Wireless Internet Network Communications Architecture

Definition

The communications architecture discussed in this tutorial is an open, packetbased, networking strategy that enables integration of voice, data, and multimedia for wireless mobile networks worldwide.

Overview

The Internet created a paradigm in the wireline telecommunications industry that resulted in the development of new services and applications based on Internet protocol (IP) technology. The influence of the Internet and IP technology has extended to encompass the cellular industry where standards bodies, operators, and radio access network (RAN) equipment vendors have embraced IP as the networking architecture of choice for delivering a whole new class-ofservice application offerings. This tutorial describes this wireless IP–based communications architecture and discusses some of the benefits cellular operators can expect to gain by employing it.

A brief overview of the architecture's structural components is provided along with an explanation of how its open, packet-based characteristics enable quick development and delivery of end-to-end solutions that are able to take advantage of new technology as it emerges. Future convergence paths are also explained to set the context for understanding the graceful progression to IP–based wireless technology.

Upon completion of this tutorial, you should be able to accomplish the following:

- describe the new-world, wireless IP–based communications architecture
- identify and discuss the benefits cellular operators can realize by implementing this architecture

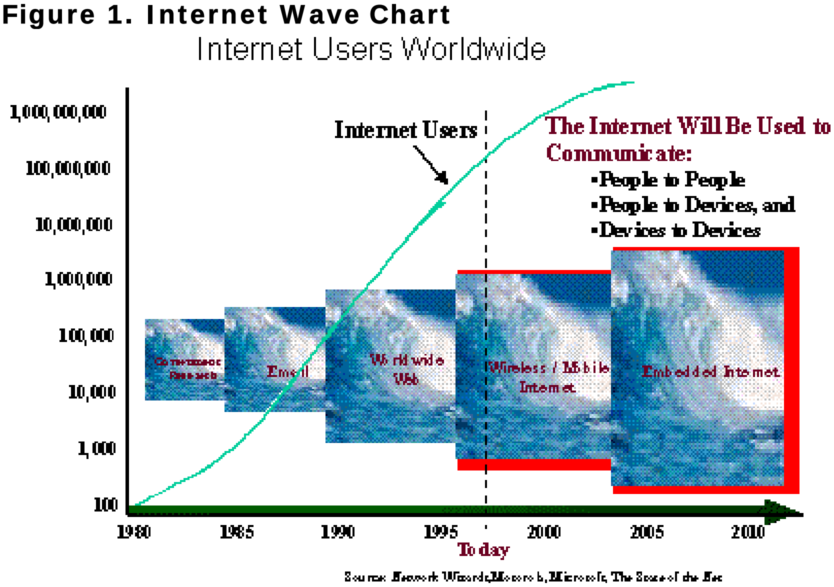
Topics

1. Introduction: IP Everywhere

The Internet is unprecedented in its impact on the world community of industries, institutions, and individuals. In some way, the Internet has touched most of our lives in terms of how we communicate, how we promote our products, how we teach our children, and how we invest our time. No media adoption curve has been faster than the Internet's. In the United States alone, it took almost 40 years for 50 million people to use radio and 15 years for 50 million people to use TV and cellular communications. Internet users reached the 50-million mark in just 5 years.

During that time, the world became increasingly mobile, defined by the take-it-with-you philosophy we have developed regarding information and our access to it. For the wireless cellular industry, that shift in attitude has created the opportunity to add mobility to Internet accessibility—effectively allowing subscribers to carry the power of the Internet with them anywhere at any time (see *Figure 1*).

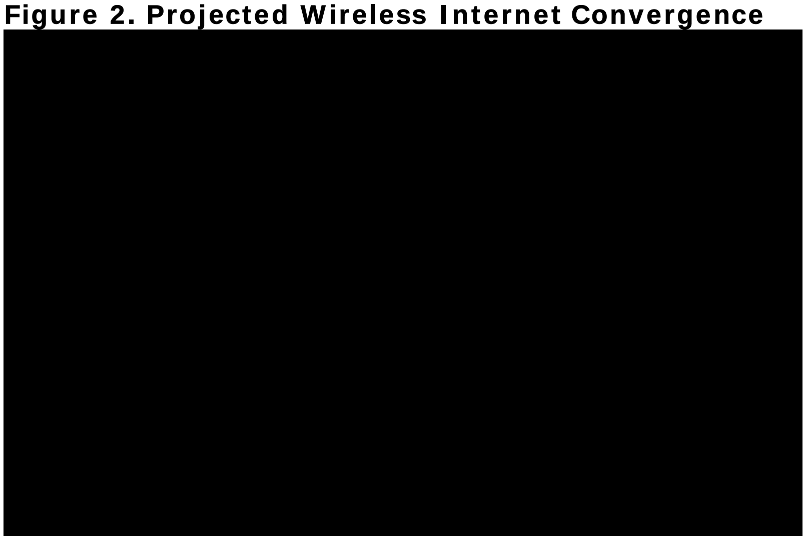
Figure 1. Internet Wave Chart



The convergence of wireless and Internet usage is already underway. Globally, Internet users as a whole are projected to increase from about 200 million at present to almost 1 billion by the year 2005. During the same period of time, global wireless subscribers are expected to increase from 300 million to over a billion.

With these market dynamics in mind, several industry-leading businesses have agreed that next-generation wireless networks will leverage the packet-based technology of IP. This strategy provides operators with the unique opportunity to deliver a multitude of new services to mobile cellular subscribers in a manner more customizable than previously possible (see *Figure 2*).

Figure 2. Projected Wireless Internet Convergence

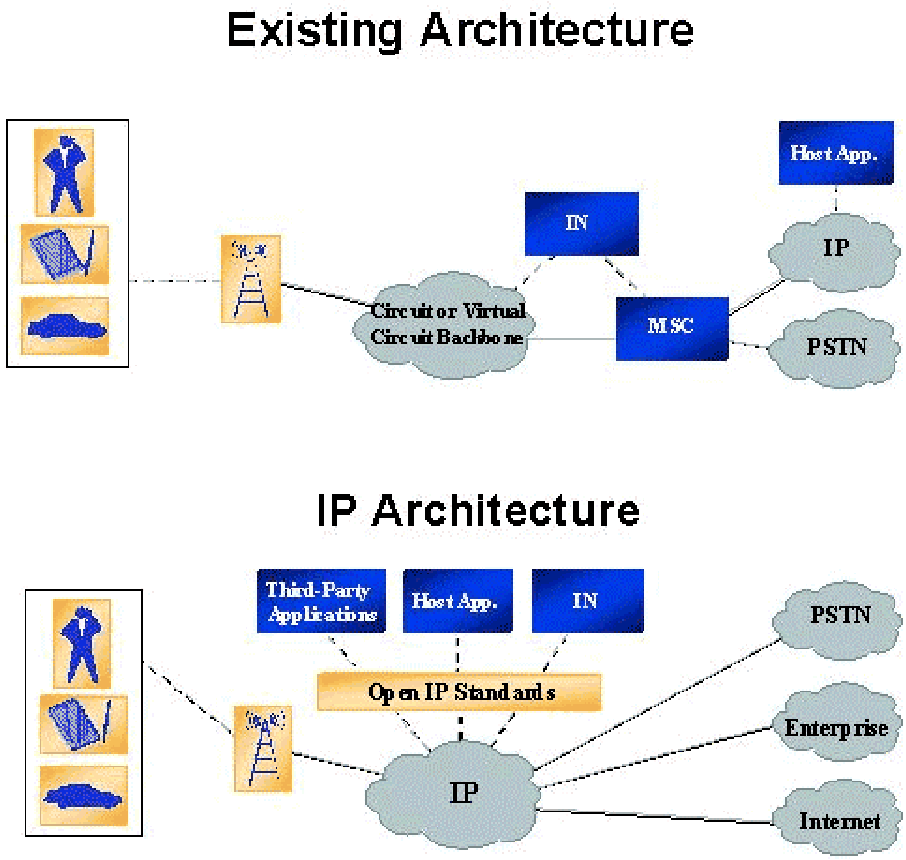


As the industry continues to invest heavily in advancing IP technology for supporting real-time applications such as voice with reliable service and toll quality, it is expected to further accelerate the introduction of new network capabilities that are defined within IP standards for network implementations.

2. Wireless Packet-Based Networking

Next-generation architecture will be flexible, open, and standards-based. It will facilitate a smooth migration from existing hierarchical circuit-switched technology to peer-to-peer, packet-switched networks. These wireless networks of the not-so-distant future will be able to take advantage of the true peer-to-peer communications technology of IP to deliver better value to service operators and end users alike (see *Figure 3*).

Figure 3. Existing Architecture versus IP Architecture



There are four key deliverables that the wireless IP network of the future must provide:

- **superior end-user experience**—The network must be customizable, easy to use, and allow fast access to all services from a single device.
- **orderly network migration**—There must be a smooth migration path from existing network protocols to the new wireless IP network, and the new network must demonstrate superior performance.
- **reduced cycle time to commercialize applications**—The network must make Internet applications easy to implement in the wireless world. Thus, existing services are made immediately available, while new applications may be made available in the wireless world at the same time or faster than they are made available to wireline users.
- **reduced cost of ownership**—The new network must make the business case for the wireless Internet achievable, particularly for worldwide operators and service providers.

3. Wireless IP: A Conceptual Model

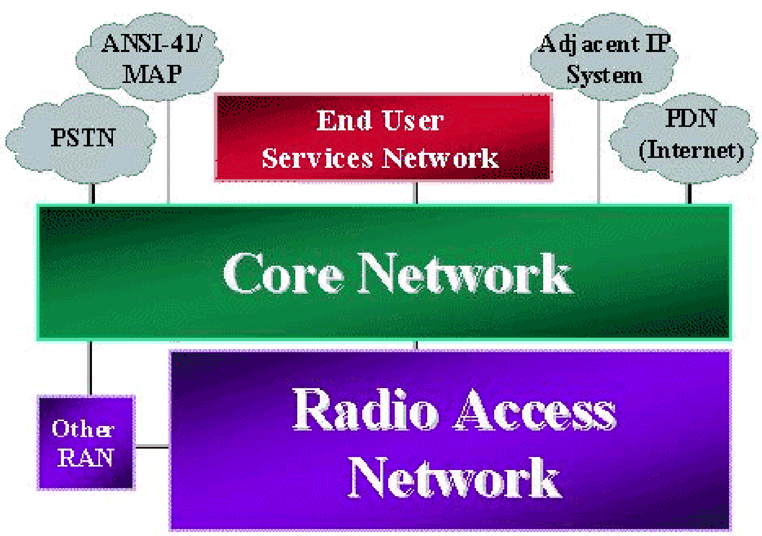
The following sections will describe a new-world, wireless IP–based network model being developed jointly by two of the world's leading communications enterprises: one in the wireless communications industry and the other in the IP–based Internet communications business. Together, these two enterprises are creating a mobile wireless IP network that meets tomorrow's requirements by providing opportunities previously only imagined. Among such opportunities is the ability to make wireless an integral part of the Internet—rather than just another access technology.

The resulting communications architecture is designed to deliver greater functionality to wireless networks by delivering value-added services coupled with superior performance. This architecture consists of the following elements:

- radio access network
- core network
- end-user services network

The architecture assures that these functional elements are seamlessly interconnected and facilitates connecting additional networks to the core network. These additional networks include the Internet and other packet-switched IP networks; traditional telephone service networks, including public switched telephone network (PSTN) and integrated services digital network (ISDN); and legacy signaling system 7 (SS7), interim standard–41 (IS–41) mobile application part (MAP) and Global System for Mobile Communications (GSM) MAP information transport networks (see *Figure 4*).

Figure 4. Wireless IP Network Architecture



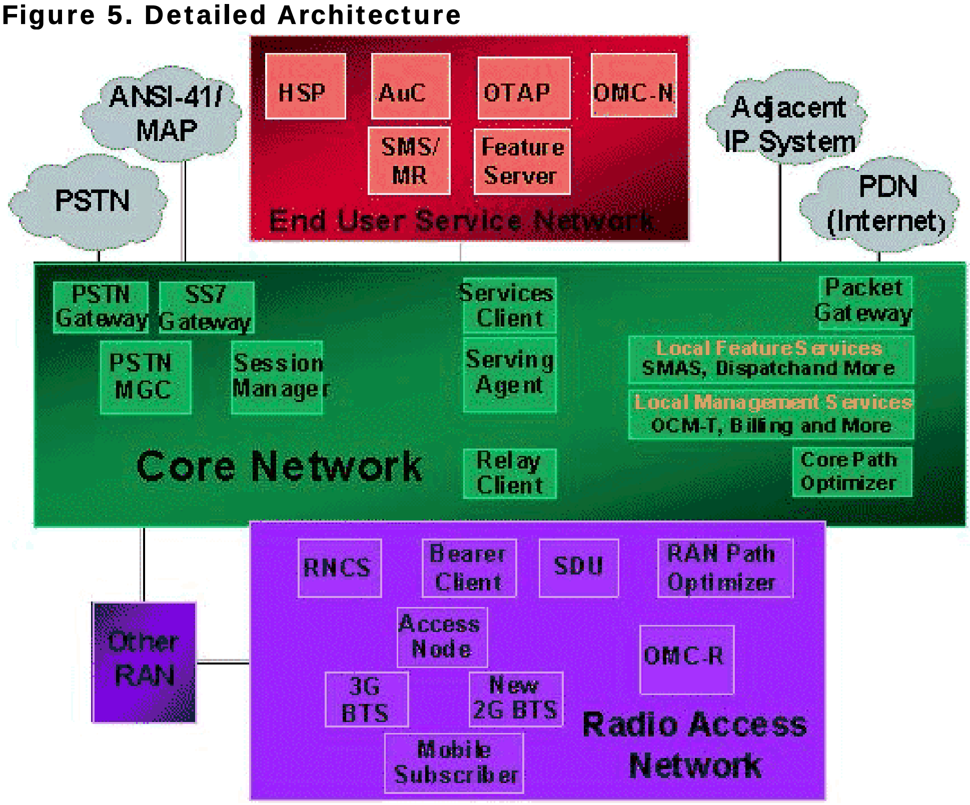
Functional Components

The architecture defines the following three service planes that contain specific functional components:

Radio Access Plane

This contains the radio access functional network elements that work together for providing the mobile subscriber network access over an air interface. The radio access network (RAN) provides the basic transmission, radio control, and management functions needed for the mobile subscriber to access the resources of the core network and the end-user services network. It is this access network that terminates the air interface to the mobile station (MS) and converts the air frames to packet format for transporting traffic between mobile subscribers or extending the reach of the mobile subscriber to other RANs and external networks. The network topology for provisioning the RAN is a key element in terms of defining the flexibility for backhaul options from the base transceiver station (BTS) to include bandwidth options that are higher than the current T1 and E1 deployments. Also, given that T1 and E1 backhaul rates will require continued support in the foreseeable future, the choice of protocol for backhaul transport becomes an important criteria for assuring maximum efficiency on the lower-speed T1 and E1 links (see *Figure 5*).

Figure 5. Detailed Architecture



Core Network Plane

This contains the functional network elements that work together for linking subscribers with feature servers and internetworking gateways to external networks such as the Internet, PSTN, corporate enterprise intranet, and other RANs. The core network also provides the interface into network management and connects RANs with mobility management, security, and signaling functions. For third-generation network deployments, the core network will be recognized as the key investment operators make for securing a superior competitive position by offering an extensive variety of services.

The core network is designed to be access technology–independent. The core network leverages IP for control and transport. The peer-to-peer network is enhanced by using client/server technology within the network, presenting the mobile subscriber with a network environment that is already familiar because of its Internet feel. The core network is designed to leverage the enhancements available by moving to packet with the definition of open interfaces to provide the operator the ability to enhance the system offering, commission features from third parties, and reduce overall operating costs. The network is a unique combination of functions that leverages the individuality imposed by a mobile network with the proven concepts of IP. The core network is designed with the understanding that an active subscriber may have multiple active sessions but may not be physically connected, thus enabling an always-connected, always-on subscriber experience. The importance of a services client acting on behalf of the subscriber and its awareness of all of the different sessions is one of the unique features found in this network architecture. The aim of the architecture is to repeat the success of open interfaces found in wireline networking. These objectives will be achieved via a core and RAN network architecture that leverages existing standards but permits the possibility of extending newly defined open interfaces for new, mobile-oriented, end-to-end services that will range from multimedia, mobile video, Web browsing, and electronic commerce.

End-User Services Plane

This plane hosts a variety of services that is available to mobile subscribers based on their access profiles. These services may be provided by operators and third-party content and service providers and include Internet and private value-added network content such as news and information, video, and other media that can be delivered to consumers through their wireless subscriber devices. The end-user services network contains specific functions and, when interoperating with core network functions, the mobile subscriber will experience the feel of a wireline network with the added value of being completely unrestricted by the bounds imposed by the wireline network. The services delivered to the subscriber will include the expected voice mobility enhanced by the expanded ability to execute any IP–based application transparently in the eyes of the subscriber. This experience will be enhanced even further with the anticipated deployment of new IP–based services specifically designed to leverage the concept of mobility.

These three architecture planes work harmoniously as layered networks for delivering complete end-to-end service to mobile subscribers.

Network Service Functionality

The fundamental premise driving the new communications architecture is the convergence of the voice and data realms. However, there are basic differences in the traditional regulation and provisioning of these services. In this model, the core network plays a central role in connecting a myriad of host services to subscriber access networks.

The architecture permits services to drive the functionality and added value of the wireless network. A key set of common functions and basic services must be supported to have a viable service offering. This key set of functions and services includes the ability for subscriber terminals to register, originate, receive, maintain (i.e., hand off or hand over), and clear voice and data sessions via one or more different media types. It also includes an initial set of supplementary services that add features to these basic call capabilities. The set of services offered will be expanded as value-added services, developed by third parties, and added to the network through open interfaces.

The common set of services enabled by the architecture is as follows:

- **packet services**—This is the data transport, providing carriage for services such as voice and data, that facilitates the delivery of wireless services. IP services include transparent support of existing IP applications and new value-added IP services that specifically leverage the advantages of a mobile environment.

- **common functions**—This is the base layer of functions, such as call registration and origination, that supports all subsequent layers of services and upon which all other layers of functions are based.

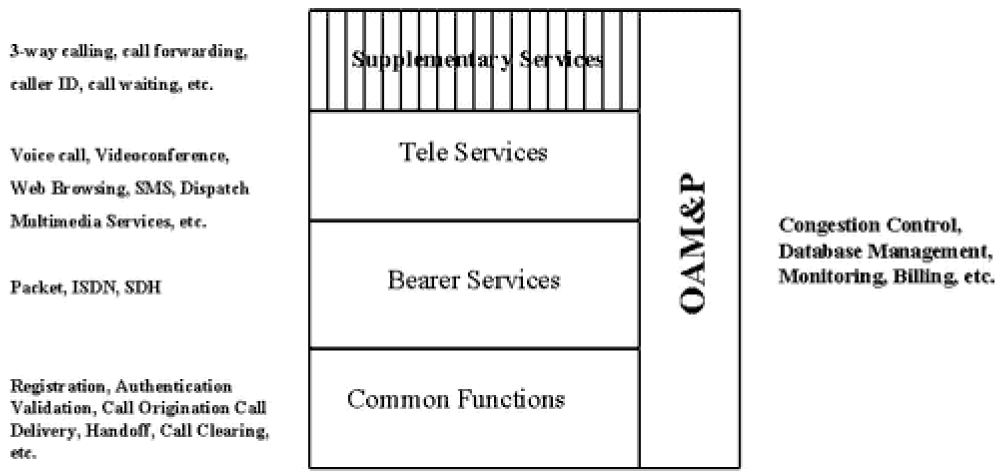
- **teleservices**—These are the basic services delivered to the end user, such as voice calls and data sessions.

- **supplementary services**—These are the enhanced teleservices, such as caller ID and teleconferencing, plus new supplementary services enabled by an IP–based services model.

- **operations, administration, maintenance, and provisioning (OAM&P)**—These are the supervisory functions, such as network monitoring and billing tracking, that keep the network operating efficiently and effectively.

- **value-added services**—These are the services residing outside the alliance architecture's core network offering that are supplied by the network operator, content provider, and enterprise and endpoint applications and services (see *Figure 6*).

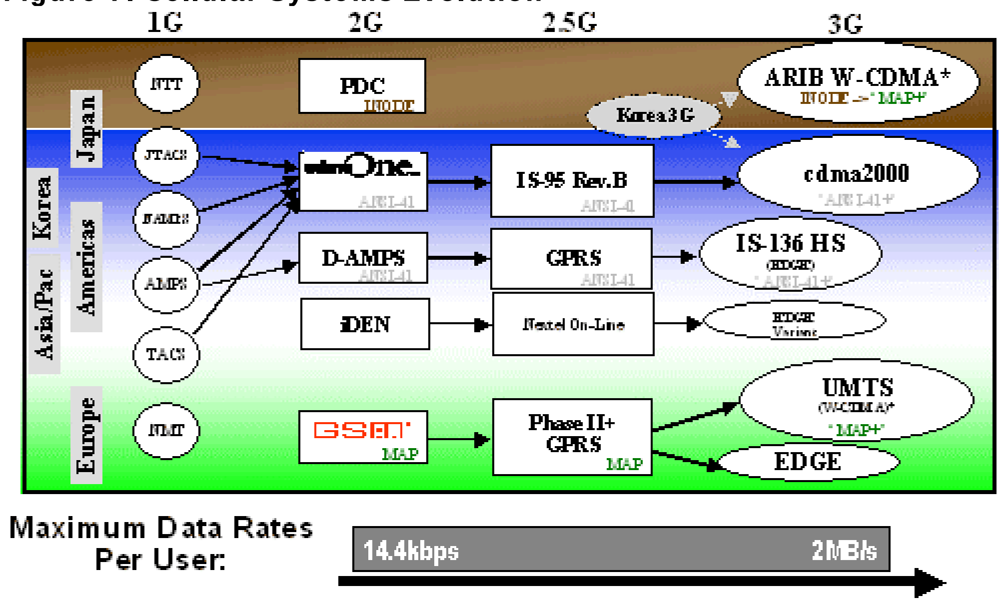
Figure 6. Service Provisions



4. Orderly Migration: A Phased Implementation

The generations of cellular systems can be categorized by their data-handling abilities. Today's second-generation (2G) systems are designed to support circuit-switched voice and rates up to 14.4 kps. The next-generation systems, including general packet radio service (GPRS) and IS–95B systems, can support packet service with data rates of 64 kbps or slightly higher. Trials for this generation are underway with such operators as France Telecom, Cellnet, and DDI in Japan. Third-generation (3G) wireless systems, which will be deployed in the year 2000, offer even higher-speed packet data services. Data rates for 3G systems will reach 384 kbps for pedestrian usage and up to 2 Mbps for fixed applications, opening opportunities for extensive wireless multimedia services (*Figure 7*).

Figure 7. Cellular Systems Evolution



As a quick recap, the reader now has a basic understanding of the functional components of the new communications architecture and a conceptual understanding of the cellular network evolution. The phased implementation discussion will now show how these various components can be gracefully added to existing networks for the following purposes:

- extending the operator's service offering to include high-speed packet data services
- using the deployment of data services for establishing the basis for building up a core network
- leveraging the core network for extending subscriber reach to other external networks and enhancing operator service-delivery opportunities

Phase-One Implementation

GSM and cdmaOne networks are circuit-oriented, and the service offerings delivered by these circuit networks have been focused primarily on voice and simple paging services. Beginning in 1998, there have been small deployments of data-enabling network elements—but in a circuit-mode rather than a packet mode. Packet mode reduces the dependency on the mobile switching center (MSC) for delivering data services; i.e., the data network connection is directly connected to the RAN, instead of being routed through the MSC. Enabling packet data services off the RAN and bypassing the MSC is the beginning step for separating the circuit-based world of the PSTN and the packet-based worlds of public data networks (PDNs) and the Internet.

Phase one for implementing the architecture begins with deploying GPRS or the public switched data network (PSDN) for enabling packet data services in GSM and cdmaOne networks. The alliance offers a complete GPRS solution that includes both the serving GPRS serving node (SGSN) and gateway GPRS serving node (GGSN) frame relay, asynchronous transfer mode (ATM), or some other link-layer transport capable of carrying IP packets. This wide-area, IP–based network is referred to as the GPRS data network and is regarded as a data overlay network. The SGSN plays the important role of interfacing with the RAN and mobility management elements of the GSM network—all of which have been upgraded in some respect for enabling packet data services in a circuit-based RAN network. A subscriber with a GPRS–enabled mobile station can initiate a packet data session via the RAN to the SGSN. The SGSN can route the data between it and the MS to another SGSN or to the GGSN for accessing an external data network. The GGSN is the IP gateway into external data networks, and it can deliver to the MS IP–based data services that are consistent with the look and feel of the Internet or other IP–based networks the subscriber may be accustomed to accessing via a wireline environment.

For cdmaOne networks, the alliance is offering the 3G PDSN for enabling packet data services. The PDSN can connect to the RAN locally to the base station controller (BSC), or—much like the GPRS implementation—the PDSN can connect over a wide-area, IP–based network using frame relay, ATM, or some other link-layer transport capable of carrying IP packets.

The phase-one implementation can be succinctly articulated as leveraging the deployed, IP–enabling, data services–network elements as the foundation for creating a core IP–based network. This core network will provide interoperability between RANs and connectivity to external networks and support the feature servers operators will deploy for increasing the number and variety of subscriber services. It will also provide the flexibility for fast deployment of new service offerings.

Phase-Two Implementation

Phase-two implementation can be planned by operators as a sequential step after completing phase one or as a parallel step to be implemented along with the deployment of phase one. In other words, as phase one requires the deployment of IP–enabling network elements, the operator can select data-enabling network elements that can also enable those functions associated with a core network. Data services itself will be a core network feature function representing a pooled resource for many RANs. This parallel phase-two implementation strategy helps the operator future-proof the network by planning the core network as a logical expansion of the data services network. The core network will be delivering IP–based services to the subscriber, and these services will include both voice and data applications.

Phase-Three Implementation

The synergy with phased investments already made begins to have its greatest impact for the operator in terms of reducing the network operations and provisioning costs and increasing new streams of revenue associated with the flexible creation and scalable deployment of new subscriber service offerings. Phase three is the build out of the core with internetworking gateways, packet voice call-control and signaling, and the new feature servers that will generate revenue streams for the operator.

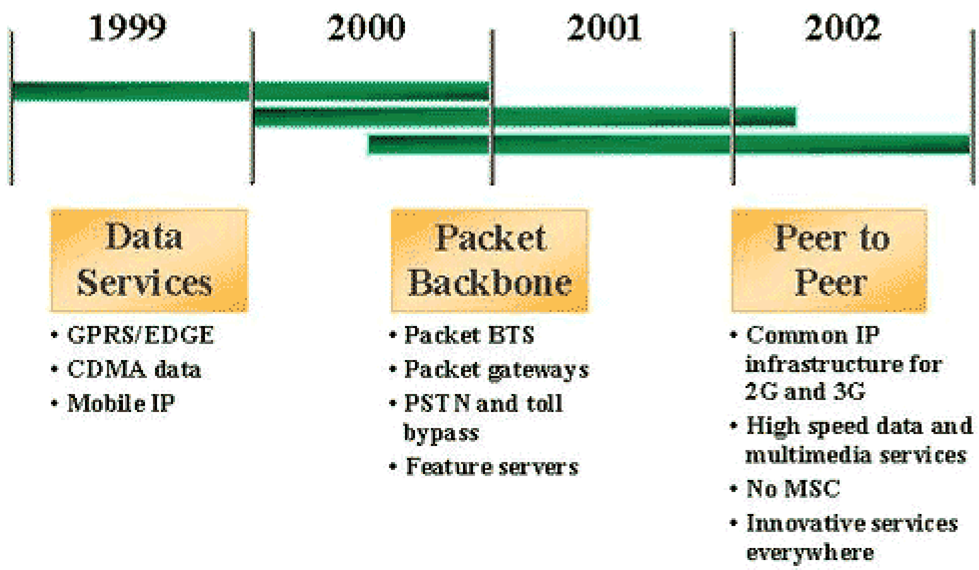
The role of the circuit-based MSC will continue to regress in favor of the statistical gains delivered by packet voice and IP–based authentication, security, and mobility management. The circuit gateway will functionally migrate to the MSC for providing MS to PSTN or PSTN to MS call control. Digital signal processors (DSPs) on the circuit gateway will hold the vocoding algorithms for converting between a voice call encapsulated in an air interface frame and pulse code modulation (PCM). The voice-over–IP (VoIP) gateway function could be provided as an extended feature to the circuit gateway or the PDSN and the new 3G SGSN for universal mobile telecommunications system (UMTS) networks. The VoIP gateway will hold the vocoding algorithms converting between a voice call encapsulated in an air interface frame and an IP end point that may be an IP–enabled phone, enterprise IP–based private branch exchange (PBX), personal computer (PC), or any other voice-enabled IP device.

The feature servers play the role of service creation and service delivery, and the session manager working with the home service provider (HSP) provides subscriber authentication. Combined with the core network, the operator will be positioned to offer end-to-end, IP–based services and differentiate subscriber access to these services based on class of service, with class of service having quality-of-service (QoS) associations. A subscriber can be offered a menu of services and classes, and the operator can custom-tailor a service subscription to the needs of the individual while leveraging the savings and synergies produced by the whole of the subscriber population.

Broad Timing for Phased Implementation

All discussions of timing are ultimately qualified by the characteristics of the market that a specific operator is operating within and the business plans unique to each operator; e.g., new spectrum licenses are required for UMTS, wideband code division multiple access (W–CDMA), and personal communications system (PCS) bands. Therefore, timing will be discussed in a more general context of radio technology, geographic region, and what has been articulated by operators either directly or indirectly via industry research organizations (see *Figure 8*).

Figure 8. Projected Roll Out



In the context of radio technology, there are three 2G technologies that are creating a plan for offering 3G cellular services: GSM, CDMA, and time division multiple access (TDMA). Operators for all three technologies are considering delivering packet data services as follows:

- GSM via GPRS
- CDMA via the packet data serving node (PDSN) or IWU
- TDMA via GPRS

GPRS packet data services will be deployed in network trials during the second half of 1999 with commercial service deployment anticipated by early 2000. GSM operators around the world are expressing strong interest in being the first in their markets to deliver GPRS packet data services. While many of the trials are in Europe (having the greatest density of GSM subscribers), the rest of the world's GSM operators are equally enthusiastic.

CDMA packet data services share many of the same issues as GPRS with respect to the MS being the limiting element for delivering the higher-speed data rates promised by 3G radio. The general availability of CDMA packet data services will begin in Japan and Korea in mid-2000, while most North American operators will commercially deploy packet data services by the early part of 2001.

Earlier in 1999, TDMA operators elected to forego their own packet data services development in favor of adopting GPRS for its time-to-market advantages. The time frame for GPRS trials in TDMA networks is anticipated by early 2000. Commercial availability is expected during mid-2000.

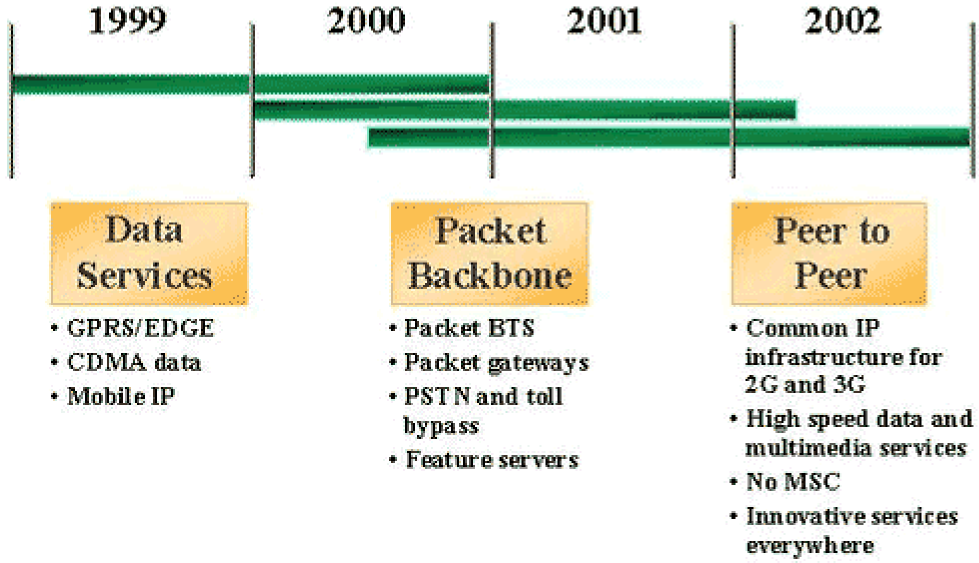
Core network deployments in phase two are anticipated to begin with those visionary operators who already recognize the many advantages associated with creating a core network infrastructure. These operators clearly understand the core network as a prerequisite for implementing a 3G radio network and supporting the interoperability with 2G and other external networks. Core network request for information (RFIs) and request for proposal (RFPs) have already been issued, and vendor decisions will be made during the balance of 1999. For some operators, the core network is simply an extension of IP data networks already in place. For others, the core network is a new step away from the circuit-based networks they understand so well.

The build out of the core network with internetworking gateways and feature servers will begin immediately after the core is provisioned. The packet data gateways already discussed will become a pooled resource available to many RANs for delivering new classes of IP data services. VoIP and circuit gateway trials will be initiated, and, as call control for VoIP matures, so will the increase in voice traffic as an IP service with a correlated decrease in the voice calls traversing the MSC.

5. Summary: Advantages of the New Wireless IP Communications Architecture

A new communications architecture that will enable true peer-to-peer wireless communication and client/server operation is being developed jointly by leaders in the mobile communications and Internet networking industries. The resulting new architecture will deliver a world-class, IP–based networking solution to wireless network operators worldwide. The architecture supports current wireless standards and assists operators in their migration efforts to the emerging 3G wireless systems.

Figure 9. Wireless IP Vision and Value Proposition for Global Operators



Four primary attributes of the architecture and the value propositions they represent for network operators are as follows:

- **superior end-user experience**—The architecture specifically targets the open philosophy and application-enabling capacity of IP for creating an RAN and core network infrastructure designed with the subscriber in mind and tuned for supporting the many new feature characteristics delivered by innovations in mobile station technology. The mobile subscriber will enjoy a freedom unequaled by other network access and service-delivery systems.

- **orderly operator network migration**—The architecture provides operators with an orderly migration path to IP–based networking for achieving peer-to-peer, nonhierarchical communication and a client-server operation while maintaining interoperability with the existing RAN infrastructure. An operator can introduce new, IP–based services while maintaining support for existing services and capabilities. Furthermore, each operator can choose how and at what speed it should deploy 3G wireless systems. A distributed network model will demonstrate significant gains in system performance, quality of service (QoS) capacity, and scalability. Operations costs will be reduced, and more intelligent operations, maintenance, and provisioning will be enabled across the network.

- **reduced cycle time to commercialize applications**—The architecture permits the separation of subscriber services and the wireless network, thereby enabling network operators flexibility in deploying end-user services and applications independent of wireless switch manufacturers. Through open, external application programming interfaces (APIs), operators and third-party developers are able to deliver new features and applications in a rapid fashion. The end result is an expanded solution set, with faster and more economical deployment for generating new revenue streams for the operator.

- **reduced cost of ownership**—The architecture will provide the framework for innovative technology enhancements. The wireless network will include features such as an interworking function to optimize the bearer path and processing resources to ensure that the right resources are being assigned for optimal service delivery. Network operators can reduce operating costs through the higher efficiencies and scaling of IP packet transport. The distributed client/server operation of the network allows network functions to be co-located or spread out to allow for greater operational efficiency and reduced costs.

Self-Test

1. Standards bodies, operators, and RAN equipment vendors have embraced _________ as the networking architecture of choice.

   a. ATM

   b. IP

   c. frame relay

2. No media adoption curve has been faster than the Internet's.

   a. true

   b. false

3. The _____________ provides mobile subscriber network access over an air interface.

   a. core network plane

   b. end-user services plane

   c. radio access plane

4. The _____________ provides the interface into network management.

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    b. end-user services plane

    c. radio access plane

5. The _____________ contains specific functions that will enable subscribers to experience the feel of a wireline network without the restrictions.

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    b. end-user services plane

    c. radio access plane

6. According to the wireless IP conceptual model, the __________ plays a central role in connecting a myriad of host services to subscriber access networks.

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    b. end-user services plane

    c. radio access plane

7. ____________ are the services residing outside the alliance architecture's core network offering that are supplied by the network operator and content provider.

    a. Packet services

    b. Teleservices

    c. Value-added services

    d. Supplementary services

8. GSM and cdmaOne networks are packet-oriented.

    a. true

    b. false

9. The role of the circuit-based MSC will continue to regress in favor of the gains delivered by the packet voice and IP–based authentication, security, and mobility management.

    a. true

    b. false

10. A new communications architecture that will enable true peer-to-peer wireless communication and client-server operation is being developed jointly by leaders in the wireline and Internet industries.

    a. true

    b. false

Correct Answers

1. Standards bodies, operators, and RAN equipment vendors have embraced _________ as the networking architecture of choice.

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    See Overview.

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    See Topic 1.

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10. A new communications architecture that will enable true peer-to-peer wireless communication and client-server operation is being developed jointly by leaders in the wireline and Internet industries.

   a. true

   b. false

   See Topic 5.

Glossary

API
application programming interface

ATM
asynchronous transfer mode

BSC
base station controller

BTS
base transceiver station

CDMA
code division multiple access

DSP
digital signal processor

GGSN
gateway GPRS serving node

GPRS
general packet radio service

GSM
Global System for Mobile Communications

HSP
home service provider

IP
Internet protocol

ISDN
integrated services digital network

MAP
mobile application part

MS
mobile station

MSC
mobile switching center

OAM&P
operations, administration, maintenance, and provisioning

PBX
private branch exchange

PCM
pulse code modulation

PCS
personal communications system

PDN
public data network

PDSN
packet data serving node

PSDN
public switched data network

PSTN
public switched telephone network

QoS
quality of service

RAN
radio access network

RFI
request for information

RFP
request for proposal

SGSN
serving GPRS serving node

SS7
signaling system 7

TDMA
time division multiple access

UMTS
universal mobile telecommunications system

VoIP
voice over IP

W–CDMA
wideband code division multiple access