name and reputation behind a joint venture, the partner must have: brand equity, significant funding, and experience in the consumer space. Virgin Mobile certainly brings the latter two factors to the table in the United States. Its brand equity, largely derived in the United States from its Virgin Megastores and Virgin Atlantic Airways, pales compared to its reputation in the UK, where it is a household name. Companies that could conceivably become MVNOs in the United States include organizations such as Viacom's MTV, Microsoft, and retail giants such as Wal-Mart. MTV has terrific brand equity in the youth segment with ample cross-advertising opportunities, whereas Microsoft could possibly combine its Internet service with mobile voice and data services for a 'total next-generation communications' solution. Wal-Mart could use its experience as a provider of high-quality, low-cost consumer goods with thousands of existing stores to heavily market its own brand of prepaid wireless service."[25]

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[25] Yankee Group, The State of the Wireless Union – 2001 Edition, November 2001.

- **Minimize Investment in Infrastructure** – In order to minimize its fixed costs and to increase its flexibility, the MVNO should limit its investments in infrastructure like HLRs, switches, and billing systems.
- **Strong Relationship with the Wholesale Minutes Provider** – The MVNO must be able to establish a long-term relationship with the wireless operator. The operator must see the MVNO as a competitive weapon against other providers and not as a competitor in the market. According to the Yankee Group, MVNOs in the US will perhaps solve a thorny problem for the US wireless operators: they "are running out of non-subscribers who can pass a credit check. This forces operators to focus either on the intensely competitive high-ARPU business traveler segment or the less attractive low-ARPU segments of youths, minorities, and senior citizens. Mobile virtual network operators (MVNOs), such as Virgin Mobile USA, offer an attractive solution to this dilemma. The lower-ARPU, higher-churn customers reside with the MVNO, whereas the network partner is able to realize revenues derived from the MVNO without diluting its existing customer metrics."[26]

3.2.3 Financial Market Outlook for MVNOs

Financial Markets will likely assess MVNOs based purely on their ability to attract adequate numbers of subscribers and their overall cost to acquire new customers. Because of the fact that the business model is relatively new and untried, the markets may allow for a variety of MVNOs to gain initial financing while the business model matures.

3.2.4 Competitive Position of Wireless Operators

The overall competitive position of a given wireless operator will depend upon several factors including:

- **Subscriber Base** – The viability of the wireless operator is primarily determined by their ability to reach a critical mass of subscribers

- **Subscriber Churn Rate** – The wireless operators must also have a relatively low churn rate when compared to their competitors.
- **Ability to Provide Nationwide Network** – The ability to serve customers throughout a large region without incurring roaming charges is also critical to the long-term viability of the wireless operator.
- **Transition to 3G** – The overall cost of upgrading the network and the migration path to 3G technologies is also critical for the survival of wireless operators.

3.2.5 Basis of Competition Within the Wireless Industry

Figure 3-2 uses Clayton Christensen's framework from his book "The Innovator's Dilemma" to plot the capabilities of the these three primary types of wireless data networks. In addition, the figure plots the likely paths for data rates demanded by some of the more popular applications envisioned for wireless data networks.

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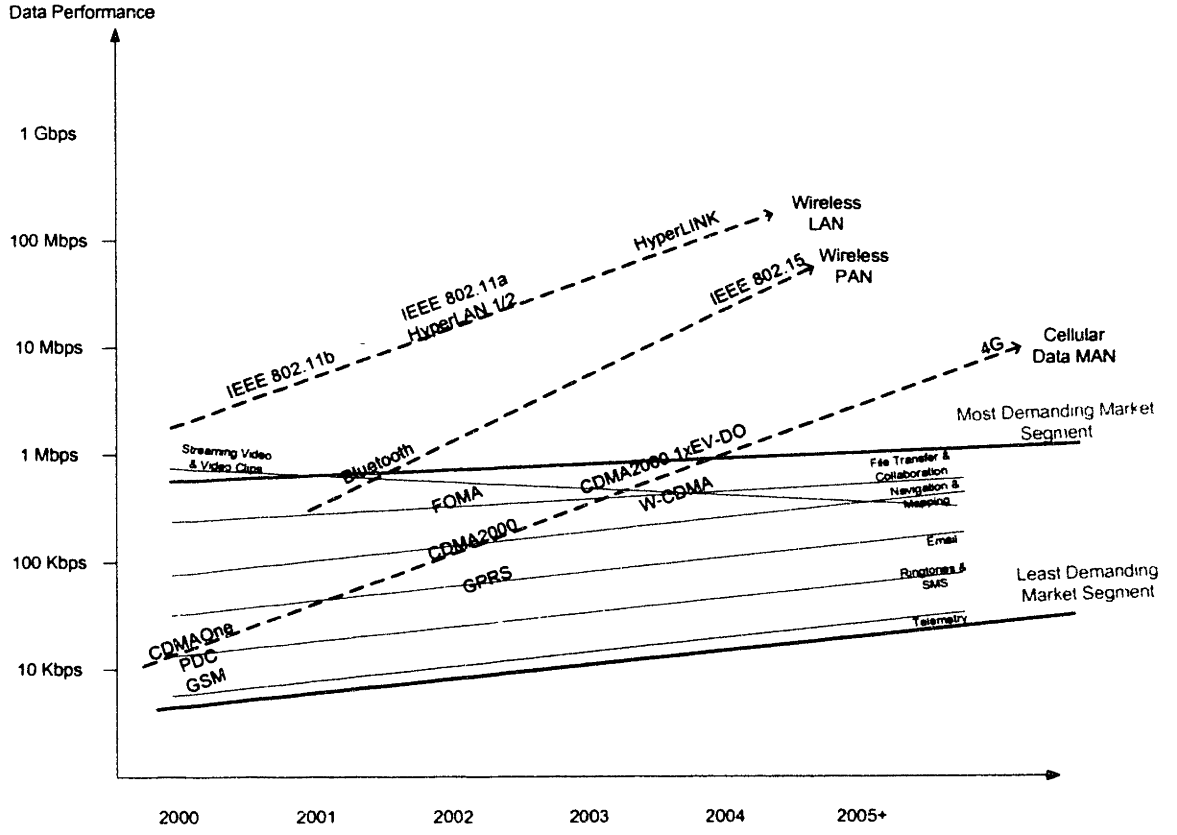
[26] The Yankee Group, The State of the Wireless Union – 2001 Edition; Wireless/Mobile Services Report Vol. 2, No. 15 – November 2001, by Roger Entner.

Figure 3-1 Trajectories of Wireless Data Applications vs. Wireless Data Network Capabilities



The figure indicates all three wireless networks are likely to begin to exceed an individual user's needs in terms of data bandwidth performance in the very near future.[27] As "performance overshoot" progresses, competition based on data bandwidth and overall capacity of these systems is no longer important.

It is also important to note that, strictly speaking, the market for wireless services is a composite of many applications for each user. This is based on the assumption that by the end of 2002, devices will likely communicate on two of the three network types (likely MAN and PAN), and that by the end of 2003, devices will be able to access all three networks.

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[27] It must be noted that bandwidth is shared among several devices in many situations. Thus, strictly speaking, exceeding an individual user's needs is in no way a hard boundary due to the aggregate data bandwidth requirements of a multiplexed population of devices.

Quoted in a recent WR Hambrecht conference call titled "The Viability of 3G,"[28] Professor Christensen made the following point:

> 3G appears to be a classic example of an established industry attempting to cram a new technology into an existing business model. Over the course of the past several years, the wireless industry has become focused on the wireless Internet (new technology) as a supplemental revenue opportunity to voice. To harvest this opportunity, the wireless industry has attempted to transfer the desktop PC Internet (existing business model) to mobile phones. In order to do so, the industry has aggressively moved to expand wireless network bandwidth by issuing expensive 3G licenses and initiating costly 3G network deployments. However, wireless Internet access may not require the full desktop PC Internet experience for the foreseeable future. For example, NTT DoCoMo's i-Mode has been extremely successful in Japan with fairly limited bandwidth capabilities (roughly 9.6 kbps), and one of the most successful i-Mode applications has been the ability to download simple cartoon pictures, which requires minimal bandwidth. Moreover, we note that short message service (SMS) has become a "killer application" in Western Europe, and also requires very minimal bandwidth.

In his comments, Prof. Christensen argues that the business model for 3G is flawed and the user demand for data bandwidth may have already been exceeded. If this is true, the wireless operator's ability to extract a premium (i.e., increasing Annual Revenue per User or ARPU) is very limited.

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[28] WR Hambrecht, The Viability of 3G Conference Call Featuring Clay Christensen, June 28, 2001.

3.2.6 Skimming of Data Delivery by WLAN and PAN Networks

Wireless LANs have clearly become a concern for most wireless operators. Initially the wireless operators dismissed the devices due to their limited range and low rate of adoption. Recently these systems have gained widespread acceptance with consumers and enterprises, forcing operators to re-think their strategies. For example Dr. Keiji Tachikawa, President and CEO of NTT DoCoMo, sees WLANs as a complementor for 3G networks. DoCoMo plans to offer IEEE 802.11b service by April 1, 2002. The service will eventually allow users to download massive data files to devices and then provide updates through the wide-area 3G networks.[29] The degree to which data services are "skimmed" by these alternative networks is an important factor to consider when assessing the wireless value chain.

3.2.7 Financial Market Outlook for Wireless Operators

Financial Constraints on the wireless operators may force them to spin off portions of their business operations or consolidate with other operators. Currently the major service providers are heavily dependent upon the corporate debt market and their own cash flow in order to finance capital equipment expenditures. Any change in the outlook of the financial markets (in general) toward the industry could constrain the wireless operator's ability to operate efficiently.

Wireless operators have certain constraints regarding the length of time to recover their investment in capital equipment. This is typically set at five to seven years, but may be reduced as the time between technology transitions is condensed.[30]

3.2.8 Wireless Operator's Capital Expenditures

Figure 3-3 summarizes a forecast made by Yankee Group in 2001 that shows the magnitude of investment required to bring the 3G technologies to market. It should be noted the forecast estimates project spending of upwards of $400 billion over the six-year period.

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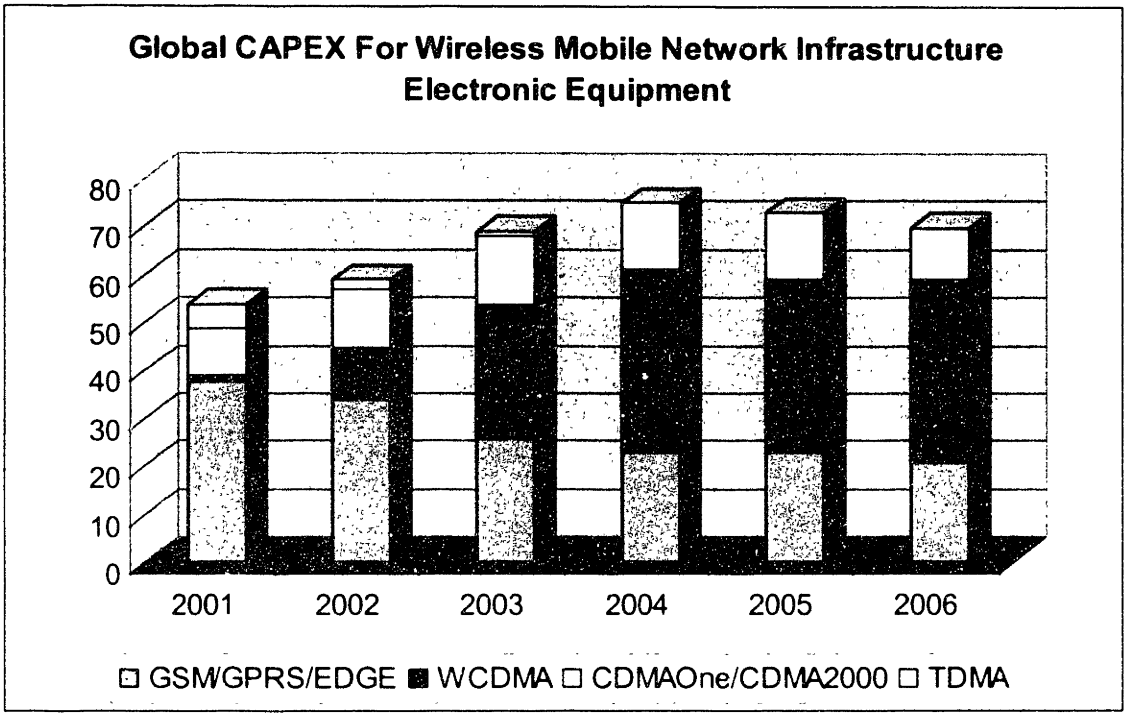
[29] Information gathered during lecture on March 27, 2002 at NTT DoCoMo headquarters in Tokyo, Japan.

Figure 3-2 Global Capital Equipment Forecast for Wireless Electronic Equipment[31]



Financing these investments is a major challenge for the industry and the financial markets.

3.2.9 Wireless OEM's Level of Adoption of a Modular System Architecture

Modular systems have known advantages over proprietary systems, including:

- An increase in the rate of innovation within the system modules
- An increase in the flexibility with which systems can be customized
- A reduction in the level of complexity facing an organization

According to Baldwin and Clark, the modularity of a given system is defined by three components (visible design rules): "an architecture, which specifies what modules will

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[30] For example, Dr. Keiji Tachikawa, President and CEO of NTT DoCoMo indicated that DoCoMo does not expect capital equipment investments to be paid back for at least five to six years.

[31] Source: Yankee Group Report, Infrastructure Capex How Much Will It Cost, and Which Vendors Will Win? , September 2001.

be part of the system and what their functions will be, interfaces that describe in detail how the modules will fit together, connect, and communicate, and standards for testing a module's conformity to the above."[32]

Although the wireless industry currently has defined architectures, interfaces, and standards, none of the systems conform precisely to any of these standards. In fact, the Big Six OEMs use the vagueness of the standards to block the compatibility of components. A close examination of the industry standards reveals huge ambiguities intentionally written into the standards to allow the interfaces between components to become essentially proprietary.[33] Also, some of the systems have significantly different architectures from the current dominant design due to this methodology of protecting the established base and incremental innovation.[34]

3.2.10 Wireless Subsystem Supplier's Adoption of Emerging Technologies

The following sections describe emerging technologies that could impact the architectures of wireless systems and thus disrupt the wireless equipment value chain. This is based on the assumption that the subsystem suppliers will adopt these technologies more rapidly than the R&D units inside the wireless OEMs.

- **Internet Protocol Based Wireless Radio Access Networks** - One of the emerging technologies is the packetization of the wireless telecom networks. This encompasses both the internal inter-connections of the wireless network components and their eventual inter-connection to the wireline phone network. This is a trend that could level the playing field for new entrants. The standards committees within the industry are currently working to model architectures and protocols, which conform to Internet standards.

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[32] Carliss Y. Baldwin and Kim B. Clark, Managing in an Age of Modularity, Harvard Business Review Sept.-Oct 1997.

[33] I witnessed this process firsthand during the development of EIA/TIA IS-41-C standard.

[34] Most notable is Lucent's system, which distributes the functionality of the BSC between their 5ESS MSC and their BTS.

- **Mesh Networks and Inter-Access Node Routing** - Most wireless networks today are designed as a "star" topology with the basestation controller (BSC) connected directly to 50 to 150 basestations. By contrast, some network firms provide "a new peer-to-peer, multipoint-to-multipoint 'mesh' wireless network that enables each node to communicate directly with another while obviating the need for expensive hubs or base stations."[35]

- **Smaller, Lower Cost Radio Systems** - As the industry has grown, the trend toward ever-smaller radio access points has continued. This "technology" actually encompasses several incremental improvements in radio amplifier efficiency, mechanical enclosures, and integrated circuit sizes.

- **Specialized Waveforms Designed for Data** - Several companies are vying for attention with so called "4G" technologies designed to emphasize data transmission and Voice-over-IP.

- **Free Space Optics** - Another emerging technology is optical frequency wireless point-to-point transmission. This technology could potentially reduce the cost of deploying and operating wireless networks to a fraction of what we see today. It also has the potential of becoming the standard for business data transmission.

- **Smart Antenna and Other Interference Rejection Technologies** - Application of cost-effective spatial beam forming and/or other interference rejection technologies is becoming more viable. However, the performance of these technologies depends upon their ability to be embedded into signal processing circuits controlled by component vendors. Agreements must be reached within standards organizations and between the technology and component vendors in order for these techniques to be widely adopted.

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[35] February 28, 2002, "Mesh Networks Joint Venture Announced", www.cellular-news.com.

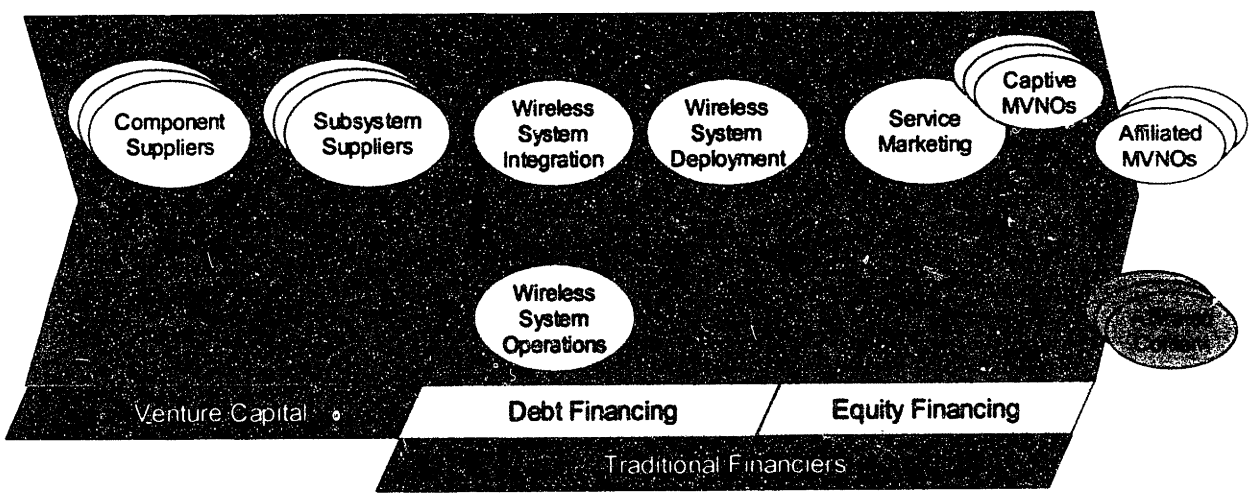
4 Causal Loop Modeling and Scenarios for an Evolved Wireless Value Chain

This chapter describes a framework for modeling the dynamics between the major firms along the wireless equipment value chain. First, it illustrates how the core functional elements of an evolved wireless value chain may emerge and the potential for new business arrangements. Next, a model is constructed for the entire value chain describing the interaction of each participant in terms of causal loop diagrams. Finally this model is used to generate a number of scenarios that describe possible paths of evolution that could bring about restructuring of the industry.

4.1 Evolved Wireless Service Delivery Value Chain

Figure 4-1 describes the functional elements that could exist inside an evolved wireless service value chain under various market and regulatory conditions. The following sections will describe the roles of each of the new wireless players.

Figure 4-1 Evolved Wireless Service Value Chain



Wireless Equipment Suppliers

If the interfaces between various subsystems become standardized, the wireless equipment suppliers will break into two tiers: Component Suppliers and Subsystem Suppliers. The Component Suppliers will appear very similar to their structure today, however they will work in networks and in partnership within specific groups of Subsystem Suppliers in order to stay current on the system issues facing these

important customers. In turn, Component Suppliers will maintain a much broader contact within the industry through standards forums, specialized subsystem groups, and contacts with their preferred Wireless System Integrator. The focus of these groups will be toward constant innovation within their specialized domain and relatively free flow of information between subsystem suppliers. Given this structure of the industry, the Wireless Equipment Suppliers will more likely be financed through networks of Venture Capital funds that include both corporate VCs as well as pure financial VCs.

Wireless Bandwidth Wholesalers

This segment of the value chain represents a radical shift based on economies of scale for operation of nationwide consolidated wireless systems. These firms combine the Wireless Systems Integration and Deployment Planning functions of the wireless equipment manufacturer with the Network Operations functions of the traditional operator. These companies will own the spectrum licenses and will consolidate the properties of the current wireless operators. Network operations will scale up to handle a minimum of 30 million subscribers.

The Wholesale Bandwidth providers will have the primary need for capital equipment debt financing. They will sign long-term contracts with the "Pure Play" Wireless Service companies for bandwidth at various service quality levels. Thus, these providers will contract for the minutes of many millions of customers and realize significant economies of scale. Also, the Wholesale Bandwidth providers will find financing much easier due to the relative predictability of their cash flows. In addition, because of the relative commoditization of the Wireless Subsystems due to the standardization of interfaces and modular functionality, the capital equipment costs will fall and the company's overall profitability will rise. Finally, banks and other financial institutions will find the aggregation of customers and minutes of use can be conveniently securitized and sold into secondary markets.

"Pure Play" Wireless Service Companies

The so-called "Pure Play" Wireless Service Companies will combine the marketing divisions of the wireless service providers with the MVNO model and captive content. In a way these companies will be analogous to cable television companies that match

content to particular bases of consumer. Of course, the difference is that the wireless Internet allows nearly infinite flexibility in terms of providing specialized and personalized channels of content through affiliated service MVNOs and specialized devices to small "micro-segments" of customers.

These Wireless Service Companies will have "captive" and "affiliated" MVNOs that will project their brand image to the end consumer. The role of these MVNOs is to:

- provide a differentiable service through brand name, community/status, and experience for a commoditized product,
- to reduce the revenue risk to the operators currently encumbered with physical networks by guaranteeing wholesale minutes into the future, and
- to allow for the micro-segmenting and provision of mass-customized services to like-minded groups of users.

The "Pure Play" Wireless Service companies will have much more flexibility in their financing. They will essentially be valued based on their abilities to retain customers and provided convincing content. They will most likely be either equity financed, due to their limited physical asset base, or self-financed if their revenue stream is somewhat stable.

4.2 Causal Loop Model

This section uses the causal loop diagrams of System Dynamics[36] to analyze how the various players in the wireless service value chain relate to each other. This section will build a "thought simulation" of the wireless equipment value chain from the top down. Figure 4-2 shows the top level of the model. The major players include the Wireless operators, the Wireless OEMs, the Consumers, MVNOs, and the Subsystem Suppliers. A detailed view of this complete model is shown in Appendix B.

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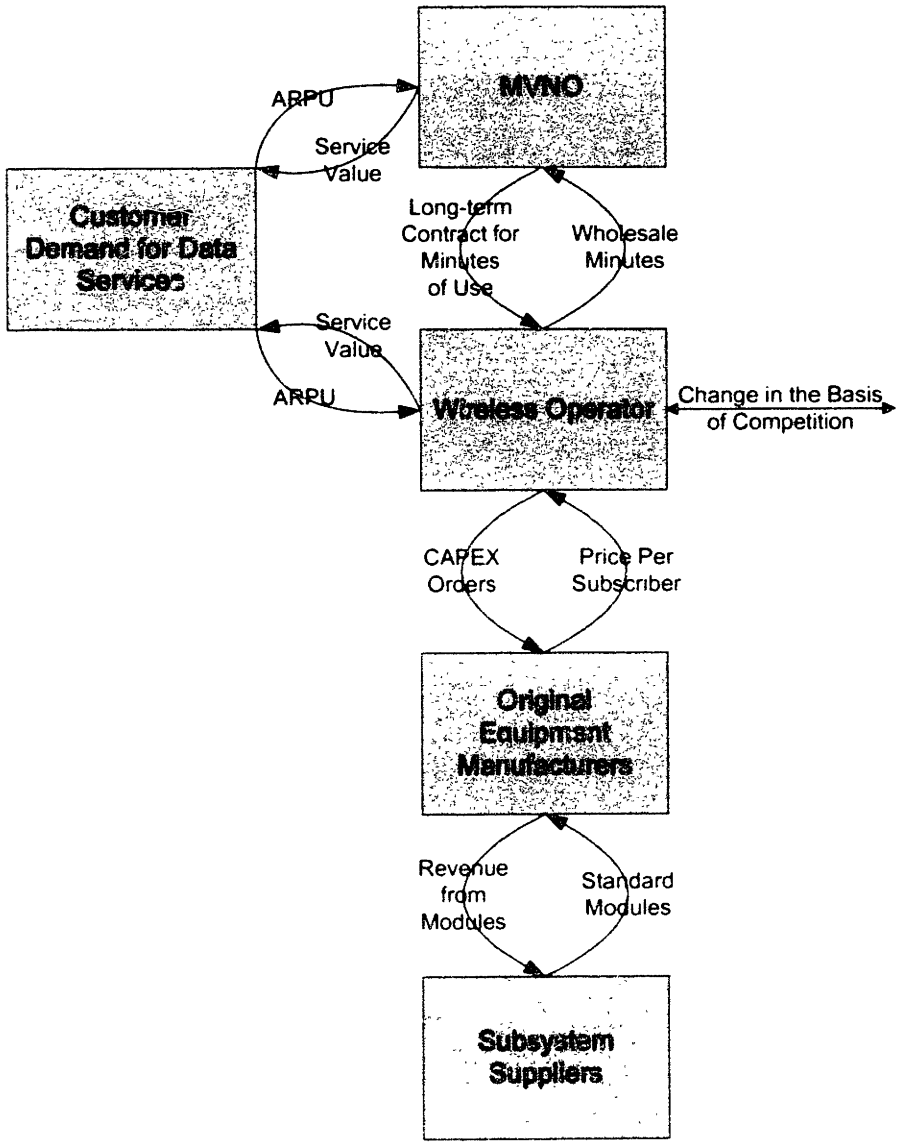
[36] Business Dynamics, John D. Sterman, 2000.

Figure 4-2 Causal Loop Model of Wireless OEM Value Chain

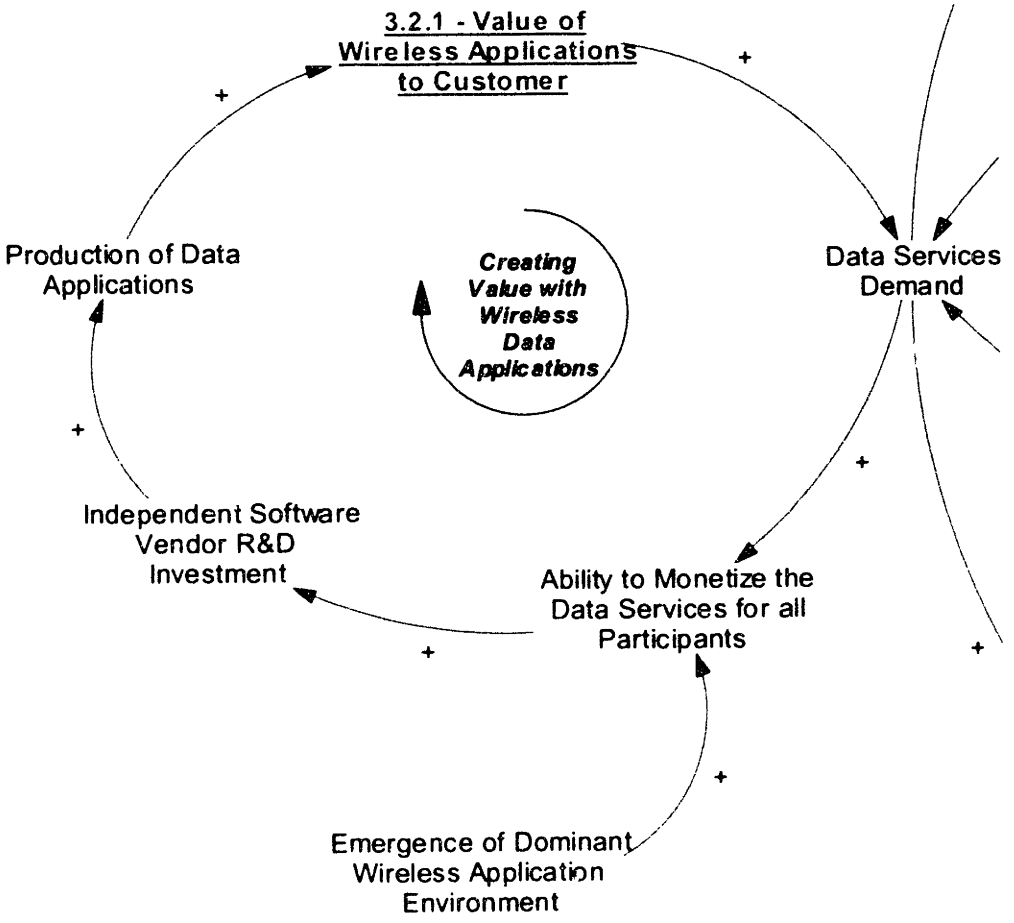


4.2.1 Customer Demand for Wireless Data Applications

Figure 4-3 shows a causal loop diagram representing the customer demand for wireless data services. The driving force of this reinforcing loop is the value of wireless applications to the customer (as described in section 3.2.1). This factor determines the overall data service demand, which, in turn, determines the ability of wireless operators to monetize the data services for all the participants in the value chain. The ability to

equitably share profits from service offering will create the incentive for innovation and will spur the ISVs to invest in R&D. Investments in R&D result in the production of additional new applications and services. Finally, the end users determine the value of the new applications and the loop feeds back upon itself.

Figure 4-3 Customer Demand for Wireless Data Applications



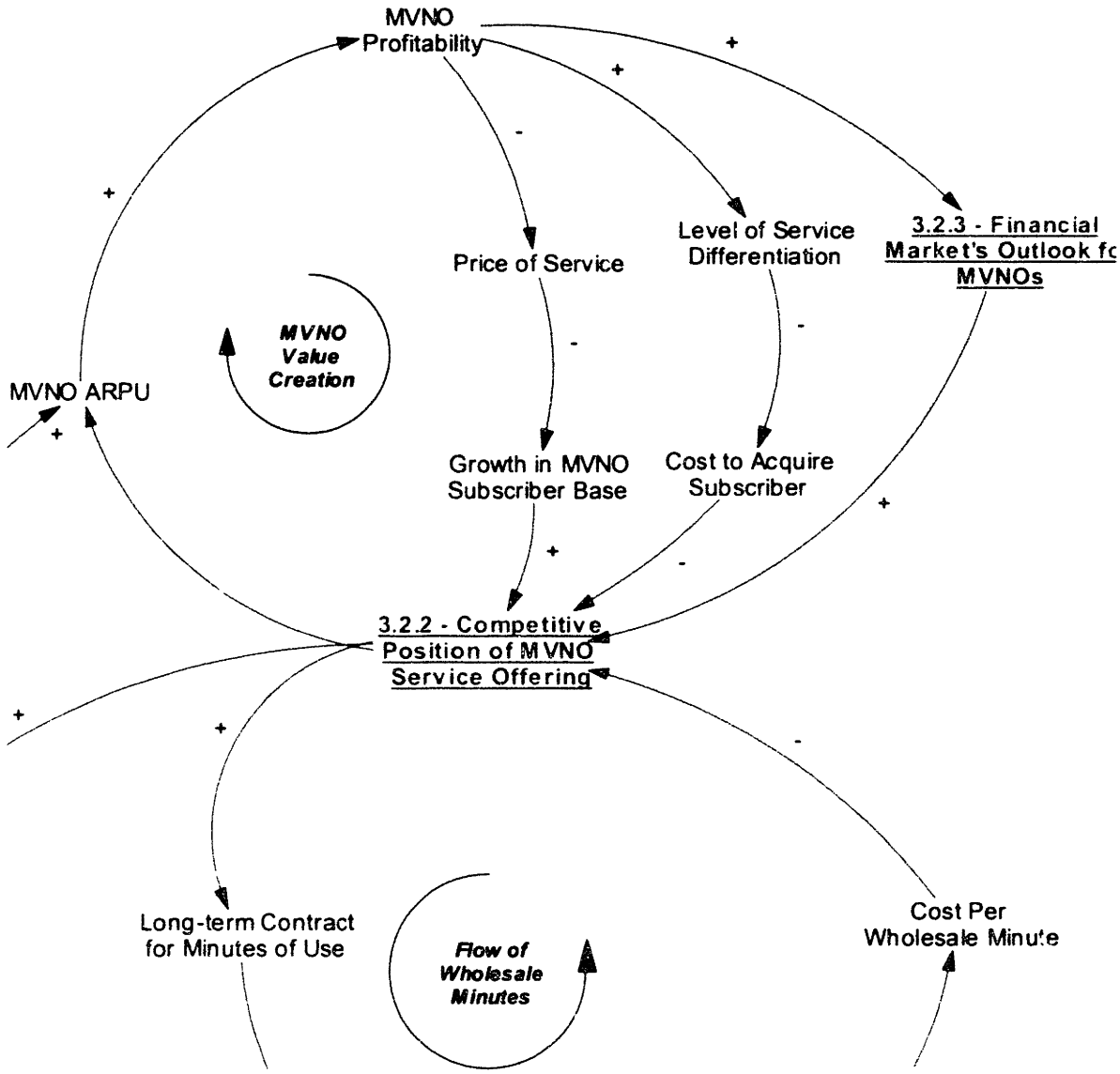
4.2.2 Mobile Virtual Network Operator (MVNO)

Figure 4-4 describes the dynamics of the MVNOs. Initially the MVNO brings a level of brand recognition, trust, and affiliation to form the potential subscriber base. This affiliation may be due to the current relationship the company has with the customer (e.g., a relationship with a major retailer is one form of affiliation). The driving forces for this loop are the "Competitive Position of the MVNO Service Offering" (as described in section 3.2.2) and the "Financial Market's Outlook for MVNOs" (as described in section

3.2.3). The Competitive Position of the MVNOs Service Offering determines the MVNO ARPU, which determines MVNO Profitability. An increase in the MVNO Profitability allows the MNVO to lower their average Price of Service, which in turn increases the Growth in MVNO Subscriber Base. In addition, MVNO Profitability drives their Level of Service Differentiation, which reduces their overall Cost to Acquire Subscribers. Also, the Financial Market's Outlook for MVNOs directly impacts the Competitive Position of the MVNO Service Offering. Finally, these three loops drive the overall competitive position of the MVNO, which directly affects its ARPU and drives back into the MVNO's overall profitability.

Another important interaction of the Competitive Position of the MVNO Service Offering is the cost of wholesale minutes from the MVNO's operator partners. The MVNO's overall viability determines the degree to which it can obtain minutes-of-use under long-term contracts.

Figure 4-4 MVNO Causal Loop Model

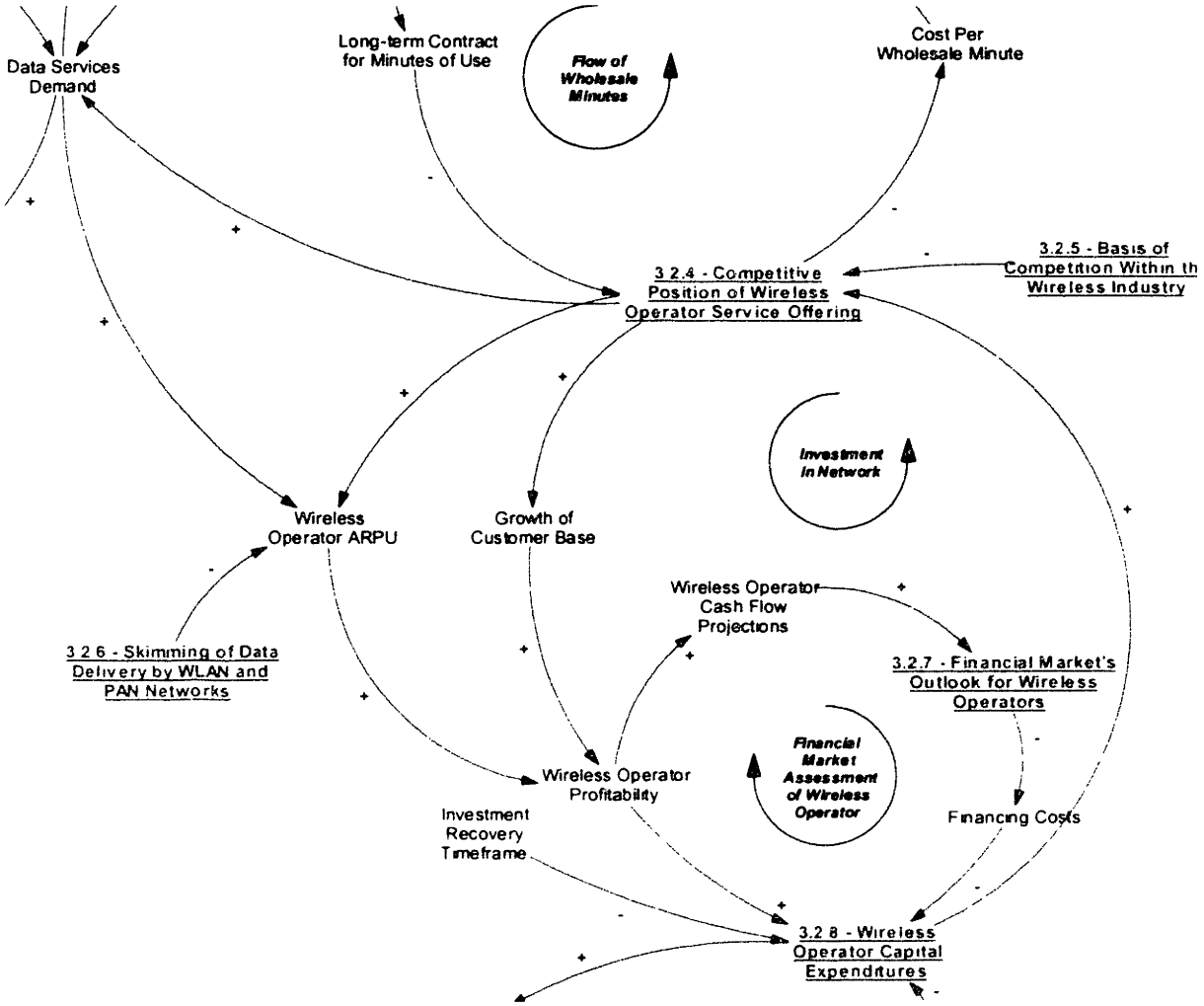


4.2.3 Wireless Operator

The causal loop diagram in Figure 4-5 represents the dynamics of the wireless operator. These reinforcing loops are driven by the overall competitiveness of the wireless operator's service offering (as described in section 3.2.4), which is, in turn, determined by the basis of competition between the wireless operators (as described in section 3.2.5). The wireless operator's profitability stems from its ability to grow its customer base at a reasonable ARPU. In addition, it must select a strategy that will prevent the most valuable data traffic from being "skimmed" by WLANs and PANs (as described in section 3.2.6).

Some of the operator's profits must be reinvested into the network to maintain its competitive standing. In turn, the Financial Markets assess this balancing act and compute cash flow projections and an overall "outlook" for the operator. The wireless operator depends upon the financial market's outlook (as described in section 3.2.7), which determines its financing costs. Also, the operator must consider the timeframe over which it intends to recover the cost of the equipment investment. The operator determines the budget for capital expenditures on an annual basis (as described in section 3.2.8). Some of this budget is spent on orders to Wireless OEM's for additional equipment, which is typically contracted at a certain cost per subscriber.

Figure 4-5 Casual Loop Model of Wireless Operator

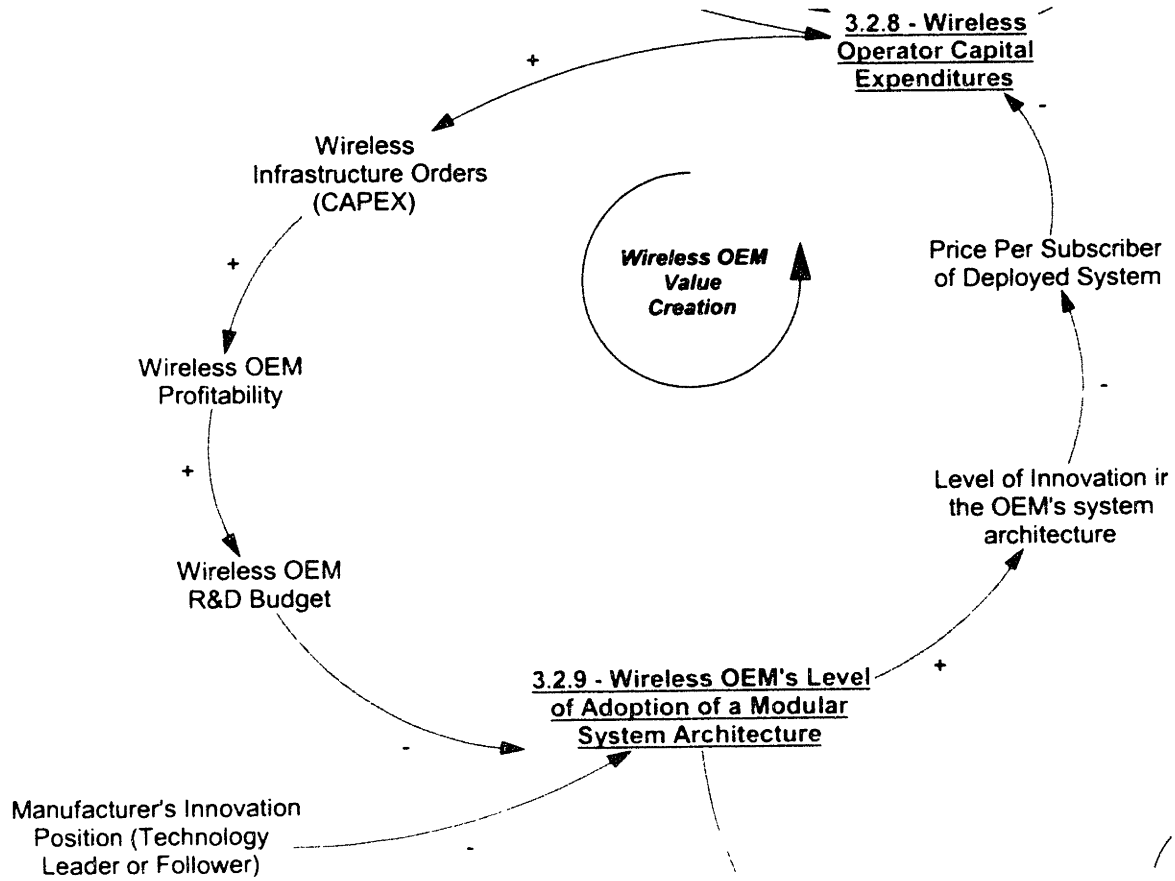


4.2.4 Wireless Original Equipment Manufacturers

Wireless OEMs live and die by the cycles of equipment purchases made by the operators. The OEM's profitability is determined by the economies of scale it can reach. The dynamics of these economies of scale are represented in the Figure 4-6. R&D absorbs a large portion of the OEM's gross profits. In turn, the level of R&D required is determined by the rate of technology transition. These same factors, along with the overall organizational view as a technology leader or follower, determine the OEM's propensity to adopt a modular architecture (as described in section 3.2.9). The wireless OEM's adoption of the modular architecture determines the level of innovation and also directly impacts the OEM's costs (on a per subscriber basis) to manufacture

and to deploy systems. This is based on the assumption that innovations from subsystem suppliers will either increase the capacity of the system per unit cost, or will simplify the manufacture of systems. The cost per subscriber in the deployed system is reflected in the price charged to the operator.

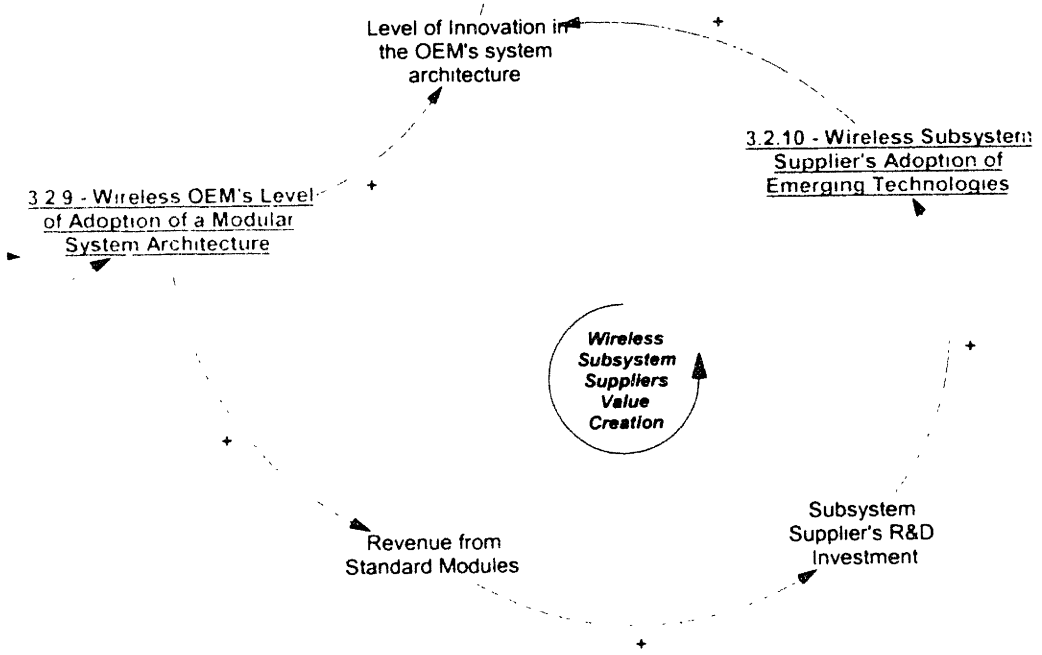
Figure 4-6 Wireless OEM Causal Loop Model



4.2.5 Wireless Subsystem Suppliers

Figure 4-7 shows the dynamics of the Wireless Subsystem Supplier. The degree to which the Wireless OEM adopts modular architectures will affect the level to which the OEM can outsource the design of certain components to allow the integration of standardized subsystems into their overall system designs. The subsystem suppliers will use the revenue from the modules that it sells to invest in R&D. In turn, this R&D impacts the availability of additional modules and the degree to which the supplier will adopt new emerging technologies (as described in section 3.2.10). Thus, there is a direct correlation between the OEM's propensity to outsource and integrate, and the overall level of innovation that is present in the OEM's system architecture.

Figure 4-7 Wireless Subsystem Supplier Causal Loop Model



4.3 Scenarios

This section outlines five different scenarios regarding the possible future directions of the wireless service industry and value chain. In each scenario, a different driving force is selected to begin a chain of events, which impact the structure of the industry.

4.3.1 Scenario #1 - Commoditization of Wireless Services

This scenario projects a situation where the overall demand for data services remains subdued. In this scenario, we begin with figure 4-3 and the loop "Creating Value with Wireless Data Applications". We assume that a dominant wireless application environment emerges and that ISVs produce a broad set of applications for various wireless services. However, the driving force "3.2.1 - Value of Wireless Applications to Customer" fails. That is, as the customers fail to see the value of wireless data applications, data service demand falls well below expectations.

Next, we examine the impact of this lack of demand on the MVNOs and then the Wireless Operators. Examining figure 4-4 and the loop "MVNO Value Creation", the lack of "Data Service Demand" has a direct impact on these reinforcing loops. That is, the MVNO finds that ARPU is limited, which has a triple effect of not allowing the firms to reduce their prices, invest in service differentiation (e.g., new applications or contents), or improve their reputation with financiers. In turn, the MVNO is inhibited from growing its customer base and lowering its cost to acquire new customers. This impacts the "Competitive Position of the MVNO Service Offering." This lack of profits reduces the MVNO's competitive position within the industry.

From the point of view of the Wireless Operators, a similar effect is noted. The lack of data service demand causes the wireless operator's ARPU to fall, which reduces the operator's profitability. In figure 4-5, the first impact of this reduced profitability can be seen if we focus on the loop "Investment in Network". Here the operator begins to restrict its capital expenditures, reduce its outstanding debt, and begins to operate as a stable utility instead of a growth company. In addition, if we examine the driving force "Financial Market's Outlook for Wireless Operators", the impact of reducing the outlook is to increase the financing costs the operator faces, thus further reducing the wireless operator's investment in the network. Overall, this scenario will reduce technology

innovation and encourage business model (process) innovation. The result of these dynamics is that the wireless operator curtails investment in the network (i.e., reducing the driving force "Wireless Operator Annual Capital Expenditures"), which also has the impact of reducing the competitive position of the operator's service offering.

Next, we examine the interaction between the MVNOs and Wireless Operators. This is represented by the loop "Flow of Wholesale Minutes". It can be seen that in the face of a declining competitive position, the Wireless Operator will gradually increase the "Cost Per Wholesale Minute" to the MVNO, further reducing the competitive position of the MVNO. This will discourage the MVNO from signing long-term contracts with the Wireless operator, which further reduces the operator's competitive position. The result of this process is that the MVNO business model will likely fail as the market for wireless data is commoditized.

Next, we examine the impact of this scenario on the Wireless OEMs and Subsystem Suppliers. In figure 4-6 and the loop "Wireless OEM Value Creation", as the "Wireless Operator Capital Expenditures" drop, the OEMs will be faced with a strategic challenge. As profitability is reduced, they cannot afford to support their massive R&D budgets and thus can no longer remain vertically integrated "one-stop shops" for wireless technology. Therefore they begin to pursue a strategy of outsourcing their least profitable components. This is evident in the driving force "Wireless OEM's Level of Adoption of a Modular System Architecture". The adoption of an modular architecture would include moving these interfaces into the standards bodies in order to ensure that multiple subsystem suppliers would appear. The wireless OEMs would attempt to ensure that they could attract enough interest for several low-cost suppliers to enter the market for these modules. In turn, the subsystem suppliers would be encouraged from the "Revenue from Standard Modules" to invest in R&D, driving "Wireless Subsystem Supplier's Adoption of Emerging Technologies." This process has the virtue of increasing the level of architectural innovation and reducing the overall cost per subscriber for equipment.

In this scenario, the wireless operators become purveyors of a commoditized product: wireless voice telephony. The basis of competition has shifted from growth at

any cost to a more stable environment where growth comes from consolidation of the major players. Equipment prices and costs continue to drop and consolidation moves upstream in the value chain toward the wireless OEMs. Approximately three to six large operators would own the market for these services. Like an electric utility, each strives to compete on the basis of lower costs. Active innovation in the industry is not rewarded per se.

4.3.2 Scenario #2 –Wireless Data Services Explosion

In this scenario, we begin again by examining figure 4-3 and the impact the driving force "Value of Wireless Applications to Customer". In this scenario a series of "killer applications" appear on the market and creates rapid adoption of a host of wireless devices by both business users and consumers. While the mantra of the proponents of the third-generation wireless technologies has been "data" focused on the consumer market, the productivity increases obtainable in the Enterprise market place a high value on the reliability of the always-on data services.

Examples of the types of viable services are:

- **Enterprise Operations** – These services bundle of a number of applications for the wireless Internet including: asset tracking, inventory management, parts and logistics management, order entry and procurement management, financial tracking, call dispatch, customer order tracking, and accessing product support documentation. Essentially many of the business processes that were restricted to networked computers become available on wireless handsets. These bundled applications encourage wide-scale adoption first by the large firms, then the medium scale, and finally the small enterprises. The rate of transition from the 2G to 3G networks accelerates, thus improving the competitive position of the wireless operators service offering. However, the basis of competition does continue to shift. For the enterprise market, access to always-on data services becomes "mission critical". In order to react to this need, the wireless operator must rethink the economics of deployment and ensure that networks provide a higher quality of service and are more reliable.

- **M-Commerce** - The consumer segment adopt the use of handheld devices to make micro-payments for small purchases. Mobile users will also indulge in notification-driven M-Commerce. Mobile commerce is another catalyst for increasing the usage of the wireless data networks. Soon, credit cards and cash become unnecessary as micro-payments begin to be accepted for a wide variety of services including food and beverage vending machines, public transportation fares, cinema tickets, and newspapers.
- **Multi-media Messaging Service (MMS)** – These services are targeted at consumers and extend today's text-only "Short Message Services" with the ability to attach video and audio clips. The service becomes much more compelling as the phenomenon of Instant Messaging migrates from the fixed PC to the mobile wireless device. Because of its ability to focus communities of users and because of the strong additional value of the always-on wireless connection, wireless messaging takes off.
- **Home Networking** - The wide-scale adoption of wireless networks in the home leads to demand for wireless services over the wide-area networks. The home becomes a computerized center for the collection of data and content that includes libraries of music, video, home movies, photos, books on tape and more. In this scenario, peer-to-peer (P2P) and device-to-device (D2D) networks dominant the indoor residential space. Computer networks and content servers spring up in the home. Software is designed to allow sharing of content among computers, televisions, audio equipment, and portable wireless devices (e.g., smart phones with MP-3 and video players built in).

The surge in demand for data applications accelerates the use of data bandwidth. Given the emergence of a dominant wireless application environment, the ISVs are able to participate in the growth of the market and thus are encouraged to innovate by producing even more applications. This process reinforces the loop "Creating Value with Wireless Data Applications."

The surge in "Data Service Demand" is apparent in figure 4-4 and the next two loops: "MVNO Value Creation" and "Flow of Wholesale Minutes." The surge opens

opportunities for MVNOs to provide specialized services bundled with content intended for individual firms and groups of affiliated consumers. The MVNOs develop around content and applications that cater exclusively to certain types of businesses or organizations. Devices, applications, and content are customized for these "micro-segments" and integrated along with a business's internal enterprise data to maximize productivity. Thus, the "Competitive Position of MVNO Service Offering" is increased. In turn, this trend increases the rate at which MVNOs emerge and increases the demand on the traditional wireless operators to forgo marketing services directly and instead provides them with a strong supply of low-cost wholesale minutes in exchange for long-term contracts for minutes of use. The "Financial Market Outlook for MVNOs" increases and financiers begin to reward pure-play MVNOs with equity pricing that reflects the growth opportunities. In turn, the value of the newly created MVNO's equity rises sharply after its initial public offering.

However, the scenario also assumes that the driving force "Basis of Competition Within the Wireless Industry" does continue to shift (see figure 4-5). For the enterprise market, access to always-on data services becomes "mission critical." In order to react to this need, the wireless operator must rethink the economics of deployment and ensure that networks provide a higher quality of reliable service. In addition, the demand turns wireless LANs from competition into complementary assets for most wireless operators, increasing the "Competitive Position of the Wireless Operator Service Offering" and overall operator viability.

Due to their inability to react to the MVNOs, the financial markets penalize the traditional wireless operators. Thus, the driving force "Financial Market Outlook for Wireless Operators" decreases. The restrictions placed on the cash flow that can be earmarked for marketing these types of efforts causes many of the operators to re-think their overall strategies. Reacting to this trend, small wireless operators (fewer than 10 million subscribers) decide to divide their businesses into a "wholesale minutes" operation and an MVNO. The larger wireless operators seem confused by this turn of events. Being more conservative, they initially attempt to sign on MVNOs to drive minutes to their "superior" networks.

As shown in figure 4-6, the Wireless OEMs benefit dramatically from the demand by both traditional and wholesale wireless operators for additional equipment and coverage, and quality of service becomes the major issue for mission critical applications. Thus, the wireless OEMs still must strive to provide lower cost systems and innovative solutions to the coverage problems. Arrays of architectural solutions are attempted by the larger OEMs. Given the surge in demand for equipment, the structure of the relationship between the OEMs and their suppliers remains intact. Thus, the driving force "Wireless OEM's Level of Adoption of a Modular System Architecture" is muted, as is the Subsystem supplier's investment in R&D and the "Wireless Subsystem Suppliers Adoption of Emerging Technologies."

However, the changes in the industry structure are not over. Given the surge in the loop "Wireless OEM Value Creation" a number of OEMs decide to open negotiations with the wireless operators to take up operation of their networks. The Wireless OEMs provide long-term guarantees for steadily declining wholesale minute charges to these operators. In return, the operators relinquish their spectrum licenses and each gains a significant equity stake in the combined operation.

4.3.3 Scenario #3 – Early Adoption of Modular System Architecture

This scenario begins by examining figure 4-6 and the loop "Wireless OEM Value Creation". In this scenario, a single Wireless OEM adopts modular system architectures ahead of the competition. The driving force "Wireless OEM's Level of Adoption of a Modular System Architecture" increases the revenues to a specific network of subsystem suppliers chosen by the OEM. This "captive" network of suppliers invest heavily in R&D, thus increasing the "Wireless Subsystem Supplier's Adoption of Emerging Technologies" and the level of Innovation in the OEM's system architecture. This surge in innovation in turn lowers the price per subscriber for the deployed systems. Also, the resulting surge in demand for the new architecture eventually pushes the wireless OEM into the leading market share position within the industry.

Next, we examine figure 4-5 and the impact of this trend on the wireless operators "Investment in Network" and the "Financial Market's Outlook for Wireless Operators". A

few wireless operators agree to adopt the new architecture in order to gain a competitive advantage. As their competitive position increases, their ARPU and customer base grows. The financial markets begin to recognize the value of the new architecture by rewarding these operators with lower financing costs and punishing their slower competitors. Overall, the driving force "Competitive Position of Wireless Operator Service Offering" is increased for this set of pioneers. This, in turn, allows the wireless operators to solicit a number of affiliated MVNOs, which increase the "Flow of Wholesale Minutes" and the "MVNO Value Creation" loops with an impact similar to Scenario #2. By adopting the new architecture, the operators are more immune to any perturbations in Data Services Demand.

4.3.4 Scenario #4 – Shift in the Basis of Competition

This scenario begins with a shift in the driving force "Basis of Competition Within the Wireless Industry" as shown in figure 4-5. Customer preferences for increased bandwidth are not realized and competition shifts instead to reliability of the network and coverage. This change has an immediate impact on the "Competitive Position of Wireless Operator Service Offering," reducing the operators ARPU and slowing the growth of their customer base. In turn, the "Financial Market's Outlook for Wireless Operators" turns negative due to their weakening cash flow position, similar to the changes noted in Scenario #1. This impacts the wireless OEM's ability to purchase equipment, driving down "Wireless Operator Capital Expenditures."

Due to the change in environment from the reduced capital expenditures, the Wireless OEMs are forced to reduce their R&D, increasing "Wireless OEM's Level of Adoption of a Modular System Architecture" simultaneously for many of the OEMs (see figure 4-6). Each wireless OEM scrambles to spin-out subsystem units and to build a network of subsystem suppliers. In figure 4-7, the Wireless Subsystem Suppliers anticipate a surge in "Revenues from Standard Modules" and invest heavily in R&D, thus increasing "Wireless Subsystem Supplier's Adoption of Emerging Technologies." As in Scenario #1, the "Price Per Subscriber of Deployed Systems" drops, further stimulating "Wireless OEM Capital Expenditures."

As the "Competitive Position of Wireless Operator Service Offering" increases, the tendency is for the operators to sell additional minutes of use to the MVNOs. In the long-term, this process reinforces the loops "Flow of Wholesale Minutes" and "MVNO Value Creation." Again, the wireless operators are left in a position where they are more immune to lower "Data Service Demand" due to their improved cost structure.

4.3.5 Scenario #5 – Skimming the Cream

In this scenario, Wireless LANs take the majority of valuable traffic (see figure 4-5). Due the growth of Wireless ISPs, the availability of "hot spot" coverage increases dramatically. In addition, the devices begin to provide physical interfaces to WANs, LANs, and PANs, and contain integrated software, which hides the complexities of these multi-tiered networks from the end user. This impacts the driving force "Skimming of Data Delivery by WAN and PAN Networks."

This skimming effect has a direct and immediate effect as the wireless operator's ARPU drops immediately. In addition, some users forgo the need for WAN connections altogether and thus "Growth in Customer Base" stagnates. These effects combine to more strongly reduce "Wireless Operator Capital Expenditures" than in previous scenarios. In addition, the "Financial Market's Outlook for Wireless Operators" drops dramatically, further restricting the operator's ability to invest in their networks. The "Competitive Position of Wireless Operator Service Offering" is under severe attack by the WISPs. Desperate for minutes of use, the operators sign contracts with MVNOs at attractive prices. Thus, the "Flow of Wholesale Minutes" and the "MVNO Value Creation" loops are reinforced.

The impact of the severe drop in "Wireless Operator Capital Expenditures" is most severely felt by the Wireless OEM and Wireless Subsystem Suppliers. The revenue from this part of the value chain declines rapidly. The Wireless OEMs consolidate under the impact. Some OEMs abandon manufacturing altogether, similar to Scenario #2, however, they do so from a position of weakness. Subsystem suppliers are run out of business as the revenue dries up. Overall, the level of innovation in the OEM's architectures in reduced dramatically.

4.4 Impact of the Scenarios on Wireless Equipment Value Chain

Table 4-1 summarizes the impact of each of the scenarios on the competitive position along the wireless equipment value chain. In the table, the market power either increases (+) or decreases (-).

Table 4-1 Impact of Scenarios on the Competitive Position Along the Wireless Equipment Value Chain

Scenario	Subsystem Suppliers	Wireless OEMs	Wireless Operators	MVNOs
#1 – Commoditization of Wireless Services	+	-	-	-
#2 – Wireless Data Service Explosion	+	+	+	+
#3 – Early Adoption of Modular System Architectures	+	+	+	+
#4 – Shift in the Basis of Competition	+	-	-	+
#5 – Skimming the Cream	+	-	-	+
Summary	+	-	-	+

In conclusion, this analysis of the various scenarios shows that the outlook for MVNOs and Subsystem Suppliers is bright. In contrast, the outlook for the Wireless Operators and Wireless OEMs is worse under three of the five scenarios. Thus, these scenarios begin to form the basis for a more detailed analysis of particular firms within the industry.

5 Case Study: Nokia vs. Ericsson[37]

This chapter explores the implications of the scenarios developed earlier in terms of how competitive battles between industry rivals within the various segments of the industry could play out. Specifically, it focuses on the pending and officially declared battle for supremacy in the wireless equipment market between the longtime Nordic rivals: Nokia vs. Ericsson. These companies are the two largest wireless OEM's in the world. Even so, the firms' strategies have dramatically diverged in recent years. Thus, it is very likely that the success of each firm under different scenarios will be quite different.

This section begins with a description of the current strategy of each firm, followed by a comparison of these strategies in different regions of the world. This is followed by a comparison of how well the strategies may serve these firms under the conditions of five scenarios discussed in the previous chapter.

5.1 Nokia Networks Current Strategy

Nokia Networks is currently the second largest wireless OEM with estimated revenues in 2002 of $7.3 billion and an operating margin of 13.7%. While its revenues are down by almost 17% year over year, Nokia continues to be competitive in 2G systems as evidenced by its recent contract with AT&T Wireless and Cingular to provide GSM overlays for their TDMA systems.[38] Nokia Network's strategy contains the following elements[39]:

- **Multiple Attack Points** – Nokia strives to keep its competitors off-balance by exploiting several competitive advantages in parallel. These multi-faceted strategies, combined with the flexibility of not owning the entire value chain, provide unique strategic niches that Nokia can exploit.
- **Innovation Along the Value Chain** - Nokia's strategy is to differentiate its products by focusing not only on developing superior technology, but also on

[37] This chapter is partially based on a paper I co-authored with Philip Lim and Arvind Venkateswaran for 15.912, Technology Strategy

[38] UBS Warburg Report, Nokia February 4, 2002, p. 9

influencing the full value chain, from operations to marketing, sales, and service. Nokia strives to ensure that innovation does not become a function limited to just R&D or product development. Instead, it should be practiced along the entire value chain within the company.

- **First Mover to Exploit Shifts in the Industry Environment** - Nokia seeks to exploit shifts in the industry environment that limit its competitors. The company uses these "levers" to make its strategy more effective. By staking out new market space, the company subverts traditional industry and segment definitions. The risks are cannibalization and the expense of trying to move the industry.
- **Rapid Product Development Across "Platform" Families** – Nokia's product development is characterized by a series of rapid incremental innovations across a family of product platforms. The technologies and platforms are kept relatively stable, while cost reduction and minor functional variations are gradually introduced. While this process has been fully developed in the mobile handset division, the Network division is trying to imitate these successes.
- **Technology Sharing and Open Architectures** - Nokia is striving to become the low-cost 3G systems OEM by licensing its key modules to its competitors and then by working to open the internal interfaces that had been essentially proprietary in the past. On February 20, 2002, Nokia announced that it would begin efforts to expose the architecture for its network systems and create a business unit designed to market its access network and switching components. The strategy was described by Total Telecom as follows:

> "So far the communications industry has been rather vertical – each vendor has their own hardware, middleware and applications," said JT Bergqvist; senior vice president of Nokia Networks. "This type of industry structure will not support efficiently high amounts of data... We need a totally different cost structure in wide area coverage systems." Bergqvist said the company is calling for other vendors to join it in throwing open development of network

[39] Daniel Steinback, The Nokia Revolution.

> elements. "Nokia will want to share technology with other infrastructure vendors," he said. The company has created a new Technology Modules unit, which will develop module products and sell them both to Nokia's own systems business and to competing vendors. The first products will be available in mid-2002. Nokia said it has already approached a number of potential vendor customers. The purpose of the initiative is to drive open interfaces within network elements, Bergqvist said. As part of this plan, Nokia announced its Open IP Base Station Architecture proposal, under which it is calling for infrastructure vendors and module suppliers to pool their skills in creating shared platforms and modules, available on the open market.[40]

Nokia sees this effort as "growing the pie" for both the suppliers and Nokia. In a limited way, multi-vendor supported interfaces have already been supported for GSM networks. Nokia sees their current efforts as building upon this base of interfaces. The ultimate goal is to reduce the overall costs of network equipment. Nokia sees the radio interface becoming increasingly commoditized over time.

This strategy of developing an external vertical network has played a fundamental role ever since the company opted to not invest in semiconductors or component production. Nokia can be characterized as implementing a "product follower" strategy in terms of upstream technology development. However, Nokia Networks more recently sees itself emerging as a product leader.[41]

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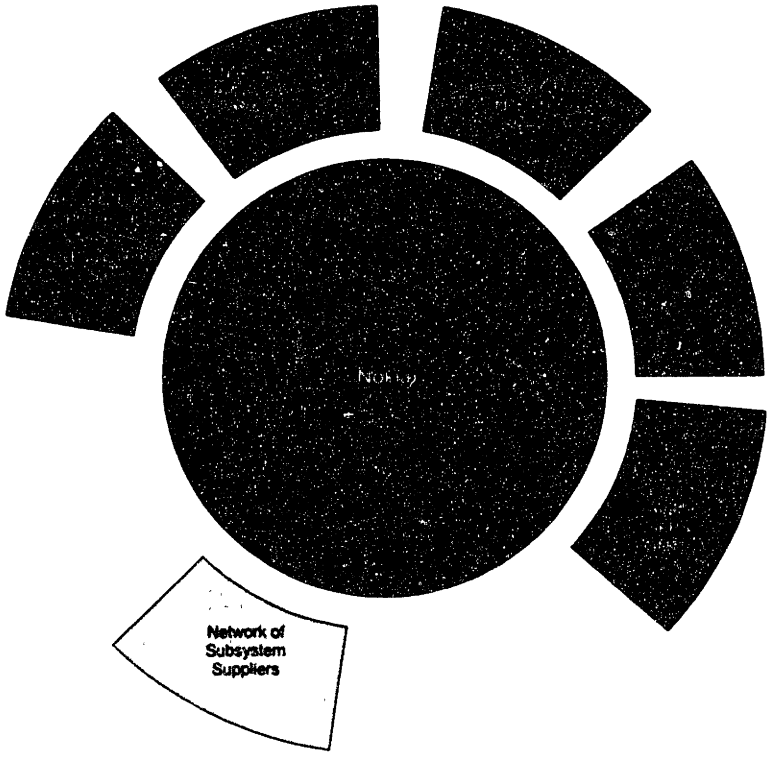
[40] February 20, 2002, "Nokia to sell networking technology to other vendors", Emily Bourne, Total Telecom

[41] Some of the information for this section and the next was gathered from our MOT 2002 International Trip, which included a presentation, by Dr Tatu Koljonen of Nokia Networks, Beijing

5.2 Nokia's Complementary Assets[42]

Along with the key elements of Nokia's strategy, the firm brings a number of specific complementary assets into play. Figure 5-1 illustrates the complementary assets that Nokia provides as part of its current strategy.

Figure 5-1 Nokia Complementary Assets



The details of each of these complementary assets are explained as follows:

- **Nokia Brand Name** - The strongest asset that Nokia has is its brand name which is seen as "cool and innovative" by its customers. However, the brand image for network equipment is unlike for mobile handsets since the customers are dramatically different (consumers vs. a wireless operator's technologists). In

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[42] Teece, D.J (1987). "Profiting from Technological Innovation: Implications for Integration, Collaboration,
Licensing and Public Policy." The Competitive Challenge, ed. D. Teece, Ballinger Publishing, Cambridge
(MA) pp 185-219 (Chapter 9).

general, the brand image is not as important for infrastructure sales as it is for handsets.

- **Strong Cash Flow and Aggressive Vendor Financing** - Nokia is leveraging the strong cash flow from its mobile phone operations to cover the costs of vendor financing in order to gain additional market share. The long-term return is increased market share in 3G systems, which can be inferred from the company's position in terms of overall wins for 3G system contracts in the past 3 years (see Table 5-1 below). Nokia's current vendor financing (committed and uncommitted) was $3.7 billion, the vast majority of which pertains to future 3G businesses.[43]

Table 5-1 Third Generation System Contracts (1999 - 2001)[44]

Vendor	% of 3G System Contracts
Ericsson	34%
Nokia	27%
Siemens/NEC	16%
Nortel	10%
Lucent	6%
Alcatel	5%
Motorola	3%

- **Focus on European Standards** - Nokia Networks is focused on the open standards from Europe, including GSM, GPRS, and W-CDMA. Nokia does not have offerings for either North American standards: CDMA or TDMA. Nokia sees higher profit margins in the European Standards due to lower costs from greater economies of scale. Also, since Nokia spends far less than others (Ericsson) on

[43] UBS Warburg Report, Nokia February 4, 2002, p. 7.
[44] ING Barings Research.

R&D, the firm needs to focus its energies on a more limited group of air interface standards.

- **Bundling of Handsets** - Because Nokia has such a strong position in mobile handsets, it can use its pricing power to cross-subsidize the sale of 3G systems. These cross-subsidies allow Nokia to bundle handsets at favorable terms to wireless operators.
- **Market Segments** - Nokia Networks will likely continue to focus on the second and third wireless operators in the European markets, along with AT&T Wireless and Cingular in the US, and J-Phone in Japan.

5.3 Ericsson's Current Strategy[45]

Ericsson is currently the leading wireless OEM with estimated revenues in 2002 of $19.2 billion and an operating margin of 20.7%. Ericsson supplies fully integrated systems for all major worldwide standards. Ericsson's strategy contains the following elements:

- **Migration to Third Generation Networks** – Ericsson expects to ramp production of 3G network equipment in late 2002, with volume business coming online in 2003. Migration path of GSM operators depends upon an implementation of GPRS first, followed by W-CDMA later.
- **Organizational Restructuring** – Ericsson implemented a "reduction in force" amounting to more than 5% of its total employment in 2001. Marketing units were heavily affected, but R&D units were preserved. The goal was to save more than $1 billion per year in overhead costs. In addition, the company undertook a program to spin off a number of "non core" divisions during 2001 (e.g., Ericsson's cable and defense electronics businesses). Another move was to transfer a number of manufacturing operations to Flextronics of Singapore. Finally Ericsson announced an outsourcing agreement for base station power amplifiers with Power Wave.

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[45] Derived from presentations given at the Ericsson Strategy and Technology Summit, September 4, 2001

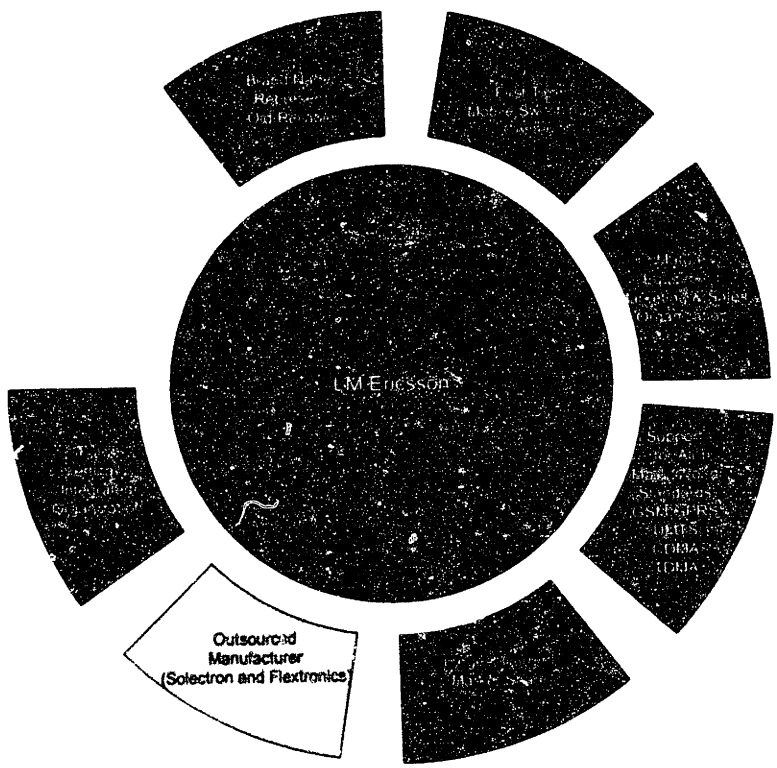
- **Focus on Cash Flow and Operating Margins** – The outlook for the financial health of Ericsson has been severely challenged by the downturn in the US and Asian economies, especially in terms of Telecom capital expenditures. The company is focused on improving its cash flow and current margins, not the future per se. The goal is to see operating margins improve to at least 10%, while returning to positive cash flow.
- **Internally Driven R&D** – Ericsson continues to strive to control the direction of technology evolution by using internal R&D without leveraging outside partners (except for wireless internet content). While they participate in the standardization process, they do not allow for "coopetition" with external suppliers. As a result, Ericsson's R&D resources are stretched thin. Ericsson supports all of the major worldwide standards and a number of application layer standards including Bluetooth and WAP.
- **Synergies in Technology Platforms** – Ericsson would like to share hardware platforms across any number of technologies. Cooperation between the W-CDMA and CDMA groups is an example of this type of collaboration, however, the level of platform sharing may be relatively low when compared to Nokia.
- **Shared Networks** – Ericsson supports the "shared network" architecture for clients, reducing the initial cost of a 3G rollout by 20%.
- **Proprietary Interfaces** – Ericsson resists efforts to open the internal interfaces to their equipment. Ericsson relies on the cross-subsidies between the Radio Access Network (BTS and BSC) and the Core Network (MSC, HLR, and other equipment).
- **Become the Lowest Cost Producer Through Vertical Integration** – Ericsson strives to become the lowest cost producer of wireless systems through rigid control of development and the supply chain. This strategy implies a vertically integrated organization. Ericsson wishes to use pricing power as part of its strategy to keep weaker players away from its first-tier customers.

- **Mobile Infrastructure Industry Environment** – Ericsson continues to see the current environment for wireless infrastructure sales as its major challenge. They believe that spending is going to continue to be scrutinized by the operators based upon the following factors: 1) Financial health of the operator, 2) Pricing pressure in the market, which is expected to intensify for new contracts, 3) Operator consolidation, network sharing, and exits from 2G and 3G market, 4) 3G network delays, and 5) Cut back in travel hurting EBITDA of operators as roaming profitability suffers, in return impacting capital equipment decisions.

5.4 Ericsson Complementary Assets

Ericsson also brings a number of specific complementary assets that form a basis for its overall strategy. Figure 5-2 illustrates the complementary assets that Ericsson provides as part of its current strategy.

Figure 5-2 Ericsson Complementary Assets



- **Ericsson Brand Name** – Ericsson's brand name stands for reliability and dependability, which is related to its position as the world's leading wireless OEM.
- **Switch Product History** – Ericsson's roots are in the wireline telephony business, having produced some of the earliest wireline switching systems in the 1920s and 1930s. Ericsson has successfully negotiated the transition to digital switches in the 1960s and into wireless telephony in the early 1980s.
- **Large Marketing and Sales Organization** – Given Ericsson's leading presence in many markets throughout the world, Ericsson has a large marketing and sales organization that it uses to maintain its strong relations with first-tier customers.
- **Complete Product Offering** – Ericsson can offer a given customer all of the major worldwide technology standards including PDC, TDMA, CDMA, GSM/GPRS, and W-CDMA. This enables Ericsson to take a "technology neutral" stance when addressing a given customer's needs.
- **Leading Market Share Position** – Ericsson can exploit economies of scale due to its large lead in worldwide market share.
- **Outsourced Manufacturing** – As mentioned above, Ericsson has attempted to outsource the non-core manufacturing operations to Solectron and Flextronics.

5.5 Strategic Comparison of Nokia and Ericsson

In order to fully develop a set of scenarios for the level of competition between Nokia and Ericsson, it is necessary to compare their strategies across a number of dimensions. Table 5-2 suggests a set of strategic factors where Nokia and Ericsson's strategies differ to the highest degree.

Table 5-2 Strategic Factors of Nokia and Ericsson

Factor	Nokia	Ericsson
1) Air Interface Standards	Focus on European Standards including GSM, GPRS, W-CDMA	Full complement of worldwide standards including TDMA, CDMA, GSM, GPRS, and W-CDMA
2) Technology Innovation	Product Follower	Product Leader
3) Level of Vertical Integration	Network of Suppliers External Component Suppliers	Vertically Integrated Supply Chain Contract Manufacturing Internal Components
4) Approach to Vendor Financing	Use mobile phone business cash flow to allow aggressive vendor finance	Cautious strategic vendor finance

- **Air Interface Standards** - While Ericsson has hedged against all the various air interfaces, Nokia has chosen to focus primarily on the European standards (GSM-GPRS-EDGE-W-CDMA). In this respect, Nokia is more focused in its market segment. By concentrating predominantly on one standard, Nokia seeks to achieve economies of scale in expertise and equipment. In corollary, the associated overhead costs for Nokia are relatively lower. At the same time, focusing on one standard further allows Nokia to concentrate on providing superior service to its customers.

- **Technology Innovation** - In conjunction with its broad focus, Ericsson also adopts a "product leader" strategy. In particular, Ericsson has invested heavily on both W-CDMA and CDMA2000, betting on the widespread worldwide adoption of data services and 3G. Specifically, Ericsson believes that there is a strong link between R&D and a company's market position. In an interview with Industry Week, Kurt Hellstrom, President and CEO of LM Ericsson, said that Ericsson the firm continued spending on research and development R&D despite the economic downturn, even though such spending could hurts the its balance sheet. Such relentlessness has enabled Ericsson to hold the largest patent portfolio in the market and for 3G. Jan Uddenfeldt, VP Technology Mobile

Systems, summarizes Ericsson's research model that has given Ericsson a dominant position in mobile telephony as follows:

> "A position of world leadership carries with it certain demands on being the first company to launch products, and the ability to be first, in turn, requires our participation in establishing standards, which - as the cycle continues - puts demands on comprehensive and sophisticated research with a strong sense for future market trends."

- **Level of Vertical Integration** – Nokia and Ericsson have chosen diametrically opposite strategies when it comes to control over their suppliers and thus their respective levels of integration. Ericsson resembles a classic vertically integrated conglomerate, while Nokia has signaled that it is moving toward a disintegrated supply chain. On February 20, 2002, Nokia announced that it would begin efforts to expose the architecture for its network systems and create a business unit designed to market its access network and switching components. Nokia sees this effort as "growing the pie" for both the suppliers and itself. In a limited way, multi-vendor supported interfaces have already been supported for GSM networks. Nokia sees their current efforts as building upon this base of interfaces and introducing de-facto standards for subsystem modules. In doing so, Nokia hopes to "commoditize" the hardware platforms and lower the overall costs of network equipment. The long-term impact of this move may be the disintegration of the wireless equipment value chain.

- **Approach to Vendor Financing** – While Ericsson prefers to be relatively conservative when it comes to vendor financing, Nokia has become very aggressive lately. As shown in table 2-3, Nokia's exposure to vendor finance is 58% of its wireless system annual revenue, while Ericsson's is only 6%.

In addition, it is useful to compare the Technology and Standardization strategies of each company. Figure 5-3 compares the technology strategies of the two companies. The diagram shows that both companies are following a similar strategy with respect to the appropriability of their respective technologies and maintaining tightly-held complementary assets. That is, both Nokia and Ericsson pursue a strategy of following

the telecommunications standards body's recommendations, while attempting to retain proprietary internal interfaces.

Figure 5-3 Comparisons of Nokia and Ericsson Technology Strategies

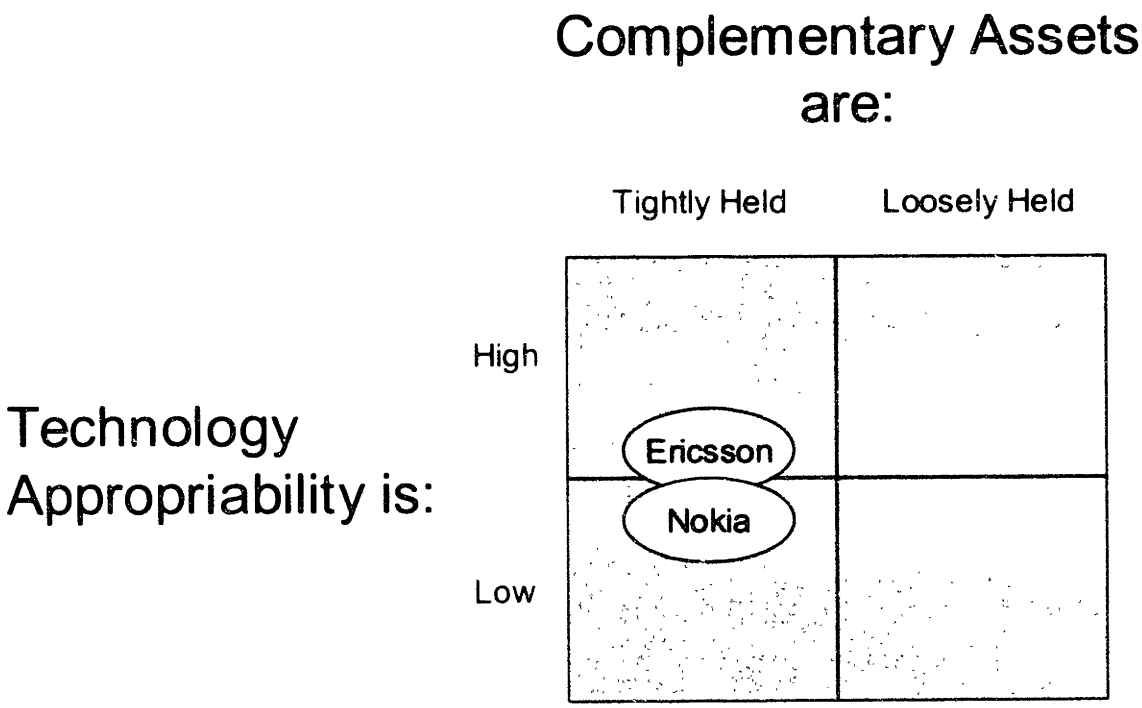
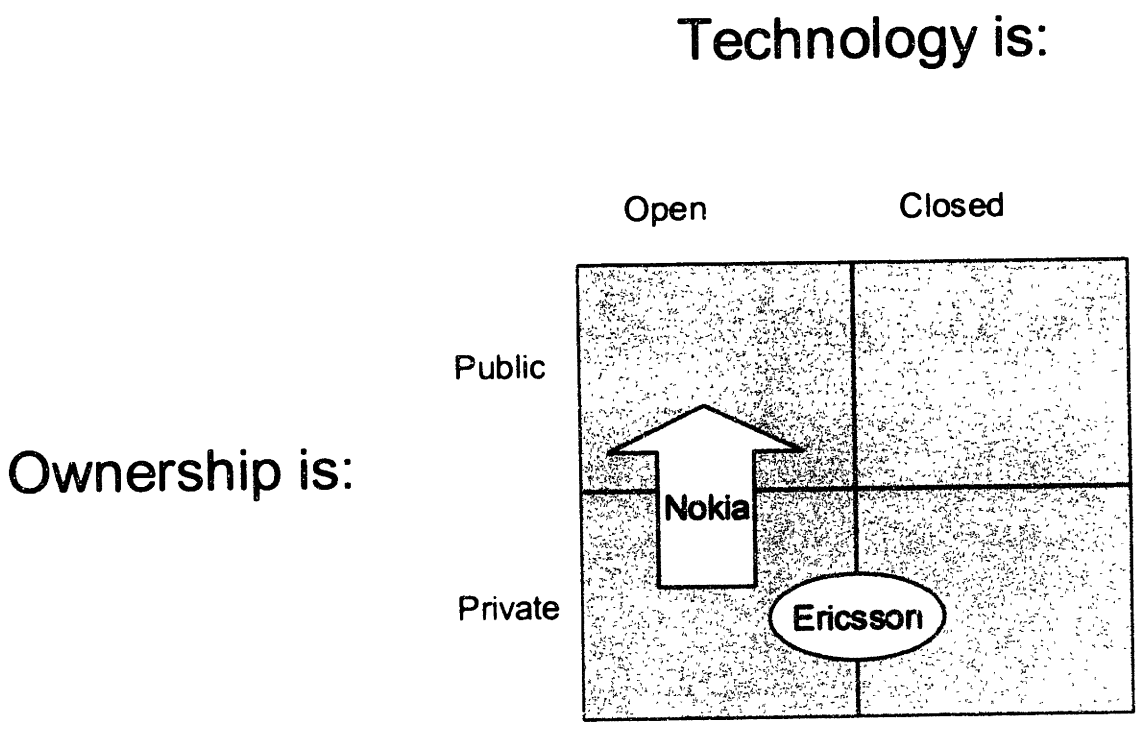


Figure 5-4 shows that Nokia is starting with private/open standards and will eventually migrate to public/open standards for much of their equipment. The goal of this part of their strategy is to commoditize the air interface portion of the wireless systems. Meanwhile, Ericsson remains firmly entrenched with mostly private/closed (proprietary) standards with a few open interfaces in their systems.

Figure 5-4 Comparisons of Nokia and Ericsson Standards Strategies



5.6 *Future Scenarios and Possible Outcomes*

Table 5-3 compares the likely strategic outcome for Nokia and Ericsson based on the scenarios developed in chapter 4. As can be clearly seen by the table, Nokia's strategy is more robust under all scenarios except the case where wireless data usage explodes.

Table 5-3 Comparison of Nokia and Ericsson Strategic Factors vs. Scenarios

Scenario	Factor	Nokia	Ericsson	Outcome
Scenario #1 - Commoditization of Wireless Services				
	1	X		
	2	X		
	3	X		
	4		X	**Nokia Wins**
Scenario #2 – Wireless Data Explosion				
	1		X	
	2		X	
	3		X	
	4		X	**Ericsson Wins**
Scenario #3 - Early Adoption of Modular System Architectures				
	1	X		
	2	X		
	3	X		
	4	X		**Nokia Wins**
Scenario #4 – Shift in the Basis of Competition				
	1	X		
	2	X		
	3	X		
	4		X	**Nokia Wins**
Scenario #5 – Skimming the Cream				
	1	X		
	2	X		
	3	X		
	4		X	**Nokia Wins**

In summary, the analysis presented here shows that Nokia's strategy is clearly more robust than Ericsson's. Thus, Nokia should gain market share over time as their strategy unfolds and they are able to exploit their competitive advantages. On the other hand, Ericsson needs to take this challenge very seriously. They should revamp their current strategy and move towards open standards more aggressively.

6 Warning Signals and Strategic Implications

This chapter describes the potential warning signals that can be monitored by strategic planners. It also describes a number of potential strategic actions that could be taken by each firm within the wireless equipment value chain.

6.1 Warning Signals

In "The Art of the Long View", Peter Schwartz advises:

> You always work out the warning signals in advance because they're less open to misinterpretation that way. You can't use your fears or confidence to influence your judgment about which future is unfolding.[46]

The purpose of this chapter is to describe some warning signals that should indicate the dynamics of the overall wireless equipment market. As Mr. Schwartz advises, it is vitally important to work out the interpretation of these signals in advance in a calm environment.

6.1.1 Wireless Subscriber Statistics

There are countless sources for data on wireless subscriber statistics. I have found two very good primary sources. First, there is the CTIA's Semi-Annual Wireless Industry Survey, which is available on its website. This survey gives a top-level view of the overall growth and profitability of the wireless industry in the US. Second, there is the Legg Mason report titled the Wireless Industry Scorecard, which is published quarterly. This report gives detailed breakdowns of each of the top US operators, including their net subscriber additions, ARPU, churn, and capital equipment expenditures. In addition to these primary sources, there are countless company and industry reports available from investment banks and consulting agencies. In particular, the strategic analyst should pay close attention to:

- **Growth in Total Subscribers**–The overall rate of growth of subscribers is key to understanding the dynamics in the market. Specific data and updated projections should be compared to the diffusion curve projections to determine if the forces affecting adoption have changed significantly. Of course, the assumptions made

with respect to these projections are more important than the projections themselves. Compare these assumptions to those made here and update the model.

- **ARPU**–ARPU determines the level of profitability for the operator. Recently we have seen that the drop in ARPU has slowed dramatically. If data adoption takes off, then ARPU should rise dramatically as usage rises and the wireless operators are able to charge a premium for these services.
- **Churn Rate of Wireless Operators that Promote Wireless Data Applications**–Look for discrepancies in the churn rate among the Big Six nationwide operators. If you find a significant improvement from the mean of the industry, then investigate the factors that may be contributing to this difference.

6.1.2 WLAN and Wireless Internet Service Provider (WISP) Growth

Unless proven otherwise, the overall growth in the Wireless LAN market can be interpreted as a competitor for data usage on the wide-area networks. It is important to watch both the overall growth in the number of WLAN devices sold and the number of WISP access points installed as indicators of the success of the model. Also, the wireless operator's movement into this market should be monitored.

6.1.3 Sales of Wireless Enabled PDAs and Smartphones

As argued previously, the adoption of data services is critical to determining the overall direction of the market. Reports that differentiate the types of devices (mapped into the general classes outlined here) are helpful in determining the potential demand for data services. If the adoption of a broad class of devices is unexpectedly high, then a more optimistic forecast for data service adoption is warranted. On the other hand, if the primary device is essentially a "data capable" handset with a minimal set of data features, then caution should be exercised in how these diffusion numbers are interpreted.

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[46] Peter Schwartz, The Art of the Long View, p 200

6.1.4 Trends in the "Profit Pool"

Examine the profitability of the major players in each segment of the value chain on an annual basis. If the wireless operators continue to show low profitability relative to their suppliers, then we should expect the pressure to build on the "upstream" direction of the value chain towards reduction in costs.

6.1.5 i-Mode Outside Japan

Will i-Mode service take off in Europe or the US? Since i-Mode is the model for the most successful data service offering in the world, we should watch as it is introduced through partner operators in Europe and the US. Examples include e-Plus and KPN Mobile, which have recently partnered with NTT DoCoMo to begin offering its i-Mode in German, Belgium and the Netherlands by May 2002 using GPRS[47]. In addition, agreements are being forged with AT&T Wireless to offer the service in the US. However, some analysts are skeptical that i-Mode will succeed outside of Japan:

> The roots of i-Mode success lie in the specific user patterns in Japan. For example, in Japan commuters usually spend a long time on trains to go to work or to school. In Europe and US a much higher proportion of workers take their car to work and cannot use their mobile phone while driving the car. Therefore the success lies more in the so-called "killer applications", customized, keeping in mind specific user segments. The business and operating models are more likely to determine the success of a service rather than the choice of technology.[48]

6.1.6 Formation of Strong Subsystem Suppliers

As wireless companies spin off their subsystem equipment divisions, opportunities will arise for consortiums among these players to form stronger subsystem suppliers. A recent example is the combination of Andrew Corporation and the recent Lucent spin-off of Celiant:

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[47] February 21, 2002, "DoCoMo's 'i-Mode,' Three Years On, Seeks New Growth", Reuters
[48] February 28, 2002, "NTT DoCoMo IPO", http://www.mobileipos.com/nttdocomo.asp

> US mobile equipment vendor Andrew Corp. said on Tuesday it has agreed to pay US$470 million in cash and stock for privately-held, fellow manufacturer Celiant Corp. Andrew said the acquisition of Celiant, which was spun out from Lucent Technologies last year, will enhance its position as the market leader in wireless subsystems infrastructure products. The company will also become the world's largest independent supplier of wireless power amplifiers, which boost signals between transmission towers and mobile handsets.[49]

6.1.7 Growth of MVNOs

Growth in the number of firms entering the wireless market as MVNOs is a first-order determinant of the success of this business model. In addition, the quality of the brand that is adopted for these ventures is a critical issue to watch. For example, British Telecom is considering returning to the mobile services business as an MVNO after spinning off its wireless operator mmO2.

6.1.8 Business Performance of MVNOs

The overall performance of the MVNOs is critical for determining whether they can be viable partners to existing operators. So far, Virgin Mobile is the most successful MVNO.[50]

6.1.9 Announcement of Infrastructure Sharing Agreements

The proliferation of infrastructure sharing agreements will impact the overall profitability of the major wireless equipment suppliers. The degree to which these networks are converted into separate vs. permanently shared networks is important. These dynamics will be an indication of the level to which one or the other operators would be receptive to shifting from being a traditional operator towards being a "captive MVNO."

6.2 Strategic Recommendations

This section summarizes a set of strategic recommendations for each segment of today's wireless network value chain, based on the scenarios developed in the previous

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[49] February 19th, 2002, Total Telecom, "Andrew buys Celiant for US$470 million"
[50] February 20, 2002, Virgin Mobile Expects to Outperform U K Rivals, Reuters

chapter. Given these dynamics, I recommend that the various firms along the wireless value chain consider the following actions.

6.2.1 Component Suppliers

There are several strategic actions that component suppliers should undertake to improve their position on the industry value chain. First, the suppliers should actively participate in the development of open network architectures and standards. These activities should be fully monitored so that the supplier can evaluate the impact these new architectures may have on their patent portfolios and strategic positions. Second, since it is likely that subsystem suppliers will benefit in the future evolution of the value chain, the component suppliers should consider a move up the value chain into the business of providing these standard modules, or variations based on their intellectual property. Third, the suppliers should add capabilities in home wireless networks to the product line. Next, the component suppliers must continuously innovate within their own product lines to steer clear of the "commoditization" strategy of the Wireless OEMs. Finally, as a last resort, the suppliers should consider supplying "toolkits" to subsystem manufacturers and wireless OEMs that allow these firms to customize the characteristics of the component to their specific design (i.e., encourage customer "lock-in").

6.2.2 Subsystem Suppliers

Subsystem suppliers also must take a number of strategic actions to protect their valuable competitive positions. First, like the component suppliers, they should participate in the development of open network architectures and standards. Second, they should diversify their product line to include alternative technologies or products tailored to a specific niche market or applications. Third, they should expand their product line to include home wireless networking components. Next, they should consider acquiring the subsystem R&D units from existing wireless OEMs that are in financial difficulties. Finally, they should establish JVs with other subsystem suppliers that have complementary product offerings.

6.2.3 Wireless OEMs

As can be seen from the analysis of Nokia and Ericsson in the previous chapter, OEMs are in the most precarious positions along the value chain. The good news is that there are specific actions they can take to improve their outlook. First, the OEMs should separate the business operations of the R&D units and reorganize along the lines of the open network architectures. Goals should be set for each R&D unit and they should be required to compete with outside vendors. Second, the OEMs should spin off units as separate companies should they fail to perform or if the industry environment encourages this type of organization. Next, the OEMs should separate their network deployment and operations groups into stand-alone subsidiaries. Finally, the OEMs should develop the core of a network operations capability as an option that would allow them to move into this market in the future.

6.2.4 Wireless Operators

The wireless operators have an equally muddled future path. Fortunately there are also several strategic actions that they can take to improve their chances. First, they can split their business operations into separate "network acquisition and operations" and "service development and marketing" units. Next, they can reduce the level of handset subsidies gradually over time to improve their overall cash flow. In addition, the wireless operators can shift the emphasis of marketing and capital equipment expenditure to focus on the coverage issues present in their current networks as the basis of competition shifts from data service performance to network service reliability. Finally, the operators should look for compelling opportunities, as the industry consolidates, to acquire weaker competitors.

6.2.5 MVNOs

The outlook for MVNOs is promising, but also faces many challenges. MVNOs should look for compelling groups of affiliated users and license the brand name surrounding this affiliation. MVNOs should evolve from the current "single brand" model towards firms that are "serial MVNOs." In this model, firms would establish the infrastructure and complementary assets required to run an operation and then expand across many brands and affiliations.

7 Conclusion

This thesis should be considered a starting point for any thorough analysis of firms along the wireless equipment value chain. It has provided adequate data, references, and background information to construct a specific analysis of the competitive position of any firm that is considering revising their current strategy. In doing so, the document has identified the driving forces that impact the industry environment today. It also supplies a model of the major players in the value chain, which can be considered a starting point for a thorough System Dynamics analysis of any portion of the value chain. This thesis also offered a strategic and competitive analysis of the two largest wireless OEMs: Nokia and Ericsson, in order to "dry run" the model. Finally, it has given a list of warning signs and the possible strategic actions that various members of the wireless equipment value chain should take.

The following sections address the questions that initially inspired this thesis. While I have attempted to answer many of my specific initial questions, these sections actually provide a general sense as to the direction I think that industry will evolve.

Dominant System Architectures and Business Models

Under current conditions, the structure of the wireless equipment value chain is pre-disposed to dramatic change. In the most pessimistic case, Scenario #1, the weakened demand for wireless data services cause the industry to come under increasing pressure as revenues and margins flattened. In turn, this pressure will reward the efficient (low cost) producer of wireless equipment. It is my belief that this scenario is the most likely outcome over the next 2-5 years. As subscriber growth slows within the developed world and China and India fail to fully replace this market demand, wireless equipment manufacturers like Ericsson will be forced to restructure. At first these firms will merely downsize in an attempt to align their expenses to the market. However, over time this strategy will be shown to be inadequate. Nokia has already seen this trend and has begun to position itself accordingly. To a lesser extent, Lucent and Nortel have already restructured due to the financial market's insistence and may be in a better position to follow Nokia's lead. On the other hand, Motorola and Siemens are closer to

Ericsson in their view of the future of industry. These firms remain relatively vertically integrated and rely on closed architectures.

The dominant architecture of wireless systems is on the threshold of change. As the interfaces between the various functional elements that make up these complex systems become "open" to all firms, a series of smaller firms will move in to supply core modules for base stations, controllers, and switches. Nokia's initiative in February of 2002 will be seen as a catalyst for this movement towards public, open standards. Nokia should embrace these new entrants and harness their innovations in much the same way as Intel has done in the PC business over the past several years.

However, this scenario does leave a "gap" between what the wireless equipment manufacturers have traditionally seen as their "territory" and the new reality of these lower cost entrants. It is my belief that traditional manufacturers will have to make a choice. Companies close to Nokia on the above spectrum will likely choose to continue to provide system integration and deployment functions, but on a much larger scale. These companies will form networks of component and subsystem suppliers that will rapidly drive down the level of capital invested per subscriber. Companies that are closer to Ericsson should consider moving into the "wholesale minutes" business as an aggregator of existing networks. These companies will have to move quickly to negotiate with existing wireless operators to provide this service. In addition, they will have to carefully articulate the advantages of this approach in order to secure the necessary financing.

Basis of Competition in the Wireless Industry

From section 3.2.5, it is clear that the wireless industry is rapidly exceeding the majority of consumer's needs for wireless data bandwidth. Under these conditions, the industry will shift to a new basis of competition. It is my belief that this basis of competition will inevitably be towards system reliability and coverage. This shift will take place in 2003 and 2004 as 3G systems become more widely deployed.

This shift in the basis of competition will spur the need for increased coverage. Coverage inside buildings and in suburban and rural areas will be necessary. However, the force of "NIMBY" or "not in my back yard" will continue to restrict the ability of

companies to install cell towers. I believe that more "stealthy" solutions to coverage will become prevalent and that the number of cell sites will grow to roughly ten times what we see today. Associated technologies such as "fake tree" cell towers and more inventive installation schemes will become more common. In addition, the pressure on lowering the cost of individual cell sites will continue to grow. One of the side benefits of this trend towards smaller cell sizes will be an increase in the utilization of the existing spectrum.

Evolution to a Horizontal Industry Structure

The emergence of open standards will be the catalyst for a more horizontally structured industry. This scenario is analogous to the transformations that overtook the computer industry in the 1980's. I believe that this transformation has already begun, and that it will accelerate and be completed before this decade is over. Ultimately, the industry will be left with a broad range of firms, as follows:

- **Component Suppliers** - The component companies will remain intact for the most part, but their reliance on proprietary standards to capture value will be challenged by an industry that relies on open architectures. Over time they will create value by continually following the PC semiconductor industry, yielding corresponding improvements in performance and cost.
- **Subsystem Suppliers** - A strong set of subsystem manufacturers will emerge. Some of these will grow from the interest of the component companies to re-capture value in other segments of the market. Others will come from spin-offs of the R&D units of the largest equipment companies. Still others will grow organically based on venture capital investments and great ideas or be formed by the merger of weaker subsystem suppliers.
- **Equipment Integrators** – These will be "pure play" integrators that source subsystems from other manufactures in much the same way that modern auto and aircraft manufacturers do today. They will play a heavy role in the system design and standardization of the network architecture, but they will rely on large networks of smaller firms to supply the necessary subsystems.

- **Wholesale Minute Providers** – These companies will emerge as the consolidators and worldwide operators of wireless networks. They will focus on providing systems that yield competitive quality of service and improving coverage. These companies will look for novel solutions and a lower cost structure to enable them to make the necessary capital investments.
- **Mobile Virtual Network Operators** – Because of their ability to address particular market needs at the application level, MVNOs will thrive as the model for marketing and supplying wireless services to the end customer. The current marketing organizations within the existing wireless operators will become "captive" MVNOs with special access to their networks.
- **Content Suppliers** – Specialist firms that can produce relevant content will grow exponentially as the value proposition becomes clearer. That is, as the cost of delivering content to a smaller and smaller audience is reduced, the number of "channels" will expand.

Financial Market's Visible Hand

Today's moribund financial markets will take a more active role in the future as the "value" of the 3G wireless becomes more clear. As the restructuring of the wireless equipment value chain takes place, data concerning the actual operations of individual firms will become visible as the industry becomes more horizontally integrated. This should make the economics of the value chain more transparent to the financiers and allow them to model the industry more accurately, thus reducing their risk premium. This trend will raise the level of confidence in the industry as a whole from its current depths. In addition, the as the value proposition for installing and maintaining higher quality networks is in place the confidence of the financial markets to invest in these networks will return.

The debt and equity markets will focus on the areas of the value chain where their instruments make the most sense. That is, venture capital markets will focus on the wireless component and subsystem manufacturers, the debt markets will concentrate

on financing the wholesale bandwidth providers, and the public equity markets will converge on the MVNOs and service firms.

An Alternative View

The view outlined above could be flawed. Perhaps scenarios #2, which predicts a surge in demand for wireless services, will come to pass. In this case the current trajectory of the wireless industry will continue forward through the deployment of 3G systems. The component companies and the oligopoly of wireless equipment manufacturers will continue to thrive on double-digit profit margins. Subsystem suppliers will continue to be marginalized. A long period of consolidation among wireless operators will ensue.

While this scenario is indeed possible, it will only serve to postpone the inevitable point at which the wireless industry, like the airlines, automobiles, and railroads, will become a commoditized business with relatively low profit margins throughout the value chain.

Summary

The wireless equipment value chain will continue to evolve in a less than predictable manner. Depending upon their positioning, firms in the industry will see these changes as either threats or opportunities. Neither the hyperbole of early 2000, nor the moribund outlook of 2002, is an accurate assessment of the potential and direction of this dynamic industry. While the hopes of the incumbent players and their investors is on resurgence in demand and a return to the growth of the late 1990's, this decade is more likely to see less growth in demand and more focus on the quality of the service overall. In addition, the profitability of the industry is likely to attract more players, and thus more competition, in the very near future. This competition will lower costs and encourage companies to invest more of their capital expenditures on compelling services that offer real intrinsic value to their customers.

Appendix A Analysis of Data Application Demand and Revenue

This appendix provides a framework for analyzing the demand and revenue generated in the US from the adoption of data applications over 3G systems. The appendix begins by presenting a survey of the types of applications that are enabled by 3G data networks. This is followed by an analysis of the types of devices and networks that these applications may map onto. Finally, the appendix presents a model for data application demand and revenue in the US market. This appendix should suggest an entire new vein of research that I have chosen not to explore at this time, thus the analysis may seem sketchy in places.

Survey of Current Data Applications

Figure A-1 shows a summary of data services extracted from several research reports by independent investment banks.[51] These services were subjectively evaluated using the criteria above and an aggregate score was assigned to each service offering.

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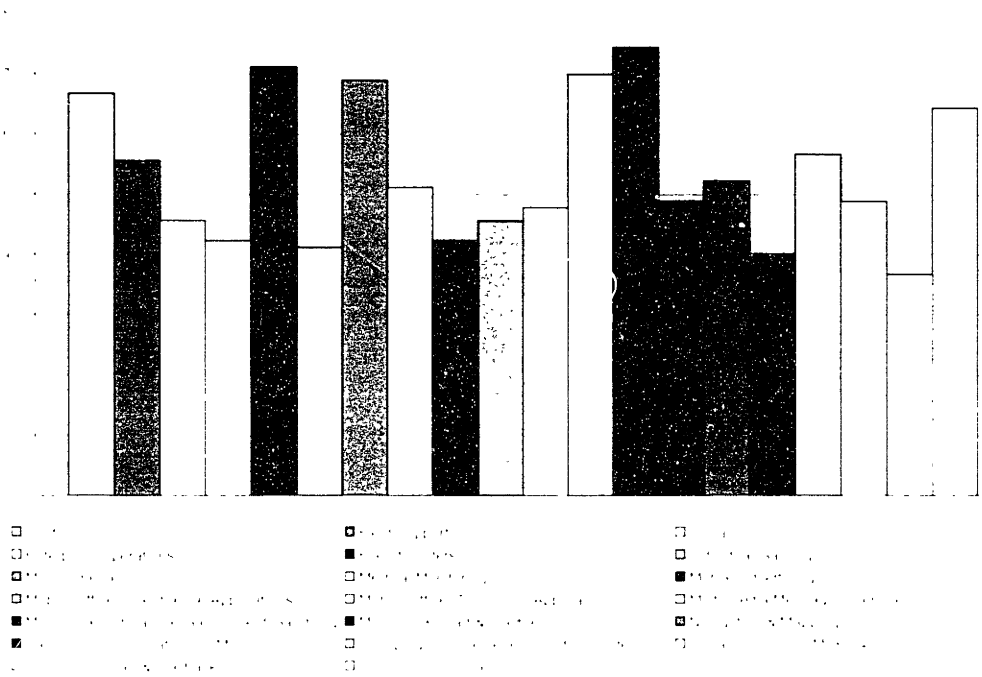
[51] HSBC Trinkaus & Burkhardt, Wireless Applications: Ready, Set, Go! November 1st, 2001; Bear Sterns, Mobile and Internet Applications, June 2001; Stephens, Inc., M-Applications, Oct. 2000

Figure A-1 Proposed Wireless Data Services



- **Alerts** – Includes news, corporate messages, and short message services
- **Field Support** – These are the various business operations that are taken daily by field service personnel including call dispatch, customer tracking, accessing product support documentation, signatures/approvals, logistics management, parts/spares ordering, and inventory management
- **E-mail** – This service includes laptops connected to an ISP or corporate server via wireless modem
- **Enterprise Operations** - Asset tracking and inventory management, parts and logistics management, order entry and procurement management, and financial management and tracking
- **Friend Finders** – This service is a combination of Location and Instant Messaging Services on a Handheld The handset would provide a map of the area and would place the location of messaging "buddies" nearby

- **Individual Gaming** – This service provides single player offline gaming with no network connection. Offline games are downloaded to the mobile terminal from the network or via PC connection; when played no revenue is generated for the network operator.
- **M-Commerce** - Wireless subscribers use the handheld devices to make micro-payments for things such as tolls, fares for public transportation, and buying sodas at vending machines. Mobile users will also indulge in notification-driven M-Commerce. For example, a mobile user might act on a notification that an item of interest is available at a nearby shop.
- **Medical Monitoring** – This service provides wireless monitors (wristbands, chest bands, etc.) that send information via a wireless connection to continuously monitor the patient.
- **Mobile Advertising** - Discounts or minutes of ads coupled with free minutes of airtime are sent to the subscriber in order to entice users to accept the ads. Promotions are targeted or micro-marketed to a specific segment of user.
- **Mobile Office Stand-alone Applications** - Applications (e.g., Word & Excel) can operate without continuous data connection.
- **Mobile Office Thin-client Applications** - Primarily used to connect mobile workers to CRM and ERP databases
- **Multi-media Messaging Service (MMS)** – Extends SMS with video and audio clips attached.
- **Multi-player Interactive Online Gaming and Gambling** - Online games are played via the network operator's network and have a permanent connection to other players.
- **Music Downloads and Playback** – This is a content service that provides music and music video downloading and playback.
- **Navigation and Mapping** – This service provides route planning and guidance.

- **Sales Force Automation/Wireless CRM** – This is a service bundle that includes calendar and contact management, order entry and order management, lead management and distribution, point of sale (POS) pricing and configuration.
- **Shopping Assistants and Product Finders** – This service uses a UPC scanner built into the mobile device to allow users to build shopping lists, comparison shop for prices, etc.
- **Streaming Video and Clips** – This service would provide video feeds and clips for news, weather reports, sports updates. For online playback, a data stream is played back directly at the terminal without interim storage.
- **Video Download and Playback** – This service allows for offline playback of downloaded videos. The video data is initially loaded into the terminal before it is subsequently viewed. This process is particularly suitable for the transmission of larger volumes of data at low bandwidth.
- **Wireless Pet Collars** – A collar sends pet's location at regular intervals.

Mapping Data Applications to Market Segments, Devices, and Networks

Figure A-2 shows the dimensions across which it is possible to analyze each potential mobile data application. The market segments range from the Large Enterprise to Consumer. The devices include everything from desktop computers to voice/data phones. The potential networks include 3G WANs, WLANs, and PANs as described in section 2.7.

Figure A-2 Dimensions Impacting the Adoption of Wireless Data

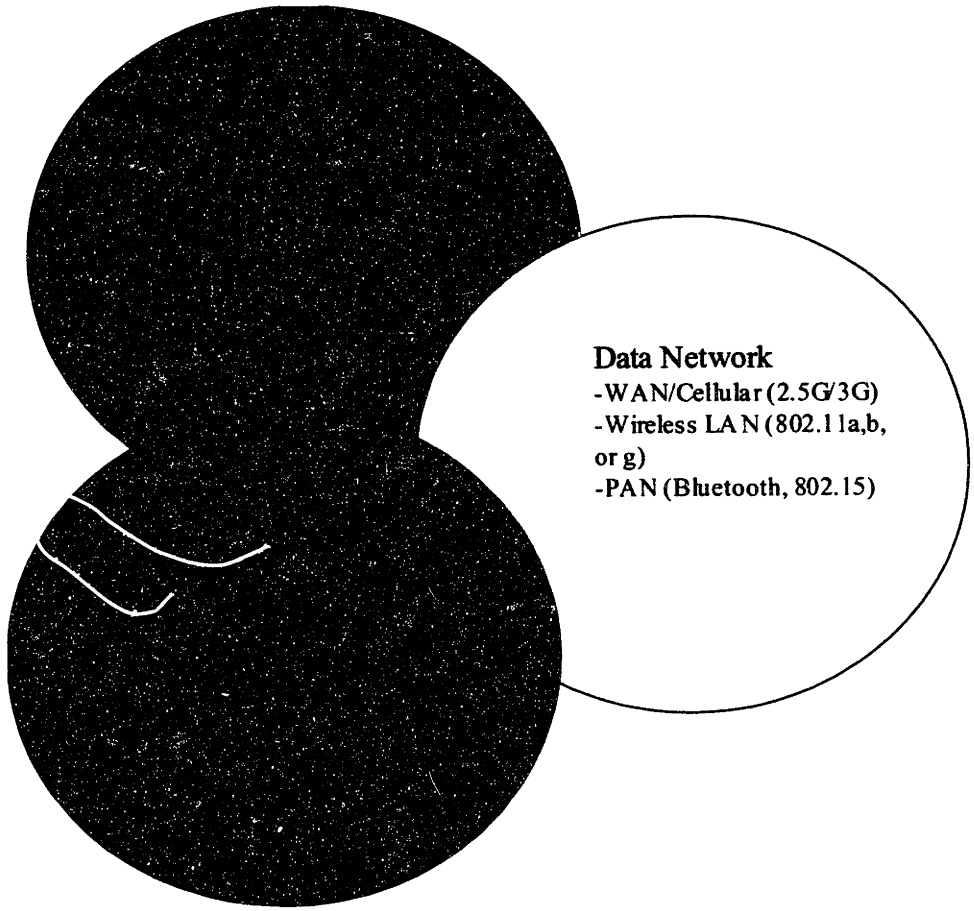


Figure A-3 and A-4 show how the "obvious" mobile data applications can be mapped to the Enterprise and Consumer markets[52] across these variety of possible wireless devices and networks.

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[52] The data for this figure have been compiled from a more extensive analysis of the wireless data market and will be provided in an Appendix.

Figure A-3 Enterprise Wireless Data Application Space

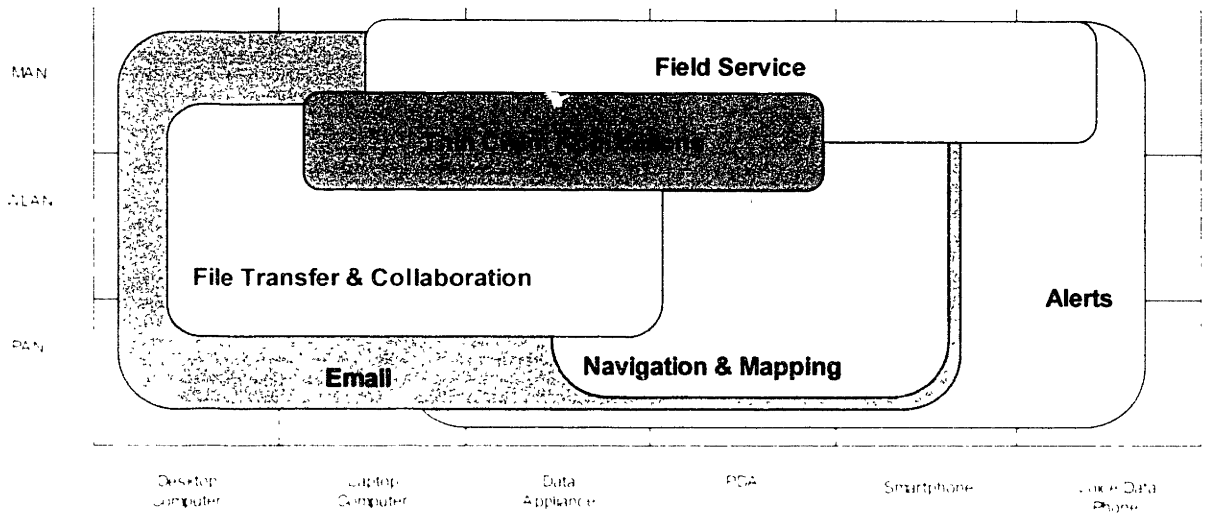


Figure A-3 shows the likely applications and devices for the enterprise market segment. The most compelling applications are email and alerts, which will likely be supported across a wide range of devices and data networks. File transfer, video clips, and navigation and mapping will most probably be supported on a more limited range of devices and networks. Finally field service support and thin-client access to corporate data will mostly be supported only on MANs and perhaps some WLANs.

Figure A-4 Consumer Wireless Data Application Space

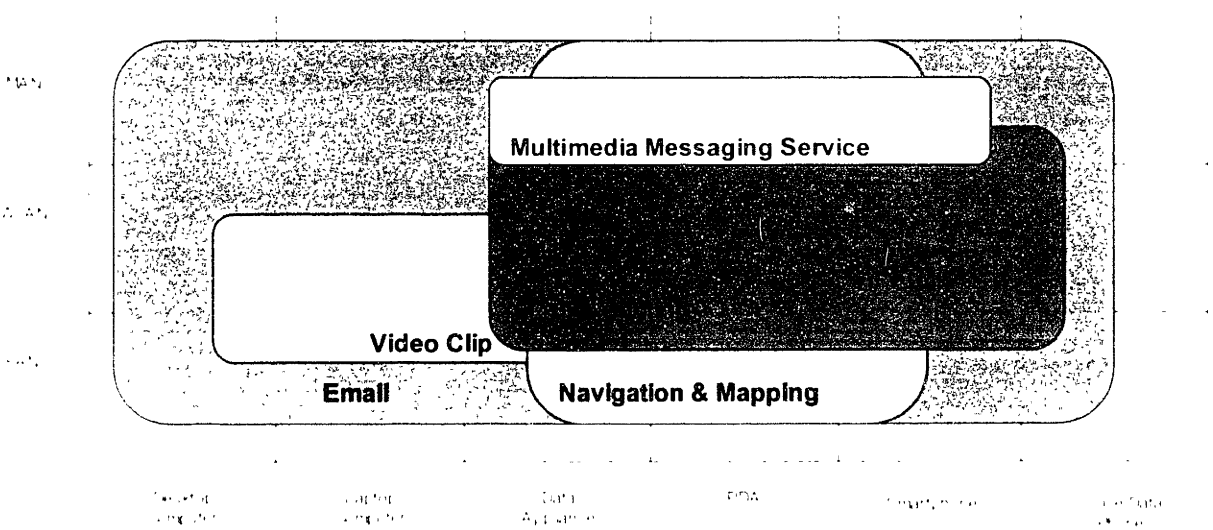
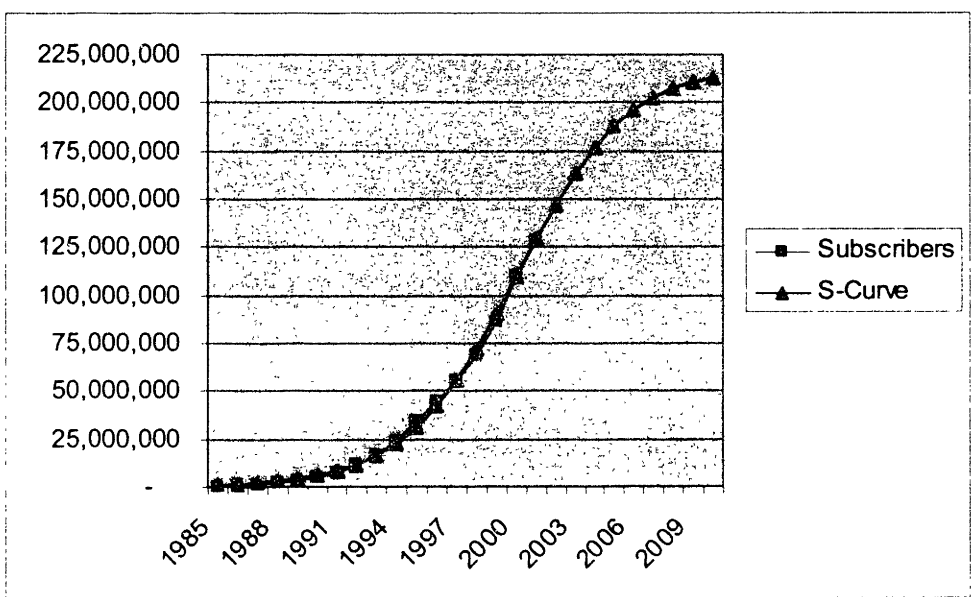


Figure A-4 shows the likely applications and devices for the consumer market segment. The most compelling application again is email. Mobile gaming, navigation and mapping, and video clips will likely be popular across a range of devices and networks. While the MMS and friend finder services are likely to be used only on the MAN.

A Model for Data Service Demand

According to my projection of an S-curve model onto the historical pattern of wireless subscriber growth in the US, as shown in the figure A-5, the rate of growth of subscribers in the US is likely to plateau and decline over the next several years. This model can be considered as valid and would result in an overall penetration rate in the US of approximately 75%, which is not unheard of today (e.g., Finland and the UK).[53] It is reasonable to expect that the wireless operators in the US will find the means to increase the overall penetration of wireless systems to meet or exceed this rate of penetration.

Figure A-5 S-Curve Projection for Future Subscriber Growth in the US



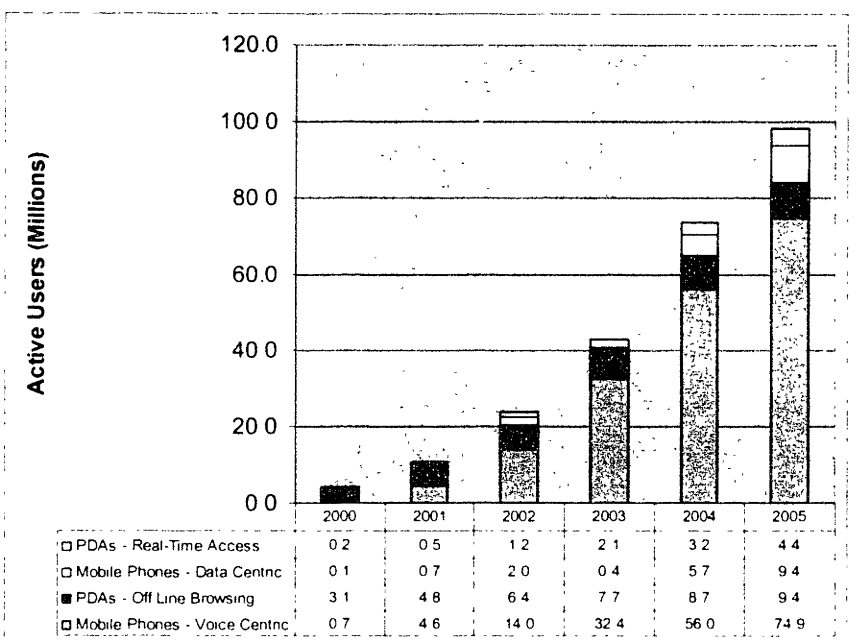
However, even assuming this rate of growth in the subscriber base, the ARPU for wireless operators will stagnate as the result of limited adoption of data services. Since

[53] For reference, the penetration rate in the US in 2001 was approximately 42%.

revenue for voice services will continue to decline as these services become further commoditized (much like long distance service today), the operators will rely exclusively on the growth of ARPU for data services to make up for this shortfall. However, data service revenue is driven by bandwidth usage. In this scenario, the users adopt services that primarily require the one-time downloading of an applet followed by limited daily interaction with a server. Due to the need to open the wireless Internet, operators have relinquished control of the interface between the content servers and the mobile data subscribers. Thus, the majority of revenue derived from the transaction is related to the bandwidth usage. Given the nature of the applications, this revenue stream will be disappointing.

Figure A-6 shows a projection for the likely growth in the data user population distinguished by the type of device that the subscriber is using.

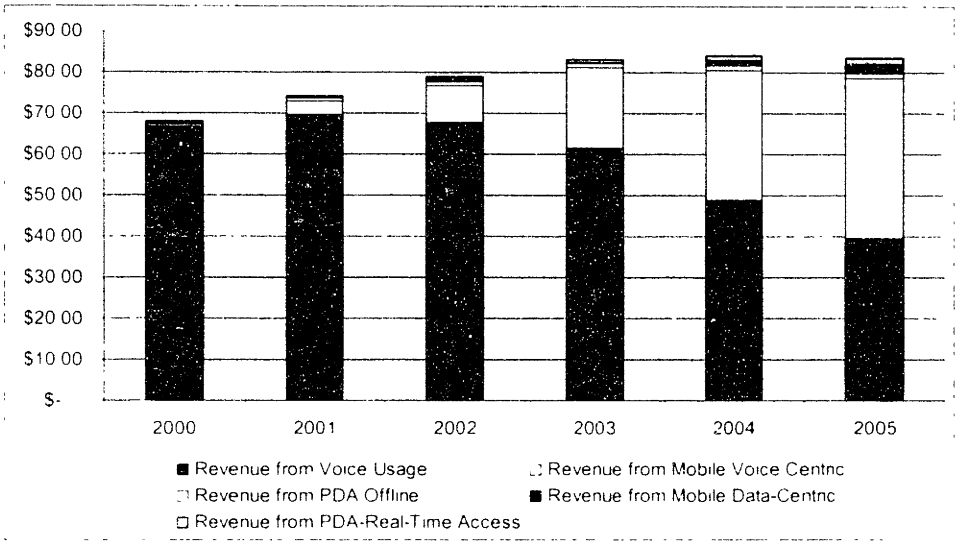
Figure A-6 Projection of Data Service Users by Device Type



	2000	2001	2002	2003	2004	2005
PDAs - Real-Time Access	0 2	0 5	1 2	2 1	3 2	4 4
Mobile Phones - Data Centric	0 1	0 7	2 0	0 4	5 7	9 4
PDAs - Off Line Browsing	3 1	4 8	6 4	7 7	8 7	9 4
Mobile Phones - Voice Centric	0 7	4 6	14 0	32 4	56 0	74 9

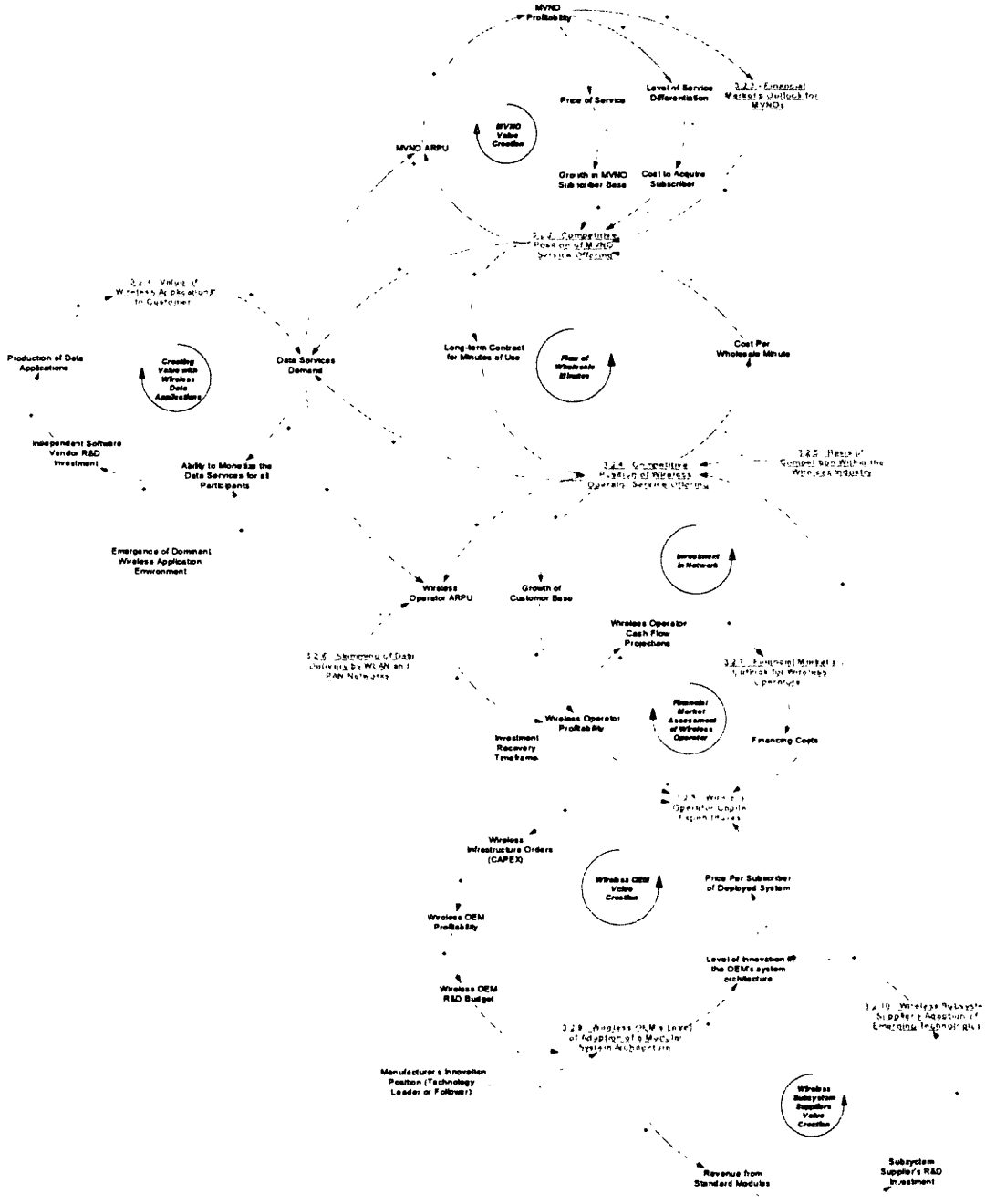
Figure A-7 is the result of modeling the above US subscriber growth pattern in addition to a limited adoption of wireless data services. The diagram clearly shows that by 2003 or 2004 the revenue within the US wireless industry will be in absolute decline.

Figure A-7 Modeling the ARPU Based on Device and Subscriber Projections



Appendix B Combined Causal Loop Model[54]

This appendix provides a combined view of the causal loop model for the Wireless Equipment value chain.



[54] This model is shown in detail in Chapter 4.

Appendix C Glossary of Terms[55]

3G (Third Generation or IMT-2000) – The next generation of wireless technology after PCS. 3G is characterized by high-speed, high-bandwidth services that support a variety of applications, including wireline quality voice and high-resolution video, wirelessly. 3G or IMT-2000 is an initiative of the International Telecommunication Union that seeks to integrate the various satellite, terrestrial, fixed and mobile systems currently being deployed and developed under a single standard or family of standards to promote global service capabilities and interoperability after 2000.

Advanced Mobile Phone Service (AMPS) - The standard air interface for analog cellular in the United States.

Affiliate – Companies that assist larger carriers with building out a nationwide network; the affiliate may use the primary carrier's brand name, network operations, customer service or other facilities.

Air Interface – The operating system of a wireless network. Standard wireless air interfaces include AMPS, TDMA, CDMA, and GSM.

Airtime – 1)Time that a wireless phone is connected and in use for talking; includes use for making and receiving calls. 2) Actual time spent using a wireless phone.

Amplifier - Used to boost sound in analog systems.

ARPU (Average Revenue Per Unit) – Measures the average monthly revenue generated for each customer unit, such as a cellular phone or pager, that a carrier has in operation. ARPU is an indicator of a wireless business' operating performance. Severely declining ARPU typically is a negative sign that may indicate a carrier is adding too many low-revenue generating customers to its rolls.

ASIC (Application-Specific Integrated Circuit) - An integrated circuit tailored for a particular piece of electronic equipment. It is intended for sale to only one company and typically developed to meet that company's design objectives for a particular application. Not to be confused with an application specific standard processor, which, like an ASIC, is designed for use in a particular piece of equipment but is intended for sale to multiple companies.

Authentication – A fraud prevention technology that takes a number of values--including a 26-character handset identifier or A-Key, not sent over the air--to create a shared secret value used to verify a user's authenticity.

Band - 1)The range of frequencies between two defined limits. 2) The specific geographic area which the customer is entitled to call in a Wide Area Telephone System (WATS).

Bandwidth – The width in Hertz of a band of frequencies. Also, the amount of data that can travel through a given digital system.

Base Station - Fixed radio station used to send, receive, and transport signals.

Bluetooth – A form of Personal Area Network (PAN) standardized by Ericsson and Nokia. The system is seen as a wireless replacement for cables. It allows wireless phones to form local networks with printers, digital pens, keyboards, and other accessories.

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[55] Abridged from the PCIA website Glossary of Terms at http://www.pcia com/wirelesscenter/resources_glossary_n2z.htm

Broadband - Referring or pertaining to an analog circuit that provides more bandwidth than a voice grade telephone line, i.e., a circuit that operates at a frequency of 20KHz or greater. Broadband channels are used for high-speed voice and data communications, radio and television broadcasting, some local and data networks, and many other services.

BSC (Base Station Controller) – This is a system that is typically located near the wireless switch (MSC). The system provides connectivity for tens of BTSs.

BTS (Basestation Transceiver Subsystem) – This is the official name given to the equipment that sits at the radio tower and provides communication to the mobile telephone.

Busy Hour - The 60-minute time span during the day with the maximum average traffic density.

CALEA (Communications Assistance to Law Enforcement Act) – 1994 legislation that gives law enforcement agencies the right to place wiretaps on new digital wireless networks. CALEA also requires wireless and wireline carriers to make their digital networks able to support law enforcement eavesdropping and wiretapping equipment and activities.

Carrier – Term used to describe a company that provides telecommunications services, both wireless and wireline.

CDMA (Code Division Multiple Access) - A spread spectrum air interface technology used in some digital cellular, personal communications services and other wireless networks.

CDMAOne – A brand name applied to the US IS-95 standard that first used CDMA technology. The standard was considered a second generation (2G) air interface.

CDMA2000 – A brand name applied to the US 3G standard. The standard is backward compatible with CDMAOne systems.

Capacity - The average amount of traffic that a circuit or circuit group can handle.

Cells – Geographic area with its own set of frequency channels that broadcast signals to cellular and PCS phones.

Cell Site – Location of a wireless antenna and network communications equipment.

Channel - A path for electrical transmission between two or more points without common carrier-provided terminal equipment; also called a link, line, circuit, or facility.

Churn - Annual turnover/replacement of pager units among subscribers.

Circuit - Physical connection of channels, conductors, and equipment required to provide a complete communications pathway.

Circuit-Switched Data – Calls from one point to another that travel along the same set of physical media (wires, fiber, radio) for the entire duration of the call. Connecting to an Internet service provider from a cellular phone using a modem is a form of circuit-switched data.

Collocation - Placement of multiple antennas at a common physical site to reduce environmental impact and real estate costs and speed zoning approvals and net work deployment. Collocation can be affected by competitive and interference factors. Some companies act as brokers, arranging for sites and coordinating several carriers' antennas at a single site.

Coverage Area – The geographic area served by a wireless system or carrier.

CTIA (Cellular Telecommunications and Internet Association) – Industry consortium with involvement in marketing, standards setting, industry forums, and lobbying for the US wireless industry.

Customer Acquisition Cost – Average cost to a carrier for signing up a subscriber. Factors included are handset subsidies, marketing, advertising and promotions.

DECT (Digital European Cordless Telephone) – Wireless and cordless office phone system in Europe.

Digital Switch - Switching equipment designed, designated or used to perform switching of digital switches.

E-911 (Enhanced 911) – Wireless 911 service that provides the automatic number identification (ANI) and automatic location information of a wireless phone used to contact a 911 call center. This information makes it easier and faster for police and rescue services to locate someone in distress who is calling from a wireless phone.

EDGE (Enhanced Data rates for GSM Evolution) provides higher data rates than GPRS and introduces a new modulation scheme called 8-PSK. EDGE is also being adopted by the TDMA community in the US for their migration to UMTS.

ESN (Electronic Serial Number) – The unique identification number embedded in a wireless phone by the manufacturer. Each time a call is placed, the ESN is automatically transmitted to the base station so the wireless carrier's mobile switching office can check the call's validity. The ESN cannot be altered in the field. The ESN differs from the mobile identification number, which is the wireless carrier's identifier for a phone in the network. MINs and ESNs can be electronically checked to help prevent fraud.

European Telecommunications Standards Institute (ETSI) – European standards-setting body.

FCC (Federal Communications Commission) - An independent federal agency of the U.S. government, authorized by the Communications Act of 1934, responsible for managing private and commercial communications spectrum and regulating communications services in the United States.

FDMA (Frequency-Division Multiple Access) – Technology that divides the broadcast spectrum and dispenses it to multiple users. Users share the same spectrum by being assigned a certain frequency channel for use during a call.

Filter - In telecom, equipment that permits the transmission of certain frequencies while excluding others.

FM (Frequency Modulation) – A method of superimposing a signal on a carrier wave in which the frequency on the carrier wave is continuously varied.

Frequency Re-use Technique that enables wireless carriers to increase their system capacity with a limited number of channels. Works by sufficiently separating transmitters that use the same frequency or set of frequencies so that they do not interfere with one another.

GPRS (General Packet Radio Service) is an extension of the GSM system that provides a packet-data always-on connection to wireless phone users. The GPRS system works along side the GSM system using the same TDMA channel structure.

GPS (Global Positioning System) – Satellite-based navigational system used for personal tracking, navigation and automatic vehicle location technologies.

GSM (Global System for Mobile communications) – Digital wireless telecommunications standard widely used throughout the world.

Handoff – The process of transferring a wireless phone call in progress from one cell transmitter to another without interruption of service.

Home Coverage Area – Area within which wireless phone calls are considered local calls and therefore do not incur long-distance or roaming charges.

HLR (Home Location Register) – A database connected to the wireless system that stores subscriber information and allows access to the wireless system through authentication.

IDEN (Integrated Digital Enhanced Network) - A Motorola Inc. enhanced specialized mobile radio network technology that combines two-way radio, telephone, text messaging and data transmission into one network.

IEEE - The Institute for Electrical and Electronics Engineers

IMT-2000 – The International Telecommunication Union's name for third generation (3G) GSM. Also see entry for 3G.

IS-41 – Network standard that allows all switches to exchange information about subscribers.

IS-54 – First generation of TDMA technology.

IS-95 – CDMA standard.

IS-136 – Latest generation of TDMA technology.

ISM (Industrial, Scientific, and Medical) band. This is spectrum near 2.4GHz that has been set aside as "unlicensed" spectrum for a range of applications. Originally the band was proposed for Industrial, Scientific, and Medical wireless applications. Today the band is widely used by cordless telephones and IEEE 802.11b WLAN systems.

ISV (Independent Software Vendor) – An independent firm that is licensed to produce software according to a specific application level interface. Typically the interface is licensed by the application environment developer at low royalties to attract a network of ISVs.

ITU (International Telecommunications Union) – Agency of the United Nations created to further the development of telecommunications services worldwide. ITU also oversees the global allocation of spectrum for future uses.

Micro-cells – Low power, low-cost cell sites designed to provide coverage in enclosed spaces, such as offices, subway stations, etc.

Microcellular - A technology that directs the cellular signal into an isolated spot, leaving broader coverage to conventional cell sites.

Microwave Radio - A radio frequency used extensively for long-distance telephone transmission. Digitally encoded messages are sent through microwave channels either between terrestrial antenna, via satellite, or through waveguides.

MIN (Mobile Identification Number) - Uniquely identifies a mobile unit within a wireless carrier's network. The MIN often can be dialed from other wireless or wireline networks. The number differs from the electronic serial number, which is the unit number assigned by a phone manufacturer. MINs and ESNs can be electronically checked to help prevent fraud.

MOU (Minutes of Use) - A measurement of wireless subscriber activity directly affecting revenue.

MSA (Metropolitan Statistical Area) – U.S. Census Bureau term referring to the coverage area of a city as in a wireless phone network. MSAs are the largest metro areas in the U.S. There are 306 MSA in the United States.

MSC (Mobile Switching Center) – This is the name of the type of digital switching system that is specialized to handle mobile telephone calls.

MTA (Major Trading Area) – Service area comprised of several contiguous BTAs. MTA's were designed by Rand McNally and adopted by the FCC. There are 51 MTAs in the United States.

Network - 1) Series of points connected by communications channels. 2) Switched telephone network is the network of telephone lines normally used for dialed telephone calls. 3) Private network is a network of communications channels confined to the use of one customer.

NIMBY (Not In My Backyard) - Public sentiment that opposes local placement of "undesirable" facilities such as antenna towers or toxic waste dumps.

Original Equipment Manufacturer (OEM) - Maker of equipment that is marketed by another vendor, usually under the name of the reseller. The OEM may only manufacture certain components, or complete computers, which are then often configured with software, and/or other hardware by the reseller.

Packet Switching - Data transmission technique in which data messages are divided into blocks, or packets, of standard length each of which has address and control information coded into it.

PCIA (Personal Communications Industry Association) – Leading wireless industry trade association representing companies from all parts of the wireless industry, including PCS, paging, cellular, messaging, LMDS and SMR.

PCS (Personal Communications Services) – Two-way, 1900 MHz digital voice, messaging and data service designed as the second generation of cellular. The FCC allocated the PCS spectrum in 1993 to increase competition in the mobile phone industry. The introduction of PCS added six possible new PCS players in most markets, which had previously been limited to 2 cellular companies.

PDC (Personal Digital Cellular) – A TDMA based system that is used primarily in Japan.

Peak – Time of day when there are high levels of traffic on a wireless system. Wireless carriers usually charge more for calls placed during peak hours.

PHS (Personal Handyphone System) - The extended cordless system used primarily in Japan.

POPS (Persons of Population) – Wireless industry term for population or number of potential subscribers in a market.

Pre Paid – Refers to a service offered by wireless carriers that allows subscribers to pay in advance for wireless service. Pre paid was created to meet the needs of credit-impaired customers and those who adhere to a strict budget.

RBOC (Regional Bell Operating Company) – One of seven regional phone companies created from the AT&T divestiture in 1982.

RF (Radio Frequency) – A radio signal.

Roaming – Traveling outside a wireless carrier's or subscriber's local or home coverage area. There is usually an additional charge for roaming.

Roaming Agreement – An agreement between wireless carriers that allows subscribers to use their phones on systems other than their home systems.

RSA (Rural Service Area) – 1) One of 428 non-metropolitan areas in the United States covered by a cellular or PCS license.

Service Area – Geographic area served by a wireless carrier or system. See also Coverage Area.

Service Plan – Contract between a wireless carrier and a wireless subscriber that details the terms of the service, including access and activate rates, roaming charges, peak and off-peak charges, etc.

SIM (Subscriber Identity Module) Card – Synonymous with Smart Card. A plastic card containing important data about a person's identity to allow access to a network or premises. Also, a card containing subscriber information, often inserted into GSM phones for roaming to different countries.

Smart Antenna - An antenna system whose technology enables it to focus its beam on a desired signal to reduce interference. A wireless network would employ smart antennas at its base stations in an effort to reduce the number of dropped calls, improve call quality and improve channel capacity. Also known as "Adaptive Array Antennas." Smart antenna technology continually monitors a received signal and dynamically adapts signal patterns to optimize wireless system performance. The arrays use signal-processing algorithms to adapt to user movement, changes in the radio-frequency environments and multi-path and co-channel interference.

Smart Phone - A class of wireless phones typically used to describe handsets with many features and often a keyboard. What makes the phone "smart" is its ability to handle data, not only voice calls.

SMS (Short Messaging Service) – Electronic messages sent on a wireless network.

Soft Handoff - Procedure in which two base stations-one in the cell site where the phone is located and the other in the cell site to which the conversation is being passed- both hold onto the call until the handoff is completed. The first cell site does not cut off the conversation until it receives information that the second is maintaining the call.

Spectrum Allocation - Federal government designation of a range of frequencies for a category of use or uses. For example, the FCC allocated the 1900 MHz band for personal communications services. Allocation, typically accomplished in years-long FCC proceedings, tracks new technology development. However, the FCC can shift existing allocations to accommodate changes in spectrum demand. As an example, some UHF television channels were recently reallocated to public safety.

Spectrum Assignment - Federal government authorization for use of specific frequencies or frequency pairs within a given allocation, usually at stated a geographic location(s). Mobile communications authorizations are typically granted to private users, such as oil companies, or to common carriers, such as cellular and paging operators. Spectrum auctions and/or frequency coordination processes, which consider potential interference to existing users, may apply.

Spectrum Cap - A limit to the allocated spectrum designated for a specific service.

Spread Spectrum - A communications technique in which the modulated information is transmitted in a bandwidth considerably greater than the frequency content of the original information.

SS7 (Signaling System 7) - An international high speed signaling backbone for the public switched telephone network.

Subscriber – Individual with a subscription or contract for wireless service with a carrier.

Switch - A piece of equipment that establishes and routes communication paths between separate extensions.

TDMA (Time Division Multiple Access) - A digital air interface technology used in cellular, PCS and ESMR networks. TDMA works by dividing the broadcast spectrum by time on one frequency to increase capacity. D-AMPS systems divide a 30 kHz band into enough time slices for three users.

Telematics - The integration of wireless communications, vehicle monitoring systems and location devices.

Telecommunications Act of 1996 - Legislation created to stimulate competition in telecommunication services, especially between wireless and wireline carriers. Among other things, the Act gave RBOCs the right to offer wireless long distance service to their local wireless customers.

Time Division Multiplexing - A method of combining several communications channels into a single circuit by dividing the transmission path into a number of discrete time slots and assigning each channel its own intermittently repeated slot.

Thin Client - A pen-based tablet computer used on a wireless local area network.

Third Generation – (3G or IMT-2000) The next generation of wireless technology after PCS. 3G is characterized by high-speed, high-bandwidth services that support a variety of applications, including wireline quality voice and high-resolution video, wirelessly. 3G or IMT-2000 is an initiative of the International Telecommunication Union that seeks to integrate the various satellite, terrestrial, fixed and mobile systems currently being deployed and developed under a single standard or family of standards to promote global service capabilities and interoperability after 2000.

Turnkey - An entire system with hardware and software assembled and installed by a vendor and sold as a total package.

UMTS (Universal Mobile Telecommunications System) - Europe's approach to standardization for third-generation cellular systems.

Unified Messaging - Software technology that allows carriers and Internet service providers to manage customer e-mail, voice and fax messages from any phone, PC or information device.

Unlicensed Spectrum – An allocation of spectrum that is set aside for use by unlicensed services.

Vendor - Seller of telecommunications services or equipment.

VLR (Visitor Location Registry) - A network database that holds information about roaming customers.

Voice Mail – Feature on some wireless phones that allows for the recording and storage of telephone voice messages.

W-CDMA (Wideband Code Division Multiple Access) – The third generation standard for CDMA offered to the International Telecommunication Union by GSM proponents.

Wireless - 1) The latest digital radio communications technology found in cellular phones, pagers, PCS phones and other radio-based communications. 2) Using the radio-frequency spectrum for transmitting and receiving voice, data and video signals for communications.

Wireless Internet - An RF-based service that provides access Internet e-mail and/or the World Wide Web.

Wireless IP - The packet data protocol standard for sending wireless data over the Internet.

Wireless LAN/Wireless Local Area Network - Local area network using wireless transmissions, such as radio or infrared instead of phone lines or fiber-optic cable to connect data devices.

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