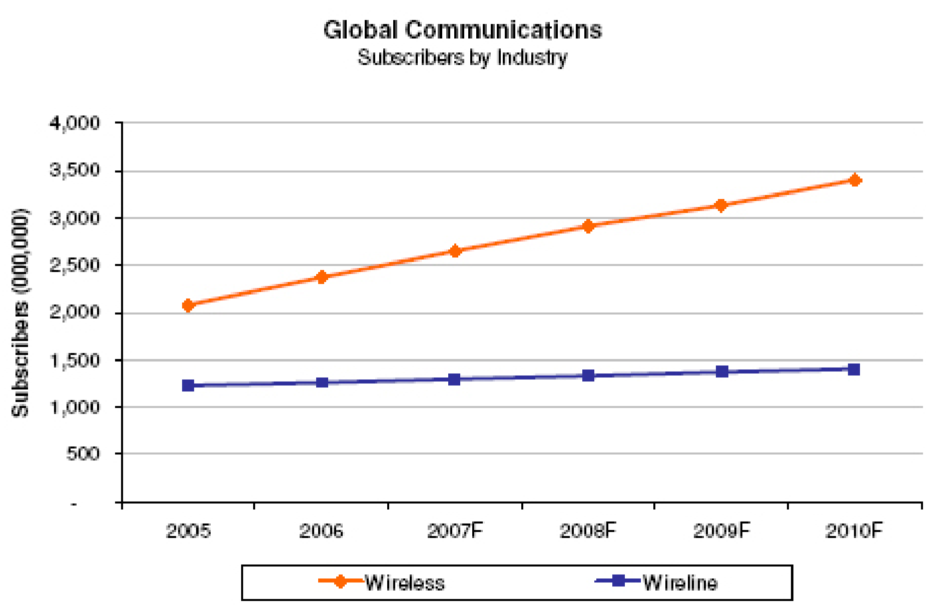
White Paper

Mobile Networks Tutorial

Introduction

The wireless industry has grown dramatically in the past 10 years, surpassing the number of wireline subscribers since 2001. Subscribers are giving additional value to mobile phones devices which have become much more than just for communication, with the adoption of 3G technology, mobiles are now multimedia devices delivering a variety of applications including music, games, video, internet, and e-mail among others.



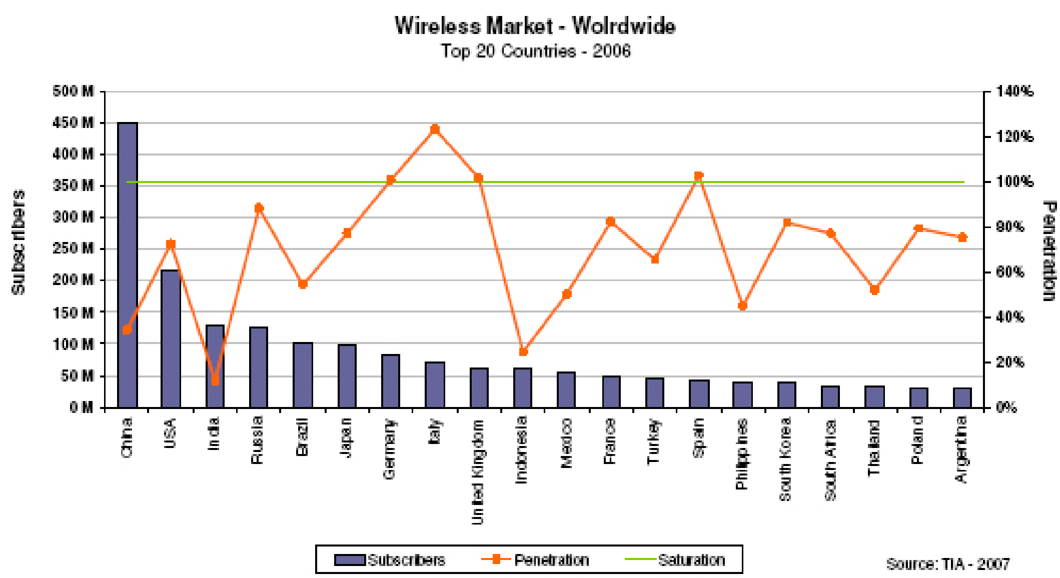
Source: TIA 2007

In addition, the wireless industry is expected to have a sustainable growth in the next 4 years, where the compound annual growth rate from 2005 to 2010 is estimated at 10.3%. The drivers for this growth differ from each network, but they can be categorized in the three following areas:

- Service coverage, several countries still have a low penetration rate and their investment priority is to expand their network and offer mobile services to more users.

- Quality of service, countries that have several competing mobile operators have gone from quantitative to qualitative where quality of service is their priority in order to gain market share.
- Network upgrades and new applications, countries that have reach coverage and service quality are expanding the applications to users including services such as location, gaming, music, and video.

The top 20 countries base on the number of wireless subscribers that are driving most of the industry's investments are the following:



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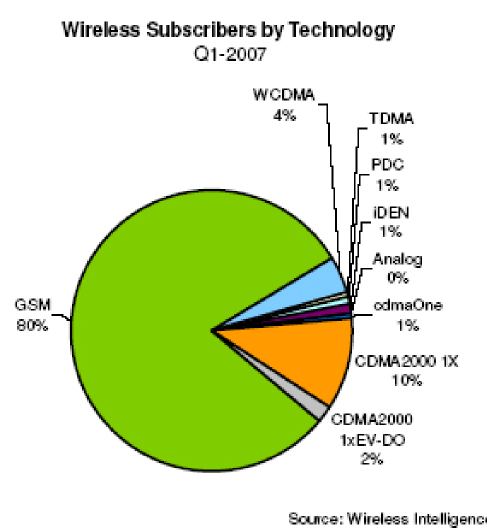


Wireless communications have evolved from analog (AMPS) to digital (TDMA and CDMA).

The technology that is dominating the market is GSM (2G) with 80% of the global subscribers.

The wireless technology evolution is taking place to provide additional bandwidth to users and enable the additional data applications that users are demanding. For this, 2G networks are evolving into 2.5G or 3G technologies such as WCDMA and CDMA2000.

The main standardization groups that have defining the recommendations for wireless in order to achieve interoperability are the 3rd Generation Partnership Project (3GPP), the European Telecommunications Standards Institute (ETSI) and International Telecommunications Union (ITU).

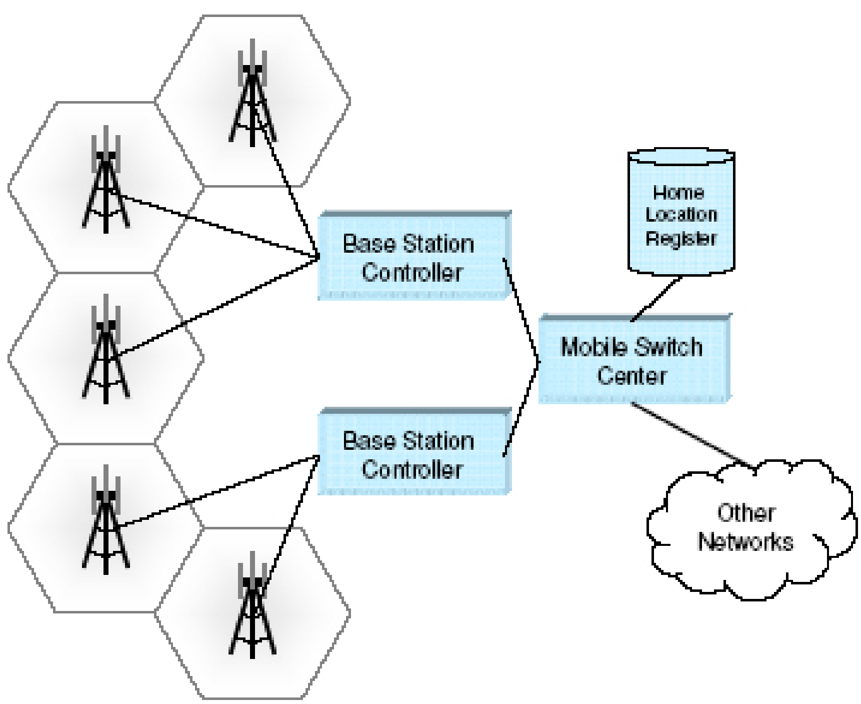
Wireless Networks Fundamentals

Mobile communications systems are cellular in nature, where the network is divided into a number of cells, or geographic coverage; within each cell is a base station (BTS), which contains the radio transmission and reception equipment. It is the BTS that provides the radio communication interface for mobile phones within the cell.

The coverage area of a given cell depends on a number of factors, including the BTS transmission power, the mobile transmission power, the height of the BTS antennas, and the topology of the landscape. The coverage of a cell can range from 100 meters to tens of kilometers.

Network Architecture

A number of BTS are connected to a Base Station Controller (BSC), among other things the BSC manages the handoff of calls from one BTS to another as the mobile moves from cell to cell. Connected to the BSC is the Mobile Switch Center (MSC), also referred as Mobile Telephone Switch Office (MTSO). The MSC manages the setup and tear down of calls to and from mobiles. The MSC also interface with one or more Home Location Registers (HLR) where mobile subscriber's data is held and plays a critical role in mobility management including the tracking of mobiles as they move in the network; as mobiles move from MSC to MSC the HLR is notified in order for the call to be routed correctly.



Frequency Division Multiple Access (FDMA)

FDMA is the simplest technique used in mobile communications for multiple-access. In FDMA the spectrum is divided into a number for radio channels of a specified bandwidth, and a selection of these channels is used within a given cell. Separate channels are used in each direction, from BTS to mobile (downlink) and from mobile to BTS (uplink).

Normally a fixed separation exists between the uplink and downlink frequencies, which is known as duplex distance; for example, in North America the duplex distance is 45MHz. Another technique used for the uplink and downlink management is the time division duplex (TDD) where only one channel is used for both uplink and downlink transmissions. TDD is not very common in North America but is widely used in Asia.

Time Division Multiple Access (TDMA)

In TDMA, radio channels are divided into a number of time slots where mobiles are allocated, and the mobile knows the time slot to use for the duration of the call.

TDMA systems can also divide the bandwidth in smaller channels as in FDMA and these channels are divided into time slots. The difference between a pure TDMA and TDMA with FDMA is that in the TDMA system a given mobile does not have exclusive access to the radio channel. There are many ways to implement TDMA systems, GSM being one of them.

Code Division Multiple Access (CDMA)

In CDMA, all users share the same radio frequency at the same time with a technique called spread spectrum, which involves spreading the signal over a wide bandwidth. Each user is allocated a code or sequence, and the bit rate of the sequence is much greater than the bit rate of the information being transmitted by the mobile. The information signal for the user is modulated with the sequence assigned to the mobile, and at the far end, the receiver looks for the sequence used.

In CDMA, the capacity is limited by the amount of noise in the system, as each additional mobile is added, the total interference increases, and it becomes harder to extract a given mobile's unique sequence from all other mobiles. Eventually, the noise floor reaches a level where the inclusion of additional mobiles significantly impedes the system's capability to filter out the transmission of each mobile.

CDMA2000, WCDMA, and TD-CDMA are implementations of CDMA systems, where CDMA2000 and WCDMA being FDD-based systems. A significant advantage of any CDMA system is the fact that it practically eliminates frequency planning, since CDMA is designed to deal with interference and in fact, it allows a given RF carrier to be reused in every cell.

Roaming

Mobility implies that mobiles are able to move freely around the network and from one network to another. This requires that the network tracks the location of a mobile to certain accuracy so that calls destined for the mobile may be delivered.

The basic operation is as follows:

- When a mobile is on, it sends a registration message to the local MSC, which includes unique identification for the mobile.
- The identification allows the MSC to identify the HLR to which the mobile belongs.
- The MSC sends a registration message to the HLR to notify that the mobile is being served.
- The HLR sends a cancellation message to the MSC that was previously serving the mobile.
- The HLR sends a confirmation to the MSC that is serving the mobile.

When mobile communications were introduced the air interface specifications were standardized, but the exact protocol used between the MSC and the HLR was vendor specific, which resulted in a new standard, for example in North America is the IS-41 and it is used for roaming in AMPS, IS-136 and IS-95 systems; in Europe it was defined under GSM Mobile Application Part (MAP).

Handoff/Handover

Handoff or Handover is the ability of a mobile to maintain a call while it is moving within the network. In general it means that the mobile is transitioned from one radio channel and/or time slot to another. The handoff can be between two sectors in the same BTS, between two BSC, between two MSC from the same operators or between two networks.

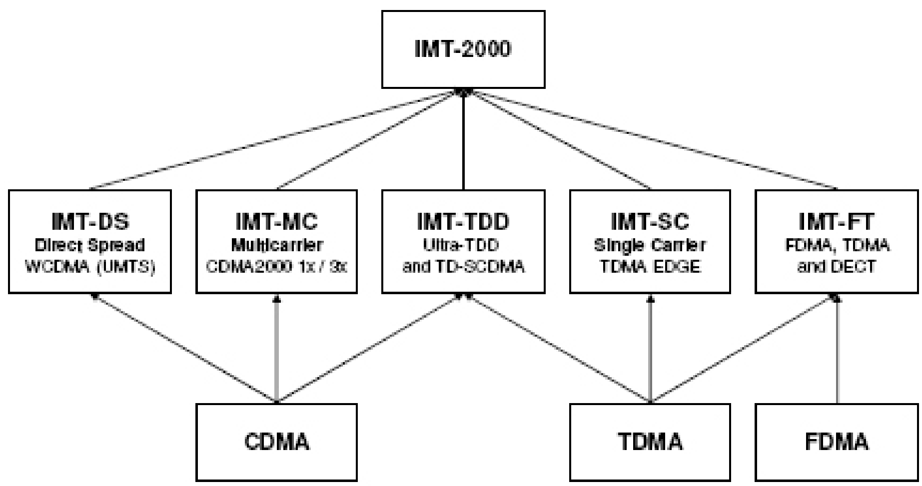
It is also possible to handoff a call between two channels in the same cell, when a given channel is experiencing interference that is affecting the communication quality.

The handoff uses a technique known as mobile assisted handover (MAHO) where the network provides a list of nearby BTS frequencies and the mobile performs periodic measurements (signal strength and signal quality – BER) of the signals received from those BTS and it sends the corresponding measurement results to the network, the network analyses the reports and makes a determination on how the handoff should occur.

3G Technologies

Systems such as GSM and CDMA were optimized for voice services and not for data communications, however users are now demanding data services (internet, messaging, e-mail, etc) as well as mobility.

The ITU created a group named International Mobile Telecommunications (IMT-2000) who developed a number of recommendations addressing user bandwidth (144kbps for mobile services and 2Mbps for fixed services), richness of service offerings (multimedia services), and flexibility (networks that can support small or large number of subscribers). The IMT-2000 also specifies the operation in the 2GHz band.



In 1999, the ITU selected five technologies for wireless services:

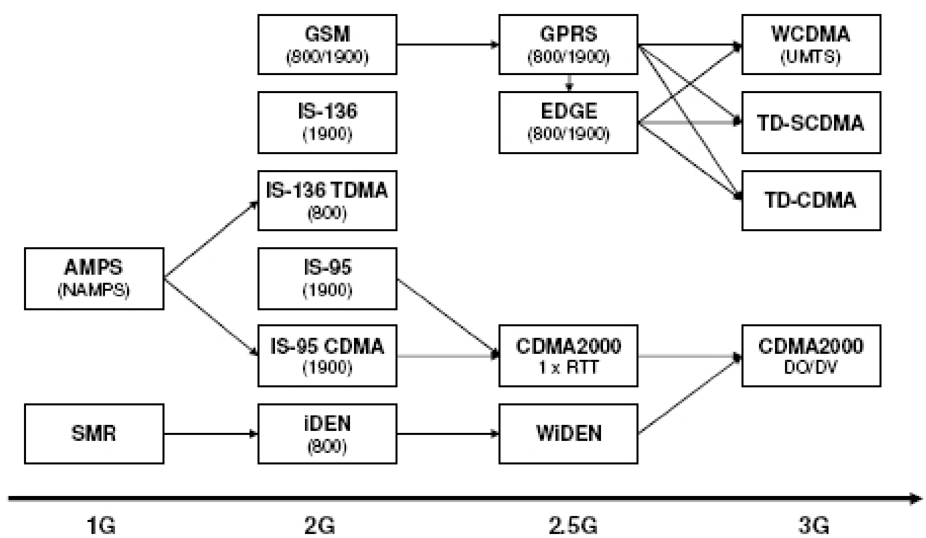
- Wideband CDMA (WCDMA)
- CDMA2000 (an evolution of CDMA IS-95)
- TD-CDMA / TD-SCDMA (Time Division CDMA and Time Division Synchronous CDMA)
- UWC-136 (an evolution of IS-136)
- DECT

Wireless Migration

The migration path from 2G to 3G is referred to as 2.5G and involves an interim position for data services that are more advanced for 2G but not as robust as the 3G data services. The migration strategies are:

- Technology Overlay
- Spectrum Segmentation

The choice of either strategy depends on the technology being used, the spectrum availability, capacity constraints, and marketing.



Mobile Data

Mobile data is one of the logical features for wireless and has different meanings and requirements depending on what application is being served. Mobile data is vertical or subscriber specific.

2G Technology	Data Capability	Spectrum Required	Notes
GSM	9.6/14.4 kbps	200 kHz	Circuit switched data
IS-136	9.6 kbps	30 kHz	Circuit switched data
IDEN	9.6 kbps	25 kHz	Circuit switched data
CDMA	9.6/14.4 kbps	1.25 MHz	Circuit switched data
IS-95A/J-STD-008	64 bps (IS-95B)		Circuit switched data
2.5G Technology	**Data Capability**	**Spectrum Required**	**Notes**
HSCSD	28.8/56 kbps	200 kHz	Circuit/Packet data
GPRS	128 kbps	200 kHz	Circuit/Packet data
Edge	384 kbps	200 kHz	Circuit/Packet data
CDMA2000-1XRTT	144 kbps	1.25 MHz	Circuit/Packet data
3G Technology	**Data Capability**	**Spectrum Required**	**Notes**
WCDMA	144 kbps vehicular 384 kbps outdoors 2 Mbps indoors	5 MHz	Packet data
CDMA2000-EVDO/EVDV	144 kbps vehicular 384 kbps outdoors 2 Mbps indoors	1.25 MHz	Packet data
TD-CDMA	144 kbps vehicular 384 kbps outdoors 2 Mbps indoors	5 MHz	Packet data
TD-SCDMA	144 kbps vehicular 384 kbps outdoors 2 Mbps indoors	1.6 MHz	Packet data

WCDMA enhancements are referred to as High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSPUPA), both facilitating greater throughput.

CDMA2000 data enhancements are referred as Evolution Data Optimized (EVDO) or High Rate Packet Data (HRPD) and Evolution Data and Video (EVDV).

Global System for Mobile Communications – GSM

The purpose of GSM was to create a single European-wide digital system to enable seamless roaming between countries as well as features and capabilities not possible with analog systems. In 1982 the Conference on European Post and Telecommunications (CEPT) embarked on developing this system under the group Group Speciale Mobile (GSM), that in 1989 was taken by the ETSI from whom the first set of technical specifications was finalized and the technology was given the same name as the group that originally developed it - GSM.

The first GSM network was launched in 1991 followed by several more in 1992 with roaming capability, being a huge success inside and outside of Europe. The meaning of GSM was changed to Global System for Mobile communications.

GSM became the European standard for digital cellular systems operating in the 900 MHz band, offering international roaming, high voice quality, increased security and the ability to develop advanced systems features.

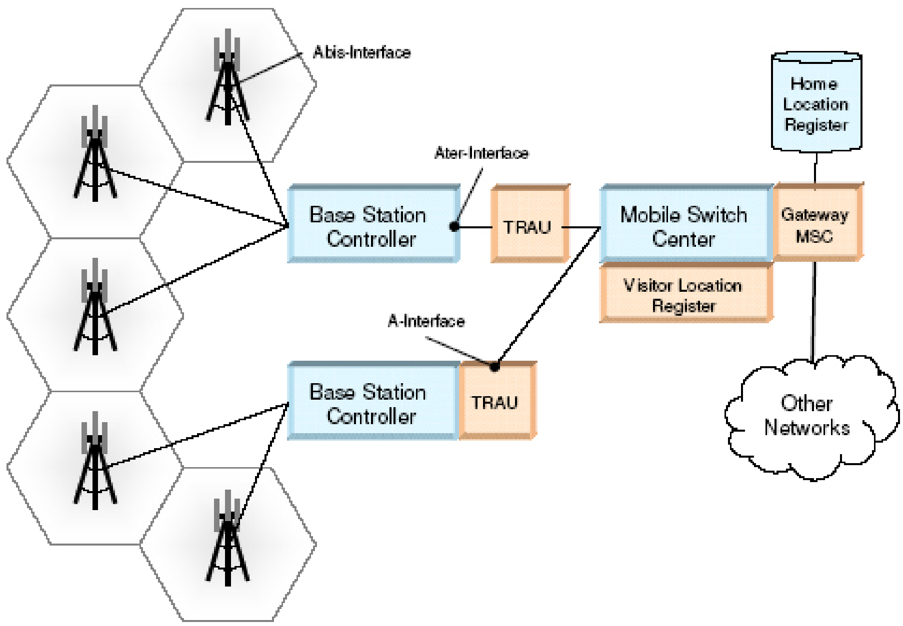
GSM is a TDMA system with FDD using Gaussian Minimum Shift Key (GMSK) as the modulation scheme. TDMA mains that multiple users share the same RF channel on a time-sharing basis; FDD means that different frequencies are used for the mobile's uplink and downlink transmissions.

The GSM radio channel is 200 kHz wide. GSM has been deployed in several frequency bands, namely, the 900, 1800 and 1900 MHz.

	GSM-900	Extended GSM	DCS-1800	PCS-1900
Uplink (Mobile to Network)	890-915 MHz	880-915 MHz	1710-1785 MHz	1850-1910 MHz
Downlink (Network to Mobile)	935-960 MHz	925-960 MHz	1805-1880 MHz	1930-1990 MHz

In GSM a given band is divided in 200 kHz carriers, for example, in GSM-900 the first uplink is at 890.2 MHz and the last downlink is at 914.8 MHz serving a total of 124 RF carriers. Furthermore, each RF carrier is divided into 8 timeslots (0-7) and these are the transmitted in a frame structure. Each frame lasts approximately 4.62ms such that each timeslot lasts approximately 576.9ms for the 124 RF carriers. All RF carriers might allocate traffic, however there must be one timeslot in a cell allocated for control-channel purposes.

GSM Network Architecture



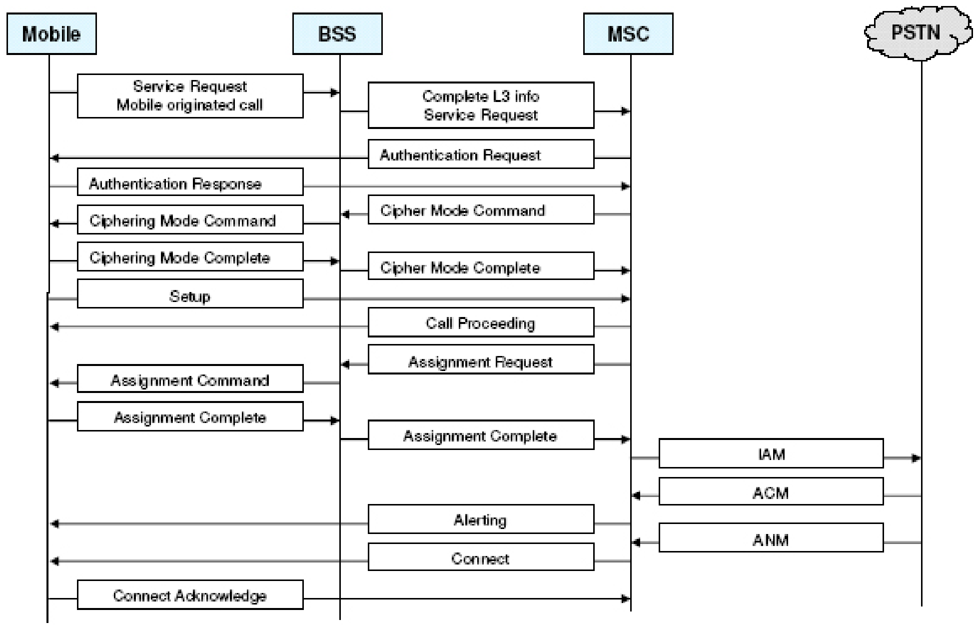
In GSM the subscriber identity module (SIM) is located in the mobile and contains user-specific information, including the identity of the subscriber, the subscriber authentication information, and some subscriber service information.

The Visitor Location Register (VLR) is a database that contains the mobile information while it is within the coverage of the MSC.

The function of the Transcoding and Rate Adaptation Unit (TRAU) is to convert the coded speech to/from standard 64kbps digital channels.

The main purpose of the Gateway MSC (GMSC) is to query the HLR to determine the location of the mobile; the response from the HLR indicates to the MSC where the mobile is located. The call is then forwarded from the GMSC to the MSC serving the mobile.

GSM Call Setup



Code Division Multiple Access – CDMA

Code Division Multiple Access is a technology where all users share the same frequency at the same time, assigning a unique code sequence to the users, where the code bit rate is far higher than the bit rate of the information being sent. At the receiving end, knowledge of the code sequence used for a given signal allows the signal to be extracted.

CDMA became a viable technology in 1989 demonstrated by Qualcomm. Great claims were made about the potential capacity improvement compared to AMPS as well as the potential improved voice quality and simplified system planning. CDMA was standardized in 1993 as IS-95 and systems were deployed primarily in USA and Korea over an 800MHz band.

CDMA is unique to wireless mobility in that it spreads the energy of the RF carrier as a direct function of the chip rate at which the system operates. The CDMA system using Qualcomm technology has a chip rate of 1.228MHz. The chip rate is the rate at which the initial data stream, the original information is encoded and then modulated. The chip rate is the data rate output of the Pseudorandom Number (PN) generator of the CDMA system. The receiving system must de-spread the signal using the same PN code sent by the transmitter, if it is different or not in synchronization the information received would be unintelligible.

The chip rate also has a direct effect on the spreading of the CDMA signal. The number of PN chips per data bit is referred to as the processing gain or the amount of jamming, or interference power that is reduced going through the de-spreading process. Processor gain is the improvement in the signal-to-noise ration of a spread spectrum system.

The pilot channel carries no data, but it is used by the mobile to acquire the system and assist in the process of soft-handoff, synchronization, and channel estimation. A separate pilot channel is transmitted for each sector of the cell site. The pilot channel is uniquely identified by its PN offset. The PN sequence has some 32,768 chips that when divided by 64, result in a total of 512 possible PN codes available for use.

The link budget allocation directly influences the performance of the CDMA system because the link budget is used to determine power settings and capacity limits for the network. Two links are used: forward and reverse, which each use different coding and modulation formats.

CDMA Channels

The CDMA channel assignment for cellular is defined based on the requested use of the primary and secondary CDMA channels; if a dual mode mobile does not find a pilot channel on either primary or secondary channel then it reverts to an analog mode. PCS on the other hand has a different set of preferred channels that are recommended. The mobile initialization algorithm will search in its preferred block for a pilot channel using the preferred channel, which are designated by the operator.

PCS Block	CDMA Channel	CDMA Assignment	Preferred channels
A (15 MHz)	0-24	Not Valid	
	25-275	Valid	25, 50, 75, 100, 125, 150, 175, 200, 225, 250, 275
	276-299	Conditionally Valid	
D	300-324	Conditionally Valid	
	325-375	Valid	325, 350, 375
	376-399	Conditionally Valid	
B	400-424	Conditionally Valid	
	425-675	Valid	425, 450, 475, 500, 525, 550, 575, 600, 625, 650, 675
	676-699	Conditionally Valid	
E	700-724	Conditionally Valid	
	725-775	Valid	725, 750, 775
	776-799	Conditionally Valid	
F	800-824	Conditionally Valid	
	825-875	Valid	825, 850, 875
	876-899	Conditionally Valid	
C	900-924	Conditionally Valid	
	925-1175	Valid	925, 950, 975, 1000, 1025, 1050, 1075, 1100, 1125, 1150, 1175
	1176-1199	Not Valid	

Forward Channel

The forward CDMA channel consists of the pilot channel, one sync channel, up to 7 paging channels, and potentially 64 traffic channels. The cell site transmits the pilot and sync channels for the mobile to use when acquiring and synchronizing with the CDMA system. When this occurs, the mobile is in the mobile station initiation state. The paging channel, also transmitted by the cell site, is used by the mobile to monitor and receive messages that might be sent during the mobile station idle state or system access state.

The pilot channel is transmitted continuously by the cell site. Each cell site uses a time offset for the pilot channel to uniquely identify the forward CDMA channel to the mobile. The cell site can use 512 different time-offset values. If multiple channels are assigned to a cell site, the cell still will use only one time-offset value, which is employed during the handoff process.

The sync channel is a forward channel that is used during the system acquisition phase. Once the mobile acquires the system, it will not normally reuse the sync channel until it powers on again. The sync channel provides the mobile with timing and system-configuration information.

The sync channel uses the same spreading code and time offset as the pilot channel for the same cell site. The sync channel frame is the same length as the pilot PN sequence. The information sent on the sync channel is the paging channel rate and the time of the base station's pilot PN sequence with respect to the system time.

The cell site uses the paging channel to send overhead information and mobile specific information. The cell site will transmit at a minimum one paging channel for each supported CDMA channel that has a sync channel.

Once the mobile has obtained the paging information for the sync channel, it will adjust its timing and begin monitoring the paging channel; each mobile monitors only a single paging channel.

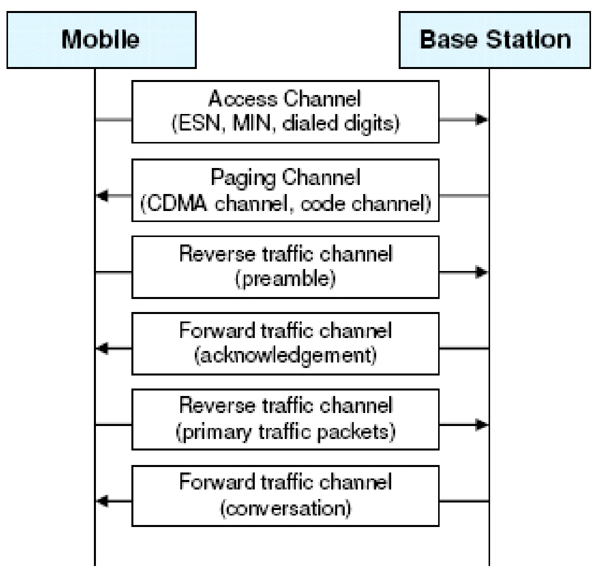
The forward traffic channel is used for transmission of primary or signaling traffic to a specific mobile during the duration of a call. The forward traffic channel also transmits the power control information on a sub-channel continuously as part of the closed-loop system. The forward traffic channel also will support the transmission of information at 9600, 4800 or 1200bps using a variable rate that is selected on a frame-by-frame basis, but the modulation symbol rate remains constant.

Reverse Channel

The cell site continuously monitors the reverse access channel to receive any message that the mobile might send during the system access state. The reverse channel consists of an access channel and the traffic channel. The access channel provides communication from the mobile to the cell site when the mobile is not using a traffic channel. One access channel is paired with a paging channel, and each access channel has its own PN code. The mobile responds to the cell site's messages sent on the paging channel using the access channel.

The reverse and forward control channels use a similar control structure that can vary from 9600 to 1200bps, which enables the cell or mobile to alter the channel rate dynamically to adjust for the traffic; when a pause occurs in the speech, the channel rate decreases so as to reduce the amount of energy received by the CDMA system, thus increasing overall system capacity.

CDMA Call Setup



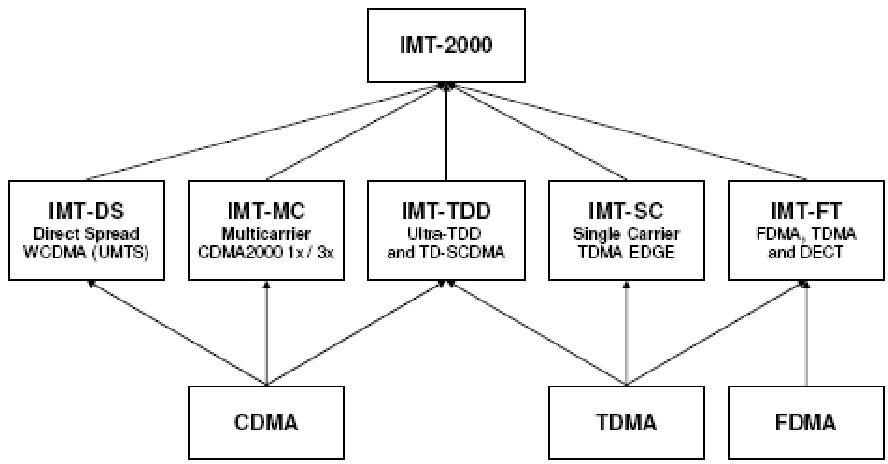
Handoffs

The handoff process in CDMA can take several variants:

- Soft handoff, involves an inter-cell handoff and is a make-before-brake connection.
  The connection between the mobile and the cell site is maintained by several cell sites during the process. A soft hand-off can occur only hen the old and new cell sites are operating on the same CDMA frequency channel.
- Softer handoff, is an intra-cell handoff occurring between the sectors of a cell site and is a make-before-break type. The softer handoff occurs only at the service cell site.
- Hard handoff, is meant to enable a mobile to hand off from a CDMA call to an analog call. The process is functionally brake-before-make and is implemented in areas where CDMA service is no longer available. The continuity of the radio link is not maintained during the hard handoff. A hard handoff also can occur between two distinct CDMA channels that are operating on different frequencies.

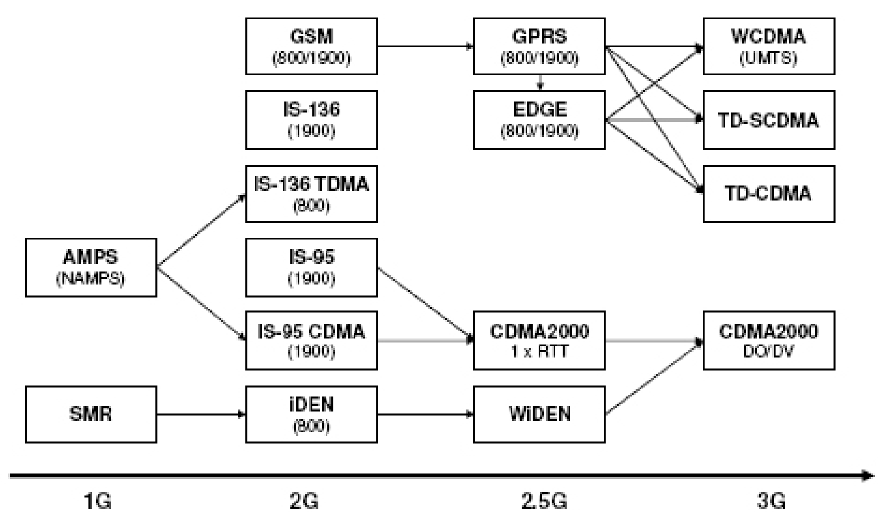
3G – Third Generation Wireless

The rapid increase of demand for data services, primarily IP have been a key driver for the evolution of wireless technologies. The third generation is the enabler of high-speed data wireless mobility, and it is defined in ITU IMT-2000 including specifications for high quality, global roaming, multimedia applications, flexibility for evolution, and high-speed data.



Migration to 3G

The interim platform that bridges 2G systems into a 3G environment is referred to 2.5G, which some plans reserve a dedicated spectrum just for data applications. In IMT-2000 the data goals are: 144 kbps for vehicles, 384 kbps for pedestrians and 2 Mbps for indoor applications.



2G	2.5G	Enhancement	Migration to 3G
GSM	GPRS, EDGE	HS-Data 144.4 kbps Use of existing radio spectrum	WCDMA, TD-SCDMA, TD-CDMA
IS-136	GSM, GPRS, EDGE	HS-Data 144.4 kbps Use of existing radio spectrum	WCDMA, TD-SCDMA, TD-CDMA
CDMA (IS-95)	CDMA2000 (1xRTT)	HS-Data 144.4 kbps Use of existing radio spectrum	EVDO (IS-856) and EVDV

General Packet Radio Services – GPRS

GPRS is designed to provide packet-data services at higher speeds than those available with GSM circuit-switched data services. In theory, GPRS could provide speeds up to 171kbps, over the air interface, however the practical maximum is 100 kbps and the typical implementation is around 50kbps.

The greater speeds provided by GPRS are achieved over the same air interface (200kHz channel divided by 8 time slots), providing the mobile access to more than one time slot and modifying the channel coding. The most common coding scheme for packet-transfer is CS-2 which enables a given time slot to carry data at 13.4kbps, where if a mobile has access to multiple timeslots it can reach a data rate of 53.6kbps.

The greatest advantage of GPRS is the fact that it is a packet-switching technology, this means that a given user consumes RF resources only when sending or receiving data. If a user is not sending data at a given instant, then the time slot on the air interface can be used by another user.

GPRS users can be grouped in three classes:

- Class A. Supports the simultaneous use of voice and data services, the mobile can hold a voice conversation and transfer GPRS data at the same time.
- Class B. Supports simultaneous GPRS connection and GSM connection but not the simultaneous use of both services. The mobile can be registered on GSM and GPRS at the same time but cannot hold a voice conversation and transfer data at the same time.
- Class C. Can connect to either GSM or GPRS but not at the same time.

Air Interface

The GPRS air interface is built on the same foundations as the GSM air interface, the same 200kHz RF carrier and the same timeslots per carrier. This allows GSM and GPRS to share the same RF resources. Although GPRS uses the same basic structure as GSM, the introduction of GPRS means the introduction of a number of new logical channel types and new channel coding schemes to be applied to those logical channels.

When a given timeslot is used to carry GPRS data or control signaling, then it is known as a Packet Data Channel (PDCH), such channels use a 52-multiframe structure, where 12 radio blocks carry user data and signaling, 3 idle frames are used, and there are 2 Packet Timing Control Channels (PTCCHs). Each radio block occupies 4 TDMA frames such that 12 radio blocks are used in a multiframe, in other words a radio block is equivalent to 4 consecutive instances of a given time slot.

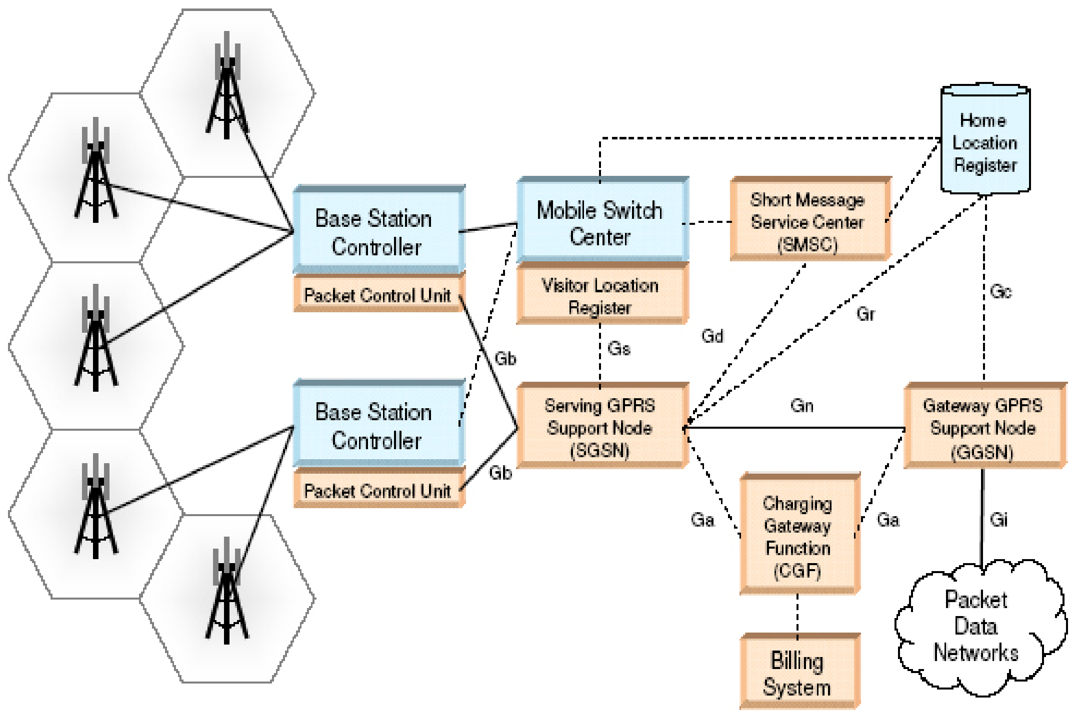
Control Channels

Similar to GSM, GPRS requires a number of control channels, as follows:

- Packet Common Control Channel (PCCCH). An optional channel that consists on several logical channels including:
  - Packet Random Access Channel (PARCH). Applicable only in the uplink, this is used by a mobile to initiate a transfer of packet signaling or data.
  - Packet Paging Channel (PPCH). Applicable only in the downlink, this is used by the network to page a mobile prior to a downlink packet transfer.
  - Packet Access Grant Channel (PAGCH). Applicable only in the downlink, this is used by the network to assign re sources to the mobile prior to packet transfer.
  - Packet Notification Channel (PNCH). This is used for Point-to-Multipoint Multicast (PTM-M) notifications to a group of mobiles.
- Packet Broadcast Control Channel (PBCCH). This is an optional channel used to broadcast GRS-specific system information.
- Packet Timing Control Channels (PTCCH). Is used for control of the timing advance of the mobile.
- Packet Associated Control Channel (PACCH). Is a bidirectional channel used to pass signaling and other information between the mobile and the network during packet transfer.

Network Architecture

GPRS is effectively a packet-data network overlaid on the GSM network. It provides packet data channels on the air interface as well as a packet-data switching and transport network that is substantially different from the standard GSM switching and transport network.



- **PCU**. The PCU is a logical network element that is responsible for air-interface access control, packet scheduling on the air interface, and packet assembly and reassembly.
- **SGSN**. Is analogous to the MSC in the circuit-domain, but performing in a packet domain, including mobility management, security, and access control functions.
- **Gb**. It is a frame-relay interface to pass signaling, control, and user data to or from the SGSN.
- **Gr.** It is a SS7 interface and it uses the Mobile Application Part (MAP), it is used to provide location updates to the HLR for GPRS mobiles and to retrieve mobile information for any mobile that is located in the service area of the SGSN.
- **Gs**. It is a SS7 interface and it uses the Signaling Connection Control Part (SCCP), it enables coordination between the MSC and the SGSN mobile that support both circuits witched services (voice) controlled by the MSC and packet-data services controlled by the SGSN.
- **Gd**. It is a SS7 interface and it is used to interface with the SMCC to enable GPRS mobiles to send and receive short messages.
- **Gn**. It is an IP-based interface used to carry signaling and user data.
- **Gc**. It is a SS7 interface that uses MAP and it is used to determine the SGSN serving mobiles.

Enhanced Data Rates for Global Evolution – EDGE

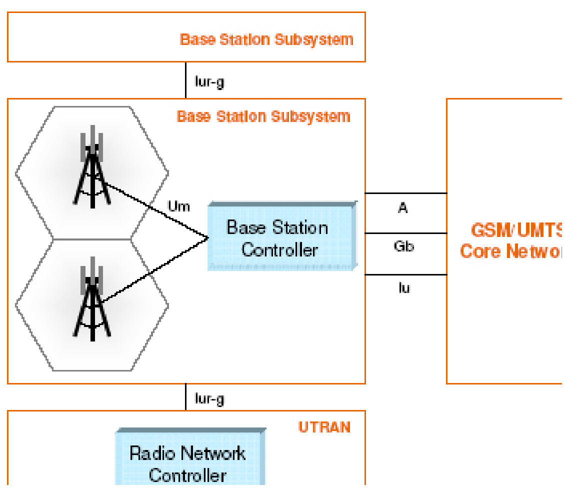
The basic goal with EDGE is to enhance the data-throughput capabilities of a GSM/GPRS network by changing the air-interface modulation scheme from Gaussian Minimum Shift Keying (GMSK) used in GSM to 8-Phase Shift Keying (8-PSK). The result is that EDGE in theory can support speeds of up to 384 kbps.

8-PSK involves a phase change of the carrier signal according to the incoming bit stream in groups of 3 bits at a time. This modulation however is more sensitive to noise than GMSK, the direct result is that if a BTS supports both GMSK and 8-PSK modulations and has the same output power for both, then the cell footprint is smaller for 8-PSK than for GMSK.

A key advantage of EDGE over UMTS is its deployment cost, where UMTS requires the acquisition of a new spectrum and also the build-out of new radio access network.

Network Architecture

The GSM/EDGE Radio Access Network (GERAN) connects 3 interfaces (A, Gb, and Iu) to the core network. Two Base Station Subsystems (BSS) may be connected to each other with an Iur-g interface. A BSS and an RNC may also be connected via an Iur-g interface.



Protocol Architecture

The radio interface is layered into three protocol layers:

- Layer 1 - Physical layer.
- Layer 2 - Data link layer.
- Layer 3 - Network layer.

Layer 2 is split into Radio Link Control (RLC), Medium Access Control (MAC) protocol and Packet Data Convergence Protocol (PDCP).

The protocol architecture is divided into Control (C-) and User (U-) planes. The RLC and MAC protocols and the physical layer carry data from both C- and U-plane. In the C-plane, Layer 3 is partitioned into sub-layers where the lowest sub-layer, denoted as Radio Resource Control (RRC), interfaces with layer 2 and terminates in the GERAN.

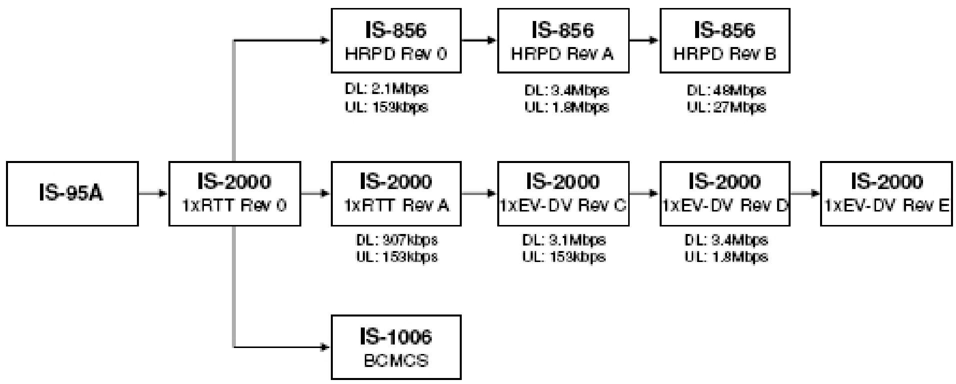
The GERAN can be requested by the Core Network to prevent loss of data according to the quality of service requirements of the bearer in question (i.e. independently of the handovers on the radio interface), as long as an inter-BSS handover does not take place.

This is a basic requirement to be fulfilled by the GERAN retransmission functionality as provided by the RLC sub-layer. However, in case of the inter-BSS handover, the prevention of the loss of data may not be guaranteed autonomously by the GERAN but relies on the duplication avoidance functions in the Core Network.

CDMA2000

CDMA2000 is part of the IMT-2000 specification for third generation and it has the unique characteristic that supports 3G while enabling a logical migration from 2G platforms.

CDMA2000 suite of systems include IS-2000 as well as Evolution Data Optimized (EVDO, IS-856).



The fundamental principle is the high-speed packet data network designed for mobility using Internet Protocol (IP).

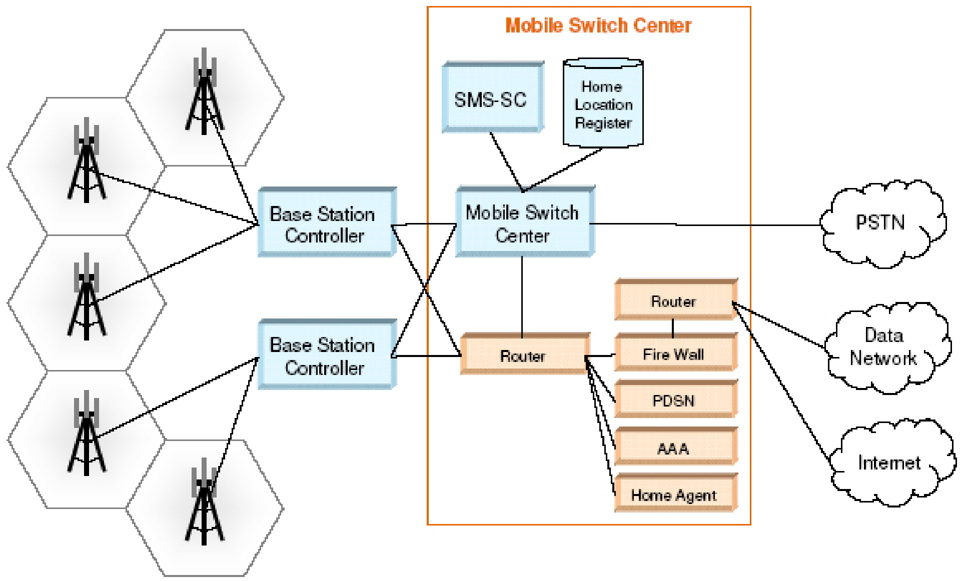
IS-2000 (1xRTT) is fully backward compatible with the IS-95 and J-STD-008 specifications, collectively called cdmaOne. The changes to the network include the following:

- BTS with multimode channel element cards.
- BSC with IP routing capability.
- Introduction of Packet Data Server Node (PDSN).

IS-856 also referred to as EVDO, is a packet only wireless access platform that is an overlay on existing CDMA2000 (1xRTT) network.

The 1xRTT and EVDO systems use a single carrier requiring 1.25MHz of radio spectrum, which is the same as the existing cdmaOne system's channel –bandwidth requirement. However, the 1xRTT platforms can use different voice coders and more Walsh codes, 256/128 instead of 64, allowing higher data rates and voice traffic than cdmaOne. EVDO is a packet system that facilitates a host of IP applications and is a separate system from 1xRTT. Typically, EVDO systems are an overlay on 1xRTT systems, allowing 1xRTT and EVDO services to coexist.

Network Architecture



Packet Data Server Node (PDSN)

The PDSN is essential for packet-data services, and performs the following major functions:

- Establishment, maintenance and termination of Point-to-Point Protocol (PPP) sessions with the mobile.
- Supports simple and mobile IP packet services.
- Establishment, maintenance and termination of logical links to the radio network across the radio-packet interface.
- Initiates the Authentication, Authorization, and Accounting (AAA) for the mobile to the AAA server.
- Receives service parameters for the mobile client from the AAA server.
- Routes packets to and from the external packet-data network.
- Collects usage data that is relayed to the AAA server.

Authentication, Authorization, and Accounting (AAA)

The AAA provides the authentication, authorization and accounting functions for the packet data network associated with CDMA2000 and uses the Remote Access Dial0In User Service (RADIUS) protocol. The AAA communicates with the PDSN via IP and performs the following major functions:

- Authentication associated with PPP and Mobile IP connections.
- Authorization (service profile and security key distribution and management).
- Accounting.

Home Agent (HA)

The HA is also compliant with IS-835 which is relevant to HA functionality within a wireless network, the HA performs the function of tracking the location of the mobile.

Router

The router has the function of routing packet traffic within the CDMA2000 system and it is also responsible for the interface outside of the CDMA2000 system, including the functions of a Fire Wall.

Home Location Register (HLR)

The HLR used in existing CDMA systems need to store additional mobile information associated with packet-data services. The HLR performs the same role for packet services as it does for voice services in that it stores the mobile's packet-data service options and terminal capabilities along with the traditional voice options.

Base Transceiver Station (BTS)

The BTS is responsible for allocating resources of power and Walsh codes with 1xRTT systems and timeslots and modulation for EVDO systems.

With CDMA2000 the use of several carriers per sector is possible, as with IS-95 systems. In addition the use of 1xRTT and EVDO in the same site and sector is possible employing different carriers.

The BTS decides the mobile assignment based on the services requested (voice or packet), the radio configuration, and the mobile type. For example the BTS can downgrade the mobile to a lower rate if the service required in not a handoff, the service requested is not available or if alternative resources available. The following are some of the resources the BTS allocates to a mobile:

- The Fundamental Channels (FCH).
- The FCH forward power.
- The Walsh codes.

The BTS has several enhancements over IS-95/J-STD-008 including the following:

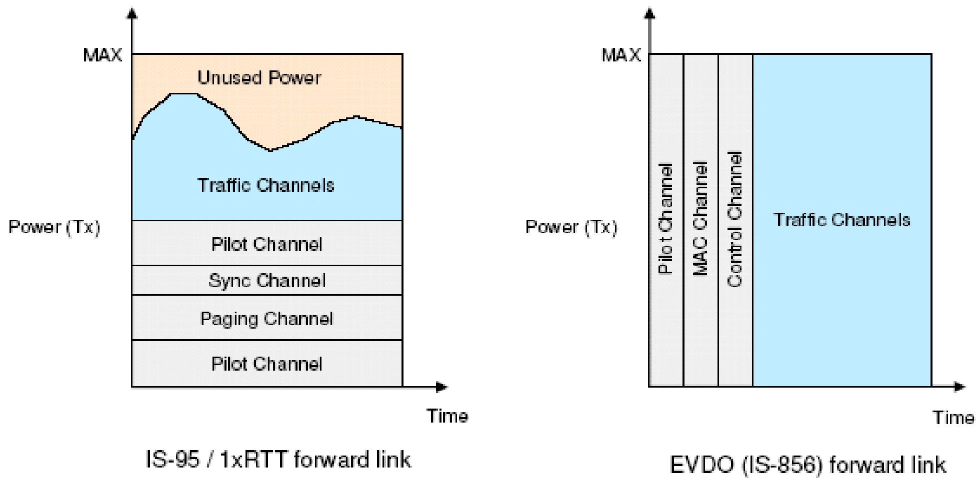
- Improved power control.
- Transmission diversity.
- Different modulation-schemes.
- New coders.
- Uplink pilot channels.
- Expansion of Walsh codes.
- Different channel-bandwidth.
- Packet-data capability.

Evolution Data Optimized (EVDO)

EVDO is also known as High Rate Packet Data (HRPD) and was initially implemented as a single carrier to improve forward-link throughput, however it was evolved to a multi-carrier with improved forward and reverse links.

1xEVDO is a data only system occupying 1.25MHz spectrum in FDD, using a 1.288Mcps chip rate, which is the same as 1xRTT facilitating its integration with existing 1xRTT systems; there are however fundamental differences in EVDO including the following:

- Virtual soft handoff where the mobile monitors the Signal to Interference and Signal to Noise Ratio (SINR) of the pilots in the active set and informs the network via the reverse channel the identity of the best serving sector.
- Rate adaptation, in which constant power is maintained.
- Single mobile communication.

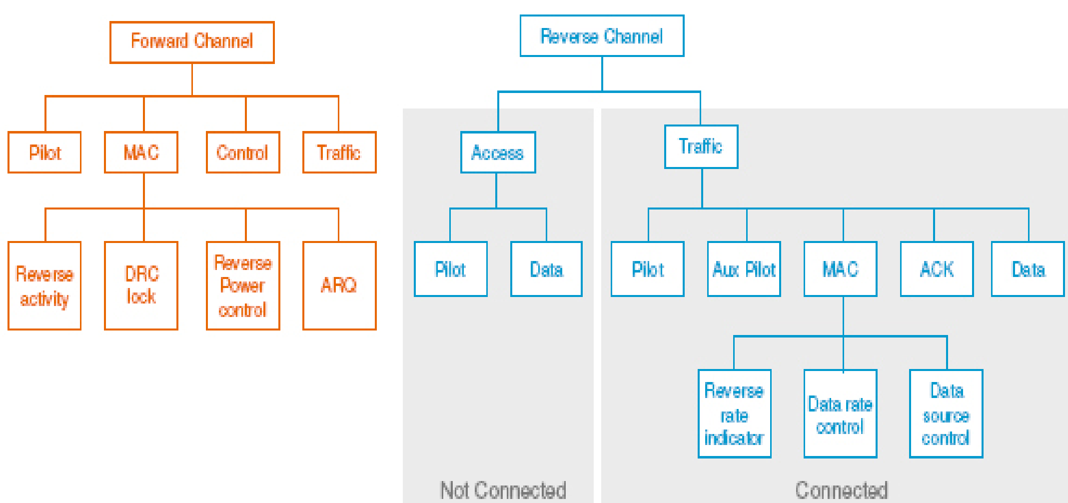


EVDO uses a data scheduler to maximize the overall throughput of the system and user experience. The scheduler determines the data rate, the code allocated, and packet queuing.

The maximum data rate is a function of the SINR and the code allocated.

EVDO Revision A

EVDO Rev A improves the packet-handling capability and is backwards compatible with EVDO Rev 0. EVDO Rev A is an all-IP-based air interface that integrates VoIP, high-speed data, enhanced multimedia capabilities, higher system capacity, and improved QoS for low latency applications. In addition, it supports enhanced multicast capabilities for the delivery of bandwidth intensive Video and Audio applications.



Multicast in EVDO Rev A provides a method for operators to deliver several video and audio channels to a large number of mobiles with three times the capacity of EVDO Rev 0.

Universal Mobile Telecommunications Service - UMTS

UMTS is the evolution of GSM and includes the following two air-interface proposals submitted by the ITU to meet the requirements of IMT-2000.

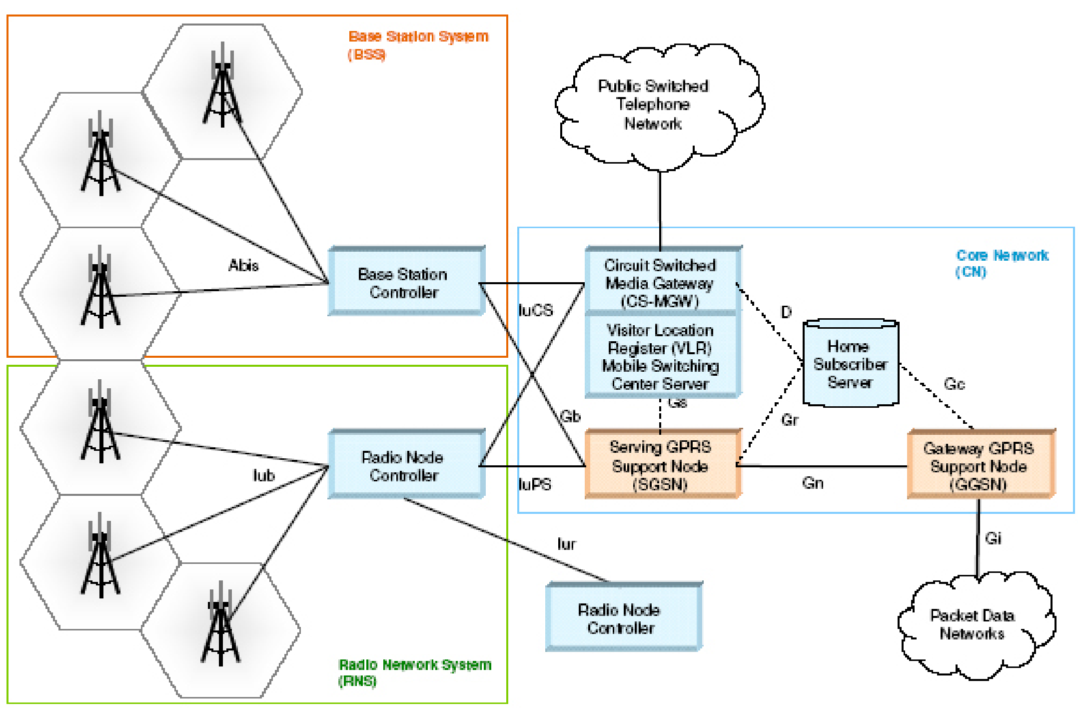
- Frequency Division Duplex (FDD), paired 5 MHz carriers are used in the uplink and downlink as follows: uplink of 1920 to 1980MHz and downlink of 2110 to 2170MHz. Although a 5MHz is the nominal carrier spacing, it is possible to have a carrier spacing of 4.4 to 5MHz in steps of 200kHz.
- Time Division Duplex (TDD). A number of frequencies have been defined, including 1900 to 1920MHz and 2010 to 2025MHz, and a given carrier is used for both uplink and downlink and no separation is required.

In any CDMA system, user data are spread to a far greater bandwidth that the user rate though application of a spreading code, which is a higher-bandwidth pseudo-random sequence of bits known as chips. The transmission from each user is spread by a different spreading code, and all users transmit at the same frequency at the same time. At the receiving end, the signal from one user is separated from those of other users by dispreading the set of received signals with the spreading code applicable to the user in question.

The ratio of the spreading rate (the number of chips per second) to the user data rate (the number of user data symbols per second) is known as the spreading factor. The greater the spreading factor, the greater is the ability to extract a given user's signal. In other words the higher the chip rate the higher number of users can be supported; alternatively, for a set number of users, the higher the chip rate the higher the data rates can be supported for each user.

From a network architecture perspective many of the GSM network elements are reused in UMTS, where the MSC, HLR, SGSN, GGSN can be upgraded to support GSM and UMTS simultaneously. However, the radio access network in UMTS, known as UMTS Terrestrial Radio Access Network (UTRAN) and the elements that constitute the UTRAN, are different than GSM, therefore the reuse of GSM-BTC is limited. For BTS, some can be upgradeable to UMTS.

Network Architecture

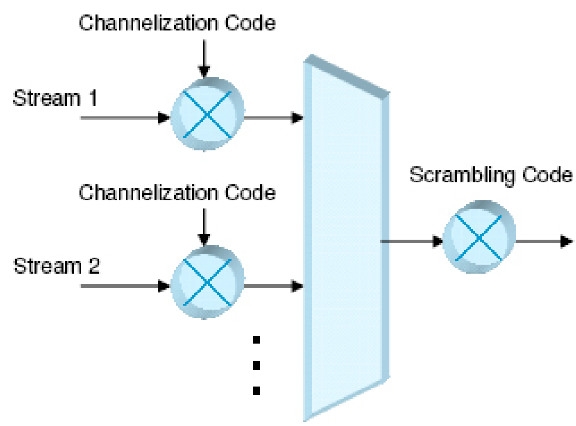


The above diagram represents a basic configuration of a public land mobile network supporting circuit switched and packet switched services and interfaces.

Air Interface

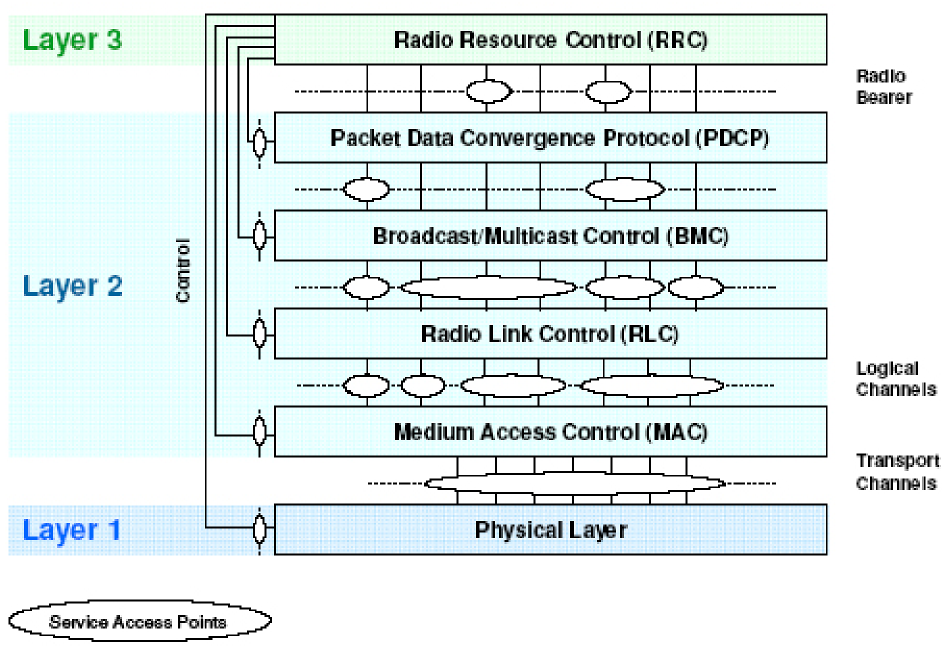
UMTS takes a two-step approach for the air interface transmission:

- Channelization Code: It is used to combine or separate multiple data streams from a given user, where the data streams are spread to the chip rate of a spreading code that operates at 3.84Mcps. The channelization codes are known as Orthogonal Variable Spreading Factor (OVSF) codes.
- Scrambling Codes: Are used to separate transmission from different users, where the combined set of spread signals is scrambled also at the chip rate.



Protocol Architecture

The radio interface is composed of the following three layers:



Physical Layer

The UMTS Terrestrial Radio Access (UTRA) has two operation modes:

- Frequency Division Duplex (FDD), where the uplink and downlink transmissions use two separated radio frequencies.
- Time Division Duplex (TDD), where the uplink and downlink transmissions use the same radio frequency with synchronized time intervals.

At the lowest level the physical layer covers the Radio Frequency (RF) processing, spreading, scrambling and modulation, coding and decoding for support of forward error correction, power control, timing advance, and soft handover execution.

The physical layer transport services to MAC and higher layers through transport channels that are classified as follows:

- Common Transport, where there is a need for in-band identification of the mobile.
  - Random Access Channel (RACH)
  - Forward Access Channel (FACH)
  - Downlink Shared Channel (DSCH)
  - Uplink Shared Channel (USCH)
  - Broadcast Channel (BCH)
  - High Speed Downlink Shared Channel (HS-DSCH)
- Dedicated Transport, where the mobiles are identified by the physical channel, such as code and frequency for FDD, and time slot and frequency for TDD.
  - Dedicated Channel (DCH)
  - Enhanced Dedicated Channel (E-DCH)

The physical layer is expected to perform the following functions in order to provide the data transport service:

- Macro-diversity distribution/combining and soft handover execution.
- Error detection on transport channels and indication to higher layers.
- FEC encoding/decoding of transport channels.
- Multiplexing of transport channels and de-multiplexing of coded composite transport channels.
- Rate matching of coded transport channels to physical channels.
- Mapping of coded composite transport channels on physical channels.
- Power weighting and combining of physical channels.
- Modulation and spreading/demodulation and dispreading of physical channels.
- Frequency and time (chip bit, slot, frame) synchronization.
- Radio characteristics measurements including FER, SIR, interference power, among others and indication to higher layers.
- Inner-loop power control
- RF processing.
- Synchronization shift control.
- Beam forming.
- MIMO transmission.
- Hybrid ARQ soft-combining for HS-DSCH and E-DCH.

Medium Access Control

The Medium Access Control (MAC) provides the following services to the upper layers:

- Data transfer. Provides unacknowledged transfer of MAC Service Data Units (SDU) between peer MAC entities. This service provides data segmentation on HS-DSCH but not for other transport channel.
- Reallocation of radio resources and MAC parameters. It is perform on request of RCC including MAC reconfiguration, change of transport format sets, change of transport channel type.
- Reporting of measurements. Local measurements such as traffic volume and quality indications reported to RCC.

The MAC provides data transfer services on logical channels, classified as follows:

- Control Channels
  - Broadcast Control Channel (BCCH).
  - Paging Control Channel (PCCH).
  - Dedicated Control Channel (DCCH).
  - Common Control Channel (CCCH).
  - Shared Channel Control Channel (SHCCH).
  - Multimedia Broadcast Multicast Service (MBMS) point-to-multipoint Control Channel (MCCH).
  - MBMS point-to-multipoint Scheduling Channel (MSCH).

- Traffic Channels
  - Dedicated Traffic Channel (DTCH)
  - Common Traffic Channel (CTCH)
  - MBMS point-to-multipoint Traffic Channel (MTCH)

The MAC functions include the following:

- Mapping between logical channels and transport channels.
- Selection of appropriate transport format for each transport channel depending on instantaneous source rate.
- Priority handling between data flows for one mobile.
- Priority handling between mobiles by means of dynamic scheduling.
- Identification of mobiles on common transport channels.
- Multiplexing/demultiplexing of upper layer Protocol Data Units (PDU) into/from transport blocks delivered to/from the physical layer on common transport channels.
- Multiplexing/demultiplexing of upper layer PDUs intro/from transport blocks sets delivered to/from the physical layer on dedicated transport channels.
- Multiplexing/demultiplexing of upper layer PDUs into transport blocks delivered to/from the physical layer on HS-DSCH.
- Traffic volume measurement.
- Transport Channel type switching.
- Ciphering.
- Access Service Class selection for RACH transmission.
- Hybrid Automatic Repeat Request functionality for HS-DSCH and E-DCH transmission.
- Data segmentation/reassembly for HS-DSCH.
- In-sequence delivery and assembly/disassembly of higher layer PDUs on HS-DSCH.
- In-sequence delivery and assembly/disassembly of higher layer PDUs on E-DCH.

Radio Link Control

The services provided by the Radio Link Control (RLC) to the upper layer are the following:

- Transparent data transfer.
- Unacknowledged data transfer.
- Acknowledge data transfer.
- Maintenance of Quality of Service as defined by upper layers.
- Notification of unrecoverable errors.

The RLC functions are the following:

- Segmentation and reassembly.
- Concatenation.
- Padding.
- Transfer of user data.
- Error Correction.
- In-sequence delivery of upper layer PDUs.
- Duplicate Detection.
- Flow Control.
- Sequence number check.
- Protocol error detection and recovery.
- Ciphering.
- Service Data Unit discard.

Broadcast/Multicast Control

The Broadcast/Multicast Control (BMC) provides the following functions:

- Storage of cell broadcast messages.
- Traffic volume monitoring and radio resources request for Cell Broadcast Service (CBS).
- Scheduling of BMC messages.
- Transmission of BMC messages to mobiles.
- Delivery of cell broadcast messages to upper layer (Non-Access Stratum).

Packet Data Convergence Protocol

The functions of the Packet Data Convergence Protocol (PDCP) are the following:

- Header compression and decompression.
- Transfer of user data.
- Support for lossless Serving Radio Network Subsystem (SRNS) relocation or lossless Downlink Radio Link Control Protocol Data Unit size change.

Radio Resource Control

The Radio Resource Control (RRC) handles the control plane signaling of layer 3 between mobiles and the UMTS Terrestrial Access Network (UTRAN).

The RRC performs the following functions:

- Broadcast of information provided by the non-access stratum (core network).
- Broadcast of information related to the access stratum.
- Establishment, re-establishment, maintenance and release of an RRC connection between the mobile and the UTRAN.
- Establishment, reconfiguration and release of Radio Bearers.
- Assignment, reconfiguration and release of radio resources for the RRC connection.
- RRC connection mobility functions.
- Paging/notification.
- Routing of higher layer PDUs.
- Control of requested QoS.
- Mobile measurement reporting and control of the reporting.
- Outer loop power control.
- Control of ciphering.
- Slow DCA.
- Arbitration of radio resources on uplink DCH.
- Initial cell selection and re-selection in idle mode.
- Integrity protection.
- Initial configuration for CBS.
- Allocation of radio resources for CBS.
- Configuration for CBS discontinuous reception.
- Timing advance control.
- MBMS control.

Wireless Evolution

Mobile networks will continue to evolve to properly deliver the services customers are demanding, not only related to content deliver such as video (Mobile TV) but also regarding the seamless transition of technology (circuit and packet) and networks (wireless and wireline) though an IP Multimedia Subsystem (IMS).

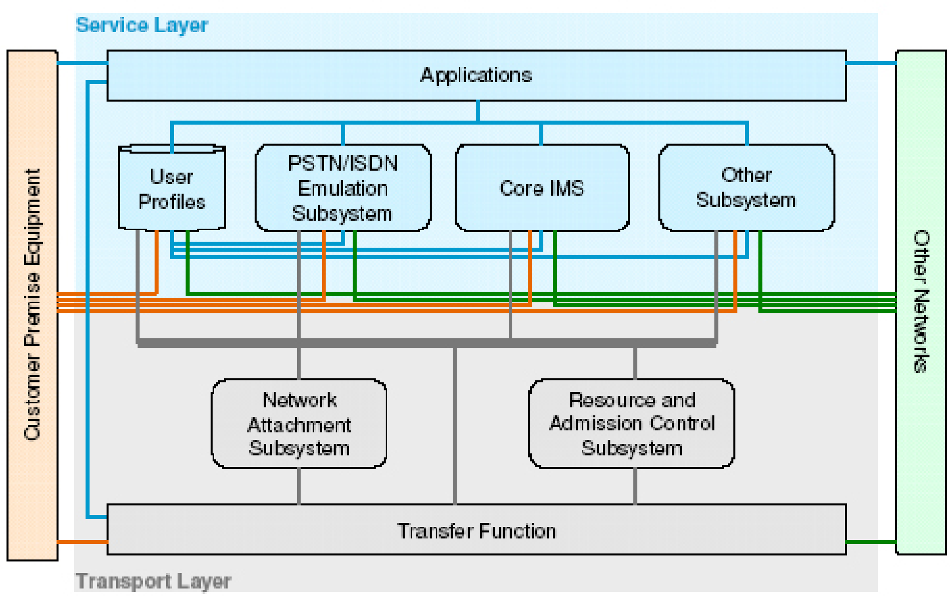
IP Multimedia Subsystem (IMS)

The IP Multimedia Subsystem (IMS) is a standardized Next Generation Networking (NGN) architecture that provides a service control platform enabling the creation of new multimedia and multi-session applications using wireless and wireline capabilities. IMS is a convergence enabler merging circuit and packet services onto an IP platform.

The aim of IMS is not only to provide new services but all the services, current and future, that the Internet provides. In this way, IMS will give network operators and service providers the ability to control and charge for each service. In addition, users have to be able to execute all their services when roaming as well as from their home networks.

IMS platforms have the following major attributes:

- IP-based session control based on SIP, allowing the setup, modification, and teardown of various types of IP sessions, including VoIP, video, and instant messaging.
- End-to-end quality of service
- Packet and circuit-switched network interoperability.
- IPv6 support.



Mobile TV

Television, just like voice, music, and text will be part of the mobile service (Mobile TV). It is expected that Mobile TV will be a mass market service in few years.

Wireless networks were originally designed for point-to-point communications to serve users individually (unicast). The concept of transmitting the same information to multiple users (multicast) has been standardized using multicast technologies. Multiple scalable broadcast technologies exist today and can deliver broadcast type applications to multiple users simultaneously (broadcast).

As live streaming of movies and multimedia content and capabilities grow, the average size of the content itself increases. As a result, the optimization capabilities of broadcast and multicast technologies become commercially attractive. In particular, the increasing focus on high quality video and audio content encourages mobile operators to optimize delivery over the air interfaces that leverage the use of scarce spectrum resources.

The goal of these technologies is to use the network capacity required to deliver the same content to multiple recipients in more efficient ways. Without such technologies the number of simultaneous sessions sustainable in a cellular network is limited by the local serving cell capacity and so mass events that demand high bandwidth peaks are difficult to manage.

Technologies

Digital Video Broadcast – Handheld (DVB-H)

DVB-H is the extension of existing DVB-T to support terrestrial broadcasting of video streams to multiple handheld mobiles (the main enhancements are savings on battery power and support of mobility with a smaller antenna). The existing TV broadcasting network is fully reusable with an upgrade to the DVB-H standard. Besides audiovisual and TV streams, DVB-H carries IP-based data including files, notifications and auxiliary data streams for additional services.

System specification work on IP datacast over DVB-H will define an end-to-end solution that addresses the broadcast channel and its functions (IP encapsulation, Electronic Service Guide, service and content protection, and, QoS) as well as an interactivity channel (purchases, payment).

Two alternatives exist for the introduction of DVB-H: upgrade of an existing DVB-T infrastructure (when available) or the creation of a new dedicated DVB-H infrastructure which could reuse existing UMTS sites, or the combination of these two.

DVB-SH requires a satellite as well as terrestrial repeaters in urban areas that could be integrated in UMTS sites. Moreover, the proximity of the S-UMTS bands to the terrestrial UMTS bands allows an easy integration in existing cellular sites. The feeder and antenna systems can be reused with a simple upgrade.

Multicast/Broadcast Mode Service (MBMS)

MBMS could be used in two modes. As well as multicasting multimedia streams over a GSM or IMT-2000/3G/UMTS network to multiple mobiles subscribed to the service, or to broadcast to all mobiles in the geographic area covered by the base station.

TDtv (MBMS over TD-CDMA) makes use of the UTRA TDD technology, commonly known as TDCDMA, to broadcast mobile TV streams in existing UMTS TDD licensed spectrum; it is based on the 3GPP MBMS architecture, with layer 1 enhancements to increase coverage and capacity.

Introduction of MBMS requires a software upgrade of UMTS network elements initially in hotspot areas.

Digital Media Broadcasting (DMB)

DMB is an evolution of DAB (Digital Audio Broadcasting) technology in which mobile user's access TV content over their mobile handset and in-car terminals. As well as streaming TV, DMB can also carry IP-based data including files, notifications and auxiliary data streams for additional services. The satellite-based implementation S-DMB is restricted to Asia and in Europe the focus is on the terrestrial T-DMB.

T-DMB requires an upgrade to an existing DAB infrastructure as the currently existing infrastructure has been planned for automotive or outdoor reception and indoor reception is consequently weak.

MediaFLO

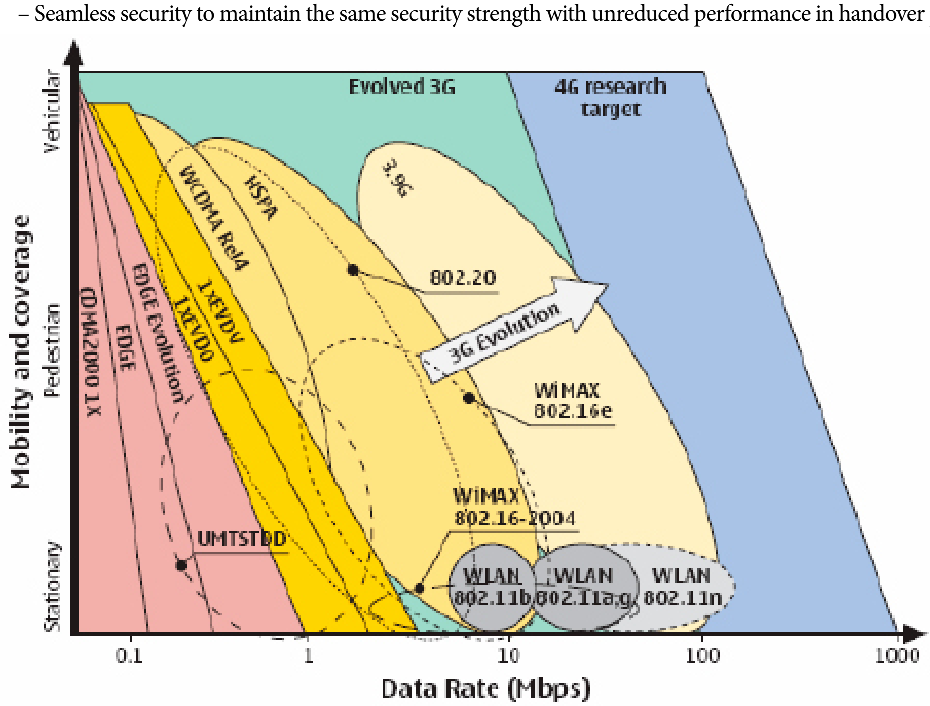
MediaFLO is based on the Forward Link Only (FLO) specification for "Terrestrial Mobile Multimedia Multicast" (standardized as TIA-1099). MediaFLO is an end-to end system that enables broadcasting of video streams, audio-only streams, clip-cast media, and data-casting to mobile devices, including handheld receivers.

The system is designed to optimize coverage, capacity and power consumption as well as overall user experience for handheld receivers using the TIA-1099 air interface standard. The system can reuse existing broadcast network infrastructure such as sites, antennas, DVB-T transmitters that are upgradeable to support the FLO modulator, and other ancillary equipments, in either a Multiple Frequency Network (MFN) or Single Frequency Network (SFN).

MediaFLO can leverage existing high power broadcasting infrastructure (sites, antennas, DVB-T transmitters that are upgradeable to support FLO modulator, and other ancillary equipments) or lower power cellular infrastructure depending on the spectrum regulation.

Technology trends

- Software-defined radio technology has become a main element in the wireless infrastructure and handset implementations. Because of this technology, new and advanced radio technologies are easily introduced and deployed by the Network operators and Service providers to differentiate their services.
- Mobile terminals may form a closed network, or an ad hoc network, which enables direct communications between them. Transmission speed could be independent between an uplink and a downlink. Systems Beyond IMT-2000 are expected to act as platforms to effectively deliver traffic within and between the ad hoc networks and to offer additional values to them, such as advanced mobility management techniques.
- Mobility management will be more than supporting higher speed objects such as vehicles. It will be needed to support applications with very large IP multimedia traffic needs, and with diversified communications including person-to-person, machine-to-machine, machine-to-person and vice versa.
- The concept of seamless services will be extended beyond handover and roaming services.
- Diverse end-users' individual needs will require flexibility to deal with their preferences or contexts.
- The network security environment will include:
  - A highly efficient security mechanism, in a multimedia environment, to process high-speed and high volume information flows.
  - User's transparent access authentication and authorization mechanisms to provide protection in different access environments.
  - Security infrastructure supported across service providers.
  - Scalable capacity of security servers to provide service for massive network usage.
  - Seamless security to maintain the same security strength with unreduced performance in handover procedures.



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