

Addressing the Complexity of Multimedia Wireless Computing Solutions

by

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

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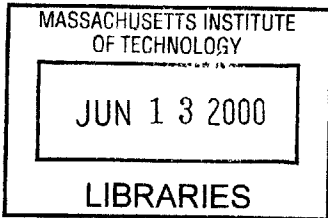
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ABSTRACT

The new age of Wireless/Mobile Computing is upon us. This is a part of the convergence between Information Technology, Telecommunications and Media that will reshape the way society operates. At the dawn of this new era, it is a challenge to navigate through uncharted territory where a plethora of necessary components such as the Internet, hardware, software, firmware, network infrastructure and communication devices collide, where new technologies and standards are emerging rapidly to outdate the old. In an effort to maintain market leadership and based on customer needs and demand for faster, more efficient and more convenient ways to capture and deliver images, Kodak Professional DCS is looking to employ the latest off the shelf technologies to allow their cameras to wirelessly deliver images to their intended destinations. Adding wireless transmission features to the Kodak's digital cameras can present tremendous value to end customers, thereby helping to increase market share for Kodak in the face of stiff competition. The challenge of delivering wireless digital image transfer to consumers lies in the limitations and the complexity of a burgeoning but less than mature wireless industry. It requires the integration of a plethora of components, many of which still lack defining standards. These components include: wireless network technologies and providers, network protocols, wireless radios, cellular phones, software architectures and firmware, the camera hardware and operating system and data connection cables.

This thesis will address the complexities related to delivering wireless computing solutions to a fast-moving market, with special focus on multimedia wireless solutions. The thesis maps out the current wireless computing terrain and selects the most suitable methodologies, architecture and components to deliver wireless multimedia solutions to Kodak Professional Digital Camera Systems (DCS) customers. The thesis goes through two specific wireless multimedia projects I designed for Kodak Professional DCS. One deals with the transmission of images directly from DCS cameras via cellular wireless wide area networks (WWAN), and the other deals with networking of DCS cameras within wireless local area network (WLAN) environment. The WWAN project was implemented and the prototype was demonstrated with very positive results at PMA, one of the largest professional photography trade shows of the year. The WLAN project is under consideration for implementation by the DCS engineering team. The thesis also examines the emerging Wireless Computing industry and how it will impact the way people and businesses operate.

Thesis Advisors: Sandy Jap, Associate Professor, Sloan School of Management
Alvin Drake, Professor, Department of Electrical Engineering

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Dedication

I would like to dedicate this thesis to my lovely wife Kim, who has given me amazing support through out the past 5 years of our marriage. We are a team and without her I would be incomplete.

This dedication also goes to all of our family members in Seattle who has been behind us with their love and support all the way.

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Chapter 1. Introduction

1.1 Thesis Objective

The Objective of this thesis is to explore and map out the complex and emerging wireless computing terrain and identify the most suitable methodology, architecture and components required to deliver a set of integrated wireless multimedia solutions to Kodak Professional Digital Camera customers. The thesis goes through two specific wireless multimedia projects I helped design for Kodak Professional DCS. One deals with the transmission of images directly from DCS cameras via cellular wireless wide area networks (WWAN), and the other deals with networking of DCS cameras within the wireless local area network (WLAN) environment. The WWAN project was implemented and the prototype was demonstrated with very positive results at PMA, one of the largest professional photography trade shows of the year. The WLAN project is under consideration for implementation by the DCS engineering team. The thesis also examines the emerging Wireless Computing industry, that will undoubtedly have a significant impact on the way people and businesses operate.

1.2 Statement of the Problem:

Kodak Professional Digital Cameras (DCS) wants to maintain market leadership and fulfill customer needs and their demand for faster, more efficient and more convenient ways to capture and deliver images. As part of this effort, Kodak Professional DCS is looking to employ the latest off-the-shelf technologies that will allow their cameras to wirelessly deliver images to its intended destinations. It will eliminate the time-consuming and cumbersome need to transfer files to a laptop, edit and convert the images and then send images from the laptop via an attaching cell phone, or a wired connection. Adding wireless transmission features to Kodak's digital cameras can present tremendous value to the end customer, thereby helping to increase market share for Kodak in the face of stiff competition. Furthermore, wireless transmission can lead to a host of other multimedia related services and products including Image Kiosks, Internet multimedia, Mobile multimedia, etc. that can further drive Kodak's business in the digital future.

The challenge of delivering wireless digital image transfer to consumers lies in the limitations and the complexity of a burgeoning but less than mature wireless industry that requires the integration of a plethora of components. Many of the components still lack defining standards. They include: wireless network technologies and providers, network protocols, wireless radios, cellular phones, software architectures and firmware, the camera hardware and operating system, and data connection cables. Other issues include the compromise between cost, performance, time to market and the customers projected adoption based on VOC.

1.3 Motivation

One cornerstone for the Eastman Kodak Company from the days of George Eastman himself was to very easily and conveniently deliver pictures to customers. Even though the processes of delivering these pictures may be very difficult and complex, Kodak has always tried to make these processes as transparent to the end users as possible. The saying of “You push the button, we do the rest,” holds true in today’s digital world as much as it did for the past 100 years in the traditional sensitized film world.

Digital technology is one of the major corporate strategies of Eastman Kodak Company going into the year 2000. As this transition takes place, we have to continue to find ways to make delivering images in the digital age as simple as pushing a button. Wireless Computing Networking can impact the long-term positioning of Kodak Professional Digital Camera System in the marketplace by making the complex simple. Gaining the technological and competitive edge through innovation can truly benefit Kodak’s long-term positioning. By providing customers with features they ask for (and sometimes ones that do not realize possible), Kodak can continue to successfully lead the picture industry in the new millennium.

1.4 Wireless Computing Industry Overview

The convergence of Information Technology, Telecommunications, and Multimedia will take place over the next several years. The wireless computing frontier represents the next leap forward towards this convergence and towards even higher productivity and

efficiency for society. Wireless Computing can affect many areas within Kodak by bringing the convenience and productivity improvement, not only to customers, but also to the workforce itself.

Wireless technology is rapidly evolving and continuing to improve. Voice was the first “killer application” for wireless communications. Soon there will be data and multimedia applications that many never thought possible. The Wireless revolution will depend upon technology improvements, the adoption of standards, and how well the customers are served. Here are some major trends that are taking shape:

- Wireless infrastructure for wide area networks (WWAN) is evolving from slow data rate connectivity towards 3G (third generation) technology where bandwidth can be over 2 Mbps, allowing the Internet to be “everywhere”. 4G wireless systems that are even further out will offer multiple functionalities in one hand set (voice, data, video-conferencing, SMS, image, and other applications), as well as global roaming and integration with WLAN & WATM networks.
- Wireless standards such as IEEE 802.11, and IEEE 802.15 (Bluetooth) are being established to deliver interconnectivity between assortments of information appliances in localized environments. Environments include wireless local and personal area networks (WLAN and WPAN).
- Hardware devices that allow communication to take place are becoming smaller, cheaper, faster, with more features to provide a better experience for users. Smart phones and PDAs are converging, and other devices such as digital cameras, laptops, vending machines, and kiosks are being wirelessly enabled.
- Software architectures, Operating systems (OS), and protocols are converging towards standards. Palm, Windows CE, and EPOC are dominating the mobile OS space. Internet Protocol (IP) will be a foundation. There will be interim communication architectures such as WAP and middleware and web-clipping that will be used while improvements are made and or better architecture and standards prevail.

- New roles are being shaped as Network Operators and Banks battle for the mobile service portal and transaction space – capturing revenue from customers through value added services (VAS.) There are two battles being waged. One is the battle of standards with the other being the battle for the customers. While technology standards are taking shape, the battle for customer’s “eyeballs”, attention, loyalty, and ultimately their wallets, will be intense.
- New applications and Services will yield dramatic productivity and lifestyle improvements within the next five years. Many of which will be personalized and location base driven – meaning services that deliver value to you intelligently based on where you are at that time.

There is no doubt that the wireless computing industry will yield dramatic changes in the way we operate. Power lies in the ability to access and deliver information and be productive, or entertained anywhere, anytime.

1.5 Kodak Wireless Projects

My project was to help the Advance Technology group at Kodak Professional with prototyping new features on their Professional Digital Cameras that will allow them to communicate wirelessly with PCs and other devices. The application environments involve both high bandwidth wireless Local Area Networks (WLAN) as well as low bandwidth wireless Wide Area Networks (WWAN). This research project is aimed at not only delivering additional features to the existing product line within Kodak Professional DCS, but also to help explore other wireless computing devices/appliances and wireless computing applications within Kodak.

I worked on two separate wireless multimedia projects. One is for the WWAN environment, to deliver images to any server from a remote location using a DCS camera connected to a cellular phone. The project was intended to enable mobile transfer of images from virtually anywhere using low bandwidth wireless networks. The solution is

ideal for photo journalist (PJ) customers who need to deliver their images to headquarters quickly and efficiently.

The second project aims to find a way to network DCS cameras to a server via high-speed WLAN connections. The server would have the ability to treat the camera as a client or hardware memory device and download selected pictures. One server can have access to multiple cameras, establishing a master station that can monitor cameras in the field. This project is intended for applications such as coverage of sporting events or image capture and marketing within theme parks.

Due to my background and interest in wireless computing as well as the lack of bandwidth within the DCS engineering team, I was asked to start and head efforts for the two wireless projects. I was responsible for researching the approach and design, as well as the implementation of plans for the projects. Both projects were designed and definition of work completed during my internship. The WWAN project was implemented, while the WLAN project is still being investigated by DCS engineering for future implementation.

Other areas of my research project touch on relationships between cameras and kiosks in a WLAN environment, kiosks and servers in a WWAN environment, other wireless digital image applications, productivity improvements for the mobile workforce using wireless computing, and some other wireless computing applications in the consumer arena including email, e-commerce, and Automobile PCs. The research includes studies of the latest in hardware, software and network technologies that will enable the wireless computing space. The scope of my thesis will focus on how to deliver multimedia wireless solutions to Kodak Professional Digital Cameras users, and as additional research I will examine how breakthrough technologies like wireless computing can impact Next Generation Manufacturing (NGM) and improve the way people and businesses operate.

1.6 Thesis Chapter Overview

This thesis is divided into five chapters:

Chapter 1 is an introduction to the thesis. Overview of problem and solution, and structure of the thesis.

Chapter 2 provides the setting and background for the Kodak wireless multimedia project. It describes the marketplace for KRPO digital cameras, the technology and product overview, as well as the scope and context of the project. Within this chapter, it also describes the motivation for the project and key concerns of the customers through the voice of the customer (VOC). Finally, this chapter overviews the approach and solution to achieve the project objectives.

Chapter 3 explores today's wireless computing industry and helps map out the different components and terrain to better understand how to proceed. This chapter will examine three major segments of the wireless market: WPAN, WLAN, WWAN. For each segment I will identify key characteristics (strengths and limitations) and key technologies and tradeoffs to consider. This chapter will also address the specific challenges facing multimedia wireless solutions and interim alternatives to deal with these challenges. This chapter also looks at the greater Wireless Computing Future to explore other areas where wireless computing can be applied which can increase business and personal productivity and change the way we compute and operate in the twenty-first century.

Chapter 4 describes the application of two major projects that can be implemented for Kodak Professional DCS. The chapter details each project and the reasons for specific choices made for specifications. This chapter breaks down the WLAN and WWAN project into its components to allow the reader a more comprehensive look at the work involved for the two different projects I was responsible for.

Chapter 5 concludes with the results and outcome to date of the projects and provides a view for KRPO DCS's path forward. The chapter also outlines some other synergies in other areas of Kodak that may benefit from the use of wireless technology and how it can help shape part of Kodak's digital future. This chapter further presents the author's views on key learnings that have been drawn as a result of this research and some recommendations for the sponsored company related to the topic at hand.

Chapter 2. Problem Setting and Background For Wireless Kodak Professional DCS Project

2.1 Background

Eastman Kodak Company History and Background

Founded in 1880 by George Eastman with a patent on Dry Plate photography, the Eastman Dry Plate Company went on to incorporate film by 1884, and in 1892 officially became the Eastman Kodak Company. Today, Kodak is headquartered in Rochester, New York and ranks as a premier multinational corporation and one of the 25 largest companies in the United States with over \$14 billion in annual revenue.

George Eastman had four basic Business Principles:

- mass production at low cost
- international distribution
- extensive advertising
- a focus on the customer.

Eastman saw all four principles as closely related. Mass production could not be justified without wide distribution which, in turn, needed the support of strong advertising. From the beginning, he imbued the company with the conviction that fulfilling customer needs and desires is the only road to corporate success.

To his basic principles of business, he added these policies:

- foster growth and development through continuing research
- treat employees in a fair, self-respecting way
- reinvest profits to build and extend the business.

The history of Eastman Kodak Company is one of progress in development of these basic principles and policies. Eastman Kodak Company today develops, manufactures and markets consumer and commercial imaging products. Products of each major segment (Consumer, Kodak Professional, Health Imaging) include film, photographic paper,

processing services, photo finishing equipment, chemicals, cameras and projectors, digital cameras, printers and scanners, chemicals and related services, medical films, motion picture film, audiovisual equipment, etc.

Digital Products Business part of Kodak Strategy

While maintaining its leadership in the traditional film business, Kodak has focused much energy on the digital future. Kodak Professional Digital Camera Systems (DCS) is the world's leader in developing and marketing high-performance digital cameras to professional photographers. As the camera world moves further into the digital arena, Kodak Professional needs to maintain its market power. This market is driven by technological innovation, and Kodak must maintain its superior design capabilities. Digital technology is one of the major corporate strategies of Eastman Kodak Company going into the twenty-first century.

The different market segments served by Kodak Professional are the commercial studio, portrait studio, photojournalism, applied (medical, scientific and industrial) and high-end amateurs. Out of these segments, the product mix has been focused (in descending order) on photojournalism, commercial studio, as well as applied and portrait studio.

2.2 Kodak Professional DCS Market, Technology and Product Overview

2.2.1 Market Overview

The market for professional digital cameras is very competitive and previously focused more on performance and technology than price. There are about 15 competitors in this market who, in 1999, were competing for an estimated revenue of \$250 million.

Competitors include large companies such as Canon, Nikon, Fuji, Minolta and Sony that Kodak also competes with in film photography. Smaller companies, such as Leaf and PhaseOne, are also included in this market. The Kodak-manufactured professional digital cameras are the market leaders in this industry. Two of the top nine companies in the high-resolution digital camera market have their products manufactured by Kodak.

Market Becoming More Competitive

A prime example of the increased competition is shown by the September 1999 introduction of Nikon's D-1 Professional Digital Camera – the first real threat to Kodak's dominance in the market-place. Now with true competition in the market, Kodak needs to deliver better features to the customer in order to maintain its leadership as well as open up new opportunities.

A major differentiator between the professional digital cameras is the resolution and quality obtained by the image sensor, which captures and processes the image into a digital output. Kodak also has tremendous capabilities in image processing after the digital capture. The rest of the camera is a traditional SLR, except that many of the inside components (motors, etc.) of the camera are removed to make room for the image sensors, circuit boards and color LCD display. The use of SLR bodies was originally based on the assumption that professional photographers and photo journalists (PJs) have invested a lot of money on Nikon and Canon lenses and would be more willing to buy a digital camera should it allow them to continue using their high performance lenses. Those assumptions may have been correct at the time, but many customers are now buying professional digital cameras because they can obtain and deliver quality images much faster, save money, and simply because they can now do their jobs better. One major reason for Kodak's leadership in this market has been the inability of competitors to match the digital resolution obtained by the Kodak digital cameras.

The competitors, however, are making strides in this area. Other than Kodak's internal expertise in image sensor manufacturing, there are a very limited number of sensor suppliers, providing these companies with pricing power in the market. The technological expertise and high start-up costs required also reduce new entrants from entering the market. Today, although Kodak is still the leader in providing superior imagers, others in the market are closing the gap, thereby making it easier for new entrants to compete in the high-end digital camera marketplace. New arrivals will be more integrated units that come in smaller form factors and will be packed with the latest features. Kodak must be able to respond to these challenges with compelling new products of their own at an increasingly competitive price.

2.2.2 Technology Overview

As their competitors' technology improves, Kodak Professional can only ensure itself that it will remain the market leader in this high-tech industry by meeting the performance needs of their professional customers in as many ways as possible. As stated above, the main driver of the professional digital camera industry is the technology and performance of the image sensor used in the camera. Kodak must continue to innovate and keep improving image quality to stay ahead of its competitors. The two competing image sensor technologies are the charged-coupled devices (CCD) and complementary metal-oxide silicon (CMOS) devices.

The CCD was invented in the late 1960s by researchers at Bell Labs. Although originally conceived as a new type of computer memory circuit, CCD sensors were quickly used in many applications including signal processing and imaging – the latter because of the light sensitivity of silicon. The CCD sensor in a digital camera is the primary tool to capture an image. The sensor collects light and converts it to a charge and subsequently emits a signal that results in a digital image. Kodak's CCD sensors are comprised of thousands of pixels grouped in either a linear or matrix array to register the overall light intensity of each point in a scene. A color image can be obtained with the addition of filters, in a proprietary red-green-blue pattern, during the CCD sensor manufacturing process.

Kodak uses its proprietary CCD technologies to make the highest resolution cameras on the market. In 1998, the resolutions on the two main products developed and manufactured for Kodak Professional were 1.5 million-pixels (or mega-pixel) in the DCS 315 and 2.0 million-pixels in the DCS 520 camera model. In 1999, the newly introduced DCS 560 features an image sensor with a 6 million-pixel resolution. In comparison, the image resolution of photographic film is about 16 million pixels, but digital technology is forecasted to meet such resolution in the next five years.

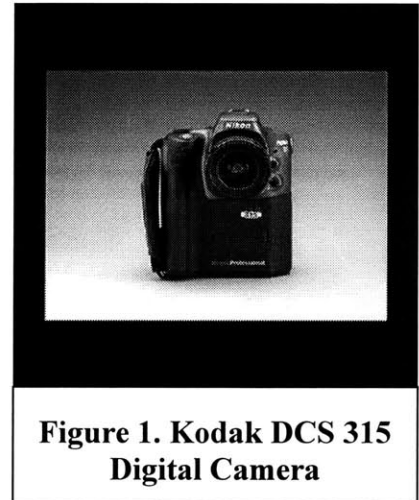
In contrast, the CMOS devices are currently not able to achieve such high resolution as the CCD. However, many engineers at Kodak believe that in the next five years CMOS may be able to match or even go beyond the resolutions offered by CCD sensors. One advantage of the CMOS technology is that it utilizes the same processes used to make microprocessors. Therefore, CMOS sensor manufacturing could inherently achieve higher process yields that would significantly reduce the price of these sensors. In response to the CMOS threat, Kodak formed an alliance with Motorola to work together on the next generation of image sensors. This partnership will allow Kodak to share its world-leading digital image sensor design expertise, while enabling Motorola to utilize its world-class process technologies.

Other than the image sensors, Kodak also has developed tremendous competence in the way the images are processed digitally. This is also another area in which Kodak distinguishes itself from the competition. Furthermore, current Kodak Professional digital cameras have multiple communication/storage ports that allow the camera to be more flexible and expansive than any other camera on the market. The key is treating the camera more as a system, which allows the user to more effectively do their job.

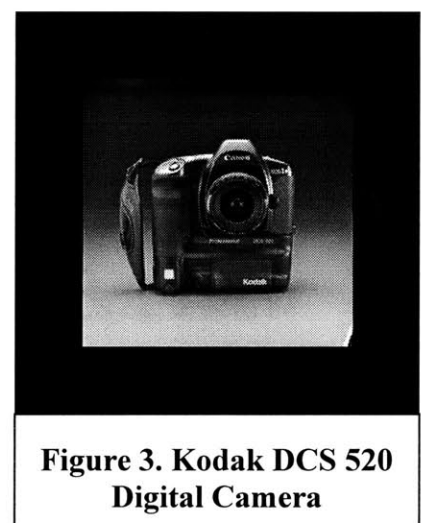
2.2.3 Product Overview

The digital camera product lines of Kodak Professional include the following main model families: DCS 315, and DCS 500 / 600 series. Next generation products in the pipeline will not be discussed in this paper.

DCS 315. The DCS 315 camera is the most affordable camera product. It combines a high-resolution digital camera with the versatility and functionality of a Nikon SLR. The camera features a 1.5 mega-pixel CCD sensor with variable ISO speeds (100-400). The camera can use interchangeable lenses from Nikon. This allows the re-use of lenses (previously used with the reloadable cameras) which lowers the photographers' cost of switching to digital. The camera also includes a color LCD that allows instant review of the images as well as storage of exposure information, date/time stamping, thumbnail images and voice recording. Finally, the camera has dual PCMCIA slots for removable PC cards that store the images.



DCS 500 & 600 Series. The DCS 500 & 600 series are the flagship digital cameras for Kodak Professional. The DCS 520 includes a 2 mega-pixel, full ISO 200-1600, and rapid burst rates of up to 3.5 images per second. In addition, it is built around the Canon EOS camera subsystem, which allows for interchangeable lenses. As the newest product in the product line, the DCS 560 features a 6 mega-pixel sensor, ISO 80-200, and is also built on the Canon EOS camera subsystem. The DCS 600 series is essentially the same as the 500 series except they use Nikon F-1 camera bodies and lenses.



2.3 Project Scope and Context

"With the slogan "you push the button, we do the rest," George Eastman in 1888 put the first simple camera into the hands of a world of consumers. In so doing, he made what had been a cumbersome and complicated process easy to use and accessible to nearly everyone.

Through the years, Kodak has led the way with an abundance of new products and processes that have made photography simpler, more useful and more enjoyable. Today, our work increasingly involves digital technology, combining the power and convenience of electronics with the quality of traditional photography to produce systems that bring levels of utility and fun to the taking, "making" and utilization of images.

What George Eastman began remains a goal of Eastman Kodak Company today, to provide convenience and quality to our customers so more and more people can experience the special wonders of photography and capture and re-live their more cherished moments."

*George M. C. Fisher
Chairman, President and CEO
Eastman Kodak Company*

The Wireless Computing/Networking project can impact the long-term positioning of Kodak Professional Digital Cameras in the marketplace as well as in many other areas within Kodak. My background and interest in the wireless computing and networking arena led me to Kodak's latest development efforts in this area. Kodak, in fact, has multiple projects that involve wireless computing, from both a product development standpoint as well as an operational and productivity improvement standpoint. Gaining the technological and competitive edge with the most advanced technologies and concepts can truly benefit Kodak's long-term positioning.

My primary project is to help the Advance Technology group at Kodak Professional with prototyping new features on the Professional Digital Cameras. These features will allow the DCS cameras to communicate wirelessly with computers, in both high-speed wireless Local Area Networks (WLAN) as well as low bandwidth wireless Wide Area Networks (WWAN).

The WLAN project involves building the capability for multiple DCS cameras to be connected and monitored by a host server wirelessly within a localized environment, such as a sports arena, allowing the host server to be able to pull images from the cameras without disturbing the photographer.

The WWAN project involves building the capability for images to be sent directly from the camera to any receiving computer in the world via a cellular phone. This eliminates

the need for photographers to carry around a heavy laptop, transfer the images to the laptop, edit the image and then send the image via a separate wireless modem or cell phone.

Other areas of application for wireless computing for Kodak touch on:

- Relationships between cameras and kiosks in a WLAN environment
- Kiosks and servers in a WWAN environment
- Wireless images transfers for people to communicate
- Wirelessly enabling information appliances with computers and printers
- Productivity improvement capabilities for the mobile workforce using wireless computing from emails and calendars, field service and sales force automation programs.

The thesis examines how the latest in hardware and software technologies can enable and change the way businesses operate for the better.

2.4 Voice of the Customer (VOC)

There had long been demand from the customer for better means of transmitting data/images from the camera to its intended destination. Voice of the customer had been gathered from various fronts, and the results were tabulated into spread-sheets. From the data of the VOC came some interesting results that formed the basis of the project. The VOC were collected from interviews of more than ten news agencies in several countries, both locally and in Europe. Below is a summary of the results as it pertains to transmission of images from the camera after capture. Most of the customers interviewed are in the Photo Journalist (PJ) market segment, which also consists of Kodak Professional DCS's largest customer base.

Summary:

Of the pictures that PJs must deliver, most are sent from a remote location rather than personally coming back to the office with the images. The remote transmission is typically done by transferring pictures to a laptop, editing them to a smaller file format and sending them out via either a cell phone or land-line phone modem. Reliability and usability are very important to the customers. The

VOC results show that significant numbers of PJ customers are asking for better ways to remotely transmit their images. Their goal is to be able to effectively and efficiently deliver their images to the right hands. Their pay as well as the news agency's profit depends on getting those "great shots" delivered first. Other news agencies and publications that purchase the images from the source will be less willing to pay for pictures of an event that already had coverage from someone else. Getting great shots to market first is key in the PJ environment.

2.5 Approach To Solution

This section describes the procedure and time line for the thesis and project. Discuss the approach used to come up with a solution, and detail some of the reasons behind the approach.

Procedure and Time Line:

The project follows the procedures outlined below (dates are June 1999 through Apr 2000):

- June Learn about the Kodak Professional DCS business and technologies; get to know organization and sketch out project plan
- July Research Professional Digital Camera market environment, gather and understand VOC data. Outline project requirements
- Aug Research wireless computing arena and necessary components, gather data, attend trade show, prepare midstream presentation
- Sept Conduct analysis based on results of data analysis; Prepare roadmap recommendations based on analysis results
- Oct Identify suitable components according to project definition and needs. Solidify business model, buy in and funding for project.
- Nov Begin implementation of prototype based on roadmap, analyze other applications within Kodak for wireless computing.
- Dec Continue implementation of project and the exploration of the emerging wireless computing market. Prepare final presentations

Jan Consolidate data and results, prepare thesis, and present results and additional recommendations.

Feb Prepare thesis document

Mar Complete thesis draft and obtain thesis approval

Apr Complete thesis final draft, turn in drafts to appropriate offices

Approach:

My approach for the Kodak Professional DCS wireless solution projects consists of eight steps:

- Understand the Professional Digital Camera Market
- Understand VOC and What Customers Want
- Understand Kodak's position and competence
- Understand Capabilities and Limitations of Wireless Space (hardware, software, firmware, networks, technology, etc.)
- Explore Options for Kodak Wireless Multimedia Solution
- Propose Architecture and Design Plan
- Help Develop Prototype
- Recommend Future Adaptations

First, I must understand the needs of the customer through VOC. There were already some VOC data that had been collected in the previous 12 months. The best way to understand Kodak's own position and core competence was to interview internally.

Next, research was to be conducted on all that is available on the wireless computing space to find suitable networks and equipment/software vendors and technologies for the U.S. and for Europe. This understanding must be applied to help explore all options that can facilitate a rapid proof of concept and prototype development.

The bulk of the research came in exploring the evolving industry of wireless computing. This was done through going to trade shows, calling and interviewing vendors for hardware, software, networks, services, etc. Obtaining information on the web was very useful here. Talking to industry experts also helped a great deal.

Although there is a lack of wireless computing expertise within the Kodak Professional DCS group, there are scattered amounts of expertise throughout Kodak in different divisions who are working on other types of wireless projects as well. Harnessing some of their experience can certainly be helpful in the future.

Next came the task of sorting through the options down to ones that would fit Kodak's needs the most. Selection criteria are based on the camera's hardware and firmware specifications, the project objectives and requirements, limitations in funding and other resources. The culmination of all of the above went into the architecture and design proposal, to recommend a design that will meet the needs of current customers as well as attract future users of our products. Planning and definition of work was created for each project and prototyping and testing begins. Finally, suggestions could be made for future releases of the cameras on features, functions and architecture.

Note: Much of the market research was done through interviews inside and outside of Kodak, and through web and printed media.

2.6 Project Solution Overview

Below is an overview to the WLAN and WWAN project solutions. More details is shared in Chapter 4 of this thesis. As described above, I led the research and design of two separate wireless multimedia projects with different requirements and end results.

WWAN Project:

The first project is to develop a proof of concept prototype that can deliver digital images to a server from a remote location with a Kodak Professional DCS camera using a cell phone as a dialup modem. The project was intended to enable a mobile transfer of images from virtually anywhere using low bandwidth wireless networks. Ideal customers are photo journalists who need to deliver their images to headquarters quickly and efficiently.

The appropriate networks were selected for the U.S. and Europe (the two major markets being served). Several of the latest model digital phones were selected as a dialup modem that connects to a remote server using Z-modem protocol with appropriate adaptors used to connect phone and camera. Software controls and Graphical user interface (GUI) were also developed.

to connect phone and camera. Software controls and Graphical user interface (GUI) were also developed.

I completed the design and definition of work for this project during my internship. The project was implemented, and the end result was a working prototype that was demonstrated at the PMA show in Las Vegas in early Feb 2000. Quality Assurance (QA) is underway, and roll-out to the public is expected by the second quarter of this year.

WLAN Project:

This project was aimed at finding a way to network DCS cameras to a server via high-speed WLAN. The server would have the ability to treat the camera as a network client or hardware memory device and select pictures to bring across from camera to server. One server can have access to multiple cameras. The proposed solution would consist of choosing the appropriate WLAN equipment platform within the IEEE 802.11 standard. Software development for the camera and server side would be outsourced to a leading wireless middleware solution provider. The solution would use a Proxim RangeLan2 card in the camera's PCMCIA slot to communicate with a server (likely a laptop) via an Access Point. The GUI for the camera and the application for image processing on the server would be developed internally. A communication stack would be developed for the camera's operating system (OS) to talk with the Proxim card, which in turn talks to the server. The application for the server would be able to monitor multiple cameras out in the field as clients view thumb-nail sketches of the images captured by these client cameras and then could select particular shots to download to the server.

I also completed the design and definition of work for the WLAN project which is currently being evaluated for implementation by the DCS engineering team.

2.7 Summary.

For over one hundred years, the Eastman Kodak company has followed the basic principles and policies set forth by George Eastman himself. This includes the policy to foster growth and development through continuing research. The Kodak Professional Digital Camera division and the Advance Technology group is doing just this to improve market competitiveness and fulfill customer demand and requests. Due to increased

productivity of its users and lead the industry into the next millennium. Two wireless multimedia projects were identified. One for the low bandwidth WWAN environment allowing a user to send images directly from the camera to a server via a cellular or satellite phone from virtually anywhere in the world, and the other for the higher bandwidth WLAN environment, allowing multiple cameras to be networked wirelessly to a server, which can monitor images captured on each camera and upload the selected picture. The approach used for these projects was to understand the professional digital camera market, the customers, internal competence and to understand the current wireless computing industry and what is available to help implement the projects, sort out the viable options, and define the design and work to implement the projects. The WWAN project has been completed and will be soon available to Kodak's customers. The WLAN project still being investigated by DCS engineering for future product release.

Chapter 3. Wireless Computing Industry Background

3.1 Wireless Computing Industry Today

The convergence of Information Technology, Telecommunications, and Multimedia is underway. The wireless and mobile computing frontier represents the next leap forward towards this convergence and towards even higher productivity and efficiency for what some people have referred to as the “Mobile Information Society”. The Wireless revolution will depend upon technology improvements, the adoption of standards, and how well the customers are served. Here are some major trends that are taking shape:

- Wireless infrastructure for wide area networks (WWAN) is evolving from slow data rate connectivity towards 3G (third generation) technology where bandwidth can be over 2 Mbps, allowing the Internet to be “everywhere”. 4G wireless systems that are even further out will offer multiple functionalities in one hand set (voice, data, video-conferencing, SMS, image, and other applications), as well as global roaming, and integration with WLAN & WATM networks.
- Wireless standards such as Bluetooth, IEEE 802.11, and 802.15 are being established to deliver interconnectivity between assortments of information appliance in localized environments. Environments include wireless local and personal area networks (WLAN and WPAN).
- Hardware devices that allow communication to take place are becoming smaller, cheaper and faster, with more features to provide better experience for users. Smart phones and PDAs are converging, and other devices such as digital cameras, laptops, vending machines, and kiosks are being wirelessly enabled.
- Software architectures, Operating systems (OS), and protocols are converging towards standards. Palm, Windows CE, and EPOC is dominating the mobile OS space. Internet Protocol (IP) will be a foundation. There will be interim communication architectures such as WAP and middleware and web-clipping

that will be used while improvements are made and/or better architecture and standards prevail.

- New roles are being shaped as Network Operators and Banks battle for the mobile service portal and transaction space – capturing revenue from customers through value added services (VAS.) The two battles being waged are the battle of standards and the battle for the customers.
- New applications and Services will yield dramatic productivity and lifestyle improvements within the next five years, many of which will be personalized and location base driven – meaning services that deliver value to you intelligently based on where you are at that time.

There is no doubt that the wireless computing industry will yield dramatic changes in the way we operate. Power lies in the ability to be access and deliver information, be productive, anywhere, anytime. This chapter is aimed at surveying different components of the wireless computing space and providing enough background information to better navigate the fast-changing terrain.

Understanding the Wireless Market Place:

To understand the wireless computing space, we must examine the different market segments and components that make up this space. The wireless industry can be divided into three major segments that are separated by environment and applications. Each segment requires different components and has different characteristics and different applications. For the time being, one should not simply say “wireless computing” without being more specific as to what environment and application is being referred to.

WPAN vs. WLAN vs. WWAN:

The first distinction we must make is the difference between the Wireless Personal Area Network (WPAN) market, Wireless Local Area Network (WLAN) market and Wireless Wide Area Networks (WWAN) market.

WPAN is designed for communication of information appliances (IA) within close proximity of one another (10 meters or less.) For the purpose of this paper, HomeRF is

described within the WPAN framework. Key components to WPAN include the embeddable radio transceiver, the standards and protocol for transmission, and security and access control. Key differential issues are range and cost.

WLAN are allowed greater power and thus extends to far greater distances than WPAN, allowing computers and IAs to be networked together in an environment such as an office building, a warehouse, airport, hotel, etc. WLANs also allow roaming and backbone network access. (Note that similar technology is used for what is described as wireless metropolitan area networks, (WMAN) IEEE 803.16 (typically licensed systems), but for the purposes of this paper they will be described in the same category as WLAN.) The components for WLAN are the radio transceiver, access points (repeaters) and the protocols that network them together.

Finally, WWAN extends into wide area cellular and satellite coverage. WWAN is more complex than the first two environments. Key components include the network infrastructure that provides signals, the carriers who bill for the services, the transmission standards/protocols that determine performance of the data link, the cellular modems which can be handsets or dedicated modems, the computers or IAs themselves, and the software architecture or middleware that enables applications to be delivered via a given data network.

3.2 Wireless Personal Area Network (WPAN)

Technologies in the WPAN arena are driven by the Bluetooth standard. This represents technology that is typically embedded on information appliances that can transmit and receive within 10 meters of each other. With over 1,500 members of the Bluetooth Special Interest Group (SIG), development of specification version 1.1 was announced in July 1999. The roadmap for the SIG calls for Bluetooth end products to become available from a wide variety of suppliers. The current Bluetooth standard has the advantage of low power consumption and is embeddable to most information appliances such as cell phones, laptops, PDAs, printers, and much more. The current proposed throughput is less than 1 Mbps. The number of nodes (number of users in one local network environment) is still limited to 7, with a range of about 10 meters.

WPAN will evolve in the coming year with IEEE 802.15.3 standard being pushed by IEEE to far greater bandwidth (up to 40Mbps supporting multimedia), and greater range. HomeRF, which is an effort to push for low power, short range and a higher bandwidth standard than Bluetooth for networking home computer/IAs is perceived to be caught in the middle of Bluetooth and WLAN technologies. It lacks the performance of the 802.15.3 specifications, and potentially costs more. Home RF could be characterized as a “trimmed down 802.11” technology.

The primary applications for WPAN will involve devices communicating within the proximity of a room without the use of wires. Using WPAN technology, Cell phones, Laptops, PDAs, Digital Cameras, Kiosks, Printers, etc. can communicate with one another and transfer information back and forth. A useful example of WPAN is in the case of your cell phone wirelessly communicating with your Laptop or PDA, to eliminate need for connection cables and allow your computing device to dial out to the internet even when your cell phone is in your pocket or handbag.

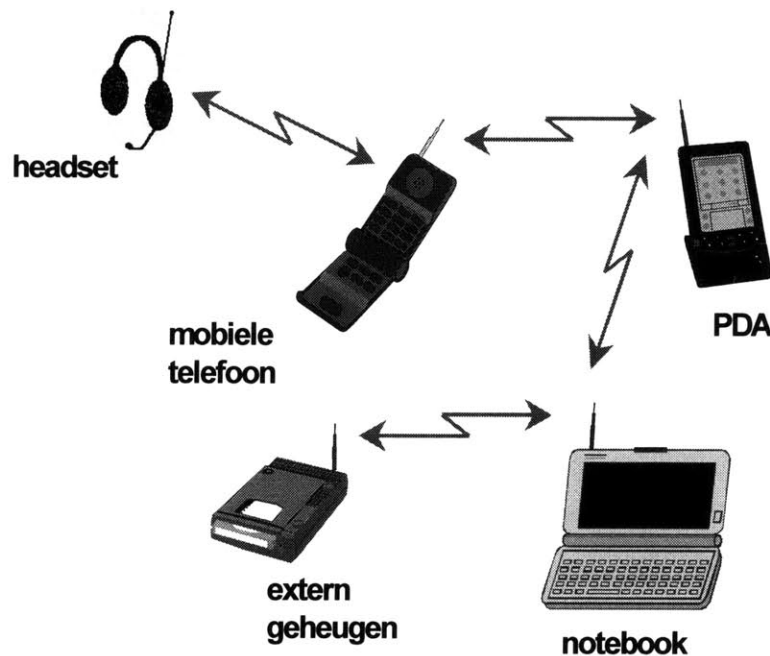


Figure 3.1: WPAN illustration

BlueTooth:

Bluetooth is being pushed as the de facto standard for personal area wireless networks. It is a low-power, short-range, flexible, wireless technology specification designed for local area voice and data communications. The system operates in the ISM 2.45 GHz band, providing license-free operation in the United States, Europe and Japan. The goal is to open a whole new dimension of applications and appliances by enabling short-range, low-power, unlicensed, wireless connectivity from the hand-held device to a myriad of other devices including PCs, consumer electronics, point-of-sale transaction terminals, cell phones, pagers, Internet proxies and other electronic devices.

Current Bluetooth Specs:

Bluetooth uses a short-range radio link built into a 9 mm x 9 mm microchip. The protocol enables the exchange of information between many devices, including mobile telephones, PDAs, notebook PCs, handheld PCs, associated peripherals, and home hubs, which may include Home RF. The radio will operate on the globally available 2.45 GHz ISM "free band," meaning there will be no hindrance for international travelers using Bluetooth-enabled equipment.

The Bluetooth baseband protocol is a combination of circuit- and packet-switching, making it suitable for both voice and data. Each voice channel supports a 64 Kbit/s synchronous (voice) link, and the asynchronous channel can support an asymmetric link of up to 721 Kbit/s in either direction, while permitting 57.6 Kbit/s in the return direction. All in all, this is sufficient to cope with the vast majority of proposed data rates over cellular systems. The nominal link range is 10 cm to 10 m, but links can be extended to more than 100 m by increasing the transmission power.

The software framework in the proposed specification would require Bluetooth-compliant devices to support a basic level of interoperability. The level of compliance will vary depending on the device application. For some applications, this will extend from radio module compliance and air protocols, to application-level protocols and object exchange formats. Below is a Functional Diagram of the BlueTooth Stack.

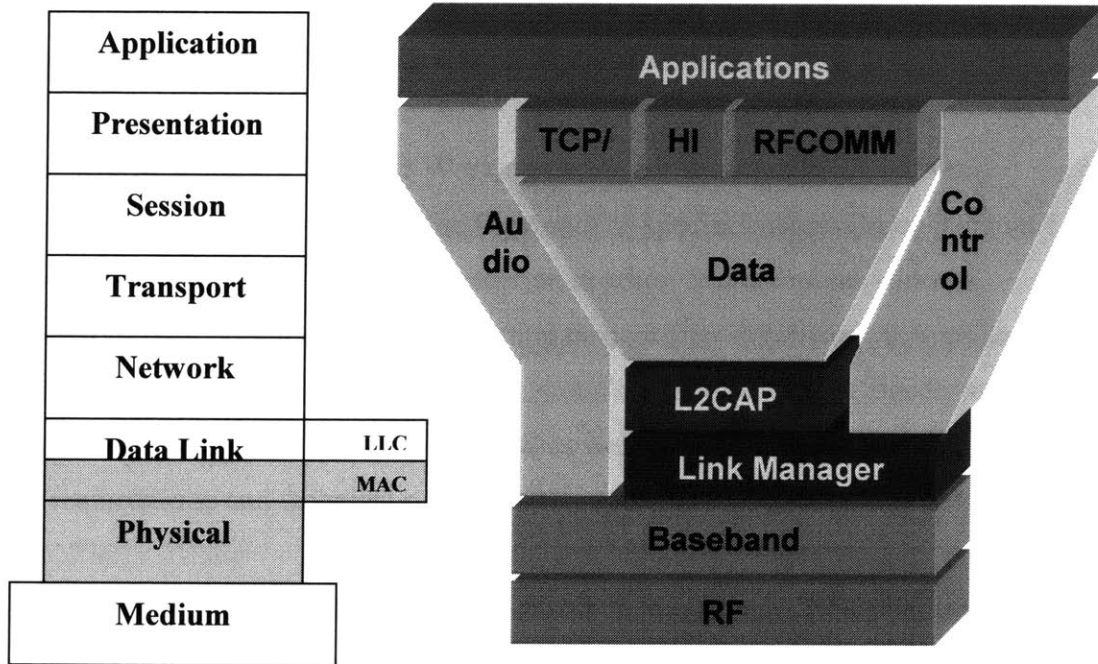


Figure 3.2: Functional Diagram of the Bluetooth Stack (source: Motorola)

802.15.3 High Speed WPAN:

The initial Bluetooth standard is lacking in several respects and there is a ground swell being built towards a new standard that will be faster, have greater range and be more robust than the current 802.15.1 standard. A group of talented engineers within Kodak has developed a patented wireless transmission technology they hope will now be the standard that supports multimedia. This technology is being proposed to the IEEE organization as the 802.15.3 standard.

The IEEE 802.15 WPAN Working Group is doing work in an accredited Standards Development Organization. Both the HomeRF Working Group and the Bluetooth Special Interest Group are informal consortia-based groups defining wireless networks.

HomeRF could be characterized as a "trimmed down 802.11". Bluetooth is a newer addition to the wireless space and comes closer to satisfying WPAN requirements.

The primary 802.11 design criteria are different from those of the WPAN. The WPAN functional requirements are simpler, yet there is a much greater concern over power consumption, size, and realizable product cost. This is due to the WPAN focus on the requirements of wearable computing and peripherals.

The first project of the IEEE 802.15 Working Group for Wireless Personal Area Networks (WPANs) is derived from the Bluetooth™ Special Interest Group Version 1.0 Specification, Foundation Core and Foundation Profiles, that addresses wireless networking of protocols and mobile computing devices (e.g. organizers, laptops, and cell phones). This is in keeping with the working group's objective to work closely with special interest groups and industry consortia, as well as with industry to solicit input on market requirements and technical solutions.

One of the major goals for IEEE 802.15 as well as for the Bluetooth Special Interest Group (SIG), is global use of wireless personal area network (WPANs) technology. Devices using the IEEE 802.15 WPAN and Bluetooth technology will provide country-to-country usage for travelers. They will be able to be used in cars, airplanes and boats and truly be international.

Because of this, much of the Bluetooth(TM) technology is focused on a single specification that meets the worldwide regulatory requirements that fall into two categories: security and spectrum/power. As the radio link will contain private business and personal data/voice, security is a requirement. As security is heavily regulated worldwide, the technology has to conform or work with the various worldwide agents to ensure it meets these requirements.

The Bluetooth specification allows portable and mobile computing devices, such as organizers, laptops and cell phones, to communicate with one another and interoperate

and is focused on security and global spectrum/power requirements. The standards created by the 802.15 working group will provide the foundation for a broad range of interoperable consumer devices by establishing universally-adopted standards for wireless digital communications. The goal of the 802.15 group is to create a consensus standard that has broad market applicability and deals effectively with the issues of coexistence with other wireless networking solutions. As mobile wireless technology increases, IEEE 802.15 standards are anticipated to be a major growth area for IEEE Local and Metropolitan Area Network standards (IEEE 802 standards), and the IEEE-SA.

In regard to spectrum and power, the technology needs to travel with the user. Unlike a typical WLAN that is set up in one area and rarely moved, WPAN mobile devices travel with the users. As such, the technology needs to be designed such that a single technology meets the spectrum power requirements of the world.

Possibilities:

Imagine a world where you can be linked to whatever you think of, to manage your life, to consult, to transact, to travel simply, to do business creatively, or to share an idea or a joke with a friend. Imagine a world where your Personal Area Network serves you with what you need when you need it, allowing you to do more with your life.

- You have instant, automatic access to your personal and business data
- Your electronic devices wirelessly and spontaneously synchronize with each other
- You access your email and Intranet / Internet from wherever you are
- You are able to instantly network with airlines, hotels, theatres, retail stores and restaurants for automatic check-in, meal selection, purchases and electronic payments

Bluetooth enables the creation of wireless Internet gateways that allow Bluetooth-equipped devices to access the Internet quickly and easily. This kind of network can host an infinite suite of User Applications, such as being able to wirelessly synchronize with your desktop and access your e-mail and Intranet / Internet from remote locations.

Imagine being able to spontaneously network with airlines, hotels and car rental agencies for automatic check-in, seating / room assignments, meal selection, purchases and

electronic payment. Personal Area Networks also allow devices to work together and share each other's information and services. For example, a web page can be called up on a small screen and then can be wirelessly sent to a printer for full-size printing. Personal Area Networks can even be created in one's vehicle, helping to bring increased safety and convenience via devices such as wireless headsets and Bluetooth speaker systems.

Despite the great things that Bluetooth and WPAN is promising to deliver, there are significant technological and consumer behavioral challenges to overcome. For example, how will tens or hundreds of devices within a localized environment such as an airport or shopping mall talk to each other? How will security be handled? Can the information on my wireless PDA be stolen by someone else within my proximity? Can others detect my presence at a location without my permission? Will I be intruded by unwanted spam wherever I go? These are some of the questions that must be addressed before the wonderful possibilities of WPAN becomes ubiquitous.

(Source: Motorola, and IEEE)

3.3 Wireless Local Area Network (WLAN)

Technologies in the WLAN arena allow for networking of computers with locally installed transmitters and receivers at greater bandwidth and range than WPAN at this time. Bandwidth for WLAN is relatively high. Currently popular versions from companies such as Proxim, Lucent, Symbol, Aironet, RadioLan, and others allow for throughput of about 1.6Mbps. Soon these throughput rates will increase to 11Mbps and even 20Mbps or higher. WLAN solutions can be very effective in keeping computers and devices networked without the tether of wires in a localized environment such as a building, a warehouse, or a compound. There are more and more WLAN solutions being deployed around the world, from enterprise solutions in Walmarts, warehouses, hospitals and office buildings, to limited horizontal solutions at some major airports and hotels that provide travelers high-speed internet access. The drawback of WLAN is its coverage area and power consumption. Many of these high frequency (2.4Ghz or higher) systems can only cover a few hundred feet in diameter, hence making them “local” and require large numbers of transmission points in order to have adequate coverage, which makes it costly. Furthermore, the radios drawing a fair amount of power and size is still a concern, making it unsuitable at the time for an embeddable radio. For many companies, a WLAN solution can still be very attractive in terms of flexibility, effectiveness and even cost when compared to alternative wired networks.

There are two very different spread spectrum RF technologies being used for the 2.4GHz wireless LAN environment with both supporting the common IEEE 802.11 MAC standard. They will be described in the following sections. (Note that some WLAN manufacturers are stepping up to the 5GHz frequency range for larger bandwidth delivery; however, the tradeoff is typically in range and early cost.) For purposes of this report, we will primarily focus on the popular 2.4GHz range. The FCC and its counterparts outside of the U.S. have set aside bandwidth for unlicensed use in the so-called ISM (industrial, Scientific and Medical) bands. Spectrum in the vicinity of 2.4GHz, in particular, is being made available worldwide.

Spread Spectrum

The name “spread spectrum” is given to a series of products that spread their transmitted signals over a wide range of a given frequency spectrum. They, therefore, avoid concentrating power in a single narrow frequency band. . This allows unlicensed devices to share or have “multiple access” to the spectrum. The two main alternatives within the IEEE 802.11 standard are Direct Sequence Spread Spectrum (DSSS) and Frequency Hopping Spread Spectrum (FHSS). The following sections will discuss the advantages and disadvantages of the two competing technologies.

DSSS

DSSS avoids excessive power concentration by spreading the signal over a wider frequency band. Each bit of data is mapped into a pattern of “chips” by the transmitter. At the destination, the chips are mapped back into a bit, recreating the original data. Because each chip pattern is unique and 8 to 11 bits long, it is easier to detect the string, and make a decision about where a 1 or 0 was sent, than to detect a 1 or 0.

Several DSSS products in the market allow users to deploy more than one channel in the same area. They accomplish this by separating the 2.4 GHz band into several sub-bands, three of which are non-overlapping and can contain an independent DSSS network.

Because DSSS truly spreads power density across the 20 MHz spectrum, the number of independent (i.e. non-overlapping) channels in the 2.4 GHz band is small. The maximum number of independent channels for any DSSS implementation on the market is three.

FHSS

FHSS spreads the signal by transmitting a short burst on a 1 MHz narrow band, "hopping" to another frequency for another short burst and so on. The source and destination of a transmission must be synchronized so they are on the same frequency at the same time. All FHSS products on the market allow users to deploy more than one channel in the same area. They accomplish this by implementing separate channels on different, hopping sequences. Because there are a large number of possible sequences in the 2.4 GHz band, FHSS allows many non-overlapping channels to be deployed.

Comparison of DSSS and FHSS

With two technologies to choose from, users are apparently faced with a difficult technology choice. To make this decision easier we can look at practical attributes of FHSS and DSSS products developed for the 2.4 GHz band. Choosing one over the other

should depend on the application and the usage environment. There are inherent advantages to each technology.

Advantages to FHSS:

1) Immunity to Interference from Outside Sources

DSSS networks may be more hampered by outside interference than FHSS networks that can “hop” frequencies without experiencing as much degradation. Because of its “frequency agile” nature, FHSS is more immune to outside interference than DSSS. The main difference between FHSS and DSSS is: FHSS allows multiple cells (using different hop sequences – a type of CDMA) in the same area at the same time and is good if the interference is also wide band because the power density over a narrow band is higher. DSSS allows faster data rates and is more immune to narrow band interference. DSSS however receives all the energy of any transmission in its channel and has to detect the signal intended for it, which means overlapping cells have to be on different channels and can affect the front ends.

2) Immunity from Multipath Interference

“Multipath” interference (caused by the signal bouncing off walls, doors or other objects and arriving at the destination at different times) is more easily avoided by FHSS systems than DSSS. FHSS can come in handy in areas with much reflection. DSSS can show some improvement if antenna diversity is used. However, building in antenna diversity causes the final product to be larger, heavier and more costly.

3) Total Network Capacity

Because of their efficiency, FHSS networks are inherently able to provide three to four times more total network capacity than DSSS networks. In the 2.4 GHz band, the maximum number of non-overlapping 2 Mbps channels for a DSSS system is 3 (for a total of 6 Mbps capacity). FHSS networks have more capacity both in theory and in practice. Theory predicts at least three times as much total network capacity. In practice, Proxim's RANGELAN2 offers 15 non-overlapping 1.6 Mbps channels (for a total of 24 Mbps aggregate capacity). This is four times as much gross bandwidth as any DSSS

product in the 2.4 GHz band. DSSS now has a CCK modulation method at 11 Mbps, which makes it 33 Mbps.)

4) Network Scalability

Adding a second Access Point (AP) to an area in an FHSS network and configuring it to a new channel number immediately doubles the bandwidth in that area. Users roaming into the area will be randomly assigned to one of the two APs, effectively doubling the accessible wireless bandwidth for this area. Because of the nature of their method, DSSS products do not permit roaming between channels. Roaming communities must be all on the same channel in order to initiate the communications. If DSSS APs are placed on the same channel, they will interfere with each other.

5) Performance Consistency

"In a large installation where the maximum distance is too great for all radios to communicate with each other, there will be multiple access points which are geographically overlapped to ensure continuous coverage. A single terminal may be within range of up to three access points and may also see lower power signals from other access points. In this common scenario, the availability of a large number of different cells with FHSS is a large advantage. This is in contrast to the maximum of three DSSS networks that can overlap without constantly interfering with each other." (Source: "Benefits of FHSS" Symbol Technologies)

6) Power Consumption

For mobile applications, low power consumption is critical since mobile users require long battery life to stay mobile. DSSS inherently consumes more power than FHSS products, requiring heavier batteries or more frequent recharges. Power amplifiers for DSSS transmitters are less efficient than their FHSS counterparts. This causes significantly higher power consumption in the DSSS products.

7) Security

Data from DSSS products is more easily intercepted than data from a FHSS product.

FHSS was originally deployed by the military because of the fact that it is difficult to intercept and jam. This advantage is now available to commercial users. There are infinite combinations of dwell times and hopping sequences. Capturing an FHSS signal would require significant development time and concerted effort.

DSSS products, on the other hand, use a simple (usually 11-bit) spreading code that allows the transmission to be easily mapped back into the original data, and all use the same code to make systems work together out of the box. Look at <http://grouper.ieee.org/groups/802.11> for a paper on security for WLANs. Intercepting a DSSS signal simply requires capturing the signal and translating it back to the original data using a well-defined algorithm.

Advantages to DSSS:

1) There is a larger installed base of DSSS Products, due to a variety of reasons including higher data rates, better potential for noise immunity, and cost. Much of this installed base is 902 MHz products. Unfortunately, 915 MHz has its own deficiencies (such as lack of worldwide availability, narrow bandwidth and lack of standards) that have caused the WLAN standard to exclude 900 in favor of 2.4 GHz band. The recent emergence of the 2.4 GHz band is allowing users to suppliers to make new choices. Most manufacturers, including many that invested in DSSS for the 915 MHz band, are investing in FHSS today.

2) DSSS Products Have Better Range

This is one major advantage claimed by DSSS product manufacturers. Many public tests have compared 915 MHz DSSS with 2.4 GHz FHSS. The 915 MHz products showed the range advantage that one would expect due to the greater propagation of RF signals in the 915 MHz band. The comparison between 2.4 GHz products show a slight but not dramatic difference in terms of range.

3) DSSS Products Have Better Throughput

To support this point, DSSS suppliers show results from public tests of small wireless network configurations. Point to point throughput is considerably variant within DSSS

and FHSS product categories. Different environments will sometimes yield different results. DSSS products do have higher throughput when there is no interference, but if there is interference, the actual throughput could significantly degrade.

Conclusion

Wireless LANs support valuable applications that offer increasingly improved productivity and quality and revenues in many markets around the world. Implementers of these applications have the choice of two different spread spectrum RF technologies, DSSS and FHSS. This choice is a critical "platform decision" that affects the future growth and capabilities of their wireless backbone network. Choosing the right RF technology for a specific application and environment is key when it comes to end performance. Vendors that support primarily DSSS are Lucent WaveLan, Telxon, AT&T GIS, RadioLan. Vendors that support primarily FHSS are Proxim, Symbol, Intermecc, Norand, etc. (although some of these vendors do support DSSS as well.

3.4 Wireless Wide Area Network (WWAN)

WWAN refers to cellular and satellite networks that expand the scope of coverage beyond a localized environment and give users the freedom to roam virtually anywhere on earth. As mentioned before, WWAN environments face issues of low bandwidth, non-ubiquitous cellular coverage and high cost of satellite coverage. The average bandwidth throughput is now about 9600bps, with some localized metropolitan areas having 28.8Kbps provided by Metricom Ricochet. Infrastructure will be built to support 3G, (3rd Generation) cellular technology. Bandwidth for 3G is expected to reach over 1Mbps in three to five years. The building of 3G infrastructure will take time and will also be very expensive, from cost of frequency spectrum licenses to the implementation of hardware and software support.

Coverage for WWAN is improving, but it continues to be an issue to end users.

Reliability for wireless services is poor when compared to that of wired services. Very seldom do you pick up your home phone and find it not working or have your phone call dropped in the middle of a conversation. In the wireless environment, most users expect to be in and out of coverage and to have dropped calls.

Bandwidth will also continue to be an issue, because as bandwidth slowly increases, the traffic will also increase, and different types of applications will readily absorb any bandwidth that may become available. Unlike the wired world where laying down more fiber or cables that can provide virtually unlimited bandwidth, transmission of data over the air is still limited by laws of physics as well as by regulations of the FCC. The good news is large companies are investing heavily into providing greater WWAN bandwidth; therefore, bandwidth will slowly improve over time.

As mentioned above, the WWAN industry delivers voice and data via either cellular networks or satellite networks. It is also important to point out that within the framework of each WWAN provider lie not only the wireless portion which allows for communication between handsets and towers or satellites, but there is sophisticated wired land line infrastructure that ties everything together and allow data to flow from point to point across the greater internet. Our focus will be on the wireless portion of the infrastructure, with some mention of the wired backbone that supports the overall operation of wireless services.

This section will be divided into several sub-sections.

- 3.4.1 Cellular Technology overview
- 3.4.2 Network Carriers / Operators
- 3.4.3 Other Wireless Data Networks
- 3.4.4 Road to Third Generation technology
- 3.4.5 Satellite Networks
- 3.4.6 Other Components to WWAN

3.4.1 Cellular Technology Overview:

The wireless cellular industry can be broken down into two major components: Wireless Network Infrastructure and Wireless Communications Technology. This industry primarily uses current voice cellular infrastructure and is continuing to improve the data communication portion towards providing faster, better, and cheaper service to the end users. Cellular data users typically connect to the Internet via a wireless modem or through a serial port to their data-ready cellular phone. These networks currently offer “Circuit Switch” service much like the wired phone lines one has at home. The benefits are that users understand dial-up connection to the Internet and that cellular networks are pervasive. The fundamental drawback is network reliability and cost. If a connection is dropped, which often happens to our cellular phone calls due to coverage area or other interference, then the user must start over by re-dialing the internet or server connection. This can be particularly frustrating if you were in the middle of sending a large file and must start over. In practice, connecting to the Internet via the cell phone today provides very low bandwidth connectivity- usually 9.6Kbps to 14.4Kbps or less. The reason today’s cellular networks can only provide such low bandwidth is because data is allocated to the same radio bandwidth as a voice call. Since voice encoders (vocoders) in current networks digitize voice in the range of 8 to 13Kbps, that is about the amount available for data. In the future, these networks will offer Packet Data service like today’s CDPD (Cellular Digital Packet Data), and soon to come GPRS (General Packet Radio Service) and EDGE (Enhanced Data Rates for GSM Evolution), and ultimately, Third Generation (3G) solutions such as UMTS (Universal Mobile Telecom Systems). Unlike circuit switching, packet data is more robust and is much more suitable for the

wireless environment. It provides users with an “Always On” model and dramatically improves the overall user experience for wireless data applications. The next generation mobile data communication will offer significantly better bandwidth to allow for an assortment of applications and services that will change the way society operates.

Wireless Cellular Network Infrastructure

A simplified wireless cellular network infrastructure consists of these main elements:

Mobile Station or Terminal (MS) - The MS is typically a cellular phone or it can be a cellular modem connected to laptop, or PDA (personal digital assistant such as a Palm or CE device) or smart pagers can also be considered a mobile terminal. The MS provides the end-user with access to the network’s services via the radio path.

Base Station (BS) - The BSs are geographically dispersed sites that communicate with the MSs via the radio path. The BSs are stationary and provide coverage of specific geographic regions, while the MSs are free to move throughout the service area. BSs can be mounted on towers, buildings, or any structure that provides an optimal Line of Sight (LOS) coverage.

Mobile Switching Center (MSC) - The MSC communicates with the BSs and exchanges messages with the wired line Public Switched Telephone Network (PSTN) and other wireless networks. This wired portion of the overall infrastructure can handle much larger volumes of data when compared to the wireless portion, leaving the bottleneck for bandwidth very much in the section between BS and MS.

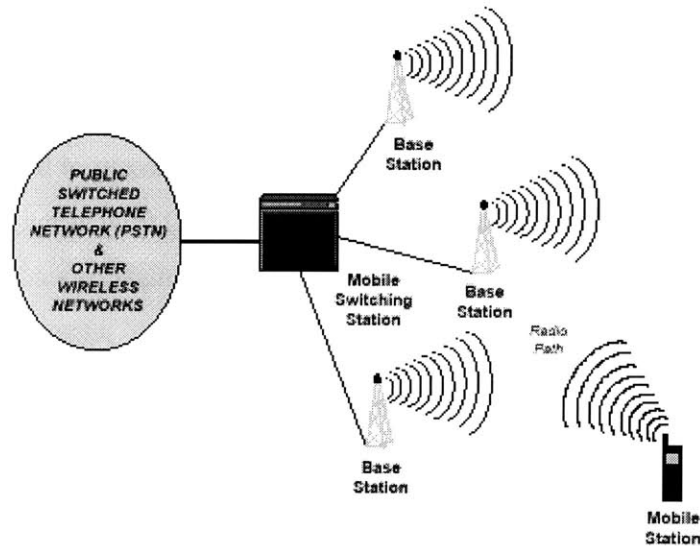


Figure 3.3: Simplified Wireless Cellular Network Infrastructure

Wireless Cellular Communications Technology

Wireless communications technology has experienced tremendous evolution in the past 20 years. The first generation of wireless networks were deployed in the 1980s at cellular frequencies of (800 MHz). These networks used analog transmission modes, such as AMPS (Advanced Mobile Phone System), the U.S. standard. Within 10 years, many of these networks reached their capacity. To accommodate growing demand, the second generation of wireless networks were put into place using digital transmission modes. These networks were based on FDMA (Frequency-Division Multiple Access), where each user is assigned to a different frequency band, and TDMA (Time-Division Multiple Access), where each user is assigned to a different time slot, and late in the 1990's CDMA (Code Division Multiple Access).

In the early 1990s, TDMA emerged as the dominant digital transmission standard. A number of TDMA networks were implemented as an adjunct to the existing analog networks. The U.S. standard was based on TDMA technology, and the European standard, GSM (Global System of Mobile Communications), was also based on TDMA technology. Today, GSM uses 800Mhz and 1900Mhz in Europe and 900Mhz and 1800Mhz in the U.S. GSM is currently the most popular transmission standard used around the world having over 200 million users in over 100 countries. Much of Europe

today is standardized on GSM. This allows users to roam from country to country without having to worry about losing coverage. The billing is simply transferred to the appropriate operator that services the user's account.

The FCC wanted to prevent dominance of existing players and wanted to promote competition. That is why the U.S. uses different frequencies than the rest of the world. This creates a lack of standards worldwide and requires special phones that can function in both environments.

Digital technologies offer a number of benefits over their analog counterparts including improved spectral efficiency, encryption, enhanced services (e.g. facsimile), better robustness, lower operation costs, reduced power consumption, and smaller/lighter handsets. However, looking toward the next century, more bandwidth and capacity will be required to deliver voice, video, data, facsimile and more, seamlessly to end users, regardless of their location in the world. These services are commonly referred to as Personal Communications Services (PCS). Toward this end, in 1993, wireless communications reached another milestone when the U.S. Congress allocated a new spectrum which were designated PCS frequencies (1.8 to 2.0 GHz). Within the same timeframe, a new transmission mode was proposed based on CDMA (Code-Division Multiple Access) technology, which offered additional benefits not afforded by TDMA. Traditional TDMA systems are narrowband systems; and therefore, their dimension is limited. TDMA systems cannot accommodate additional users once all of the time slots have been assigned. CDMA systems are based on a spread spectrum convention whereby the number of users is only limited by the bandwidth and the amount of interference. Multiple conversations can be spread across a wide segment of broadcast spectrum by assigning one of 4.4 trillion unique codes to distinguish it from the other calls being transmitted simultaneously. CDMA results in increased capacity, higher voice quality, fewer dropped calls, better security and privacy, lower power consumption, reduced operating costs, and enhanced services. CDMA and PCS have ushered in the latest generation of wireless networks.

3.4.2 Network Carriers & Operators:

Today in the United States, there are more transmission mode standards being offered to customers than any other country in the world. CDMA is becoming a dominant standard. Carriers include: Sprint PCS, Bell Atlantic Mobile, Frontier Cellular, Airtouch and others. TDMA has also left a legacy with many of the major networks still using the standard, such as AT&T, GTE, etc. Nextel has created its own nationwide iDEN (Integrated Dispatch Enhanced) TDMA-based network that has a strong customer base. Now GSM has arrived in the U.S., and carriers like Omnipoint and Voice Stream are delivering services across the country. Most of the carriers have now rolled out their data services to allow for circuit switch connections to the Internet. Cost of these services is still quite high, ranging from 10 cents a minute to 39 cents a minute. These prices are expected to go down in time.

European carriers (sometimes referred to as Operators) are fewer due to regulations. These carriers include Vodafone, Telia, Telenor, Sonera, British Telecom, Netcom, etc. In Asia there are many powerful wireless operators as well, from NTT DoCoMo in Japan to Cable & Wireless HKT, SmarTone, and Hutchinson in HongKong.

NTT DoCoMo i-Mode:

The largest telecom company in Japan is now providing a wireless data service called iMode. This service is similar to CDPD but uses its own protocol. iMode has gained tremendous acceptance within Japan. Many users of iMode are young people, with entertainment being a popular value added service. The data bandwidth is about 9.6Kpbs, and coverage is very good in Japan. Since it is packet data, it has the always-on feature, which enables some types of applications that circuit switch systems do not offer, and can be more cost-effective. There are over 1500 independent content or application providers that deliver added value to iMode customers. According to McKinsey, NTT is seeing revenue increase from iMode users that are 12% - 15% higher than those not using iMode services.

Penetration and user habits:

Adoption of wireless voice and data is still growing at a rapid pace. Many analysts predict that there will be over 1 billion world-wide subscribers of wireless communication services by the year 2004. Today, penetration in the U.S. market has

grown to about 30% but is still lagging when compared to parts of Europe, particularly Scandinavia, where penetration is above 60%. Penetration in Hong Kong is about 47% and is expected to climb to over 80% by 2003. To compare Europe and the U.S., there may be different factors that result in these differences in penetration. First, Europe is very much standardized on GSM, while the U.S. has many competing standards. The billing system is different in Europe than it is in the U.S. In Europe, incoming calls are not charged to the wireless customer, but are paid for by the caller. This eliminates the users' worry of giving their number to the wrong people. By freely giving one's phone number to others, there is a viral effect that shows "everyone has a cellular phone; therefore, I must also." Furthermore, U.S. carriers charge customers based on buckets of minutes, and not pay-as-you go like Europe. European customers are not as sensitive to how many minutes they have used each month. In fact, many European customers do not have a land line and simply use their cell phone as their permanent phone.

Another feature that is provided by GSM and not by CDMA is the Short Messaging Service (SMS). These are text-based messages that can be sent over the GSM network much like a paging service. This service has grown dramatically in Europe and in some cases has become about 10% of a carrier's revenue stream. Many value the added service using the SMS platform has been developed. This includes banking and stock quotes and simply communicating with friends. SMS in the U.S. has not yet taken off for a variety of reasons – not the least of which is the different standards being offered to consumers, preventing any viral effect from users.

Virtual Operator:

A Virtual Operator does not own the infrastructure for wireless service. Rather, it negotiates contracts with carriers to sell airtime service and handle the customer acquisition and interface. One aggregator of cellular data services is GoAmerica, who resells airtime or bandwidth provided by other major carriers. The advantage is having a nation-wide coverage without having to deal with billing and roaming issues.

GoAmerica made deals with most carriers to resell the data, while they act as integrator as well as a value added reseller. GoAmerica distributes hardware as well as services and has plans of being a portal.

3.4.3 Other Wireless Data Networks:

There are other networks outside of the voice networks we typically see. They are data-only networks used for paging and other data services. **Bell South Wireless (Mobitex Network) and American Mobile (ARDIS Network)** has the most pervasive data cellular coverage in the United States, with roughly 90% nationwide coverage. However, the true throughput of these networks are relatively low, typically less than 4800bps. Mobitex was originally developed by Ericsson and is now deployed by various carriers in the world. Here in the U.S., Bell South is the predominant Mobitex carrier. The Mobitex network is the infrastructure of fixed equipment that is necessary to provide communication between the wireless terminals, which may be used in wearable, mobile or fixed applications. A Mobitex network can be configured in many different ways ranging from a large public network providing nationwide coverage to a small, privately-owned network serving a single company or region.

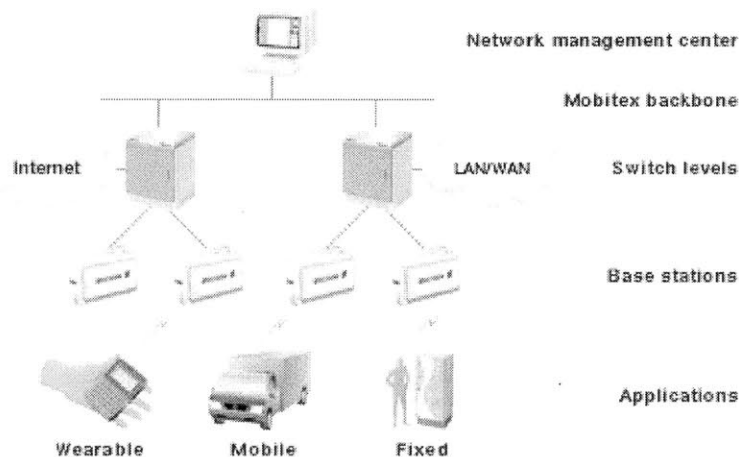


Figure 3.4 Mobitex Network Configuration

The basic functionality for a Mobitex network is provided by a number of radio base stations (BAS) and one or more switches (MX). Each base station serves a single radio cell, which may have a diameter of up to 30 km in certain applications. Together, the radio base stations provide an area with coverage and determine the capacity of the network. Wireless devices communicate with the nearest base station but are also able to

roam freely between radio cells and from base station to base station as the user changes location. The MX switches routes traffic to and from the base stations and provides connections between wireless devices and fixed terminals. Typically, there are many switches in a Mobitex network, possibly organized in a hierarchy of regional and area switches, that are all connected by fixed links. The MX also provides an important gateway function to other networks. In the standard Mobitex configuration, this consists of an X.25 gateway implemented directly in the MX, with a number of other gateway options available. The Network management center (NCC) handles all operation and maintenance tasks, including network configuration, alarm handling, subscriber administration and billing information. Mobitex is not native TCP, and requires middleware to translate any winsock type applications in order to communicate on the network. Middleware companies that can facilitate communications on these networks include Dynamic Mobile Data and Nettech. Mobitex and ARDIS networks deliver data in 512 character packets. The delay and delivery order is not guaranteed, and they charge per message packet, the time and cost per image sent make these networks impractical.

Cellular Digital Packet Data (CDPD)

CDPD is a WWAN that enhances the services provided by cellular carriers. Unlike current cellular connections called a circuit-switched connection, CDPD provides seamless service while roaming using packet data. There is no need to dial a roamer access number to gain data service. CDPD is becoming much more widely adopted, though it is very U.S. centric, with most of the services available in the United States. CDPD now covers most major metropolitan areas. CDPD is sometimes referred to as “Wireless IP”, as it is little more than a protocol layer built directly onto TCP/IP. This makes CDPD ideally suited for Internet connection. CDPD is an instant on network, and provides 19.2Kbps access with real throughput averaging 9600bps.

Unlimited access to CDPD networks generally costs \$39/month and up. Several carriers providing coverage to most of the nation are deploying the CDPD network. The carriers consists of:

Ameritech Cellular	AT&T Wireless
Bell Atlantic Mobile	BC Tel Mobility
GTE Wireless	SNET Mobility
Comcast Cellular	Southwestco

CDPD Technology:

CDPD technology is a packet data service that is always on and is used for data only. CDPD differs significantly from traditional circuit-switched connections. Data transmissions are broken down into packets of data. Where there is no data to transmit, there are no packets and, hence, no communication charges. CDPD uses the same cellular frequencies and the same cellular infrastructure. A typical cell site may be equipped to handle up to 30 simultaneous voice calls using a pair of frequencies managed by the cellular system. A second pair of frequencies is used for CDPD traffic only without interfering with voice calls. Because packet data users share the same line much like a network user on a LAN, each packet is encoded with a destination, origin and the message. This way all packets reach its destination without the need to establish a dedicated connection. CDPD uses standard network protocols, TCP/IP (Transport Control Protocol/Internet Protocol), allowing many existing applications to operate over the network. Note that CDPD equipment must be added to standard cellular networks in order for coverage to take place.

The biggest problems facing software developers writing for new wireless data communication networks are delays, dropped packets, duplicated or out-of-order packets and cost. Mobile applications should allow plenty of time for packets to arrive at their destination, communication protocols that require an acknowledgement for each packet should not be used. This would also save on the cost of CDPD, because acknowledgement packets cost just as much as message packets.

3.4.4 Road to 3G – Next Generation Wireless WAN Technologies

On the road to Third Generation (3G) wireless communication technology lie a variety of different technologies that will bridge the gap. These technologies are commonly referred to as 2.5G. They include: GPRS (General Packet Radio Service), EDGE (Enhanced Data Rates for GSM Evolution), WCDMA, Ricochet, etc. 3G technology will reach bandwidths of over 2Mbps using standards such as CDMA2000 and UMTS (Universal Mobile Telecom Systems).

The global standards body for communications is the International Telecommunications Union (ITU). The 3G standards effort is called International Mobile Telephone 2000 (IMT-2000). IMT-2000 mandates data speeds of 144 Kbps at driving speeds, 384 Kbps for outside stationary use or walking speeds, and 2 Mbps indoors. Since high-speed services such as WLANs already offer speeds of up to 11Mbps, it's difficult to predict the expected market demand for 2Mbps indoor service when 3G networks roll out. The technology that will provide 384 Kbps in 3G networks is the same technology that will be deployed in 2.5G networks, albeit at slightly lower data rates in the 50 to 150 Kbps range. But this is still some ten times faster than most options today. 2.5G services will be released in the year 2000, well in advance of 3G networks that won't start rolling out until 2002 at the earliest.

Despite specifications by ITU, the IMT-2000 standards will not necessarily result in one unifying 3G technology that is the same all over the world. The differences between UMTS (what Europe and Asia will likely adopt) and CDMA2000 (likely for U.S.) and even what the Japanese may independently come up with, need to somehow converge for the benefit of the consumers. Becoming apparent during the transition to 3G is the demand for global roaming, thus different networks must be able to interoperate. Also, there should be a smooth transition from 2G to 2.5G to 3G, thus multimode handsets must also be part of the equation.

Table 3.1 describes the various wireless data communication technologies that are here today or are expected to roll out in the next three to five years.

These technologies are slowly converging, beginning with a convergence of IS-136 and GSM data services, and followed by a harmonization of the 3G versions of GSM and CDMA. While differences will continue to exist, the systems will interoperate more readily.

There are some other important trends to note. The first is that standard bodies are working not just on radio technologies, but also on the networking infrastructure. One objective is to allow users to seamlessly roam from private networks (e.g. Ethernet, WLAN) to public networks. Such roaming will require the implementation of standards

such as Mobile IP. Another goal is to simplify the connection between mobile computers and wireless devices through personal-area network (PAN) technologies such as Bluetooth. Yet another trend is voice over IP. As terrestrial networks start using IP for voice and multimedia, it will be important for such IP communications to extend all the way to the wireless device. Perhaps the most important trend of all is for ubiquitous coverage. This will be achieved not just by converging wireless standards, but also by sophisticated new devices that operate in multiple modes and at multiple frequencies. This is the world of tomorrow.

Core Technology	Service	Data Capability	Expected Deployment
GSM	Circuit-switched data based on the standard GSM 07.07	9.6 Kbps or 14.4 Kbps	Available worldwide now
	High-speed circuit-switched data (HSCSD)	28.8 to 56 Kbps service likely	Limited deployment 1999 and 2000 as many carriers will wait for GPRS
	General Packet Radio Service (GPRS)	IP and X.25 communications over Kbps	Trial deployments in 2000, rollout of service 2001
	Enhanced Data Rates for GSM Evolution (EDGE)	IP communications to 384 Kbps. Roaming with IS-136 networks possible.	Trial deployment in 2001, rollout of service 2002
	Wideband CDMA (WCDMA) Universal Mobile Transmission Standard (UMTS)	Similar to EDGE but adds 2Mbps indoor capability. Increased capacity for voice.	Initial deployment in 2002 or 2003
IS-136	Circuit-switched data based on the standard IS-135	9.6 Kbps	Some carriers may offer service, not widespread because key carriers already offer (CDPD)
CDMA	Circuit-switched data based on the standard IS-707	9.6 Kbps or 14.4 Kbps	Available by some carriers now
	IS-95B	IP communications to 64 Kbps	Expected in Japanese markets by early 2000
	CDMA2000 - 1XRTT	IP communications to 144 Kbps	Trial deployment in 2001, rollout of service 2002
	CDMA2000 - 3XRTT	IP communications to 384 Kbps outdoors and 2 Mbps indoors	Initial deployment in 2002 or 2003.
Metricom Ricochet	ISM 2.4Ghz band packet based technology used in Metropolitan area	28.8Kbps, expected to go up to 128Kbps	Limited service in U.S. available now 28.8Kbps, faster service roll out 2001
iMode NTT DoCoMo	Packet Data service like CDPD based on proprietary technology	9.6Kbps expected to go up to 1	Service Widely now available in Japan only expansion expected
iDEN	TDMA based circuit-switched technology by Nextel, expected to have packet data soon	19.2Kpbs circuit-switch, expected to go up to 33.3Kpbs when packet data becomes available	Circuit switch roll out already in progress in U.S. Packet data roll out in mid 2000 expected

Table 3.1: Summary of forthcoming cellular-data services.
(Source: Rysavy Research)

Investments In Next Generation Technologies:

As indicated by the above table, there will be many choices for Operators/Carriers to choose from. Many carriers will be reluctant to invest in 3G UMTS technology right away. The major reason is cost. UMTS licenses are very expensive. In March 2000, bids for UMTS licenses alone were up to £600 million pounds. Furthermore, because completely new equipment must be installed, the cost of infrastructure can be another \$3 to \$4 billion dollars. Most GSM carriers are putting their bets on a service called General Packet Radio Service (GPRS), a 2.5G technology. GPRS can combine up to 8 (out of 8 available) time slots in each time interval for IP-based packet data speeds up to a maximum theoretical rate of 160 Kbps. GPRS can be added to GSM infrastructures quite readily. It takes advantage of existing 200 kHz radio channels and does not require new radio spectrum.

The phase after GPRS is called Enhanced Data Rates for GSM Evolution (EDGE). EDGE is able to deliver data rates up to 500 Kbps but requires new infrastructure and can be much more costly to roll out when compared to GPRS. McKinsey in Europe believes that Operators will skip EDGE and go straight from GPRS to UMTS.

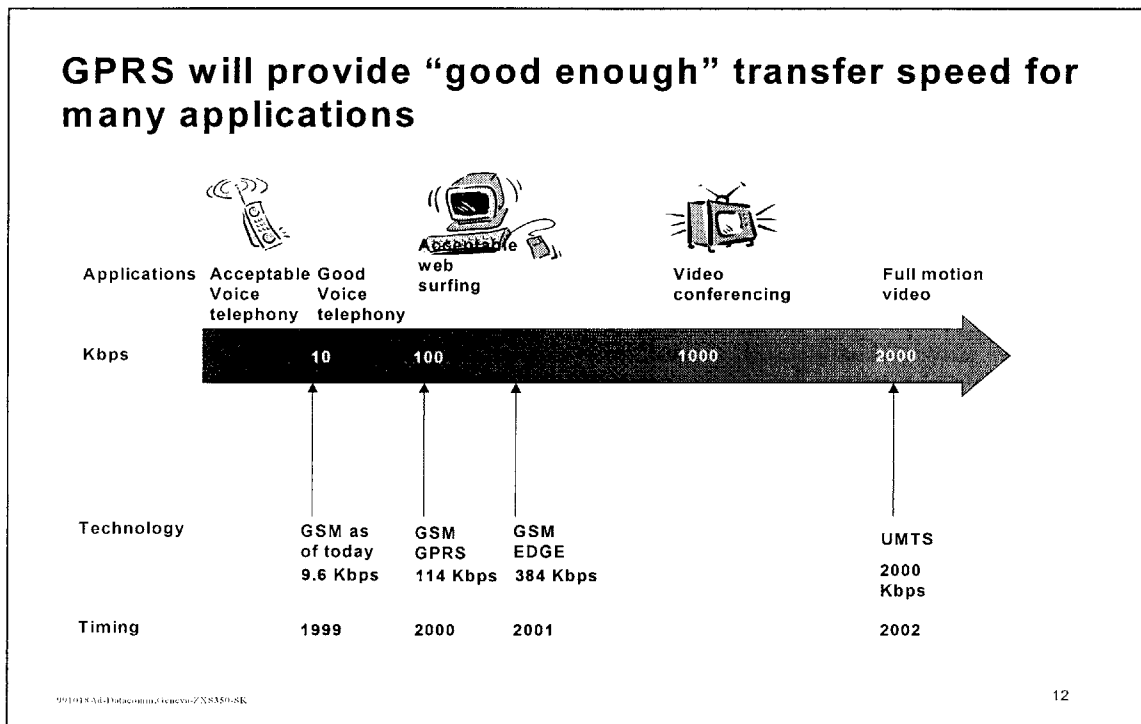


Figure 3.5: Illustration of technology path to 3G

(Source: McKinsey, Oslo)

The 3G version of GSM, Wideband CDMA or WCDMA, is based on CDMA technology. This version of CDMA deviates from American standards, although it uses the same spread spectrum principles. For data, WCDMA adds the capability for 2Mbps data rates indoors. The data networking for WCDMA will likely be based on EDGE/GPRS infrastructure protocols, such as the GPRS Tunneling Protocol.

The earliest WCDMA deployment is expected in Japan in 2002. IS-136 carriers might eventually use WCDMA technology, though a wideband TDMA (WTDMA) approach has also been proposed.

Beyond IS-95B, CDMA evolves into 3G technology in a standard called CDMA2000. CDMA2000 comes in two phases. The first, with a specification already completed, is 1XRTT, while the next phase is 3XRTT.

3G cellular technology is a huge technological and market phenomenon, but it needs to be understood in the context of other developments. Other high-speed wireless-data solutions will be available. For instance, don't overlook Metricom's Ricochet network. Paul Allen and MCI WorldCom are pouring significant new investment into expanding coverage area and putting in a new high-speed service at 128 Kbps. Japan will also try to promote its own standards. They have essentially sat on the sideline in the first two generations of cellular technology development, and it appears they are not planning on doing so for 3G. NTT DoCoMo is extremely aggressive in pushing towards 3G, perhaps with their own standard. The Personal Handyphone System (PHS) deployed widely in Asia is a form of cellular technology limited to pedestrian use and will soon offer 64Kbps data service.

There is no question that a myriad of new applications will be possible with next-generation, wireless-data networks, but keep in mind that these are massively complex networks, and it will take both time and large investments to develop and deploy the technology. Many of the advantages that these networks will offer are already available using existing data services. Organizations that gain experience with wireless technologies today will be the ones best positioned to take advantage of new networks tomorrow. (Source: Rysavy Research, McKinsey.)

3.4.5 Satellite Communications Overview:

There are several major mobile satellite communications providers. Three of them are designed for mobile handset voice and data communications: Iridium, Globalstar and ICO. The other are Teledesic, which is aimed at delivering broadband Internet-in-the-Sky globally via “Terminals” on the ground rather than mobile handsets, and Orbcomm, which provides low bandwidth data and messaging services via a low earth orbit (LEO) satellite constellation. The following section will examine each of these providers and their technology to better understand the benefits and limitations of satellite communications. Iridium and Globalstar are both aimed originally at serving voice calls to global customers. They meet the needs of cellular users who roam outside of coverage areas, people who work in remote areas where terrestrial systems do not exist, residents of under-served markets who can use their fixed-site phones to satisfy their needs for basic telephony, and international travelers who need to keep in constant touch. The technologies are now being expanded to provide data communications as well. The major advantage is global coverage. The disadvantages are cost, bandwidth throughput, and the necessity to have a direct line of sight (LOS), which means one must be outdoors with a clear path to the sky. Because it requires more power to send the high frequency signals up to the satellites, the antennas and handsets are also larger and heavier.

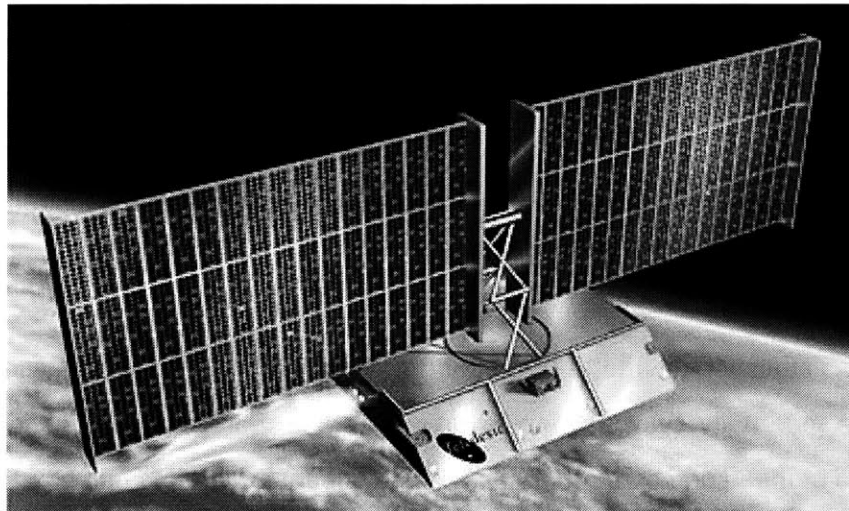


Figure3.2: Satellite in Low Earth Orbit (LEO)

Satellite Constellations:

A lone satellite is only over part of the world at any time. It can not cover the entire world at once. To achieve the greatest coverage, a number of satellites need to be launched so that at least one satellite can be seen from every point on the earth at once. Once the geometry and the orbits of your satellites is determined so that their coverage areas (or footprints) overlay the world, you have a satellite constellation with coordinated coverage and control.

Globalstar:

Globalstar is a consortium of leading international telecommunications companies and a wholesale provider of mobile and fixed satellite-based telephony services. Globalstar provides global services in Voice calling, Short Messaging Service (SMS), Positioning* , Facsimile* and Data transmission* , all from one phone. (*: roll out begins in 2000). Globalstar coverage is now in place to supply data and voice to customers at a rate of \$1.50 per minute of usage. The data throughput rate is on average 9600bps, which enables a host of applications very similar to today's cellular data networks with much greater coverage. The only drawback is one of cost, and the line of sight "open sky" issue which prevents indoor usage unless an antenna can be established to the outside. An additional advantage of the Globalstar system is the ability for customers to use the same phone for terrestrial cellular services that are much more economical when there is coverage, and then switch over to satellite services only when there is no cellular coverage. The latest phones for Globalstar will automatically detect coverage and select the most economical service. This is one of the largest advantages, in addition to higher data bandwidth, that Globalstar has over all other existing satellite providers.

Globalstar Technology Overview:

Globalstar's constellation of 48 low-earth-orbiting (LEO) satellites, transmits calls from your wireless phone or fixed phone station to a terrestrial gateway, where they are passed on to existing fixed and cellular telephone networks in more than one hundred countries on six continents. Each satellite consists of an antenna, a trapezoidal body, two solar arrays and a magnetometer, and operates at an altitude of 1414km (876 miles).

The Globalstar system is designed to provide high-quality satellite-based telephony services to a broad range of users. Globalstar phones look and act like mobile or fixed phones with which customers are familiar. The difference is that they can operate virtually anywhere, carrying calls over an exceptionally clear, secure Code Division Multiple Access (CDMA) satellite signal. Like "bent-pipes" or mirrors in the sky, the Globalstar constellation of 48 Low Earth Orbiting (LEO) satellites picks up signals from over 80% of the Earth's surface, consisting of everywhere outside the extreme polar regions and some mid-ocean regions. Several satellites pick up a call, and this "path diversity" assures that the call does not get dropped even if a phone moves out of sight of one of the satellites. As soon as a second satellite picks up the signal and is able to contact the same terrestrial "gateway", it begins to simultaneously transmit. If buildings or terrain block your phone signal, this "soft-handoff" prevents call interruption. The second satellite now maintains transmission of the original signal to the terrestrial "gateway".

On any given call, several satellites transmit a caller's signal via CDMA technology to a satellite dish at the appropriate Gateway where the call is then routed locally through the terrestrial telecommunications infrastructure. The satellites are placed in eight orbital planes of six satellites each, inclined at 52 degrees to provide service on Earth from 70 degrees North latitude to 70 degrees South. Each gateway, which is owned and managed by the service provider for the country in which the gateway is located, receives transmissions from orbiting satellites, processes calls, and switches them to the appropriate ground network.

Globalstar Market:

As a wholesaler, Globalstar sells access to its system to regional and local telecom service providers around the world. These Globalstar partners, in turn, form alliances with additional providers. Ultimately, the caller benefits because his final service provider understands the local market and provides optimal service for the area.

Products:

Mobile phones manufactured by Ericsson, Qualcomm, and Telit are lightweight and can be used for either cellular or satellite-based calls. The phones are available with many

accessories, such as car and marine kits, which extend the phone's reach still even further.
(Source: Globalstar)

Iridium:

With 66 Satellites forming a cross-linked grid in space, the Iridium system is the first low-Earth-orbiting system for wireless telephone service. Only 780 km (485 miles) above the Earth, these satellites work differently from those at a much higher orbit (36,000 km or 22,000 miles) in two major ways. First, they're close enough to receive the signals of a handheld device; and second, they act like cellular towers in the sky - where wireless signals can move overhead instead of through ground-based cells. Also, as technology evolves, so will the benefits. Voice service for Iridium has been established and is currently in use by customers. Data service is currently in beta and will roll out some time this year. The performance of Iridium in terms of data transmission throughput is only 2400bps. The cost as well as performance of Iridium has resulted in a slow adoption rate, average cost per minute being about \$1.99. In addition, the handsets are relatively large and bulky, and current models do not allow you to use regular cellular services like the Globalstar units. The benefit, once again, would be the global coverage.

Iridium Technology Overview:

The Iridium satellites weigh about 1500 lbs and lasts 5 to 8 years. They are launched into space by the following launch vehicles: Boeing Delta 11 (5 satellites per launch) Khrunichev Proton (7 satellites per launch) China Great Wall Long March 2C (2 satellites per launch). The orbiting period for these satellites is about 100 minutes. Voice and messaging service links uses the frequency band of 1616 - 1626.5 MHz (L-Band), Intersatellite Links uses 23.18 - 23.38 GHz (Ka-Band), while Ground Links from the satellites uses 19.4 - 19.6 GHz (Ka-Band) for Downlink, and 29.1-29.3 GHz (Ka-Band) for Uplink. Data transmission rates are at 2.4Kbps. The telephone signaling and transmission technology used are Frequency Division/Time Division (FDMA/TDMA) and Quadrature Phase Shift Keying (QPSK). (Source:Iridium)



Figure 3.4 Iridium phones are currently bulkier and do not have cellular service capabilities.

ICO

ICO will begin introducing its satellite services in the first quarter of 2001. Its system will deliver digital voice, data, fax and messaging services to users all over the world. ICO's mobile phones will be similar in appearance, size and weight to standard GSM phones. Most ICO mobile phones will be dual-mode and capable of operating on ICO's satellite network and existing terrestrial cellular networks. Customers will be able to select their preferred cellular standard (e.g. GSM, D-AMPS, PDC) when they purchase a phone. CO's system will integrate mobile satellite communications capability with terrestrial networks. Handheld mobile phones will, in outdoor environments, offer services similar to those provided by normal cellular phones. In addition, the ICO system will deliver a call-attempted alert when the phone is inside a building.

The space segment

ICO will operate a constellation of satellites in medium Earth orbit, (MEO) 10,390 km above the Earth's surface. Divided equally between two orthogonal planes, each inclined at 45 degrees to the equator, the satellites will provide continuous overlapping coverage of the whole of the Earth's surface. Hughes Space and Communications International is building the satellites. Launches are due to begin in early 2000. The satellites will communicate with the ICONET, which consists of 12 satellite access nodes (Earth stations) located around the world and linked by high-capacity cable. The orbital pattern of the ICO constellation has been designed to provide significant coverage overlap, as well as high average elevation angles. Two or more satellites will be in view of both a customer and a SAN for more than 80 percent of the time in most latitudes. Each satellite will cover more than 25 percent of the Earth's surface at any given time.

Product:

ICO is developing a range of specialty phones for the maritime and land transport markets, as well as fixed residential phones and public payphones.

ICO phones are being developed by major manufacturers such as Samsung, Mitsubishi, NEC and NERA. (Source: ICO)



Figure 3.5 ICO Handsets

Teledesic (global, broadband Internet-in-the-Sky™)

Using a high-capacity broadband network that combines the global coverage and low latency of a low-Earth-orbit (LEO) constellation of satellites, Teledesic and its partners are creating the world's first network to provide affordable, worldwide, "fiber-like" access to telecommunications services such as computer networking, broadband Internet access, interactive and high-quality voice. Most users will have two-way connections that provide up to 64 Mbps on the downlink and up to 2 Mbps on the uplink. Broadband terminals will offer 64 Mbps of two-way capacity. This represents access speeds up to 2,000 times faster than today's standard analog modems.

The Teledesic Network & Technology Overview

The Teledesic Network consists of a ground segment (terminals, network gateways and network operations and control systems) and a space segment (the satellite-based switch network that provides the communication links among terminals). Terminals are the edge of the Teledesic Network and provide the interface both between the satellite network and the terrestrial end-users and networks. They perform the translation between the Teledesic Network's internal protocols and the standard protocols of the terrestrial world, thus isolating the satellite-based core network from complexity and change.

Teledesic terminals communicate directly with the satellite network and support a wide range of data rates. The terminals also interface with a wide range of standard network protocols, including IP, ISDN, ATM and others. Although optimized for service to fixed-

site terminals, the Teledesic Network is able to serve transportable and mobile terminals, such as those for maritime and aviation applications.

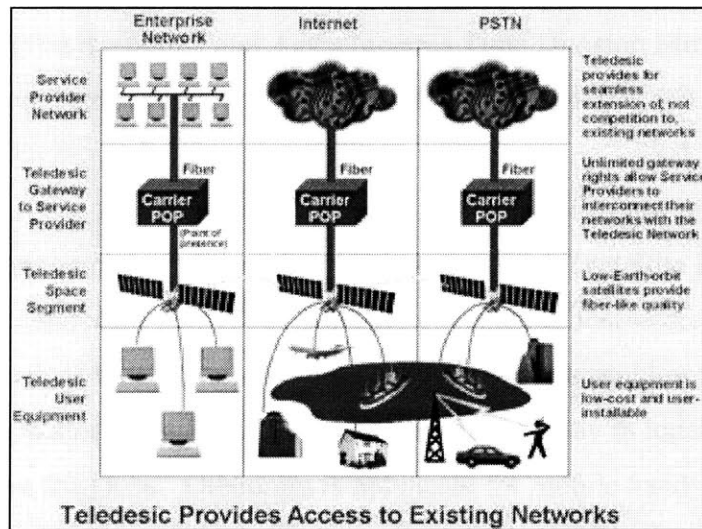


Figure 3.6 Teledesic Network

In the initial constellation, the Teledesic Network will consist of 288 operational satellites, divided into 12 planes, each with 24 satellites. Teledesic satellites operate at a low altitude, under 1,400 kilometers. Each satellite is a node in the fast-packet-switch network and has intersatellite communication links with other satellites in the same and adjacent orbital planes. This interconnection arrangement forms a robust non-hierarchical mesh, or "geodesic" network that is tolerant to faults and local congestion. The network combines the advantages of a circuit-switched network (low delay "digital pipes"), and a packet-switched network (efficient handling of multirate and bursty data).

Downlinks operate between 18.8 GHz and 19.3 GHz, and uplinks operate between 28.6 GHz and 29.1 GHz. Communication links at these frequencies are degraded by rain and blocked by obstacles in the line of sight. To avoid obstacles and limit the portion of the path exposed to rain requires that the satellite serving a terminal be at a high elevation angle above the horizon. The Teledesic constellation assures a minimum elevation angle

(mask angle) of 40 degrees within its entire service area. Using this design, the Teledesic Network is able to achieve availability of 99.9 percent or greater.

A multiple access scheme implemented within the terminals and the satellite serving the cell manages the sharing of channel resources among terminals. Within a cell, channel sharing is accomplished with a combination of Multi-Frequency Time Division Multiple Access (MF-TDMA) on the uplink and Asynchronous Time Division Multiplexing Access (ATDMA) on the downlink. (Source: Teledesic)

Orbcomm:

ORBCOMM is a commercial provider of global low-Earth orbit satellite low bandwidth data and messaging services. The ORBCOMM system enables businesses to track remote and mobile assets such as trailers, railcars and heavy equipment; monitor remote utility meters and oil and gas storage tanks, wells and pipelines; and stay in touch with remote workers anywhere on the globe. Orbcomm is not meant for mobile handset voice and data.

ORBCOMM is owned by Teleglobe, Inc. (NYSE, TSE: TGO) and Orbital Sciences Corporation (NYSE: ORB). Teleglobe Inc. is a leading global provider of broadband services with the most extensive global Internet network. Orbital is a space technology company that designs, manufactures and markets a broad range of space products and satellite-based services.

Orbcomm Technology:

The ORBCOMM system uses 137-138 MHz and 400 MHz frequencies for transmissions down to mobile or fixed data communications devices, and 148-150 MHz frequencies for transmissions up to the satellites. These frequencies, approved for use by LEO satellite systems at the World Administrative Radio Conference in February 1992, were allocated by the FCC to Little LEO mobile satellite services in January 1993. The FCC granted ORBCOMM a U.S. commercial license in October 1994.

The ORBCOMM system uses LEO satellites instead of terrestrial fixed site relay repeaters to provide worldwide geographic coverage. The system is capable of sending and receiving two-way alphanumeric packets, similar to two-way paging or e-mail. The three main components of the ORBCOMM system are: the space segment - the

constellation of satellites; the ground segment - gateways which include the Gateway Control Centers (GCCs) and Gateway Earth Stations (GESs) and the Network Control Center (NCC) located in the United States; and subscriber communicators (SCs) - hand-held devices for personal messaging, as well as fixed and mobile units for remote monitoring and tracking applications.

ORBCOMM currently has 35 satellites in its constellation. An additional launch is planned for 2000, enhancing coverage in the equatorial regions of the world.

The main function of ORBCOMM's satellites is to complete the link between the SCs and the switching capability at the NCC in the U.S. or a licensee's GCC. The satellites are "orbiting packet routers" ideally suited to "grab" small data packets from sensors in vehicles, containers, vessels or remote fixed sites and relay them through a tracking Earth station and then to a GCC.

3.4.6 Other Components For WWAN Computing

Information Appliances: Academic and trade publications are replete with predictions about the rise of the handheld/palmtop computing markets and the demise of the personal computer. The current reality is that the industry is experiencing a rapid proliferation in the number of vendors and devices being introduced into the handheld/palmtop computing market, as well as a host of other information appliances such as smart phones. Vendors offering devices include: Compaq, Casio, Novatel Wireless, NEC, HP, Symbol, Intermec, Nokia, Erricson, Qualcomm, Phillips, Hitachi, Samsung, Sharp, Vadem, Uniden, Everex, LG, Palmax, Trogon and Husky. Recently, a company from Canada named Research In Motion (RIM) has gained significant momentum with their interactive pager devices. These RIM devices use networks like Mobitex and ARDIS to deliver applications and content to users such as email, stock quotes, and much more. Faster, slimmer, more powerful, cheaper devices are on the way.

Mobile Operating Systems: Just as the number of hand-held and palmtop devices are rapidly proliferating, so too are the number of mobile 'real-time' operating systems. The three most prevalent operating systems (in terms of numbers of units and mind-share) are the Palm OS, EPOC and Windows CE. Other operating systems include GEOS, RTOS, QnX, and EMIT, and other proprietary OS.

Wireless Modems: Companies such as Sierra Wireless, Novatel Wireless, Uniden, Sage, RIM, and others, are selling wireless modems for laptop, handheld and palmtop computers. In a broad sense, there are two types of wireless modems. One type of modem is intended to connect the computing device to a cell phone for dial-up connection to the Internet. The other modem type comes with its own antenna and acts more like a network card by connecting the computing device directly to a wireless network like CDPD and Mobitex.

Mobile Software Companies: Companies that write applications for the mobile devices. These applications are not necessarily wireless; they are designed to run **locally** on the

device itself. These companies include Bsquare, Mobilesoft, CasioSoft, Puma, Sierra Imaging, and others.

Mobile and Wireless Software Technologies and Protocols:

This refers to the underlying structure (the magic glue) that makes all of the above components work together to create fully functional and effective wireless computing applications. Without it, the other pieces, no matter how good, cannot function to bring customers what they need. Thus far, there are no defining standards. There are claims of “defacto standards”, but customers’ acceptance ultimately determines the standards, and no one has yet been able to fully deliver what customers want. The three classes of technologies or approach that is competing in the wireless computing space is the Middleware and Synchronization approach, the WAP/Web based approach, and the Terminal Server approach. These three main approaches differ in many respects and offer advantages for different types of applications.

3.5 Wireless Technologies and Trends.

Here is a summary of the major trends that are occurring in the Wireless Computing Industry. They represent part of the forefront of a greater overall convergence towards a Mobile Information Society. The convergence is between Telecommunications, IT and Media. Enabling technologies represent the glue that will make this a reality in the next several years. Below is a summary list of trends within the wireless telecommunication side of the convergence.

1. WPAN – As described in the earlier section, the IEEE 802.15, BlueToothII standard is being pushed. IEEE 802.15c, based in the ISM 2.5 Ghz band, will provide high bandwidth data rates at up to 20 Mbps to 40Mbps, enough for multimedia streaming video and audio, with very low power consumption, and a range of up to 300 feet. The cost of these radios is predicted to be very low (\$10 to \$15 range) allowing many information appliances, including digital cameras, to embed them. Bluetooth II, if established, would push the envelope for WPAN

into the WLAN arena, even competing directly with WLAN. Certainly it may squeeze out HomeRF completely.

2. WLAN – There are advances in the 802.11 and 802.11b technologies that will push this field towards higher bandwidth and lower cost. Both FH and DS will see bandwidth increases. Major manufacturers including Proxim, Lucent, Symbol will come out with better, faster, cheaper models starting Q2 of this year. Lucent claims to have an 11Mbps DSSS radio card coming out this year. RadioLan claims to have a 5.8Ghz system using a Position Pulse Modulations scheme arriving this year that will achieve 10Mbps bandwidth throughput. Proxim also claims to have a new FHSS system on the way that will be faster than the old one by an order of magnitude. Plus they claim to also be coming out with a 5Ghz radio called HyperLan that would achieve 24Mbps.
3. WWAN – This area is undergoing tremendous amounts of change and has the greatest amount of diversity. On the road to 3G, (Third Generation) WWAN network connectivity, there will be transition points and interim solutions. Right now, there are various efforts to move to greater bandwidth technologies. Readers should keep in mind, the opinion of the author, that wireless network bandwidth will ALWAYS be limited. No matter how much more bandwidth is given to us, it will be readily consumed, especially when more and more users discover the benefits of being mobile and wireless. The same way as in the wired environment; whenever we get a faster modem, it is still not enough, and we keep inventing more applications and uses to gobble up any available bandwidth, especially with multimedia.
4. Hardware devices that allow communication to take place are becoming smaller, cheaper and faster with more features to provide better experience for users. Smart phones and PDAs are converging, and other devices such as digital cameras, laptops, vending machines, and kiosks are being wirelessly enabled. We are already seeing the smart phones that combine cell phone technology with a Personal Information Manager (PIM) – the PDQ by Qualcomm is one of the first examples of this convergence. It combines a CDMA phone with a Palm Pilot into one unit. The form factor still leaves much room for improvement but the trend

is taking place. Nokia 9000 communicator is another example. There are new devices coming out that have a relatively large color display that is touch sensitive. It will contain cellular capabilities, Bluetooth capabilities, possibly GPS positioning capabilities, and it is one's personal organizer – all in a fashionable and slim form factor. Devices like this will be able to better maintain customer loyalty and would be a primary vehicle for voice and Internet communications.

5. Software architectures, Operating systems (OS), and protocols are converging towards standards. Palm, Windows CE, and EPOC is dominating the mobile OS space. Internet Protocol (IP) will be a foundation. There will be interim communication architectures such as WAP and middleware and web-clipping that will be used while improvements are made and or better architecture and standards prevail. Other architecture that may gain momentum is the Terminal Server approach. Essentially, information appliances, be they smart phones, PDAs, laptops, or desktops, are treated merely as display and remote control terminals, while all processing and data storage is located on servers. Terminal and server communicates effectively across the Internet, allowing virtually any application and content to be accessed in a real-time and live session. You can literally have the power of a mainframe running in the palm of your hand. One small company that has developed such a technology is Marbles, Inc. <http://marblesinc.com> Which technology and which standard will ultimately prevail is still left to be answered. There are many forces at play in the industry, and technology is only one part of it. Companies who best execute delivering what the customers want and can strategically aligned themselves with the right market partners will be the winners in this race.
6. New roles are being shaped as Network Operators and Banks battle for the mobile service portal and transaction space – capturing revenue from customers through value added services (VAS) and e-commerce. There are two battles being waged. One is the battle of standards, and the other is the battle for the customers. To win the “battle of the customer,” players that are in strategic positions to interface the customers are seeing a shift in the traditional landscape. Operators and

banks, for example, no longer have to stick to their traditional roles as being simply a pipe for people to communicate, or a pipe for money to flow through. Now, with the information technology and telecommunication convergence, they can create business models that were previously not possible. If, for example, the cell phone itself can be used as a platform to authenticate and communicate, it can be where services are being offered and transactions are taking place. If a customer can wirelessly make payments using his/her cell phone, then there may not be a need for a credit card in these instances. Operators want to play because they can control the interface (the portal) with the customer. Now they want to control the transaction layer as well. One example: Sonera, a Finish wireless carrier already offer customers today the ability to buy movie tickets and even sodas from selected vending machines by paying for them wirelessly and getting billed for the transactions later. Banks are a natural fit for the transaction layer but also want to offer services to customers and become mobile portals that capture customers. Yet there are other players like the traditional portals (Yahoo, AOL, etc.) who want in on this space. How this battle will result still remains to be seen. Those who can best deliver the right types of services and maintain customer loyalty and ultimately shape customer habits are the winners in this battle.

7. New applications and services will yield dramatic productivity and lifestyle improvements within the next five years. Many of which will be personalized and location-base driven, meaning services that deliver value to you intelligently based on where you are at that time.

The next section will examine some of the mobile applications that are currently available and some that are likely to be delivered in the next few years.

3.6 Other Applications for Wireless Computing Industry

Many people mistakenly feel that wireless computing is simply about cutting all the wires to traditional wired computing. This is not the case for many of the reasons explained in this thesis including ones in the next section. The limitations in bandwidth, coverage, screen size, power, user habits, etc. are some of the differences between the wired world and the wireless world. People are not expected any time soon to watch motion pictures with their cell phone, nor would they compose thesis or do AutoCAD designs on their mobile PDA. At the same time, the wireless computing revolution will bring about new sets of applications that would simply not be possible in the wired world. For example, location-based service that can determine exactly where you are and provide you with relevant and sometimes critical information. You can imagine being lost or being in a new city and allowing wireless services to tell you where you are or point you to the nearest restaurant, hotel, or give historical information about the site you are seeing or shops near you that may have merchandise you need or want.

Wireless and Mobility offers freedom. Freedom to be where you want to be and still have access to what you need. Freedom to be more productive.

Wireless Applications of Today:

Below are a few wireless applications that are already available today.

- **Mobile Field Service:** Many field service workers that must repair or install equipment from fixing vending machines to copiers, these people are finding tremendous productivity gains from having job calls and customer and equipment information available to them wirelessly. These services will only improve with time.
- **UPS & FedEx:** Major delivery services have invested heavily (hundreds of millions of dollars) into wireless enabling their drivers to track packages. The return on investment has been unquestionably worthwhile.
- **Wireless Taxi:** Many of the Scandinavian countries have installed wireless dispatch systems for their taxis. The GPS unit keeps track of the

location of each driver and automatically routes the nearest available driver to the calls. Drivers reported 15% more fares as a result, and up to 20% more savings on gas, not to mention much faster service for the customers.

- E-mail: Many email services are being offered on various devices to help people stay in touch, from RIM pagers, to Palm VIIs, to simply laptops with wireless modems.
- Financial Services: This sector has been lead users for many years now. The need to be able to get quotes and make trades has been a driving factor towards adopting new technologies.
- Consumer e-commerce: Many offerings are now coming onto the scene, from Amazon to Ebay. Although slimmed down versions of the real thing, many of these offerings do work.
- Value Added Services: Other services include Mapquest, text-based directions, airline ticketing, and banking services are also being offered. The SMS text messaging system is popular in Europe and Japan, especially amongst young people.

Wireless Applications of Tomorrow:

In the future, many more applications will be offered wirelessly. People will freely use wireless computing the way they use a cell phone to communicate or surf the web today. Applications of tomorrow may look like some of the examples below:

- Guided Mobile Tours: Based on where you are, services can offer you guidance on where to sightsee, shop, eat, sleep, fill up on gas, etc.
- Real estate Searches: People may be able to drive around the neighborhood they want to live in and automatically find out what is available for sale, the average prices of homes, taxes, information on school systems, etc.

- Instant Traffic Information: Based on your location, services can provide you with real-time traffic information to your hand-held or Automobile-PC, and redirect you to the best route to avoid traffic jams.
- E-Commerce: Frictionless e-commerce can be done directly from your mobile unit using either smart cards or the device itself. When you want to purchase a product or service, you simply authorize it with your mobile device and the transaction will happen seamlessly in the background. You can transfer money not only to merchants but even to and from personal accounts, minimizing the need to carry currency at all.
- Corporate information sharing: Anything from email and calendars to sensitive customer and corporate information can be accessed remotely with proper authentication and access control.
- Voice and Image over IP: People will be able to not only hear others on their mobile devices; but when bandwidth allows, they can even see each other.

The list goes on and on. Whatever we can conceive with our imagination, it is likely to be achievable. The future is bright for wireless, but there will be challenges along the way, which leads us to the next section.

3.7 Challenges Facing Multimedia Wireless Solutions

Wireless mobility is far more complex than just substituting a wireless modem for a regular modem. Much like driving a car and flying an airplane, both get you where you want to go, but piloting an airplane is far more complex with many more variables, controls and constraints. Wireless computing in its early stages is much more complex than wired line computing. In the future, however, we foresee wireless computing will become as easy and as commonplace as commuting to work. Before that happens, though, we must deal with some inherent challenges that the industry must face.

Bandwidth:

The biggest challenge we face today in the wireless environment, particularly for multimedia, is bandwidth. There never seems to be enough of it, and some suspect that this will be an ongoing issue for a long time to come. Every time bandwidth is doubled, it is readily consumed by applications that were waiting for more. These are applications that were previously not suitable for low bandwidth, such as streaming audio and video. The new applications create more demand from users and thus create more congestion, leaving a lack of bandwidth once again. This can be seen for the Internet in the wired environment. Initially, users were running fine on 14.4Kbps, and then everyone had to move to 28.8Kbps. Then that was too slow, and the move went towards 56.6Kbps with more more graphical and bandwidth intensive applications and content came, attracting more users. Now people are getting impatient with their speed again, creating demand for ISDN, DSL, cable modems, etc. to get more and more performance. The same can also be seen in the WLAN environment. While one would think that today's 1.6 to 2Mbps is plenty fast for users, more bandwidth is now being demanded to fulfill more robust applications and facilitate more users in one area. When it comes to bandwidth, more is always better. The bottom line is what is needed to deliver the killer applications. For some non-multimedia applications, 9600bps may be enough. To really reach the masses and to really achieve multimedia, though, you should have an average throughput of 28.8Kbps or better. Packet data is also preferred over circuit switch due to the always on feature (note that cost can be an issue against packet data if you are sending large files due to being charged by the packet rather than by the minute.)

Difficulties in achieving Higher Bandwidth:

In the wired world, it is relatively easier to deliver higher performance with the same copper lines by changing modems, or even get super high performance into the Gbps range by using fiber lines to dramatically increase the size of the pipe over long distances. (The last mile issue still exists, to overcome getting the high bandwidth into people's homes and offices.)

In the wireless world, however, there are constraints from the laws of physics that makes it difficult today to increase bandwidth at the rate we have in the wired environment. For example, lower frequencies allow signals to travel longer distances at the same power output, but the data throughput is lower. Since the bandwidth at lower frequency spectrums is limited, the alternative is to move upwards in frequency. However, when you move up in frequency, the range that each transceiver can cover becomes much shorter, which means network carriers not only have to eventually replace new hardware infrastructure, but they have to place many more of them to cover the same geographical area. In some metropolitan areas of Japan today, there is data coverage that is greater than 28.8Kbps, but the cellular access points are only hundreds of feet apart and are practically on all vending machines on the streets.

Battery Power and Heat:

Furthermore, the power required to transmit at higher data rates is significantly more. This can be problematic to small mobile devices that do not have long battery life and may tend to overheat.

The bottom line is going to Third Generation higher bandwidth for WWAN will be very capital intensive and will take a number of years. The migration will be done in phases and coverage will be spread little by little just like the migration of cellular phones.

Additional Bandwidth Required for Multimedia:

As illustrated in this Kodak project, any time you deal with multimedia, performance will be directly tied to bandwidth. Large image files need to be sent across the air. Real-time streaming audio and video is in demand for wireless. Today we are dealing with an average throughput of 9600bps in the WWAN environment and 1.6Mbps in the WLAN environment. This will no doubt improve, but the performance received today is geared more towards users that truly need it, and any marginal gains they receive in productivity

are valuable enough for them to pay for it. For example, a PJ will be very happy to be able to send a JPG image of about 300 to 400Kbytes in file size to its intended destination and be more than willing to wait 5 to 8 minutes for the file to transfer, whereas a regular consumer may not find this tolerable. At the same time, the same PJ would prefer the image not be converted from a 2 to 4Mbyte TIF file to the smaller size and lower resolution JPG file. Unless he wants to spend 50 to 80 minutes just to send one picture, he would have to compromise.

Coverage:

Coverage is the next big issue. “Out coverage, out of luck” is a term commonly used. It takes time and money for carriers to provide adequate coverage. Even when an area is covered, there are likely areas where you can run into dead zones. This challenge will improve over time, but it is an issue to be aware of.

Interference:

Aside from pure coverage, sometimes interference can interrupt wireless transmission even if there is great coverage. Interference can come from structures, buildings, hills, trees, etc. and it can also come from other transmission frequencies. For example, the microwave oven can often interfere with ISM WLAN signals.

Communications Standards:

The competing standards make it difficult to choose the right one and make ubiquity more difficult, particularly if the standards do not talk to each other. That is why it is extremely important for the standards organizations and industry to agree upon unifying standards, from Bluetooth to 3G to software architecture to hardware designs.

Security and Access Control:

As more and more information appliances become enabled wirelessly, they will need to have the ability to communicate with each other effectively and securely. It is one thing to allow for communication to take place between devices. How will these devices communicate in a crowded environment? What access does each device have in relation to the other devices it comes in contact with? What security measures are in place to keep confidential material on the devices safe? These are questions and issues that need to be adequately resolved before massive adoption takes place.

Chapter 4. Kodak Project Description and Work

4.1 Project Description Overview

In this chapter, the two wireless multimedia projects I helped design for Kodak are described in greater detail. The definition of work for each project is included. Each project has its own unique challenges since they are dealing with two completely different environments. One is in the WWAN environment, and the other is in the WLAN environment. I was asked to head the research and design efforts for the two projects due to my background and interest in wireless computing. I analyzed VOC data to come up with requirements for the projects, researched the wireless computing industry for best of breed components, and created the design and definition of work for each project. Certain levels of detail and certain information will be omitted due to confidentiality with Kodak.

The challenges faced by each project were different. The WWAN project could be implemented without the need for additional software to be developed for the server. I had to determine the different design criteria and components necessary for each project.

The WWAN project design criteria were governed by:

- what networks and which phones were to be used
- what had to be programmed into the firmware to enable the application and communication
- how to minimize the time of transmission
- what protocol and method of transport should be used, such as IP, Z-modem, etc.

The WLAN project required more wireless middleware knowledge and also required more components such as server side software. It dealt with issues like:

- which WLAN technology and vendor should be used
- how to get the camera's OS to talk with the WLAN card
- how would the server interact with the camera and its file system
- performance and battery issues
- scalability issues

The two projects were treated quite separately. Originally, both were going to have much of the development outsourced to a leading third-party wireless middleware provider described from here out as the Vendor. However, DCS engineering was able to build one of the projects themselves. The efforts for the WWAN project were taken up internally while the WLAN project was put on hold for possibilities of a later implementation. To better understand why certain technologies were selected for each project, we -first take a look at the components involved, including the camera.

Specifications for Cameras:

Below are some high level specifications for the camera itself.

Kodak Professional DCS 520 & 620, capabilities:

- 1) PowerPC 50Mhz 821 processor
- 2) 32 Meg of RAM
- 3) 2 Meg EPROM
- 4) 2 PCMCIA Slots
- 5) 1 Serial connection (3 pin)
- 6) GUI: 2"X 2" color display, 3 control buttons + Spin wheel(520) or Rocker(620)
- 7) Camera Operating System is a deviation of PSOS developed internally by Kodak to best fit the needs of the camera.

The Kodak Professional DCS camera has relatively sophisticated internal computing capabilities. It has a fair amount of RAM, a decent processor, three communication ports with at least one of the PCMCIA ports being used for media storage at any given time. The color display is very nice, and although limited, the controls for the GUI can still be quite functional.

The camera's operating system was designed internally based on the kernel of an older OS named PSOS. This proprietary OS was designed to give superior performance with less overhead and fewer bugs than off-the-shelf operating systems. As a result of the

proprietary OS, particularly for the WLAN project, middleware must be developed for the camera to communicate with the wireless radio. The design must also take final code size into consideration due to the finite limits in Erasable Programmable Read Only Memory EPROM used to store the firmware needed to run the camera and other applications.

Figure 4.1 is a functional diagram of the two architectures to be built for each project.

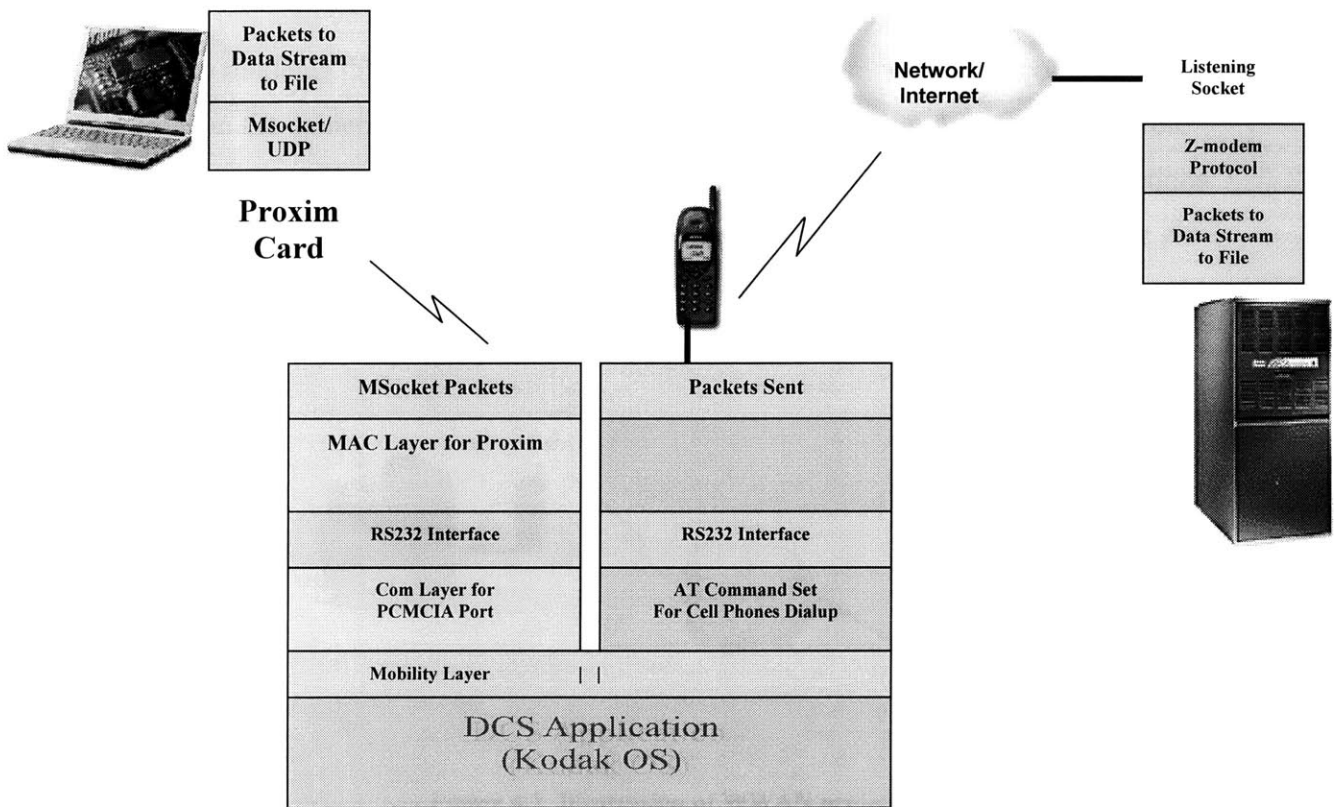


Figure 4.1 Functional Diagram for both WLAN and WWAN Projects

Two different architectures would need to be designed for the two projects, but both can function independently on the camera. The WLAN project was to implement middleware layers and sockets developed by the Vendor, along with Media Access Control MAC layer for the WLAN card by Proxim. The WWAN project initially would not be IP based, which is more straight forward to implement, but would likely be developed for IP and allow the camera to be even more of an Internet appliance.

4.2 WWAN Project

The WWAN project aims to develop a proof of concept prototype that can deliver digital images to a server from a remote location with a Kodak Professional DCS camera using a cell phone as a dial-up modem. The project was intended to enable mobile transfer of images from virtually anywhere using low bandwidth wireless networks. For the solution, CDMA and GSM networks were selected to facilitate data transport for images. Satellite networks can also be used later. Several of the latest model digital phones were selected as dial-up modems that connect to a remote server using Z-modem protocol. Software controls on the camera to communicate with the cell phone using AT commands were developed. A graphical user interface (GUI) for the camera to allow for user selections and preferences were also developed. Finally, a connector cable adapting the three pin serial port of the camera to a nine pin RS232 connector cable for the cell phones would also be used.

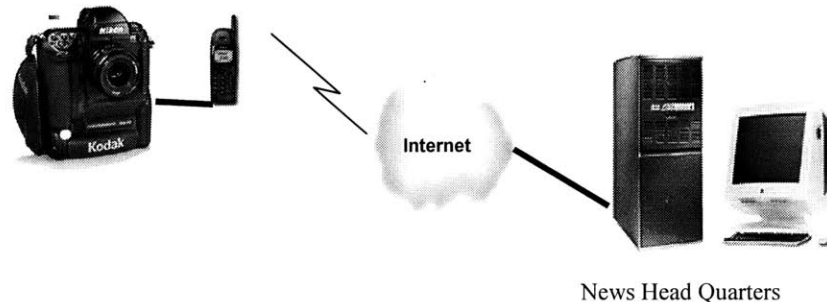


Figure 4.2 Illustration of WWAN project

Definition of Work: DCS Camera Wireless WAN Cell Phone Transmission

Kodak Professional DCS would like to provide wireless cell phone transmission functionality within the present generation DCS cameras (3xx/5xx/6xx) to enable customers to send images straight from their cameras to their intended destinations via a digital cellular phone over either a GSM or a CDMA cellular network using a Z-modem protocol. A photographer who would normally take out the storage media, place it into a laptop computer and transfer the files from their laptop to their intended destination via

cell phone, would now be able to leave the laptop at home and transmit straight from the camera via either a cell phone or a cell phone PC card.

The system consists of the following physical hardware, software and network access:

1. DCS camera with wireless firmware support (3xx/5xx/6xx).
2. A compatible digital cell phone. (Nokia 6185, or Qualcomm 860 for CDMA) (Nokia 7190 GSM-North America, and Nokia 7110 GSM rest of world, or Ericson I888 GSM dual mode)
3. Connection data cable for cell phone to RS232 connection
4. Either a 3 pin serial port adapter that connects to RS232 connection, may need null modem adapter, or
5. Serial Port PC-Card made by a Socket to be used within each DCS. The card comes with a cable that has a RS232 connector.
6. AT Command Set on firmware to talk with phone.
7. GUI that allow users to select phone, select connecting number, send tagged images, and end call.
8. Computer on receiving end with Z-modem capability installed.
9. Network Subscription account that allows for testing: (Frontier CDMA, Sprint PCS CDMA, Omnipoint GSM – in Syracuse, and 900Mhz GSM coverage for Europe and Asia)

An additional solution to add on is the High Speed Nokia PC Card, that allows use of a higher speed GSM network currently available in parts of Europe. To support this we would need to have:

1. DCS camera
2. Nokia PC card
3. Driver and AT Commands to talk with the card
4. GUI that indicates coverage, selects connecting number, send tagged images, and ends call.
5. Network Subscription – unfortunately, the only way to fully test this service is in Europe, with its 900MHZ GSM network.

Reasons for Selection:

The networks we plan to utilize are the GSM (Global System for Mobile communications) network for the rest of the world (900 & 1800MHz) and GSM for North America (800 & 1900MHz), and CDMA 800MHz and 1900MHz primarily for North America. The reason we choose GSM is because of the dominance in coverage and subscriber base. GSM has the most number of subscribers and best coverage of all 2G technologies worldwide. GSM provides about 9600bps in data bandwidth with some areas in Europe beginning to put out higher bandwidth coverage. GSM carriers in the U.S. include Omnipoint and Voice Stream. We chose CDMA for use in North America, also, due to coverage and reliability. CDMA is also widely available in the U.S. for testing and demo purposes. Dominant players in CDMA coverage include Sprint PCS with nationwide coverage (note major nationwide metropolitan areas only). Other carriers offering regional coverage on 800MHz include Frontier Cellular and Bell Atlantic. CDMA bandwidth is typically between 9600bps to 14.4kbps. Actual throughput does vary with traffic for all cellular networks, usually towards the lower end. Kodak is looking to support only a handful of phones that already have built-in modems to establish circuit switch connections on their respective networks. There are no plans to support older phones that require software modems/GSM stacks to run from the host (in our case, the camera). Kodak also wants to limit the number of new phones to support, which reduces development effort and time to market. (Each phone may require slightly different AT Commands to talk with that phone and thus require firmware updates.)

As the industry progresses towards 2.5G and 3G cellular technologies, Kodak Professional DCS should have no trouble in adopting new standards and handsets. The only thing that may be required is a new release of the firmware containing drivers for new handsets. No additional hardware change is required, making the current camera investment a safe one, and the performance increase in bandwidth will dramatically speed up their image delivery. Even global coverage is now available using satellite technologies such as Globalstar.

4.3 WWAN Results, Performance, and Future Adaptations:

The WWAN project I designed was implemented and the prototype was demonstrated with very positive results at PMA, one of the largest professional photography trade shows of the year. One of the key issues with getting better performance is to minimize the file size of the images being sent. A new feature in the DCS cameras now allow TIF files that are normally 2 to 4 megabytes in size to be converted to JPG files which are 200 to 400 Kbytes. Of course, compression does reduce image quality but can dramatically improve time of transmission. With speeds of 9600 to 14.4Kbps through the wireless networks, a typical file would take 5 to 7 minutes to transmit. This type of performance is very acceptable to PJs. A large number of them send pictures wirelessly. The difference now is they no longer need to lug around a heavy laptop, boot it up, transfer files, convert them, plug in the cell phone and then send. The convenience factor has dramatically gone up. Note that Globalstar now provides satellite coverage to virtually all areas of the globe, so DCS camera users can now send images with their cameras from just about anywhere on earth! (Note that from a cost and performance point of view, users can expect to pay 10cents to over \$1 per minute(satellite) and they can also experience dropped calls much like any cellular phone service.

In the future, both DCS cameras and cell phones will be Bluetooth- enabled and can communicate without the use of any wires. A user can simply leave the cell phone in his/her pocket or bag, and simply send the pictures away from the camera via the phone without even the need to plug the phone into the camera.

Coverage and quiriness of hand sets can at times be an issue, although this is improving. If a call is dropped in the middle of transmission, one must start the whole process over. Kodak has also employed some techniques to enhance performance by dynamically varying packet sizes sent according to environment and application. Overall, the performance of this new wireless transmission feature is very good and will only improve with time as network bandwidth improves and connectivity technology improves. In the future, DCS cameras (and also high-volume consumer cameras) may be IP based and would be able to connect the Internet wirelessly, not only to send images, but it also can have the capabilities to do a host of other applications such as instant messaging, reading email and interfacing with the web.

4.4 WLAN Project Description

The WLAN project was aimed at finding a way to network DCS cameras to a server via high-speed WLAN. The server would have the ability to treat the camera as a client or hardware memory device and select pictures to bring across from camera to server. One server can have access to multiple cameras. The solution I proposed consisted of choosing Proxim as the hardware vendor for the RF transceiver. Software development for camera and server side would be outsourced to a leading wireless middleware solution provider. The GUI for the camera and the application for imaging processing on the server would be developed internally. The solution would use a Proxim RangeLan2 card in the camera's PCMCIA slot to communicate with a server (likely, a laptop) via an Access Point. A communication stack would be developed for the camera operating system (OS) to talk with the Proxim card, which in turn talks to the server. The application for the server would be able to monitor multiple cameras on the field as clients, view thumb nail sketches of the images captured by these client cameras, and select particular shots to upload to the server.

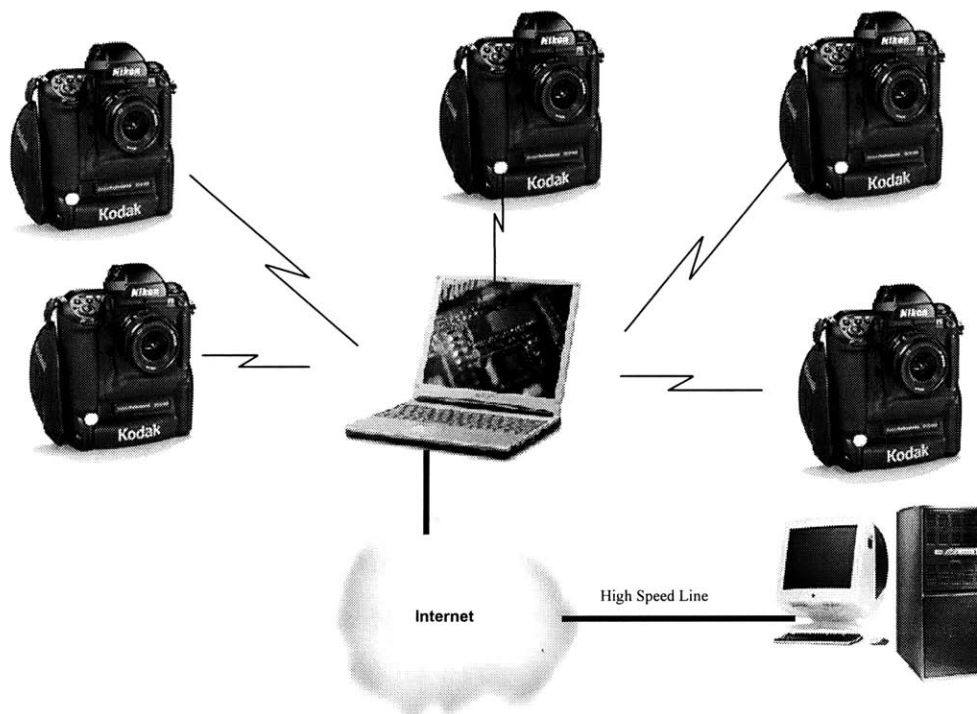


Figure 4.1 Illustration of WLAN Project

Definition of Work: DCS Camera Wireless LAN Networking

It is desired to provide wireless networking functionality within the present generation of DCS cameras (3xx/5xx/6xx) to enable immediate in-camera image access by a remote computer at specific venues, i.e., the Superbowl. As the photographers take pictures, thumbnails would be wirelessly transmitted to the remote central computer. The operator of the system would view the thumbnails from each of the cameras and send a wireless request to the specific camera generating the thumbnail image to send the full-resolution image. This functionality is expected to greatly reduce the delay in getting access to the images within each of the photographers' cameras. This should provide for almost real-time access to the imagery.

To assist in the development of this functionality, the Vendor has been solicited to provide the fundamental wireless data-pipe firmware within the camera as well as provide their Mobility Socket Layer on the computer. The applications within the camera would be developed by Kodak. These applications need to send thumbnails and process other data requests. The user application to run on the computer to view the thumbnails and request other images from the camera may be implemented by Kodak or a third party.

The system would consist of the following physical hardware:

1. DCS camera with wireless firmware support (3xx/5xx/6xx).
2. Wireless PC-Card to be used within each DCS camera (Proxim RangeLAN2 PC-Card 7400 w/ Snap-on antenna).
3. One or more Proxim RangeLAN2 Ethernet Access Point (7521 or equivalent).
4. One or more Proxim RangeLAN2 Extension Points (7540 or equivalent).
5. Local Ethernet network (10/100-BaseT).
6. Computer running Windows 95/98/NT with gobs of CPU power, DRAM and disk space.
7. Vendor Mobility Software for Windows.

Vendor items needed from Kodak in porting Mobility Socket Layer to run within DCS cameras:

1. DCS camera (one of 3xx/5xx/6xx).
2. DCS debug serial port cable.
3. Firmware build environment consisting of 1) Kodak DCS-OS documentation, 2) sample 'C' code showing all capabilities of Kodak DCS-OS, 3) firmware objects to build DCSxXX.BIN, 4) make utilities, and 5) Diab/Data D-C/PowerPC cross compiler running on Windows.
4. Proxim hardware (RangeLAN2 PC-Card 7400 w/ Snap-on antenna, RangeLAN2 Ethernet Access Point 7521)
5. Kodak to provide necessary firmware support to interface to the Proxim PC-Card as is needed throughout the Vendor development effort.
6. Kodak to provide technical support throughout the Vendor development effort.

Vendor deliverables to Kodak:

1. Full-featured Mobility Socket Layer ported for execution within a DCS camera running the Kodak DCS-OS. This is to be delivered in 'C' source code for Kodak to compile into a camera firmware binary. This source code will be provided to Kodak for its product use without royalties.
2. Driver for the Proxim RangeLAN2 PC-Card 7400 delivered in 'C' source code. This driver is to provide all wireless functionality that is possible with the ported Mobility Socket Layer. This source code will be provided to Kodak for its product use without royalties.
3. Sample wireless application written in 'C' source code ready for compilation into a camera firmware binary demonstrating ALL of the Mobility Socket Layer functionality. This application should, in addition, provide a simple "echo" functionality. Upon camera boot-up, the wireless "echo" application in conjunction with the Mobility Socket Layer and Proxim driver will identify itself to the host computer. The host computer application at that point may send data to the camera. The camera application should simply receive this data and transmit or echo it back to the computer. This will

demonstrate interfacing to the Mobility Socket Layer as well as the send-and-receive wireless functionality.

4. Sample wireless agent application (WA) running on Windows95/98/NT to monitor the presence of DCS wireless cameras in the reception area. This WA will be delivered in 'C/C++' source code form (Visual C/C++ project preferable) and will demonstrate all of the Mobility Socket Layer functionality present on the Windows platform. This sample application will be provided to Kodak for its product use without royalties. It will behave similarly to the Vendor's existing wireless agent demonstrated to Kodak, i.e. an icon to appear within the task tray box. In addition, this WA will create a folder on the computer for each camera detected. The root directory in which these folders will be created shall be definable via a Windows registry entry. These camera folders will be named using the unique serial number of each camera, i.e. K330C-00001. This WA will place all files transmitted from each camera and successfully received by the computer into their respective unique folders. Successful reception of incoming data is denoted by a file being generated within a camera folder. This WA will also monitor a single "DCS-Send" folder (registry definable) on the computer and transmit the contents within each file preset to the specified camera. Here, the specified camera is provided within the "base" portion of the file name itself, i.e. K330C-00001.001. The extension is used to allow multiple files to be created for transmission to the same camera without waiting for a prior file to be transmitted. The WA will delete the file from the "DCS-Send" folder following the successful transmission of that file's contents.

Reasons for Selection:

The reason for selecting Proxim was several folds. First, Proxim uses FHSS (Frequency Hopping Spread Spectrum) technology which is better suited for the types of environments being designed for. Stadiums, for example, have many interfering structures that can cause more problems for DSSS technologies, as explained in Chapter 3. Furthermore, the power consumption of FHSS is lower, thus prolonging the battery life of the camera. In addition, Proxim is a leader in WLAN technology and has a dominant market share as well as proven track record. Proxim plans to come out with much faster products in the year 2000. Some modifications must be made to upgrade to

the new product, or Kodak can simply start with the next generation product rather than migrate from the last. Higher bandwidth (11Mbps) will significantly increase the overall performance of the DCS WLAN project.

The client server software architecture described above appears to be the most elegant in terms of minimizing additional development efforts and being able to use existing server and camera side framework to deal with the exchanging information.

The Vendor was selected over other third-party middleware providers mainly due to their expertise in the wireless arena. The Vendor has developed wireless solutions for a number of major enterprises and also has a proven track record. Its Chief Technology Officer demonstrated clear understanding of Kodak's needs and proposed an elegant architecture that would perform the tasks required.

4.5 WLAN Results, Performance, and Future Adaptations:

I completed the WLAN project design and definition of work during my internship. The DCS engineering team is evaluating the implementation of this project. We did some performance testing using laptops in the same WLAN environment with Proxim equipment. The transfer of a 2 megabyte TIF image took approximately 30 to 40 seconds. The performance using a DCS camera to transmit may be worse than that of a laptop, due to less processing power. Further, there would be some slow-down of the transfer if the photographer is snapping more shots during the transmission. If the project were implemented, improving bandwidth as well as compression should dramatically improve overall performance.

Potential applications for resulting product could be: Fifteen news photographers covering the Superbowl can continue shooting their shots on the field relatively undisturbed while an editor monitors the images that are being taken using a laptop somewhere inside the stadium. If there is a shot the editor wants, he/she would select and transfer that image onto the laptop for processing. If that shot is really worthy, it could be instantly sent to the New York headquarters since the laptop is also tied to the internet via a T1 or higher speed connection. The editor could, in fact, even monitor the entire Superbowl photo shoot in New York through the network. This would allow the shot of the winning touchdown to be delivered to the right hands and available for sale before the

extra point is even scored. These types of new applications can be much more efficient and cost effective as compared to the old ways of delivering images. PJs previously had multiple “runners” who would pick up from the photographer a digital storage medium (when it is full), run it up to a room where the files are transferred onto a computer, then the images would be reviewed and the “right” shots are selected. The time it takes to accomplish the same goal is orders of magnitude longer. In the PJ business, time is money. Other possible features that allow the editor and photographer to communicate over the wireless network can create additional value. For example, the editor can send a text message to the LCD display of the camera for a particular PJ, requesting a close-up shot of the quarterback from his perspective. Once communication is established, one can imagine many different applications using a networked digital image capture system. Everything from law enforcement to photo studios, to theme park imaging, and much more.

As mentioned in Chapter 3, newer, faster, better, cheaper technologies are just around the corner. This year, bandwidth performance in WLAN are expected to increase by more than 10-fold. This would dramatically improve the performance of the WLAN project. Furthermore, the ability to have wirelessly connected digital cameras can lead to many other exciting applications, such as making it easy for people to transfer images to be printed by a Kiosk or to your computer or to other people’s computers.

Here is another scenario: You walk into a super theme park, and they give you badge with a barcode that identifies who you are. As you walk around, photographers with wireless digital cameras are there for you to request that your picture be taken. After each shot, they quickly scan your badge with a pen barcode reader attached to the camera. The image is sent to a server who sorts and stores them. When you reach one of the many “Photo Booths” at the exit, you can identify yourself with your badge and all the pictures taken of you and your family will be there in one place for you to edit, add fun backgrounds and certainly purchase. When you return home, there is an email waiting for you, thanking you for your visit and inviting you to view a website that has all of your theme park pictures there, for you to email, print, or order. These are the types of value-added services that customers would be willing to pay for and can generate significant revenue and customer loyalty for the companies involved.

4.6 Some Issues with Implementation

This section provides a list of some technical and practical issues we ran into during the project. Most solutions come with tradeoffs, and many of the issues can be solved by better technologies and more elegant designs.

Initial Technical & Practical Issues With Implementation:

- 1) Low Bandwidth not suitable for wireless transmission. Average WWAN is 9600bps, while WLAN is closer to 1.6 Mbps. For JPG files WWAN may be fine, but for regular TIF files that are several megabytes large, the time to transfer is unacceptable in the WWAN environment, and only tolerable for WLAN environment. (Next generation technologies will help, but more is always better when it comes to bandwidth.)
- 2) Battery Life and power consumption can be an issue for both projects. WWAN: Battery life for the cell phone as well as the camera can become an issue if large files are transferred. In most cases, the performance is not too much worse than making phone calls on your cell phone. For WLAN applications, battery life and heat can be an issue and should be kept in mind. WLAN radios consume more power. Typically, the greater the bandwidth, the more power it consumes. (Hoping that new battery technologies in the future will help with this issue.)
- 3) Cost of airtime in WWAN environment can be an issue. Most data minutes today are still very expensive. They average from 10 cents a minute using GSM, to 39 cents a minute on the Sprint PCS network if you do not purchase a package of data minutes. This cost is predicted to go down with time.
- 4) For the WLAN project, we need the ability for camera proprietary OS to talk through the PCMCIA port to the Proxim card, using RS232 interface. MAC layer must be built for our OS. This was one reason we opted for a third party that has expertise in developing the software. (This can be a relatively longer part of the development cycle.)
- 5) For the WLAN project, Msocket packets/Ethernet Packets sent across WLAN to Proxim card/Access Point/ISA Board must be translated back to data stream and recognizable files. This is taken care of by middleware developed by the Vendor.
- 6) For the WLAN project, the need to define a convention for the files going to the host side. If they can be defined as drives and files, then existing TWAIN software can

work with the wireless network. (We address this issue with the architecture in the earlier section.)

7) For the WWAN solution: need ability for OS to talk through the serial RS232 interface using AT command set, software flow control, translate data to SLIP and send through CDMA or GSM phones via a carrier (Sprint PCS, or GSM network).

Recommend Global Star satellite network solution for the greatest coverage possible.

(Upon testing, there were no problems with the AT Command sets that were implemented.)

8) WWAN: Would the camera's three pin serial adapter be able to talk with the cell phones using software flow-control. The answer was yes. An adaptor needed to be made to provide a better fit for the cable between the cell phone and the camera.

9) WWAN: AT command set may be different for GSM phones – recommend we select one GSM phone to work with. (Latest phones coming to market will have a built-in software modem stack that will make development efforts easier.) CDMA dial-up should work with most CDMA phones. The solutions had to ensure each phone used will be able to interact with the camera through AT Commands.

10) Other issues to consider: GUI on the camera. The input mechanism for the camera is not designed to enter text such as IPTC (International Photographic Trade Commission) headers, thus making editing or putting comments on an image problematic. Ways to help improve the user experience include preset IPTC header info (certain amount of preset, sec, time, date, gps, location, etc.) Better GUI that allow characters to be inputted using existing controls, or allowing an input device such as a PDA to do the editing.

Chapter 5. Conclusion/Recommendations

5.1 Successes

The Kodak Professional DCS team has achieved levels of success for both wireless projects. More importantly, it is laying the foundation for future models of professional and consumer digital cameras that will be wirelessly enabled to deliver better and more convenient solutions for the end user. Following in the tradition of the Eastman model: "You click the button, we do the rest," the Kodak Professional DCS team is developing better features for their customers, at the same time showing the industry that they are leaders in delivering innovation.

The WWAN project was implemented and can now enable mobile transfer of images from virtually anywhere using low bandwidth wireless network connections. The end results were demonstrated at the PMA show in Las Vegas in early Feb 2000. Quality Assurance (QA) is underway, and roll-out to the public is expected by the second quarter of this year. Photo journalists and other users can now be more mobile and more efficient in doing their jobs. Without the need to lug around a heavy laptop, they can now go virtually anywhere on the planet, capture an image and send it to an intended destination via a cellular or satellite phone within seconds. This is now a reality and is only the first step towards eliminating wires all together.

Although the WLAN project is still under consideration by DCS engineering, the groundwork has been laid. Specifications and definition of work has been accomplished. WLAN multimedia applications will become a reality, whether it is done innovatively today with off-the-shelf components or is done tomorrow with next-generation WPAN technology. It is worth noting that since the Kodak Professional DCS camera is the only professional digital camera today with dual PCMCIA slots, it is possibly the only camera system that can enable a commercial WLAN accessory solution. The demand from customers is definitely here. Should Kodak choose to, the WLAN solution can be implemented in a relative shortly period of time and become another beneficial feature that competition can not yet offer.

5.2 Lessons Learned

Overall, my time spent at Kodak has been a fantastic experience. I worked with some extremely bright and motivated people, and I learned a tremendous amount throughout my six-month stay there.

The Kodak Professional DCS group is in a highly competitive fast-moving high-tech industry. It is exciting to see a tight race where companies are doing what they can to win. The battle must be won by the entire value chain, from R&D, to manufacturing and supply chain, to IT infrastructure, to marketing. Every unit has a significant impact on the overall system.

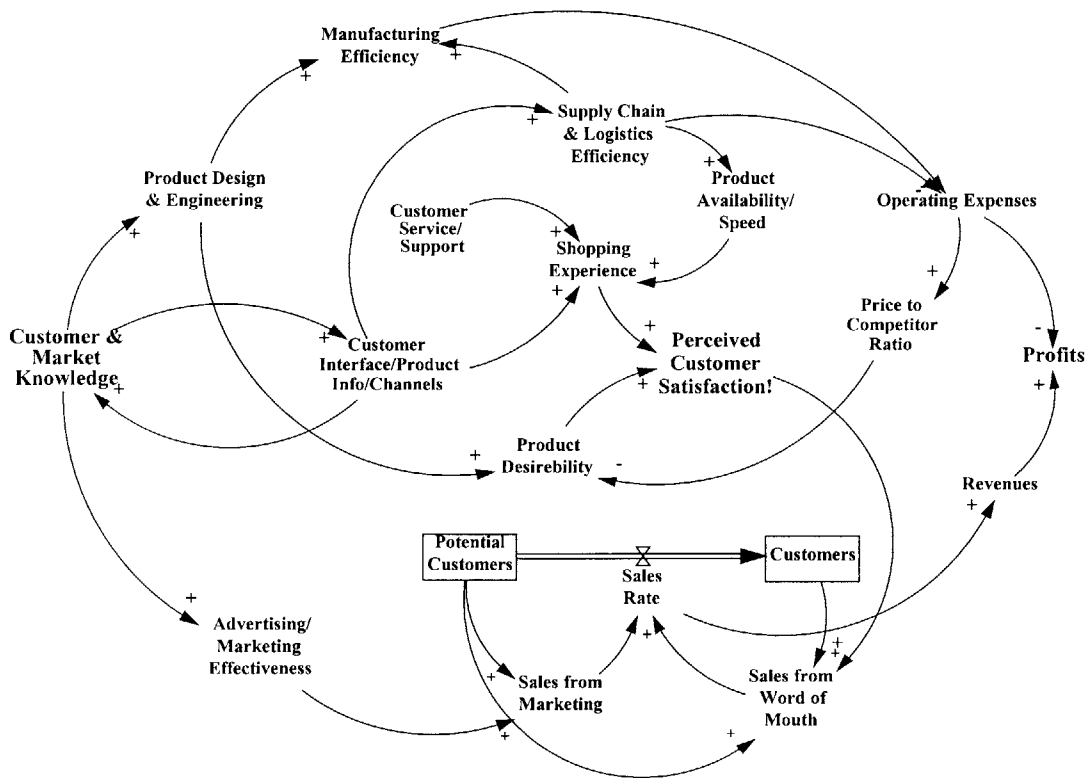


Figure 5-1: Dynamic Business Model for Kodak Professional DCS

Figure 5-1 shows my views of the dynamic business model for Kodak Professional DCS. It demonstrates how the different groups work together to create the overall system. There are many inherent reinforcing loops that help achieve customer satisfaction, increase sales and profitability, or balancing loops that have the opposite effect. (The different factors or events from Figure 5-1 are labeled here with quotation marks.)

“Customer & Market Knowledge” is key, helping drive “Product Design” as well as “Marketing & Sales”. Good “Product Design & Engineering” can lead to better “Manufacturing Efficiency” and help the company towards being the low-cost-producer. A solid “Supply Chain” also affects cost, which ultimately affects pricing of the product and profitability. “Product Desirability” is a function of quality, performance and price. When combined with good customer’s “Shopping Experience”, leads to the all-important “Customer Satisfaction” which contributes to the “word of mouth” effect and ultimately market share. I learned that keeping an eye on the entire system and value chain is very important to the long-term success of any company. Managers must have a good mental model of the business at hand and how the overall system behaves. I also learned that it is important to nurture young projects such as those in the wireless computing space to help position companies to better innovate and compete in a fast-moving and dynamic marketplace. When it comes to R&D, existing projects tend to be the squeaky wheels that get the oil, while new projects are more difficult to justify ROI and are more easily neglected or aborted. It is non-intuitive for companies to more heavily foster the youngest of ideas because these ideas are not likely to produce revenue immediately. In fact, they are simply a cost that has to be justified. Ironically, the youngest of ideas are the ones that need the most care and attention and the most resources in order for them to become something valuable later. Much like the space shuttle exerting much of its fuel in the first few hundred feet in order to lift off, many ideas and concepts also require adequate investments of money and resources for them to become valuable.

5.3 Synergies of Wireless Within Kodak..

I was surprised to find how many different groups within Kodak were also working on wireless projects. On October 8th, 1999, there was a summit event for the purpose of bringing together all of the efforts within Kodak that involve wireless. I was impressed by the initiative, and I hope this effort continues. Within Kodak alone, I have seen a variety of wireless projects, from wirelessly enabling digital cameras to other information appliances to utilizing wireless computing for the mobile work force.

The number and types of wireless applications that will be developed over the next several years is sure to grow dramatically. It is important for Kodak to develop and cultivate internal expertise in the area of wireless computing. These innovations will undoubtedly yield considerable consumer benefits as well as internal productivity improvements that will ultimately lead to better business for Kodak.

5.4 Recommendations and Path Forward

My recommendations are directed toward two fronts. One is for Kodak digital cameras and multimedia initiatives. The other is toward Kodak internal productivity improvement initiatives.

The figure below shows one scenario of the convergence between IT, Telcom, and media, and where Kodak can position itself. The key is to establish the infrastructure and business models to change consumer habits and capture revenue in the process. Wireless is a key component to this infrastructure.

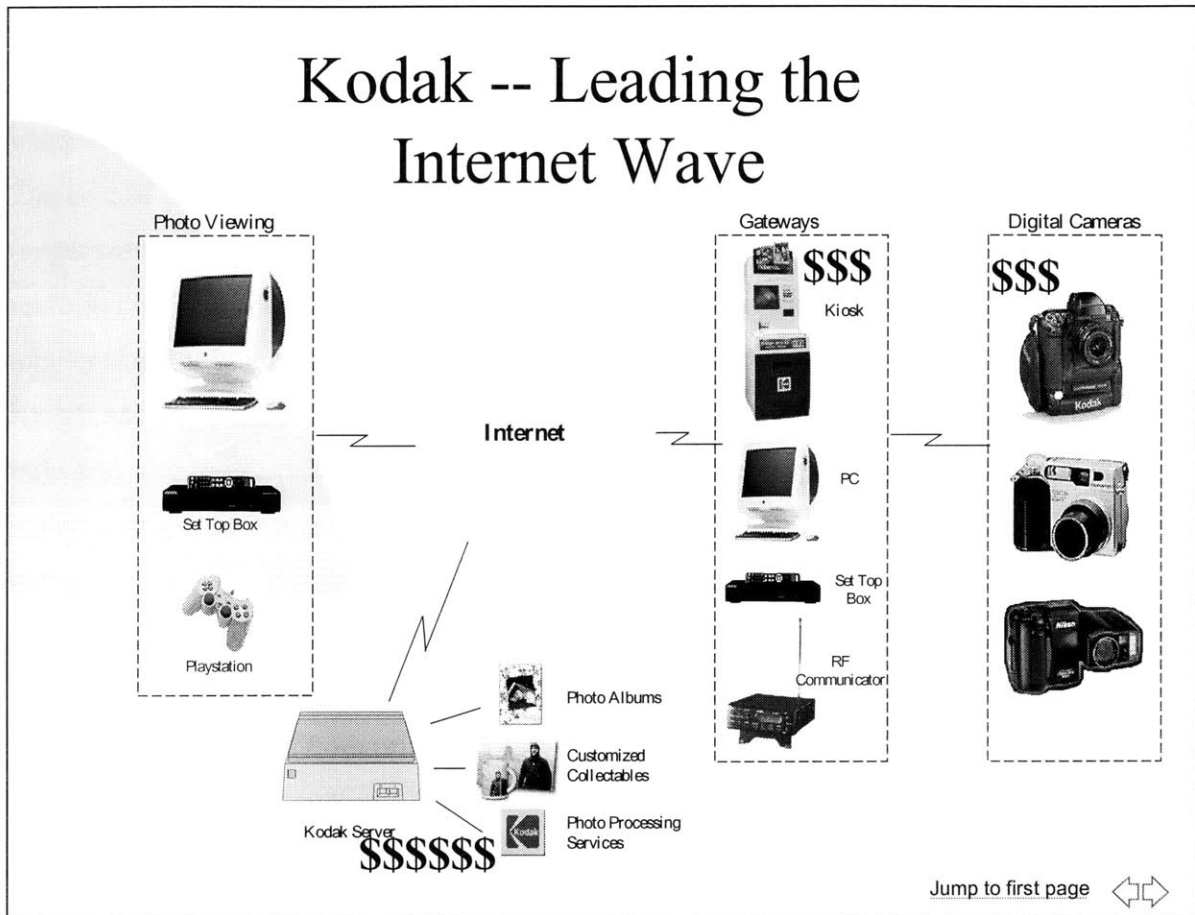


Figure 5.1 Future Convergence Model

In the future, with wireless and wired infrastructure established, Kodak can capture revenue not only from selling more cameras that are convenient to use, but also from other sources of business. It does not matter whose camera is being used. Other ways to

capture revenue include Kiosks to print images captured and Kodak value-added services that ultimately deliver images to customers by whatever means they want. Again, the value that people are willing to pay for is both quality and convenience. “You push the button, we do the rest.” Kodak must continue to leverage its brand as THE leader in the business of pictures. Whether it is traditional film and paper or digital imaging, people should have the confidence that Kodak is still the trusted source to protect their memories...the “Kodak Moments” must live on. Maintaining this valuable mind share in the rapidly-changing digital age will not be easy. A whole new generation of young people will be growing up with digital cameras, and Internet appliances. What will Kodak mean to them?

As for Kodak Professional DCS, in general, future products should continue to support wireless, both WWAN and WLAN/PAN. Bluetooth should be included in future models. The cost of implementation would include the R&D portion, the cost of components (expected at the \$10 per radio unit level), and support. The support for wireless multimedia for Kodak Professional DCS is relatively inexpensive when compared to the total cost of the camera.

Kodak has the brand recognition for superior imaging science and being leaders in the industry. For the Kodak Professional DCS market segments, performance and efficiency in delivering their images is key. Sometimes the winners in the marketplace are not the best products; they are simply the best marketed products. Aggressive marketing can also help Kodak with maintaining market share.

One note towards market trend is that the upper end and the lower end digital cameras are converging in terms of both price and performance. Will this trend reach some sort of equilibrium, or will it continue until there is no distinction between high-end consumer cameras and professional digital cameras? I suspect that as long as there is sufficient performance difference, the professionals will always be willing to pay a premium for the additional quality and features.

Other areas internal to Kodak that may benefit from wireless computing include Field Service. Kodak has already implemented, for the past several years, wireless capabilities

for Field Engineers (FE) to remotely obtain corporate information to better service their customers. However, these systems can be improved upon to more easily and cost effectively tie into the corporate IT infrastructure. The old methods of wireless FE solutions involve setting up banks of modems for FEs to dial in using their laptops via a cell phone. Middleware was written to perform very specific tasks. Development efforts were high, maintenance of the middleware was cumbersome, especially when there were hundreds or thousands of FE. There was very little flexibility for expansion into other legacy applications and data-stores. All of which means the Total Cost of Ownership is very high. Today, companies can look into more elegant ways to expand corporate applications into the wireless environment, using the latest in Internet and wireless enabling technologies. Developing the proper wireless architecture and applications can enable the FE and the other mobile workforces to become even more productive, allowing them access knowledge-base information, as well as a host of other corporate applications and data including email, calendar, sales force automations software, inventory information, etc. With location-based information, planners can even better direct automatically who is the best person to send for a particular job. There are many wireless and mobile solutions that can increase productivity for all Kodak employees, executives and field professionals that are on the road.

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This report provides a comprehensive description of the status of the wireless telecommunications and data infrastructure world wide. The data ranges from wireless technologies and networks, devices, software, marketing issues, bandwidth limitations. Useful information for surveying certain industries.

Gartner Group Report 1999 “Mobile Computing: Shortened Supply Chains, Happier Clients”

This reports outlines the major key trends in the wireless industry and many key issues still being faced. The analysis is thorough and insightful.

Forrester Research Report 1999 “Killer Apps On Non-PC Devices” This report surveys the non-PC device arena and discuss what companies must do to serve customers using these vehicles.

Forrester Research Report 1999 “Dawn of Mobile Commerce” The report describes how Mobile eCommerce will shape wireless, and how 3G is not necessary for M-commerce to take place. Innovative business models will be vastly important in winning the customer.

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to solve the problem and leverage disruptive technology, it does illustrate how companies time and time again get blindsided and get their lunches eaten. Kodak Professional DCS will face the challenges described in part by this book.

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“Internet Exchange Points”, <http://www.ep.net/>
Useful resource for getting information on public and private internet exchanges around the world.