devCentral

EDGE Capabilities, Technology, and Applications

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AT&T Wireless Developer Program

AT&T Wireless

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Revision History

Date	Revision	Description
9/16/03	1.0	Initial release

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1. Introduction

Enhanced Data Rates for Global Evolution (EDGE) is a powerful enhancement to the radio technology used by General Packet Radio Service (GPRS). EDGE dramatically improves data throughput rates and network capacity, while providing full backward compatibility for devices and applications. AT&T Wireless deployed its GSM/GPRS network in 2002 and is planning to deploy its EDGE network nationwide in the fourth quarter of 2003. GPRS/EDGE delivers an Internet Protocol (IP)-based networking capability for Global System for Mobile Communications (GSM) networks the most broadly deployed cellular technology in the world.

This paper begins with a discussion of the capabilities delivered by the AT&T Wireless EDGE network. It then discusses how EDGE technology works and how it smoothly fits into the evolution to 3G cellular networks. Finally, it thoroughly discusses how to develop applications that use EDGE to its full advantage.

1.1 Audience

The paper has been developed for corporate developers, independent software vendors, system integrators, and AT&T Wireless sales organizations. This paper assumes some knowledge of data communications, but does not assume any knowledge of wireless data networking, GPRS or EDGE.

1.2 Contact Information

If you have comments or questions regarding the information within this document, please e-mail them to devCentral, the AT&T Wireless Developer Program, at developer.program@attws.com. Please reference the name of this document in your e-mail.

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1.3 Resources

1.3.1 AT&T Wireless Resources

Details of services provided specifically by AT&T Wireless were obtained through interviews with AT&T Wireless personnel and from private internal documents.

The following are AT&T Wireless documents utilized in this document:

BlackBerry 5810 and BlackBerry 6710 Wireless Handheld™ Devices Getting Started Guide, document number 12283
http://www.attws.com/developer/technologies/blackBerry/

Developing Applications for Pocket PC and GPRS/EDGE, document number 12588
http://www.attws.com/developer/technologies/pocketPC/

Palm Wireless Application Development, document number 12899
http://www.attws.com/developer/technologies/palm/

Secure Application Deployment with GPRS/EDGE, document number 12792
http://www.attws.com/developer/network/gsmGprsSolutions/security.jhtml

AT&T Wireless Web Content: "Messaging."
http://www.attws.com/developer/technologies/messaging/

AT&T Wireless Web Content: "Wireless Java™ (J2ME)."
http://www.attws.com/developer/technologies/java/

1.3.2 Other Resources

3GPP TS 03.60, Technical Specification*, Third Generation Partnership Project, General Packet Radio Service (GPRS), Service Description, Stage 2*. Release 99.
http://www.3gpp.org/ftp/Specs/archive/03_series/03.60/

Microsoft Developer Network: *Common Performance Issues in Network Applications Part 1: Interactive Applications*
http://msdn.microsoft.com/library/default.asp?url=/library/en-us/dnwxp/html/comperfnetapppt1.asp

1.4 Terms and Acronyms

Table 1 defines terms and acronyms used in this document.

Table 1: Terms and Acronyms

Term or Acronym	Definition
3G	The next generation technology for mobile communications, using the Universal Mobile Telecommunications System (UMTS) standard. Key features of 3G systems are a high degree of commonality of design worldwide, compatibility of services, use of small pocket devices with worldwide roaming capability, Internet and other multimedia applications, and a wide range of services and devices. The main difference between 2.5G and 3G wireless is the rate at which data can be transferred. Planned rates are: 144 Kbps or higher in high mobility (vehicular) traffic, 384 Kbps for pedestrian traffic, and 2 Mbps or higher for indoor traffic.
3GPP	Third Generation Partnership Project
AMR	Adaptive Multi-Rate
API	Application Programming Interface
APN	Access Point Name
BSC	Base Station Controller
BTS	Base Transceiver Subsystem
CDMA	Code Division Multiple Access
CDPD	Cellular Digital Packet Data
ECSD	Enhanced Circuit Switched Data
EDGE	Enhanced Data Rates for Global Evolution or Enhanced Data Rates for GSM Evolution
EGPRS	Enhanced General Packet Radio Service
FTP	File Transfer Protocol
GGSN	GPRS Gateway Support Node
GMSK	Gaussian Minimum Shift Keying
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HLR	Home Location Register
HTML	Hypertext Markup Language
IEEE	Institute of Electrical and Electronic Engineers
IP	Internet Protocol
IR	Infrared

Term or Acronym	Definition
ITU	International Telecommunications Union
J2ME	Java 2 Platform, Micro Edition
LBS	Location-Based Services
MCS	Modulation and Coding Scheme
MMS	Multimedia Message Service
MS	Mobile Station (mobile computer plus communications device)
MSC	Mobile Switch Center
MTU	Maximum Transmission Unit
PC	Portable Computer
PCU	Packet Control Unit
PDA	Personal Digital Assistant
PSK	Phase Shift Keying
SGSN	Serving GPRS Support Node
SIM	Subscriber Identity Module
SMPP	Short Message Peer-to-Peer Protocol
SMTP	Simple Mail Transfer Protocol
TBF	Temporary Block Flow
TCP	Transmission Control Protocol
TDMA	Time Division Multiple Access
UMTS	Universal Mobile Telecommunications System
USB	Universal Serial Bus
VLR	Visitor Location Register
VPN	Virtual Private Network
WAP	Wireless Application Protocol
WCDMA	Wideband Code Division Multiple Access
WLAN	Wireless Local Area Network

2. EDGE Capabilities

There are many reasons to consider the AT&T Wireless EDGE network for your wireless application. EDGE offers excellent data throughput rates, significantly faster than those offered by any other nationally deployed cellular network in North America today. There are a variety of devices that support EDGE, including mobile telephone and PC card modems, and soon EDGE capability will be the norm for GSM devices. AT&T Wireless offers flexible networking options that give you a wide variety of IP address management, routing, and security approaches for connecting your network to the AT&T Wireless EDGE network. And with a wide range of complementary services such as messaging, location-based services, and mobile commerce almost any kind of communications-oriented application can be deployed.

GSM operators have deployed GPRS globally. In the United States, all of the major GSM operators are upgrading their GPRS networks to EDGE. Similar upgrades can be expected in Canada and Latin America, and to some extent in Europe as well. EDGE is fully complementary and compatible with Third Generation (3G) cellular technologies such as UMTS.

With a four time-slot device, EDGE triples the throughput rates of GPRS, with download rates of 110 to 130 Kbps and upload rates of 50 Kbps to 80 Kbps being the norm for a loaded network. These rates are as measured by applications, and not just theoretical values. Under favorable network conditions, you can achieve peak speeds as high as 180 Kbps. These speeds are two to three times the speeds of dial-up modem connections.

EDGE is 100% backward compatible with GPRS. EDGE devices will work on GPRS networks at GPRS speeds. Meanwhile, GPRS devices will work on EDGE networks at GPRS speeds.

2.1 Computing Platforms

What is the right computing platform for EDGE? The answer is any type of mobile device that you wish to use. The options are numerous, and as shown in Table 2, fall into three broad categories: phones, PDAs, and laptop/notebook computers. These options will be similar to the ones available for GPRS devices. Not all devices available that support GPRS will immediately support EDGE, but over time you can expect all data devices to become EDGE capable.

Table 2: EDGE Data Options for Different Platforms

Platform	Picture	EDGE Data Options
Mobile Telephone		Short Message Service (SMS) Multimedia Message Service (MMS) WAP micro browser As a modem for PDA or a notebook computer
Personal Digital Assistant		Devices with integrated EDGE capability EDGE modem in Compact Flash or sled form factors Bluetooth (or IR or cable) connection to EDGE phone
Notebook/Laptop or Tablet Computer		EDGE modem in PC card form factor Bluetooth (or IR or cable) connection to EDGE phone Integrated PCI EDGE modem
Application-Specific Devices (e.g., Intermec, Itronix, Symbol)		Typically contain an integrated modem

Note: Some of the above-identified options may not be available at the time of this document's publication.

Deciding which of these is the best platform for EDGE-based communications depends on what you want to do. By their nature, mobile telephones and PDAs are a very good fit because they typically communicate limited amounts of data. However, EDGE is an excellent communications option for notebook computers, and with its high speeds supports virtually any communications-oriented application. The main

consideration with notebooks is that applications can potentially transfer large amounts of data, so you need to choose both the appropriate data pricing plan and to develop or configure applications for optimum use over wireless networks. This topic is discussed in Sections 2.2, and explored further in Section 5, Application Development.

2.2 Supported Applications

A partial list of the applications that are supported by EDGE include:

- E-mail and group collaboration
- Instant messaging and SMS
- Web access
- Virtual Private Networking (VPN)
- Database access
- Multimedia (streaming video and audio)
- Picture messaging
- WAP-based applications
- Music downloads
- Intranet access
- Web-based enterprise applications including, enterprise resource planning, customer relationship management, and sales force automation

Almost any application that works over the Internet or a private IP network is a good candidate for EDGE.

2.3 EDGE and Wireless LANs (Wi-Fi)

AT&T Wireless also offers WLAN (Wi-Fi) hotspot access. Are these a better networking option than EDGE? Table 3 shows the pros and cons of EDGE compared to hotspots:

Table 3: Advantages of EDGE and Advantages of WLAN Hotspots

Advantages of EDGE (Wide Areas Wireless)	Advantages of WLAN Hot Spots
Suitable for most communications-oriented applications Typical throughput rates of 110 to 130 Kbps Far greater coverage with full cellular network footprint Consistent service from a single service provider	Well suited for transfer of large amounts of data Typical throughput rates of 5 Mbps Supports real-time multimedia such as voice over IP or interactive video

2.4 Device Configurations

Table 2 touched on the variety of devices that support EDGE such as mobile telephones and EDGE modems. There are some aspects of EDGE devices that should be considered for your application, including time slots supported and connectivity options.

A GSM radio channel is divided into eight time slots that repeat every 4.6 milliseconds. Though multiple radio channels are available in each cell sector, a GSM/EDGE device receives on one (200 KHz wide) radio channel and transmits on another (200 KHz wide) radio channel. Within each radio channel, each time slot supports one voice conversation or a certain amount of data capacity. A data device can transmit or receive by combining multiple time slots.

The maximum number of time slots available to devices for uploads or downloads is four. Some devices may have just one or two slots for uploads, though most have three or four for downloads, which is the direction of greatest data transfer for most applications. The number of time slots a device supports for downloads combined with the number of time slots it supports for uploads determines the time slot class of the device. For example, a Class 12 device supports four time slots for downloads and four time slots for uploads.

Note: Theoretically, a device can use up to all eight-time slots. However, practical considerations limit the number to four.

Note: A total of five time slots are available simultaneously, meaning that if four slots are being used for the download, only one slot is available for uploading.

The second major consideration is with mobile telephones that support EDGE. There are three common options for connecting these to computers. One is to use a data cable that connects between the phone and the notebook computer. This cable will either plug into the computer's COM port or USB port. The second option is to use IR, which is available in many phones as well as notebooks and PDAs. The third option is to use a Bluetooth radio connection. To facilitate a Bluetooth or an IR configuration, AT&T Wireless provides a utility called Communication Manager that includes a wizard for setting up the connection. From an application perspective, a tethered (e.g., Bluetooth) configuration works almost identically to an integrated solution (e.g., PDA with integrated EDGE device or computer with EDGE PC card modem.) This means that the same application can support multiple configurations.

One potential source of confusion in using EDGE is that devices may report that they are making a GPRS connection regardless of whether they are connecting via GPRS or EDGE mode. But since AT&T Wireless will have fully deployed its EDGE network by the fourth quarter of 2003, you will soon be able to assume that all connections with an EDGE device on the AT&T Wireless GPRS/EDGE network are in fact using EDGE technology.

2.5 Value-Added Service Offerings

By itself, the AT&T Wireless EDGE network offers a powerful wireless IP networking solution. However, AT&T Wireless has augmented the network with a variety of complementary service offerings that greatly expand and facilitate the number of applications that you can implement. These are listed below. Note that APIs and interfaces for these offerings are not necessarily available for all customer applications.

- **Short Message Service (SMS):** This service allows you to send and receive short text messages on mobile telephones, PDAs, notebook computers, and vertical-market devices. SMS is actually a GSM service that does not use GPRS/EDGE. SMS can be used for actual messaging, or as an alert mechanism to notify an EDGE application of an event, such as new e-mail available for download. To facilitate SMS use, AT&T Wireless provides two methods for sending SMS messages to mobile devices, including the Simple Mail Transfer Protocol (SMTP), which is an Internet e-mail interface, and the Short Message Peer-to-Peer Protocol (SMPP).

- **Multimedia Message Service (MMS)**: This service allows the transmission of more complex messages such as photos, pictures, graphics, voice clips, and short video clips.
- **Wireless Instant Messaging**: AT&T Wireless has linked its wireless network with the major instant messaging networks, including AOL Instant Messenger, MSN Messenger, and Yahoo! Messenger so you or your users can converse from your mobile telephone with others on these networks.
- **Web Optimization:** This service acts as an intermediary between the Web browser, a mobile device, and Web servers, compressing and optimizing traffic flow to increase the speed of Web browsing by a factor of two-to-four.
- **Communication Manager:** This software utility configures the EDGE connection, including Windows, Pocket PC, and Palm system settings, as well as Bluetooth and IR settings. It also includes the client used for Web optimization.
- **Location-Based Services:** AT&T Wireless provides the capability for EDGE applications to obtain the current location of the serving cell site, and provides either latitude/longitude or city/state/ZIP code information. Users can manage their privacy on an opt-in basis.
- **Mobile Commerce:** To promote mobile-commerce applications, AT&T Wireless provides both an e-wallet consumer service and alliance billing service for enterprises.
- **Java:** In cooperation with the leading companies supporting J2ME, AT&T Wireless provides tools, documentation, resources, and best practices for developing and deploying wireless Java™ applications.
- **Comprehensive Security:** Beyond the security features inherent to GPRS/EDGE technology, which include encryption and authentication, AT&T Wireless has implemented a variety of other protective measures. These include firewalls that restrict unauthorized traffic, blocking of unsolicited traffic to mobile stations, customized IP addressing and routing options for enterprises, and support for mainstream VPNs.

- **Flexible Fixed-End Connectivity Options:** How you connect your network to the AT&T Wireless GPRS/EDGE network for the backhaul is as important as the radio link. AT&T Wireless offers a variety of options, including the Internet, network VPN in conjunction with the Internet, and frame relay Permanent Virtual Circuits (PVCs). For high-availability applications, AT&T Wireless also offers redundant connectivity methods so that in the event of a failed connection, the network automatically switches to a backup connection.

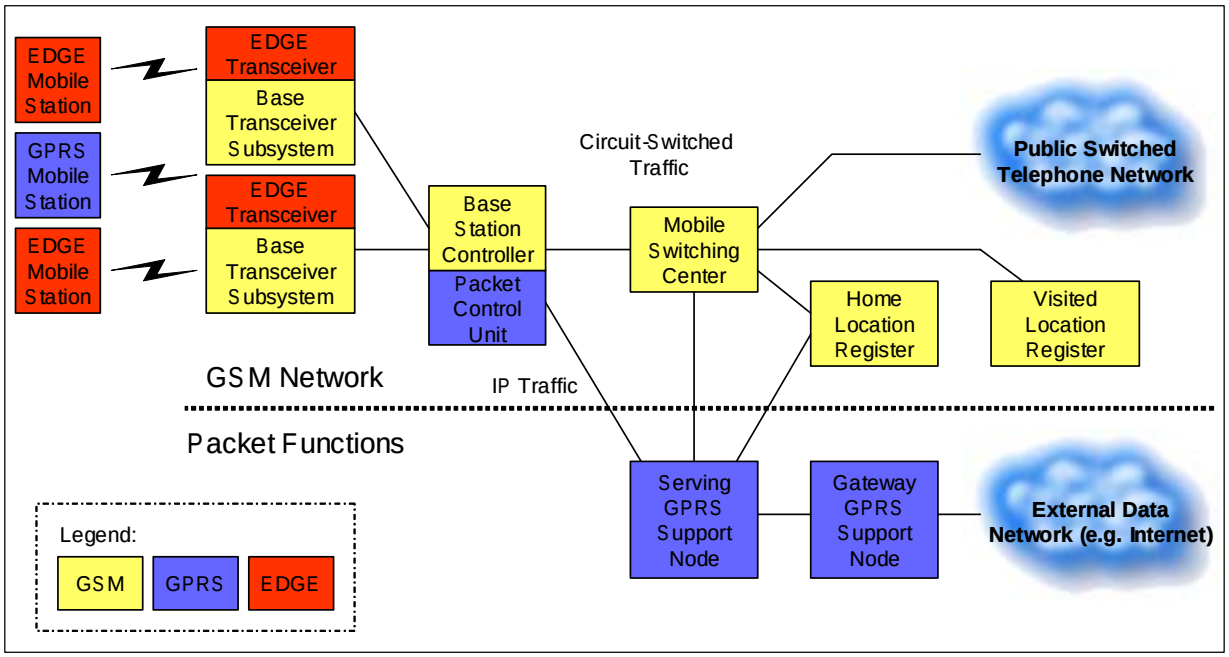
3. GPRS, EDGE, and UMTS

EDGE is a powerful step in the evolution from GSM to third generation cellular networks. This section explains how EDGE relates to GSM and GPRS networks, as well as third generation cellular systems such as UMTS. EDGE is specified in the Release 99 version of GPRS specifications.

Note: Analog cellular systems are called first generation. Initial digital systems are called second generation. Improved digital systems with high-performance data capabilities are called third generation

The original GSM networks were designed principally for voice communications. With GPRS, operators were able to provide a sophisticated IP networking capability through the addition of a packet data infrastructure consisting of Serving GPRS Support Nodes (SGSN) and Gateway GPRS Support Nodes (GGSN) (see Figure 1). GSM and GPRS use the same radio interface. At the base station controller, circuit-switched traffic is directed towards the circuit-switched infrastructure and IP packet traffic is directed at the packet infrastructure by the Packet Control Unit (PCU).

Figure 1: GSM/GPRS/EDGE Network



Since EDGE is essentially a radio technology, operators can add EDGE capability to networks upgrading the software at the Base Station Controller (BSC) and by installing EDGE radios at the Base Transceiver Subsystems (base stations). With a newer GSM/GPRS network, such as the network operated by AT&T Wireless, the radios at the BTS were already EDGE capable when installed and EDGE is only a software upgrade to the network. Older networks require an operator to install new hardware.

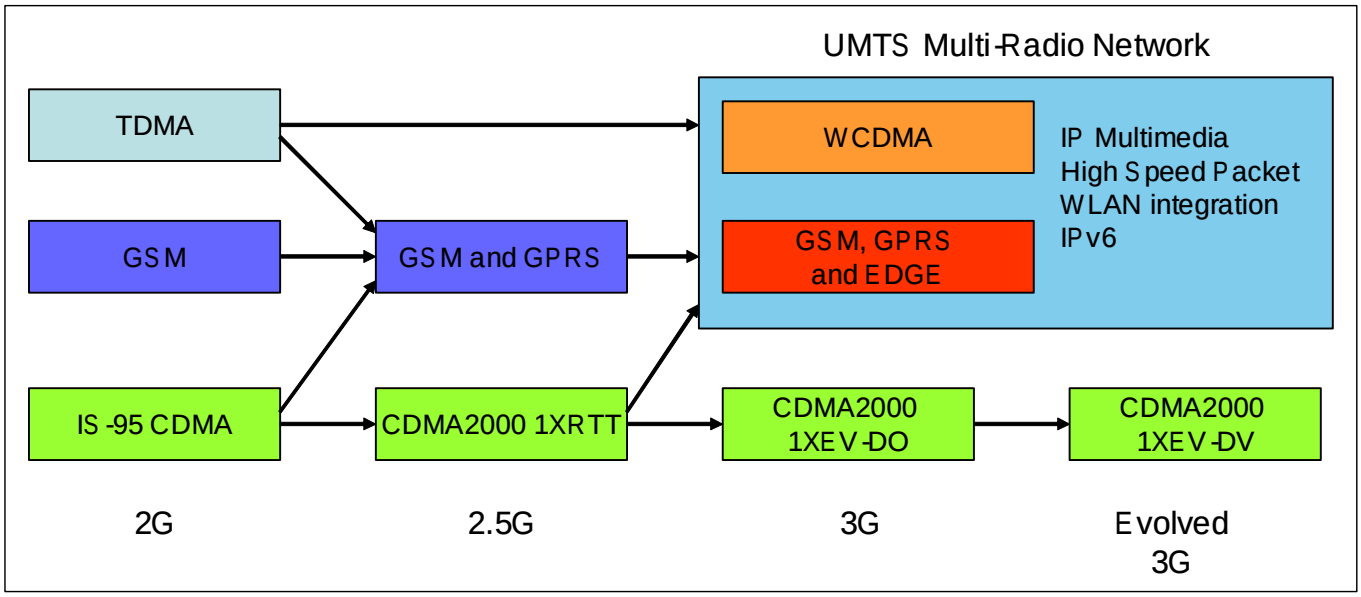
A key feature of EDGE is that it uses the same core network infrastructure as GPRS. The SGSN and GGSN (and other aspects of the packet infrastructure such as security firewalls) behave identically regardless of whether the MS is a GPRS device or an EDGE device. The benefit for applications is that they can operate using either GPRS or EDGE devices, and nothing special has to be done to work over EDGE.

EDGE is primarily a technology to improve data communications. Can EDGE be applied to voice communications? In theory, the answer is yes. However, the industry has invented different innovations for increasing voice performance and capacity, such as the Adaptive Multi-Rate (AMR) voice encoder, which actually employs techniques similar to EDGE but is better suited for voice communications.

EDGE is officially classified as a 3G technology as defined by the International Telecommunications Union (ITU). Beyond EDGE or in some cases, as an alternative to EDGE, operators around the world are either planning or deploying another 3G technology called the Universal Mobile Telecommunications System (UMTS), which employs a Wideband CDMA (WCDMA) radio interface. While similar in some respects to the CDMA technology used in CDMA2000 networks, WCDMA is a different technology. For instance, it uses 5 MHz radio channels instead of 1.25 MHz radio channels. AT&T Wireless plans to deploy UMTS in select markets in 2004.

WCDMA offers peak speeds even higher than EDGE, and is well suited for multimedia applications. WCDMA does not replace GSM/GPRS or GSM/EDGE, but works in conjunction with it in a system called the UMTS Multi-Radio Network. Here, the same core network handles both the GSM/GPRS and GSM/EDGE radio access network as well as the WCDMA radio access network. This provides backwards compatibility for GSM/GPRS and GSM/EDGE devices, and allows operators to leverage investments in existing infrastructure. Figure 2 shows the evolution path for competing CDMA technologies.

Figure 2: UMTS Multi-Radio Network



EDGE has significantly higher data throughput rates than CDMA2000 1XRTT.

4. How EDGE Works

EDGE represents a significant innovation in radio technology. When applied to GSM/GPRS networks, EDGE dramatically increases data throughputs, as well as network capacity. It does so through a combination of techniques that are described in detail below. A full understanding of how EDGE works is not necessary for application development or use of the technology, but it does offer insight into how the technology behaves in different operating conditions.

EDGE can actually be applied to both circuit-switched data service, where the service is technically referred to as Enhanced Circuit-Switched Data (ECSD), or to packet-switched data service, where the service is technically referred to as Enhanced GPRS (EGPRS). However, most GSM operators deploying EDGE, including AT&T Wireless, are concentrating on packet service.

With EDGE, the radio interface keeps the same time-slot structure as GPRS and GSM, and is still considered a Time-Division Multiple Access (TDMA) system. Many signaling (control) protocols, and all user level (IP, UDP, TCP, etc.) protocols, are the same for both GPRS and EDGE. This is possible because EDGE operates only at the physical layer (radio modulation and forward error correction) and link layers (access control and retransmissions). Higher layer protocols are unaffected. Consequently, any application developed for GPRS will immediately work with EDGE.

From an application perspective, EDGE behaves identically to GPRS, just faster and with very high reliability. From an operator deployment point of view, EDGE can be added to an existing GSM/GPRS network with minimal new hardware, especially if it is a newer network that was designed to be EDGE capable, such as operated by AT&T Wireless.

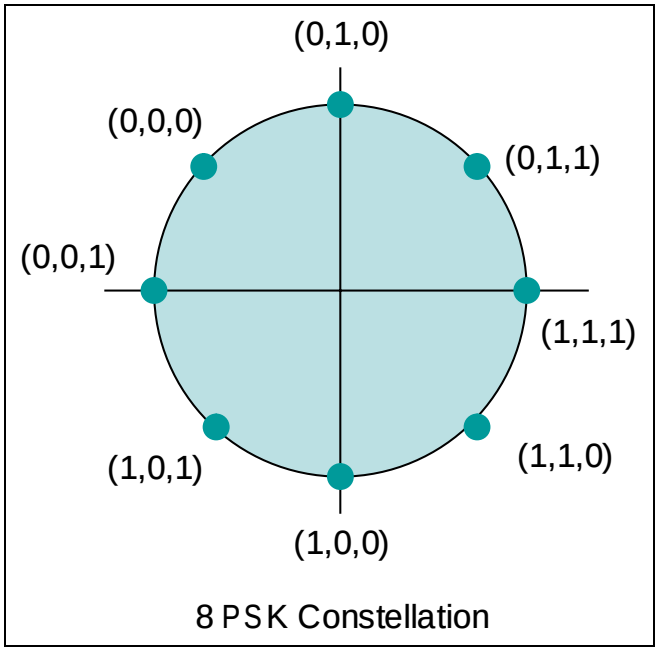
EDGE radio technology uses the following techniques to boost throughput speeds and to increase capacity: new modulation, flexible channel coding, link adaptation, incremental redundancy, an effective method of retransmitting packets, a larger addressing window, and tight interleaving. The following sections describe these techniques.

4.1 Modulation and Coding

Modulation refers to how a radio shapes a carrier waveform to encode binary data. The modulation used in GSM and GPRS is called Gaussian Minimum Shift Keying (GMSK), where each variation of the carrier signal (which is called a symbol) encodes one bit of information: either a one or a zero. EDGE also uses GMSK, but when radio conditions are good, EDGE employs a higher-order modulation called Octagonal (or Octonary) Phase Shift Keying (8 PSK), which allows three bits of information to be encoded in each symbol. This is possible because the phase (delay) can occupy one of eight positions, sufficient to encode three bits of information. The result is that the same radio bandwidth can transmit approximately three times as much data. An analogy is printing a page using a smaller font. The size of the page is the same, but contains more information.

Of course, such a huge gain does not come without a price, namely it requires a certain level of carrier signal strength relative to interference (called C/I). Fortunately, these conditions exist in much of the network coverage area, and where they don't the radio falls back to GMSK modulation. Figure 3 shows what is called an IQ phase chart that depicts the 8 phase positions and the data that each position encodes.

Figure 3: EDGE 8 PSK Constellation



In combination with 8 PSK modulation, EDGE employs multiple coding rates. Coding rate refers to how much error-correcting information is transmitted with user data to allow error recovery without having to retransmit the information. Coding is also referred to as forward-error correction. The more redundant data that accompanies the original data transmission, the more reliable the data communications will be, however it will occur at a slower rate due to the overhead of the coding.

EDGE uses the minimum amount of coding necessary to ensure reliable data communications, thus achieving the highest throughput rate possible. EDGE has four different coding rates with GMSK modulation (called Modulation Coding Schemes one to four) and five coding rates with 8 PSK modulation (MCS5 to MSC9). These are summarized in Table 4.

Table 4: EDGE Modulation and Coding Rates

Scheme	Modulation	Max Kbps	Code Rate
MCS-9	8 PSK	59.2	1.0
MCS-8	8 PSK	54.4	.92
MCS-7	8 PSK	44.8	.76
MCS-6	8 PSK	29.6	.49
MCS-5	8 PSK	22.4	.37
MCS-4	GMSK	17.6	1.0
MCS-3	GMSK	14.8	.85
MCS-2	GMSK	11.2	.66
MCS-1	GMSK	8.8	.53

In Table 4 the code rate refers to the percentage of transmitted bits constitute user data. For example, with MCS-8, 92% of bits are user data (including protocol overhead) and eight percent of bits are for error correction.

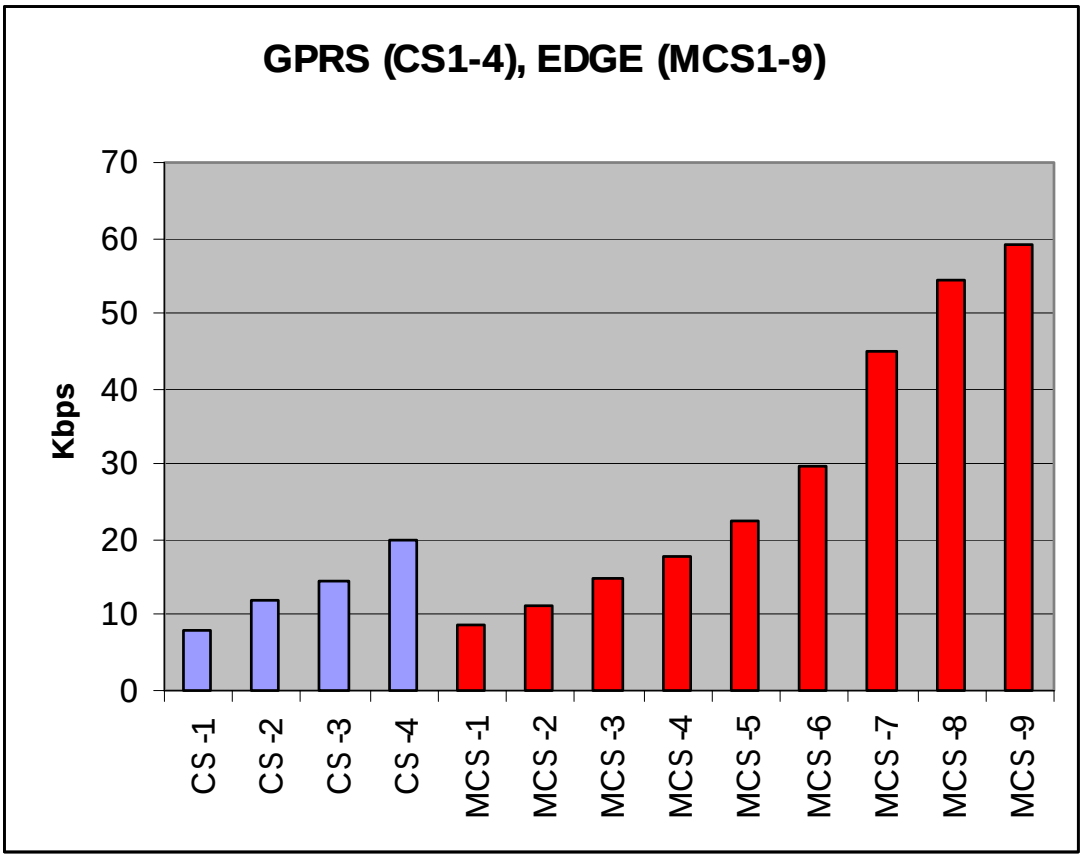
The Max Kbps column shows the resulting throughput per time slot. Note how this can vary from 8.8 Kbps under very adverse radio conditions to as high as 59.2 Kbps under ideal conditions. In comparison, a typical GPRS network operates at a rate of 12 Kbps per time slot (GPRS coding scheme 2), with throughput at the application layer after protocol overhead of about 10 Kbps.

On average with EDGE, as measured at the application layer, users can expect real throughput rates of about 30 Kbps per time slot. This is three times higher than GPRS. With many EDGE devices supporting four time

slots, users can realistically expect throughput rates of 120 Kbps and often higher, with peak rates as high as 180 Kbps.

Figure 4 compares the throughput rates of GPRS coding schemes with EDGE coding schemes. The first four columns are for GPRS, and the next nine columns for EDGE. Note that most operators including AWS have only implemented coding schemes one and two for GPRS, making EDGE deployment even more effective.

Figure 4: EDGE versus GPRS (Kbps per time slot)



EDGE meets the official International Telecommunications Union (ITU) 3G requirement of 384 Kbps at pedestrian speeds because devices can be built that use all eight time slots, and operating at MCS-9, such devices would exceed 384 Kbps. Most devices, however, will be limited to four time slots due to practical implementation considerations.

EDGE chooses the optimum modulation and coding scheme based on the radio environment in a process called link adaptation. To respond to

varying radio conditions, EDGE makes highly accurate measurements of the radio link over short time periods. This allows the EDGE to quickly adapt to changes in the radio environment.

4.2 Other Methods

There are other improvements in EDGE over GPRS, which are not detailed in this paper. Briefly, they are as follows:

- **Incremental Redundancy:** When the EDGE radio interface retransmits a packet that was received in error, it does so with a different set of forward error-correcting bits. The newly received data is mathematically combined with the previously received data, which increases the likelihood that the original data can be correctly decoded. Incremental redundancy significantly increases the efficiency of the link.
- **More Effective Packet Retransmission:** With EDGE, packets received in error can be retransmitted using a different MCS, which is important if radio conditions have changed. With GPRS, retransmission must be done using the coding scheme originally used.
- **Larger Addressing Window:** EDGE increases the size of the address range used to identify packets it is transmitting, as well as the addressing window, which refers to the number of packets being processed. This significantly decreases the likelihood of transmission delays under adverse radio conditions.
- **Interleaving:** With MCS 7 to MCS 9, EDGE interleaves blocks of data across two transmission bursts instead of across four, which increases the likelihood of correct reception in the initial transmission and reduces the number of bursts that must be retransmitted in the event of a failure. This is particularly important in combination with frequency hopping where the radio environment can change with each transmission burst.

There are a number of resulting benefits from all the methods just discussed. First, EDGE delivers the highest possible throughput rate given instantaneous radio conditions. Second, it offers a highly robust and reliable radio link. This makes applications perform better, and reduces the demands on application development for having to cope with an unreliable connection. There are a couple of aspects of EDGE that application developers should be aware of: variations in throughput and latency.

4.3 Data Throughput

As discussed above, the different modulation and coding schemes result in a wide variation of throughput speeds based on the radio environment. Does this mean that there is a six-to-one variation in throughput speeds? In theory, there is a six-to-one ratio in throughput speeds, but in practice, this is rarely true. AT&T Wireless has deployed its network so that across the coverage area it maintains a certain level of signal quality to maintain reliable voice communications. At this signal quality level, EDGE still delivers a relatively high throughput, higher than GPRS. It is only with a very poor signal, one where even a voice call would not be possible, that EDGE engages its most robust, though slowest, throughput.

Detailed simulations by EDGE vendors and field testing results by operators indicate that EDGE should deliver at least a doubling of throughput over GPRS throughout the coverage area, and close to a four times improvement across 85% of the coverage area. The result is that you should consistently see at least 20 Kbps per time slot across the coverage area, and often 30 to 40 Kbps per time slot. With a four-time slot device, this translates to typical throughput speeds of 110 to 130 Kbps. This is two to three times higher than typical dial-up modem rates.

EDGE is one of the first cellular-data technologies to implement multiple modulation and coding schemes, along with link adaptation. Some may argue that this brings a level of unpredictability to throughput performance. However, while there is indeed some variation, variation with a single modulation and coding scheme can actually be worse if the signal is poor, and each packet has to be retransmitted multiple times. Moreover, all new advanced radio links are implementing adaptable links, including UMTS with its High Speed Downlink Packet Access, CDMA2000 1XEV, and even wireless LAN technologies such as IEEE 802.11a and IEEE 802.11g.

More important than throughput is reliability. If a link can adapt and keep sending data at a slightly lower but steady rate, this will result in much more reliable application performance than a link that suddenly must retransmit multiple times, as this causes excessive delays that can cause networking and application-level protocols to time out.

Another factor that can affect throughput is network loading. If there are a large number of users, the available data bandwidth must be shared among multiple users. Individual user throughputs may go down, but this is true with any network, regardless of whether it is cellular, wireless LAN or Ethernet. AT&T Wireless carefully monitors network performance, and if

a cell site is experiencing congestion (whether for voice or data), AT&T Wireless takes appropriate measures to increase capacity, whether through enhanced radio planning the addition of radio channels or cell sites. AT&T Wireless allocates more capacity through dedicated channels for data services than most other carriers.

4.4 Latency

Latency refers to the delay in sending data across a network. Often it is measured as round trip time, such as provided by an Internet ping response. Depending on the traffic profile, latency can influence application performance as much as throughput. Section 5, Application Development, discusses strategies for accommodating latency while this section documents the extent of latency and the difference between GPRS and EDGE.

First, it is important to understand the nature of latency. There are several components:

1. **The delay in getting the smallest size packet across the network.** This is the inherent delay in the wireless network, and measures about 600 milliseconds round trip for both GPRS and EDGE.

2. **The delay in sending a payload packet that includes data.** This delay is the inherent delay mentioned in item one plus the time to transmit the data based on throughput speed. This delay depends on the size of the payload, and EDGE provides a significant advantage due to its higher throughput speed.

3. **The delay between the AT&T Wireless network and external networks, including the Internet.** This delay is typically measured in tens of milliseconds and is generally not a significant factor.

Another factor that affects latency is the establishment of Temporary Block Flows (TBFs), which is the process by which the network assigns time slots for user data. Establishing a TBF takes about one half second. Hence, the first user packet will experience this increased latency. However, once established, subsequent packets will not be affected. This is why using a ping command to measure latency will sometimes yield higher than expected values. The first ping needs to establish the TBF, whereas for subsequent pings, the TBF is already in place.

Since the network needs to make time slots available to other users, in the absence of user data, it times out the TBF in a matter of seconds. It can be much more efficient for applications to combine multiple small transactions into a single larger transaction.

EDGE, like nearly all other cellular-data networks, has some latency that can adversely affect applications that engage in a lot of back-and-forth traffic. However, applications that follow the guidelines listed in the Section 5.6 Efficient Applications will function well.

4.5 Optimum System Configuration

Since EDGE operates at throughput speeds higher than most modem connections, the default parameter values for the Windows TCP configuration may not be optimal. AT&T Wireless recommends the following values for optimal operation:

- Maximum Transmission Unit (MTU): 1,440
- TCP Receive Window: 63,360
- Selective Acknowledgement: On

These changes are made in the Windows registry.

5. Application Development

EDGE provides a high-speed communications channel suitable for virtually any IP-based application. However, there are a variety of considerations that can improve your application. Some considerations apply specifically to using EDGE technology and the AT&T Wireless EDGE network, and others apply to using cellular data networks in general.

5.1 Platform Considerations

First and foremost is the mobile platform you are targeting, as this determines what off-the-shelf applications or middleware are available, what software development tools are available, browser capabilities, power management considerations and so forth. AT&T Wireless provides extensive documentation for each platform on the devCentral Web site. The following table summarizes the options for each platform:

Table 5: Development Options for Different Platforms

Platform	Application Development Options
Mobile Telephone	Micro browser using WAP. Since the performance of WAP applications is affected more by latency than throughput, most WAP applications will perform almost the same with an EDGE connection as with a GPRS connection. Java 2 Micro Edition (J2ME) on some phones. Short Message Service (SMS) on all phones and Multimedia Messaging Service (MMS) on some phones.
PDA	Standard IP networking. Extensive development tools available for Palm, Pocket PC, and BlackBerry devices. See devCentral white papers, *Developing Applications for Pocket PC and GPRS/EDGE*, *Palm Wireless Application Development* and *BlackBerry Handheld Getting Started Guide* (all referenced in Section 1.3 of this document). Applications can be client/server or browser-based. Some VPNs available.

Platform	Application Development Options
Notebooks	Standard IP networking. Extensive development tools for a variety of notebook platforms. Applications can be client/server or browser-based. Extensive VPN options available.
Proprietary devices with embedded modems	Standard IP networking or SMS. Tools depend on the computer platform used in the device.

5.2 EDGE-Specific Considerations

There is little you have to do specifically for EDGE, as any application that functions over an IP network will function over an EDGE connection. However, keep in mind the following:

- **GPRS versus EDGE:** Since EDGE is backwards compatible with GPRS, EDGE devices operate in GPRS mode when in a GPRS coverage area. This could happen, for example, if you roam onto a partner network that has not yet been upgraded to EDGE. It is not possible for the application to determine whether the device is in a GPRS or EDGE mode of operation. Hence, design your application so it works well at GPRS speeds, and EDGE will only improve a user's experience.
- **Throughput Variation:** Since EDGE throughput can vary based on the radio environment and network loading (as discussed in Section 4.3 Data Throughput) verify that timeout values are based on conservative throughput rates. Use progress indicators for lengthy network operations to provide user feedback and allow users to abort operations. While applications do not have access to actual network metrics, they can calculate the throughput they are achieving (as is common with many FTP clients) and can display this information.

5.3 IP Addressing Options

The AT&T Wireless EDGE network is IP-based, and acts as a wireless extension of the Internet and private networks. AT&T Wireless has designed its network to provide you a variety of options with respect to IP address management and how traffic is routed. There are both standard options and a variety of customizable options. The most important options are outlined in Table 6.

Table 6: Summary of IP Addressing Options

IP Address Attribute	Options
Public versus private	The default address is a dynamically assigned, private IP address. However, a public address can be used.
AT&T Wireless-supplied versus customer-supplied	AT&T Wireless typically assigns the IP address to a device for a data session from a pool of its own addresses. However, under a custom arrangement (referred to as a custom Access Point Name), you can provide your own pools of public address for assignment to mobile devices.
Mobile terminated	For security purposes, the network prevents mobile terminated data communications (meaning communications not initiated by a mobile device). However, there are options that enable mobile termination such as using a custom Access Point Name (APN).
Dynamic DNS	AT&T Wireless provides a mechanism for you (or an application) to learn a mobile device's IP address-based on its name.

Much more can be learned about this topic in the white paper, *IP Address Management in the AT&T Wireless GPRS/EDGE Network,* referenced in Section 1.3.1.

5.4 Client/Server Versus Web-Based

One fundamental decision that must be made with regard to your application is whether to follow a client/server model or a Web-based model that uses HTML. Both are feasible using EDGE, though there are some pros and cons to consider.

The advantages of a Web-based approach are:

- **Simplified Deployment:** Your application does not have to be deployed to every mobile computer. You simply need to install the application on a Web server.
- **Portability:** The application does not have to be compiled for each mobile processor you intend to deploy. Since only HTML and script is returned to the client, any device with a browser can access and use the application.
- **Speed of Development:** Since the application does not have to be tested and debugged on multiple devices, the development time is

reduced. Because you are relying on the browser as the user interface engine, there is no client code to create.

The disadvantages include the following:

- **Possible Inefficiencies:** Depending on the nature of the application, a Web-based application may consume more data through a large number of screen updates than a client/server-based approach and may operate more slowly.
- **Requires Network Connection:** In order for your application to be useful, the user must be able to maintain a connection to the Web server. If you intend for your application to also be usable in an offline state, then a Web-based approach is not suitable.

5.5 Value Added Services

Beyond providing an excellent transport for networking applications, AT&T Wireless has developed complementary service offerings that can expand the scope and capability of your applications. AT&T Wireless has separate consumer (mMode) and enterprise offerings. These offerings, which are thoroughly documented on the devCentral Web site, are summarized in Table 7.

Table 7: Summary of Value Added Services

Service	mMode/Consumer	Enterprise
Wireless Application Protocol	All phones	All phones
SMS	All phones	All phones, some modems, Pocket PC, Palm, BlackBerry
Multimedia Messaging Service (MMS)	Some phones	Some phones
Java 2 Micro Edition (J2ME)	Certain phones, RIM Blackberry	Certain phones, RIM Blackberry
Billing Services	All phones: E-Wallet service with storage of user account information and charges appearing on user's phone bill or credit/debit card.	All devices: Alliance Billing Service with business partner managing customer relationship and AT&T Wireless handling billing and collection
Communication Manager (API)	Not used	Available for Palm, Pocket PC, and Windows platforms to manage GPRS/EDGE connections

5.6 Efficient Applications

For an optimum user experience, it is important for applications to use network resources as efficiently as possible. A fast wire line network (e.g., Ethernet) can mask inefficient network use. However, inefficient use in a wireless network translates to sluggishness and user frustration, as well as the transmission of excessive amounts of data. Well-written applications provide users best-expected performance while consuming the least amount of network resources.

Some recommendations include:

- Cache data locally and do not repeat the transmission of data that has already been sent. Send only new or changed information.
- Compress data prior to sending it. While some networks can compress data, intervening layers such as VPNs can prevent compression from being effective. Compression at the application level often yields the best results.
- Combine multiple small transactions into a single larger transaction. This is particularly effective with wireless networks as they have greater latency than wire line networks.
- Examine your data structures to ensure that they are optimal and efficient for transmission.
- Use tokens that can represent larger blocks of data.
- Do not hold up the user interface waiting for network operations to initialize or complete.
- Provide users with the ability to easily terminate transactions and abort sessions.
- Provide progress indicators to users and estimated completion times for lengthy operations. This is especially helpful because throughput rates can vary, and users need feedback on the status of operations.
- Strive for an interactive response of less than one second.
- Minimize the load on system resources, such as those incurred by sockets and TCP connections. Try to use only one TCP connection per client.
- Run unrelated transactions in parallel so that a new transaction does not depend on the completion of previous transactions.

For more ideas and for elaboration on some of the points above, refer to Microsoft's discussion of this topic titled *Common Performance Issues in Network Applications Part 1: Interactive Applications* located at the following URL: http://msdn.microsoft.com/library/default.asp?url=/library/en-us/dnwxp/html/comperfnetapppt1.asp.

5.7 Wireless Middleware

While most client/server and browser-based applications function well over EDGE connections, there are quite a few instances where using wireless middleware (or infrastructure software as it is sometimes called) will prove beneficial. The primary benefits are improved performance, reduced traffic over the wireless connection, greater immunity to loss of connection and variation in throughput, and mobility enhancements. In some cases, wireless middleware can significantly reduce overall implementation costs by eliminating the need for a complete redesign of existing applications or systems.

Middleware does increase system complexity and incurs additional costs. It is important to note that there are a wide variety of middleware solutions from multiple vendors. Table 8 is a summary of some of these solutions.

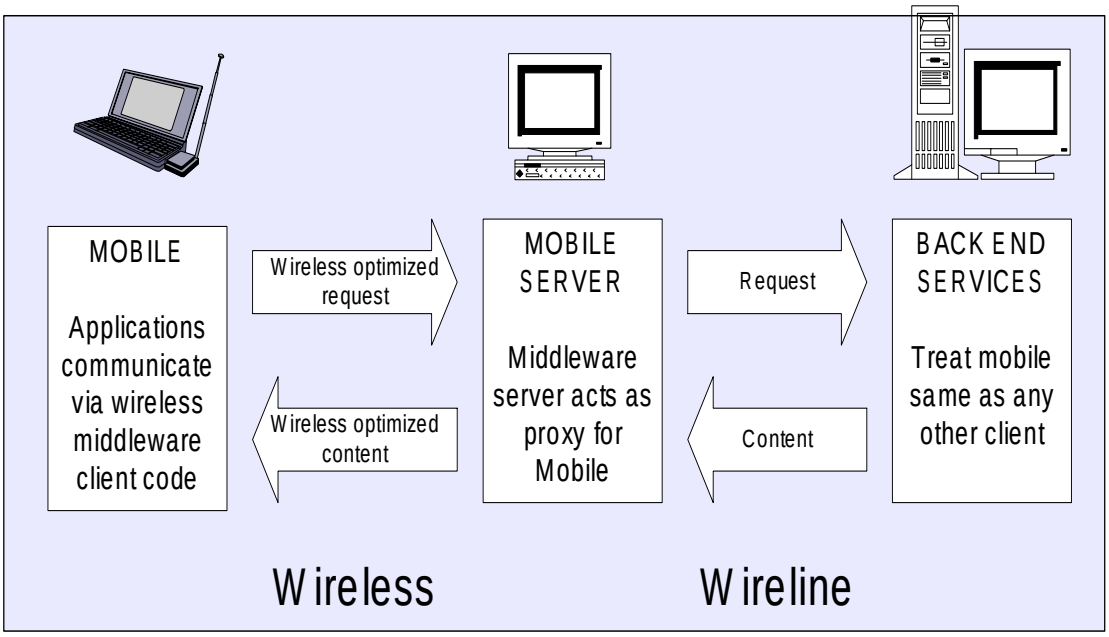
Table 8: Types of Middleware Solutions

Type	Function	Examples
Application Servers	Extend enterprise applications to mobile devices	IBM WebSphere, Oracle Application Server
Security and Performance	Enhances the performance and security of business applications running over the wireless network	NetMotion Mobility, Flash Networks, NetGain 2000
Device Management	Manages the configuration of applications running on multiple wireless devices	XcelleNet
Synchronization	Allows client applications to run locally on wireless devices and to synchronize data with back-end applications	Extended Systems XTNDConnect, Synchrologic iMobile Suite

Most middleware solutions employ an architecture where a mobile server (sometimes called a gateway) functions on behalf of the mobile application. The middleware client on the mobile station communicates with this server using protocols optimized for wireless communications.

The mobile server communicates with back-end services using standard networking/application protocols, shown in Figure 5.

Figure 5: Middleware Architecture



Some middleware solutions provide APIs that your application must use. Other middleware, (e.g., NetMotion Mobility), installs transparently and does not require any direct support from the application.

5.8 GPRS/EDGE Security and Virtual Private Networking (VPN)

GPRS/EDGE technology incorporates a number of security mechanisms, including encryption of the radio link, and authentication of mobile devices based on the Subscriber Identity Module (SIM) card.

AT&T Wireless offers further protection through firewalls that protect the infrastructure against harmful traffic, and restricts unauthorized traffic directed at your mobile stations or your enterprise networks. AT&T Wireless offers flexible options for managing IP addresses that can assist you in configuring your enterprise firewall, such as customer-supplied IP addresses. AT&T Wireless also offers a powerful feature called a Custom Access Point Name (Custom APN) where routing options can be specified such as whether mobile stations can receive unsolicited packets from external networks and whether communication with the Internet is allowed.

For more details, refer to the white paper *Secure Application Deployment with GPRS/EDGE* referenced in Section 1.3.1 of this document.

You can also deploy a VPN solution of your own choosing which extends from the VPN client on the mobile station to a VPN server located on your enterprise network. The advantage of this approach is that it secures the connection on an end-to-end basis. AT&T Wireless has extensively tested VPNs over its GPRS/EDGE network, and has found that all the major vendor solutions work well. If you are already using a specific VPN for dial-up remote access for your employees, there is a good likelihood that you can use the same VPN for GPRS/EDGE. You might also want to consider a wireless-specific VPN solution as these offer performance advantages through data compression and mobility management that allows you to maintain sessions even as you change the underlying network, such as moving from a WLAN coverage area to an EDGE coverage area.