3G Introduction

The Third Generation (3G) wireless systems offer services and thereby reduce the distinction between the range of services of wire line and wireless. It is an advanced technology and it enhances the features of second generation and adds its own advanced features. Updating cellular telecommunications network around the world are using 3G technologies.
The main reason for the evolution of 3G was due to the limited capacity of the 2G networks.
2G networks were built for voice calls and slow data transmission. But these services were unable to satisfy the requirements of present wireless revolution.
International Telecommunication Union (ITU) has defined the demand for 3G in the International Mobile Telecommunication (IMT)-2000 standards to facilitate growth, increase bandwidth, support diverse applications.
The development like 2.5G or GPRS (General Packet Radio Service) and 2.75G or EDGE (Enhanced Data rates for GSM Evolution) technologies resulted in the transition to 3G. These technologies act like bridge between 2G and 3G.

Features of 3G

It provides cost efficient high quality, wireless multimedia applications and enhanced wireless communications.
It supports greater voice and data capacity and high data transmission at low cost. 3G mobiles can operate on 2G and 3G technologies.
It offers greater security features than 2G. It supports network access security, network domain security, user domain security, application security.
It supports video calls and video conferences. It provides support from localized service like accessing traffic and high end services like weather updates. We can listen to music, watch videos online and can download huge files with in less time.

Advantages of 3G

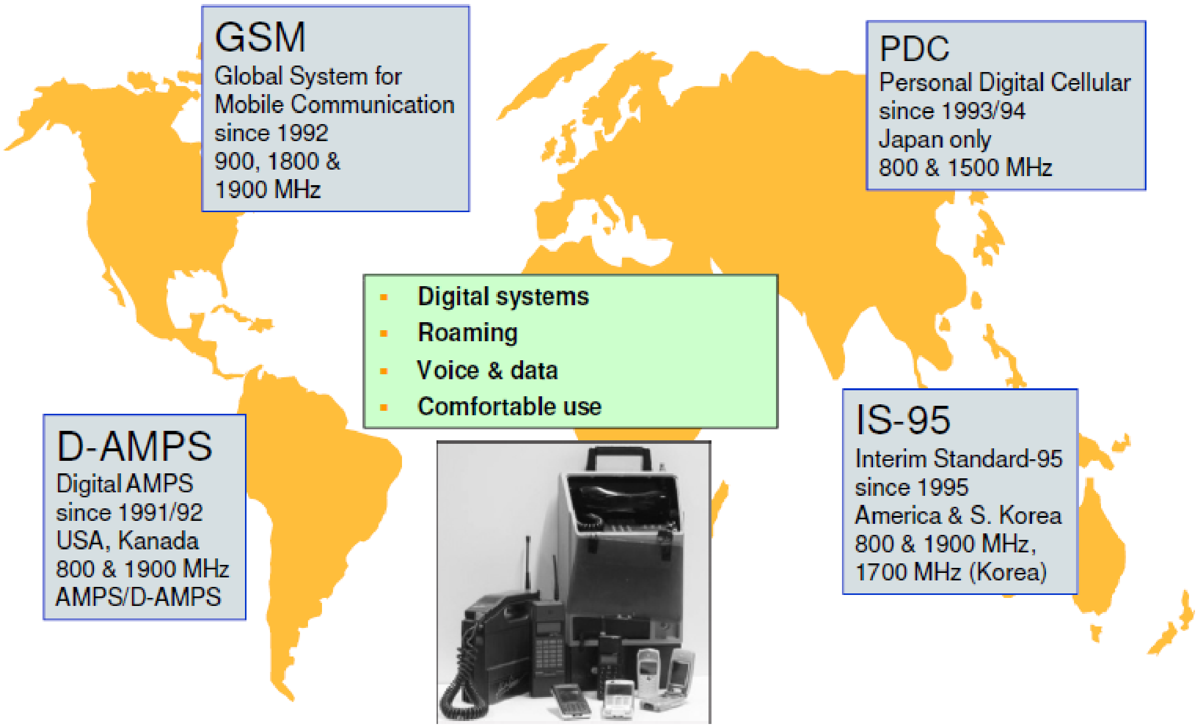
All the functions in a normal 2G mobile devices can be performed in 3G at a higher speed.
It provides faster connectivity, faster internet access and music with improved quality.

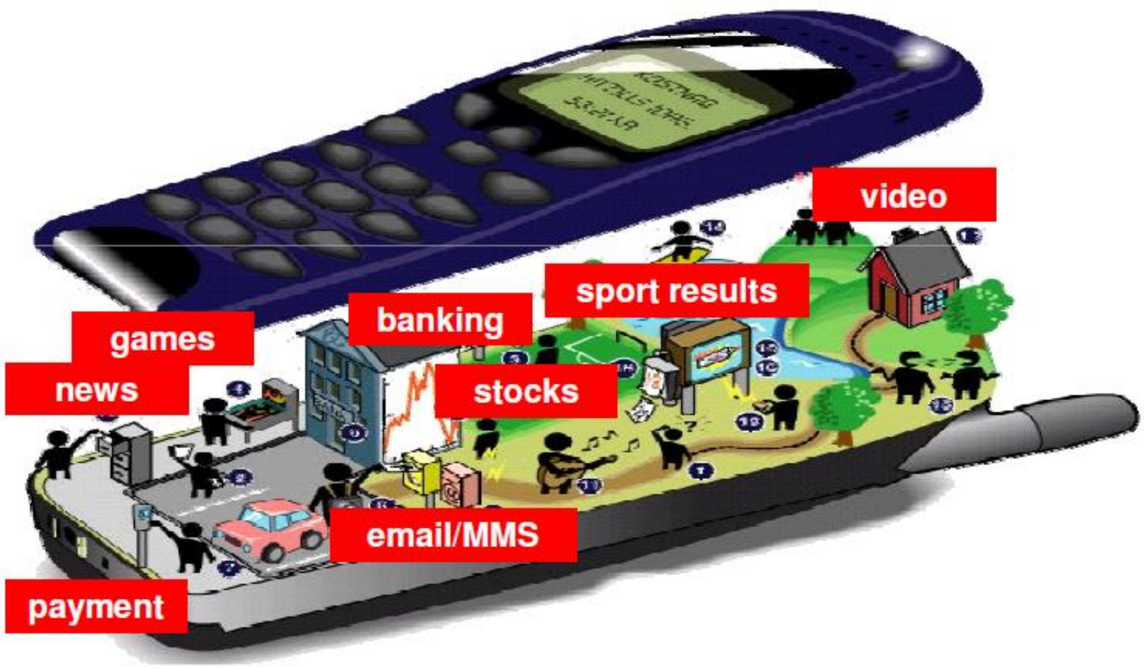
Applications of 3G

1) The 3G mobile can be used as a modem for computer which can access internet and can download games and songs at high speed.
2) It provides high quality voice calls and video calls.
3) It provides weather updates, news headlines and TV broadcasting in mobile phone.
4) It provides high speed internet facility for many applications. It can provide data transmission speed up to 2Mbits /sec.
5) It provides multimedia services such as sharing of digital photos and movies. It provides location based services and real time multi player gaming.
6) It supports virtual banking and online selling.
7) It supports teleconferencing.

Drawbacks

There are few drawbacks:
Upgrading the base station and cellular infrastructure to 3G incurs very high costs.
1) Service provider has to pay high amount for 3G licensing and agreements.
2) Problem with the availability of handsets and few regions and their costs.
3) High power consumption.


GSM
Global System for
Mobile Communication
since 1992
900, 1800 &
1900 MHz
PDC
Personal Digital Cellular
since 1993/94
Japan only
800 & 1500 MHz
Digital systems
Roaming
Voice & data
Comfortable use
D-AMPS
Digital AMPS
since 1991/92
USA, Kanada
800 & 1900 MHz
AMPS/D-AMPS
IS-95
Interim Standard-95
since 1995
America & S. Korea
800 & 1900 MHz,
1700 MHz (Korea)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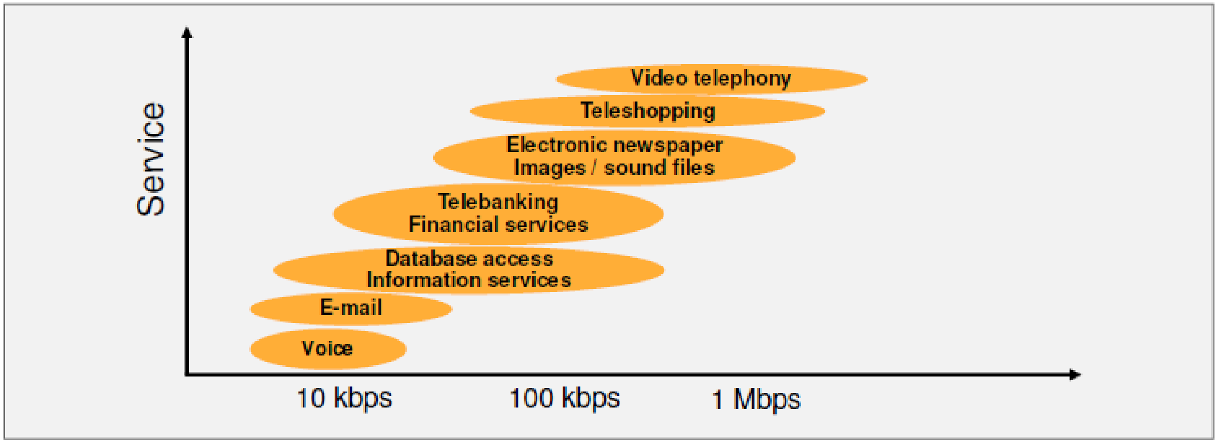
banking
games
news
stocks
email/MMS
payment

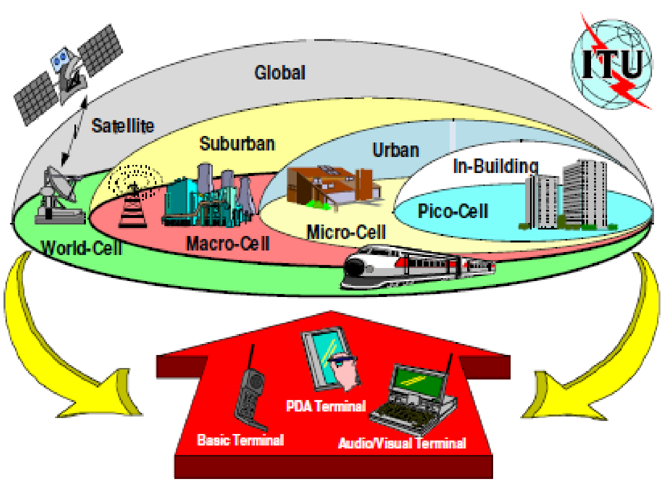


The technical development is driven by 3 main aspects:

1) More bandwidth/data rate on the Air Interface
2) ALL IP
3) Network intelligence to a “service” layer

- In 1985, the ITU (International Telecommunications Union) started work on 3G systems denoted as FPLMTS (Future Public Land Mobile Telephone Systems)
- Was later renamed to IMT-2000 (nobody knew how to pronounce FLPMTS; 2000: refers to Frequency band and year of launch)
- Key factors and main objectives for 3G systems include:
  - Worldwide coverage and seamless access, incorporating a satellite component,
  - Compatibility within IMT-2000 family
  - Downwards-compatible with 2G
  - Fixed Mobile Convergence FMC
  - High data rates & Multimedia applications
  - Circuit- and packet-oriented
  - Inexpensive, flexible access for developing countries
  - Service portability and roaming between systems

IMT 2000 is the ITU globally coordinated definition of 3G.



- During the evaluation of different proposals by the ITU it turned out that the vision of a global standard with a single radio interface was not realizable for 3G systems.

- This was due to the various 2G technologies used in different regions in the world. It would have been impossible to find one technology as an evolutionary path for all existing 2G systems.

- Therefore, a five member family concept was adopted and agreed upon at the end of 1999.

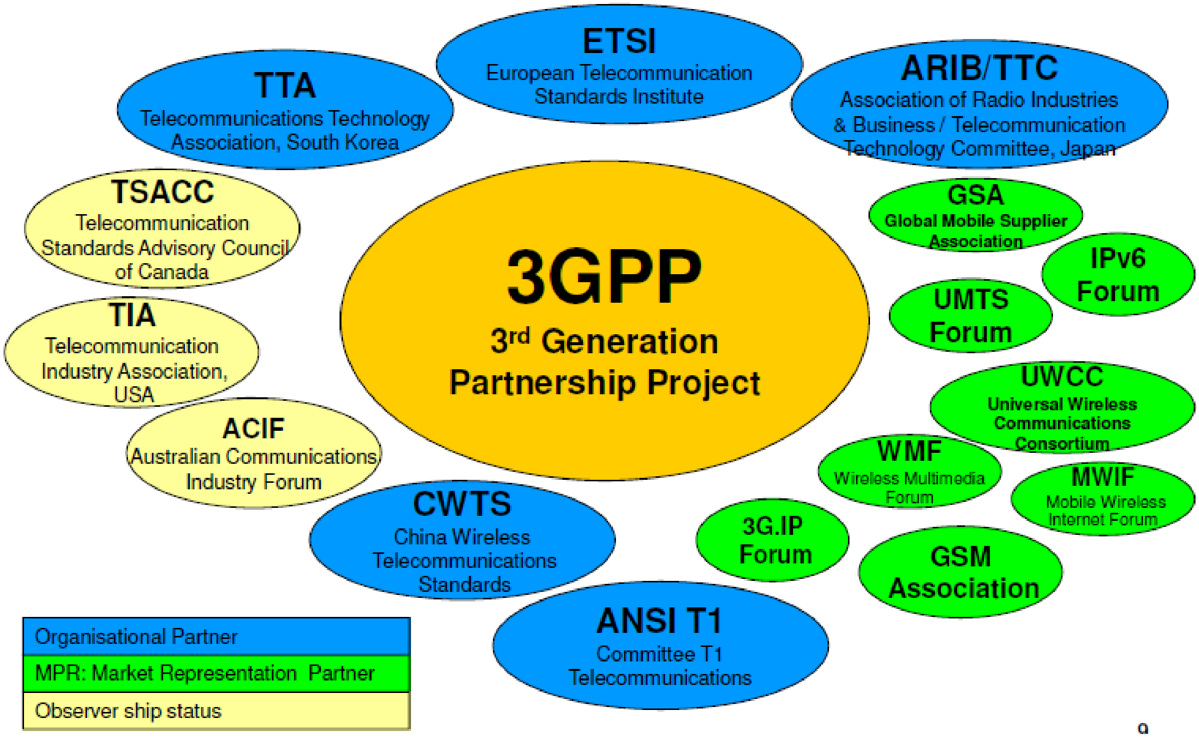
- These five standards are now being further developed in the regional standardization bodies.
  - **IMT-2000 CDMA Direct Spread**, also known as UTRA FDD including WCDMA in Japan, ARIB / DoCoMo recommendation. UMTS is developed by 3GPP.
  - **IMT-2000 CDMA Multi-carrier**, also known as Cdma2000 (3X) developed by 3GPP2
  - **IMT-2000 CDMA2000** includes 1X components, like cdma2000 1X EV-DO.
  - **IMT-2000 CDMA TDD**, also known as UTRA TDD and TD-SCDMA. TD-SCDMA is developed in China and supported by TD_SCDMA Forum
  - **IMT-2000 TDMA Single Carrier**, also known as UWC-136 (Edge) supported by UWCC
  - **IMT-2000 DECT** supported by DECT Forum

- 3GPP is a collaborative agreement between Standards Development Organizations (SDOs) and other related bodies for the production of a complete set of globally applicable Technical Specifications & Reports for:
  - a 3G System based on the evolved GSM core network and the Universal Terrestrial Radio Access (UTRA), FDD and TDD modes.
  - the Global System for Mobile communication (GSM) including GSM evolved radio access technologies.

- 3GPP has no legal status, but:
  - The 3GPP results are jointly owned by the Organizational Partners (i.e. the SDOs).
  - The Organizational Partners transpose the results into their own deliverables (e.g. Standards) .

- 3GPP is open to the members who belong to each Organizational Partner.

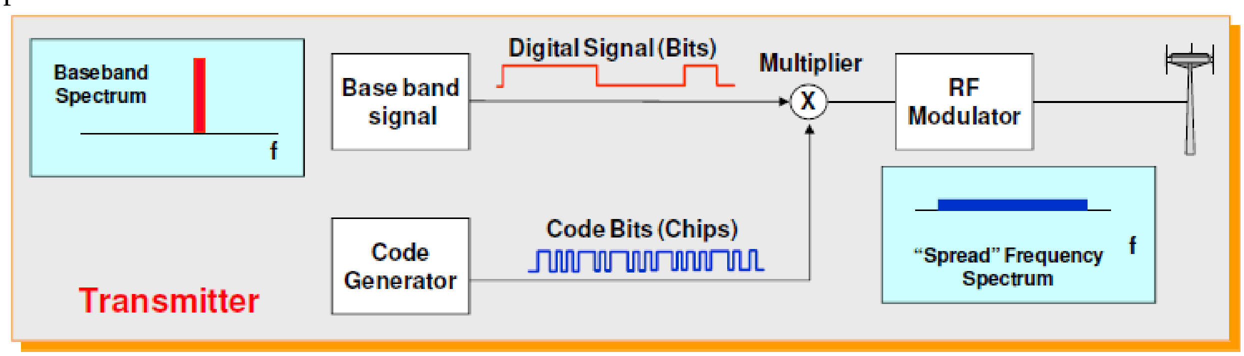
- Currently, more than 450 Individual Member companies are actively engaged in the work of 3GPP.

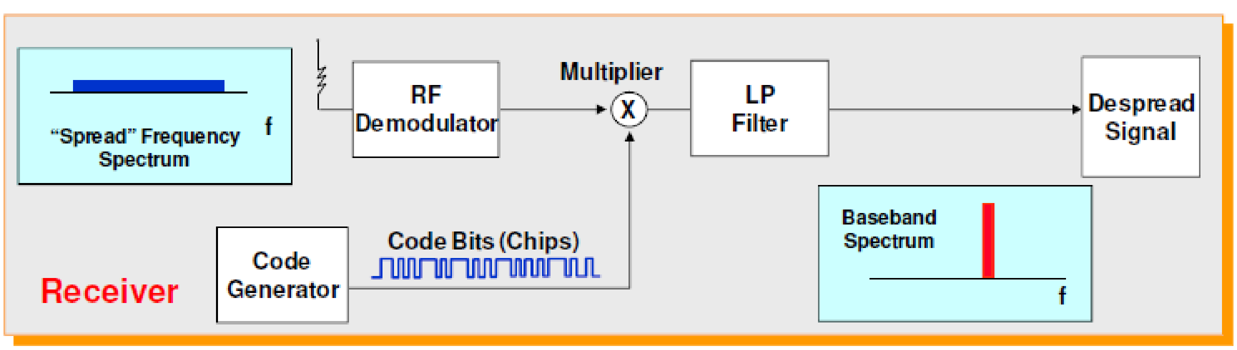


Historical Background:

1) Hedy Lamarr (Hedwig Kiesler) and George Antheil had developed a system in August 1942 that was called Frequency Hopping.
2) Idea was to build up a remote controlled torpedo and the work resulted in a patent called Secret Communication System.
3) American military was not interested until 1963 (Kuba).
4) Lamar was born 1913 in Austria and worked as an actress in Hollywood.
5) Antheil was born in Paris and had a piano bar.

Spread Spectrum Transmitter/Receiver





Channel Characteristics: Channel Data Rate:

- The maximum number of bits that can be transmitted per unit time through the physical medium. Measured in bits per second (bps).

Shannon Law

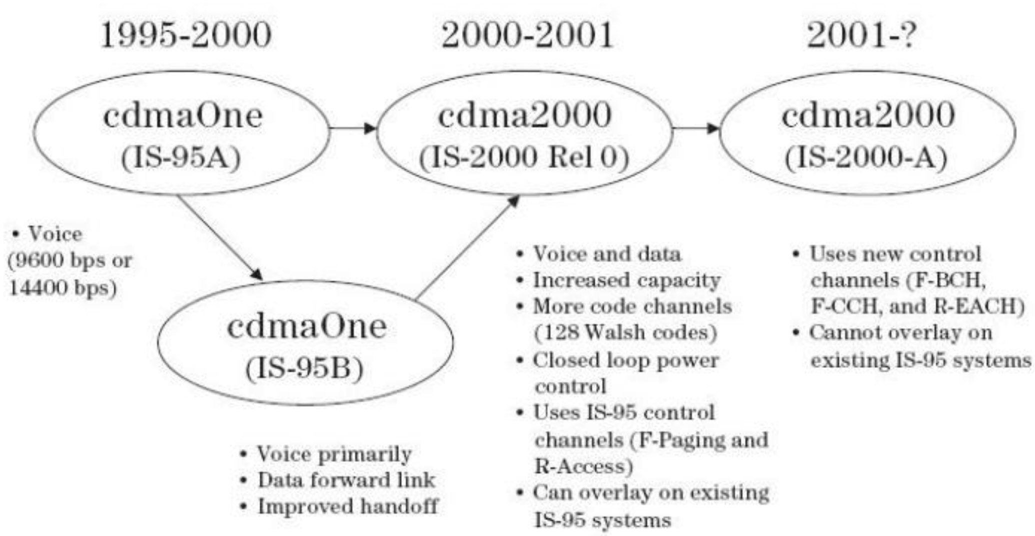
Higher Date Rate Requires

- More Bandwidth
- Better S/N (E_b/N_0) "more power"

CDMA - Transmission and Reception: Roadmap

CDMA2000: Flexible Migration Path: **MHz**
CDMA2000 allows operators the flexibility to design an evolution path that meets their unique needs.

Introduction
One of the technologies meeting the IMT-2000 requirements for a third generation (3G) global wireless communications system iscdma2000, also known as IS-2000. The Third-Generation Partnership Project 2 (3GPP2) wrote the specification for this wideband codedivision multiple access (CDMA) system as a derivative of the IS-95-B CDMA system, also known as cdmaOne. The 3GPP2 organizationalpartners are the Japanese Association of Radio Industries and Businesses (ARIB), Telecommunication Technology Committee (TTC),Telecommunications Industries Association (TIA), and Korean Telecommunications Technology Association (TTA).
Basic Concepts of cdma2000
The main advantages that cdma2000 offers over other IMT-2000 proposals are backward compatibility with cdmaOne systems and asmooth migration from second-generation (2G) cdmaOne systems to 3G. Figure 1 shows the potential evolution path from cdmaOne tocdma2000 systems.



Spreading Rate
Spreading rate (SR) defines the final spread chip rate in terms of 1.2288 Mcps. The two spreading rates are SR1 and SR3.

SR1: An SR1 signal has a chip rate of 1.2288 Mcps and occupies the same bandwidth as cdma One signals. The SR1 system doubles the system capacity, therefore, it can be considered an improved cdm aOne system. The main differences from cdma One are:

1) Fast power control and quadrature phase shift keying (QPSK) modulation rather than dual binary phase shift keying (BPSK) in theforward link
2) Pilot signal, to allow coherent demodulation, and hybrid phase shift keying (HPSK) spreading in the reverse link

SR3: An SR3 cdma2000 signal has a rate of 3.6864 Mcps (3 x 1.2288 Mcps) and occupies three times the bandwidth of cdma One. Originally, the SR3 system appeared to be viable. Upon further investigation the SR3 cdma2000 system was determined to not be viable and is no longer receiving any commercial attention at this time.

Radio Configuration

Radio configuration (RC) defines the physical channel configuration based upon a specific channel data rate. Each RC specifies a set of data rates based on either 9.6 or 14.4 kbps. These are the two existing data rates supported for cdma One. Each RC also specifies the spreading rate (either SR1 or SR3) and the physical coding. Currently there are nine radio configurations defined in the cdma2000 system for the forward link and six for the reverse link. Examples are: And operates at SR1. It does not use any of the new cdma2000 coding improvements.

RC3 is a cdma2000-specific configuration based on 9.6 kbps that also supports 4.8, 2.7, and 1.5 kbps for voice, while supporting data at 19.2, 38.4, 76.8, and 153.6 kbps and operates at SR1.

Each base transceiver station (BTS) or MS must be capable of transmitting using different RCs at the same SR.

Forward Link Air Interface

The forward link air interface for a cdma2000 SR1 channel is very similar to that of cdma One. In order to preserve compatibility, cdma2000uses the same structure as cdma One for the forward pilot (F-Pilot), forward sync (F-Sync), and forward paging (F-Paging) channels.

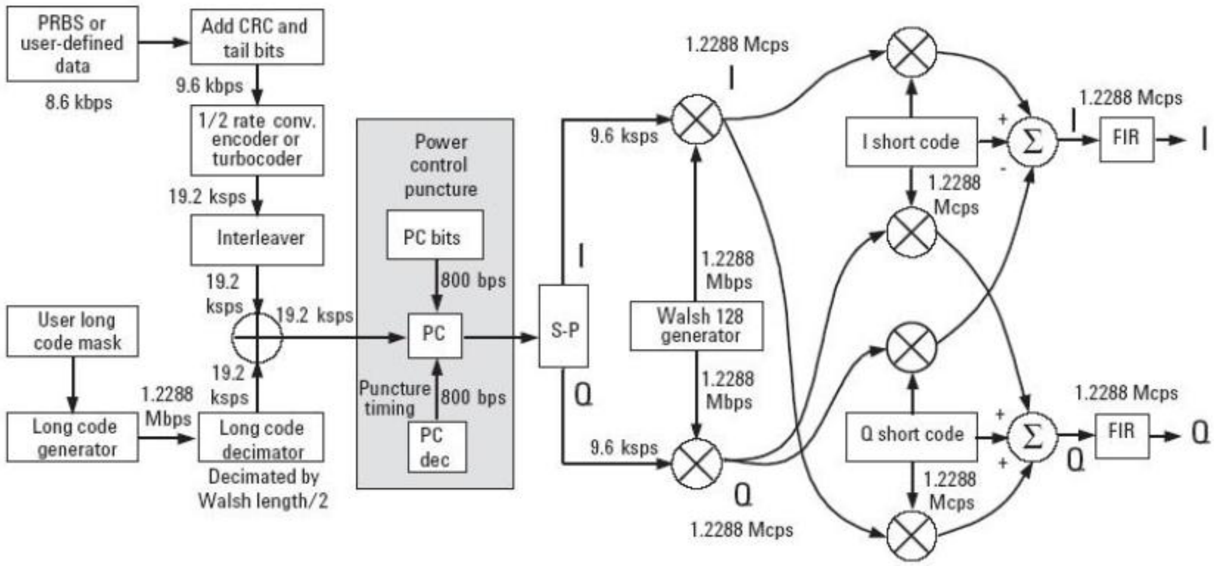
In cdma2000, each user is assigned a forward traffic (F-Traffic) channel, which consists of:

1) zero to one forward fundamental channel (F-FCH)
2) zero to seven forward supplemental code channels (F-SCCHs) for RC1 and RC2
3) zero to two forward supplemental channels (F-SCHs) for RC3 to RC9
4) zero to one forward dedicated control channels (F-DCCHs)

The F-FCHs are used for voice and the F-FCCHs and F-SCHs are used for data. The BTS may also send zero or one F-DCCHs. An F-DCCH is associated with traffic channels (either FCH, SCH, or SCCH) and may carry signaling data and power control data.

One of the main differences between cdma One and cdma2000 is that the latter uses true quadrature phase shift keying (QPSK) modulation (as opposed to dual-BPSK) for all traffic channels from RC3 to RC9. As an example, Figure 2 shows the forward link structure for an RC4 F-FCH. The coding is identical to cdma One up through the long code scrambling of the voice data. The F-FCH is optionally punctured with the reverse link power control data bits. The data is then converted from a serial bit stream into a two-bit wide parallel data stream to produce true QPSK modulation. This reduces the data rate of each stream by a factor of two. Each branch is spread with a 128Walsh code to generate a spreading rate of 1.2288 Mcps. In this case, the processing gain is doubled for each channel relative tocdma One. Each channel is transmitted at one-half the power used before, but there are now two of them for no apparent gain. The actual processing gain for each channel depends on its data rate and RC.

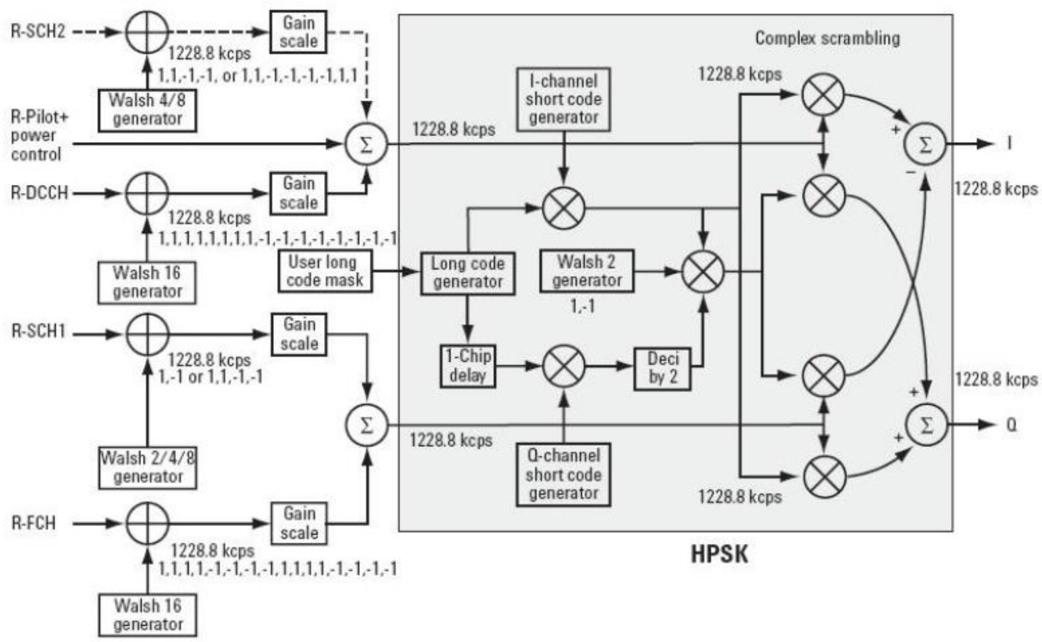
The outputs of the I and Q Walsh spreaders are then complex multiplied against the same I and Q channel short codes used in cdma One. Complex scrambling is used in the forward link instead of regular scrambling because it is a more robust scheme against interference.



Reverse Link Air Interface — HPSK

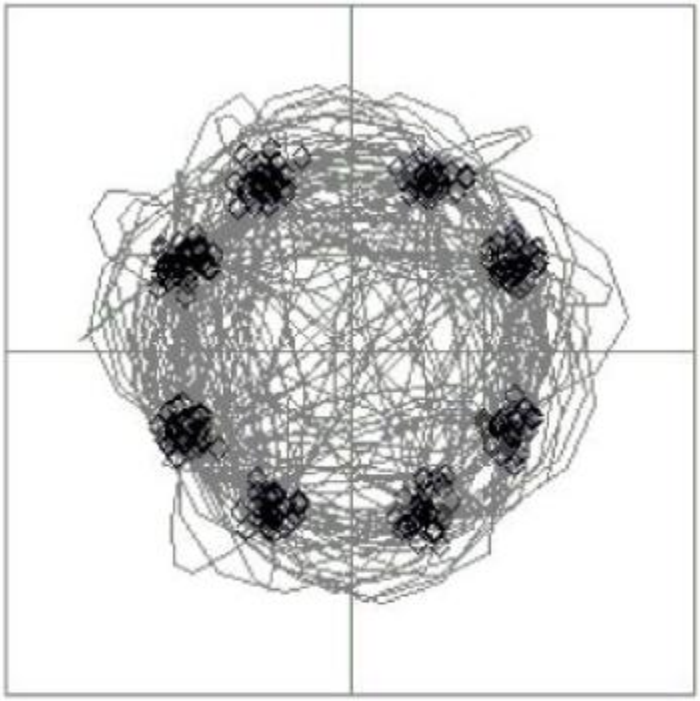
The cdma2000 reverse link is very different from cdma One. The MS can transmit more than one code channel to accommodate the high data rates. The minimum configuration consists of a reverse pilot (R-Pilot) channel to allow the BTS to perform synchronous detection and a reverse fundamental channel (R-FCH) for voice. Additional channels, such as the reverse supplemental channels (R-SCHs) and the reverse dedicated control channel (R-DCCH) can be used to send data or signaling information, respectively.

The different channels are assigned to either the I or Q path. For example, for RC3 to RC6, the R-Pilot is assigned to I and R-FCH is assigned to Q.



Channels can be at different rates and different power levels. Complex scrambling facilitates this by continuously phase rotating the constellation and thus distributing the power evenly between the axes.

Without scrambling, unequal channel powers would result in a rectangular four-quadrature amplitude modulation (QAM) constellation (assuming that only R-Pilot and R-FCH are active). With complex scrambling, the constellation for two channels generally has eight points distributed around a circle, with the angular distribution determined by the relative powers of the two channels. For example, an amplitude difference of 6 dB between the two channels results in the constellation shown in Figure 4, which is close to an 8-PSK (8-phase shift keying) constellation (an amplitude difference of 7.65 dB would result in a perfect 8-PSK constellation). If the amplitudes for the two channels are equal, then pairs of constellation points merge to give a QPSK-like constellation.

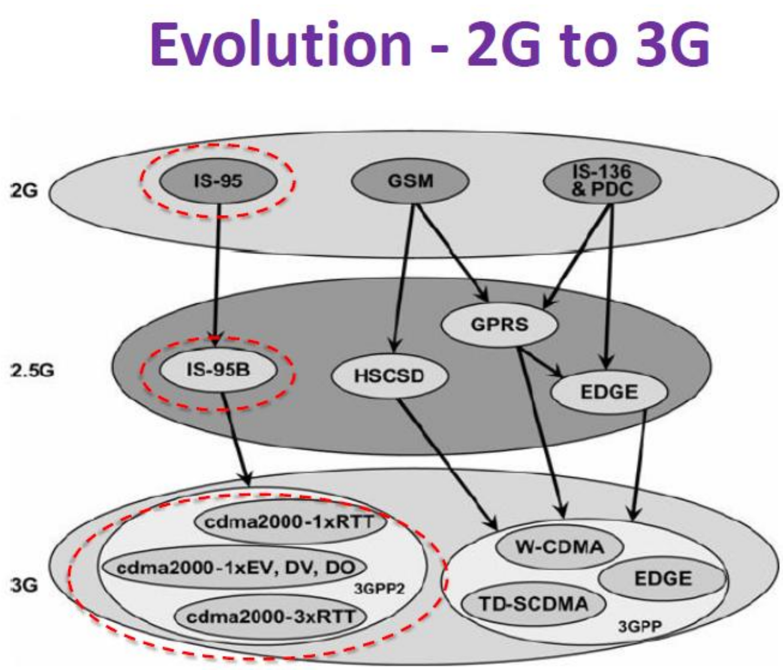


(A reverse link cdma2000 SR1 signal with an R-Pilot and an R-FCH. The amplitude of the R-FCH is 6 dB lower than that of the R-Pilot.)

Basic complex scrambling applies a phase rotation of 0, $\pm\pi/2$, or π radians to each chip. HPSK takes this idea a stage further and de fines the complex scrambling so that for every second chip, the phase rotation is restricted to $\pm\pi/2$. This constraint on the phase transitions entering the baseband pulse shaping filter reduces the peak-to-average ratio of the signal (about 1 to 1.5 dB) compared to regular complex scrambling (or regular QPSK). The HPSK technique continues to be advantageous even when the signal has more than two channels.

Forward Link Power Control

A key improvement in cdma2000 is forward link power control. The MS sends power control data back to the BTS by time multiplexing it with the R-Pilot channel. Like the existing reverse link closed loop power control of cdma One, the cdma2000 forward link closed loop power control sends 800 power control bits each second. These bits indicate whether the BTS should raise or lower its power in 1 dB, 0.5dB, or 0.25 dB. The finer steps allow tighter power control for low mobility or stationary phones. Tighter control (less power ripple) lowers the average power and thus raises the capacity of the system.



Interim Standard 95 (IS-95)

- •Also known as cdmaOne
- •64 users in a 1.25 MHz channel.
- •Can be used in 800 MHz and 1900 MHz bands.
- •Sprint and Verizon in the U.S.

Interim Standard 95 (IS-95)

- •Spectrum bandwidth:
- •1850 to 1910 MHz Mobile to Base
- •1930 to 1990 MHz Base to Mobile
- •Channels are 1.25 MHz
- •3.75 MHz in CDMA 2000, 5 MHZ in UMTS
- •Results in approximately only 48 forward/reverse channel pairs in IS-95.
- •Adjacent cell phone towers use the exact same channels as all other towers.
- •This is a major difference.
- •Allows for much better frequency reuse and makes setting up a cellular network much easier.

Upgrade path from IS-95A to IS-95B for 2.5G CDMA

- •Only one upgrade path for IS-95
- •Users can use up to 8 CDMA codes simultaneously.
- •14.4 kpbs* 8 = 115.2 kbps
- •Practical throughput is 64 kbps that can actually be achieved.
- •Also changes the method of handoff between base stations.

cdma2000

- •From IS-95/IS-95B
- •Works within original 2G CDMA channel bandwidth of 1.25 MHz.
- •Allows wireless carriers to introduce 3G in a gradual manner.
- •Can introduce 3G capabilities at each cell
- •Do not have to change out entire base stations
- •Do not have to use different spectrum.

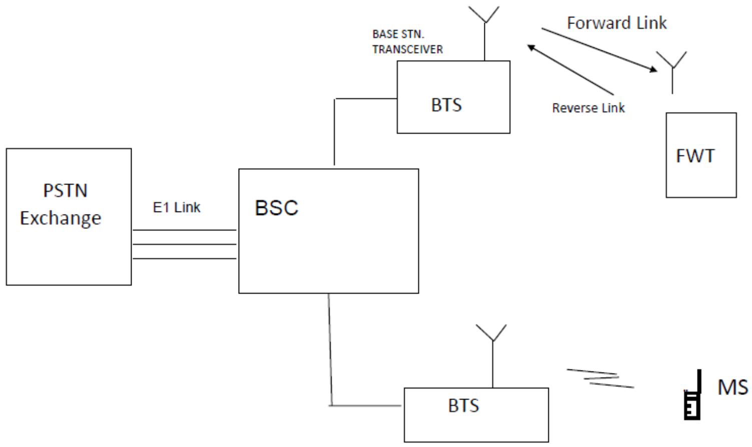
cdma2000 1xRTT

- •1X = one times the original IS-95 (cdmaOne) channel bandwidth.
- •RTT = Radio Transmission Technology
- •Commonly just referred to as cdma2000 1X.
- •Instantaneous data rate of 307 kbps.
- •Typical rates up to 144 kbps
- •Uses rapidly adjusting rates.
- •No additional RF equipment is needed.
- •All changes made in software or with additional hardware.

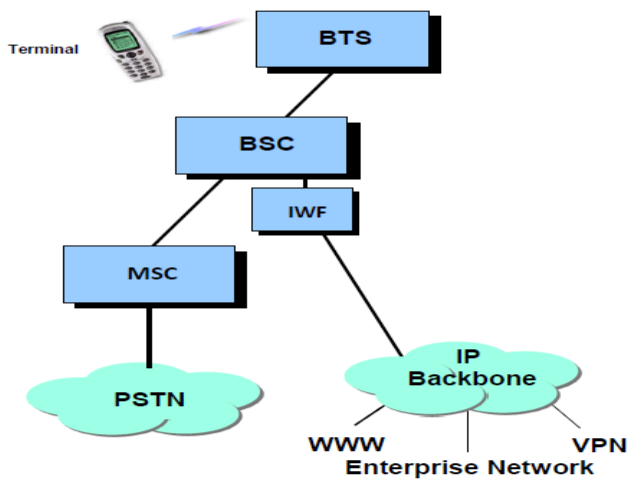
cdma2000 1xEV

- •EV = Evolutionary enhancement
- •High data rate packet standard overlaid on existing IS-95, IS-95B, and cdma2000 networks.
- •1xEV-DO
- •Data only channel
- •Restricts a shared 1.25 MHz channel strictly to data users.
- •Supports greater than 2.4 Mbps throughput per user.
- •Actual data rates usually much lower.
- •Typical: Several hundred kbps.
- •Highly dependent on number of users, propagation conditions, and velocity of mobile.

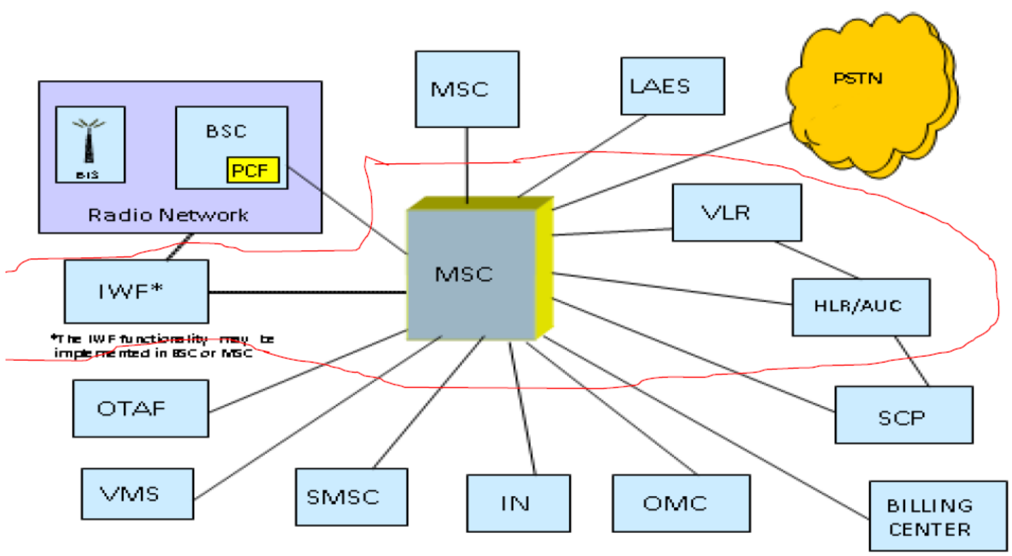
Network Architecture of BSC based IS-95 Systems:



Cdma One Network



MSC BASED CORE NETWORK FOR CDMA 2000 1x SYSTEM



MSC/VLR

MSC (Mobile Switching Center) is responsible for call establishment, routes election, call control, radio resource allocation, mobility management, location registration and channel hand off in switching areas. In addition, it generates bill in formation, coordinates services between it and the PSTN.

VLR (Visitor Location Register) acts as a dynamic data base and stores the temporary information (all data necessary to setup call connections) about the users roaming to the local MSC area.

HLR/AUC

•**HLR (Home Location Register)** serves as the primary data base repository for subscriber information (telecom service subscription information and user status), RS location information, MDN, IMSI (MIN), etc.

•Mobile subscriber profiles, locations and activities, and information about supplementary subscriber services are all seamlessly managed for the Mobile operator by the HLR.

•One HLR can serve one or more MSC.

HLR/AUC

•**AUC (Authentication Center)** is a function a l unit of the HLR, specially dedicated to the security management of the CDMA system.

•It is physically combined with the HLR.

•It stores the authentication information and ciphering key and prevents unauthorized users from accessing the system and prevents the unauthorized a die interception.

•Functional entity of HLR/AUC may be physically integrated with logical separation or it can best and alone HLR/AUC.

Interworking Function (IWF)

•IWF acts as a gateway between the wireless CDMA networks and the wire line Public Switched Telephone Network (PSTN/packet data networks).

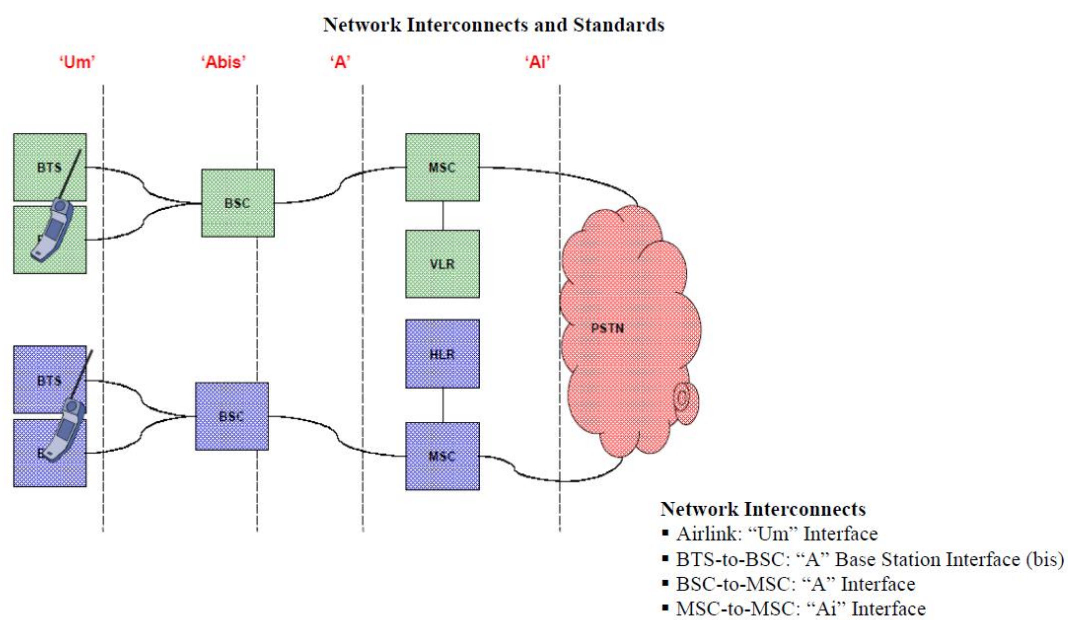
•IWF provides the inter working and protocol conversion required for offering data services to cdma One Mobile subscribers.

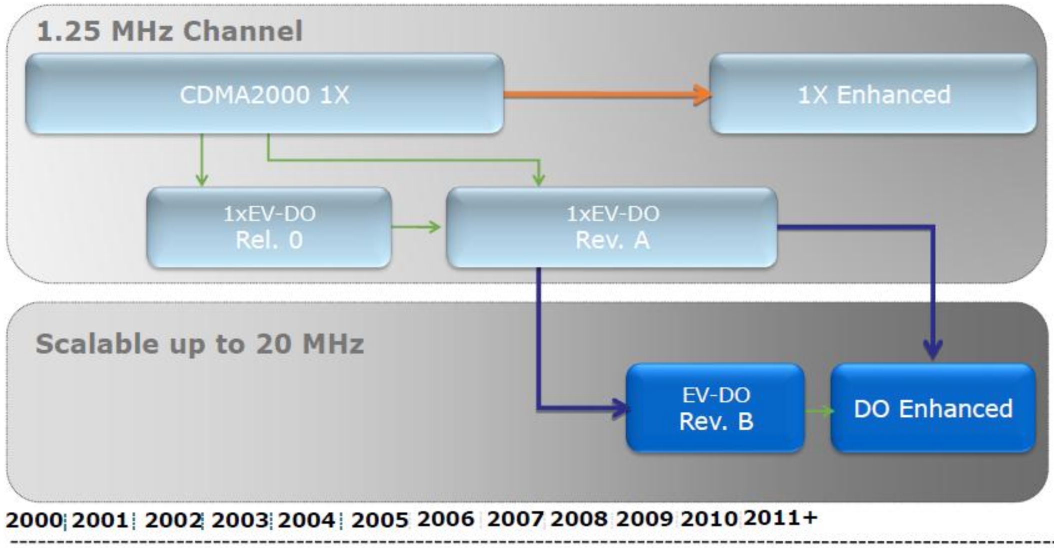
•The IWF functionality may be implemented in BS Cor MSC.

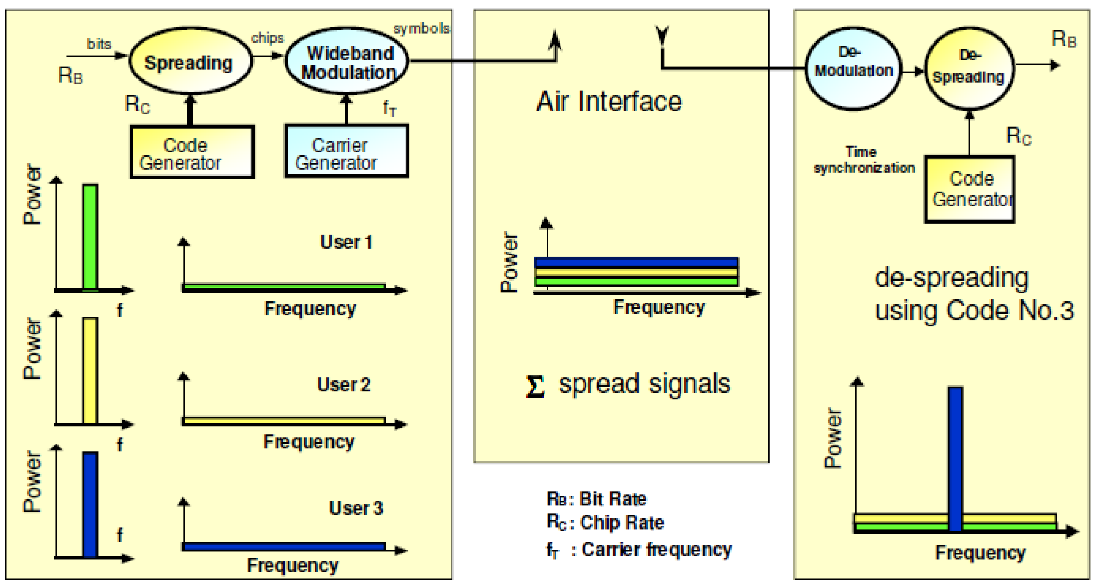
Operations and Maintenance Centre (OMC)

•OMC allows the centralized operation of the various units in the system and the functions needed to maintain the subsystems.

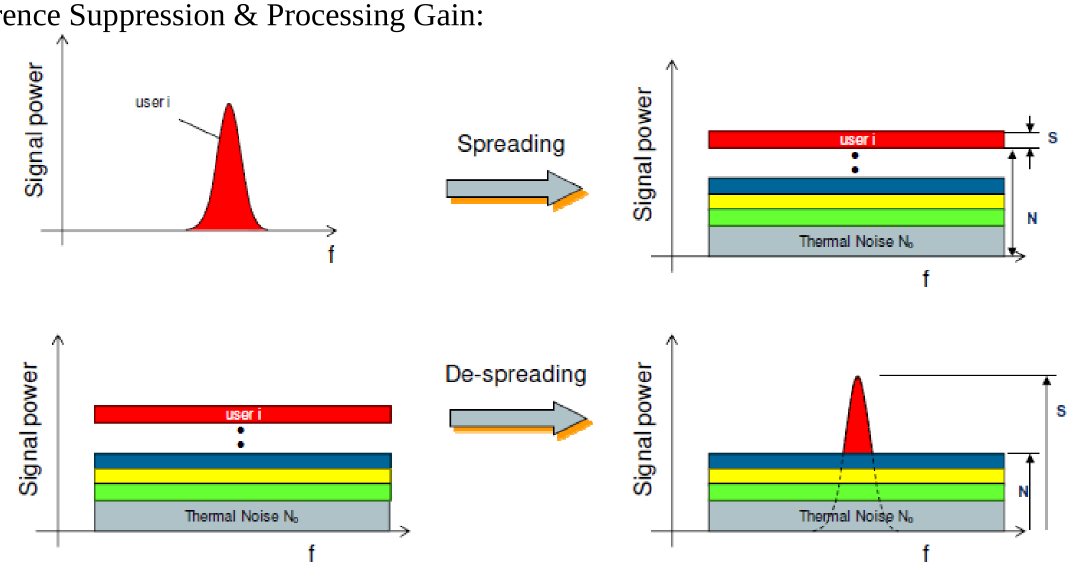
•The OMC provides the dynamic monitoring and controlling of the network management functions for operation and maintenance.



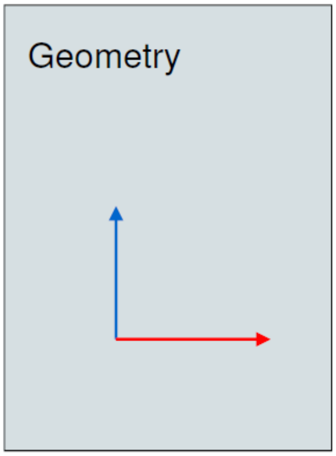




CDMA Interference Suppression & Processing Gain:



Code Orthogonality:



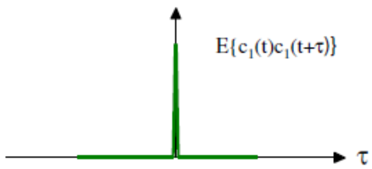
Information Theory

Orthogonal functions have zero correlation.

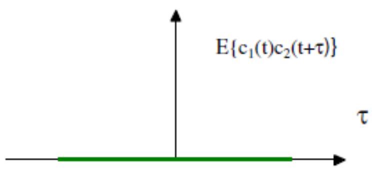
Two binary sequences are orthogonal if the process of multiplying them results in equal +1s & -1s

Example:				
	-1	-1	1	1
	-1	1	-1	1
	1	-1	-1	1

Spreading Sequences – Desired Properties:

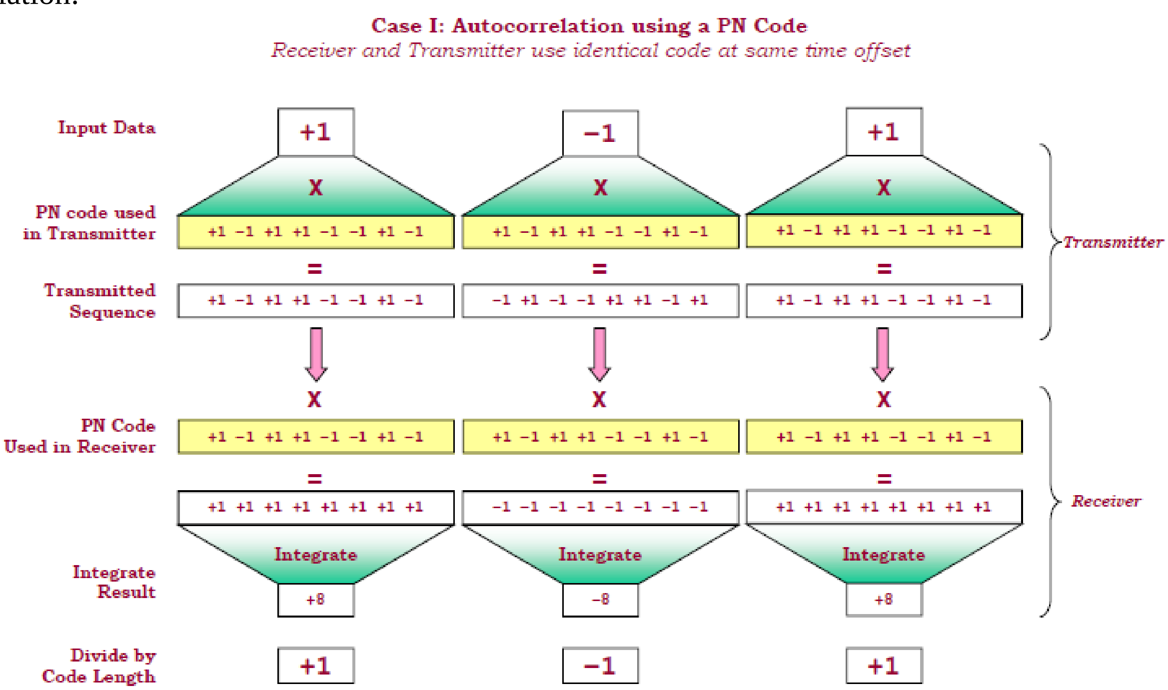


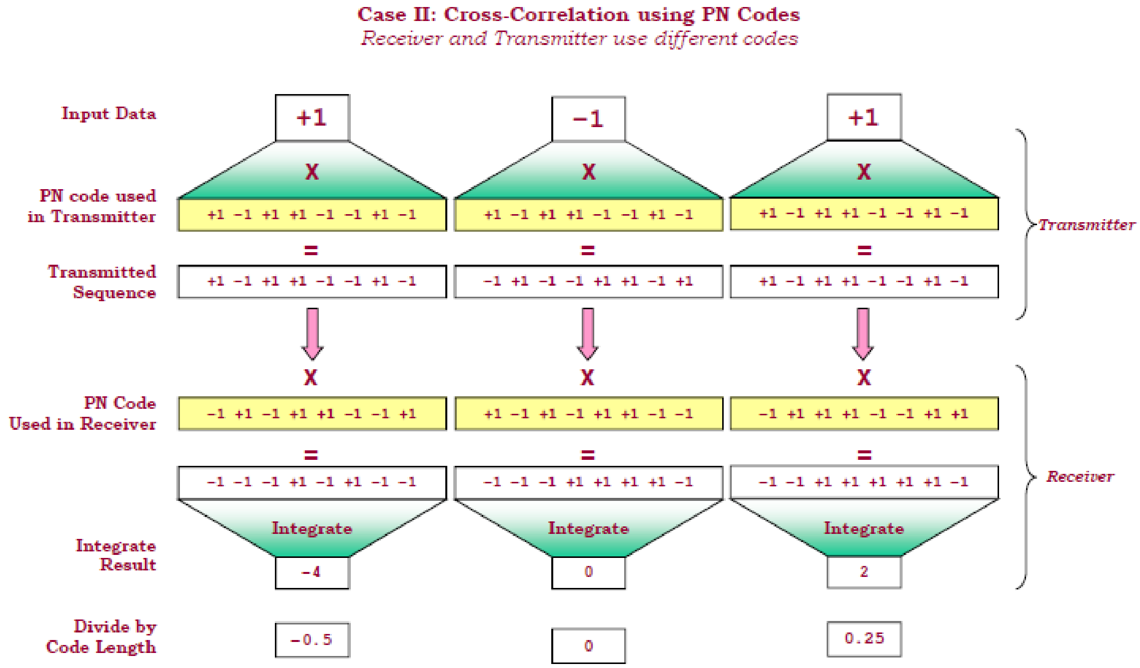
- Autocorrelation
  - suppression of self interference (non-zero time shifts of the same code)
  - ideally a delta pulse
  - in practice close to zero at $\tau \neq 0$



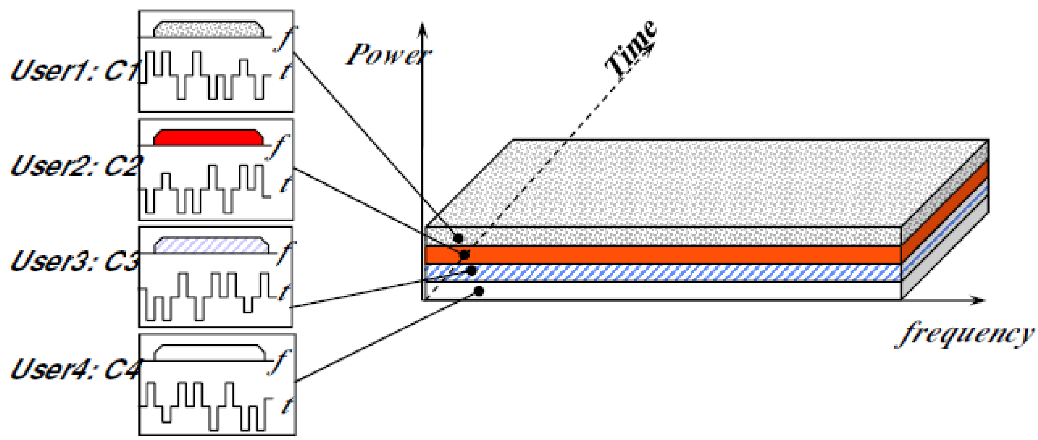
- Cross-correlation
  - suppression of inter-user interference
  - ideally zero
  - in practice close to zero

Code Correlation:





CDMA – Basic concept:

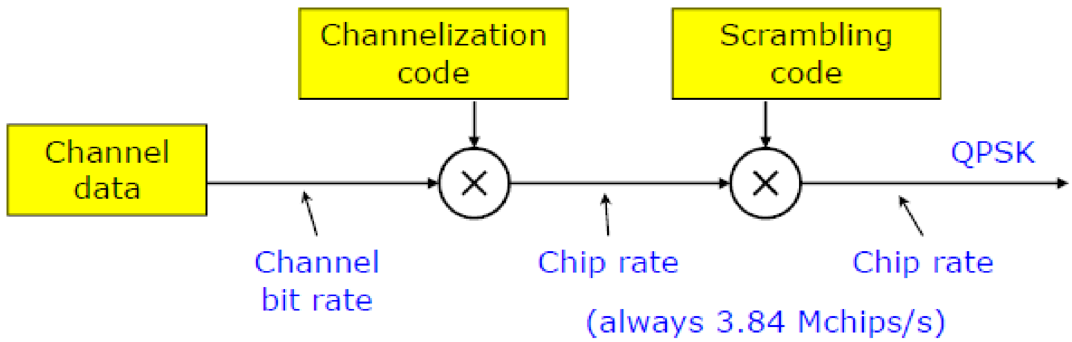


- The communications Channel is the Code.
- Physical resource occupancy is the transmit power.

  A physical resource is a Coded channel transmitted at a given level of Power for a certain time length "Frame".
- No time or frequency Orthogonality between users is required.

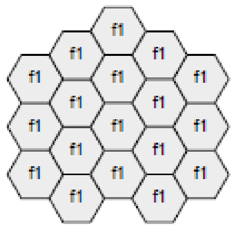
WCDMA

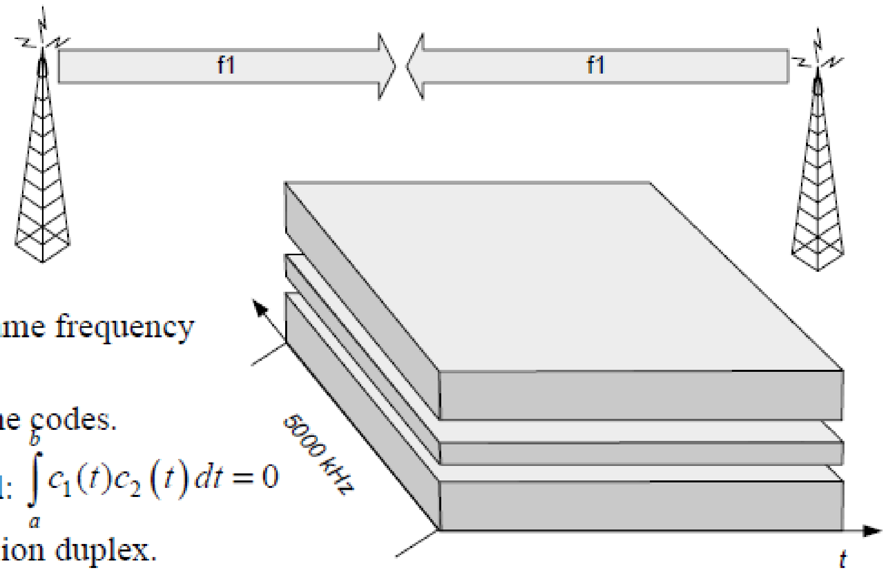
- Spreading means increasing the signal bandwidth
- Spreading includes two operations
  - ***Channelization*** (increases signal bandwidth)
    - Orthogonal Spreading
  - ***Scrambling*** (does not affect the signal bandwidth)
    - Use pseudo-noise codes



- Increases the bandwidth
  - Based on Orthogonal Variable Spreading Factor (OVSF)
  - Codes are fully orthogonal, i.e., they do not interfere with each other
  - Only if the codes are time synchronized
    - It can separate the transmissions from a single source
    - In DL: it can separate different users within one cell/sector
    - In UL: it separates the physical channels/services of one user
- Limited orthogonal codes must be reused in every cell
  - Problems:
    - In DL: Interference, if two cells use the same code
    - In UL: Mobiles are not synchronized in time
    - Two mobiles can use the same code
  - Solution is ***Scrambling***:
    - Scrambling codes are used to separate different users in the UL & different cells in the DL.

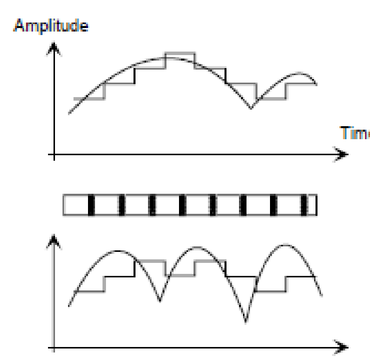
WCDMA based system





- All users share the same frequency time domain.
- Users separated by the codes.
- Codes are orthogonal: $\int_a^b c_1(t)c_2(t)\,dt = 0$
- FDD frequency division duplex.
  - Uplink, downlink in separate frequency bands
- TDD time division duplex.
  - Uplink, downlink in the same frequency band and separated in time.

Purpose of Power Control in WCDMA



- Removes near far effect.
- Mitigates fading.
- Compensates changes in propagation conditions.
- In the system level
  - decrease interference from other users
  - increase capacity of the system

- Uplink

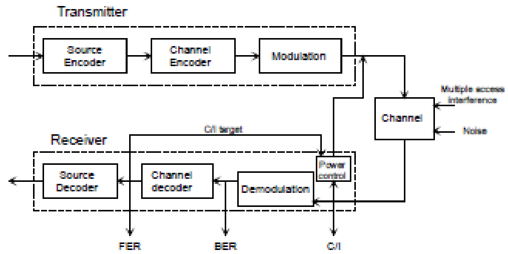
Power control in uplink must make signal powers from different users nearly equal in order to maximise the total capacity in the cell.

- Downlink

In downlink the power control must keep the signal at minimal required level in order to decrease the interference to users in other cells.

Power Control types in WCDMA

- **Open Loop power control**: for initial power setting of MS



Across the air interface

- **Fast closed loop power control**:
  - Mitigates fast fading rate 1.5 kbps.
  - On UL and DL.
  - Uses a fixed quality target set in MS/BS.
- **Outer loop power control**:
  - Compensates changes in environment.
  - Adjust the SIR target to achieve the required FER/BER/BLER.
  - Depends on: MS speed available, multipath diversity.
  - In the soft handover comes after frame selection.

WCDMA handover types.

- Intra-system handovers:
  - Intra-frequency handovers.
    - MS handover within one cell between different sectors: softer
    - MS handover between different BS:
      - Soft.
      - Hard.
  - Inter-frequency handovers.
    - Hard
- Inter-system handovers:
  - Handover between WCDMA <--> GSM900/1800: Hard
  - Handower between WCDMA/FDD <--> TDD: Hard

WCDMA handovers

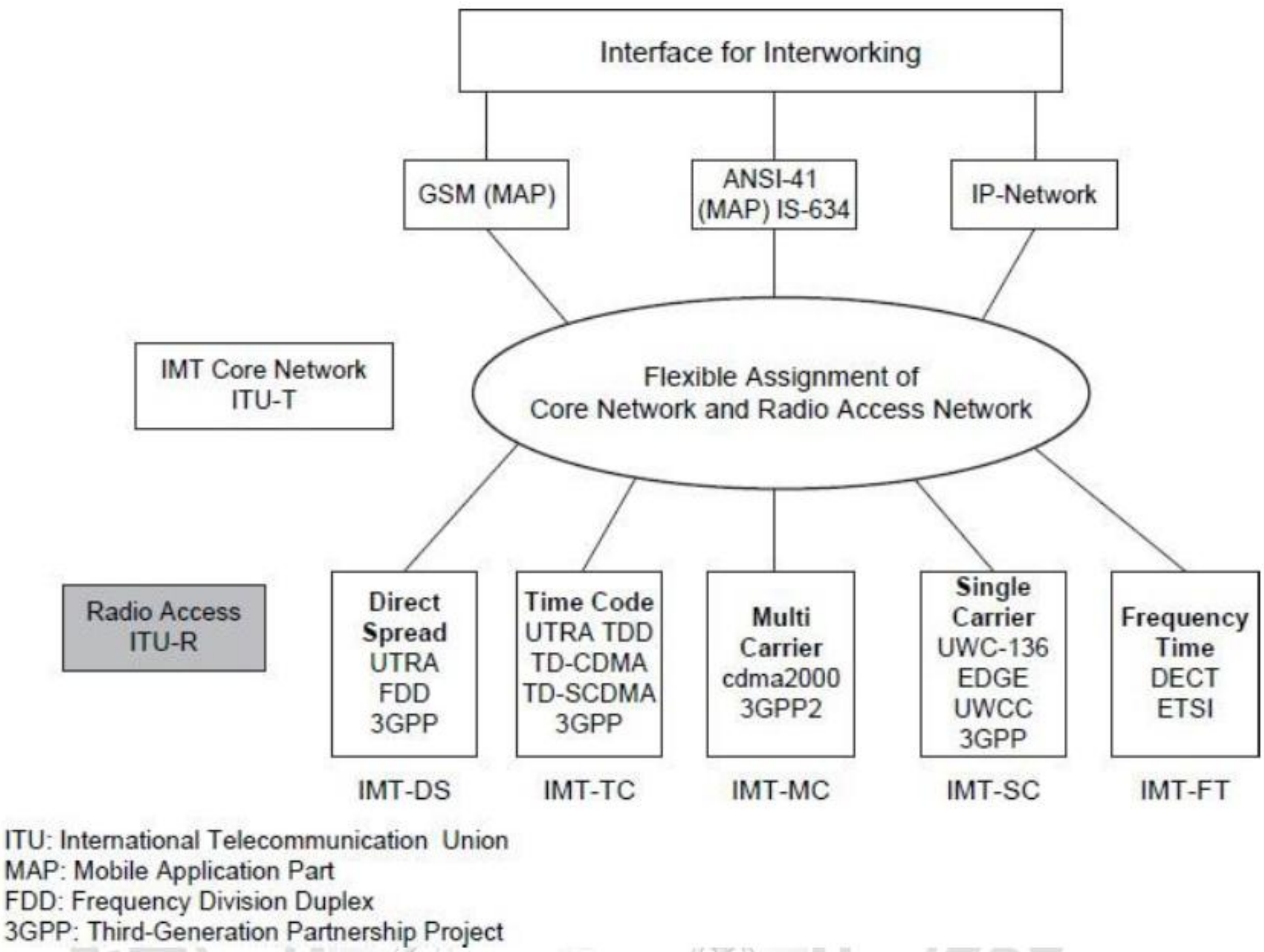
- Avoidance of near far situation for circuit switched connections
  - for high mobility users shadow fading + (slow) hard handovers would create near far situations.
- Soft/Softer handovers will improve cell capacity (around 40-60 %)
- Soft/Softer provide macrodiversity gain: compared the hard handover larger cell range.
  - Gain against shadow fading (1 -3 dB).
  - Gains against fast fading, typically 0.5 - 2 dB assumed.
- Soft/Softer essential interference mitigating tool.

IMT Family

The International Telecommunication Union (ITU) identified the long-term spectrum requirements for the future third-generation (3G) mobile wireless telecommunications systems. In 1992, the ITU identified 230 MHz of spectrum in the 2 GHz band to implement the IMT (International Mobile Telecommunications)- 2000 system on a worldwide basis for satellite and terrestrial components. The aim of IMT-2000 is to provide universal coverage enabling terminals to have seamless roaming across multiple networks. The ITU accepted the overall standardization responsibility of IMT-2000 to define radio interfaces that are applicable in different radio environments including indoor, outdoor, terrestrial, and satellite.

The above figure provides an overview of the IMT family. IMT-DS is the direct spread (DS) technology and includes WCDMA systems. This technology is intended for UMTS terrestrial radio access (UTRA)-FDD and is used in Europe and Japan.

IMT-TC family members are the UTRA-TDD system that uses time division (TD) CDMA, and the Chinese TD-synchronous CDMA (TD-SCDMA).Both standards are combined and the third-generation partnership project (3GPP)is responsible for the development of the technology. IMT-MC includes multiple carrier (MC) cdma2000 technology, an evolution of the cdma one family.



3GPP2is responsible for standardization. IMT-SC is the enhancement of the US TDMA systems. UWC-136 is a single carrier (SC) technology. This technology Applies EDGE to enhance the 2 G IS-136 standards. It is now integrated into the 3GPPefforts. IMT-FT is a frequency time (FT) technology. An enhanced version of the cordless telephone standard digital European cordless technology (DECT) has been selected for low mobility applications. The ETSI has the responsibility for standardization of DECT.

In Europe, 3G systems are intended to support a substantially wider and enhanced range of services compared to the 2G (GSM) system. These enhancements include multimedia services, access to the Internet, high rate data, and soon. The enhanced services impose additional requirements on the fixed network functions to support mobility. These requirements are achieved through an evolution path to capitalize on the investments for the 2G system in Europe, Japan, and North America.

In North America, the 3G wireless telecommunication system, cdma2000was proposed to ITU to meet most of the IMT requirements in the indoor office, indoor to outdoor pedestrian, and vehicular environment. In addition, thecdma2000 satisfies the requirements for 3G evolution of 2G TIA/EIA 95 family of standards (cdma One).

In Japan, evolution of the GSM platform is planned for the IMT (3G) core network due to its flexibility and widespread use around the world. Smooth migration from GSM to IMT-2000 is possible. The service area of the 3G system overlays with the existing 2G (PDC) system. The 3G system connects and interworks with 2G systems through an interworking function (IWF). An IMT- 2000-PDC dual mode terminal as well as the IMT-2000 single mode terminal is deployed.

UMTS as discussed today and introduced in many countries is based on the initial release of UMTS standards referred to as release 99 or R99. This (release)is aimed at a cost-effective migration from GSM to UMTS. After R99 the Release of 2000 or R00 followed. 3GPP decided to split R00 into two standards and call them release 4 (Rel-4) and release 5 (Rel-5). The version of all standards finalized for R99 is now referred to as Rel-3 by 3GPP. Rel-4 introduces QoS in the fixed network plus several execution environments (e.g., MExE, mobile execution environment) and new service architectures. Rel-4 was suspended in March 2001.

Rel-5 specifies a new core network. The GSM/GPRS-based core network will be replaced by an almost all-IP core network. The content of Rel-5 was suspended.

CDMA2000 SYSTEM

Introduction

The nets CDMA2000 are compatible with the nets cdmaOne, that which protects the investments of the operators cdmaOne and it provides a simple and economic migration to the following generation. Also, the nets CDMA2000 offers improvements in the voice quality and support for data multimedia services.

Standardization

CDMA2000 was approved as terrestrial standard of IMT-2000, CDMA2000 1X and CDMA2000 1xEV (including 1xEVDO and 1xEV-DV) constitute part of that the UIT IMT-2000 has denominated CDMA Multi-Carrier (MC).
CDMA2000 is commercially for more than three years, the first technology of third generation that made reality IMT-2000 was. The first system 3G in the world starts in Korea at the end of the 2000.
Today, 97 millions of subscribers access to CDMA2000 nets in Asia, Europe and America. Other 35 CDMA2000 nets will be deployed in the whole world in a future not very distant.

Evolution de Cdma2000

CDMA2000:

- Common denomination for IMT-2000 CDMA Multi-Carrier.

CDMA2000 1X (October 2000)**:**

- 3G Technology that it duplicates the voice capacity.
- It provides data transmission speeds up to 307 kbps in a single carrier (1.25 MHz, or 1X).

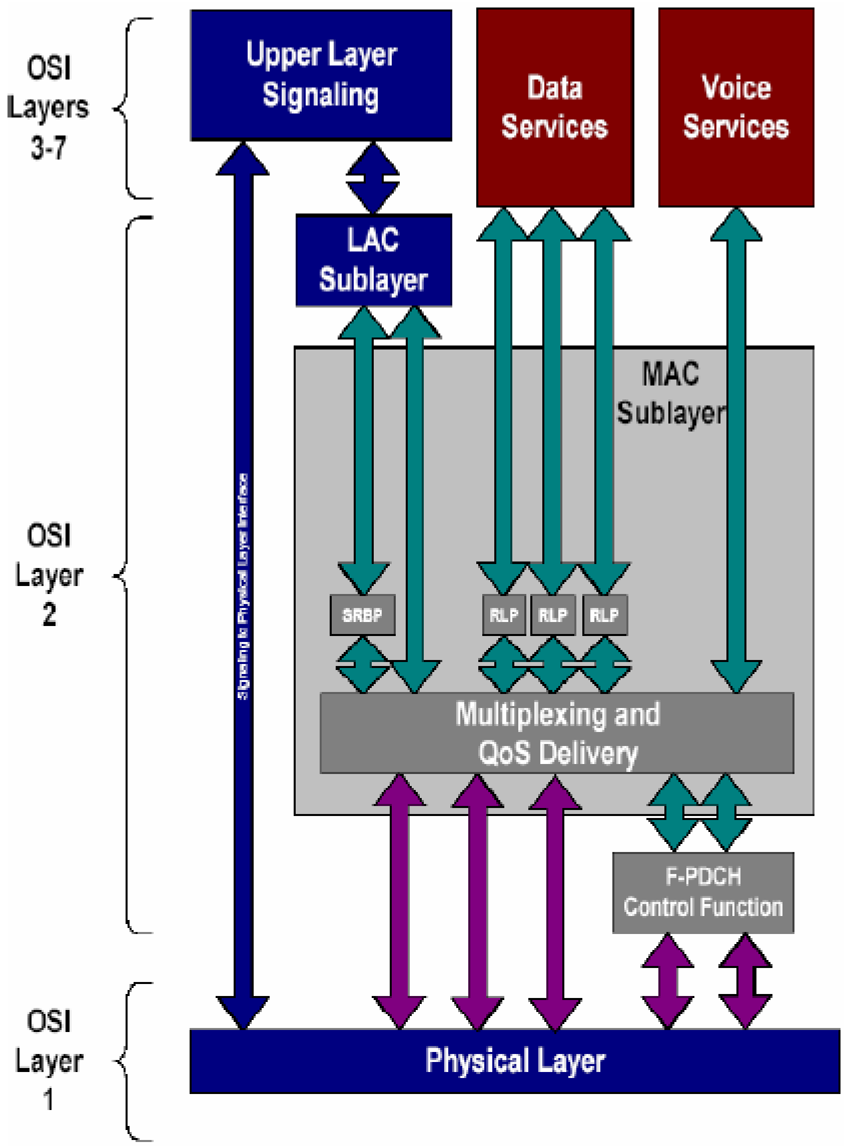
CDMA2000 1xEV :

- Evolution of CDMA2000 1X that it offers bigger data transmission speed can offer up to 2.4 Mbps in a single carrier the same as the previous one (1.25 Mhz).

CDMA2000 1xEV-DO (firsts of 2002)**:**

- 3G Technology that only uses a carrier of 1.25MHz for data.

- It reaches transmission speeds of up to 2.4 Mbps.



Logical channels Carry data over the air and are mapped directly to the physical channels(logical channels)

1) Dedicated Traffic Channel (f/r-dtch): A point to point logical channel that carries data or voice traffic over a dedicated physical channel.
2) Common Control channels (f/r-cmch control) : These are used to carry MAC messages with shared access for several terminals.
3) Dedicated signalling Cannel (f/r-dsch): A point to point logical channel that carries upper layer signalling traffic over a dedicated physical channel, for a single terminal.
4) Common Signalling Channel (f/r-csch): A point to multipoint logical channel that carries upper layer signalling traffic over a common physical channel, with shared access for several terminals.

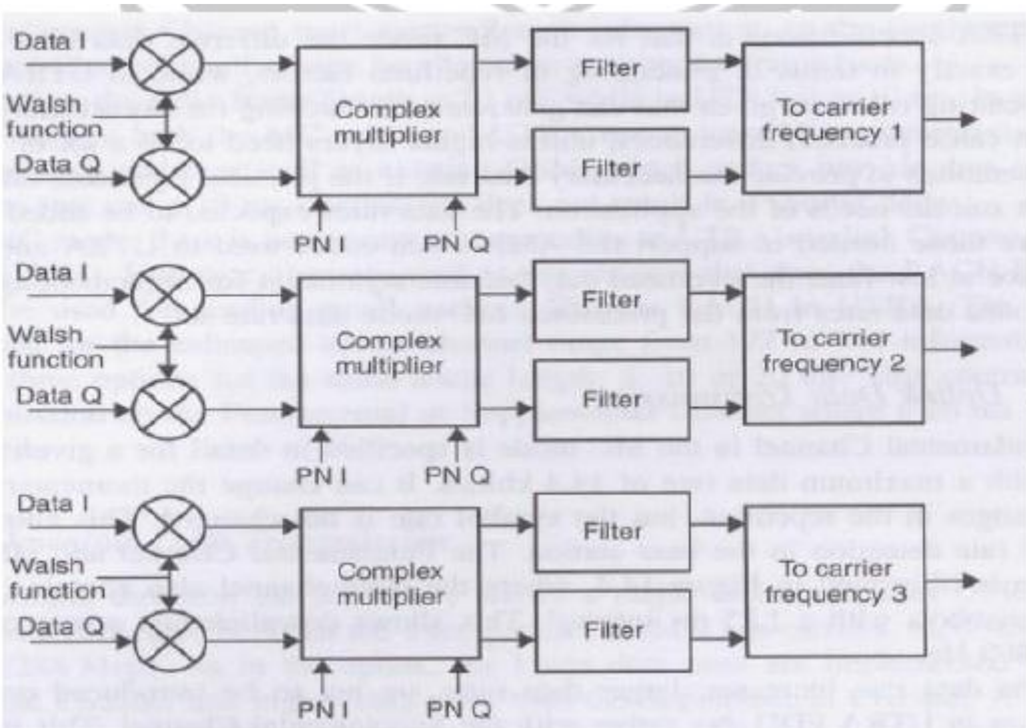
Multi-Carrier Mode

Uplink Spreading and modulation

The uplink spreading is done with Walsh functions. The uplink code used for scrambling a period of 242 -1 chips. And the access channels have a specific scrambling code with a period of 215 chips.

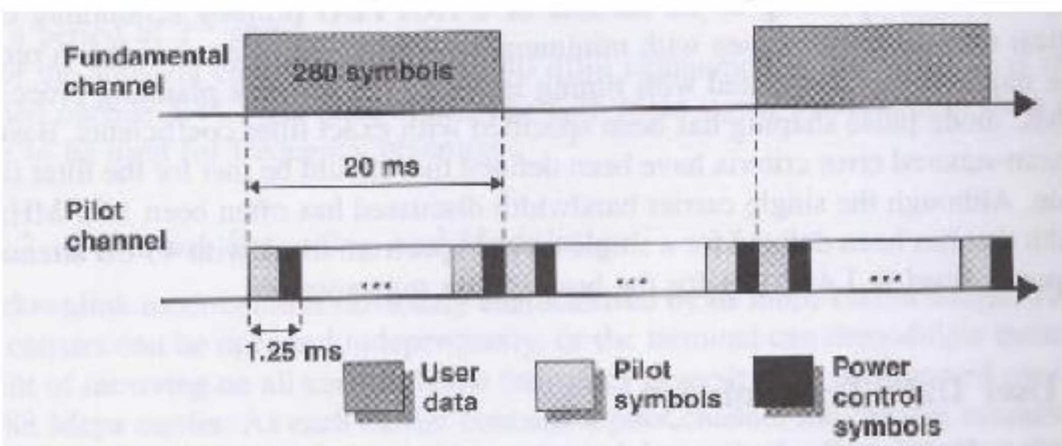
Downlink Spreading and modulation

Multi carrier nature is the characterised of downlink, the downlink carries can be operated independently or in the same time. As each carries have a pilot channel, they can be sent from different antennas to allow additional diversity.

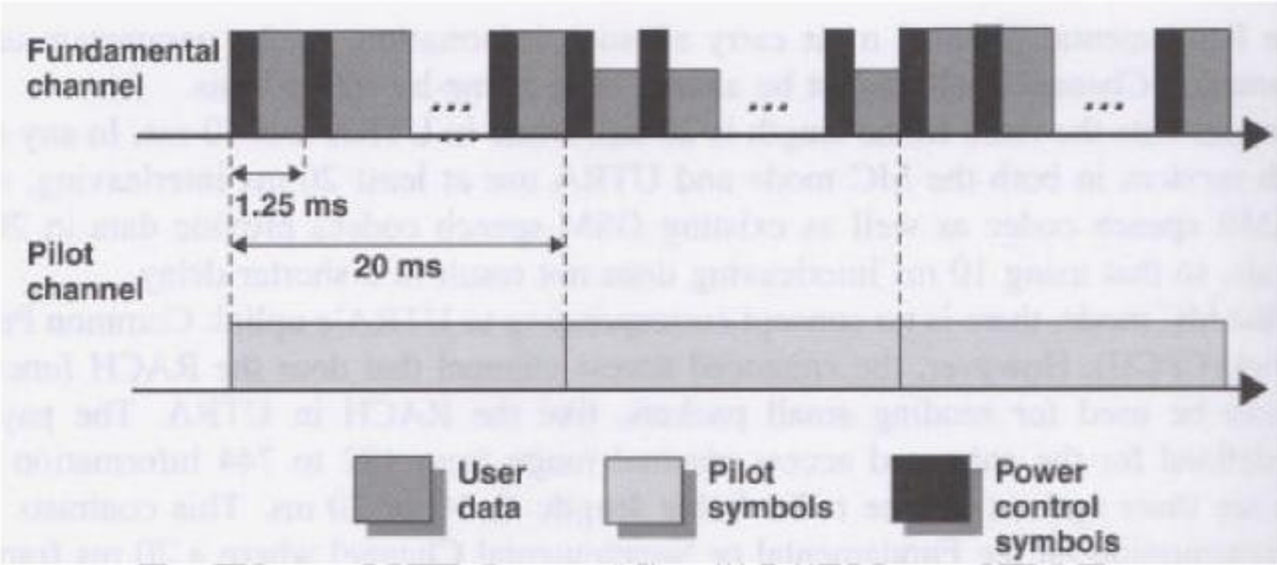


The channel on each carrier is spread with Walsh functions using a constant spreading factor during the connection, it separate channels from the same source. The spreading factors for data transmission range from 256 down to 4.Downlink modulation consisting of three carriers. Downlink scrambling is characterised by the use of a single code. MC mode is a synchronised base station, a single code is used and the different base station uses the same code with different phase (512 different phases).
The single carrier bandwidth discussed has often been 1.25 MHz, the bandwidth that has been defined for a single carrier spectrum mask with 40 dB attenuation for the power level is 1,48 MHz for the base station transmission.

User Data transmission
Uplink Data Transmission
In MC mode the fundamental channel is specific to obtain a maximum data rate(14,4 bits/s),it can change but the symbol rate is not changed. The pilot symbols and the power control symbols have a interval like 1,25 ms, it allows in the downlink fast power control (rate 800Hz). The user data he radio frame length is 20 ms.



Downlink Data Transmission
In the downlink direction the MC mode divided the user data in three parallel CDMA sub- carries, each with a rate of 1.2288 Mcps
The symbol rate for the traffic channels after channels coding and interval is multiplied by a factor of three.



Signalling

Pilot Channel:

The MC mode has a separate common pilot channel for each carrier.

Synch Channel:

It helps the terminal to acquire initial timing synchronization.

Broadcast Channel:

Typical information sent on the Broadcast channel is the availability of access channels or enhanced access channels for random access purposes.

Quick paging channel:

It indicates to mobile stations whether are accepted to receive the paging information or information in the Forward common control channel.

Common Power Control Channel:

It provides the power control information.

Common and dedicated control channels:

It is designed to carry higher layer control information for one or more terminals.

Random Access Channel:

RACH is the transport channel for the uplink, all the cell received this channel but is probably the collision. It carries control information from the terminal (such as request to set up a connection.

Physical Layer

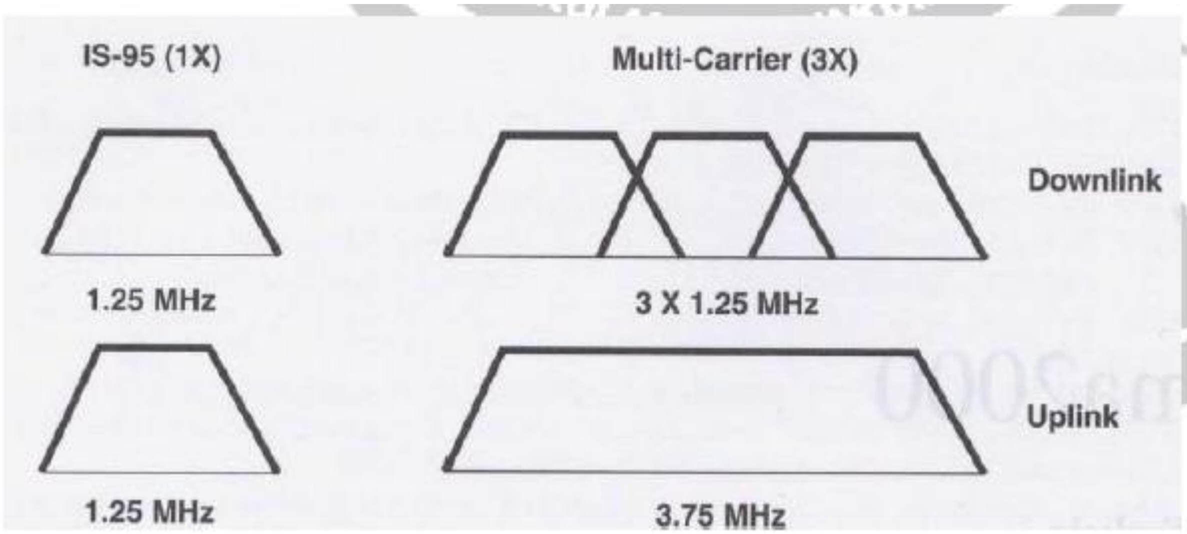
Power Control

The power control is the same that in WCDMA but it have open and fast close loops with 800Hz rate.

Spectrum

CDMA2000 is designed to operate in all the spectrum bands attributed for the wireless telecommunications services, including the analogical, cellular bands, PCS and those of IMT - 2000.

CDMA2000 facilitates the benefit of services 3G making use of a very small quantity of spectrum (1.25 MHz for carrier), protecting this way this resource important for the operators.



More than 578 terminals CDMA2000 1X and of 68 terminal CDMA2000 1xEV-DO are at the moment available, by manufacturing leaders like Audiovox, Axesstel, Ericsson, CURITEL, Handspring, Huawei, Kyocera, LG, Motorola, Nokia, Research in Motion, Samsung, Sanyo, SK TeleTech, Telular and ZTE.
Next to the telephones, they have also been thrown to the market wireless modems by AnyDATA, Sierra Wireless and others. There are plans of introducing, in a future next, many devices CDMA2000.

CDMA2000 Packet Data

In this section we describe the core packet data architecture associated with the CDMA2000 radio interface. This architecture is described in 3GPP2 recommendations and TIA standards such as [IS835] and [TS115]. It allows CDMA2000 cellular wireless service providers to offer bidirectional packet data services using the Internet Protocol. To provide this functionality, CDMA2000 utilizes two access methods: Simple IP and Mobile IP.
In *Simple IP*, the service provider must assign the user a dynamic IP address. This address stays constant while the user maintains connection with the same IP network within a wireless carrier's domain—that is, until the user does not exit the coverage area of the same Packet Data Serving Node (PDSN). Anew IP address must, however, be obtained when the user moves into a geographical area attached to a different IP network—that is, into the coverage area of another PDSN. Simple IP service does not include any tunneling scheme providing mobility on a network layer described in the beginning of this chapter and supports mobility only within certain geographical boundaries.
The *Mobile IP* access method is mostly based on [RFC2002] now superseded by [RFC3220], described in Chapter 2. The mobile station is first attached to serving PDSN, supporting FA functionality, and assigned an IP address by its Home Agent (HA). Mobile IP enables a mobile station to maintain its IP address for the duration of a session while moving through CDMA2000 or other systems supporting Mobile IP.
For mobile stations compatible with a TIA/EIA [IS-2000] standard attached to a CDMA2000-1x network, available data rate can vary between the fundamental rate of 9.6 Kbps and any of the following burst rates:

1) 19.2 Kbps
2) 38.4 Kbps
3) 76.8 Kbps
4) 153.6 Kbps

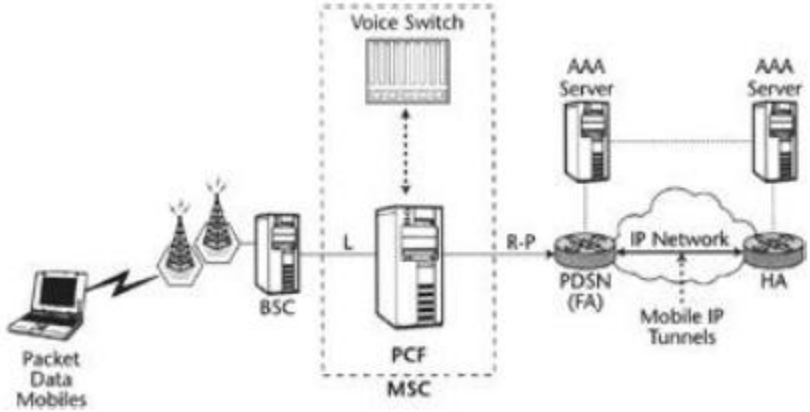
These higher-speed bursts are allocated by the infrastructure based on user need (data backlog in either direction), and resource availability (both airlink bandwidth and infrastructure elements). Bursts are typically allocated to a given mobile for a short duration of time of 1 to 2 seconds. The resource and mobile situation is then reevaluated.

CDMA2000 Packet Data Architecture

The architecture of CDMA2000 data system is based on the following components:

1) A mobile station in a form of a handset, PDA, or PCMCIA card in handheld/portable computer supporting Simple IP or Mobile IP client or both

2) CDMA2000-1x Radio Access Network (RAN)
3) Packet Control Function (PCF)
4) Packet Data Serving Node (PDSN) supporting FA functionality in case of Mobile IP
5) Home and foreign AAA servers
6) Home Agent (for the Mobile IP access method)



Mobile Station Types

There are two basic types of mobile station configurations—relay model and network model. In *relay model* mobile stations, the CDMA2000 Mobile Terminal is connected to another portable data terminal device such as a laptop, handheld computing device, or some other embedded data terminal. The relay model phone does not terminate any of the protocol layers except for the CDMA2000 physical layer (radio interface) and RLP layers. The attached data terminal device must terminate all other higher-layer protocols (PPP, IP, TCP/UDP, etc.). *Network model* mobile stations, in addition to the radio interface, terminate all necessary protocols and do not require any additional data terminal devices. The mobile phone itself provides all user input and display capabilities—as well as a user applications—to make use of the packet data network. Examples of this kind of phone include the "smart phone" or "micro-browser" phone. These devices normally include some embedded Web browsing or information service application, as well as a display screen for viewing the information retrieved from the Internet server. Such kind of terminals may also offer the ability to connect a laptop to a data network via a PPP connection terminated at the terminal itself.

WiMax vs. WLAN:

Unlike WLAN, WiMAX provides a media access control (MAC) layer that uses a grant-request mechanism to authorize the exchange of data. This feature allows better exploitation of the radio resources, in particular with smart antennas, and independent management of the traffic of every user.
This simplifies the support of real-time and voice applications.
One of the inhibitors to widespread deployment of WLAN was the poor security feature of the first releases. WiMAX proposes the full range of security features to ensure secured data exchange:

1) Terminal authentication by exchanging certificates to prevent rogue devices,
2) User authentication using the Extensible Authentication Protocol (EAP),
3) Data encryption using the Data Encryption Standard (DES) or Advanced Encryption Standard (AES), both much more robust than the Wireless Equivalent Privacy (WEP) initially used by WLAN. Furthermore, each service is encrypted with its own security association and private keys.

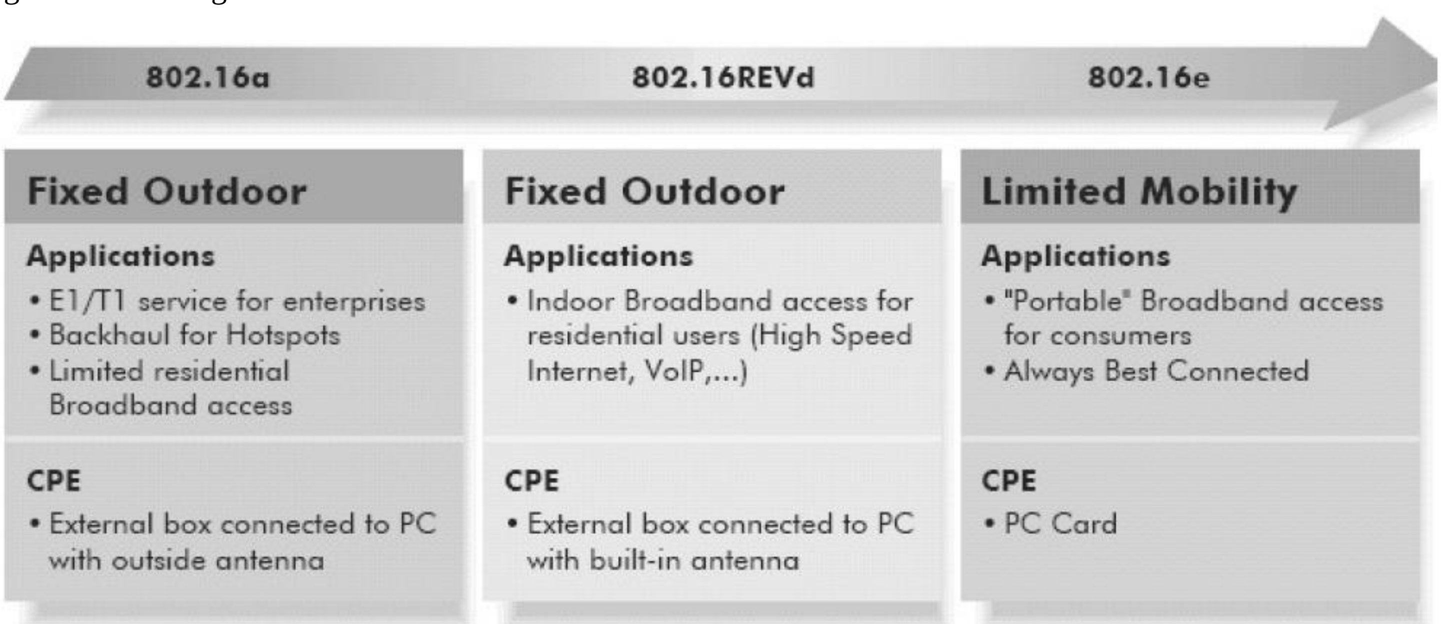
WiMax VS. WiFi:

WiMAX operates on the same general principles as WiFi -- it sends data from one computer to another via radio signals. A computer (either a desktop or a laptop) equipped with WiMAX would receive data from the WiMAX transmitting station, probably using encrypted data keys to prevent unauthorized users from stealing access.
The fastest WiFi connection can transmit up to 54 megabits per second under optimal conditions. WiMAX should be able to handle up to 70 megabits per second. Even once that 70 megabits is split up between several dozen businesses or a few hundred home users, it will provide at least the equivalent of cable-modem transfer rates to each user.

The biggest difference isn't speed; it's distance. WiMAX outdistances WiFi by miles. WiFi's range is about 100 feet (30 m). WiMAX will blanket a radius of 30 miles (50 km) with wireless access. The increased range is due to the frequencies used and the power of the transmitter. Of course, at that distance, terrain, weather and large buildings will act to reduce the maximum range in some circumstances, but the potential is there to cover huge tracts of land.
WiMax is not designed to clash with WiFi, but to coexist with it. WiMax coverage is measured in square kilometers, while that of WiFi is measured in square meters. The original WiMax standard (IEEE 802.16) proposes the usage of 10-66 GHz frequency spectrum for the WiMax transmission, which is well above the WiFi range (up to 5GHz maximum). But 802.16a added support for 2-11 GHz frequency also. One WiMax base station can be accessed by more than 60 users. WiMax can also provide broadcasting services also.

Wi-Max

Worldwide Interoperability for Microwave Access (WiMAX) is currently one of the hottest technologies in wireless. The Institute of Electrical and Electronics Engineers (IEEE) 802 committee, which sets networking standards such as Ethernet (802.3) and WiFi (802.11), has published a set of standards that define WiMAX. IEEE 802.16-2004 (also known as Revision D) was published in 2004 for fixed applications; 802.16 Revision E (which adds mobility) is publicated in July 2005. The WiMAX Forum is an industry body formed to promote the IEEE 802.16 standard and perform interoperability testing. The WiMAX Forum has adopted certain profiles based on the 802.16 standards for interoperability testing and “WiMAX certification”. These operate in the 2.5GHz, 3.5GHz and 5.8GHz frequency bands, whic typically are licensed by various government authorities. WiMAX, is based on an RF technology called Orthogonal Frequency Division Multiplexing (OFDM), which is a very effective means of transferring data when carriers of width of 5MHz or greater can be used. Below 5MHz carrier width, current CDMA based 3G systems are comparable to OFDM in terms of performance.
WiMAX is a standard-based wireless technology that provides high throughput broadband connections over long distance. WiMAX can be used for a number of applications, including “last mile” broadband connections, hotspots and high-speed connectivity for business customers. It provides wireless metropolitan area network (MAN) connectivity at speeds up to 70 Mbps and the WiMAX base station on the average can cover between 5 to 10 km. Figure 1.6. below gives WiMAX Overview.



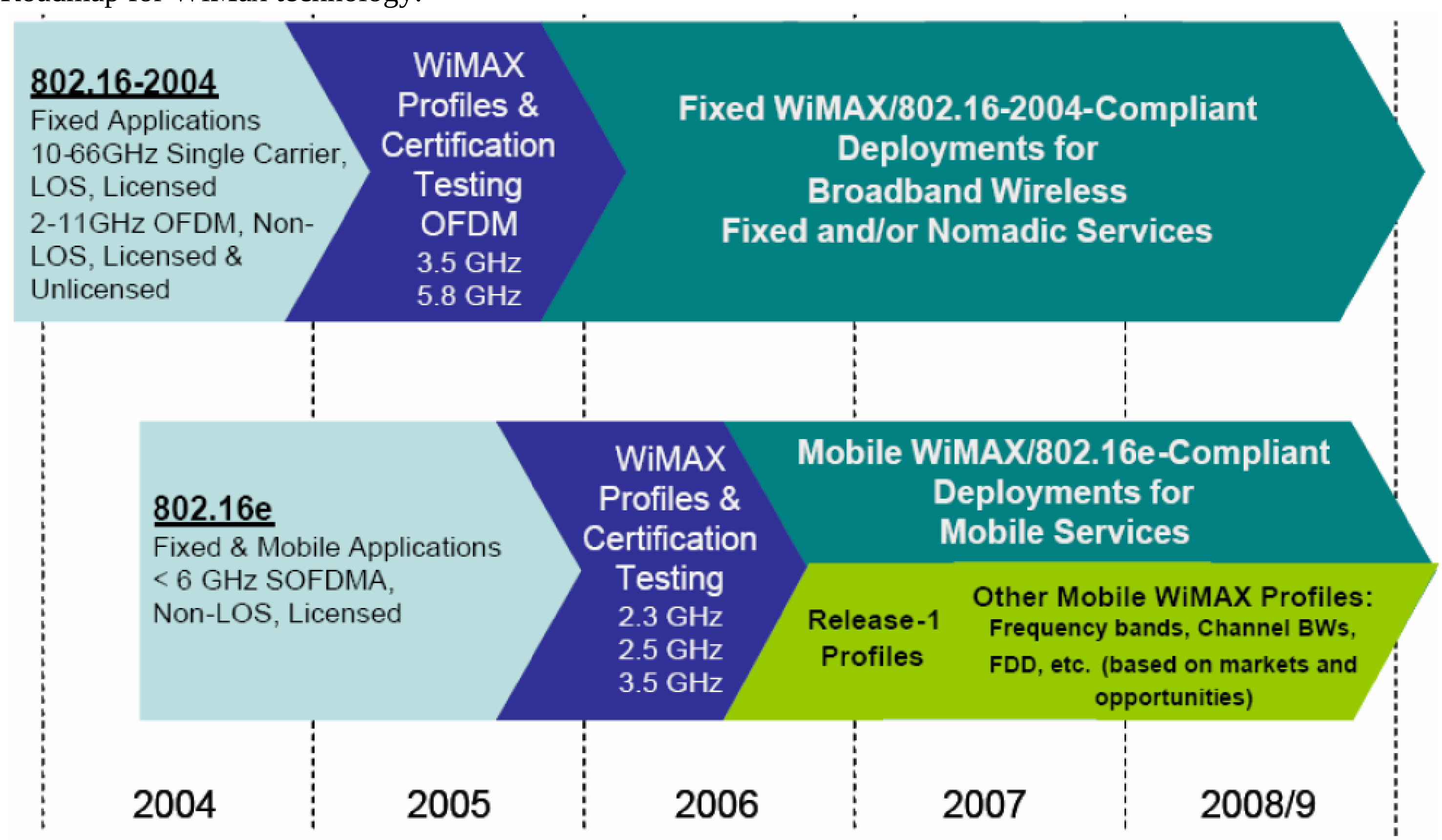
WiMax Forum
WiMAX Forum is a non-profit corporation that was formed in April 2001 by equipment and component suppliers to help to promote and certify the compatibility and interoperability of Broadband Wireless Access (BWA) equipment. As of May 2004, there are over 100 members of WiMAX Forum. WiMAX’s members, which include

Airspan, Alcatel, Alvarion, Fujitsu, Intel, OFDM Forum, Proxim, Siemens, account for over 75 percent of sales in the 2 to 11 GHz BWA market.
The WiMAX Forum (the Forum) is a coalition of wireless and computer industry companies that has endorsed and is aggressively marketing the WiMAX standard. A principal purpose of the organization is to promote and certify compatibility and interoperability of devices based on the various 802.16 specifications and to develop such devices for the global marketplace.
The Forum believes that the adoption of industry standards will be a key factor in any successful deployment of WiMAX technology. For example, one of the most significant problems with WiFi initial deployment, was the lack of any early industry standards. In the early days of WiFi deployment, the marketplace was saturated with equipment well before industry standards were adopted. As a result, equipment often lacked interoperability and was expensive.

Details for WiMAX standards:

	802.16	802.16a	802.16-2004	802.16e
Date Completed	Dec '01	Jan '03	June 2004	2Q 2005
Spectrum	10 to 66 GHz	< 11 GHz	< 11 GHz	< 6 GHz
Operation	LOS	Non-LOS	Non-LOS	Non-LOS /Mobile
Bit Rate	32-134 Mb/s	Up to 75 Mb/s	Up to 75 Mb/s	Up to 15 Mb/s
Cell Radius	1 to 3 miles	3-5 miles.	3-5 miles.	1 to 3 miles

Roadmap for WiMax technology:



As part of its deployment plan, the WiMAX Forum anticipates rollout of its technology in three phases.

Phase I (2004 - 2005): ***Fixed Location, Private Line Services, Hot Spot Back-Haul*****.**

Using the initial 802.16 standard as its cornerstone, Phase I of WiMAX deployment has already begun with the provision of traditional dedicated-line services to carriers and enterprises. Companies such as Towerstream Wireless are offering wireless Internet access to more than 600 customers in six major markets, including New York, Boston and Chicago.14 Phase I also will include such operations as aggregating public Wi-Fi hot spots to a central, high-capacity internet connection.

Phase II (2005 - 2006): ***Broadband Wireless Access/Wireless DSL*****.**

Phase II of the rollout will entail the first mass-market application of WiMAX technology. With the backing of computer industry heavyweights such as Intel Corporation and Dell, this phase will involve the delivery of low-cost, user installable premises equipment that will not have to be pointed at a base station. In conjunction with the equipment rollout, the Forum anticipates that the number of wireless internet service providers (WISPs) utilizing WiMAX compatible technology will increase exponentially.

Phase III (2007): ***Mobile/Nomadic Users*****.**

Phase III of the rollout will focus on the development of a mobile-broadband market. In this final phase, laptops and other mobile computing devices will be fully integrated with WiMAX chips and antennas, allowing mobile workers to send and receive high-bandwidth files such as schematics, videos, and multimedia presentations in real time over a wireless broadband connection. The WiMAX Forum anticipates that the technology will be deployed for the offering of other products and services, as well.

WiMAX Spectrum — Licensed and Unlicensed

As with any other spectrum based technology, successful WiMAX deployment will depend largely upon the availability and suitability of spectrum resources. For entities providing wireless communications services, two sources of spectrum are available:

1) Licensed spectrum and
2) Unlicensed spectrum.

Licensed spectrum requires an authorization/license from the Commission, which offers that individual user — or "Licensee"— the exclusive rights to operate on a specific frequency (or frequencies) at a particular location or within a defined geographic area.

In contrast, unlicensed spectrum permits any user to access specific frequencies within any geographic area inside the United States without prior Commission authorization. While users of this spectrum do not have to apply for individual licenses or pay to use the spectrum, they are still subject to certain rules. First, unlicensed users must not cause interference to licensed users and must accept any interference they receive. Second, any equipment that will be utilized on unlicensed spectrum must be approved in advance by the Commission. Because of its broad operating range, licensed and unlicensed spectrum options for WiMAX technology are extensive.

To take best advantage of the benefits provided by WiMAX systems, large block spectrum assignments are most desirable. This enables systems to be deployed in TDD mode with large channel bandwidths, flexible frequency re-use and with minimal spectral inefficiencies for guard-bands to facilitate coexistence with adjacent operators. Another key activity for the WiMAX Forum is collaborating with standards and regulatory bodies worldwide to promote the allocation of spectrum in the lower frequency bands (< 6 GHz) that is both application and technology neutral. Additionally, there is a major push for greater harmonization in spectrum allocations so as to minimize the number equipment variants required to cover worldwide markets.

The initial system performance profiles that will be developed by the WiMAX Forum for the recently approved 802.16-2005 air interface standard are expected to be in the licensed 2.3 GHz, 2.5 GHz and 3.5 GHz frequency bands. The 2.3 GHz band has been allocated in South Korea for WiBro services based on the Mobile WiMAX technology.

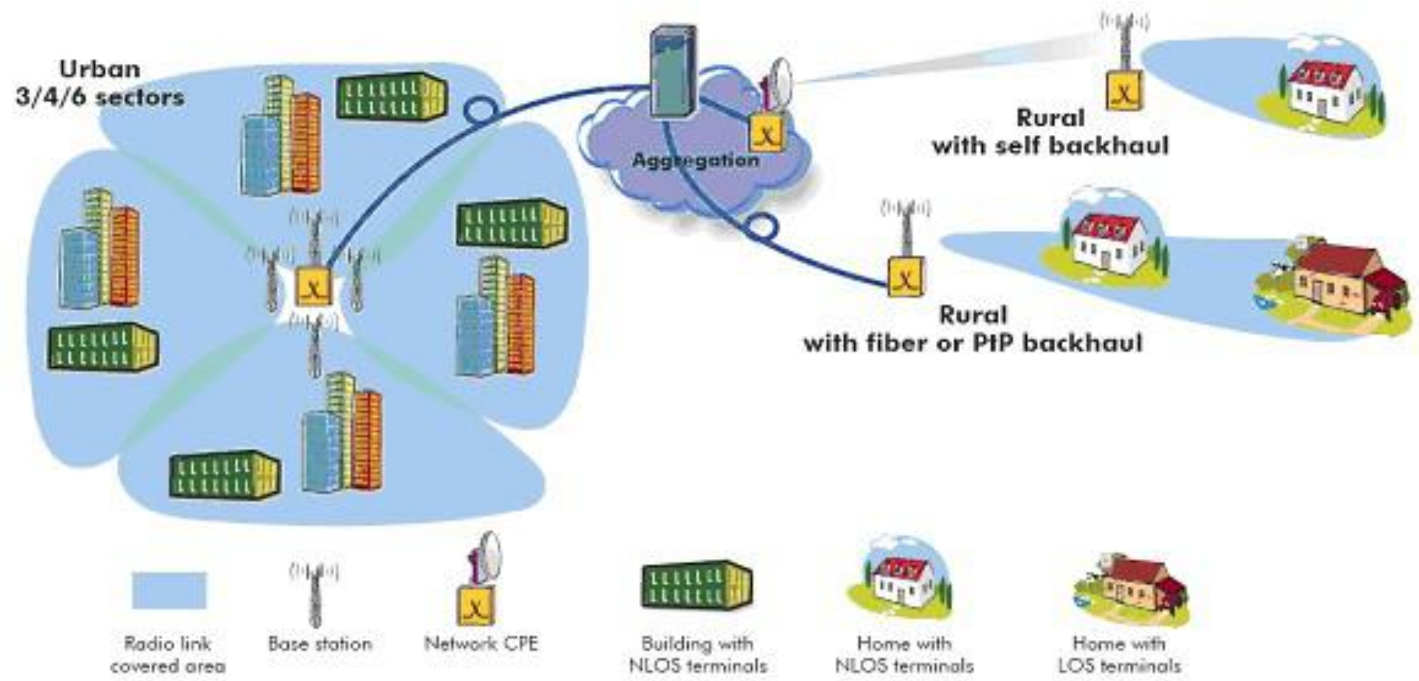
WiMAX Infrastructure

Typically, a WiMAX system consists of two parts:

1) A WiMAX Base Station**:** Base station consists of indoor electronics and a WiMAX tower. Typically, a base station can cover up to 10 km radius (Theoretically, a base station can cover up to 50 kilo meter radius or 30 miles, however practical considerations limit it to about 10 km or 6 miles). Any wireless node within the coverage area would be able to access the Internet.
2) A WiMAX receiver - The receiver and antenna could be a stand-alone box or a PC card that sits in your laptop or computer. Access to WiMAX base station is similar to accessing a Wireless Access Point in a WiFi network, but the coverage is more.

Several base stations can be connected with one another by use of high-speed backhaul microwave links. This would allow for roaming by a WiMAX subscriber from one base station to another base station area, similar to roaming enabled by Cellular phone companies.

Several topology and backhauling options are to be supported on the WiMAX base stations: wireline backhauling (typically over Ethernet), microwave Point-to-Point connection, as well as WiMAX backhaul. With the latter option, the base station has the capability to backhaul itself. This can be achieved by reserving part of the bandwidth normally used for the end-user traffic and using it for backhauling purposes. At Figure 5. we can see topologies of urban and rural areas in WIMAX deployment.



WiMAX Network IP-Based Architecture

The network specifications for WiMAX-based systems are based on several basic network architecture tenets, including those listed below. Some general tenets have guided the development of Mobile WiMAX Network Architecture and include the following:

1) Provision of logical separation between such procedures and IP addressing, routing and connectivity management procedures and protocols to enable use of the access architecture primitives in standalone and interworking deployment scenarios,

2) Support for sharing of ASN(s) (Access Service Networks) of a Network Access Provider (NAP) among multiple NSPs, - Support of a single NSP (Network Service Provider) providing service over multiple ASN(s) – managed by one or more NAPs,
3) Support for the discovery and selection of accessible NSPs by an MS or SS,
4) Support of NAPs that employ one or more ASN topologies,
5) Support of access to incumbent operator services through internetworking functions as needed,
6) Specification of open and well-defined reference points between various groups of network functional entities (within an ASN, between ASNs, between an ASN and a CSN (Connectivity Service Network) , and between CSNs), and in particular between an MS, ASN and CSN to enable multi-vendor interoperability,
7) Support for evolution paths between the various usage models subject to reasonable technical assumptions and constraints,
8) Enabling different vendor implementations based on different combinations of functional entities on physical network entities, as long as these implementations comply with the normative protocols and procedures across applicable reference points, as defined in the network specifications and
9) Support for the most trivial scenario of a single operator deploying an ASN together with a limited set of CSN functions, so that the operator can offer basic Internet access service without consideration for roaming or interworking.

The WIMAX architecture also allows both IP and Ethernet services, in a standard mobile IP compliant network. The flexibility and interoperability supported by the WiMAX network provides operators with a multi-vendor low cost implementation of a WiMAX network even with a mixed deployment of distributed and centralized ASN's in the network.

The WiMAX network has the following major features:
- Security. The end-to-end WiMAX Network Architecture is based on a security framework that is agnostic to the operator type and ASN topology and applies consistently across Greenfield and internetworking deployment models and usage scenarios. In particular there is support for:

1. Strong mutual device authentication between an MS and the WiMAX network, based on the IEEE 802.16 security framework,
2. All commonly deployed authentication mechanisms and authentication in home and visited operator network scenarios based on a consistent and extensible authentication framework,
3. Data integrity, replay protection, confidentiality and non-repudiation using applicable key lengths,
4. Use of MS initiated/terminated security mechanisms such as Virtual Private Networks (VPNs),
5. Standard secure IP address management mechanisms between the MS/SS and its home or visited NSP.

End-to-End WiMAX Architecture

The IEEE only defined the Physical (PHY) and Media Access Control (MAC) layers in 802.16. This approach has worked well for technologies such as Ethernet and WiFi, which rely on other bodies such as the IETF (Internet Engineering Task Force) to set the standards for higher layer protocols such as TCP/IP, SIP, VoIP and IPSec. In the mobile wireless world, standards bodies such as 3GPP and 3GPP2 set standards over a wide range of interfaces and protocols because they require not only airlink interoperability, but also inter-vendor inter-network interoperability for roaming, multi-vendor access networks, and inter-company billing. Vendors and operators have recognized this issue, and have formed additional working groups to develop standard network reference models for open inter-network interfaces. Two of these are the WiMAX Forum's Network Working Group, which is focused on creating higher-level networking specifications for fixed, nomadic, portable and mobile WiMAX systems beyond what is defined in the IEEE 802.16 standard, and Service Provider Working Group which helps write requirements and prioritizes them to help drive the work of Network WG. The Mobile WiMAX End-to-End Network Architecture is based an All-IP platform, all packet technology with no legacy circuit telephony. It offers the advantage of reduced total cost of ownership during the lifecycle of a WiMAX network deployment. The use of All-IP means that a common network core can be used, without the need to maintain both packet and circuit core networks, with all the overhead that goes with it. A further benefit of All-IP is that it places the network on the performance growth curve of general processing advances occur much faster than advances in telecommunications equipment because general purpose hardware is not limited to telecommunications equipment cycles, which tend to be long and cumbersome. The end result is a network that continually performs at ever higher capital and operational efficiency, and takes advantage of 3rd party developments from the Internet community. This results in lower cost, high scalability, and rapid deployment since the networking functionality is all primarily software-based services. In order to deploy successful and operational commercial systems, there is need for support beyond 802.16 (PHY/MAC) air interface specifications. Chief among them is the need to support a core set of networking functions as part of the overall End-to-End WiMAX system architecture. Before delving into some of the details of the architecture, we can note a few basic tenets that have guided the WiMAX architecture development:

1) The architecture is based on a packet-switched framework, including native procedures based on the IEEE 802.16 standard and its amendments, appropriate IETF RFCs and Ethernet standards.
2) The architecture permits decoupling of access architecture (and supported topologies) from connectivity IP service. Network elements of the connectivity system are agnostic to the IEEE 802.16 radio specifics.
3) The architecture allows modularity and flexibility to accommodate a broad range of deployment options such as:

a) Small-scale to large-scale (sparse to dense radio coverage and capacity) WiMAX networks.
b) Urban, suburban, and rural radio propagation environments
c) Licensed and/or licensed-exempt frequency bands
d) Hierarchical, flat, or mesh topologies, and their variants
e) Co-existence of fixed, nomadic, portable and mobile usage models

Support for Services and Applications. The end-to-end architecture includes the support for:

a) Voice, multimedia services and other mandated regulatory services such as emergency services and lawful interception,
b) Access to a variety of independent Application Service Provider (ASP) networks in an agnostic manner,
c) Mobile telephony communications using VoIP.
d) Support interfacing with various interworking and media gateways permitting delivery of incumbent/legacy services translated over IP (for example, SMS over IP, MMS, WAP) to WiMAX access networks and
e) Support delivery of IP Broadcast and Multicast services over WiMAX access networks.

Interworking and Roaming. Another key strength of the End-to-End Network Architecture with support for a number of deployment scenarios. In particular, there will be support of

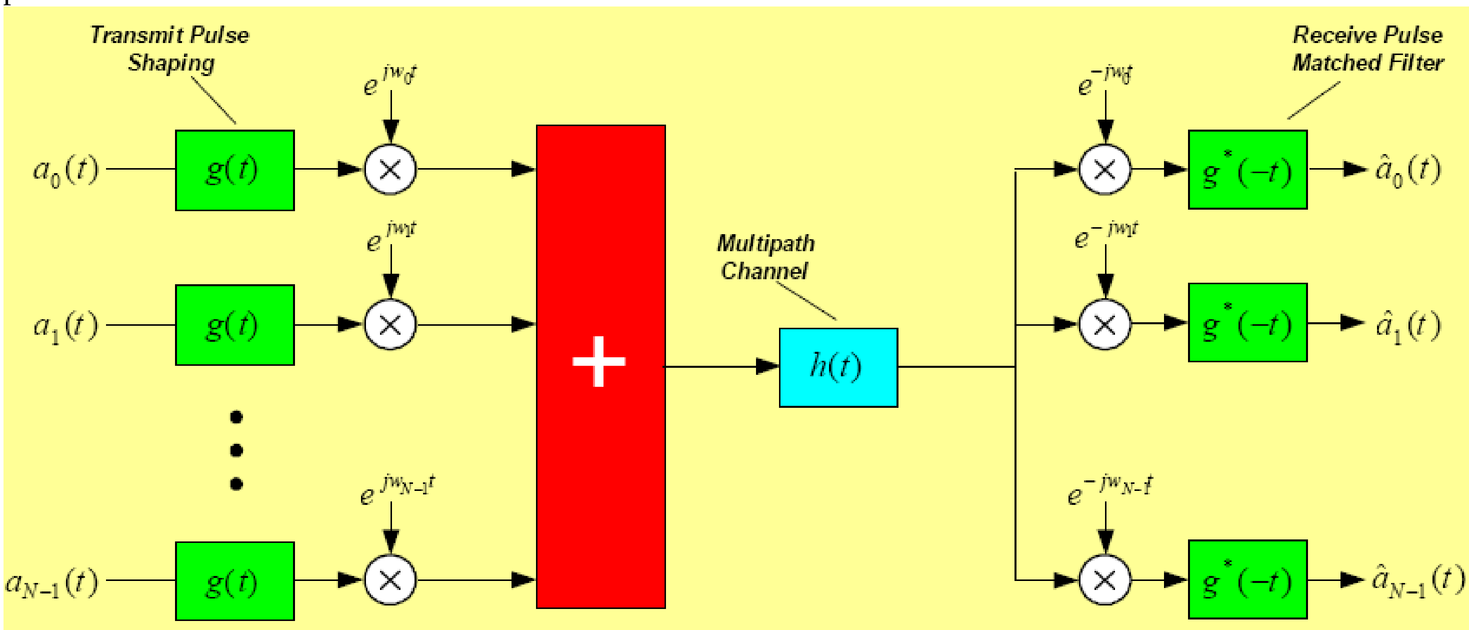
a) Loosely-coupled interworking with existing wireless networks such as 3GPP and 3GPP2 or existing wireline networks such as DSL, with the interworking interface(s) based on a standard IETF suite of protocols,
b) Global roaming across WiMAX operator networks, including support for credential reuse, consistent use of AAA for accounting and billing, and consolidated/common billing and settlement,
c) A variety of user authentication credential formats such as username/password, digital certificates, Subscriber Identify Module (SIM), Universal SIM (USIM), and Removable User Identify Module (RUIM).

WiMAX Forum industry participants have identified a WiMAX Network Reference Model (NRM) that is a logical representation of the network architecture. The NRM identifies functional entities and reference points over which interoperability is achieved between functional entities. The architecture has been developed with the objective of providing unified support of functionality needed in a range of network deployment models and usage scenarios (ranging from fixed – nomadic – portable – simple mobility –to fully mobile subscribers).

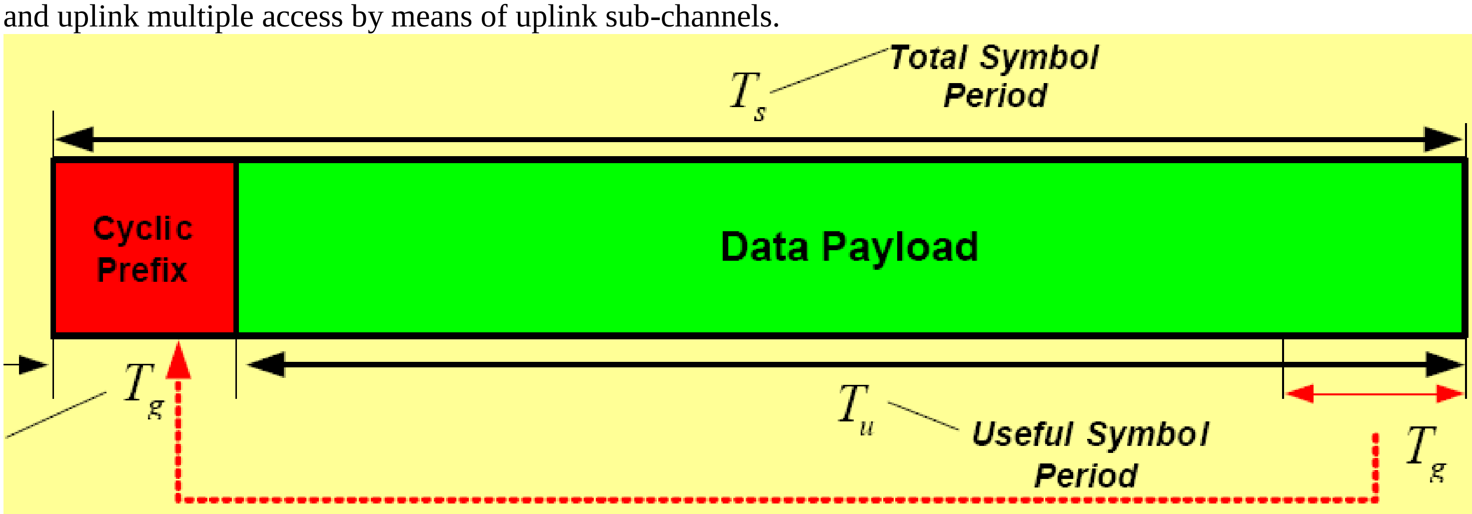
OFDMA Basics

Orthogonal Frequency Division Multiplexing (OFDM) is a multiplexing technique that subdivides the bandwidth into multiple frequency sub-carriers as shown in Figure 9.3.1. In an OFDM system, the input data stream is divided into several parallel sub-streams of reduced data rate (thus increased symbol duration) and each sub-stream is modulated and transmitted on a separate orthogonal sub-carrier. The increased symbol duration improves the robustness of OFDM to delay spread. Furthermore, the introduction of the cyclic prefix (CP) can completely eliminate Inter-Symbol Interference (ISI) as long as the CP duration is longer than the channel delay spread. The

CP is typically a repetition of the last samples of data portion of the block that is appended to the beginning of the data payload as shown in Figure 9.3.2. The CP prevents inter-block interference and makes the channel appear circular and permits low-complexity frequency domain equalization. A perceived drawback of CP is that it introduces overhead, which effectively reduces bandwidth efficiency. While the CP does reduce bandwidth efficiency somewhat, the impact of the CP is similar to the "roll-off factor" in raised-cosine filtered single-carrier systems. Since OFDM has a very sharp, almost "brick-wall" spectrum, a large fraction of the allocated channel bandwidth can be utilized for data transmission, which helps to moderate the loss in efficiency due to the cyclic prefix.



OFDM exploits the frequency diversity of the multipath channel by coding and interleaving the information across the sub-carriers prior to transmissions. OFDM modulation can be realized with efficient Inverse Fast Fourier Transform (IFFT), which enables a large number of sub-carriers (up to 2048) with low complexity. In an OFDM system, resources are available in the time domain by means of OFDM symbols and in the frequency domain by means of sub-carriers. The time and frequency resources can be organized into sub-channels for allocation to individual users. Orthogonal Frequency Division Multiple Access (OFDMA) is a multiple-access/multiplexing scheme that provides multiplexing operation of data streams from multiple users onto the downlink sub-channels and uplink multiple access by means of uplink sub-channels.



MIMO techniques

TDD Frame Structure

The 802.16e PHY supports TDD, FDD, and Half-Duplex FDD operation; however the initial release of Mobile WiMAX certification profiles will only include TDD. With ongoing releases, FDD profiles will be considered by the WiMAX Forum to address specific market opportunities where local spectrum regulatory requirements either prohibit TDD or are more suitable for FDD deployments. To counter interference issues, TDD does require system-wide synchronization; nevertheless, TDD is the preferred duplexing mode for the following reasons:

1) TDD enables adjustment of the downlink/uplink ratio to efficiently support asymmetric downlink/uplink traffic, while with FDD, downlink and uplink always have fixed and generally, equal DL and UL bandwidths.
2) TDD assures channel reciprocity for better support of link adaptation, MIMO and other closed loop advanced antenna technologies.
3) Unlike FDD, which requires a pair of channels, TDD only requires a single channel for both downlink and uplink providing greater flexibility for adaptation to varied global spectrum allocations.
4) Transceiver designs for TDD implementations are less complex and therefore less expensive.

Advanced Features of WiMAX

An important and very challenging function of the WiMAX system is the support of various advanced antenna techniques, which are essential to provide high spectral efficiency, capacity, system performance, and reliability:

1. Beam forming using smart antennas provides additional gain to bridge long distances or to increase indoor coverage; it reduces inter-cell interference and improves frequency reuse,
2. Transmit diversity and MIMO techniques using multiple antennas take advantage of multipath reflections to improve reliability and capacity.

Smart Antenna Technologies

Smart antenna technologies typically involve complex vector or matrix operations on signals due to multiple antennas. OFDMA allows smart antenna operations to be performed on vector-flat sub-carriers. Complex equalizers are not required to compensate for frequency selective fading. OFDMA therefore, is very well-suited to support smart antenna technologies. In fact, MIMO-OFDM/OFDMA is envisioned as the corner-stone for next generation broadband communication systems. Mobile WiMAX supports a full range of smart antenna technologies to enhance system performance. The smart antenna technologies supported include:

1) **Beamforming.** With beamforming, the system uses multiple-antennas to transmit weighted signals to improve coverage and capacity of the system and reduce outage probability.
2) **Space-Time Code (STC).** Transmit diversity such as Alamouti code is supported to provide spatial diversity and reduce fade margin.
3) **Spatial Multiplexing (SM).** Spatial multiplexing is supported to take advantage of higher peak rates and increased throughput. With spatial multiplexing, multiple streams are transmitted over multiple antennas. If the receiver also has multiple antennas, it can separate the different streams to achieve higher throughput compared to single antenna systems. With 2x2 MIMO, SM increases the peak data rate two-fold by transmitting two data streams. In UL, each user has only one transmit antenna, two users can transmit collaboratively in the same slot as if two streams are spatially multiplexed from two antennas of the same user. This is called UL collaborative SM.

WiMAX Network scale:

(MAN) Metropolitan Area Network	IEEE 802.16	Connects devices up to an approx. 30-mile radius
(LAN) Local Area Network	IEEE 802.11	Connects devices up to an approx. 300-foot radius
(PAN) Personal Area Network	IEEE 802.15	Connects devices up to an approx. 33-foot radius