Third Generation (3G) Wireless White Paper

Trillium Digital Systems, Inc.

March 2000

Trillium Digital Systems, Inc.
12100 Wilshire Blvd., Suite 1800
Los Angeles, CA 90025-7118
Phone: +1 (310) 442-9222
Fax: +1 (310) 442-1162
Web: http://www.trillium.com

Table of Contents

1. Introduction

Third Generation (3G) mobile devices and services will transform wireless communications into on-line, real-time connectivity. 3G wireless technology will allow an individual to have immediate access to location-specific services that offer information on demand. The first generation of mobile phones consisted of the analog models that emerged in the early 1980s. The second generation of digital mobile phones appeared about ten years later along with the first digital mobile networks. During the second generation, the mobile telecommunications industry experienced exponential growth both in terms of subscribers as well as new types of value-added services. Mobile phones are rapidly becoming the preferred means of personal communication, creating the world's largest consumer electronics industry.

The rapid and efficient deployment of new wireless data and Internet services has emerged as a critical priority for communications equipment manufacturers. Network components that enable wireless data services are fundamental to the next-generation network infrastructure. Wireless data services are expected to see the same explosive growth in demand that Internet services and wireless voice services have seen in recent years.

This white paper presents an overview of current technology trends in the wireless technology market, a historical overview of the evolving wireless technologies and an examination of how the communications industry plans to implement 3G wireless technology standards to address the growing demand for wireless multimedia services. Finally, this paper presents Trillium’s solutions which enable wireless communications and Internet infrastructure equipment manufacturers to develop 3G network elements for quick and efficient deployment.

2. 3G Wireless Market Drivers

Telecommunications service providers and network operators are embracing the recently adopted global third generation (3G) wireless standards in order to address emerging user demands and to provide new services. The concept of 3G wireless technology represents a shift from voice-centric services to multimedia-oriented (voice, data, video, fax) services. In addition, heavy demand for remote access to personalized data is fueling development of applications, such as the Wireless Application Protocol (WAP) and multimedia management, to complement the 3G protocols. Complementary standards, such as Bluetooth, will enable interoperability between a mobile terminal (phone, PDA etc.) and other electronic devices, such as a laptop/desktop and peripherals, providing added convenience to the consumer and allowing for the synchronization and uploading of information at all times.

According to Lehman Brothers, approximately 50 percent of current voice services subscribers are expected to use wireless data services by 2007, instead of 25 percent as previously forecast[1]. Lehman Brothers further predicts that, within seven years, 18 percent of cellular revenues and 21 percent of PCS (personal communications services) revenue will come from wireless data services. Cellular subscriptions are forecast to exceed one billion by 2003[2], compared with the 306 million that was forecast at the end of 1998, representing a compound annual growth of 29 percent. Demand for voice services has traditionally been a market driver. However, today, demand for data services has emerged as an equally significant market driver. After many years of stasis, the telecommunications industry is undergoing revolutionary changes due to the impact of increased demand for data services on wireline and wireless networks. Up until recently, data traffic over mobile networks remained low at around 2% due to the bandwidth limitations of the present second-generation (2G) wireless networks. Today, new technologies are quickly emerging that will optimize the transport of data services and offer higher bandwidth in a mobile environment. As a case in point, the increased use of the Internet as an acceptable source for information distribution and retrieval, in conjunction with the increased demand for global mobility has created a need for 3G wireless communications protocols.

The third generation of mobile communications will greatly enhance the implementation of sophisticated wireless applications. Users will be able to utilize personal, location-based wireless information and interactive services. Also, many companies and corporations are restructuring their business processes to be able to fully exploit the opportunities provided by the emerging new wireless data services. Many advanced wireless services are already available today, and the introduction of 3G wireless technologies will add to their ubiquity.

---

[1] Business Wire, Feb 25, 2000
[2] Mobile Data Handbook, The Road to Mobile Internet by Merrill Lynch, 24 September 1999

3. Existing Mobile Networks

3.1 First Generation Wireless Technology

The first generation of wireless mobile communications was based on analog signalling. Analog systems, implemented in North America, were known as Analog Mobile Phone Systems (AMPS), while systems implemented in Europe and the rest of the world were typically identified as a variation of Total Access Communication Systems (TACS). Analog systems were primarily based on circuit-switched technology and designed for voice, not data.

3.2 Second Generation Wireless Technology

The second generation (2G) of the wireless mobile network was based on low-band digital data signalling. The most popular 2G wireless technology is known as Global Systems for Mobile Communications (GSM). GSM systems, first implemented in 1991, are now operating in about 140 countries and territories around the world. An estimated 248 million users now operate over GSM systems. GSM technology is a combination of Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA). The first GSM systems used a 25MHz frequency spectrum in the 900MHz band. FDMA is used to divide the available 25MHz of bandwidth into 124 carrier frequencies of 200kHz each. Each frequency is then divided using a TDMA scheme into eight timeslots. The use of separate timeslots for transmission and reception simplifies the electronics in the mobile units. Today, GSM systems operate in the 900MHz and 1.8 GHz bands throughout the world with the exception of the Americas where they operate in the 1.9 GHz band.

In addition to GSM, a similar technology, called Personal Digital Communications (PDC), using TDMA-based technology, emerged in Japan. Since then, several other TDMA-based systems have been deployed worldwide and serve an estimated 89 million people worldwide. While GSM technology was developed in Europe, Code Division Multiple Access (CDMA) technology was developed in North America. CDMA uses spread spectrum technology to break up speech into small, digitized segments and encodes them to identify each call. CDMA systems have been implemented worldwide in about 30 countries and serve an estimated 44 million subscribers.

While GSM and other TDMA-based systems have become the dominant 2G wireless technologies, CDMA technology is recognized as providing clearer voice quality with less background noise, fewer dropped calls, enhanced security, greater reliability and greater network capacity. The Second Generation (2G) wireless networks mentioned above are also mostly based on circuit-switched technology. 2G wireless networks are digital and expand the range of applications to more advanced voice services, such as Called Line Identification. 2G wireless technology can handle some data capabilities such as fax and short message service at the data rate of up to 9.6 kbps, but it is not suitable for web browsing and multimedia applications.

4. Next Generation Mobile Networks

4.1 Second Generation (2G+) Wireless Networks

As stated in a previous section, the virtual explosion of Internet usage has had a tremendous impact on the demand for advanced wireless data communication services. However, the effective data rate of 2G circuit-switched wireless systems is relatively slow -- too slow for today's Internet. As a result, GSM, PDC and other TDMA-based mobile system providers and carriers have developed 2G+ technology that is packet-based and increases the data communication speeds to as high as 384kbps. These 2G+ systems are based on the following technologies: High Speed Circuit-Switched Data (HSCSD), General Packet Radio Service (GPRS) and Enhanced Data Rates for Global Evolution (EDGE) technologies.

HSCSD is one step towards 3G wideband mobile data networks. This circuit-switched technology improves the data rates up to 57.6kbps by introducing 14.4 kbps data coding and by aggregating 4 radio channels timeslots of 14.4 kbps.

GPRS is an intermediate step that is designed to allow the GSM world to implement a full range of Internet services without waiting for the deployment of full-scale 3G wireless systems. GPRS technology is packet-based and designed to work in parallel with the 2G GSM, PDC and TDMA systems that are used for voice communications and for table look-up to obtain GPRS user profiles in the Location Register databases. GPRS uses a multiple of the 1 to 8 radio channel timeslots in the 200kHz-frequency band allocated for a carrier frequency to enable data speeds of up to 115kbps. The data is packetized and transported over Public Land Mobile Networks (PLMN) using an IP backbone so that mobile users can access services on the Internet, such as SMTP/POP-based e-mail, ftp and HTTP-based Web services. For more information on GPRS, please see Trillium's General Packet Radio Service (GPRS) White Paper at http://www.trillium.com/whats-new/wp_gprs.html

EDGE technology is a standard that has been specified to enhance the throughput per timeslot for both HSCSD and GPRS. The enhancement of HSCSD is called ECSD, whereas the enhancement of GPRS is called EGPRS. In ECSD, the maximum data rate will not increase from 64 kbps due to the restrictions in the A interface, but the data rate per timeslot will triple. Similarly, in EGPRS, the data rate per timeslot will triple and the peak throughput, including all eight timeslots in the radio interface, will exceed 384 kbps.

GPRS networks consist of an IP-based Public Mobile Land Network (PLMN), Base Station Services (BSS), Mobile handsets (MS), and Mobile Switching Centers (MSC) for circuit-switched network access and databases. The Serving GPRS Support Nodes (SGSN) and Gateway GPRS Support Nodes (GGSN) make up the PLMN. Roaming is accommodated through multiple PLMNs. SGSN and GGSN interface with the Home Location Register (HLR) to retrieve the mobile user's profiles to facilitate call completion. GGSN provides the connection to external Packet Data Network (PDN), e.g. an Internet backbone or an X.25 network. The BSS consists of Base Transceiver Stations and Base Station Controllers. The Base Transceiver Station (BTS) receives and transmits over the air interfaces (CDMA, TDMA), providing wireless voice and data connectivity to the mobile handsets. Base Station Controllers (BSC) route the data calls to the packet-switched PLMN over a Frame Relay (FR) link and the voice calls to the Mobile Switching Center (MSC). MSC switches the voice calls to circuit-switched PLMN network such as PSTN and ISDN. MSC accommodates the Visitor Location Register (VLR) to store the roaming subscriber information. The reverse process happens at the destination PLMN and the destination BSS. On the data side, the BSC routes the data calls to the SGSN, and then the data is switched to the external PDN through the GGSN or to another mobile subscriber.

Figure 1 shows a GPRS network.

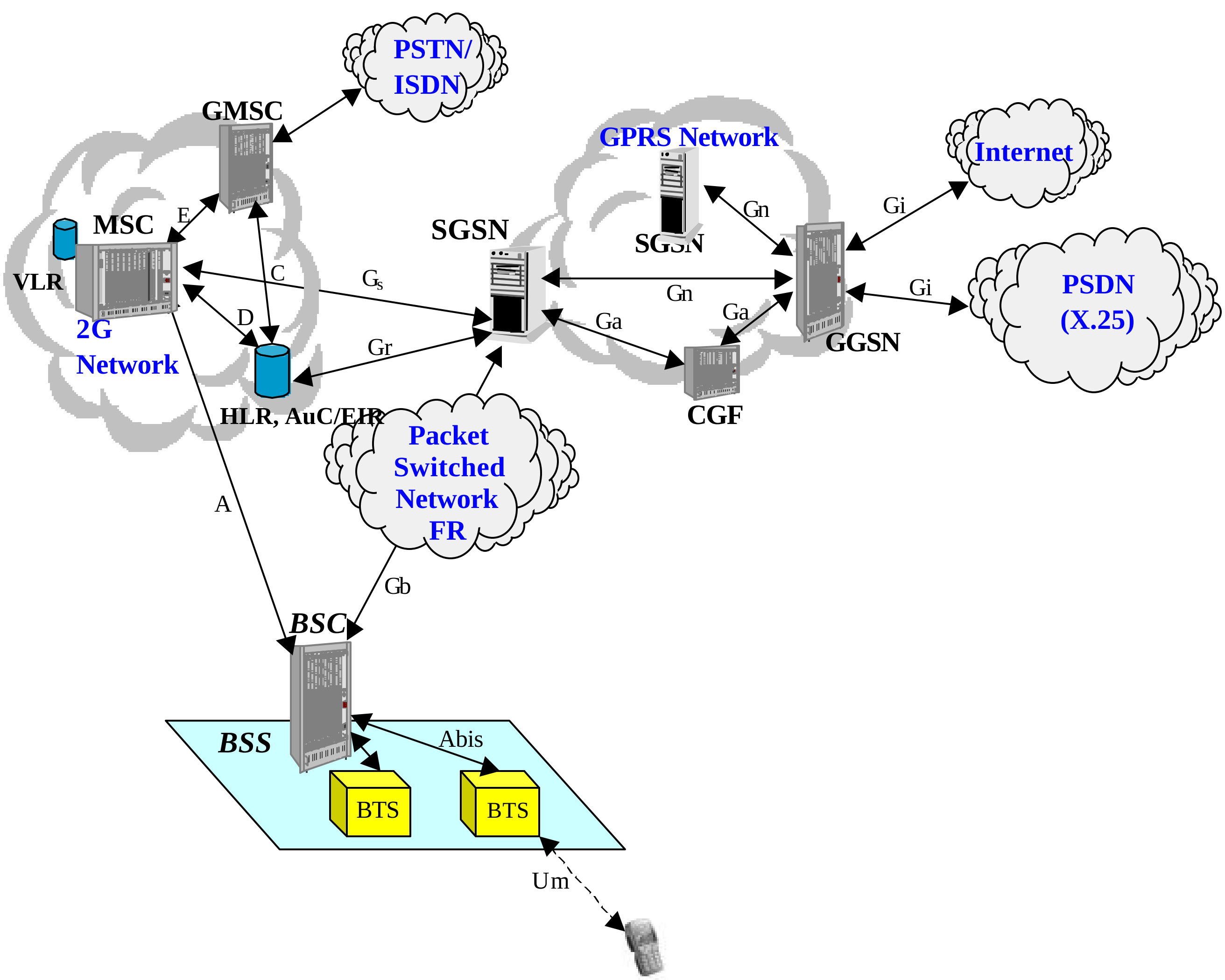
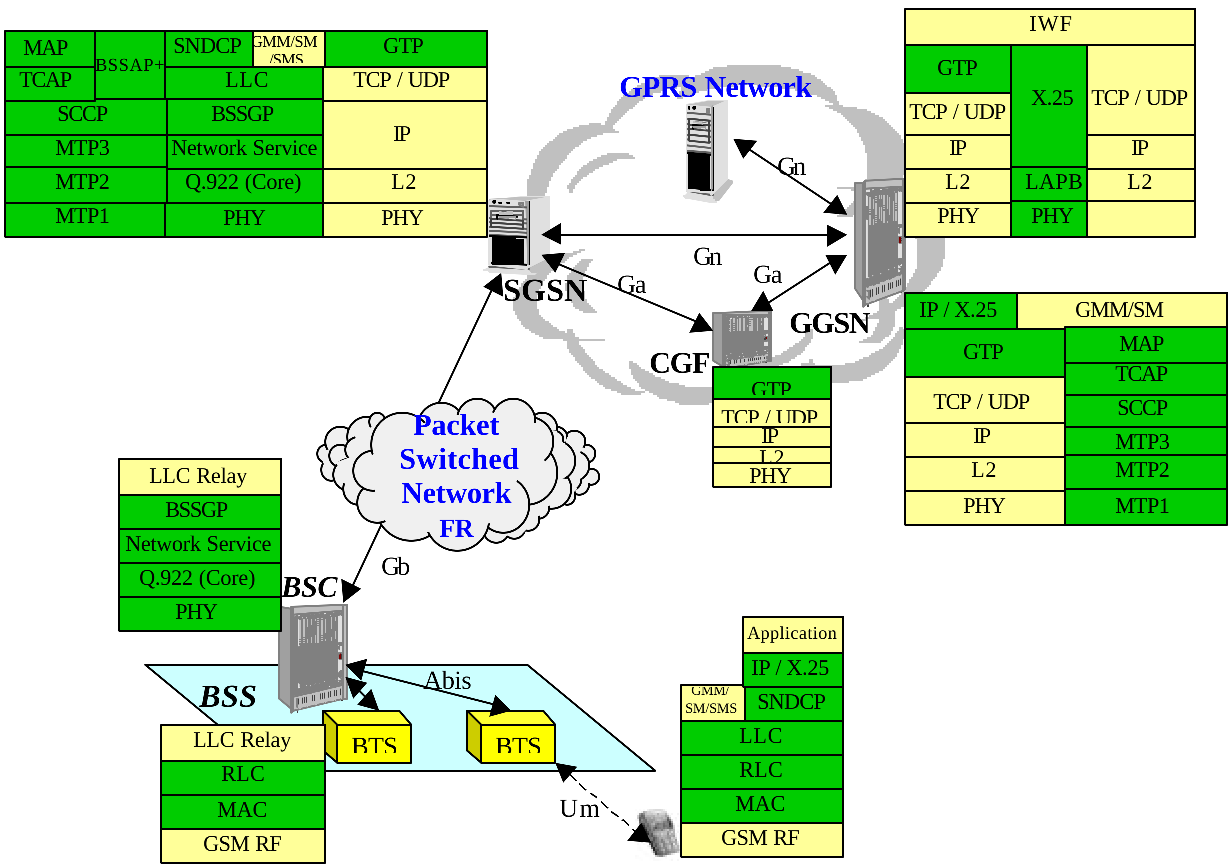


Figure 2 shows the protocols used in BTS, BSC, SGSN, GGSN, and mobile handsets:



The following is a brief description of each protocol layer in the GPRS network infrastructure:

- **Sub-Network Dependent Convergence Protocol (SNDCP)**: protocol that maps a network-level protocol, such as IP or X.25, to the underlying logical link control. SNDCP also provides other functions such as compression, segmentation and multiplexing of network-layer messages to a single virtual connection.

- **Logical Link Control (LLC)**: a data link layer protocol for GPRS which functions similar to Link Access Protocol – D (LAPD). This layer assures the reliable transfer of user data across a wireless network.

- **Base Station System GPRS Protocol (BSSGP)**: processes routing and quality of service (QoS) information for the BSS. BSSGP uses the Frame Relay Q.922 core protocol as its transport mechanism.

- **GPRS Tunnel Protocol (GTP)**: protocol that tunnels the protocol data units through the IP backbone by adding routing information. GTP operates on top of TCP/UDP over IP.

- **GPRS Mobility Management (GMM/SM)**: protocol that operates in the signalling plane of GPRS, handles mobility issues such as roaming, authentication, selection of encryption algorithms and maintains PDP context.

- **Network Service**: protocol that manages the convergence sub-layer that operates between BSSGP and the Frame Relay Q.922 Core by mapping BSSGP's service requests to the appropriate Frame Relay services.

- **BSSAP+**: protocol that enables paging for voice connections from MSC via SGSN, thus optimizing paging for mobile subscribers. BSSAP+ is also responsible for location and routing updates as well as mobile station alerting.

- **SCCP, MTP3, MTP2** are protocols used to support Mobile Application Part (MAP) and BSSAP+ in circuit switched PLMNs.

- **Mobile Application Part (MAP)**: supports signaling between SGSN/GGSN and HLR/AuC/EIR.

4.2 Third Generation (3G) Wireless Networks

3G wireless technology represents the convergence of various 2G wireless telecommunications systems into a single global system that includes both terrestrial and satellite components. One of the most important aspects of 3G wireless technology is its ability to unify existing cellular standards, such as CDMA, GSM, and TDMA, under one umbrella. The following three air interface modes accomplish this result: wideband CDMA, CDMA2000 and the Universal Wireless Communication (UWC-136) interfaces.

Wideband CDMA (W-CDMA) is compatible with the current 2G GSM networks prevalent in Europe and parts of Asia. W-CDMA will require bandwidth of between 5Mhz and 10 Mhz, making it a suitable platform for higher capacity applications. It can be overlaid onto existing GSM, TDMA (IS-36) and IS95 networks. Subscribers are likely to access 3G wireless services initially via dual band terminal devices. W-CDMA networks will be used for high-capacity applications and 2G digital wireless systems will be used for voice calls.

The second radio interface is CDMA2000 which is backward compatible with the second generation CDMA IS-95 standard predominantly used in US. The third radio interface, Universal Wireless Communications – UWC-136, also called IS-136HS, was proposed by the TIA and designed to comply with ANSI-136, the North American TDMA standard.

3G wireless networks consist of a Radio Access Network (RAN) and a core network. The core network consists of a packet-switched domain, which includes 3G SGSNs and GGSNs, which provide the same functionality that they provide in a GPRS system, and a circuit-switched domain, which includes 3G MSC for switching of voice calls. Charging for services and access is done through the Charging Gateway Function (CGF), which is also part of the core network. RAN functionality is independent from the core network functionality. The access network provides a core network technology independent access for mobile terminals to different types of core networks and network services. Either core network domain can access any appropriate RAN service; e.g. it should be possible to access a “speech” radio access bearer from the packet-switched domain.

The Radio Access Network consists of new network elements, known as Node B and Radio Network Controllers (RNCs). Node B is comparable to the Base Transceiver Station in 2G wireless networks. RNC replaces the Base Station Controller. It provides the radio resource management, handover control and support for the connections to circuit-switched and packet-switched domains. The interconnection of the network elements in RAN and between RAN and core network is over Iub, Iur and Iu interfaces based on ATM as a layer 2 switching technology. Data services run from the terminal device over IP, which in turn uses ATM as a reliable transport with QoS. Voice is embedded into ATM from the edge of the network (Node B) and is transported over ATM out of the RNC. The Iu interface is split into 2 parts: circuit-switched and packet-switched. The Iu interface is based on ATM with voice traffic embedded on virtual circuits using AAL2 technology and IP-over-ATM for data traffic using AAL5 technology. These traffic types are switched independently to either 3G SGSN for data or 3G MSC for voice.

Figure 3 shows the 3G wireless network architecture.

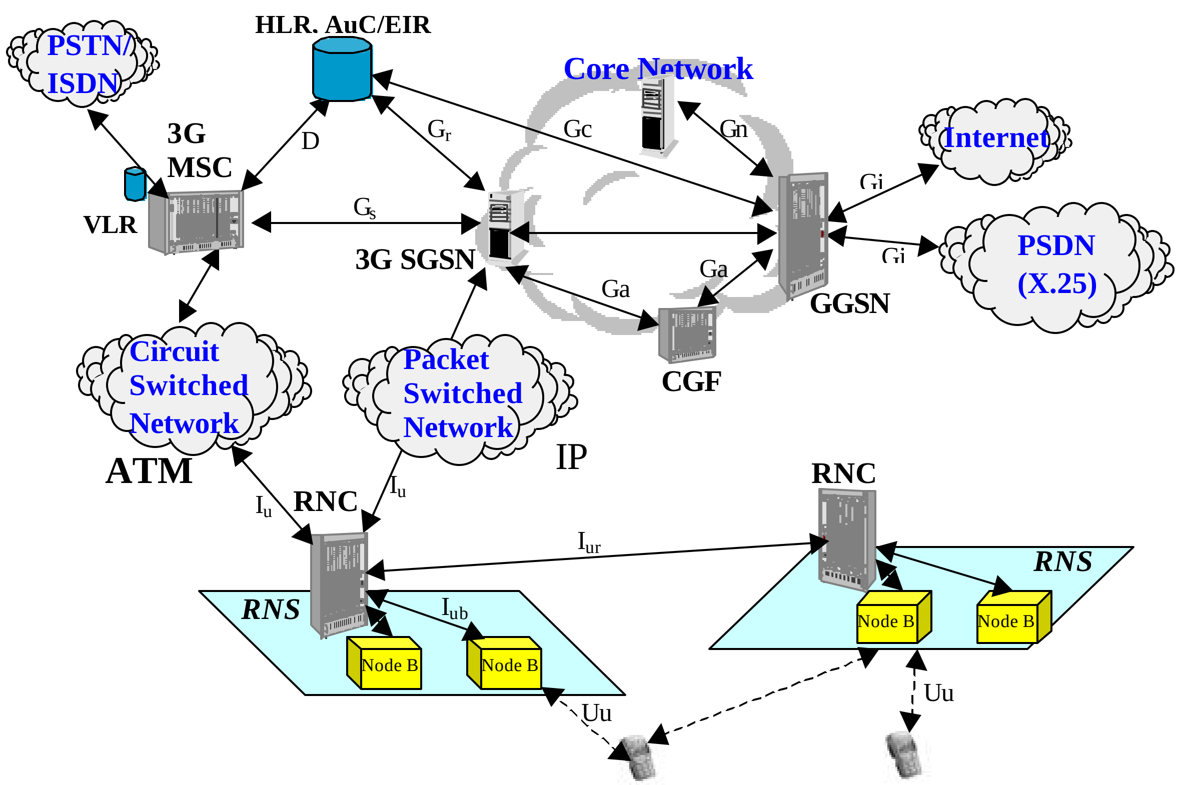
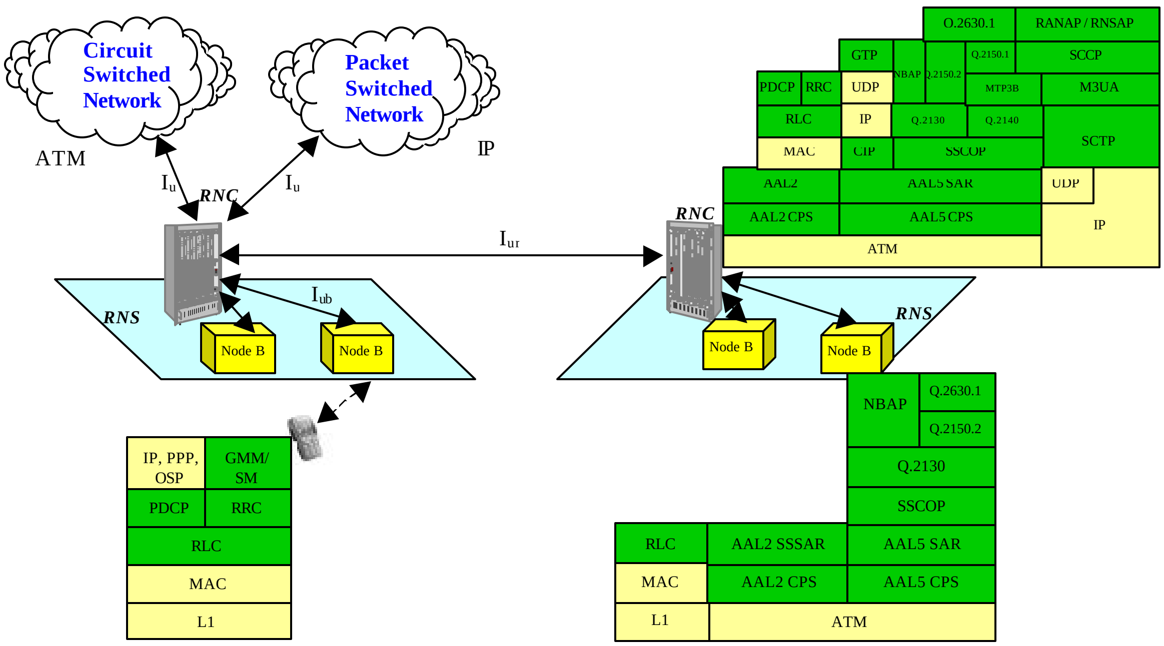


Figure 4 shows protocols used in Node B, RNC and mobile handsets.



The following is a brief description of each protocol layer in a 3G wireless network infrastructure:

- **Global Mobility Management (GMM)**: protocol that includes attach, detach, security, and routing area update functionality.

- **Node B Application Part (NBAP)**: provides procedures for paging distribution, broadcast system information and management of dedicated and logical resources.

- **Packet Data Convergence Protocol (PDCP)**: maps higher level characteristics onto the characteristics of the underlying radio-interface protocols. PDCP also provides protocol transparency for higher layer protocols.

- **Radio Link Control (RLC)**: provides a logical link control over the radio interface.

- **Medium Access Control (MAC)**: controls the access signaling (request and grant) procedures for the radio channel.

- **Radio resource Control (RRC)**: manages the allocation and maintenance of radio communication paths.

- **Radio Access Network Application Protocol (RANAP)**: encapsulates higher layer signaling. Manages the signaling and GTP connections between RNC and 3G-SGSN, and signaling and circuit-switched connections between RNC and 3G MSC.

- **Radio Network Service Application Part (RNSAP)**: provides the communication between RNCs.

- **GPRS Tunnel Protocol (GTP)**: protocol that tunnels the protocol data units through the IP backbone by adding routing information. GTP operates on top of TCP/UDP over IP.

- **Mobile Application Part (MAP)**: supports signaling between SGSN/GGSN and HLR/AuC/EIR.

- **AAL2** Signaling (Q.2630.1, Q.2150.1, Q.2150.2, AAL2 SSSAR, and AAL2 CPS): protocols suite used to transfer voice over ATM backbone using ATM adaptation layer 2.

- **Sigtran** (SCTP, M3UA): protocols suite used to transfer SCN signaling protocols over IP network.

5. Evolution to 3G Wireless Technology

Initial coverage

Initially, 3G wireless technology will be deployed as "islands" in business areas where more capacity and advanced services are demanded. A complete evolution to 3G wireless technology is mandated by the end of 2000 in Japan (mostly due to capacity requirements) and by the end of 2001 in Europe. NTT DoCoMo is deploying 3G wireless services in Japan in the third quarter of 2000. In contrast, there is no similar mandate in North America and it is more likely that competition will drive the deployment of 3G wireless technology in that region. For example, Nextel Communications has announced that it will be deploying 3G wireless services in North America during the fourth quarter of 2000.

The implementation of 3G wireless systems raises several critical issues, such as the successful backward compatibility to air interfaces as well as to deployed infrastructures.

Interworking with 2G and 2G+ Wireless Networks

The existence of legacy networks in most regions of the world highlights the challenge that communications equipment manufacturers face when implementing next-generation wireless technology. Compatibility and interworking between the new 3G wireless systems and the old legacy networks must be achieved in order to ensure the acceptance of new 3G wireless technology by service providers and end-users.

The existing core technology used in mobile networks is based on traditional circuit-switched technology for delivery of voice services. However, this traditional technology is inefficient for the delivery of multimedia services. The core switches for next-generation of mobile networks will be based on packet-switched technology which is better suited for data and multimedia services.

Second generation GSM networks consist of BTS, BSC, MSC/VLR and HLR/AuC/EIR network elements. The interfaces between BTS, BSC and MSC/VLR elements are circuit-switched PCM. GPRS technology adds a parallel packet-switched core network. The 2G+ network consists of BSC with packet interfaces to SGSN, GGSN, HLR/AuC/EIR. The interfaces between BSC and SGSN network elements are either Frame Relay and/or ATM so as to provide reliable transport with Quality of Service (QoS).

3G wireless technology introduces new Radio Access Network (RAN) consisting of Node B and RNC network elements. The 3G Core Network consists of the same entities as GSM and GPRS: 3G MSC/VLR, GMSC, HLR/AuC/EIR, 3G-SGSN, and GGSN. IP technology is used end-to-end for multimedia applications and ATM technology is used to provide reliable transport with QoS.

3G wireless solutions allow for the possibility of having an integrated network for circuit-switched and packet-switched services by utilizing ATM technology. The BSC may evolve into an RNC by using add-on cards or additional hardware that is co-located. The carrier frequency (5Mhz) and the bands (2.5 to 5Ghz) are different for 3G wireless technology compared to 2G/2G+ wireless technology. Evolution of BSC to RNC requires support for new protocols such as PDCP, RRC, RANAP, RNSAP and NBAP. Therefore, BTS' evolution into Node B may prove to be difficult and may represent significant capital expenditure on the part of network operators.

MSC evolution depends on the selection of a fixed network to carry the requested services. If an ATM network is chosen, then ATM protocols will have to be supported in 3G MSC along with interworking between ATM and existing PSTN/ISDN networks.

The evolution of SGSN and GGSN to 3G nodes is relatively easier. Enhancements to GTP protocol and support for new RANAP protocol are necessary to support 3G wireless systems. ATM protocols need to be incorporated to transport the services. The HLR databases evolve into 3G-HLR by adding 3G wireless user profiles. The VLR database must also be updated accordingly. The EIR database needs to change to accommodate new equipment that will be deployed for 3G wireless systems. Finally, global roaming requires compatibility to existing deployment and graceful fallback to an available level when requested services are not available in the region. Towards this end, the Operator Harmonization Group (OHG) is working closely with 3G Partnership Projects (3GPP and 3GPP2) to come up with global standards for 3G wireless protocols.

6. Comparison of 2G and 3G Mobile Networks

As mentioned above, although there are many similarities between 2G and 3G wireless networks (and many of the 2G and 3G components are shared or connected through interworking functions), there are also many differences between the two technologies. Table 1 compares the differences between the core network, the radio portion and other areas of the two networks.

Table 1: Comparison between 2G+ and 3G wireless networks

Feature	2G	2G+	3G
Core Network	MSC/VLR, GMSC, HLR/AuC/EIR MM, CM, BSSAP, SCCP, ISUP,TCAP, MAP, MTP 3, MTP 2, MTP 1 TDM transport	MSC/VLR, GMSC, SGSN, GGSN, HLR/AuC/EIR, CGF GMM/SM/SMS, MM, CM, GTP, SNDCP,NS, FR, LLC, BSSGP, BSSAP, BSSAP+, SCCP, TCAP, MAP, ISUP, MTP 3, MTP 2, MTP 1 TDM, Frame Relay transport	3G MSC/VLR (with added interworking and transcoding), GMSC, HLR/AuC/EIR, 3G-SGSN, GGSN, CGF GMM/SM,MM,CM,BSSAP, RANAP,GTP,SCCP, MTP3B, M3UA, SCTP, Q.2630.1 (NNI), TCAP, MAP, ISUP, MTP 3, MTP 2, MTP 1, Q.2140, SSCOP ATM, IP transport
Radio Access	BTS, BSC, MS FDMA, TDMA, CDMA MM, CM, RR, LAPDm, LAPD, BSSAP, SCCP, MTP 3, MTP 2, MTP 1	BTS, BSC, MS TDMA, CDMA, EDGE MAC, RLC, GMM/SM/SMS, LLC, SNDCP, BSSGP, NS, FR,RR, BSSAP, SCCP, MTP 3, MTP 2, MTP 1	Node B, RNC, MS W-CDMA, CDMA2000, IWC-136 GMM/SM, MAC, RLC, PDCP,RRC,Q.2630.1(UNI+ NNI),NBAP, RNSAP, RANAP, SCCP, MTP3B, M3UA, SCTP, GTP-U, Q.2140, Q.2130, SSCOP, CIP
Handsets	Voice only terminals	New type of terminal Dual mode TDMA and CDMA Voice and data terminals WAP, no multimedia support	New type of terminal Multiple modes Voice, data and video terminals WAP, multimedia mgmt
Databases	HLR, VLR, EIR, AuC	HLR, VLR, EIR, AuC	Enhanced HLR, VLR, EIR,AuC
Data Rates	Up to 9.6 Kbps	Up to 57.6 Kbps (HSCSD) Up to 115Kbps (GPRS) Up to 384 Kbps (EDGE)	Up to 2Mbps
Applications	Advanced voice, Short Message Service (SMS)	SMS, Internet	Internet, multimedia
Roaming	Restricted, not global	Restricted, not global	Global
Compatibility	Not compatible to 3G	Not compatible to 3G	Compatible to 2G, 2G+ and Bluetooth

7. Trillium 3G Wireless Solutions

Trillium offers an extensive wireless software solution portfolio for existing 2G network and for upcoming GPRS and 3G wireless systems. In addition to the protocols shown below, Trillium also offers Fault-Tolerance/High-Availability and distributed architecture enhancements to all system solutions. Trillium's solutions are shown in Tables 2 and 3 below.

Table 2: Trillium's GPRS Software Solutions (underlined)

Device Description	Required Protocols
BTS (Base Transceiver Station) - Responsible for radio transmission / reception in one or more cells within a service area to/from the mobile handsets.	<u>RLC</u>/MAC
BSC (Base Station Controller) - Responsible for controlling the use and the integrity of the radio resources.	<u>NS, BSSGP, Q.922(core</u>)
2G-SGSN (Serving GPRS Node) - Provides voice and packet data services and management of mobile subscribers.	<u>SNDCP, BSSAP+, LLC, BSSGP, NS, Q.922 (core), GTP, MAP, TCAP,SCCP, MTP3, MTP2, MTP 1,</u> GMM/SM/SMS
2G-GGSN (Gateway GPRS Node) - Provides a gateway interface to external Packet Data Networks (PDN) and manages the routing of the tunneled mobile network protocol data units (PDUs) across the PDN.	<u>GTP, MAP, TCAP, SCCP, MTP 3, MTP 2, MTP 1,</u> GMM/SM, <u>X.25</u>, <u>LAPB</u>
2G-CGF (Charging Gateway Function) - responsible for billing services	<u>GTP`</u>
2G-MS - The 2G mobile station (handset) enhanced to provide users enhanced voice and data services.	GMM/SM/SMS<u>, SNDCP, RLC</u>/MAC, <u>LLC</u>
2G-HLR/AuC/EIR –The 2G Home Location Register Database with User Profiles	<u>MAP,TCAP,SCCP,MTP3, MTP 2, MTP 1</u>
2G-MSC/VLR – The 2G Mobile Switching Center and Visitor Location Register Database	<u>BSSAP+,SCCP,MTP3, MTP2, MTP 1</u>

Table 3: Trillium's 3G Wireless Software Solutions (underlined)

Device Description	Replaces 2G/2G+	Required Protocols
Node B - Responsible for radio transmission / reception in one or more cells within a service area to/from the mobile handsets.	Base Transceiver Station (BTS)	RLC/MAC, NBAP, AAL2 Signaling,Q.2130, SSCOP
RNC (Radio Network Controller) - Responsible for controlling the use and the integrity of the radio resources.	Base Station Controller (BSC)	PDCP, RLC/MAC, RRC, RANAP, RNSAP, NBAP, AAL2 Signaling, SIGTRAN (SCTP/M3UA), GTP, Q.2130, SSCOP, Q.2140, MTP3B, SCCP, CIP
3G-SGSN (Serving GPRS Node) - Provides voice and packet data services and management of mobile subscribers.	2G SGSN	RANAP, SCTP/M3UA, GTP, Broadband SS7 (SCCP, MTP3B, Q.2140, SSCOP), CIP, GMM/SM/SMS, MAP, TCAP, MTP 2, MTP 1
3G-GGSN (Gateway GPRS Node) - Provides a gateway interface to external Packet Data Networks (PDN) and manages the routing of the tunneled mobile network protocol data units (PDUs) across the PDN.	2G GGSN	GTP, MAP, TCAP, SCCP, MTP 3, MTP 2, MTP 1
3G-CGF (Charging Gateway Function) - responsible for billing services	2G-CGF	GTP'
3G-MS - The 3G mobile station (handset) enhanced to provide users enhanced voice and data services.	2G-MS	GMM/SM, PDCP, RLC/MAC, RRC
3G-HLR/AuC/EIR –The 3G Home Location Register Database with User Profiles	2G-HLR/AuC/EIR	MAP,TCAP,SCCP,MTP3, MTP 2, MTP 1
3G-MSC/VLR – The 3G Mobile Switching Center and Visitor Location Register Database	2G-MSC/VLR	BSSAP+,ISUP,SCCP,MTP3, MTP 2, MTP 1, RANAP, SCCP, Q.2140, SSCOP, AAL2 Signaling

8. About Trillium

Trillium Digital Systems is the leading provider of communications software solutions for the converged network infrastructure. Trillium's source code solutions are used in more than 500 projects by industry-leading suppliers of wireless, Internet, broadband and telephony products. Trillium's high-performance, high-availability software and services reduce the time, risk and cost of implementing SS7, IP, H.323, MGCP, ATM, Wireless and other standards-based communications protocols.

Trillium actively participates in the development of 3rd generation systems by developing standards-based wireless communications protocols. It is likely that the first 3G mobile terminals will be multi-mode devices, which means that they will support a number of 2nd generation protocol standards in order to reach wide network coverage and to provide 3rd generation advanced services. Trillium has extensive know-how in all the major communications protocol standards in the world and can provide solutions for many types of networks.

Trillium designs all its portable software products using the Trillium Advanced Portability Architecture (TAPA™), a set of architectural and coding standards that ensure the software is completely independent of the compiler, processor, operating system and architecture of the target system. This makes Trillium products portable, consistent, reliable, high quality, high performance, flexible, and scaleable. This architecture also ensures that all Trillium protocols can interwork seamlessly in the same or between different networks.

As mentioned above, successful implementation, adoption, and overall acceptance of the 3G wireless networks depends largely on the ability of these new mobile networks to interface and interwork with the existing 2G and legacy networks currently deployed worldwide. Trillium offers a broad range of protocols for first- and second-generation mobile networks, legacy networks, and fixed networks. Trillium's products allow wireless communications equipment manufacturers to develop "best-in-class" next-generation mobile networks, to ensure success of the network operator and service provider, and to ensure wide acceptance of the new services by end-users.

Additional information is available at http://www.trillium.com.