PRODUCT

MP 2003-02

Mobile Internet Technologies and their Application to Intelligent Transportation Systems

January 2003

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Center for Information and Telecommunications Technologies
Falls Church, Virginia

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Sponsors:	Federal Highway Administration	**Contract No.:**	DTFH61-00-C-00001
Dept. No.:	J190	**Project No.:**	0900610F-01

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ABSTRACT

The worlds of mobile communication and the Internet are rapidly converging. This new domain, which is being touted as the "Wireless Web" or "Mobile Internet", is in its infancy and will require a number of complex technologies to mature and converge before it becomes as prevalent and as functional as its wired counterpart. While being developed to extend the reach of Internet users, these new technologies can also be used to support various ITS operations.

This report introduces the new mobile Internet technologies and describes how they could be applied to ITS. It also presents some of the technical and institutional considerations when using such technologies to support agency operations.

Suggested Keywords: mobile, Internet, wireless, prototype, Intelligent Transportation Systems (ITS)

ACKNOWLEDGMENTS

The authors wish to thank the following individuals for their administrative assistance during the initial prototyping efforts.

- Ms. **Dawn Hardesty**, Senior Engineer, Mitretek Systems
- Mr. **Thomas Farley**, Northern Virginia District Administrator, Virginia Department of Transportation
- Mr. **Kamal Suliman**, Traffic Operations Director, Smart Traffic Center, Virginia Department of Transportation
- Ms. **Amy McElwain**, Northern Virginia ITS Smart Travel Manager, Virginia Department of Transportation
- Mr. **Marlow Dixon**, Electronic Technicians' Supervisor, Smart Traffic Center, Virginia Department of Transportation
- Dr. **Morteza Salehi,** District Maintenance & Operations Engineer, Virginia Department of Transportation
- Mr. **Gottfried Kofi**, Electrical Engineer, Smart Traffic Center, Virginia Department of Transportation
- Mr. **Thomas H. Phillips,** GIS Manager, Virginia Department of Transportation

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INTRODUCTION

The worlds of mobile communication and the Internet are rapidly converging. This new domain, which is being touted as the "Wireless Web" or "Mobile Internet", is in its infancy and will require a number of complex technologies to mature and converge before it becomes as prevalent and as functional as its wired counterpart. While being developed to extend the reach of Internet users, these new technologies can also be used to support various ITS operations.

There are three general aspects of mobile Internet technology. One involves the devices used to convey information to the mobile user. Today, these mobile devices include an array of cell phones, personal digital assistants (PDA), notebook computers, etc. A second aspect of mobile Internet technology is the communication between information repository and mobile device. The wireless networks providing this connectivity include analog and digital cellular systems, enhanced second generation (2.5G) and third generation (3G) PCS, and even some of the new wireless local area networks (WLANs). The third aspect of mobile Internet technology, and the focus of this report, is the wireless application environment. Wireless application environments are the combinations of markup languages, communication protocol, and user interfaces that enable Internet-type content to be exchanged across various wireless networks using many different types of mobile device.

This report introduces some of the new mobile Internet technologies and describes how they could also be applied to ITS. As part of the research, a prototyping effort has been established to demonstrate and test the application of these technologies within the ITS domain.

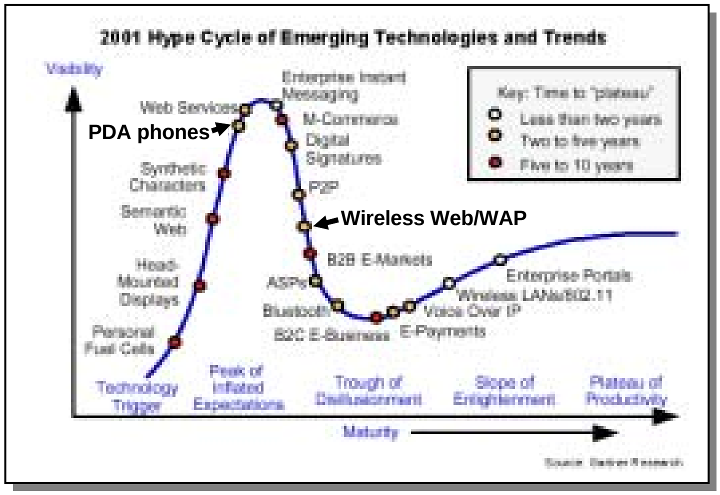
BACKGROUND

Over the past few years, a number of mobile devices and communication services have been introduced to the public by manufacturers and service providers promising to deliver the Web to the mobile user. The wireless Web (or mobile Internet) has been a mild success story in some regions, such as Asia and Europe, but has yet to take hold in the United States. As the mobile Internet does become more firmly established, it will allow mobile users to do many of the activities they can do now from a desktop computer. However, establishing this platform will require various technologies to mature.

The Hype of Mobile Internet Technologies

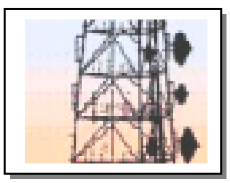
The problems of mobile Internet technologies took root when early hype got ahead of consumer demand and the level of development for solutions such as the Wireless Application Protocol (WAP) became grossly misunderstood. In the early ‘90s, Jackie

Fenn, an analyst at the research firm Gartner Group, devised "*The Emerging Technologies Hype Cycle*" to explain such buildup and illustrate the maturation of new technologies. While evolving technologies usually experience an early period of heightened and unrealistic expectation, most eventually mature to demonstrate real-world benefits.



Today, mobile Internet technologies are composed of devices, wireless networks, and wireless application environments that have yet to mature. Most of these technologies exist somewhere between "the peek of inflated expectations" and "the trough of disillusionment".

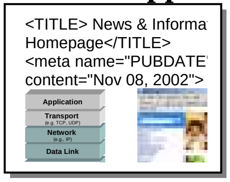
Mobile Devices: Mobile devices capable of conveying Internet content are available, but need to develop. This is particularly true in the U.S. where users typically buy a variety of devices according to their needs – business or personal, high-volume or casual.



Networks: Communications networks capable of delivering Internet content in the mobile environment have been slow to develop. The new enhanced second generation (2.5G) cellular and PCS networks have significantly improved mobile Internet performance, but the throughput on these networks is not much greater than that experienced with a fixed line dialup modem. Eventually, third generation (3G) wireless networks will emerge offering even greater capacity and faster throughput, but 3G services are still a few years away from large scale deployment in the U.S.

Within the last few years, many different providers have deployed thousands of publicly accessible wireless local-area networks (WLAN). These systems, commonly referred to as "Hot Spots", are often placed at coffee shops and hotels. While they have limited coverage, throughput is significantly greater than that offered by the wide-area wireless networks (e.g., 2.5G PCS networks), and they provide an option for the mobile user who's not quite so mobile.

Wireless Application Environments: Wireless application environments, which consist of markup languages, communication protocols, and user interfaces, are also immature. However, enhancements which include agnostic markup languages (e.g., eXtensible Markup language (XML)) and new wireless protocols will help eliminate the need for separate wired and wireless network infrastructures.



Emerging from the Hype

The three facets of mobile internet technology – mobile devices, wireless networks, and wireless application environments – are intrinsically linked and will likely mature together. Eventually the mobile Internet will evolve as the wired Internet did years ago with computers, operating systems, networks, markup languages, and protocols optimized for Internet access. This evolution is being aided by groups such as the Open Mobile Alliance (OMA) – a recently formed industry consortium with the goal of enabling interoperable mobile networking services by specifying common technical standards.

The OMA faces many hurdles, but regardless of their efforts, mobile Internet technologies continue to develop, and mobile Internet in the U.S. is poised to grow. Industry watchers feel the U.S. landscape could undergo a significant shift beginning late 2002 or early 2003. According to comScore Networks, 9.9 million Internet users (over the age of 18) in the U.S. used a PDA or a cell phone to access the Internet in the first quarter of 2002[1]. These numbers are small when considering the total number of cell phone and PDA users (19.1 and 67.2 million users respectively), and they are minute when compared to the number of users accessing the Internet with wireline technologies. These statistics indicate that the mobile Internet market – like the technology – is in its infancy. Still, 10 million users are significant. Also, these numbers don't reflect users under the age of 18, the most influential demographic for the future of mobile Internet technologies.

MARKETS AND APPLICATIONS

Today, even in their immature forms, mobile Internet technologies support a variety of applications, including: e-mail, Web browsing, file transfer, messaging/chat, mobile commerce (m-commerce), thin-client computing, event notification, and advanced traveler information services (ATIS) such as travel reservations and traffic information. Mobile Internet solutions that use more robust technologies, such as 2.5G PCS networks and advanced mobile devices, can also support more intensive applications that involve collaborative multimedia.

Most of these applications and services are intended for the general public, but there is no reason the same technologies could not also be used to extend an organization's private network(s) and expand their scope of operations. Consider using these technologies – now effectively intranet technologies – to disseminate operational information, including alerts, requests, inventory, forms, and imagery. Consider using them to collect such information from the field. Several industries (e.g., manufacturing, retail, distribution, and entertainment) realized this potential years ago and are currently using mobile Internet technologies to support their day-to-day operations. These technologies offer similar operational and financial benefit to transportation industry.

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[1] "Ten Million Internet Users Go Online via Cell Phone or PDA", comScore Media, 28 Aug 2002. http://biz.yahoo.com/iw/020828/045881.html

Establishing Mobile Internet Technologies within the ITS Domain

The National ITS Architecture reveals a number of potential applications particularly suited for mobile Internet technologies. The way in which these technologies are currently marketed suggests their primary value to ITS would be support for ATIS – typically some form of communication between center and traveler subsystems. While mobile Internet technologies clearly support ATIS, their most beneficial application (within the ITS public sector) might be the exchange of operational information with field personnel. The following Architecture interfaces exemplify this type of communication.

- Traffic Management Subsystem – Traffic Operations Personnel
- Transit Management Subsystem – Transit Fleet Manager
- Emergency Vehicle Subsystem – Emergency Personnel
- Parking Management Subsystem – Parking Operator

Whether to provide ATIS, extend the capabilities of operations personnel, or support other ITS functions, mobile Internet technologies are enhancing the ways in which ITS subsystems can exchange information. Some transportation and public safety related organizations have already begun to incorporate these new technologies.

- **Advanced Traveler Information Services (ATIS)**
  - Virginia launched the 'My Mobile Virginia' service in July of 2002 becoming the first state in the nation to make their homepage and government information services accessible by wireless devices.
  - The 'Travel Shenandoah' information service, which was established through a public-private partnership, was introduced in April of 2000. The service has since undergone a name change to "511Virginia.org" in order to capture the benefits of the system's connection to Virginia's new traveler information number, 511.

- **Emergency Management**

  Northern Shenandoah Valley PDA Pilot – a component of the Northern Shenandoah Valley ITS Public Safety Initiative – is an effort to help develop emergency services for rural areas.

- **Law Enforcement**

  The Garden City, N.Y., Police Department is using mobile Internet technologies to wirelessly access information from the State's newly created database known as the Counter Terrorism Network (CTN). The CTN is a conduit for Federal agencies to post terrorist alerts and Homeland Security information.

There are other instances in which rudimentary mobile Internet technologies are being used within the transportation and public safety domains. However, there are many more situations for which the technologies could be used, particularly those supporting operations such as incident management /incident reporting (e.g., the National Model), Infostructure support, and DOT construction and maintenance activities.

They could also support efforts involving evacuation management, transit and commercial vehicle operations, special events coordination, emissions control, etc. Within the next few years, the numbers and types of ITS operations that can be supported by mobile Internet technologies will grow, and understanding how these technologies might support such efforts will be essential.

WIRELESS APPLICATION ENVIRONMENTS

As noted previously, mobile Internet technologies comprise mobile devices, wireless networks, and wireless application environments. Devices and networks are typically not developed or maintained by the user, and these components are therefore selected from what vendors and providers have to offer. This report focuses on the application environment – the one facet of mobile Internet technology that can be controlled and developed by the user. The application environment consists of various markup languages, communication protocols, and user interfaces. These elements, in conjunction with a mobile device and wireless network connectivity, are used to establish mobile Internet services. In turn, these services are used to access information by way of an application service provider (ASP). Figure ES-1 illustrates this hierarchy.

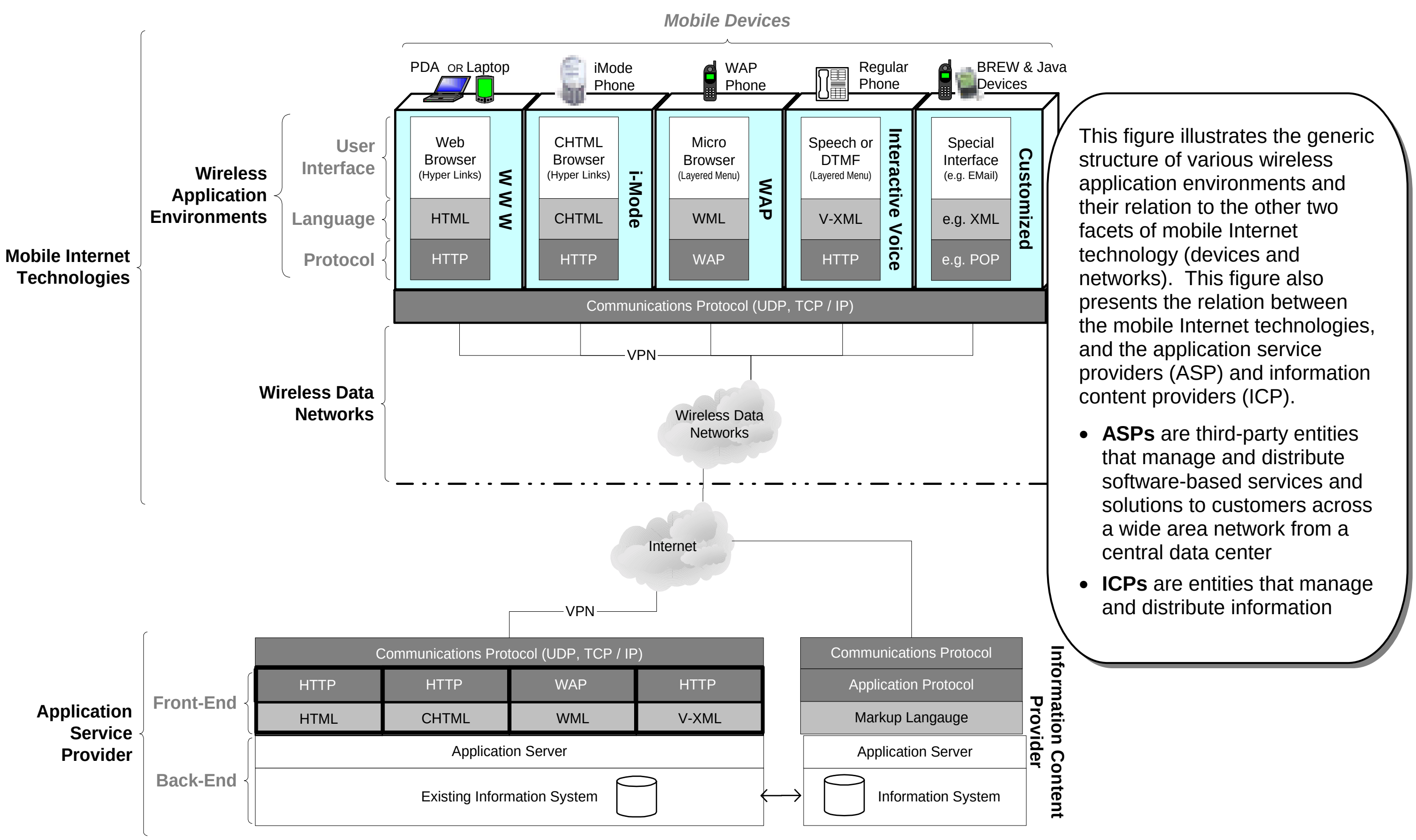


Figure ES-1. Wireless Application Environments & Mobile Internet Services

This report presents some of the more common wireless application environments addressing not only markup languages, protocols, and user interfaces, but also standards, service and content providers, and advantages/disadvantages relative to each environment.

The Wireless Application Environment for WWW Service

The World Wide Web (WWW) is the most popular client-server information tool on the Internet. Web servers communicate with client devices (e.g., personal computers) to provide any number of applications, including search engines, e-commerce, e-trading, e-banking, and various forms of entertainment.

Until recently, the WWW had been restricted to wireline connectivity – primarily because mobile devices had far less computing power and display capabilities then desktop systems. However, mobile computing has advanced significantly, and when equipped with a network interface, some of the newer mobile devices can be used to establish WWW services

The Wireless Application Environment for WAP Service

Wireless Application Protocol (WAP) is an open, global specification that allows users to access Internet-type content via thin-client devices, such as cell phones, pagers, and two-way radios. WAP will also support more complex mobile devices, such as PDAs, but the most common device is a WAP-enabled cell phone, or "WAP Phone".

WAP was conceived in the mid '90s by several companies within the wireless industry, including Unwired Planet (now Openwave Systems), Motorola, Nokia, and Ericsson. These companies established the WAP Forum and in 1997 released the first draft of the WAP specification. The WAP Forum has since become part of the Open Mobile Alliance (OMA). Today, there are several hundred members of the OMA using the specification to develop applications for manufacturers, operators, and providers within various market sectors. There are also several million WAP users world wide, but primarily in Europe.

The Wireless Application Environment for I-MODE Service

I-mode is a mobile Internet product developed by Japanese telecommunications company NTT DoCoMo. In February1999, NTT DoCoMo launched its I-mode service in Japan, where over 81% of the world's mobile Internet users reside. As of January 2002, I-mode accounted for over 60% of this market with more than 30 million subscribers, and I-mode has overtaken traditional Japanese Internet service providers to become the country's largest Internet access platform, wireline or wireless.

A version of the I-mode service had been planned for the U.S. market since DoCoMo bought a 20% stake of AT&T Wireless for $9.8 Billion in November 2000. In April 2001, AT&T began rolling out M-mode – a service that's based on I-mode, but the applications and content, which is part of the DoCoMo product, are being designed for the U.S. market. M-mode is the service behind AT&T Wireless' "M Life" campaign, which was launched in conjunction with the widespread deployment of their GPRS (2.5G PCS) network in January/February 2002.

Customized Wireless Application Environments

In addition to (or in lieu of) WWW, WAP, or I-mode services, one could establish customized wireless application environments. In the mobile domain, most custom environments are created in either a Java Runtime Environment (JRE) or Binary Runtime Environment for Wireless (BREW). This report does not address custom environment development other than to introduce these two development platforms.

A Wireless Application Environment for an Interactive Voice Response Service

Interactive Voice Response (IVR) services are different from the other services addressed in this report. While the technologies used to establish this service comprise a user device, an application environment, and a communications network, these elements are not confined to the mobile domain. IVR services can be supported by any network (wireline or wireless) that's part of the Public Switched Telephone Network (PSTN). And users can use any device (fixed or mobile) that's supports voice communication over the PSTN. However, from the perspective of this report, one should consider mobile devices and wireless networks.

An IVR system will prompt callers to input numeric and alphanumeric data using the mobile device keypad. The system will process this information and then respond to the caller with pre-recorded or synthesized audio. Automatic speech recognition (ASR) systems enhance an IVR system by making a voice interface available to the user. This allows them to respond and enter data by speaking instead of punching keys.

In addition to the enabling technologies, IVR services are also different from the previous services because the content exchanged is in audio form. This restricts the applications for which the technology can be used, but the simplicity of data entry (speaking, not key strokes) can be useful, particularly in a mobile environment. For applications that don't require visual information or large amounts of data, this can be a very effective solution. It's already become popular for customer support operations and for ATIS with in the ITS domain. The new 511 services use IVR/ASR systems. While primarily considered as a means to disseminate information, these systems can be used to collect information as well.

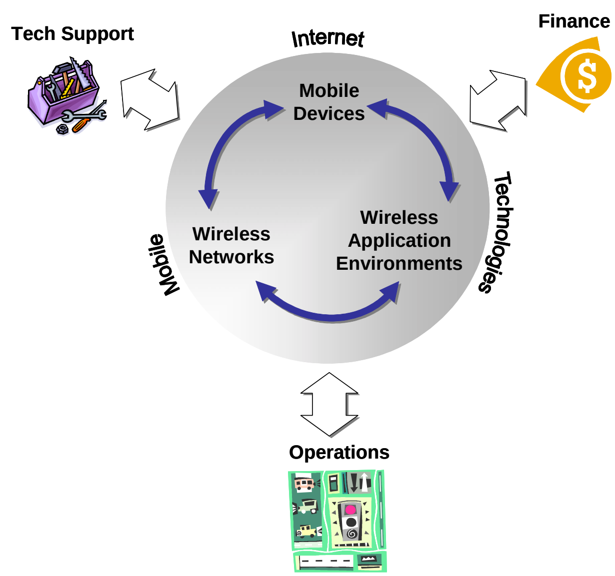
SUMMARY, RECOMMENDATIONS, AND ADDITIONAL RESEARCH

Mobile Internet technologies are far from being firmly established, particularly in the United States. However, they're developing rapidly. Mobile devices are improving, and with each new release, they become more user-friendly and less expensive. Faster and more reliable wireless data networks are being deployed. There are now multiple 2.5G PCS options in most major metropolitan and suburban areas, and several companies deploying publicly accessible WLANs (i.e., "hot spots). In addition, wireless application environments are beginning to converge. Markup languages are moving toward XML variants, and protocols are moving toward a common stack capable of supporting different application environments.

While mobile Internet technologies have yet to mature, they should not be disregarded. Recall that only a few years ago the wireline Internet was not nearly the resource it is today. Transportation agencies should understand the state-of-the-practice for mobile Internet technologies. They should follow the state-of-the-art, understand the potential of technologies, and consider how they might apply to ITS.

Selecting Mobile Internet Technologies

There are several factors in selecting the appropriate mobile Internet technologies. As previously discussed, the three components are intrinsically linked, making the selection of devices, networks, and application environments interdependent. There are also institutional aspects (operations, technical support, and finance) that influence the selection of each component.



- **Operations**: How are the mobile Internet technologies going to be used? What services and applications should they support? How well and where should they operate? Many operational parameters (e.g., function, performance, availability) will be defined by technical user requirements.

- **Technical Support:** Appropriate mobile Internet technologies should be manageable by the organization's technical support facilities. One of the support group's major hurdles is getting these new technologies to work with 'existing' infrastructure in a way that benefits the company. This involves a host of issues including back-end systems integration, security implementations, systems maintenance, etc. This can be a hefty challenge, particularly when the organization chooses to implement more than one solution.

- **Finance:** Managers often struggle to build a return-on-investment model that warrants spending on mobile Internet technologies, particularly when the technologies are immature. Is the proposed technical solution (i.e., selection of mobile Internet technologies) financially feasible? Does the organization have the financial resources to accommodate the solution and its integration with the organization's existing infrastructure? Is the technical solution financially justifiable? What are the financial cost-benefits for implementing a particular solution? Does operational benefit outweigh financial cost?

Because employees increasingly rely on cell phones, PDAs, and other mobile devices to do their work, many organizations are being forced to adopt mobile Internet technologies whether they fit their overall business strategy or not. There's no reason to assume this scenario will not someday apply to transportation agencies as well, if it hasn't already.

This report introduces some of the operational, financial, and tech support considerations when selecting mobile internet technologies. However, the appropriate solutions will depend on where and for whom the systems are deployed and will take into account the specific user requirements as well as organizational support services and financial resources.

Prototyping

Concept prototyping is the next step in this research initiative. The objective is to exhibit various mobile Internet technologies and demonstrate their potential within the ITS domain. Prototyping began prior to the release of this report, and eleven different solutions have been developed and tested in the laboratory environment. Three application environments have been used; WWW, WAP and IVR. These environments are supported by various networks and devices. Additional solutions will include M-mode and possibly J2ME or BREW.

The Virginia Department of Transportation (VDOT) has volunteered to assist FHWA with this research by hosting field-testing efforts at their Smart Traffic Center (STC) in Arlington, VA. The prototypes will initially be used to support STC field maintenance operations, which include repair, preventive maintenance, and operational support for CCTV, VMS, and other field systems. Additional applications may be established to support work zone, safety service patrol, and others field operations.

Details of the prototyping effort, including configurations, applications, users, and assessments will be available in the spring of 2003 and will be documented in a subsequent report. Institutional issues, such as potential operational and financial benefits will also be addressed.

SECTION 1

INTRODUCTION

The worlds of mobile communication and the Internet are rapidly converging. This new domain, which is being touted as the "Wireless Web" or "Mobile Internet", is in its infancy and will require a number of complex technologies to mature and converge before it becomes as prevalent and as functional as its wired counterpart. While being developed to extend the reach of Internet users, these new technologies can also be used to support various ITS operations.

1.1 PURPOSE

This report introduces some of the new mobile Internet technologies and describes how they could also be applied to ITS. As part of the research, a prototyping effort has been established to demonstrate and test the application of these technologies within the ITS domain.

1.2 SCOPE

There are three general aspects of mobile Internet technology. One involves the devices used to convey information to the mobile user. Today, these mobile devices include an array of cell phones, personal digital assistants (PDA), notebook computers, etc. A second aspect of mobile Internet technology is the communication between information repository and mobile device. The wireless networks providing this connectivity include analog and digital cellular systems, enhanced second generation (2.5G) and third generation (3G) PCS, and even some of the new wireless local area networks (WLANs). The third aspect of mobile Internet technology, and the focus of this report, is the wireless application environment. Wireless application environments are the combinations of wireless communication protocol, markup languages, and user interfaces that enable Internet-type content to be exchanged across various wireless networks using many different types of mobile device.

1.3 ORGANIZATION

This document is divided into four additional sections and two appendices:

- Section 2 provides background on mobile Internet technologies.
- Section 3 introduces the generic and transportation-specific applications of these technologies.
- Section 4 addresses the various wireless application environments and the mobile Internet services they support.
- Section 5 offers a summary and recommendations from this phase of the research. It also introduces the next phase of the effort – concept prototyping.
- Appendix A provides a list of commercially available mobile devices.
- Appendix B addresses various wireless network options and provides a list of some commercially available services.

SECTION 2

BACKGROUND

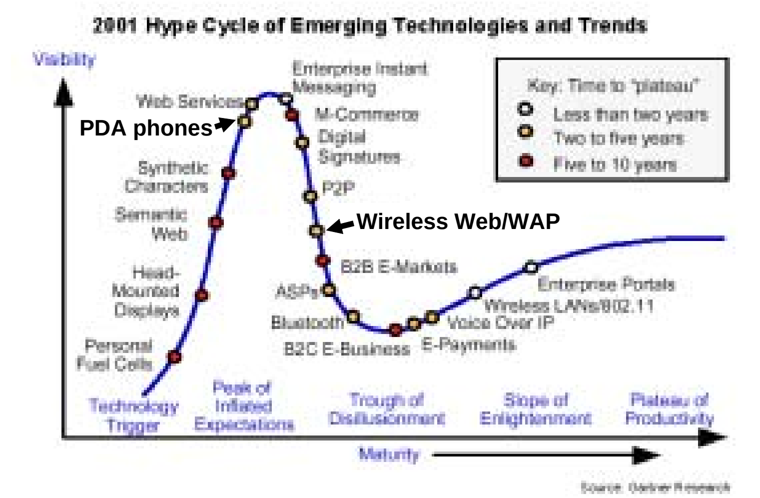
Over the past few years, a number of mobile devices and communication services have been introduced to the public by manufacturers and service providers promising to deliver the Web to the mobile user. The wireless Web (or mobile Internet) has been a mild success story in some regions, such as Asia and Europe**,** but has yet to take hold in the United States. Irrespective of region, it's currently viewed as a pale substitute for the wired version of the Internet.

As the mobile Internet becomes more firmly established, it will allow mobile users to do many of the activities they can do now from a desktop computer. However, establishing this platform will require various technologies to mature.

2.1 THE HYPE OF MOBILE INTERNET TECHNOLOGIES

The problems of Mobile Internet technologies took root when early hype got ahead of consumer demand and the level of development for solutions such as the Wireless Application Protocol (WAP) became grossly misunderstood. In the early '90s, Jackie Fenn, an analyst at the research firm Gartner Group, devised "*The Emerging Technologies Hype Cycle*" to explain such buildup and illustrate the maturation of new technologies (side bar). While evolving technologies usually experience an early period of heightened and unrealistic expectation, most eventually mature to demonstrate real-world benefits.

Today, mobile Internet technologies are composed of devices, wireless networks, and wireless application environments that have yet to mature. Most of these technologies exist somewhere between "the peek of inflated expectations" and "the trough of disillusionment".



Technology trigger. A breakthrough, public demonstration, product launch or other event that generates significant press and industry interest.

Peak of inflated expectations. A phase of over-enthusiasm and unrealistic projections during which a flurry of publicized activity by technology leaders results in some successes but more failures as the technology is pushed to its limits.

Trough of disillusionment. The point at which the technology becomes unfashionable and the press abandons the topic, because the technology did not live up to its over-inflated expectations.

Slope of enlightenment. Focused experimentation and solid hard work by an increasingly diverse range of organizations lead to a true understanding of the technology's applicability, risks, and benefits. Commercial off-the-shelf methodologies and tools become available to ease the development process.

Plateau of productivity. The real-world benefits of the technology are demonstrated and accepted. Tools and methodologies are increasingly stable as they enter their second and third generation. The final height of the plateau varies according to whether the technology is broadly applicable or only benefits a niche market.

- **Mobile Devices:** Mobile devices capable of conveying Internet content are available, but need to develop. This is particularly true in the U.S. where users typically buy a variety of devices according to their needs – business or personal, high-volume or casual. Many users will make do with bare-bones cell phones, while others will have newer devices such as PDAs. This divergent approach complicates the process of conveying information. Device manufacturers are starting to address the issue by developing convergent devices, such as smart-phones and PDA-phones. They are also working to incorporate more refined user interfaces, which define the look and feel of wireless applications. A poor user interface is one of the more common problems reported by mobile users.

Source: Hewlett-Packard Co.

Source: Nokia

"We estimate that these devices [PDA-phones smart-phones] will be used by 30% or more of the population in industrialized nations by 2003 for making telephone calls, sending e-mail, watching video, transmitting documents and data, conferencing, and other forms of computation and communication in general"

- *The Top 10 Emerging Technologies;* The Futurist, July 1, 2001

- **Networks:** Communications networks capable of delivering Internet content in the mobile environment have been slow to develop. Today, many users still rely on second generation (2G) cellular and PCS networks, which are extremely slow and can't support the data rates required by most users. The new enhanced second generation (2.5G) cellular and PCS networks have significantly improved mobile Internet performance, yet the throughput on these networks is not much greater than that experienced with a fixed line dialup modem. This may or may not be acceptable to users that have become accustomed to wired broadband services, such those supported by DSL or cable modems. Regardless, 2.5G networks are rapidly maturing, and while not available in every market, they can be found in most major metropolitan areas.

ENHANCED SECOND GENERATION (2.5G) CELLULAR AND PCS TECHNOLOGIES

General Packet Radio Service (GPRS)
- Packet data service for GSM-based networks
- Burst data rates: up to 115 kbps (mobile), 170 kbps (fixed)
- Average data rates: 20 – 30 kbps
- Observed data rates at MTS labs: ~20 kbps
- U.S. Carriers: Cingular, AT&T, and T-Mobile

CDMA 2000 1X
- New radio transmission technology (RTT) and packet data service for CDMA networks (CDMA 1XRTT)
- Burst data rates: up to 144 kbps
- Average data rates: 40 - 60 kbps
- Observed data rates at MTS labs: ~60 kbps
- U.S. Carriers: Sprint, Verizon
- Future variants: **1XEV** (Evolution), **MC3X** (multi-carrier); each supporting greater capacity and faster data rates

For more information, refer to Appendix B

Eventually, third generation (3G) wireless networks will emerge offering even greater capacity and faster throughput. However, 3G services are still a few years away from large scale deployment in the US. While these services are evolving rapidly in Japan and Korea, those countries built their wireless infrastructures on 3G architecture from the beginning. In the U.S., much of the wireless infrastructure must be reestablished, and the capital expenditure necessary to develop 3G services is prohibitive. In addition, while the technology exists, providers in the US won't deploy 3G networks without adequate spectrum, which is in need, or without a market, which has yet to develop.

THIRD GENERATION (3G)
CELLULAR AND PCS TECHNOLOGIES

Wideband Code Division Multiple Access (WCDMA)

- New radio transmission technology (RTT) for what had been GSM-based networks.
- Data rates: 384 (mobile) and 2048 kbps (fixed)
- US Carriers: Cingular, AT&T, T-Mobile

Code Division Multiple Access 2000 (CDMA 2000)

- The evolution of enhanced second generation CDMA technology
- Data rates: 384 (mobile) and 2048 kbps (fixed)
- US Carriers: Sprint, Verizon

For more information, refer to Appendix B

In the last year or two, many CMRS and wireless Internet service providers have deployed thousands of publicly accessible wireless local-area networks (WLAN). These systems, commonly referred to as "Hot Spots", are often placed at coffee shops and hotels, but they're now appearing at locations such as bus depots, airports, and other transit terminals. While these systems have limited coverage, throughput is significantly greater than that offered by the wide-area wireless networks (i.e., the 2G, 2.5G PCS networks), and they provide an option for the mobile user who's not quite so mobile.

- **Wireless Application Environments**: Wireless application environments, which consist of wireless communication protocols, markup languages, and user interfaces, are also immature. Some developers have tried to establish mobile Internet support by using markup languages that were designed – and work well – for desktop computers. Unfortunately, these languages can translate into a number of problems for users with mobile devices, such as useless links, poorly displayed images, and Web pages that demand too much scrolling.

  A slightly better way to move Web pages to mobile devices is to recode and/or port applications along with the information they support; in general, a handheld-friendly version of a Web page is created. However, this is a time-consuming process that will not likely cover the wide array of screen sizes and resolutions on mobile devices in use today.

  To overcome these obstacles, developers are beginning to use "platform agnostic" programming languages that work in both wired and wireless environments. The most prominent example of such languages is XML (extensible markup language), but others include XHTML (extensible hypertext markup language) – a subset of

XML, and non-SGML (non-standard generalized markup language). These languages can address the variation of display characteristics on mobile devices (e.g., screen size, resolution) without recoding or porting applications. They will also be particularly crucial as voice navigation, location-based services and other features unique to wireless are added to network systems. Enhancements within the wireless application environment, such as the use of these newer programming languages, will eliminate the need for companies to maintain separate wired and wireless Internet infrastructures, which many have found to be a costly proposition.

2.2 EMERGING FROM THE HYPE

The three facets of mobile internet technology – mobile devices, wireless networks, and wireless application environments – are intrinsically linked and will likely mature together. Eventually the mobile Internet will evolve as the wired Internet did years ago with computers, operating systems, networks, markup languages, and protocols optimized for Internet access. But for this evolution to occur, mobile devices must improve, faster packet-switched wireless networks must be deployed, and flexible wireless application environments must be developed. Such needs have led network providers, device manufacturers, and software developers to work together on mobile networking standards.

In June 2002, the Open Mobile Architecture initiative and the WAP Forum merged into a new mega-consortium called the Open Mobile Alliance (OMA). Also folded into the OMA were the Location Interoperability Forum, Multimedia Message Service (MMS) Interoperability Group, and others. The primary goal of the OMA is to enable interoperable mobile networking services by specifying common technical standards. This new group is light on specifics about what it intends to standardize, but they indicate that the standards selected (or developed) will be independent of the underlying communication networks and mobile devices.

The OMA faces many hurdles, but regardless of their efforts, mobile Internet technologies continue to develop, and mobile Internet in the U.S. is poised to grow. Many industry watchers feel the U.S. landscape could undergo a significant shift beginning late 2002 or early 2003. According to comScore Networks, 9.9 million Internet users (over the age of 18) in the U.S. used a PDA or a cell phone to access the Internet in the first quarter of 2002[1]. These numbers are small when considering the total number of cell phone and PDA users (19.1 and 67.2 million users respectively), and they are minute when compared to the number of users accessing the Internet with wireline technologies. These statistics indicate that the mobile Internet market – like the technology – is in its infancy. Still, 10 million users are significant. Also, these numbers don't reflect users under the age of 18, the most influential demographic for the future of mobile Internet technologies.

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[1] "Ten Million Internet Users Go Online via Cell Phone or PDA", comScore Media, 28 Aug 2002. http://biz.yahoo.com/iw/020828/045881.html

2.3 BRINGING MOBILE INTERNET TO THE CORPORATE ENVIRONMENT (ENTERPRISE)

Most companies are taking their time to adopt the mobile Internet. Integrating the necessary technologies is not only a hefty challenge for IT departments, but managers often struggle to build a return-on-investment model that warrants spending on wireless devices, services, and integration. Still, some organizations are being forced to adopt it whether it fits their overall business strategy or not because workers increasingly rely on cell phones, PDAs, and other mobile devices. ***Note:*** *This same scenario will someday apply to transportation agencies as well, if it hasn't already.*

While systems integration can be slow and will occur in a very dynamic environment, most companies understand the potential of mobile Internet technologies and the role these technologies will play in future operations. In the mean time, the corporate world must switch its thinking of the mobile Internet as a "high speed" multimedia browsing experience to one that accounts for specific needs, which may be a relatively slow experience for the time being.

2.4 ESTABLISHING MOBILE INTERNET TECHNOLOGIES WITHIN THE ITS DOMAIN

Transportation agencies should understand the state-of-the-practice for mobile Internet technologies. In addition, they should follow the state-of-the-art, understand the potential of technologies that have yet to mature, and consider how they might apply to ITS.

Today, even in their immature forms, mobile Internet technologies support a variety of applications, including: e-mail, Web browsing, file transfer, messaging/chat, mobile commerce (m-commerce), thin-client computing, event notification, and advanced traveler information services (ATIS) such as travel reservations and traffic information. Most of these applications and services are intended for the general public, but there is no reason the same technologies could not also be used to extend an organization's private network(s) and expand their scope of operations. Consider using these technologies – now effectively intranet technologies – to disseminate operational information, including alerts, requests, inventory, forms, and imagery. Consider using them to collect such information from the field. Section 4 of this report addresses mobile Internet technologies that could support such operations. Again, while discussing mobile devices and communications networks, we focus on wireless application environment.

SECTION 3

APPLICATIONS

This section introduces some of the general applications and developing vertical markets for mobile Internet technologies. In addition, some generic and specific transportation and public safety related applications are introduced.

3.1 GENERAL APPLICATIONS AND DEVELOPING VERTICAL MARKETS

A growing number of people are seeking “anywhere” access to information. As within the fixed office or home environment, access within the mobile environment is typically established through an Internet or intranet connection.

- Internet: The Internet is a rapidly developing public network that connects millions of computers and over 450 million users worldwide. There are many ways to access the Internet, the most common of which is through a commercial or private Internet Service Provider (ISP).

- Intranet: Intranets are networks belonging to an organization, usually a corporation, accessible only by the organization's members, employees, or others with authorization. Secure intranets (e.g., a virtual private network (VPN)) are now one of the fastest-growing segments of the Internet since they are much less expensive to build and manage than private networks.

With mobile network connectivity, one has the ability to support a variety of applications while on the move. Today, some of the more popular include:

- E-mail
- File transfer
- Messaging or chat
- E-commerce
- Thin-client computing (i.e., users run applications on remote computing systems)
- Event/Alert notification

Mobile Internet solutions that use more robust technologies, such as 2.5G PCS networks and advanced mobile devices, can also support more data intensive applications, including:

- Voice over IP (VoIP) (i.e., packetized voice)
- Streaming media (i.e., packetized audio/video)
- Collaborative multimedia (voice, data, and video)

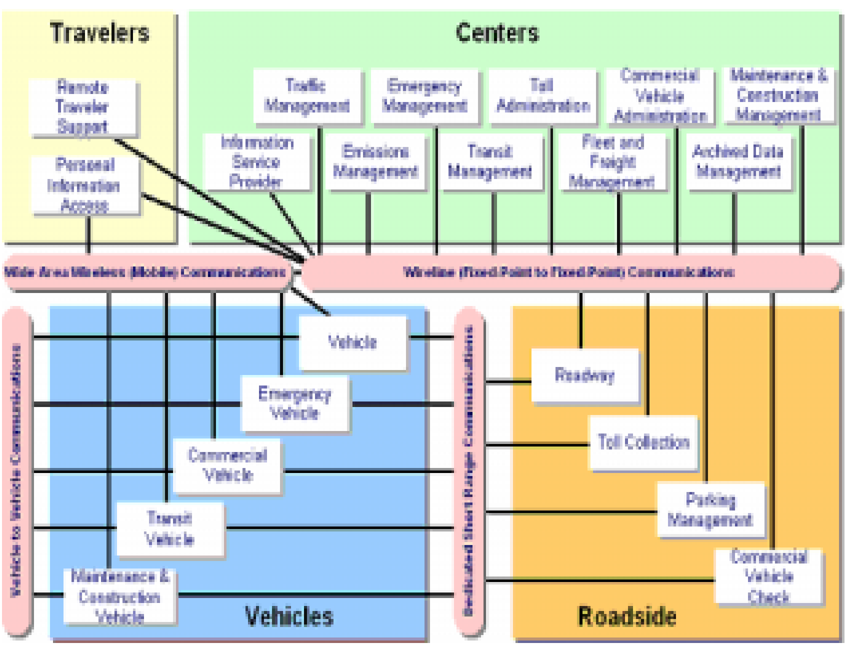
Several industries realized the potential of mobile Internet technologies years ago and are currently using them to support their day-to-day operations. These vertical markets include:

- Manufacturing
- Healthcare and telemedicine
- Education
- Retail
- Warehousing
- Distribution
- Telecommuting
- Entertainment

Mobile Internet technologies can also be used to support ITS.

3.2 GENERIC ITS APPLICATIONS

The National ITS Architecture provides a common framework for planning, defining, and integrating intelligent transportation systems. It defines the functions (e.g., gather traffic information) that are required for ITS, the physical entities or subsystems where these functions reside (e.g., a center or a vehicle), and the information flows that connect these functions and subsystems together into an integrated system. The information passed between center-, traveler-, roadside-, and vehicle-type subsystems are supported by a number of communications systems, wireline or wireless, wide-area or short-range, as illustrated by Figure 3-1.



Centers: Provide management, administrative, and support functions for the transportation system. Each communicates with other centers to enable coordination between modes and across jurisdictions.

Roadside: Intelligent infrastructure distributed along the transportation network. Perform surveillance, information provision, and plan execution control functions. Operation is governed by center subsystems.

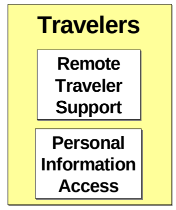
Traveler: Equipment used by travelers to access ITS services pre-trip and en-route. Includes elements owned and operated by the traveler (e.g., PDA) as well as those owned by information providers (e.g., a kiosk).

Vehicle: general driver information and safety systems applicable to all vehicle types. Transit, Emergency, and Commercial Vehicles add capabilities unique to these special vehicle types.

Source: National ITS Architecture

Figure 3-1. National ITS Architecture Information Flow

The National ITS Architecture reveals a number of potential applications particularly suited for mobile Internet technologies. The way in which these technologies are currently marketed suggests their primary value to ITS would be to support advanced traveler information services (ATIS) – typically some form of communication between the center and traveler subsystems. While mobile Internet technologies would clearly support ATIS, their most beneficial application (within the ITS public sector) might be the exchange of operational information with field personnel.



Within the scope of the National ITS Architecture, traveler subsystems are used specifically for gaining access to traveler information. There are two types of traveler subsystem, Remote Traveler Support (RTS) and Personal Information Access (PIAS). RTS are fixed resources. PIAS include PDAs, cell phones, and other mobile devices and are therefore more relevant to this report.

Traveler information is most often provided by the ISP subsystem and includes:

- Common travel times, advisories, and transit schedule exceptions
- Traveler routing, yellow pages information, and service payments
- Trip planning (coordinated with traffic conditions, incidents, etc.)

Tables 3-1, 3-2, and 3-3 identify Architecture interfaces for which it's assumed the subsystem and user must be collocated.

Table 3-1. National ITS Architecture Center—User Interfaces

Center Subsystem	User (terminator)
Maintenance and Construction Management Subsystem	Maintenance and Construction Center Personal
Traffic Management Subsystem	Traffic Operations Personnel
Transit Management Subsystem	Transit Maintenance Personnel
Transit Management Subsystem	Transit System Operator
Transit Management Subsystem	Transit Driver
Transit Management Subsystem	Transit Fleet Manager
Emergency Management Subsystem	Emergency System Operator
Archived Data Management Subsystem	Archived Data Administrator

* As defined by the Architecture, users are a class of 'terminator'

Table 3-2. National ITS Architecture Vehicle—User Interfaces

Vehicle Subsystem	User (terminator)
Maintenance and Construction Vehicle Subsystem	Maintenance and Construction Field Personnel
Maintenance and Construction Vehicle Subsystem	Driver
Emergency Vehicle Subsystem	Emergency Personnel
Transit Vehicle Subsystem	Transit User
Transit Vehicle Subsystem	Driver

* As defined by the Architecture, users are a class of 'terminator'

Table 3-3. National ITS Architecture Roadside—User Interfaces

Roadside Subsystem	User (terminator)
Toll Collection Subsystem	Toll Operator
Parking Management Subsystem	Parking Operator
Parking Management Subsystem	Driver
Roadway Subsystem	Maintenance and Construction Field Personnel
Roadway Subsystem	Pedestrians

* As defined by the Architecture, users are a class of 'terminator'

With the appropriate mobile Internet technology, these users (e.g., Traffic Operations Personnel, Toll Operator) do not have to be physically located within a center or vehicle, or within the vicinity of a roadside subsystem. The mobile technologies effectively extend the interface allowing users to interact with subsystems from the field. This can substantially expand the scope of operations and may provide significant operational and financial benefit. Some of these potential benefits are presented in Section 5 of this report.

Whether to provide ATIS, extend the capabilities of operations personnel, or support other ITS functions, mobile Internet technologies are enhancing the ways in which ITS subsystems exchange information. Some transportation and public safety related organizations have already begun to incorporate these new technologies.

3.3 SPECIFIC TRANSPORTATION AND PUBLIC SAFETY RELATED APPLICATIONS

The following are just some of the growing number of transportation and public safety related applications that currently incorporate mobile Internet technologies.

- **Advanced Traveler Information Services (ATIS)**
  - In July of 2002, Virginia became the first state in the nation to make the state homepage and government information services accessible by wireless devices. ‘My Mobile Virginia’ is a service of the Virginia Information Providers Network (VIPNet), which offers mobile users access to government information and services through various types of mobile devices with Internet access. Through the My Mobile Virginia homepage, mobile users can find contact information for all branches of Virginia government, including the Virginia State Police, the Department of Emergency Management, the Red Cross, and Blood Services of Virginia. There is also ATIS for lodging, dining, and attractions, and the State Parks.

  - In the fall of 2002, Microsoft Corporation launched their “My Car” service, which is part of the MSN® Auto site on the WWW. For more than 65 major cities, this ATIS offers real-time traffic alerts delivered to any mobile phone, pager, or PDA. The service is customized for each individual user. After signing up (autos.msn.com), users supply information about their mobile device and wireless network, and they select preferences, such as what days and times alerts should be delivered, and which regions of a chosen city should be monitored. In addition to traffic alerts, My Car provides city maps, gas prices, and service and repair information. Additional features will be added in the future.

  - ‘Travel Shenandoah’ is a traveler information service, providing information about traffic conditions, tourist destinations, and other traveler and emergency services. Travel Shenandoah was structured as a public-private partnership including, among others, VDOT, the Virginia Tech Transportation Institute (VTTI), Shenandoah Telephone (SHENTEL), the Virginia State Police (VSP), and the Shenandoah National Park. The information system supporting Travel Shenandoah went live in April of 2000 and was formally introduced to the public in late July 2000. The system has also undergone a name change to "511Virginia.org" in order to capture the benefits of the system's connection to Virginia's new traveler information number, 511. Data for the system comes from two main sources: the Virginia State Police's Computer Aided Dispatch (CAD) system and VDOT's Virginia Operational Information System (VOIS). Information (in various forms) is delivered via cable TV, cellular phone, and the Internet, including the mobile Internet.

- In May 2002, the Colorado Department of Transportation (CDOT) began providing their "unwire" service, which enables travelers to get real-time information about statewide weather and roadway conditions. Users can access the "unwire" service (**go.cotrip.org**) through any web-enabled mobile device. CDOT is also considering support for additional information such video from roadway CCTV systems and highway speeds and travel times.

- The Condition Acquisition and Reporting System (CARS) was developed by the Minnesota Department of Transportation (Mn/DOT), Castle Rock Consultants, and others. As part of this system, Mn/DOT developed a web enabled cell phone system that allows snow plow operators to make manual entries to the statewide roadway conditions system while in the field. The system also involves support for the CARS-511consortium's traveler information system.

- In the spring of 2002, transit officials from Manchester England deployed a pilot network that allows individual bus terminals to send information to the passengers' mobile phone. Messages will include information such as how long it will be before the next bus arrives. In 2003, the City will begin installing this technology in 2,900 buses and 2,100 transit stops in Greater Manchester.

- In 140 Seattle-area parking lots, commuters can now pay for parking with a WAP phone. The cost is 25 cents per parking transaction. Users can also be sent a message reminding them that the paid parking time is about to expire.

- **Emergency Management**

  - Northern Shenandoah Valley PDA Pilot – a component of the Northern Shenandoah Valley ITS Public Safety Initiative – is an effort to help develop emergency services for rural areas. This joint initiative, which began in the Spring of 2001, involves medical professionals, transportation officials, and law enforcement and public safety representatives from VDOT, Virginia State Police, the COMCare alliance, the Applied Research Lab at Penn State, various regional hospitals, private companies, and others local agencies in Shenandoah County, VA.

The PDA pilot was designed to help emergency medical service (EMS) personnel collect a patient's medical/injury data in the field and then pass this information to the receiving hospital and/or other incident responders. In this particular pilot, the mobile devices used to collect information were Palm Pilots™; the wireless communication was a circuit switched cellular (CSC) technology. CSC is typically not adequate for mobile Internet, but it is often the only type of commercial wireless service in rural markets. One of the study's objectives was to demonstrate what could be accomplished with the technologies available in rural areas. Some of the advancements in mobile Internet technology, such as video compression techniques, might offer significant improvement for this effort. Other advancements, such as 3G PCS, may never be available in some rural environments.

- In the fall of 2002, the Washington, D.C. government announced that it intends to equip some of their ambulance and fire truck personnel with mobile devices computers to help track patient information.

- **Law Enforcement**
  - The Garden City, N.Y., Police Department is using Aether's PocketBlue™ products to wirelessly access real-time information from a newly created New York state database known as the Counter Terrorism Network (CTN). The CTN is a conduit for Federal agencies to post terrorist alerts and Homeland Security information. The system is also used to query the National Crime Information Center (NCIC), New York Department of Criminal Justice (DCJS), the Department of Motor Vehicles (DMV) as well as send and receive wireless messages and alerts. PocketBlue™ supports a wide range of handheld devices. The communication network used most often is CDPD.

  - Police officers in North Wales, UK, will be using mobile devices with wireless LAN services to gain access to the applications and databases they need for administrative tasks. The project will enable "…the officers to spend 15 percent more time in the field, an equivalent of 150 additional officers on the street"[1].

There are other instances in which rudimentary mobile Internet technologies are being used within the transportation and public safety domains. However, *there are many more applications for which the technologies could be used, particularly those supporting agency operations*, such as:

- Incident Management /Incident Reporting (including multimedia 'Amber Alerts')
- Infostructure support (field data collection, information dissemination)
- DOT construction, maintenance, and safety service management

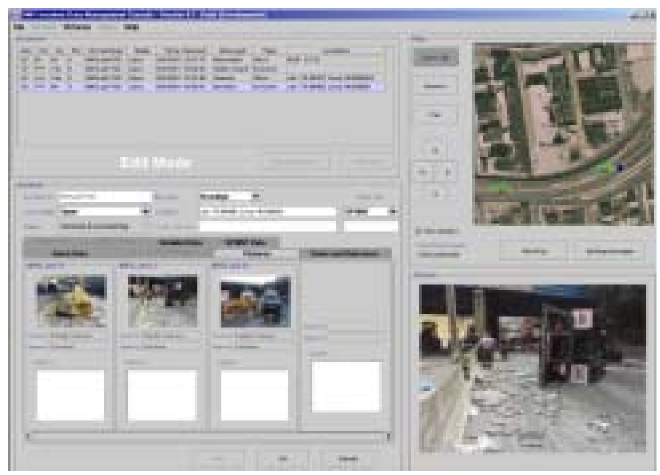
[1] "Police mobile data project will put more officers on the beat", Cushing, CW360°, 3 October 2002

The following exemplify some of these operations:

- **New York State DOT Integrated Incident Management System (IIMS)**

  The New York State DOT (Region 11), in partnership with a number of Federal, state, and local agencies, is developing a real-time integrated incident management system (IIMS) designed to enhance communication among incident managers at operations centers and incident response personnel at incident scenes.

  In the field, specially equipped vehicles have a laptop computer, a digital camera, GPS receiver, and a CDPD modem for communication. Information retrieved from these field units is shared among multiple centers (e.g., transportation, police, fire/EMS, environmental protection, public works, and emergency management) and the corresponding agencies that respond to and manage incidents. This IIMS will also tie in the Motorist Interchange Communication Environment (MICE) system, which is the New York City DOT's current incident reporting system.



Source: New York State DOT

  One of the more advanced features of the new IIMS allows cameras on the vehicles to automatically transmit still frames back to the center upon arrival at incident scenes. While the communications is not adequate for transmitting live or streaming media video, compression techniques are used so that still frame images can be transmitted relatively quickly.

  As the project continues, coordinators are attempting to improve the technology and enhance the services. One of the service enhancements involves capturing roadside CCTV images and the inserting them into reports that can then be sent to field personnel – in vehicles or on foot. *Technological improvements might include use of the new mobile Internet technologies*.

  Note: For more about the IIMS, visit http://www.dot.state.ny.us/reg/r11/iims/index.html

- **The National Model**

  In 1994, the Iowa Department of Transportation joined with other state and local government agencies to design and implement a system that would increase the accuracy and reduce the processing of accident reports. Based on the success of this system and the State's experience with electronic data collection, in 1997, Iowa was selected by the FHWA as a partner for the National Model project. This initiative was designed to serve a model for all states to draw upon in their efforts for improving highway safety data collection and management processes.

Through the re-engineering of Iowa's system, the National Model introduced a new generation of data collection tools, known as TraCS (Traffic and Criminal Software). TraCS is used in combination with the other resources needed for field data collection, including laptop computers, wireless communication networks, and centralized workstations. Together, the complete system allows field users (e.g., law enforcement officers, EMS crews, traffic investigators) to electronically file and retrieve reports and exchange information with various agency databases.

The National Model project now involves 20 states; several other states and Canadian provinces are considering use of the system as well. A National steering committee comprised of those licensed to implement TraCS meets periodically to share issues and to review and prioritize enhancements regarding the system. One such enhancement might involve support for some of the new mobile Internet technologies. The use of PDAs and other new mobile devices would allow TraCS to be used for additional field operations, such as officers on foot or bicycle patrol.

Note: For more information about the National Model, visit http://www.dot.state.ia.us/natmodel

- **DOT Operations Management**

The following activities could be significantly enhanced with mobile Internet technologies

Construction

- Reporting work-zone lane closure conditions: Construction inspectors could transmit real-time information about actual lane closure conditions to the district office, traffic management center, fire & rescue services, police, and the news media. This information might include closure times, delays, incidents, and miscellaneous motorist impacts.

- Materials testing: Construction inspectors could obtain reports from the district or central office needed for accuracy in testing bituminous concrete, portland cement, concrete and other materials. Information might include soil conditions, concrete air & slump values, asphalt density, miscellaneous materials certification, and mix designs.

- Safety officer: The regional safety officer could collect data and update the central office on the status of incidents on roadway projects. Information might include incident type, injury status, noted safety violations, incident witnesses, and corrective actions.

Maintenance

- Inventory management: Maintenance crews could enter inventory information into their centralized database while performing on-site inspections of signs, lighting, guardrail, impact attenuators, mile markers, and miscellaneous delineators.

- Schedule work: Construction and maintenance inspectors could exchange information with a central database that tracks work performed on guardrail, paving, roadway marking, and signing schedules. This information might include location, materials, project limits, work completed, and pay quantities.

- Signal maintenance: Signal crews could provide real-time status of problem calls and send updates to the central signal controller. The information exchanged might include failure type, cause, corrective action, location, materials used/needed, and repair priority.

Safety Service Patrol

- Safety service: Safety service patrol personnel could provide real-time status of motorist incidents helping clear incidents more promptly. Information might include location, incident type, injury status, number of vehicles involved, number of lanes closed, corrective actions, and equipment needed.

There are still many other areas in which mobile Internet technologies could be used, such as evacuation management, transit and commercial vehicle operations, ATIS for special events or within the National Parks, emissions control, etc. For this report, the purpose of listing applications is twofold: first, to illustrate the developing interest in mobile Internet technologies within the transportation and public safety domains, and secondly, to suggest the technologies' potential for supporting additional applications.

Within the next few years, the numbers and types of ITS applications that can be supported by mobile Internet technologies will grow. Understanding how these technologies might support such applications will be essential.

SECTION 4

WIRELESS APPLICATION ENVIRONMENTS

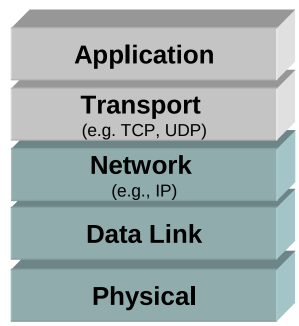
Mobile Internet technologies comprise mobile devices, wireless networks, and wireless application environments. Devices and networks are typically not developed or maintained by the user, and these components are therefore selected from what vendors and providers have to offer. This report focuses on the application environment – the one facet of mobile Internet technology that can be controlled and developed by the user.

> The selection of mobile devices and wireless networks will be based on user requirements and various institutional issues. We address these matters in Section 5 of this report.

The application environment consists of various communication protocols, markup languages, and user interfaces:

- A **communications protocol** is an agreed-upon format for transmitting data between two devices. The Internet is based on a protocol structure referred to as the "TCP/IP" stack. In this report, we address the upper layer protocols – primarily those at the application layer, which establish timing, administration, and file management capabilities, and those at the transport layer, which provide data flow for the application layer. At the network layer, Internet Protocol (IP) is common among all the application environments addressed in this report. Those protocols at the lower layers are not particularly relevant to this study.

TCP/IP Stack

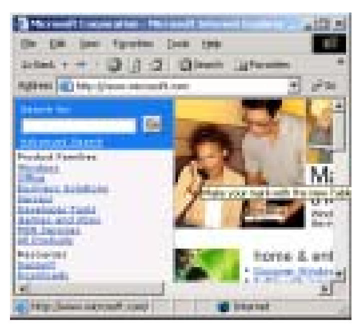


- A **markup language** is a system for marking or tagging documents to indicate their logical structure and format, and provide instructions for electronic transmission and display.

Hypertext Markup Language (HTML)

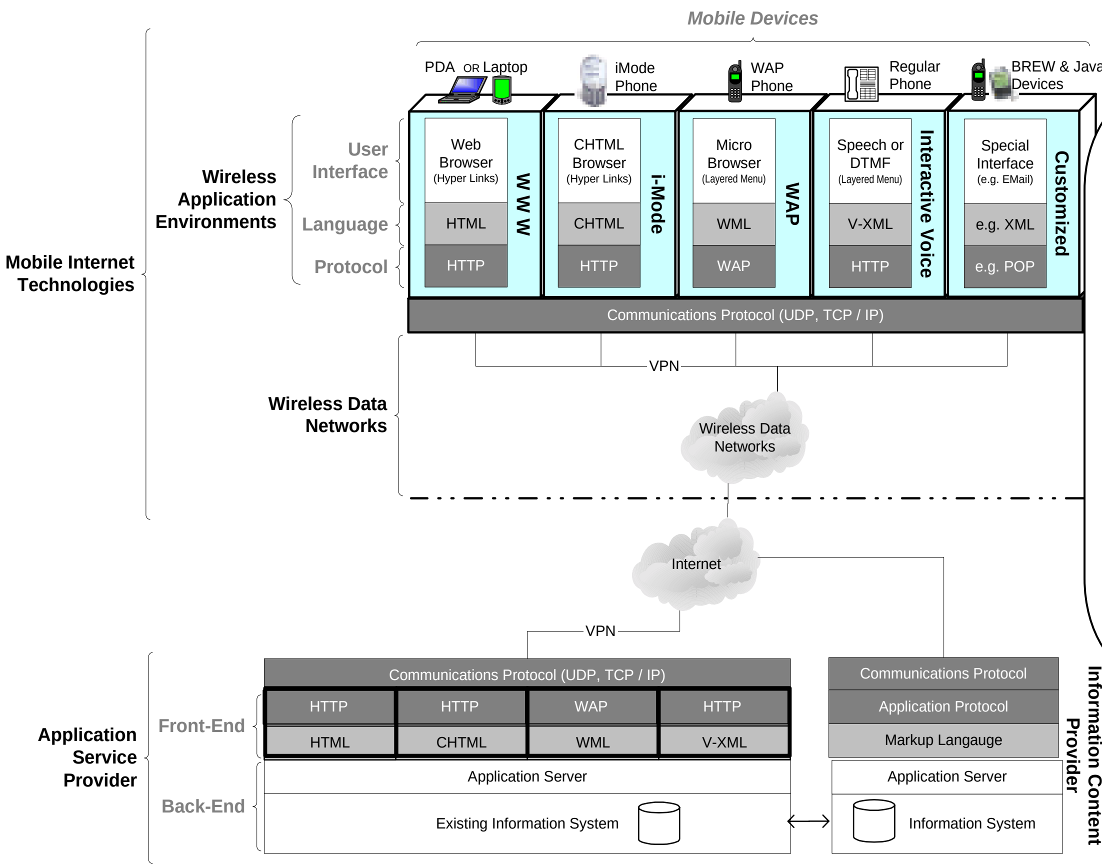
```
<HTML>
<HEAD>
<TITLE>USATODAY.com - News & Information Homepage</TITLE>
<meta name="PUBDATE" content="Nov 08, 2002">
<meta name="DESCRIPTION" content="Up-to-the-minute news
```

- The **user interface** establishes a set of commands or menus through which a user communicates with a program. A command-driven interface is one in which the user enters commands. A menu-driven interface is one in which the user selects command choices from various menus displayed on the screen. Graphical user interfaces (GUIs), created with applications such as Web browsers, use windows, icons, and pop-up menus.



Microsoft® Internet Explorer™ Web Browser

These elements, in conjunction with a mobile device and wireless network connectivity, are used to establish mobile Internet services. In turn, these services are used to access information by way of an application service provider (ASP). Figure 4-1 represents this hierarchy.



This figure illustrates the generic structure of various wireless application environments and their relation to the other two facets of mobile Internet technology (devices and networks). This figure also presents the relation between the mobile Internet technologies, and the application service providers (ASP) and information content providers (ICP).

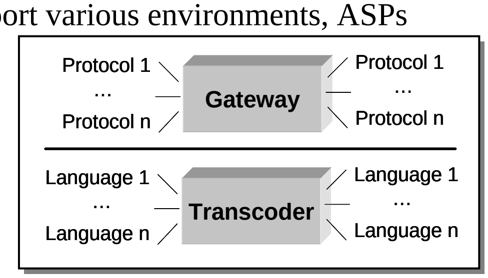
- **ASPs** are third-party entities that manage and distribute software-based services and solutions to customers across a wide area network from a central data center
- **ICPs** are entities that manage and distribute information

Figure 4-1. Wireless Application Environments & Mobile Internet Services

Application service providers offer information access services. Some of the information may belong to the ASP, but most resides with the millions of information content providers (ICP) connected to the Internet. Most ASPs support the wireline Internet population, but many are now developing access services for the mobile sector as well. In doing so, one of their greater challenges is resolving how to support a variety of mobile devices and wireless data networks with their existing information system. The current, and most common, solution involves a flexible system design that consists of front-end and back-end modules, as shown in Figure 4-1.

> Within the ITS domain, a transportation agency might assume the role of an application service provider or an information content provider. The appropriate function will depend of various factors. We address some of these issues in Section 5 of this report.

The front-end is a flexible module, which gathers markup languages and communication protocols to support different mobile devices. To support various environments, ASPs can establish specific and independent front-end systems, as illustrated in Figure 4-1, and/or they can use protocol gateways and language transcoders. Some of these options are addressed in this section, and considerations for appropriate solutions are presented in Section 5.



The back-end is typically a more static module providing the interface between and information database and various front-end configurations. Figure 4-2 provides more detail about how front-end and back-end modules work together.

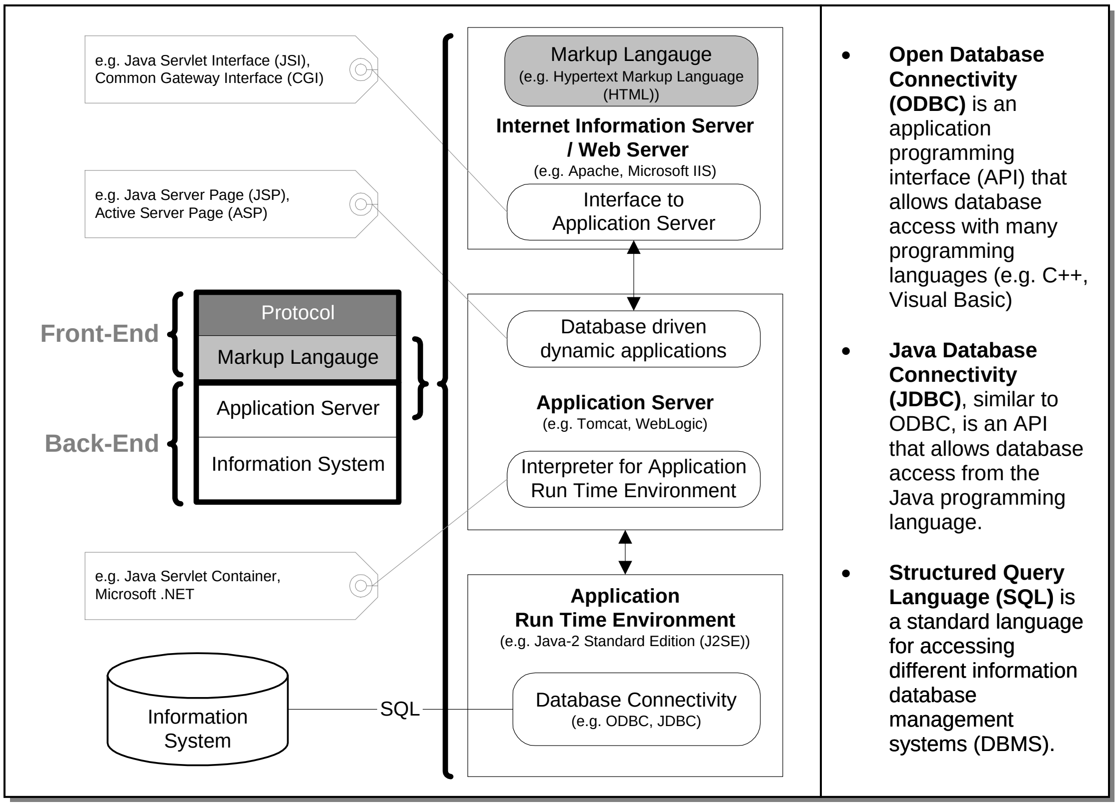


Figure 4-2. Typical Front-End and Back-End Information Access

An Internet information server (IIS), which is often referred to as a Web server, makes the front-end module available. To facilitate dynamic database driven applications, the IIS must interface the application server, which makes back-end module available. This back-end subsequently provides database connectivity.

This type of hierarchy allows ASPs to provide for different wireless application environments. Those reviewed in this report are identified in Table 4-1.

Table 4-1. Wireless Application Environments and Mobile Internet Services

Mobile Internet Service		**WWW**	**WAP**	**I-MODE**	**Customized**	**Interactive Voice**
Wireless Application Environment	User Interface	Web Browser using hyperlinks	Micro Browser using a layered menu	I-MODE Browser using hyperlinks	Cusomized	Audio Components using voice & DTMF in a layered menu
	Language	HTML	WML	CHTML	(e.g., XHTML)	V-XML
	Protocol	HTTP	WAP	HTTP	(e.g., POP)	HTTP

The following subsections address each of these application environments and the mobile Internet services they support.

4.1 THE WIRELESS APPLICATION ENVIRONMENT FOR WWW SERVICE

The World Wide Web (WWW) is the most popular client-server information tool on the Internet. Web servers communicate with client devices (e.g., personal computers) to provide any number of applications, including search engines, e-commerce, e-trading, e-banking, and various forms of entertainment.

Until recently, the WWW had been restricted to wireline connectivity – primarily because mobile devices had far less computing power and display capabilities then desktop systems. However, mobile computing has advanced significantly, and when equipped with a network interface, some of the newer mobile devices can be used to establish WWW services.

The wireless application environment used to support WWW services is illustrated in Figure 4-3 and is typically comprised as follows.

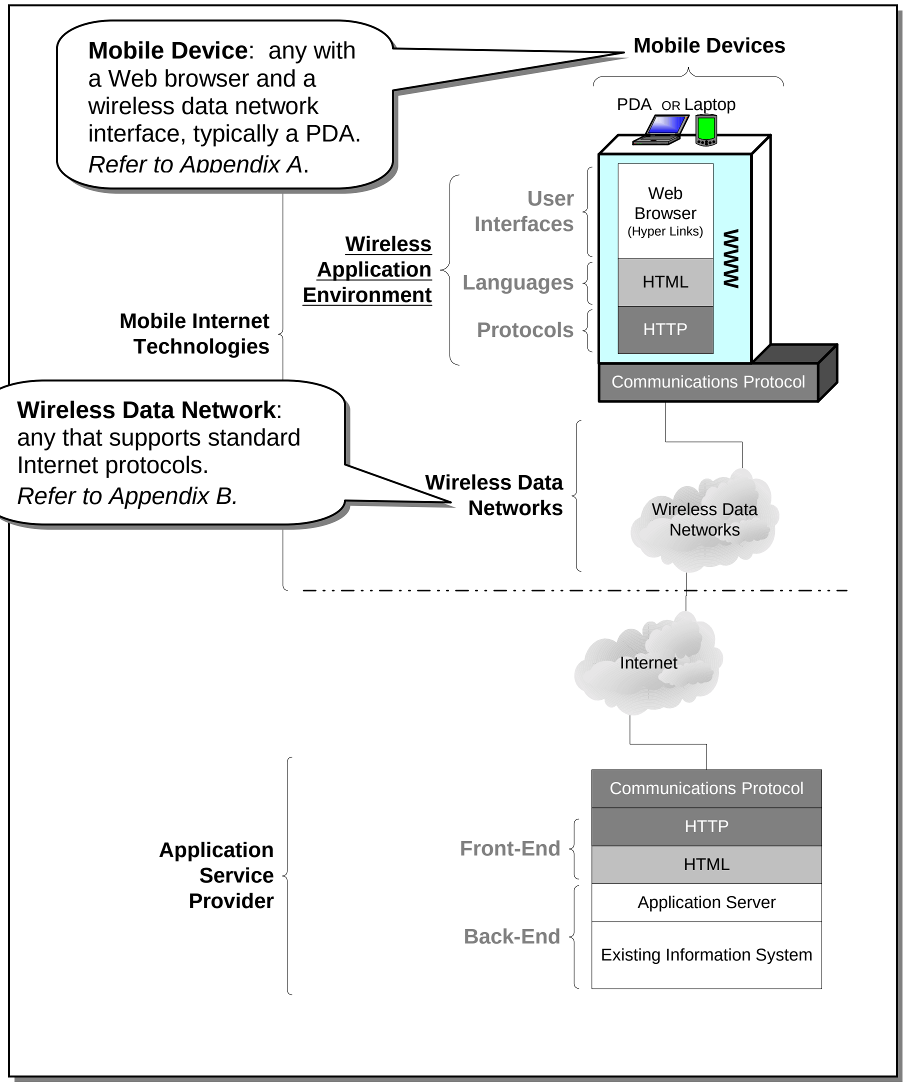


Figure 4-3. WWW Mobile Internet Service

- **User Interface**: The user interface for mobile devices using WWW services is established with a HTML Web browser. A Web browser is a software application used to locate and display Web pages (formatted graphics and text). In addition, most modern browsers can present multimedia information, including sound and video. Laptop computers are typically configured with a standard HTML Web browser, such as Microsoft® Internet Explorer™. PDAs are configured with less comprehensive versions of these browsers (e.g., Microsoft® Pocket Internet Explorer™).

- **Markup Language**: HyperText Markup Language (HTML) is the authoring language used to create documents on the World Wide Web. It's similar to the standard generalized markup language (SGML), although not a strict subset. HTML defines the layout of a Web document by using a variety of tags and attributes to structure text, format graphics, and specify links (hypertext links) to other Web pages. In addition to being used for publishing content, it's also used by Web browsers to display content.

- **Communication Protocol**: HyperText Transfer Protocol (HTTP) is the application protocol used by the World Wide Web. HTTP defines what actions Web servers and browsers should take in response to various commands. For example, when you enter a URL in your Web browser, this actually sends an HTTP command to the Web server directing it to fetch and transmit the requested Web page. HTTP is called a stateless protocol because each command is executed independently, without any knowledge of the commands that came before it. This is the main reason that it's difficult to implement Web sites that react intelligently to user input. This shortcoming of HTTP is currently being addressed in a number of new scripting languages, including VBScript and JavaScript.

  JavaScript & VBScript:

  Scripting languages that can interact with HTML source code, enabling Web authors to design interactive sites.

  At the transport layer, the WWW services rely on either the Transmission Control Protocol (TCP) or the User Datagram Protocol (UDP). TCP is a connection-oriented protocol that guarantees delivery of data between hosts. It also guarantees that packets will be delivered in the same order in which they were sent. Unlike TCP, UDP is a connectionless protocol that provides few error recovery services. However, it requires less transmission overhead. UDP is used primarily for broadcasting messages over a network.

4.1.1 Standards

The first Internet draft of HTTP was written by the World Wide Web Consortium (W3C) in 1996. The W3C has ceased development of the protocol since all HTTP extensions and HTTP/1.1 (the current version) are stable specifications.

The W3C is currently working on the next generation markup language – Extensible Hyper Text Markup Language (XHTML). XHTML is a family of current and future document types and modules that reproduce, subset, and extend HTML, reformulated in XML. XHTML ensures that layout and presentation stay true-to-form over any platform. This is particularly important in the mobile domain where there are large variations in device display characteristics (e.g., screen size, resolution). The latest version of the XHTML standard was drafted by the W3C in 2002.

4.1.2 Service and Content Providers

In general, all the entities on the WWW are information content providers for mobile WWW services. However, unless a provider's information is properly formatted, it will likely be unsuitable for display on a PDA. Those who do format their content for mobile devices (or do so for others) are considered mobile WWW ASPs. Some of the more common ASPs are:

- Mobile MSN
- Mobile Windows Media
- Mobile Yahoo

* *Such providers might be used to access publicly available transportation-related information, including: traffic video, weather, map data, and roadway congestion.*

4.1.3 Advantages and Disadvantages

Some of the advantages of using a WWW mobile Internet service (as opposed to other types of mobile Internet service) include:

- Less complex system integration
  - The wireless application environment is formed on broadly accepted standards (e.g., HTML, HTTP)
  - Many servers are preconfigured with support for WWW services, so from a technical perspective, it's fairly easy for organizations with existing Web servers to establish mobile WWW internet services
  - Most mobile devices carry a standard HTML Web browser. Although the operating system in some PDAs do not currently support some active components (e.g., JavaScript).
- When compared to devices used for other mobile Internet services (e.g., WAP, I-mode), many mobile devices used for WWW service
  - Have better display characteristics (e.g., high resolution graphics, formatted text)
  - Have an external network interface allowing the use of various wireless modems, which subsequently allows more network options.
  - Have more easily upgradeable operating systems.
- There are <u>many</u> WWW content providers, a growing number of which offer transportation-related information.

Currently, some disadvantages of using WWW mobile Internet service include:

- The content on most Web servers is not formatted for display on PDAs. Content providers that wish to be accessible via mobile WWW services must reformat their content for mobile devices, or have an ASP do it for them.
- When compared to devices used for other mobile Internet services (e.g., WAP, I-mode), the mobile devices for WWW services:
  - Consume more power
  - Are larger and more cumbersome
  - Are usually more expensive

4.2 THE WIRELESS APPLICATION ENVIRONMENT FOR WAP SERVICE

Wireless Application Protocol (WAP) is an open, global specification that allows users to access Internet-type content via thin-client devices, such as cell phones, pagers, and two-way radios. WAP will also support more complex mobile devices, such as PDAs, but the most common device is a WAP-enabled cell phone, or "WAP Phone".

Thin-client devices are those designed to be small and less complex so that the bulk of data processing can occur on the server.

WAP was conceived in the mid '90s by several companies within the wireless industry, including Unwired Planet (now Openwave Systems), Motorola, Nokia, and Ericsson. These companies established the WAP Forum and in 1997 released the first draft of the WAP specification. As noted previously, the WAP Forum has become part of the Open Mobile Alliance (OMA). Today, there are several hundred members of the OMA using the specification to develop applications for manufacturers, operators, and providers within various market sectors. There are also several million WAP users world wide, but primarily in Europe.

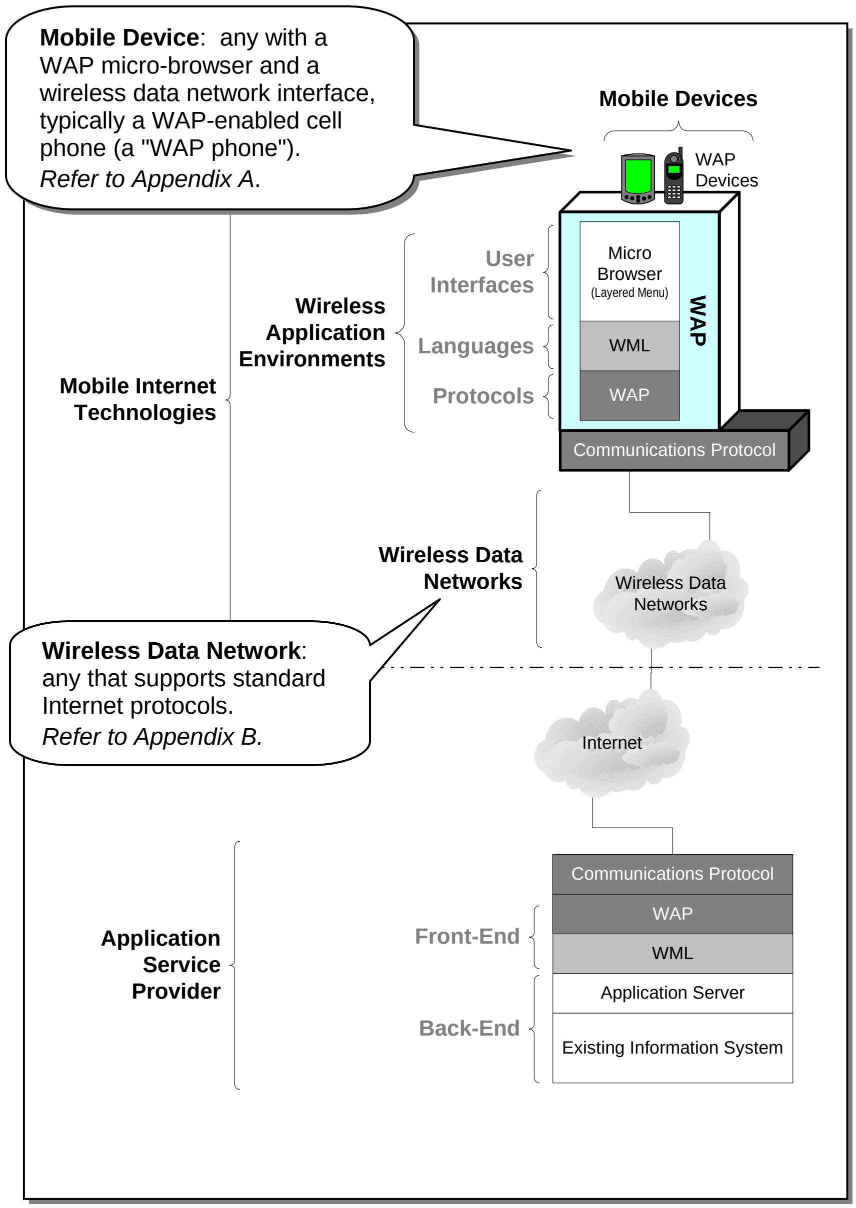


Figure 4-4. WAP Mobile Internet Service

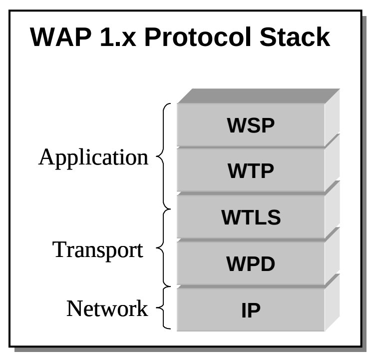
The wireless application environment used to support WAP services is illustrated in Figure 4-4 and is comprised as follows.

- **User Interface**: The user interface for mobile devices using WAP services is established with a micro-browser. Micro-browsers are small software applications that have been optimized for thin-client devices. They make minimal demands on hardware, memory, and CPU; allow for a compact user interface with simple scrolling navigation functions; and can accommodate the low-bandwidth constraints of a many existing wireless data networks.

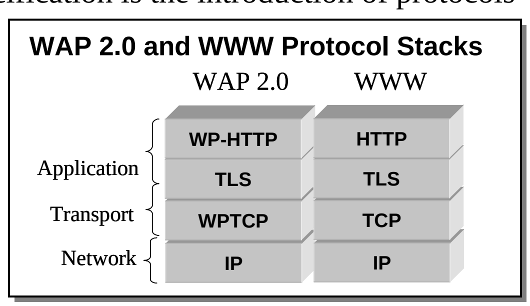
- **Markup Language**: The markup language used for WAP services is the Wireless Markup Language (WML). WML is an XML 1.0 variant that was designed to enable applications within the constraints of handheld devices, such as small screens and one-hand navigation without a keyboard or mouse. WML has a smaller set of markup tags than HTML, and unlike the flat structure of HTML documents, WML documents are divided into specific units of user interaction (called "cards") that are easily navigable with a micro-browser. WAP also supports WMLScript, which is similar to JavaScript, but makes fewer demands on memory and CPU power.

  WML is the language defined by the most recently approved specification, but the WAP 2.0 proposed specification calls for use of the XHTML Mobile Profile (XHTMLMP), which is an extension of the XHTML basic profile. As noted previously, XHTML is the new platform agnostic language being developed by the W3C to replace and enhance HTML.

- **Communication Protocol**: The approved WAP 1.x specifications incorporate two protocols at the application layer: the wireless session protocol (WSP) and the wireless transaction protocol (WTP). These protocols were designed to provide HTTP/1.1 functionality and incorporate new features that allow an efficient and reliable exchange of data over wireless data networks. At the transport layer, the 1.x specifications define the wireless datagram protocol (WDP) – a connectionless-oriented protocol derived from the user datagram protocol (UDP). The 1.x specifications also include the wireless transport layer security (WTLS) protocol, which is an optional layer that has encryption facilities to support secure transactions, such as those needed for e-commerce applications. All of these protocols have been optimized for the unique constraints of the wireless environment: low bandwidth, high latency, and less connection stability.



  A key feature of the proposed WAP 2.0 specification is the introduction of protocols that are more compatible with standard Internet protocols (i.e., the TCP/IP Stack), and in particular those used for the WWW. This change has been motivated by the emergence of 2.5G and 3G packet data networks that provide TCP/IP support directly to the mobile device. In the proposed specification, the application



layer protocol is Wireless Profiled HTTP (WP-HTTP) – a profile of HTTP designed for the wireless environment yet fully interoperable with HTTP/1.1. At the lower layers, the specification uses standard Transport Layer Security (TLS) and a wireless profile of TCP that will provide connection-oriented services in a wireless environment.

**** Note***: *The WAP 2.0 specification is backwards compatible and will support the protocols defined in the 1.x specification as well.*

4.2.1 Standards

The WAP specification is controlled by the Open Mobile Alliance (OMA) (http://www.openmobilealliance.org), a recent consolidation of the Open Mobile Architecture initiative, the WAP Forum, and others. The most recently approved specification is WAP 1.2.1 (June 2000), but WAP 2.0 is now available in its proposed version and is under active review and validation by the OMA membership, as well as the general public. In addition to enhancing the markup language and the communication protocols (as identified in the previous sections), the new specification will add or enhance features, such as "WAP Push", which allows content to be sent or “pushed” to devices by server based applications, and the multimedia messaging service (MMS), which allows the delivery of multimedia content.

4.2.2 Service and Content Providers

ASPs typically provide WAP services for their customers (i.e., content providers) in one of two ways: by developing custom applications or by using a WAP protocol gateway and a language translator (or transcoder) to convert WWW services to WAP services. There are advantages and disadvantages to each, as noted throughout this section.

Some of the more common ASPs for WAP service include the CRMS providers, such as AT&T Wireless, Sprint PCS, Verizon Wireless, and Cingular. Others include Openwave Systems and Wireless Developer.

Information content providers that wish to be accessible via WAP services can either develop custom applications themselves, or have an ASP develop the applications. The following content providers have custom applications.

- Finance: Fidelity, Schwab
- Travel: Map Quest, Expedia.com
- Sports: ESPN, Go2Score
- Entertainment: Ticket Master, MovieFone
- News: The New York Times, The Washington Post
- Weather & Traffic: The Weather Channel, Go2Weather
- E-commerce: Amazon.com, eBay.com

* *Certain such providers might be used to access publicly available transportation-related information, including: traffic video, weather, map data, and roadway congestion.*

In a general sense, ASPs using transcoders and WAP gateway products support the millions of content providers on the WWW. Yahoo!, Inc. and Google are two such providers. However, transcoders only work well for static HTML content (i.e., Web pages that always contain the same information). Dynamic and interactive Web pages that use scripting languages, such as Java Script or VBScript, along with HTML (as most Web pages do today) are much more difficult for transcoders to handle and the translated information is most often unsuitable for mobile devices. In addition, transcoders can not currently support any database driven applications.

> ***Script:*** Another term for macro or batch file, a script is a list of commands that can be executed without user interaction.
>
> ***Script Language:*** a simple programming language with which you can write scripts.

As WAP migrates to the use of XHTML, the need for translation will be significantly reduced, if not eliminated. Until then, customized applications will be the most common solution.

4.2.3 Advantages and Disadvantages

Some of the advantages of using WAP solution include:

- WAP is an open, global specification
- WAP is designed for thin-client devices. When compared to devices used for WWW mobile Internet services, WAP enabled devices:
  - Are smaller and less cumbersome
  - Consume less power
  - Are usually less expensive

Currently, some disadvantages of a WAP solution are:

- Most mobile devices
  - Have small display screens
  - Have micro-browsers that require data entry by alpha numeric keypad strokes
  - Do not have easily upgradeable operating systems. When technology changes, equipment must often be replaced.
- WML supports limited text formatting (only **bold**, *italic*, and <u>underline</u>) and imaging (only wireless bitmap images), but this should change with WAP 2.0
- Although some of the newest WAP phones are built with color display, the current specification does not support color for text and image. This too should change with WAP 2.0.
- More complex system integration:
  - The wireless application environment is formed on less common specifications (e.g., WML, WSP, and WTP). Again, this will change with WAP 2.0.
  - ASPs must upgrade their front-end systems, either by building a specific WAP front-end, or by integrating a WAP gateway and a language transcoder.
  - For content providers to be accessible via WAP services, they must either customize their applications or contract with an ASP to support their applications. Even if the ASP uses translators, until XHTML is established as a WWW standard, some customization of the content provider's application will be required.
- Not many content providers have content formatted for a WAP phone, although the numbers are growing.

4.3 THE WIRELESS APPLICATION ENVIRONMENT FOR I-MODE SERVICE

I-mode is a mobile Internet product developed by Japanese telecommunications company NTT DoCoMo. In February1999, NTT DoCoMo launched its I-mode service in Japan, where over 81% of the world's mobile Internet users reside. As of January 2002, I-mode accounted for over 60% of this market with more than 30 million subscribers, and I-mode has overtaken traditional Japanese Internet service providers to become the country's largest Internet access platform, wireline or wireless.

I-mode is more than just a mobile Internet access; it's part of DoCoMo's wireless business model that provides users a variety of services, such as games, organizers; the "**I-area"** service that provides location-specific content; and the "**I-motion"** service that can exchange video and audio files.

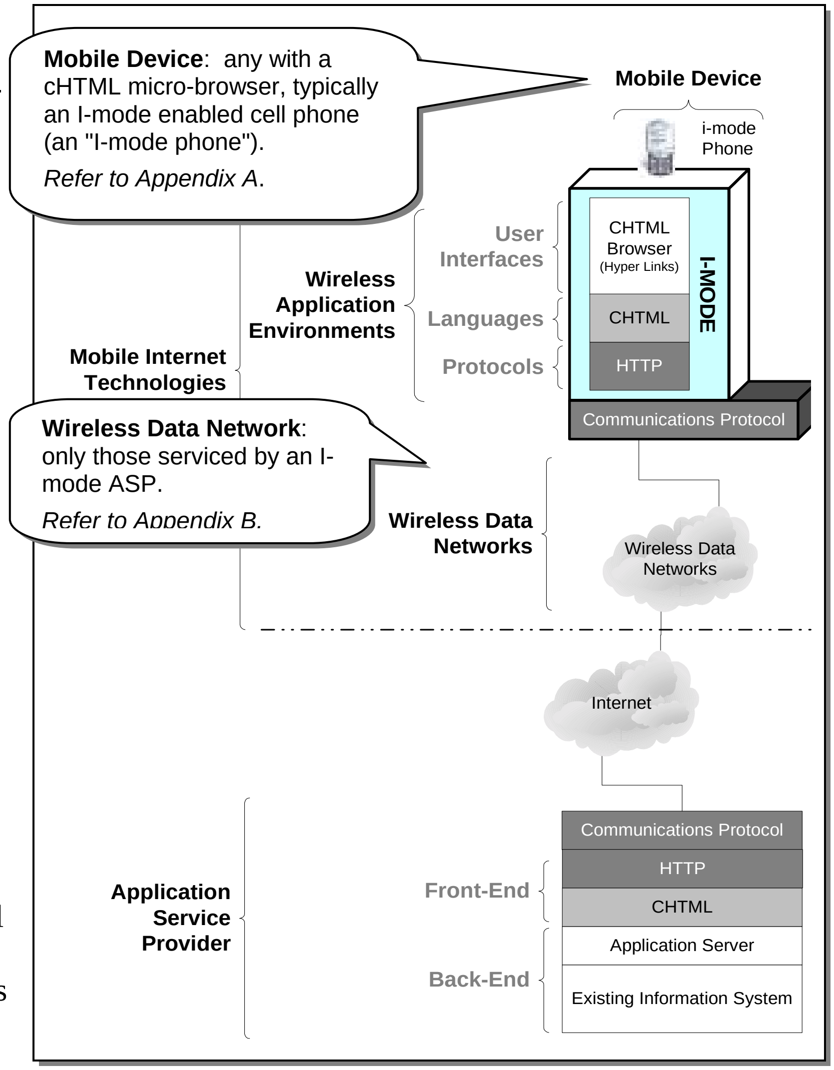


Figure 4-5. I-mode Mobile Internet Service

In Japan, I-mode is available only to users who have signed up for DoCoMo's phone service. Their original network was a 2G wireless packet data network, which is relatively slow but still used by most I-mode users in Japan. In the spring of 2001, the company launched the world's first commercial 3G wireless service using a WCDMA system that can support speeds in excess of 384 kbps and handle mobile multimedia services, such as I-motion. The 3G network currently operates in a 30km radius of central Tokyo only, but is being expanded to establish coverage in Japan's major markets.

> **Note:** NTT DoCoMo is not the only mobile Internet provider in Japan. It has two competitors, each with about 20% of the Japanese market: J-Phone, with the J-Sky service, and KDDI, with the EZweb service. KDDI provides a WAP-based service

The wireless application environment used to support I-mode services is illustrated in Figure 4-5 and is comprised as follows.

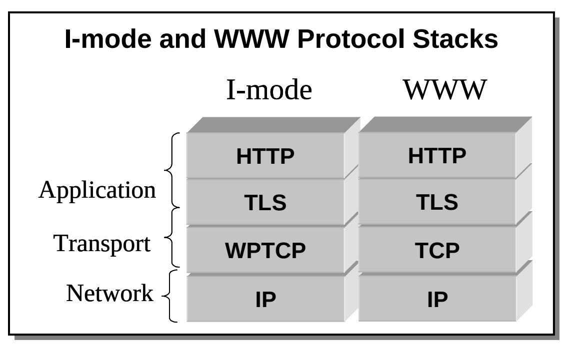
- **User Interface**: Like WAP, a micro-browser is used to establish the user interface on I-mode enabled devices. The original I-mode micro-browser was developed by Japan-based company Access Company, Ltd., and DoCoMo used its leverage with handset manufacturers to develop appropriate handsets for this micro-browser. I-mode micro-browsers are designed to work with compact HTML (cHTML).

- **Markup Language:** The markup language used for I-mode services is cHTML – a subset of HTML designed to enable applications within the constraints of handheld devices. CHTML was also created by Access Company, Ltd. The cHTML standard specifies a subset of HTML that was selected based on the hardware restrictions for the mobile devices, including, small memory, low-power CPU with limited battery life, small display with restriction on colors, and limited input options.

  While client-side scripting languages are not supported, CGI-bin and other server-side scripting languages can be used with cHTML to build interactive page content. CHTML can also support GIF-formatted images and J2ME-based applications. J2ME, or Java 2 Platform Micro Edition, allows developers to use Java to create applications and programs for wireless and mobile devices.

- **Communication Protocol**: Like WWW services, the I-mode service uses HTTP as the application layer protocol. To improve wireless transmission efficiency, DoCoMo created Wireless Profiled TCP (WPTCP), a version of TCP that's optimized for wide-area wireless communication. I-mode protocol gateways in DoCoMo's network translate WPTCP to standard TCP, and vise versa.

  In general, I-mode uses a WWW protocol structure (i.e., HTTP over TCP/IP). This means that existing Internet gateways and Web servers can be used without change. It also means that Transport Layer Security (TLS) can be used for security features across the wireless network. TLS is a standard protocol that guarantees privacy and data integrity between clients and servers communicating over the Internet.



4.3.1 Standards

I-mode is a product developed and maintained by NTT DoCoMo, and the I-mode browser is a proprietary solution. However, programming languages and protocols on which the service is built are open standards approved by the W3C and the IETF. These organizations are also supervising development of the languages and protocols to be used in future specifications, such as XHTML.

4.3.2 Service and Content Providers

NTT DoCoMo is the only I-mode ASP in Japan. Other telecommunications companies that have partnered with DoCoMo over that last few years now function as ASPs in other parts of the world (we note some of these later in this section). ASPs provide I-mode services for two types of content providers, official and unofficial.

Official content providers are directly connected to the ASP's network, which means that data is not transported over the Internet on its way from the content provider's server to the mobile user. Official sites are provided direct menu access (i.e., one touch links) on I-mode enabled devices. These providers are charged by the ASP for this capability, but in turn, they charge the mobile user for their content.

Unofficial content providers are all other content providers on the Internet. The ASP enables Internet access from I-mode devices by using an I-mode gateway to bridge the ASPs network and the Internet. Unofficial sites must be "browsed" by the mobile user, but these content providers don't pay to be accessible.

There are now more than 3,000 official and 51,000 unofficial I-mode content providers on just DoCoMo's networks in Japan. Providers that wish to have their content accessible via I-mode services can exchange content with the ASP in one or more of the following ways:

- As cHTML, the language designed for I-mode.
- As HTML; although the application would need to be customized for small screens and avoid any of the elements excluded in cHTML
- As HTML behind a cHTML–HTML transcoder; the transcoder translates cHTML to/from HTML and removes or converts all non-I-mode-compatible HTML constructs.

In general, the millions of entities on the WWW could establish content for I-mode services by using a HTML – cHTML transcoder. Since cHTML is a subset of HTML, these transcoders are much more effective than those used for WAP and can support translation of some server-side scripting languages (e.g., CGI-bin) used for interactive content. Still, these transcoders are limited, and much of the content would likely be formatted improperly for mobile devices. As I-mode and WWW migrate to XHTML, the need for translation will be significantly reduced, if not eliminated. Until then, customized applications will be the most common solution.

I-mode in the U.S.?

Since its domination of the Japanese market, DoCoMo has set its sites on bringing I-mode to the rest of the world. The company quietly bought a minority stake in the following companies.

- **Hutchison Whampoa**, Hong Kong, December 1999 (19% stake)
- **Dutch KPN Mobile** Netherlands, May 2000 (15% stake)
- **Telecom Italia Mobile:** Italy, 1997
- **SK Telekom:** South Korea, July 2000 (10% stake)
- **KG Telecom:** Taiwan, November 2000 (20% stake)
- **Tele Sudeste Cellular Participacoes**: Brazil, September 1998 (7% stake)

Hutchison Whampoa became the first company other than DoCoMo to establish I-mode service in May 2000, followed in June by SK Telekom. In Europe, Dutch KPN Telecom and Telecom Italia Mobile began to roll out I-mode service across Holland, Germany, Belgium, and Italy in the spring of 2002. Each of these telecommunications providers is now an I-mode ASP.

A version of the I-mode service has been planned for the U.S. market since DoCoMo bought a 20% stake of AT&T Wireless for $9.8 Billion in November 2000. In April 2001, AT&T began rolling out M-mode – a service that's based on I-mode, but the applications and content, which is part of the DoCoMo product, are being designed for the US market. M-mode is the service behind AT&T Wireless' "M Life" campaign, which was launched in conjunction with the widespread deployment of their GPRS (2.5G PCS) network in January/February 2002. There are approximately 30 cities in the US for which AT&T provides GPRS service, including; Chicago, IL, Dallas, TX, Los Angeles, CA, New York, NY, and Washington, DC.

Oddly, the technology behind M-mode was initially WAP-based. However, AT&T is now developing the service based on the I-mode platform. In addition, the newest M-mode micro-browsers will be designed to support not only cHTML, but also WML – the language used for WAP services. These actions are viewed as a preemptive approach to deal with the eventual convergence of WAP and I-mode technologies.

WAP and I-mode Convergence

The WAP 2.0 specification will adopt support for HTTP and WPTCP, which are part of the I-mode technical specification. In addition, both WAP and I-mode technical specifications will eventually adopt support for XHTML.

According to AT&T Wireless, there are over 100 companies and organizations in the US signed on to supply official content for the M-mode service. These include:

- Finance: Ameritrade, The Wall Street Journal
- Travel: Hotelguide, Trip.com
- Sports: ESPN, SportsFeed.com
- Entertainment: ClubFone, TVGuide
- News: ABC, CBS
- Weather & Traffic: Mobile Gates Traffic, The Weather Channel
- E-commerce: Amazon.com, eBay.com

* *Certain such providers might be used to access publicly available transportation-related information, including: traffic video, weather, map data, and roadway congestion.*

4.3.3 Advantages and Disadvantages

Some of the advantages of using I-mode (or M-mode) solution include:

- The service, like WAP, is designed for thin-client devices. When compared to devices used for WWW mobile Internet services, I-mode/M-mode enabled devices:
  - Are smaller and less cumbersome
  - Consume less power
  - Are usually less expensive

- CHTML (used for I-mode) is more flexible than WML (used for WAP). CHTML can
  - Support rich color displays and formatted text
  - Support some scripting languages and development platforms (J2ME) that allow for interactive sites

- Less complex application development than a WAP solution
  - For content providers to be accessible via I-mode/M-mode services, they must either customize their applications or contract with an ASP to support their applications (AT&T Wireless is currently the only ASP in the US). However, applications based on existing WWW content should be easier to rebuild for I-mode/M-mode services since cHTML is a subset of HTML – the WWW markup language. Furthermore, if relying on an ASP's transcoders, the translation between cHTML and HTML is much better than that for WAP (WML – HTML). Regardless, until XHTML is established as a WWW standard, some customization of the content provider's application will likely be required.

Currently, some disadvantages of an I-mode/M-mode solution are:

- Most mobile devices
  - Have small display screens
  - Have micro-browsers that require data entry by alpha numeric keypad strokes
  - Do not have easily upgradeable operating systems. When technology changes, equipment must often be replaced.
- While based on some open standards, such as HTTP and HTML, I-mode and M-mode are proprietary technologies, and the only licensed ASP in the US at this time is AT&T Wireless.
- There are not many "official" M-mode content providers in the U.S., and most "unofficial" content providers don't have content formatted for M-mode phones. However, the number of providers is growing, including those that offer transportation-related information.

4.4 CUSTOMIZED WIRELESS APPLICATION ENVIRONMENTS

In addition to (or in lieu of) WWW, WAP, or I-mode services, one could establish customized wireless application environments. In the mobile domain, most custom environments are created in either a Java Runtime Environment (JRE) or Binary Runtime Environment for Wireless (BREW). These new development platforms allow programmers to avoid writing separate applications for many different kinds of mobile device.

Note: *This report does not address custom environment development other than to introduce these two development platforms.*

Java Runtime Environment (JRE)

Java is a high-level object-oriented programming language developed by Sun Microsystems. It's similar to C++, but simplified to eliminate language features that cause common programming errors. Java 2 Micro Edition (J2ME) allows developers to use Java when building applications for mobile devices. It also establishes the JRE – a development platform built for devices that have small amounts of memory, such as mobile phones. J2ME is an open standard, and applications developed in the JRE will run on any J2ME-enabled mobile device.

Binary Runtime Environment for Wireless (BREW)

BREW is a proprietary development platform created by Qualcomm. While a proprietary standard, the platform does comprise open source-code, and anyone can develop applications. Most BREW applications are written in C or C++ (referred to as native applications), but BREW also supports programming in Java.

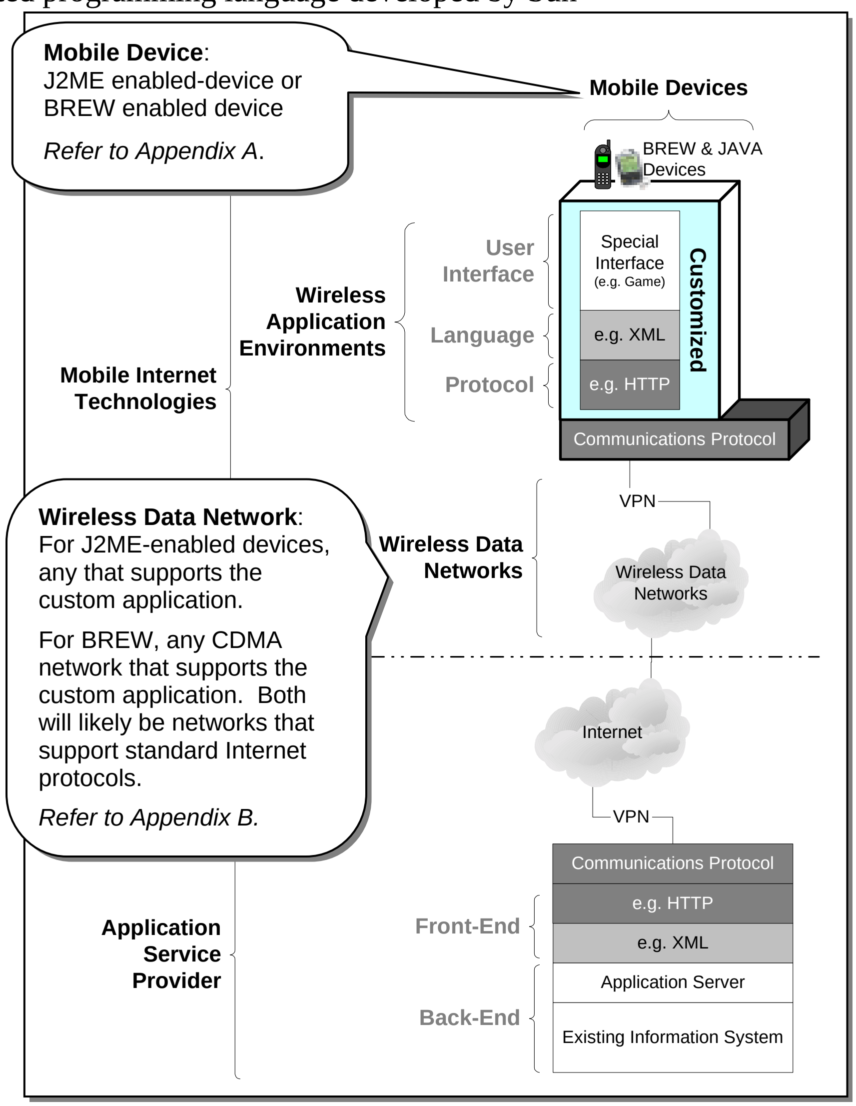


Figure 4-6. Customized Mobile Internet Services

BREW was first introduced in January, 2001. At present, there are at least three wireless network providers in the U.S. that offer custom solutions as part of select service packages (Verizon Wireless, Sprint PCS, and Alltel Corp.). Customers can download applications onto their BREW-enabled phones.

The typical structure of a customized wireless application environment is illustrated in Figure 4-6 and is comprised as follows.

- **User Interface**: The user interface for custom applications could be established with something as simple as a POP email client, or as complex as the GUI for a networked multimedia game. It's a custom solution.
- **Markup Language**: For custom applications, the markup language could be any, but it will most likely be based on flexible languages, such as XML or XHTML.
- **Protocol**: Like the language, the protocols could involve any. However, they will most likely be based on the TCP/IP stack.

4.4.1 Standards

Java, J2ME, and the JRE are open standards maintained by Sun Microsystems (java.sun.com). BREW is a proprietary standard developed and maintained by Qualcomm. Since BREW is an open-source development platform, developers have access to the source code for programming, but the standard is closed.

4.4.2 Advantages and Disadvantages

Some advantages of developing a custom environment are:

- Customized solutions can support specialized features and operations
- BREW and JRE are thin-client development platforms designed for thin-client devices. As noted previously, these devices typically require less power, are less cumbersome, and are less costly than PDAs and other mobile computing devices.

Some disadvantages of developing a custom environment are:

- Both the JRE and BREW are immature and need further development
- Thin-client devices have small display screens and require data entry by alpha numeric keypad strokes.
- Custom applications often require more routine maintenance and may require significant modification with changes in the application environment.

Some advantages of a JRE solution:

- Since JAVA, J2ME, and JRE are open standards, many more vendors can incorporate the JRE platform into their devices
- As a result of open standards and more devices, there are also more J2ME applications available.

Some disadvantages of a JRE solution:

- The JRE platform requires more processing power and is not quite as fast or efficient as BREW. However, for applications on a mobile device, this might not be as critical. In other words, the applications developed for a mobile device are usually not that process intensive, yet.

Some advantages of a BREW solution:

- The BREW platform is embedded on the system kernel (the bottom layer of machine code) of the Qualcomm chipset. This enables faster and efficient processing for native applications (i.e., applications developed in C or C++).
- BREW can support many different programming languages (e.g., C, C++ and Java). In theory, a BREW-enabled device could support an application developed with J2ME. However, this requires a more powerful mobile device that's capable of supporting JRE running on top of BREW. This is analogous to running Mac OS on top of Windows OS. It can be done, but is not practical.

Some disadvantages of a BREW solution:

- BREW is a proprietary standard and applications are designed for only those devices which have Qualcomm's chipsets and use CDMA networks.

4.5 A WIRELESS APPLICATION ENVIRONMENT FOR AN INTERACTIVE VOICE RESPONSE SERVICE

Interactive Voice Response (IVR) services are different from the other services addressed in this report. While the technologies used to establish this service comprise a user device, an application environment, and a communications network, these elements are not confined to the mobile domain. IVR services can be supported by any network (wireline or wireless) that's part of the Public Switched Telephone Network (PSTN). And users can use any device (fixed or mobile) that's supports voice communication over the PSTN. However, from the perspective of this report, one should consider mobile devices and wireless networks.

An IVR system will prompt callers to input numeric and alphanumeric data using the mobile device keypad. The system will process this information and then respond to the caller with pre-recorded or synthesized audio. Automatic speech recognition (ASR) systems enhance an IVR system by making a voice interface available to the user. This allows them to respond and enter data by speaking instead of punching keys.

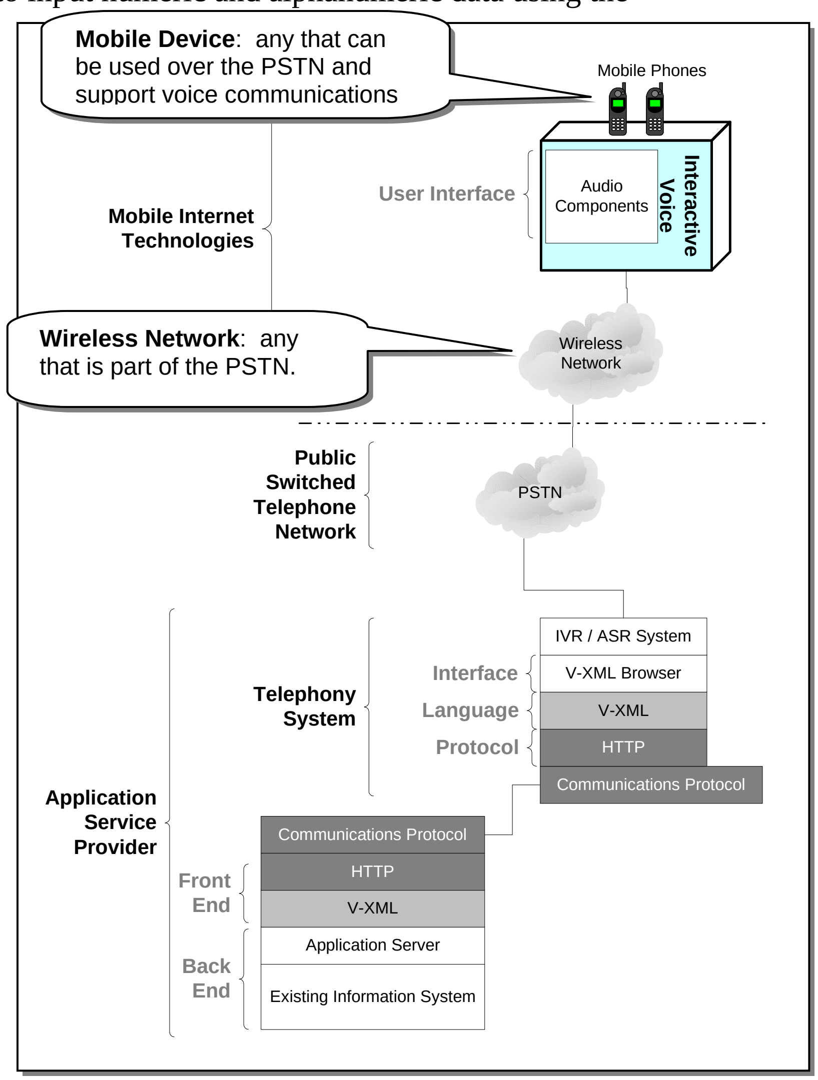


Figure 4-7. IVR Mobile Internet Services

In addition to the enabling technologies, IVR services are also different from the previous services because the content exchanged is in audio form. This restricts the applications for which the technology can be used, but the simplicity of data entry (speaking, not key strokes) can be useful, particularly in a mobile environment. For applications that don't require visual information or large amounts of data, this can be a very effective solution. It's already become popular for customer support operations and for ATIS with in the ITS domain. The new 511 services use IVR/ASR systems. While primarily considered as a means to disseminate information, these systems can be used to collect information as well. The wireless application environment used to support IVR services is illustrated in Figure 4-7 and is typically comprised as follows.

- **User Interface**: For IVR services, the user interface is established with audio components (microphones and speakers) on the mobile device. Data entry originates at the mobile device. IVR systems accept only DTMF input while IVR/ASR systems accept either DTMF or voice. Both systems respond to the user with pre-recorded and/or synthesized audio.

  > **Dual Tone Multi-Frequency (DTMF):** a system used by touch-tone phones, in which specific frequencies, or tones, are assigned to each key so that it can easily be identified by a microprocessor.

  A VXML browser, which is a resource of the ASP and not the individual mobile device, establishes the interface between the IVR/ASR system and the provider's application server and information systems. The most common browsers include: TellMe's Voice XML Browser, Nuance's Voice Web Server, and BeVocal's Café.

- **Markup Language**: The markup language used to support interactive voice services is Voice XML (VXML). VXML is an application of XML designed to structure Web-based data so that it can be exchanged with the user through an IVR/ASR system.

- **Protocol**: The standard WWW protocols (HTTP over TCP/IP) are used for communication between the ASP application server and telephony system. Any telephony system interfacing the PSTN can be used to connect the user and the ASP.

How it all works

When a user calls, the IVR/ASR system accepts the call through an open telephony port (ASPs require many ports to serve their vast number of potential users). The IVR/ASR will then send a request to the voice-enabled application server through the VXML browser. The application server will process the request, translate all the required session information (e.g. language model, audio prompts, grammar) into VXML format, and respond to the browser. Based on the VXML content, the IVR/ASR system will respond to the user with either pre-recorded or computer-synthesized audio. When the user replies, with either voice or DTMF, the IRV/ASR system will translate the phonetic input into data, and send the information back to the application server. Essentially, the server and the user can "talk".

4.5.1 Standards

VXML was originally established in the mid 90's as part of AT&T's "Phone Web" and Lucent's "Tele Portal" research initiatives. AT&T, IBM, Lucent Technologies, and Motorola later developed the first standard, VXML 1.0. The W3C has since been developing the standard, and the current version, VXML 2.0, has been improved to handle more complicated speech recognition techniques, such as natural human speech recognition, which allows users to speak more naturally on the phone.

Some of the new speech recognition systems include multiple acoustic models that support different languages (e.g. French, German, and Spanish) and multiple accents on each language (e.g. U.S. English, British English, Spanish English). The systems are implemented at the discretion of the ASP.

4.5.2 Service and Content Providers

To establish adequate services, ASPs – often called voice portal service providers – must have significant telephony infrastructure (leased or owned) to provide connectivity between their IVR/ASR system and the PSTN. Consequently, there are not many ASPs. Some of the major ASPs for IVR service include:

- TellMe Networks, Inc.
- BeVocal, Inc.
- VoiceGenie Technologies, Inc.
- Lucent Technologies

ASPs typically provide IVR services for their customers (i.e., content providers) in one of two ways: The ASPs will develop and maintain custom applications for these providers, or the ASPs will use their telephony system to support the applications developed and maintained by the content provider. In the later instance, content providers design the applications, transcribe content in VXML, and feed this data to the ASP. Most content providers prefer the former option, since it requires less maintenance on their behalf.

The following content providers have IVR services:

- Financial: E-TRADE
- Customer Service: AT&T
- Catering: Domino's Pizza
- E-commerce: Amazon.com

There are also many State DOTs using IVR services to support their ATIS programs.

4.5.3 Advantages and Disadvantages

Some advantages of using an IVR solution include:

- No special device is needed by the user. Any standard phone (mobile or fixed) can be used.
- It does not require a wireless <u>data</u> network. Any network connected to the PSTN will work. Subsequently, there are more wireless network options, and typically better coverage for each option.
- VXML is an open standard being developed by the W3C.

Disadvantages of an IVR solution include:

- There is no practical automated conversion or translation from HTML (Web documents) to VXML and therefore a provider's existing WWW content is not accessible via IVR services. Content providers must either develop custom applications or contract with an ASP to support their applications – the later option may be an advantage when considering the cost of establishing and maintaining separate VXML content.
- Voice recognition systems are by no means perfected, and users often experience frustration with voice recognition errors.

- Applications are limited due to the audio-only information content
- Applications must operate efficiently by exchanging small amounts of information.
  - Users cannot retain significant amounts of audio (as opposed to having a visible document to read)
  - Applications cannot contain graphical content.
  - User input must be predefined. Users cannot input text in an ad hoc fashion as they could do with WWW, WAP, or the other mobile Internet services.

SECTION 5

SUMMARY, RECOMMENDATIONS, AND ADDITIONAL RESEARCH

Mobile Internet technologies are far from being firmly established, particularly in the United States. However, they're developing rapidly. Mobile devices are improving, and with each new release, they become more user-friendly and less expensive. Faster and more reliable wireless data networks are being deployed. There are now multiple 2.5G PCS options in most major metropolitan and suburban areas, and several companies deploying publicly accessible WLANs (i.e., "Hot Spots"). In addition, wireless application environments are beginning to converge. Markup languages are moving toward XML variants, and protocols are moving toward a common stack capable of supporting different application environments.

While mobile Internet technologies have yet to mature, they should not be disregarded. Recall that only a few years ago the wireline Internet was not nearly the resource it is today. Transportation agencies should understand the state-of-the-practice for mobile Internet technologies. They should follow the state-of-the-art, understand the potential of technologies, and consider how they might apply to ITS.

5.1 SELECTING MOBILE INTERNET TECHNOLOGIES

There are several factors in selecting the appropriate mobile Internet technologies. As noted previously, the three components are intrinsically linked, making the selection of devices, networks, and application environments interdependent. There are also institutional aspects (operations, technical support, and finance) that influence the selection of each component.

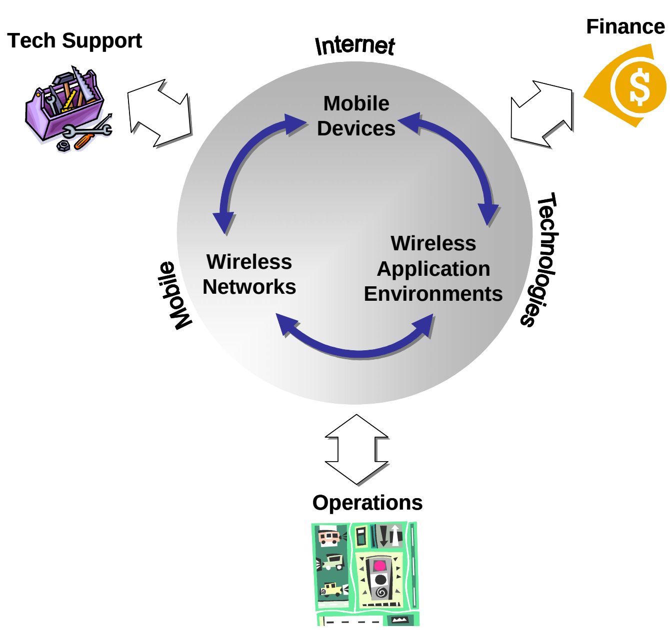


Figure 5-1. Influencing the Selection of Mobile Internet Technologies

- **Operations**: How are the mobile Internet technologies going to be used? What services and applications should they support? How well and where should they operate? Many operational parameters (e.g., function, performance, availability) will be defined by technical user requirements.

- **Technical Support:** Appropriate mobile Internet technologies should be manageable by the organization's technical support facilities. One of the support group's major hurdles is getting these new technologies to work with 'existing' infrastructure in a way that benefits the company. This involves a host of issues including back-end systems integration, security implementations, systems maintenance, etc. This can be a hefty challenge, particularly when the organization chooses to implement more than one solution.

- **Finance:** Managers often struggle to build a return-on-investment model that warrants spending on mobile Internet technologies, particularly when the technologies are still immature. The following are just some of the basic financial considerations.

  - Is the technical solution (i.e., selection of mobile Internet technologies) financially feasible? Does the organization have the financial resources to accommodate the solution and its integration with the organization's existing infrastructure?
  - Is the technical solution financially justifiable? What are the financial cost-benefits for implementing a particular solution? Does operational benefit outweigh financial cost?
  - Does the organization have the resources to deal with wireless network service providers – perhaps multiple providers, perhaps multiple accounts?
  - Can 3rd party entities be used to support maintenance on devices? Can they be used to develop and/or maintain the selected application environments?

Because employees increasingly rely on cell phones, PDAs, and other mobile devices to do their work, many organizations are being forced to adopt mobile Internet technologies whether they fit their overall business strategy or not. There's no reason to assume this scenario will not someday apply to transportation agencies as well, if it hasn't already.

Figure 5-2 presents one general approach to selecting mobile Internet technologies. This diagram will help the selection process, but more formal decision methods (e.g., decision trees, influence diagrams) should be used in accordance with agency policy and procedure.

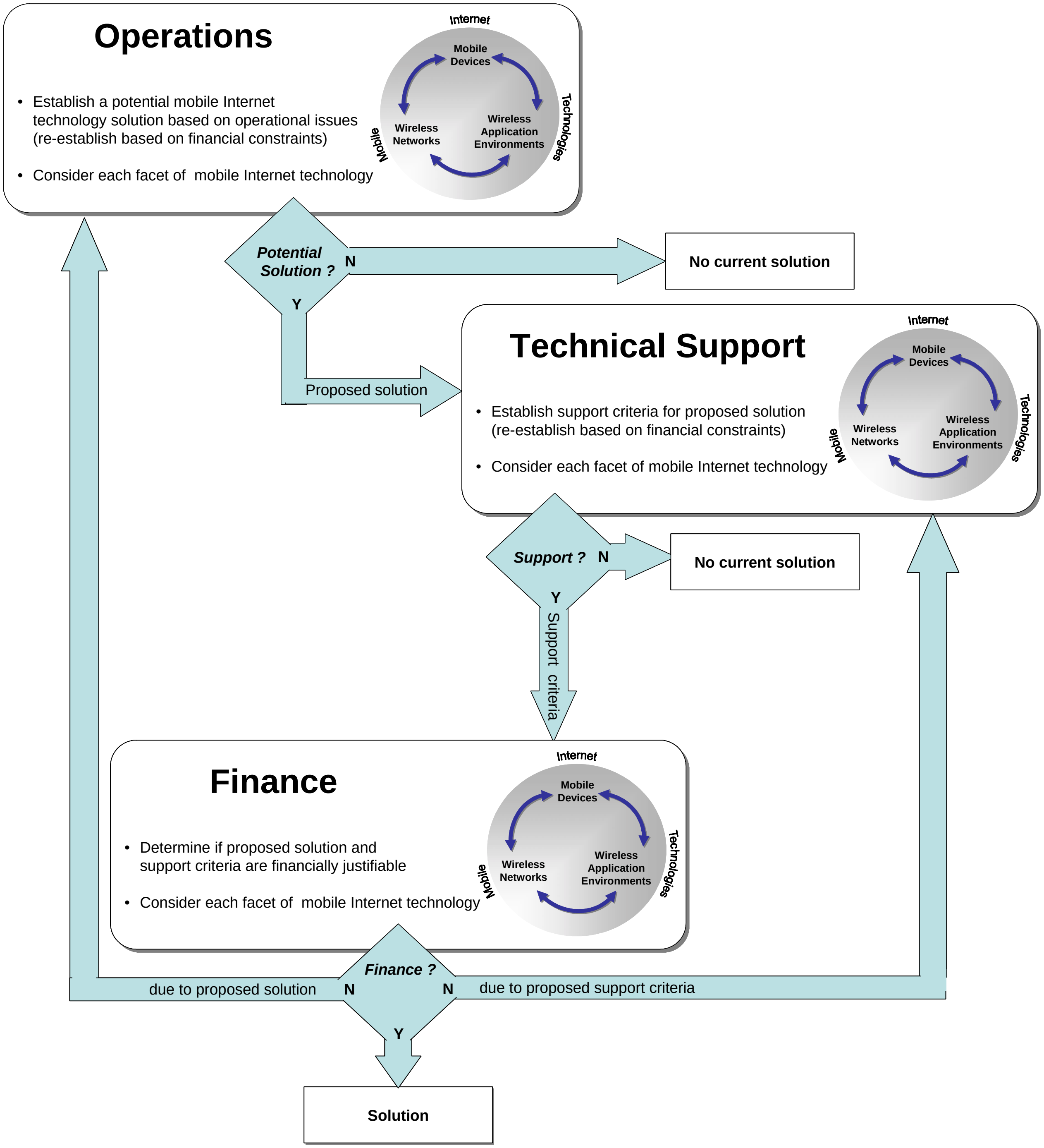


Figure 5-2. Generic Approach to Selecting Mobile Internet Technologies

The following subsections introduce some of the operational, technical support, and financial considerations for each facet of mobile Internet technology.

5.1.1 Selecting a Mobile Device

Mobile devices are one of the two facets of mobile Internet technology not developed by the user. However, the device(s) can be selected from a multitude of commercially available products. The following are some considerations when choosing a mobile device.

> *A PDA has advanced display characteristics, but is it affordable?*
>
> *A WAP phone might be affordable, but will it meet operational requirements?*

- **Operational Considerations:**
  - What services must the device(s) support? Voice? Video? Data?
  - What applications must the device(s) support? Web browsing? E-mail? Custom applications?
  - To support the required applications and services, does the device have sufficient features: display characteristics, processing power, battery-life, size, and weight?
  - How easy is the device to operate in the field? What is the user interface? What are the data entry mechanisms (voice, stylus, and/or keypad)?
  - Does the device need to be hardened for harsh environments – most of those available today are not.
  - Does the device have an internal wireless modem? Must it operate on a particular type of wireless network, or on a specific provider's network(s)?
  - Does the device have/require an external network interface? This will allow the use of various wireless modems and subsequently more network options.

- **Technical Support Considerations**
  - Does the organization have a technical support group with the resources and expertise to provide maintenance on the selected device(s)?
  - Can the devices be reconfigured and reprogrammed by technical support personnel?
  - Can a 3rd party entity (e.g., a wireless network service provider) be used to provide maintenance on these devices?

- **Financial Considerations**

  Consider the following in addition to those general financial issues noted in Section 5.1.
  - Are the devices affordable?
  - What are the life-cycle costs of the device(s)?
  - Can the device(s) be leased, or must they be purchased?
  - Are the devices available for purchase (or lease) through a 3rd part entity (e.g., wireless network service provider)
  - Can the devices be replaced with newer devices as part of a provider's service contract?

There are also technical considerations based on the interdependence of the mobile internet technologies. The choice of device(s) will influence the network(s) and wireless application environment(s) that can or should be used. For example:

- A particular mobile phone supports WAP services and perhaps some custom applications, but it does not support WWW services. *(device ←→ environment)*
- An M-mode phone may have the required display characteristics and form factor, but it also requires used of AT&T wireless data networks. *(device ←→ network)*

A list of mobile devices is provided in Appendix A. It's not a complete list as there are literally hundreds of options. This appendix is presented only to show the different types of device (e.g., PDA phone, WAP phone, M-mode phone).

Note: *We do not endorse or oppose any particular product noted in this report. Selection of any specific product will be subject to the requirements of those implementing the system.*

5.1.2 Selecting a Wireless Data Network

Most wireless networks are not developed or maintained by their users. While private networks could be established, the wireless service providers (e.g., CMRS providers, wireless Internet service providers (WISPs)) offer a growing number of commercially available options. Consider the following when choosing a wireless data network, provider, and service.

> *A 2.5G PCS network might support higher data rates and 'always on' packet-based data services, but is it affordable?*
>
> *A particular 2G wireless data service might be affordable, but will it meet operational requirements?*

- **Operational Considerations**
  - When, where, and how will the wireless data service be used?
  - Does the network provide adequate coverage? Is roaming available, and if so, does it include data services?
  - What are the network's availability and reliability factors? What are the quality-of-service (QoS) provisions?
  - What data rates (or throughput) do your applications require? Will a 2G CSC network suffice, or will a 2.5G packet-based network be required (or be desirable). Does your application require large or small data transactions? Are they frequent or infrequent? While current 'high-speed' data services offered by CMRS providers are based on new 2.5G technologies, throughput is roughly equivalent to that provided by fixed-line dial-up connections.
  - Can a WLAN option be used? Coverage is limited, but throughput is significantly greater than that offered by the wide-area wireless networks (i.e., the 2G, 2.5G PCS networks). Several providers have begun deploying WLAN technologies for Internet access at publicly accessible locations, such as transit terminals. If WLAN technologies can be used, is it necessary to

roam between WLAN and wide-area wireless networks? Such provisions are now offered by many CMRS providers.

- What information security issues does the network introduce? (side bar)

- **Technical Support Considerations**
  - Can the organization establish and maintain connectivity between their facilities and the wireless network service provider's infrastructure?
  - Can security policies be supported when connecting the organization's existing networks with a commercially available wireless network?
  - Can the organization's technical support group handle network configuration for the mobile devices to be used on this network?
  - Does the technical support group have the resources and expertise to handle system administration for multiple field units in a mobile network? Can network configurations (e.g., mobile IP addresses) be modified?

> **Information Security**
>
> Information security should be considered when establishing any new network, particularly for this instance in which mobile Internet technologies are being used to access enterprise level information.
>
> Security is primarily an issue of policy and implementation, but it's important to identify types of security that might be needed. There are many different security services (e.g., confidentiality, access control, and authentication); each employed with various security mechanisms (e.g., virtual private networks (VPN), firewalls). Refer to *"Protecting Our Transportation Systems: An Information Security Awareness Overview",* EDL document #3243.
>
> What do the organization Information Management policies require? Will the necessary security mechanisms hinder a particular mobile Internet solution?

- **Financial Considerations**

  In addition to the general financial issues addressed in Section 5.1, consider the following.

  - Are wireless data services priced by air-time, by the amount of data sent/received, or by flat rate? Are options available?
  - What wireless services are financially optimal for the required applications? An application requiring small but frequent transactions might be best served (financially) with services priced by the amount of data. An application requiring large but infrequent transactions might benefit from services priced by 'air time'.
  - Can multiple users/devices be established and managed under a single account? Many CMRS still require individual accounts to be established for wireless data service, primarily because they don't have the account management facilities in place.
  - What are the recurring and non-recurring costs associated with the service?
  - Are the services (in proper quantities) affordable? Justifiable?
  - What are the contractual obligations with the service provider? Are there penalties for canceling services?
  - Are wireless modems (or mobile devices) included in the service package?

There are also technical considerations based on the interdependence of the mobile internet technologies. In other words, the choice of network(s) will influence the device(s) and wireless application environment(s) that can or should be used.

Appendix B addresses various wireless data network options and provides a list of some commercially available services. It's not a complete list and is presented only to identify different types of networks (e.g., 2G PCS, 2.5G PCS, WLAN); as well as some providers and their current service offerings. Note that the services, performance, coverage, pricing, and other features associated with these offerings vary with location and change frequently. The information in the appendix is presented only to establish a basis.

Note: *We do not endorse or oppose any particular wireless data service noted in this report. Selection of any specific service will be subject to the requirements of those implementing the system.*

5.1.3 Selecting a Wireless Application Environment

The application environment is the one facet of mobile Internet technologies that can be readily controlled and developed by the user and is therefore the technical focus of this report. Details of the various environments are addressed in Section 3, including the advantages and disadvantages to each, but in general, consider the following when selecting an application environment.

> *A WAP application environment might offer an affordable solution, but will system maintenance become burdensome?*
>
> *A WWW application environment might be easily established and supported, but it requires the more expensive mobile devices.*

** Review Section 3 for details of these issues*

- **Operational Considerations**
  - What services and applications must the environment support?
  - What types of user interface are needed, a micro-browser-based GUI or an audio interface? Is a custom interface required?
  - Can the application environment support the types of content to be exchanged (e.g., images, interactive documents, color)?
  - How stable are the standards on which the application environment is formed? Are standards open or closed? How are the standards likely to change? How will these changes affect a solution?
  - Is a custom application environment (e.g., one established using BREW or J2ME) required? *This is not the same as developing a custom application*.
  - Are users to have organizational intranet access only, or do they require access to the Internet? For example, will they need access to MapQuest.com® or Weather.com®? If so, is the content from these publicly accessible sites compatible with the desired solution?
  - Should the organization function as a wireless ASP or simply an information content provider? Does the solution <u>require</u> the organization to function in either capacity?

If the organization is functioning as an ASP,

- What front-end systems (e.g., language transcoders, protocol gateways) are required?
- Can existing back-end systems be used, or will additional equipment (e.g., new servers) be required? Do the existing back-end systems hold content in the proper format? If not, how much formatting does the solution require?
- How much application development does the solution require?

If functioning as a content provider only,

- Can existing back-end systems be used?
- If applications development is required, what 3rd party entities can be used? Independent developers? ASPs? Is a dedicated connection required between your back-end systems and these 3rd party entities? How do they require content to be formatted?

- **Technical Support Considerations**

  Does the organization have a technical support group with the resources and expertise to establish and maintain the application environment(s)?

  If the organization is functioning as an ASP,

  - Can this group integrate the necessary front-end systems with their existing infrastructure? Can they provide adequate maintenance on these systems?
  - Can they support upgrades and maintenance on existing and/or new back-end systems, including content formatting?
  - Can this group support applications developed by the organization or 3rd party developers?

  If functioning as a content provider only,

  - Is this group required to support connections between the organization's back-end systems and 3rd party facilities?
  - If 3rd party entities are used to develop applications, are they required to support and maintain these applications as well? How is the organizations technical support group involved?

- **Financial Considerations**

  In addition to those financial issues presented in Section 5.1, consider the following.

  If the organization is functioning as an ASP,

  - What are the costs associated with obtaining the required front-end systems? Additional backend systems? What are the life-cycle costs?
  - What are the costs for integrating, maintaining, and supporting these systems?

- What are the costs associated with developing applications within the organization (e.g., using corporate application developers)? What are the costs associated with maintaining and supporting these applications? How do these costs compare to those for a 3rd party entity to develop, support, and/or maintain your applications?
- If using a 3rd party entity, what are the contractual obligations? With the organization functioning as an ASP, these would primarily involve application development activities.

If functioning as a content provider only,

- What are the costs associated with any new back-end systems, including procurement, integration, support, and maintenance expenses?
- Are there any additional support and maintenance costs for existing systems?
- If applications development were required, what 3rd party entities would be used? What are the associated costs and contractual obligations? With the organization functioning as a content provider, these parties would typically include application developers and ASPs.
- What are the cost associated with maintaining and supporting your applications? Do 3rd party entities support and/or maintain your applications?
- What are the costs associated with communications between your back-end systems and any 3rd party facilities?

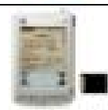
There are also the technical considerations based on the interdependence of the mobile internet technologies (i.e., the application environment will influence the networks and devices that can be used).

This report introduces some basic selection criteria. However, the appropriate solutions will depend on where and for whom the systems are deployed and will take into account the specific user requirements as well as organizational support services and financial resources.

5.2 PROTOTYPING

Concept prototyping is the next step in this research initiative. The objective is to exhibit various mobile Internet technologies and demonstrate their potential within the ITS domain. Prototyping began prior to the release of this report, and eleven different solutions have been developed and tested in the laboratory environment. Three application environments have been used; WWW, WAP and IVR. These environments are supported by various networks and devices, as indicated in Table 5-1.

Table 5-1. Mobile Internet Technologies - Initial Prototyping

Mobile Device		Wireless Network	Application Environments
Compaq iPAQ 3870 (Sierra AirCard 555)	 	**Provider:** Verizon Wireless **Technologies:** Data: CDMA 1xRTT Voice: CDMA CSC	**WWW & IVR**
T-Mobile Pocket PC Phone Edition		**Provider:** T-Mobile USA **Technologies:** Data: GSM GPRS Voice: GSM CSC	**WWW & IVR**
Palm i705		**Provider:** Cingular Wireless **Technologies:** Data: TDMA (Mobitex)	**WWW**
Motorola i95cl		**Provider:** Nextel **Technologies:** Data: TDMA (iDEN) Voice: TDMA CSC	**WAP & IVR**
Samsung SPH A460		**Provider:** Sprint PCS **Technologies:** Data: CDMA CSC Voice: CDMA CSC	**WAP & IVR**
Ericsson T68		**Provider:** T-Mobile USA **Technologies:** Data: GSM GPRS Voice: GSM CSC	**WAP & IVR**

Additional solutions will include M-mode and possibly J2ME or BREW. The necessary back-end and front-end systems to support these application environments have also been established.

The Virginia Department of Transportation (VDOT) has volunteered to assist FHWA with this research by hosting field-testing efforts at their Smart Traffic Center (STC) in Arlington, VA. The STC is the heart of the agency's Northern Virginia District operations and is used to help manage the large amount of daily traffic on the roadways throughout the region.

The prototypes will initially be used to support STC field maintenance operations, which include repair, preventive maintenance, and operational support for CCTV, VMS, and other field systems. Additional applications may be established to support work zone, safety service patrol, and others field operations.

Details of the prototyping effort, including configurations, applications, users, and assessments will be available in the spring of 2003 and will be documented in a subsequent report. Institutional issues, such as potential operational and financial benefits will also be addressed.

Note: *This effort is intended only to demonstrate the technologies and not address the specific needs of any particular agency.*

BIBLIOGRAPHY

Text

Biesecker, Keith J., 2000, “*Broadband Wireless, Integrated Services, and their Application to Intelligent Transportation Systems (ITS)”*, Washington, DC, Mitretek Systems / U.S. Department of Transportation.

Federal Government Documents

US Department of Transportation, Architecture Development Team, Iteris, Inc., Lockheed Martin, April 2002, “ITS Architecture: Executive Summary”

US Department of Transportation, Architecture Development Team, Iteris, Inc., Lockheed Martin, April 2002, “ITS Architecture: Physical Architecture”

US Department of Transportation, Lockheed Martin Federal Systems, Odetics ITS Division, January 1997, “ITS Architecture: ITS Communications Document”

WWW/Internet Documentation

“Police mobile data project will put more officers on the beat”, Cushing, CW360°, 3 October 2002. http://www.cw360.com

“Ten Million Internet Users Go Online via Cell Phone or PDA”, comScore Media, 28 Aug 2002. http://biz.yahoo.com/iw/020828/045881.html

APPENDIX A

MOBILE DEVICES

This appendix provides a list of some of the commercially available mobile devices. It's not a complete list as there are literally hundreds of options. The information is presented only to illustrate different types of devices.

Note: *We do not endorse or oppose any particular product noted in this report. Selection of any specific product will be subject to the requirements of those implementing the system.*

A.1 WAP PHONES

The following WAP phones are available in the U.S.

Sony Ericsson T300 This GSM phone comes with a color display and a detachable camera. It supports Multimedia Messaging Service (MMS), WAP, and a GPRS data connection. Wireless Network: GSM/GPRS Extra: Detachable Camera Current Price: ~ $100	 Source: Sony Ericsson Mobile Communications
Sony Ericsson T68i This tri-band (900, 1800, & 1900 MHz) phone comes with a color display and a detachable camera. It supports Bluetooth, Multimedia Messaging Service (MMS), WAP, M-mode, and a GPRS data connection Wireless Network: TDMA, GSM/GPRS Extra: Detachable Camera, Bluetooth Current Price: ~ $200	 Source: Sony Ericsson Mobile Communications

Sanyo 5300 This dual band tri-mode CDMA java phone comes with a color display and a built-in digital camera. It supports J2ME, WAP, and a 1xRTT data connection Wireless Network: CDMA CSC/1xRTT Extra: Built-in camera Current Price: ~ $400	 Source: Sprint PCS
Motorola T720 This dual band tri-mode CDMA java phone comes with a color display and supports J2ME, WAP, and a 1xRTT data connection. Wireless Network: CDMA CSC/1xRTT Current Price: ~ $300	 Source: Verizon Wireless
Motorola i95cl This TDMA java phone comes with a color display and support two-way radio, J2ME, WAP, and an iDEN data connection. Wireless Network: TDMA iDEN Current Price: ~ $350	 Source: Nextel Communications

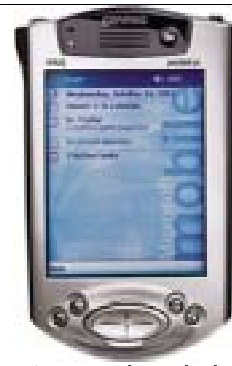
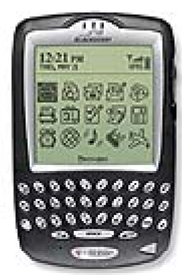
A.2 I-MODE / M-MODE PHONES

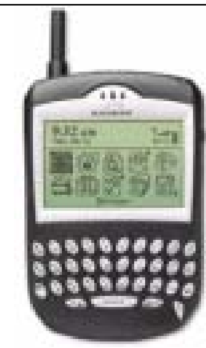
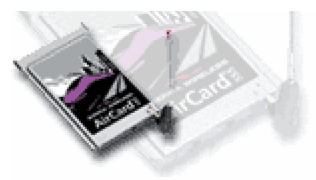
The following are I-mode/M-mode phones available in Japan, Europe, and the U.S.

NTT DoCoMo P504is This is the latest model I-mode phone available in Japan Wireless Network: PDC/PDC-P Extra: Built-in Camera, Infrared port Current Price: ~ ¥ 22,000	 Source: NTT DoCoMo
Nokia NM502i This is the 1st Nokia I-mode phone designed for NTT DoCoMo's i-mode service in Japan Wireless Network: PDC/PDC-P Extra: Supports English and Japanese Current Price: ~ ¥ 20,000	 Source: NTT DoCoMo
NEC N21i This European I-mode phone comes with a color display and an I-mode browser that supports both I-mode (cHTML content) and WAP (WML content) Wireless Network: GSM/GPRS Extra: Detachable Camera, Bluetooth Current Price: ~ € 250	 Source: KPN Mobile – E-Plus
Motorola T720 This American M-mode phone comes with a color display and support J2ME and WAP Wireless Network: GSM/GPRS Current Price: ~ $300	 Source: Motorola, Inc.

A.3 PERSONAL DIGITAL ASSISTANTS (PDA)

Some PDAs have built-in wireless modems. Others have expansion packs used to access external modems. The following are examples of PDAs and wireless modem cards available in the U.S.

Hewlett-Packard iPAQ Pocket PC This series of Hewlett-Packard PDA comes with a color display, up to 400MHz processor, 64MB of RAM running on Windows Pocket PC 2002 Wireless Network: any via wireless modem card (e.g., 802.11b, 802.11a, Bluetooth, 1xRTT, GPRS, etc.) Extra: Built-in Bluetooth Current Price: $300 and up Model Shown: H3870 (with Bluetooth) ~ $650	 Source: Hewlett-Packard
Dell Axim X5 Handheld This series of Dell PDA comes with a color display, up to 400MHz processor, 64MB of RAM running on Windows Pocket PC 2002 Wireless Network: any via wireless modem card (e.g., 802.11b, 802.11a, Bluetooth, 1xRTT, GPRS, etc.) Current Price: $300 and up	 Source: Dell Computer Corporation
Palm i705 Handheld This Palm pilot comes with a built in wireless modem which connects this handheld device to the Internet through Palm.Net wireless service. Wireless Network: Mobitex (operated by Cingular) Current Price: ~ $200	 Source: Palm, Inc.
RIM Blackberry 6710 Java based – J2ME Wireless Network: GSM/GPRS Current Price: ~ $500	 Source: T-Mobile USA

RIM Blackberry 6750 Java based – J2ME Wireless Network: CDMA CSC/1xRTT Available: **Verizon Wireless** – 2003 1st Q	 Source: Research In Motion Limited
RIM Blackberry 6510 Java based – J2ME Wireless Network: TDMA iDEN Current Price: **~** $500	 Source: Research In Motion Limited
Sierra AirCard 555 1xRTT modem card Wireless Network: CDMA CSC/1xRTT Current Price: ~ $300	 Source: Sierra Wireless
Merlin G100 GPRS modem card Wireless Network: GSM/GPRS Current Price: ~ $275	 Source: T-Mobile USA
Motorola iM 1100 iDEN modem card Network: TDMA iDEN Current Price: ~ $350	 Source: Nextel Communications

A.4 PDA PHONES

PDA phones integrate PDA and mobile phone technologies. As a result, they can be used for mobile voice and data services. The following are examples of PDA phones available in the U.S.

Nokia 9290 Communicator Wireless Network: GSM/GPRS Current Price: ~ $600	 Source: Nokia
Pocket PC Phone Edition Wireless Network: GSM/GPRS Current Price: ~ $500	 Source: T-Mobile USA
Handspring Treo 3000 Wireless Network: CDMA CSC/1xRTT Current Price: ~ $500	 Source: Sprint PCS

A.5 BREW AND JAVA PHONES

Both BREW and Java phones can be used to download and install custom applications. BREW phones come with Qualcomm's BREW. Java phones come with Sun Microsystems JRE. The following are some of the BREW and Java phones available today.

Sharp Z800 – BREW Phone Wireless Network: CDMA CSC Current Price: ~ $150	 Source: Wireless Software.info
Audiovox CDM9500 – BREW Phone **Samsung A530 – BREW Phone** Wireless Network: CDMA CSC/1xRTT Current Price: ~ $200, $300	  Source: Verizon Wireless
Samsung A500 – Java Phone **Sanyo 5300 – Java Phone** Wireless Network: CDMA CSC/1xRTT Current Price: ~ $300, $400	  Source: Sprint PCS
Nokia 6200 – Java Phone Wireless Network: GSM/GPRS/EDGE Available: 1Q 2003	 Source: Nokia

APPENDIX B

WIRELESS DATA NETWORKS

This appendix introduces some of the commercially available wireless data networks in the U.S. This is not a complete list, nor is it a comprehensive tutorial of the wireless network technologies. Refer to the following reports for more details on these technologies: *"Broadband Wireless, Integrated Services, and their Application to Intelligent Transportation Systems"* [ITS Electronic Document Library No. 13164], and *"Commercial Mobile Radio Service Applications in Public Transi*t".

This section also provides some current service offerings and pricing data, however this information should be used only to establish a basis. Services, performance, coverage, pricing, and other features associated with these offerings vary with location and change frequently.

Note: *We do not endorse or oppose any particular wireless data technology or service noted in this report. Selections will be subject to the requirements of those implementing the system.*

B.1 MOBILE DATA NETWORKS

While limited in performance, the following mobile data networks have some compelling cost advantages compared to the 2G, 2.5G, and 3G cellular and PCS systems.

- **ARDIS:** Advanced Radio Data Information Service (ARDIS), a two-way packet radio service, was introduced to serve IBM field engineers. It was launched in 1983 as a joint venture between IBM and Motorola. ARDIS uses 25 kHz channels and operates in the 800MHz band with a 4.8 kbps data rate (19.2 kbps in some markets). It's deployed in approximately 400 metropolitan areas, reaching over 90% of the urban business population and 80% of the total U.S. population including Alaska, Hawaii, Puerto Rico, and the U.S. Virgin Islands. ARDIS has 45,000 users in the U.S. and another 7,500 in Canada. IBM remains ARDIS' largest customer with more than 12,000 field engineers using the service.

- **Mobitex:** RAM Mobile Data, a joint venture of Bell South and RAM Broadcasting Corporation, introduced the Mobitex system to the U.S in 1991. Mobitex is a packet switched network designed to use narrowband channels (12.5 kHz) for data only communications at 8 kbps. It operates in the 800-900 MHz bands in the U.S. and the 450 MHz bands in Canada. RAM Mobile Data became part of the merger that formed Cingular Wireless in the late '90's. Today, Cingular's Mobitex network covers over 90% of U.S. urban business population.

- **Ricochet**: The Ricochet network re-emerged in 2002 after former owners (Metricom) were forced into bankruptcy in August 2001. The new owners, formerly Aerie Networks and now Ricochet Networks, have slowly begun to roll out new services. The network is a proprietary micro cellular data network established with radios tacked onto traffic light poles and buildings, allowing users (fixed or mobile) to connect to the Internet anywhere within the coverage area. Throughput can reach average rates of up to 176 kbps, but service is currently limited to only a few metropolitan areas, including Denver, CO. and San Diego, CA. and New York, NY.

B.2 ANALOG AND 2ND GENERATION (2G) CELLULAR AND PCS

- **Analog Cellular Systems:** Most commercial analog cellular systems were deployed in the early 1980s. These systems, which were based on the Advanced Mobile Phone Service (AMPS) standard, use the 800 - 900 MHz frequency band. AMPS systems that provide voice and circuit switched data services are widely available in the U.S., but they are declining in use and popularity.

  Cellular Digital Packet Data **(CDPD)** was introduced by IBM as a packet switching overlay to AMPS analog cellular systems. CDPD was designed to take advantage of idle voice channels to support wireless data transmission. However, most systems now use dedicated channel configurations in order to maintain service availability. CDPD supports both Internet protocol (IP) and ISO Connectionless Network Protocol (CLNP). Hence, it supports wireless access to the Internet and other public packet-switched data networks. The maximum theoretical transmission rate is 19.2 kbps per channel, but the actual throughput averages approximately 9 kbps. *With the enhancement of digital cellular and PCS systems, many providers (which include Verizon Wireless and AT&T Wireless) are phasing out their CDPD services.*

- **Second Generation Cellular and PCS Systems:** There are three second generation (2G) cellular and PCS network standards used within the US: Global System for Mobile Communications (GSM), IS-136, and cdmaOne. 2G PCS systems operate within the 1900 MHz PCS bands; 2G cellular systems operate within and the 800 MHz bands.
  - **GSM** is a Time Division Multiple Access (TDMA) based standard developed in Europe. It allows up to eight voice circuits in a 200 kHz channel. Circuit switched data is also possible at either 9.6 or 14.4 kbps.
  - **IS-136** is also a TDMA-based standard. IS-136 uses 30 kHz channels; each supporting up to three voice circuits. The specification also allows for 9.6 kbps circuit switched data.
  - **cdmaOne** is Qualcomm's IS-95-based Code Division Multiple Access (CDMA) standard. CDMA, in general, allows many users to simultaneously access a 1.25MHz channel. There is no specific number of concurrent users, but the channel will degrade as it approaches capacity. Circuit-switched data at rates of up to 14.4 kbps are also specified.

B.3 ENHANCED SECOND GENERATION (2.5G) CELLULAR AND PCS

Enhanced second generation (2.5G) cellular and PCS networks improve upon 2G capacities and data rates.

- **CDMA2000 1xRTT**: The first 2.5G variant of a CDMA technology is CDMA2000 1xRTT (single carrier radio transmission technology). 1xRTT is designed to double second generation voice capacity and support always-on packet data transmissions at speeds of up to 153.6 kbps on both the forward and reverse links. The two primary CDMA2000 1xRTT providers in the U.S. are Verizon Wireless and Sprint PCS.

- **General Packet Radio Service (GPRS)**: The most prevalent 2.5G variant of GSM-based systems is GPRS – a packet data service that will support both IP and X.25 protocols. The technology uses a combination of dedicated and dynamic allocated time slots for packet data transmissions. With eight time slots, fixed users can achieve a data rate of 171 kbps. For mobile users (actually in motion) the maximum data rate drops to 115 kbps. It's unlikely that all eight time slots would go to one user; therefore, the actual user rates will be much less. Providers will adjust the allocation of time slots based on demand. The primary GPRS providers in the U.S. are AT&T Wireless, T-Mobile, and Cingular Wireless.

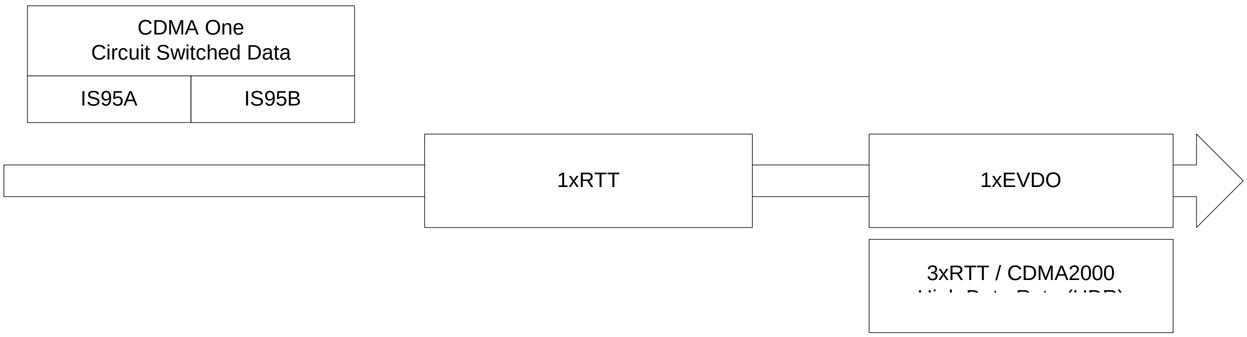
- **Integrated Digital Enhanced Network (iDEN):** iDEN is a proprietary technology from Motorola that's used to support Nextel's TDMA network. Nextel uses iDEN for its packet data service – *PacketStream*, which can provide compressed data at up to 56kbps.

B.4 3G CELLULAR AND PCS NETWORKS

Third generation (3G) cellular and PCS technologies are being standardized by the International Telecommunications Union (ITU) as part of the International Mobile Telecommunications 2000 (IMT-2000) effort. Originally, there were ten proposals before the ITU, but there are two primary standards in place for the U.S market: IMT-Multi-Carrier (MC) and IMT-Direct Sequence (DS). IMT-MC is based on **CDMA2000**, which is the evolution of cdmaOne, and IMT-DS is based on Wideband CDMA (**WCDMA**), which is the evolution of GSM and IS-136 TDMA technologies.

By loose ITU definitions, 3G systems will provide users with data rates of up to 2.048 Mbps. The minimum data rate of 144 kbps will support users in vehicles moving over large areas at high speeds. A data rate of 384 kbps will provide for users that are stationary or moving at pedestrian speeds, and a data rate of 2.048 Mbps will support fixed office users.

The migration path to CDMA2000 (IMT-MC)



14.4kbps → 28.8kbps → 57.6kbps → 144kbps → 384kbps - 2.4Mbps

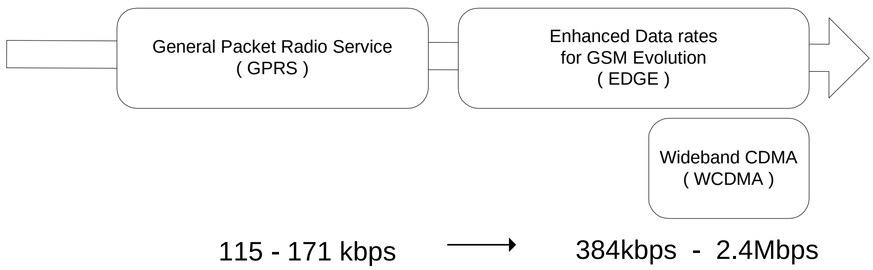
- **CDMA2000 1xRTT:** The first phase of CDMA2000 is 1xRTT, which was discussed previously. Data rates can reach 153.6 kbps on both the forward and reverse links

- **CDMA2000 1xEV and 1xEVDO:** Supplemental phases in the development of CDMA2000 include 1xEVDO (1x Evolution - Data Only) and 1X EV (1x Evolution). CDMA2000 1xEVDO dedicates one carrier (1.25MHz) to high-speed packet data, while one or more additional carriers are used for voice services. CDMA2000 1xEV combines packet data and voice in the same 1.25MHz carrier, but retains the ability to maintain packet services on a separate carrier if desired. Peak data rates can reach 2.4 Mbps on the forward link and 307 kbps on the reverse link.

- **CDMA2000:** CDMA2000 uses a single 3.75 MHz carrier to establish 3G voice and data services. Data rates should range between 384 and 2048 kbps, per ITU definition.

The major US providers working toward CDMA2000 solutions are Verizon Wireless and Sprint PCS.

The migration path WCDMA (IMT-DS)



- **GPRS:** GPRS, which was addressed previously, is the first phase toward 3G services for GSM-based systems and some TDMA-based systems (e.g., IS-136). GPRS enhances these systems by enabling "always on" packet data transmissions. Peak data rates could range between 115 and 171 kbps.

- **Enhanced Data rates for GSM Evolution (EDGE):** EDGE is an enhancement to the air-interface and backhaul systems used in existing GSM and TDMA networks, and it will enable operators to offer multimedia and other IP-based services at speeds of up to 384 kbps. While existing network hardware and software can be upgraded fairly easily, EDGE requires greater signal quality than that found in an average GSM network. This means additional infrastructure (e.g., base stations) will be required for established GSM operators that wish to migrate to EDGE.

- **Wideband CDMA (WCDMA):** WCDMA is the technology behind the 3G evolution of GSM and TDMA-based systems. WCDMA is a direct sequence spread spectrum technology (5 MHz carrier for 3G digital cellular and PCS) that will support data rates between 384 and 2048 kbps, per ITU definition. Adopting a new CDMA-based scheme is a significant effort that will require new frequency allocations and infrastructure.

The major US providers working toward WCDMA solutions are AT&T Wireless, Cingular Wireless, and T-Mobile USA.

B.5 WIRELESS LOCAL AREA NETWORKS (WLANS)

Most of the WLAN technologies in the U.S. today are based on the IEEE 802.11 standard. None was specifically designed to operate in a mobile environment, yet some are (and will be) used to support mobile applications.

- **802.11**: 802.11 applies to wireless LANs that provide 1 or 2 Mbps transmission in the 2.4 GHz band using either frequency hopping spread spectrum (FHSS) or direct sequence spread spectrum (DSSS).

- **802.11b:** 802.11b is an extension to 802.11 that's based on only the DSSS technology. 802.11b can support data rates up to 11 Mbps, but these rates can be scaled back to 5.5, 2, and 1 Mbps allowing backward compatibility with 802.11 devices. 802.11b, which is commonly referred to as "Wi-Fi", underpins most of the activity in WLAN market today. It's also the technology behind many of the growing number of "Hot Spots" – publicly accessible Internet access locations.

> **Wi-Fi** is short for wireless fidelity and is meant to be used generically when referring of any type of 802.11 network, whether 802.11b, 802.11a, dual-band, etc. The term is promulgated by the Wi-Fi Alliance.
>
> Any products tested and approved as "Wi-Fi Certified" (a registered trademark) by the Wi-Fi Alliance certified as interoperable.
>
> Formerly, the term "Wi-Fi" was used only in place of the 2.4GHz 802.11b standard, in the same way that "Ethernet" is used in place of IEEE 802.3. The Alliance expanded the generic use of the term in an attempt to stop confusion about wireless LAN interoperability.

- **802.11a**: 802.11a is an extension to 802.11 that provides up to 54 Mbps. 802.11a was designed to operate in the 5GHz unlicensed bands and uses an orthogonal frequency division multiplexing (OFDM) encoding scheme rather than FHSS or DSSS.

- **802.11g**: 802.11g is designed to be backwards compatible with 802.11b devices. In addition, it adopts 802.11a's Orthogonal Frequency Division Multiplexing (OFDM) to support an optional speed of 54 Mbps.

AT&T Wireless, T-Mobile, and Verizon Wireless are some of the CMRS currently involved in providing public Internet access using WLAN technologies.

B.6 WIRELESS VOICE AND DATA SERVICE PLANS

The following are some of the voice and data service plans from some of the more common CMRS providers.

** Services and fees subject to change*
** Services have limited availability*

- ***Verizon Wireless (Mobile Web / Express Network)***
  http://www.verizonwireless.com/internet_data/index.html
  Monthly Fee: $35 - $200 Voice Calling Plan
  + $100 Unlimited Express Network (1xRTT)
  + $55 Unlimited Mobile IP (CDPD)
  + $5 Mobile Web (CSC data – uses voice minutes)

- ***Sprint PCS (Wireless Web / PCS Vision)***

  http://www.sprintpcs.com/

  Monthly Fee: $30 - $100 Voice Calling Plan

  + $10 Unlimited PCS Vision (1xRTT)

  + $5 Wireless Web (CSC data – uses voice minutes)

- ***T-Mobile USA (T-Zone / iStream)***

  http://www.t-mobile.com/

  Monthly Fee: $20 - $100 Voice Calling Plan

  GPRS Data Services:

  + $40 – up to 20MB T-Zone or iStream (GPRS); $3.5 per MB after 20 MB

  + $60 – up to 50MB T-Zone or iStream (GPRS); $3 per MB after 50MB

  + $100 – up to 200MB T-Zone or iStream (GPRS); $2 per MB after 200MB

- ***Nextel Communications (Premium Web / Packet Stream Gold)***

  http://nextelonline.nextel.com/services/nextelonline/index.shtml

  Monthly Fee: $50 - $100 Voice Calling Plan

  + $10 Premium Web (CSC data – uses voice minutes)

  + $55 Packet Stream Gold (packet data service)

- ***AT&T Wireless (Pocket Net / M-mode)***

  http://www.attws.com/

  Monthly Fee: $60 - $200 Voice Calling Plan

  + $7 – CSC data - uses voice minutes

  + $22 – Unlimited Pocket Net (CDPD)

  + $8 – up to 1 MB M-mode data (GPRS); $0.02 per KB after 1 MB

  + $13 – up to 4 MB M-mode data (GPRS); $0.02 per KB after 4 MB

  + $20 – up to 8 MB M-mode data (GPRS); $0.02 per KB after 8 MB

- ***Cingular Wireless (Dialup Wireless Internet / Wireless Internet Express)***

  http://www.cingular.com/beyond_voice/wi_pricing/

  Monthly Fee: $30 - $200 Voice Plan

  + $4 – Dial-up Wireless Internet (CSC-data - uses voice minutes)

  Monthly Fee: $17 – $30 for 100 – 500 KB Wireless Data Service (Mobitex)

  Monthly Fee: $30-$200

  + $7 – up to 1MB Wireless Internet Express (GPRS); $ 0.03 per KB after 1MB

GLOSSARY

2G PCS	Second Generation PCS
2.5G PCS	Enhanced Second Generation PCS
3G PCS	Third Generation PCS
AAL	ATM Adaptation Layer
ADPCM	Adaptive Differential Pulse Code Modulation
ALERT	Advanced Law Enforcement & Response Technology
AM	Amplitude Modulation
AMPS	Advance Mobile Phone Service
ANSI	American National Standards Institute
AP	Access Point
APCO	Association of Public Safety Communications Officials
API	Application Programming Interface
AS	Available Seconds
ASP	Application Service Provider
ASR	Automatic Speech Recognition
ATIS	Advanced Traveler Information System
ATM	Asynchronous Transfer Mode
ATMP	Address Translation and Parsing
ATSC	American Television Standards Committee
B8ZS	Bipolar Eight Zeros Substitution
BER	Bit Error Rate
BFSK	Binary Frequency Shift Keying
BPSK	Binary Phase Shift Keying
BRAN	Broadband Radio Access Network
BRI ISDN	Basic Rate Interface ISDN
BREW	Binary Runtime Environment for Wireless
BTA	Basic Trading Area
Caltrans	California State Department of Transportation
CBR	Constant Bit Rate
CCK	Complementary Code Keying
CCTV	Closed Circuit Television
CDMA	Code Division Multiple Access
CDPD	Cellular Digital Packet Data
CES	Circuit Emulation Service
CHTML	Compact HTML
CLEC	Competitive Local Exchange Carrier
CMRS	Commercial Mobile Radio Service
CO	Central Office

C-OFDM	Code-based OFDM
COTS	Commercial Off The Shelf
CPE	Customer Premises Equipment
CSC	Circuit Switched Cellular
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
CSU/DSU	Channel Service Unit / Digital Service Unit
DACS	Digital Access Cross-connect System
DARPA	Defense Advanced Research Projects Agency
DAVIC	Digital Audio Visual Council
dB	Decibel
dBm	Decibel power level referred to 1 mW
DBMS	Database Management System
DBPSK	Differential Binary Phase Shift Keying
DCE	Data Communication Equipment
DECT	Digital Enhanced Cordless Telephone
DOCSIS	Data Over Cable System Interface Specification
DOT	Department Of Transportation
DQPSK	Differential Quadrature Phase Shift Keying
DS-1	Digital Signal Level 1. Transmission standard interface for digital data used by T1 transmission lines. DS1 operates at 1.544 Mbps.
DS-3	Digital Signal Level 3. Transmission standard interface for digital data used by T3 transmission lines. DS3 operates at 44.736 Mbps and consists of 28 DS1 channels plus overhead.
DSL	Digital Subscriber Line
DSLAM	DSL access multiplexers
DSP	Digital Signal Processing
DSSS	Direct Sequence Spread Spectrum
DTE	Data Terminal Equipment
DTMF	Dual Tone Multi Frequency
DTV	Digital Television
DWDM	Dense Wavelength Division Multiplexing
E1	European Standard for high-speed digital transmission operating at 2.048 Mbps
E3	European Standard for high-speed digital transmission operating at 34 Mbps
EA	Economic Area
EDGE	Enhanced Data Rates for GSM Evolution
EFS	Error Free Seconds
EIRP	Effective Isotropic Radiated Power
EMS	Emergency Medical Services

ERC	European Radiocommunications Committee
ES	Errored Seconds
ESF	Extended Super Frame
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
FDD	Frequency Division Duplexing
FDMA	Frequency Division Multiple Access
FEMA	Federal Emergency Management Agency
FHSS	Frequency Hopping Spread Spectrum
FHWA	Federal Highway Administration
FM	Frequency Modulation
FRAD	Frame Relay Access Device
FTP	File Transfer Protocol
FWPC	Federal Wireless Policy Committee
GEO	Geostationary Earth Orbit
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
GUI	Graphical User Interface
GWCS	General Wireless Communication Service
H2GF	HIPERLAN2 Global Forum
HAR	Highway Advisory Radio
HDR	High Data Rate
HDTV	High Definition Television
HIPERLAN	HIgh PErformance Radio LANs
HRFWG	HomeRF Working Group
HSCSD	High Speed Circuit Switched Data
IAD	Integrated Access Device
ICMP	Internet Control Message Protocol
IDU	Indoor Unit
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IIS	Internet Information Server
ILEC	Incumbent Local Exchange Carrier
IMT	International Mobile Telecommunications
IMT-MC	International Mobile Telecommunications - Multi-Carrier
IMT-SC	International Mobile Telecommunications - Single-Carrier
IMT-TC	International Mobile Telecommunications - Time-Coded
IP	Internet Protocol
IPoA	Internet Protocol over ATM
ISDN	Integrated Services Digital Network

ISM	Industrial, Scientific, and Medical
ISP	Internet Service Provider
IT	Information Technology
ITFS	Instructional Television Fixed Service
ITP	Interactive Transaction Processing
ITS	Intelligent Transportation Systems
ITU	International Telecommunications Union
IVR	Interactive Voice Response
J2ME	Java 2 Platform Micro Edition
JPEG	Joint Photographic Experts Group
JRE	Java Runtime Environment
kbps	Kilobits per second
kHz	Kilohertz
LAN	Local Area Network
LEC	Local Exchange Carrier
LEO	Low Earth Orbit
LLC	Link Layer Control
LMDS	Local Multipoint Distribution Service
LOS	Line Of Sight
OGS	Office of General Services
MAC	Medium Access Control
Mbps	Megabits per second
MDF	Main Distribution Frame
MDS	Multipoint Distribution Service
MDT	Mobile Data Terminal
MEA	Major Economic Area
MEO	Medium Earth Orbit
MHz	Megahertz
MMDS	Multichannel Multipoint Distribution Service
MMS	Multimedia Messaging System
MOU	Memorandum Of Understanding
MPEG	Motion Picture Experts Group
MRC	Monthly Recurring Cost
MSAD	Multi-Service Access Device
MT	Mobile Terminal
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
MTS	Mitretek Systems
mW	milliwatt
NASTD	National Association of State Telecommunications Directors

NATSO	National Association of Truckstops and Travel Plazas
NCIC	National Crime Information Center
NIC	Network Interface Card
NPMA	Non-premptive Priority Multiple Access
NPRM	Notice of Proposed Rule Making
NRC	Non Recurring Cost
NTIA	National Telecommunications and Information Administration
NTSC	National Television Standards Committee
NYSDOT	New York State Department of Transportation
NYSTA	New York State Thruway Authority
OC-12	Optical Carrier level 12 (622 Mbps)
OC-3	Optical Carrier level 3 (155 Mbps)
ODU	Outdoor Unit
OFDM	Orthogonal Frequency Division Multiplexing
OFSK	Orthogonal Frequency Shift Keying
OMA	Open Mobile Alliance
PAN	Personal Area Network
PBX	Private Branch eXchange
PC	Personal Computer
PCM	Pulse Code Modulation
PCS	Personal Communication Service
PDA	Personal Data Assistant
PFC	Point Control Function
PIAS	Personal Information Access Subsystem
POTS	Plain Old Telephone Service
PSTN	Public Switched Telephone Network
QAM	Quadrature Amplitude Multiplexing
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RBOC	Regional Bell Operating Company
ROI	Return On Investment
RF	Radio frequency
RSSI	Received Signal Strength Indicator
RTS	Remote Traveler Support
RTT	Radio Transmission Technology
SAFD	San Antonio Fire Department
SAMA	Spread Aloha Multiple Access
SEBRA	Semi-mobile Broadband Radio Access
SES	Severely Errored Seconds
SDP	Service Delivery Point

SGML	Standard Generalized Markup Language
SIG	Special Interest Group
STA	Special Temporary Authority
SWAP	Shared Wireless Access Protocol
SwRI	Southwest Research Institute
T1	An AT&T digital T-carrier facility used to transmit a DS-1 formatted digital signal at 1.544 Mbps
T3	An AT&T digital T-carrier facility used to transmit a DS3-formatted digital signal at approximately 45 Mbps.
TCP	Transmission Control Protocol
TDD	Time Division Duplexing
TDMA	Time Division Multiple Access
TIA	Telecommunications Industry Association
TLS	Transparent LAN Services
TSCO	Thruway Statewide Operations Center
TTI	Texas Transportation Institute
TVCS	Traffic Video Camera System
TxDOT	Texas Department of Transportation
UBR	Unspecified Bit Rate
UDP	User Datagram Protocol
UHF	Ultra High Frequency
UNII	Unlicensed National Information Infrastructure
USDOD	United States Department of Defense
USDOJ	United States Department of Justice
USDOT	United States Department of Transportation
UTP	Unshielded Twisted Pair
UWB	Ultra-wideband
V.35	ITU-T standard for a high-speed, 34-pin, DCE/DTE interface.
VC	Virtual Circuit
VDOT	Virginia Department of Transportation
VHF	Very High Frequency
VMS	Variable Message Sign
V-OFDM	Vector-based OFDM
VoIP	Voice over IP (Voice over Internet Protocol)
VoIPoA	Voice over IP over ATM
VPM	Voice Processing Module
VPN	Virtual Private Network
VSB	Vestigial Sideband
VTC	Video Teleconferencing
VTOA	Voice and Telephony Over ATM

VXML	Voice XML
W	Watt
WAN	Wide Area Network
WAP	Wireless Application Protocol
WATMnet	Wireless ATM Network
WAVE	Wireless Advanced Vehicle Equipment (WAVE)
WBFH	Wide-band FHSS
WCDMA	Wideband Code Division Multiple Access
WCS	Wireless Communication Service
W-DSL	Wireless DSL
WECA	Wirelesss Ethernet Compatibility Alliance
WEP	Wired Equivalent Privacy
WLAN	Wireless LAN
WLIF	Wireless LAN Interoperability Forum
WML	Wireless Markup Language
WTB	Wireless Telecommunications Bureau
WWW	World Wide Web
XHTML	eXtensible HTML
XHTMLMP	eXtensible HTML Mobile Profile
XML	eXtensible Markup Language