# Find the answers to the following questions

1. What are the different frequency bands in GSM?
2. What are the supplementary services offered by GSM?

# Module 4

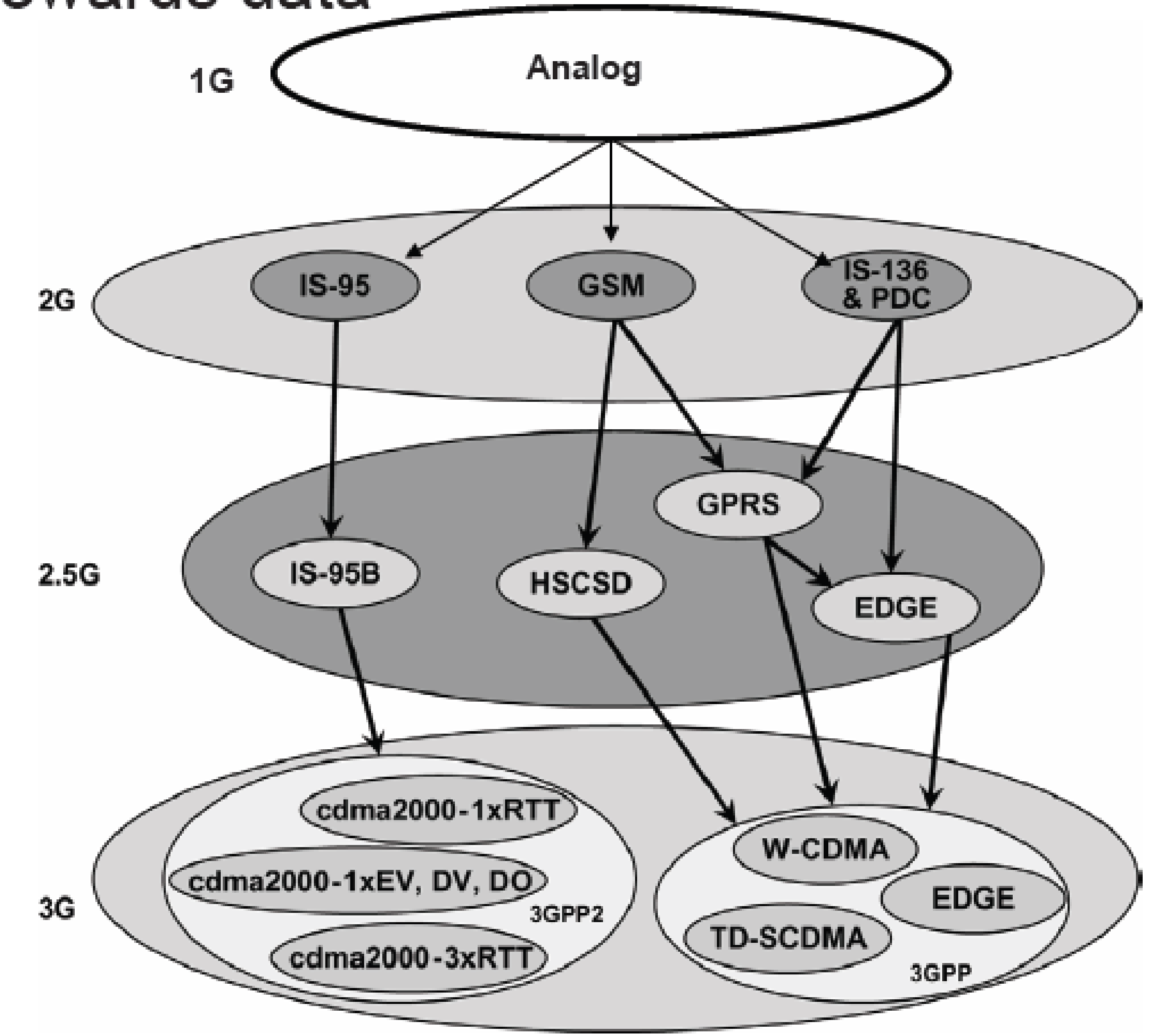
## GSM Evolution and IS 95

# Future Of GSM

- 2nd Generation
  - GSM -9.6 Kbps (data rate)

- 2.5 Generation (Future of GSM)
  - HSCSD (High Speed Circuit Switched Data)
    - Data rate : 76.8 Kbps (9.6 x 8 kbps)
  - GPRS (General Packet Radio service)
    - Data rate: 14.4 - 115.2 Kbps
  - EDGE (Enhanced data rate for GSM Evolution)
    - Data rate: 547.2 Kbps (max)
- 3 Generation
  - WCDMA(Wide band CDMA)
    - Data rate : 0.348 – 2.0 Mbps

# Various upgrade paths for wireless technologies: move towards data



# High Speed Circuit Switched Data

- High Speed Circuit Switched Data (HSCSD) is an enhancement in the **data rate of circuit switched data** in a GSM network
  - The GSM mobile telecommunication network has been designed as a circuit-switched network in a similar way to fixed-line phone networks
  - At the beginning of a call, the network establishes a direct connection between two parties, which is then used exclusively for this conversation
- HSCSD uses two techniques to increase the data rate
  - First, HSCSD makes it possible to use more than one time slot
    - GSM uses time division multiple access (TDMA)
    - Each radio channel is divided in eight time slots
    - Each time slot is allocated to a different user
    - This makes it possible to serve eight customers on one radio channel
    - HSCSD makes it possible to allocate more than one time slot to a user
    - This has led to achievable user rates of upto 76.8 kbps (if all slots are allotted to the same user)
  - It employs superior error-coding techniques to extract higher bit rates out of a single timeslot
- Pseudoasymmetric by nature
  - In pseudo-asymmetric service, the timeslot allocation for downlink and uplink is symmetric but the data rate used in uplink direction is lower than in downlink direction.

# GPRS (General Packet Radio service)

- General Packet Radio Service (GPRS) is a new bearer service for GSM that greatly improves and simplifies **wireless access to packet data networks**

- GPRS applies **packet radio principal** to transfer user data packets in an efficient way b/w MS & external packet data network
  - The packet radio principle is employed by GPRS to transport user data packets in a structure way between GSM mobile stations and external packet data networks
  - These packets can be directly routed to the packet switched networks from the GPRS mobile stations

- Salient features:
  - Important step on the path to 3G
  - Provides Data Packet delivery service
  - Provides connection to the external packet data networks through the GSM infrastructure
  - Support for leading internet communication protocols
  - Billing based on volume of data transferred
  - No hardware changes to the BTS/BSC
  - Utilizes existing GSM authentication and privacy procedures

# Applications of GPRS

- Web browsing
- Corporate & Internet Email
- Vehicle Positioning
- Remote LAN Access
- Home Automation
- Document Sharing/Collaborative working

# Comparison of GSM & GPRS

| | GSM | GPRS |
|---|---|---|
| Data Rates | 9.6 Kbps | 14.4 to 115.2 Kbps |
| Modulation Technique | GMSK | GMSK |
| Billing | Duration of connection | Amount of data transferred |
| Type of Connection | Circuit – Switched Technology | Packet - Switched Technology |

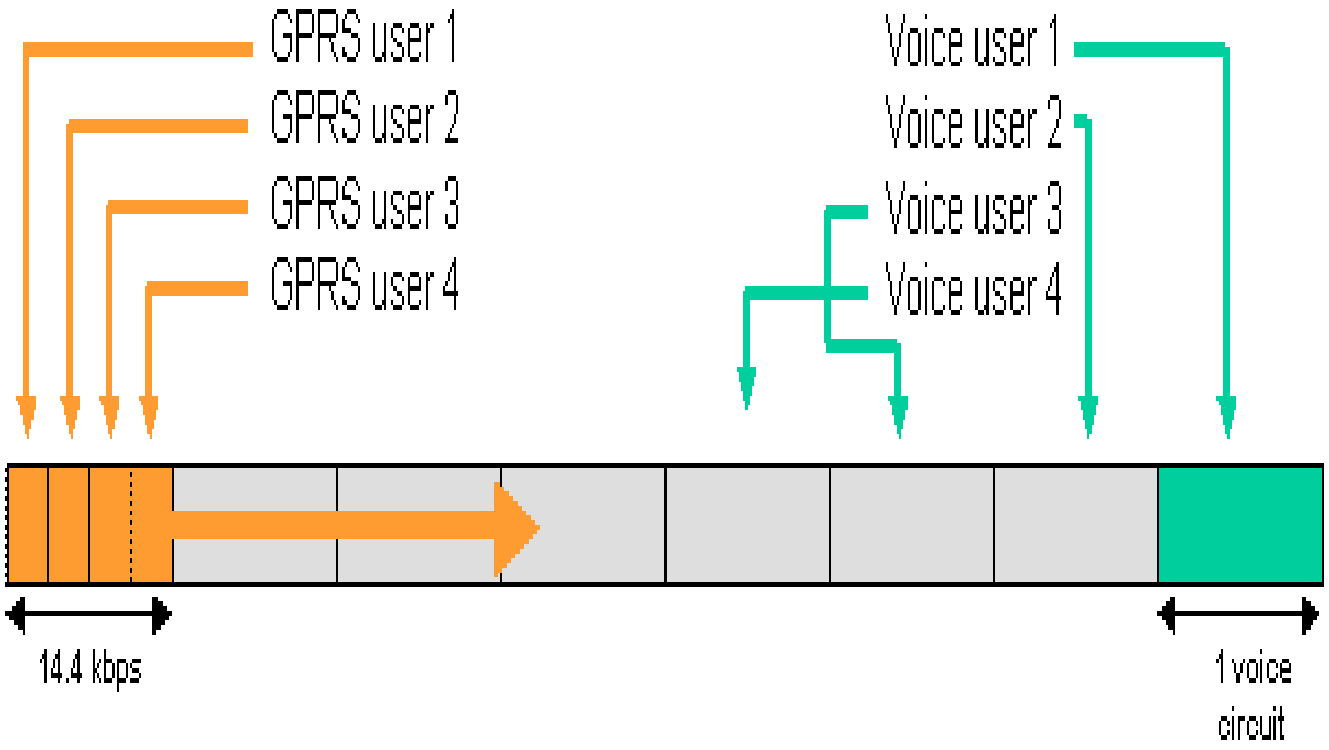
# Circuit switched v/s packet switched data

| Circuit switched data | Packet switched data |
| --- | --- |
| Was majorly dominant before GPRS was introduced<br><br>A channel is allocated to user for the duration of the connection<br><br>Time-based billing | Resources are allocated to user only for the time it takes to send each packet<br><br>A channel may be shared by many users<br><br>User pays by the packet<br><br>Ideal for “data” traffic |

# Benefits of GPRS

- New Data Services
- High Speed (Data Rate 14.4 – 115 kbps)
- Efficient use of radio bandwidth (Statistical Multiplexing)
- Circuit Switching & Packet Switching can be used in parallel
- Constant connectivity

**Statistical Multiplexing**

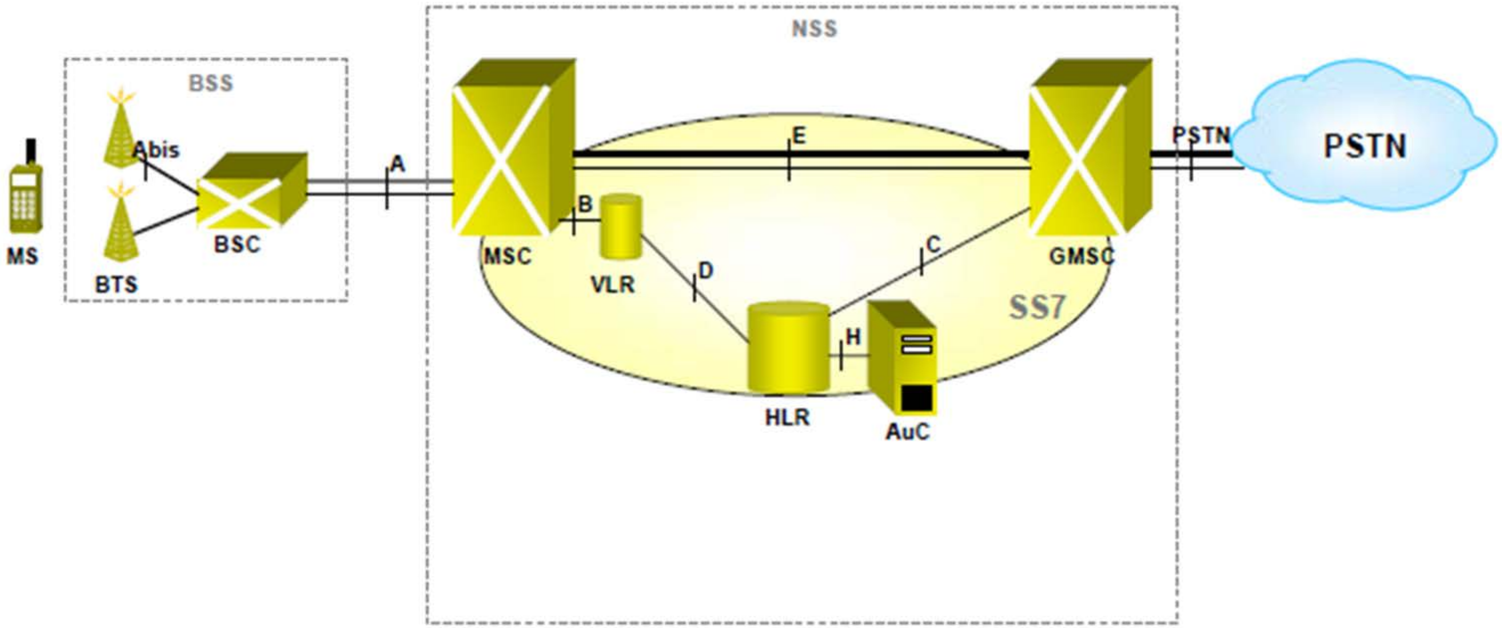



- Statistical multiplexing is allotting different instants of a time slots to multiple users

# GPRS Terminals

- **Class A**
  - MS supports simultaneous operation of GPRS and GSM services
- **Class B**
  - MS able to register with the n/w for both GPRS & GSM services simultaneously. It can only use one of the two services at a given time.
- **Class C**
  - MS can attach for either GPRS or GSM services

# GSM v/s GPRS architecture



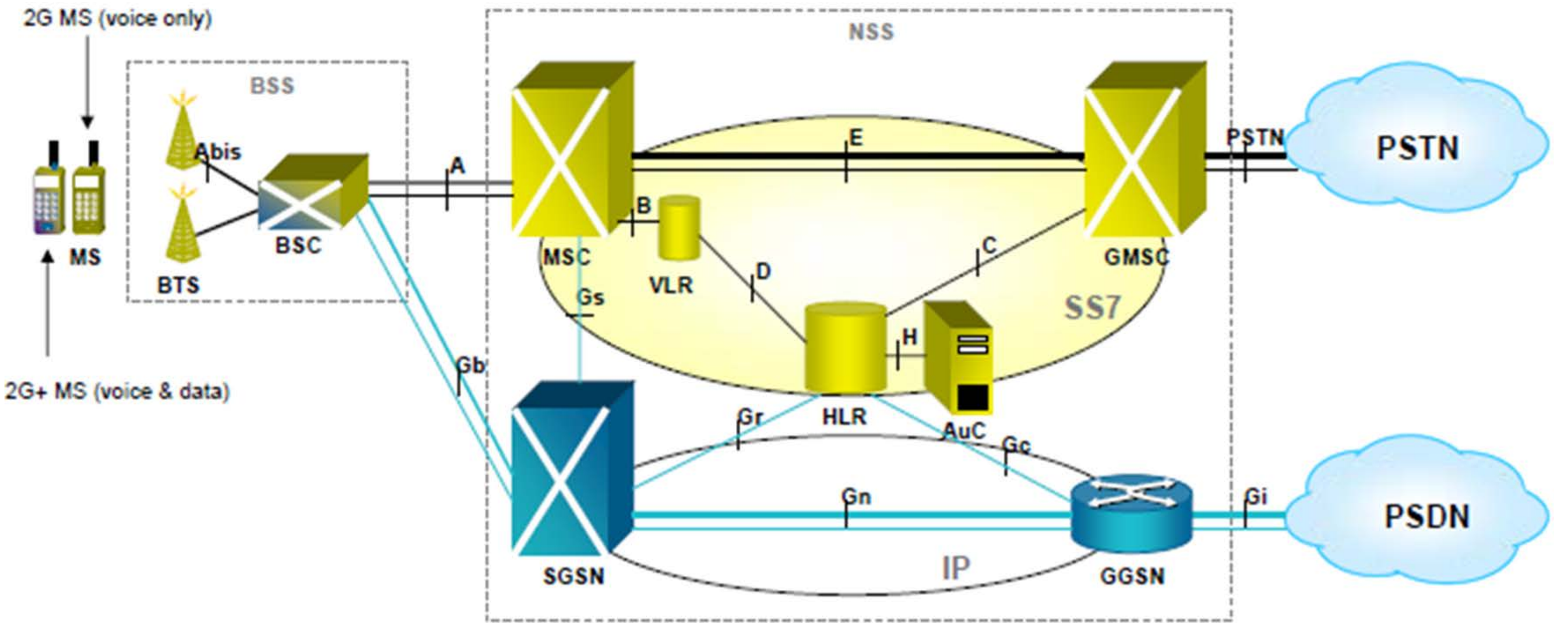

- New components:

**SGSN: Serving GPRS Support Node**
**GGSN: Gateway GPRS Support Node**

- Components needing an upgrade:

**HLR**
**MSC/ VLR**
**Mobile Station**

- When the traffic is originated at the subscriber mobile then it is transported over the air interface to BTS and then from BTS to BSC, the same way in standard GSM call
- But at output of BSC the traffic is separated, the voice is sent to the mobile switching centre as per standard GSM and the data is sent to the new device called the SGSN via the PCU (Packet Control Unit)
    - PCU performs some of the processing tasks of the BSC, but for packet data



# GPRS architecture

| SGSN | GGSN |
|---|---|
| • Delivers data packets from and to the mobile stations<br>• Packet routing and transfer from mobile station to GGSN<br>• The SGSN performs the same functions as the MSC for voice traffic as it is responsible for authentication of GPRS mobiles, registration of mobiles in the network, mobility management, and collecting information for charging for the use of the air interface | • The Gateway GPRS Support Node acts as an interface and a router to external networks<br>• The GGSN contains routing information for GPRS mobiles, which is used to tunnel packets through the IP based internal backbone to the correct Serving GPRS Support Node |

- **GPRS Register**
- GPRS Register is integrated with GSM-HLR
- Maintains the GPRS subscriber data and Routing information
- Stores current SGSN address
- Maps IMSI to a PDN (Public Data Network) address
    - PDN is the network that the user connects to, whether it is the internet or any other network

# GPRS attachment & detachment Procedure

| GPRS Attach | GPRS Detach |
|---|---|
| • User is registered in SGSN, after authentication check from HLR<br>• SGSN assigns P-TMSI to MS<br>• P-TMSI is a temporary identity issued to a GPRS enabled mobile device to track its location within in a GSM network, and is unique within a given Routing Area (RA) | • Disconnection of MS from GPRS network is called GPRS detach<br>• It can be initiated by MS or by network (SGSN or HLR) |

# Session Management in GPRS

- Mobile Station applies for PDP (Packet Data Protocol) address
  - PDP addresses are network layer addresses
  - PDP context offers a packet data connection over which a device and the mobile network can exchange IP packets
  - All packet data traffic sent from the public packet data network for the PDP address goes through the gateway (GGSN)
- For each session PDP context is created & it contains
  - **PDP type**
  - **PDP address assigned to MS**
  - Requested **QOS** parameters
  - **Address of GGSN** that serves as access point to PDN
- With active PDP context, MS is able to send or receive data packets
- Allocation of PDP address can be static or dynamic
  - Statically assigned PDP addresses are usually anchored at a GGSN in the subscriber's home network
  - Conversely, dynamically assigned PDP addresses can be anchored either in the subscriber's home network or the network that the user is visiting

# Location Management in GPRS

- Mobile station can be in 1 of the 3 states depending on traffic amount
- **Idle:** MS is not using GPRS service
- **Ready:** Performing GPRS Attach, MS gets into READY State
- **Standby:** When MS does not send any packets for longer period of time, Ready timer Expires

# Routing Area Update

- GSM Location Area(LA) is divided into several Routing Areas(RA)
- RA consists of several cells
- SGSN is informed when MS moves to a new RA
- MS sends a “Routing Area Update Request” to its assigned SGSN

# EDGE (Enhanced Data Rates for Global Evolution)

- EDGE is add-on to GPRS
  - EDGE technology increases the data rate supported by GPRS system drastically
- Uses 8-PSK modulation in good conditions
- Increase throughput by 3x  (8-PSK – 3 bits/symbol vs GMSK 1 bit/symbol)
- Offer data rates of 384kbps, theoretically up to 473.6kbps
- Uses 9 Modulation coding schemes (MCS 1-9)
  - MCS(1-4) uses GMSK
  - MCS(5-9) uses 8PSK modulation
- Radio data rate per time slot – **69.2kbps**
- User data rate per time slot – **59.2kbps (MCS9)**
- User data rate (8 time slots) – **473.6kbps**

# EDGE

## ❑9 Modulation coding schemes

| MCS NAME | MODULATION FORMAT | DATA RATE FOR ONE SLOT (KBPS) |
|---|---|---|
| MCS-1 | GMSK | 8.8 |
| MCS-2 | GMSK | 11.2 |
| MCS-3 | GMSK | 14.8 |
| MCS-4 | GMSK | 17.6 |
| MCS-5 | 8PSK | 22.4 |
| MCS-6 | 8PSK | 29.6 |
| MCS-7 | 8PSK | 44.8 |
| MCS-8 | 8PSK | 54.4 |
| MCS-9 | 8PSK | 59.2 |

- The nine modulation schemes are divided into four families:
- Family A - MCS 3, 6, 9
  Family A' - MCS 3, 6, 8
  Family B - MCS 2, 5, 7
  Family C - MCS 1, 4
- EDGE can retransmit a packet with more robust coding scheme hence re-segmentation is possible here, while in GPRS re-segmentation is not possible
  - This improves throughput
- The network automatically adapts the coding scheme according to the radio link quality
- This adaptation is done automatically for the downlink, and the network commands the mobile station (mobile phone) to use the optimum MCS for the uplink
- In order to perform this adaptation, the mobile station (for downlink transfer) and the base transceiver station (BTS) (for uplink transfer) carry out the radio link quality measurements (LQM)
- According to the radio link quality, the PCUSN can trigger a modification of the coding scheme

# IS-95: Brief review of CDMA

- CDMA is based on spread-spectrum technology, which makes the optimum use of available bandwidth
  - Different CDMA codes are used to distinguish among the different users
  - A signal is generated which extends over a wide bandwidth
  - A code called **spreading code** is used to perform this action
  - Using a group of codes, which are orthogonal to each other, it is possible to select a signal with a given code in the presence of many other signals with different orthogonal codes
- CDMA has a soft capacity i.e., the capacity of CDMA has a soft limit in the sense that we can add one additional user and tolerate a slight degradation of the signal quality
  - The greater the number of codes, the more the number of users
  - This allows many users to operate on the same frequency
  - This also allows frequencies to be reused in every cell site and sectors within a cell site
  - **Frequency reuse factor is equal to 1**
    - I.e. the total system bandwidth is available to be allocated in each cell
  - However, the use of the same frequency in the same cell site and sector increases the interference levels and decreases the capacity of the radio channels

# IS-95: Brief review of CDMA

## ❑Advantages of CDMA

- **Frequency diversity** – Frequency-dependent transmission impairments have less effect on signal

- **Multipath resistance** – Chipping codes used for CDMA exhibit low cross correlation & auto correlation

- **Privacy** – Privacy is inherent since spread spectrum is obtained by use of noise-like signals

- **Graceful degradation** – System only gradually degrades as more users access the system

# IS-95: Brief review of CDMA

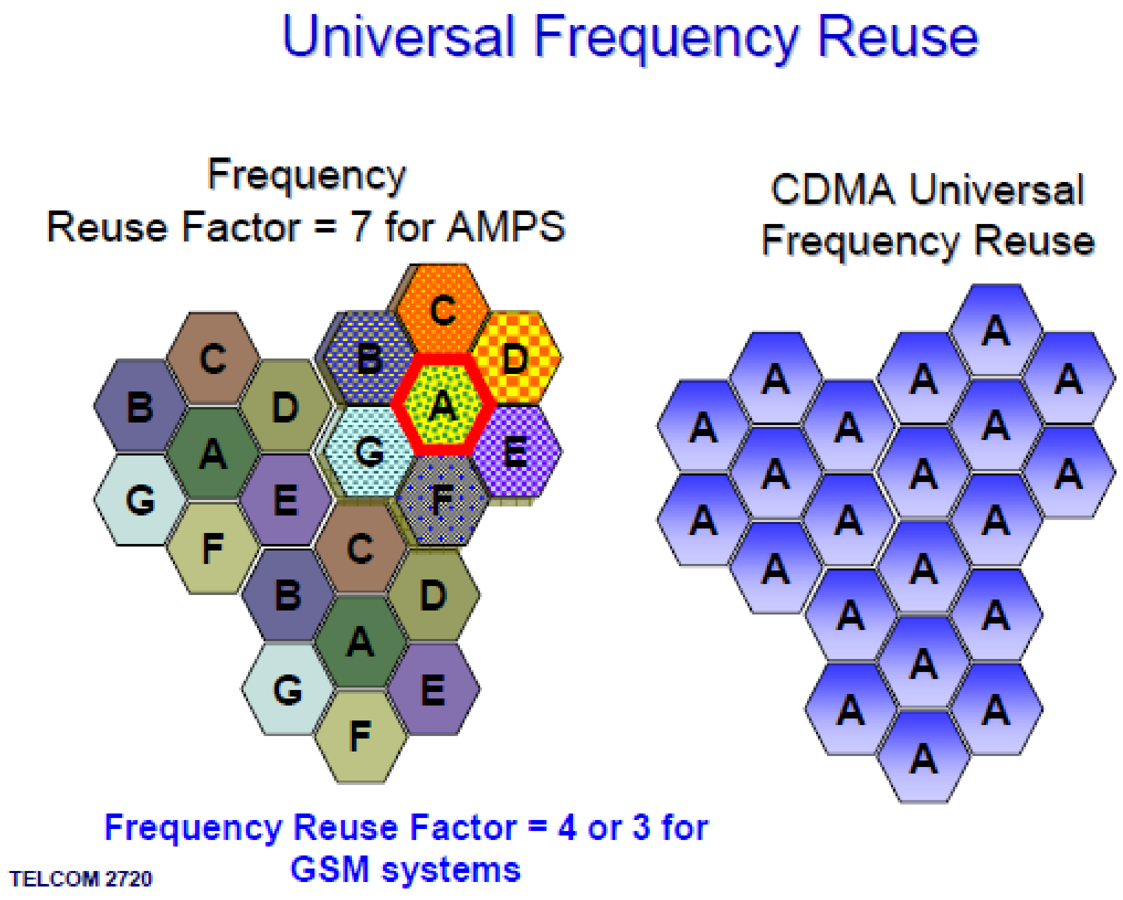
## ❑Drawbacks of CDMA

- **Self-jamming**
  - Arises from the presence of delayed replicas of signal due to multipath
  - The delays cause the spreading sequences of the different users to lose their orthogonality, as by design they are orthogonal only at zero phase offset

- **Near-far problem**
  - Signals closer to the receiver are received with less attenuation than signals farther away. (power control is the solution)

# CDMA based cellular network

- Both an access method and air-interface
- Rest of the network is very similar to GSM
- Radio resource management, mobility management, security are similar
- Power control and handoffs are different
- Uses DSSS and ECC
- Frequency reuse factor is 1
- 3 systems
    - **IS-95 2G**
    - **W-CDMA**
    - **CDMA2000**



# IS-95 (also called as **CDMAOne)**

- Was developed by Qualcomm
- It was the first-ever implementation of Code Division Multiple Access (CDMA) in mobile telecommunications, and it paved the way for numerous advances in wireless communication
- Operates on the North American Standard frequency band
- IS-95 evolved to **CDMA2000 in 3G**

# IS-95: CDMA based cellular network (Contd..)

## ❑Advantages

- Higher capacity
- Improves voice quality (new coder)
- Soft-handoffs
- Less power consumption (6-7 mW)
- Choice for 3G systems

## ❑Disadvantages

- Air-interface is the most complex
- Not symmetrical (unlike TDMA)
  - Forward and reverse channels are different
  - Forward channel synchronized
  - Forward channel uses orthogonal spreading codes
  - Reverse channel transmissions are not synchronized

# How IS-95 Works

- Operates in the bandwidth same as AMPS (Advanced Mobile Phone System which is the first generation (1G) of cellular mobile communication systems)
  - **824 to 849 MHz Mobile to Base**
  - **869 to 894 MHz Base to Mobile**

- System use **FDD/FDMA/CDMA**
  - FDD - Uplink and Downlink channels separated according to Cellular band or PCS band regulatory requirements
  - FDMA – breaks up licensed spectrum into **1.25 MHz** channels
  - CDMA – multiple users share a 1.25 MHz channel by using orthogonal spreading codes (Walsh codes)

- Adjacent cell phone towers use exact same channels as all other towers

# IS-95 CDMA Forward Channel

- The forward link uses the same frequency spectrum as AMPS

  (869  to  894 Mhz)
- Each carrier 1.25MHz – 64 channels
- Channels are separated using different spreading codes
- Orthogonal Walsh codes are used (64 total)
- 4 types of logical channels: **A pilot, a synchronization, 7 paging, and 55 traffic channels**
- After orthogonal codes, they are further spread by **short PN spreading codes**
- **Data rate: 9.6kbps**
- **Chip rate:1.2288Mcps**
- **QPSK** is the modulation scheme

# IS-95 Spreading Procedures

- Why we have two spreading codes?
  - The orthogonal codes are used to differentiate between the transmissions within a cell
  - The PN spreading codes (also called as **short codes**) are used to isolate different cells (BSs) that are using the same frequencies
  - The same PN sequence is used in all BSs
  - The offset for each BS is different
  - Of course, this requires synchronization
  - Synchronization is achieved by GPS

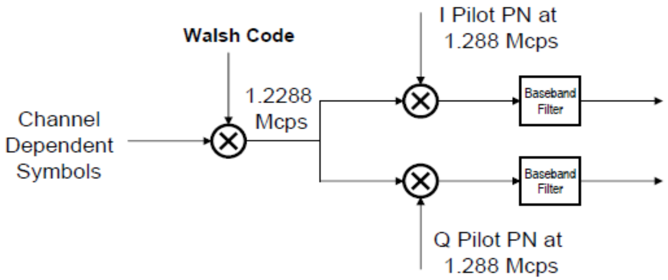



Figure 8.5: Basic Spreading Procedure on the Forward Channel in IS-95

For the spread signal to be at 1.2288 Mcps, the incoming stream must be at: $1.2288 \times 10^6/64 = 19.2$ ksps

Each forward code channel is spread by the **Short Code**, which has I- and Q-components. The spreading is thus quadrature. That is, from a single binary-valued, covered, symbol stream, two binary sequences are generated by mod 2 addition of the short code PN sequences

The PN sequence for the I channel is based on a different polynomial than the Q channel and they therefore evolve differently

In-phase $Px(x)=x^{15}+x^{13}+x^9+x^8+x^7+x^5+1$
Quadrature $Px(x)=x^{15}+x^{12}+x^{11}+x^{10}+x^6+x^5+x^4+x^3+1$

The binary I and Q outputs of the quadrature spreading are mapped into phase according to the table

| *I* | *Q* | Phase |
|---|---|---|
| 0 | 0 | $\pi/4$ |
| 1 | 0 | $3\pi/4$ |
| 1 | 1 | $-3\pi/4$ |
| 0 | 1 | $-\pi/4$ |

# Orthogonal Covering Via Walsh Codes

- 64 Orthogonal Channels for all users, assuming negligible multi-path delays

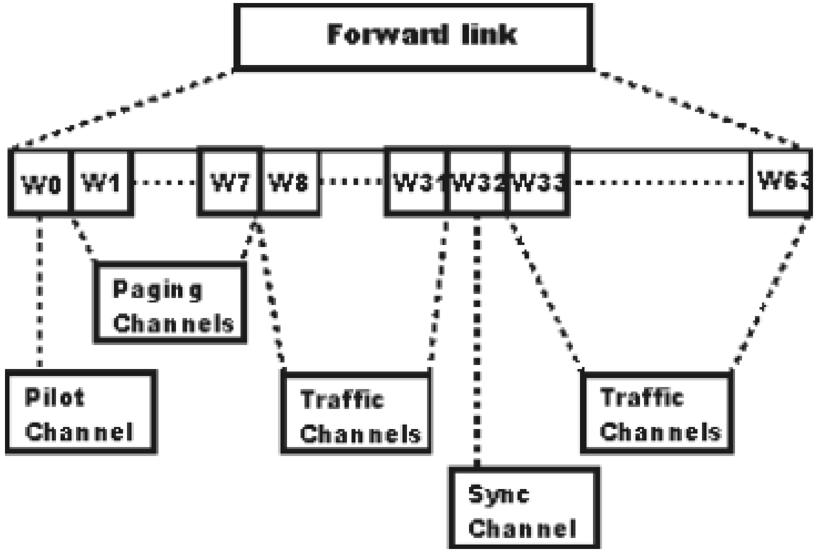
- 64 $^{X}$ 64 Walsh Matrix
  - 1 Row = 1 Walsh Code

- 64 bits per row * 19.2ksps per row = 1.2288Mcps (the output of the Walsh  generator)

- Channel 0 is assigned to the pilot and is given more power than the rest of the  channels

- Channel 32 is assigned to synchronization

- Mobile Paging Channels are usually on the lower Walsh ID’s

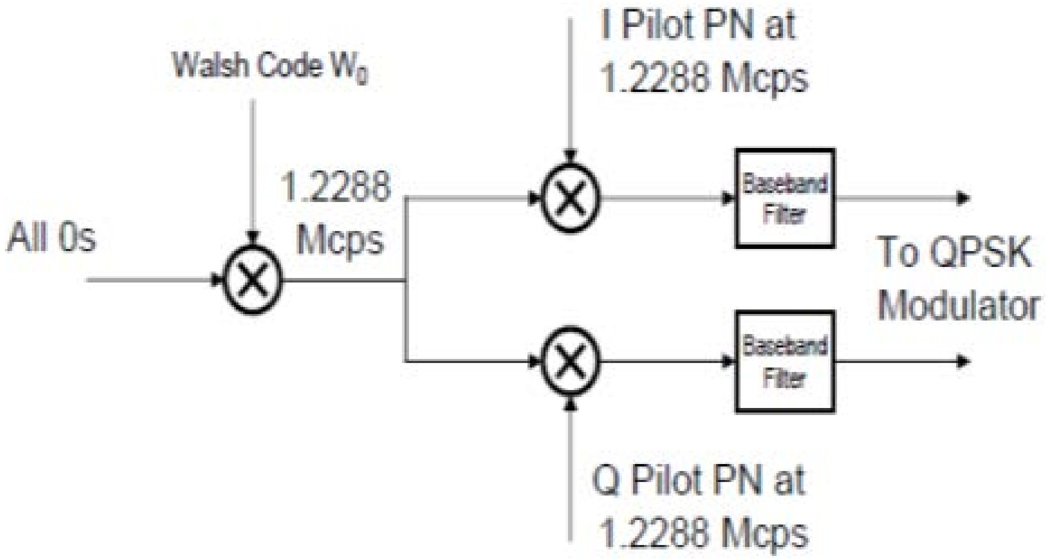


# IS-95 CDMA Forward Channel

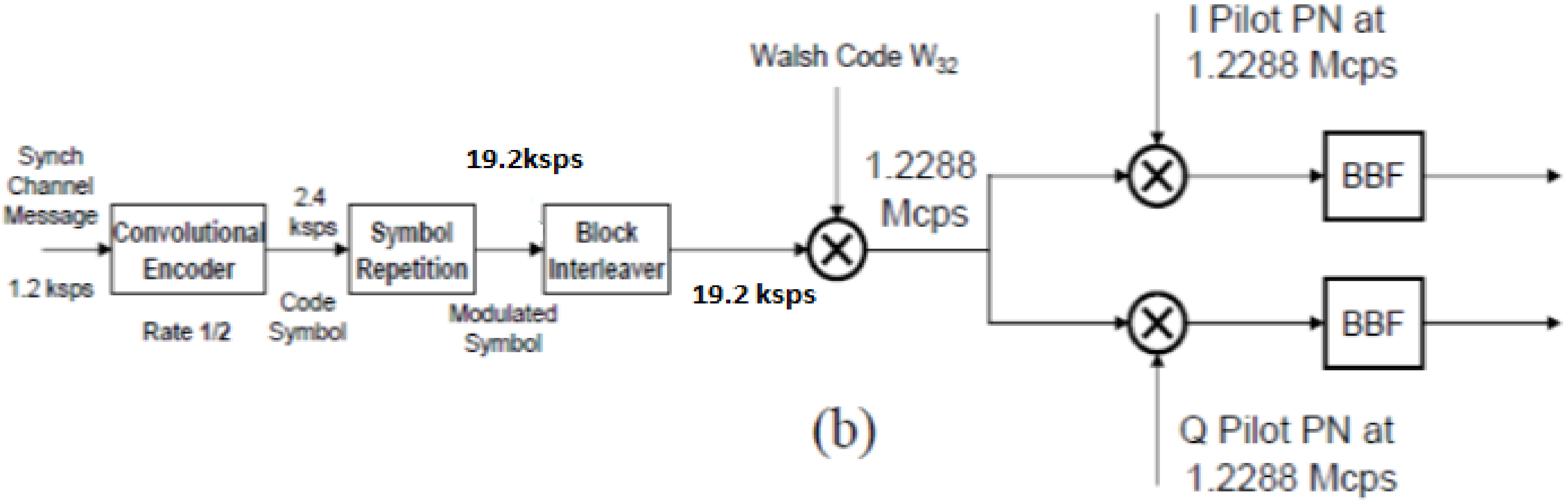
| **Pilot channel** | **Synchronization (Sync) channel** | **Paging channel** | **Traffic channel** |
| --- | --- | --- | --- |
| The pilot channel is transmitted as a reference by the base station to provide timing and phase reference for the mobiles, and carries no real data<br><br>4-6 dB stronger than all other channels<br><br>Obtained using all zero Walsh code; i.e., contains no information except the RF carrier<br><br>Spread using the PN spreading code to identify the BS<br><br>No power control in the pilot channel | Used to acquire initial time synchronization.<br><br>Synch message includes system ID (SID), network ID (NID), the offset of the PN short code, the state of the PN-long code, and the paging channel data rate (4.8/9.6 Kbps).<br><br>Uses $W_{32}$ for spreading<br><br>Operates at 1200 bps | Used to page the MS in case of an incoming call, or to carry the control messages for call set up<br><br>Uses W1-W7<br><br>There is no power control<br><br>Additionally scrambled by PN long code<br><br>The data rate is 4.8 kbps or 9.6 kbps | Carry user information<br><br>Two possible data rates<br>RS1={9.6, 4.8, 2.4, 1.2 Kbps}<br>RS2={14.4, 7.2, 3.6, 1.8 Kbps}<br><br>RS1 is mandatory for IS-95, but support for RS2 is optional.<br><br>Also carry power control bits for the reverse channel<br><br>*RS: Rate Set |

# IS-95 CDMA Forward Channel

**Pilot channel processing block diagram**




**Synch channel processing block diagram**



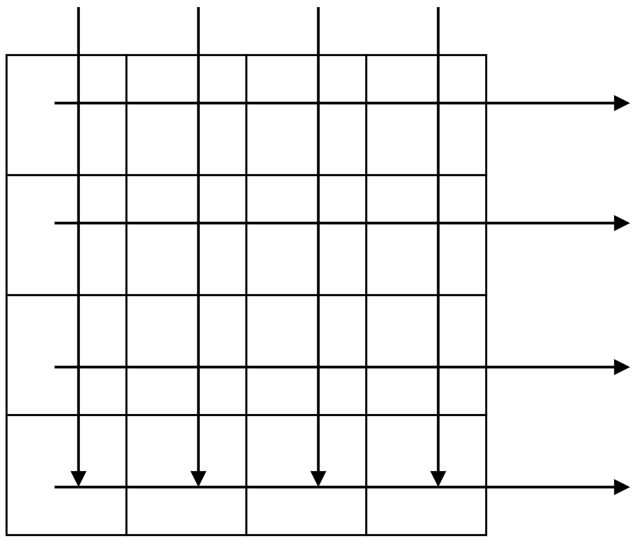

(b)

*Symbol repetition is done to maintain a constant input to the block interleaver

# IS-95 CDMA Forward Channel

## ❑Block interleaver

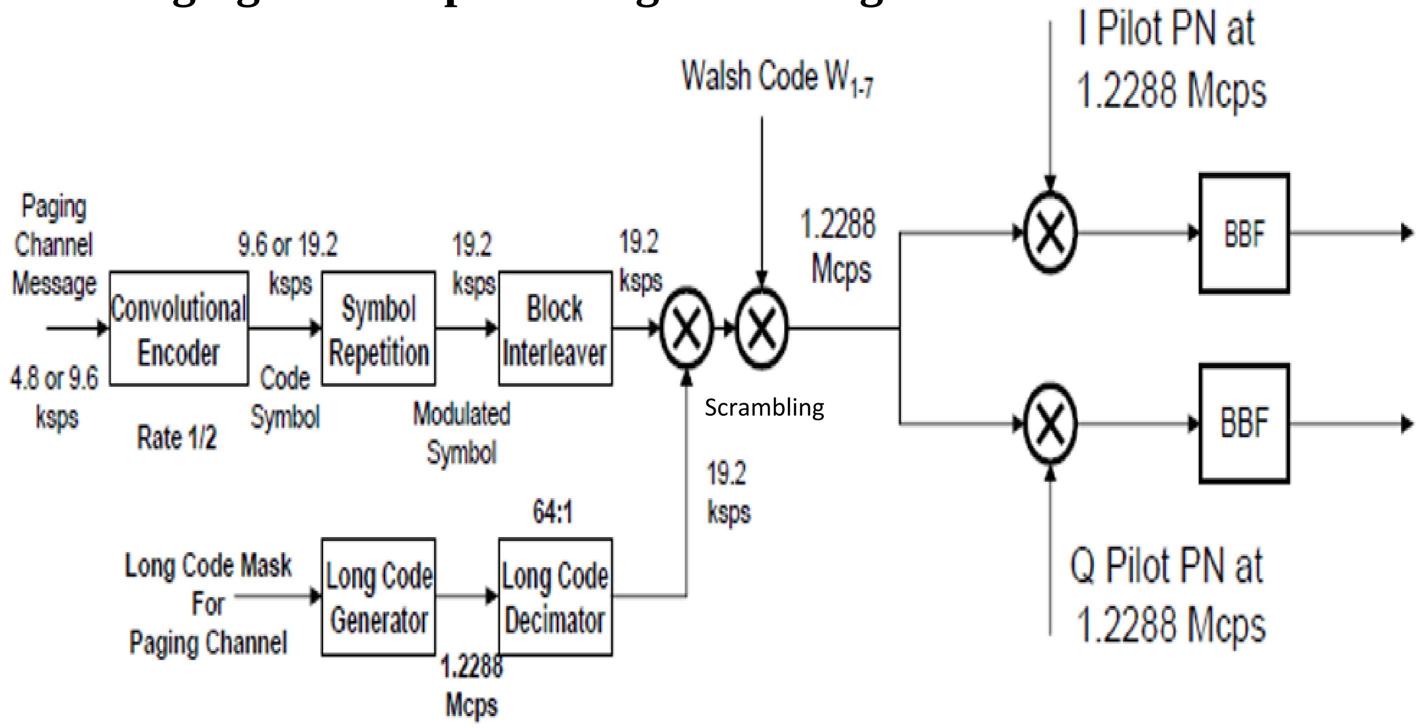
- 19.2ksps * 20ms per frame = 384 bits
- 24x16 bits = 384 bits
- Data is read in as columns and out as rows
- Separates out the entire data when consecutive data bits are sent, therefore adding to transmission  robustness



# IS-95 CDMA Forward Channel

- First the baseband information is error protected
- After this the data is repeated if it is at a rate of 4.8 kbps, otherwise it is left as it is
- Following this the data is interleaved and then **scrambled** by the decimated **long PN sequence**, and finally spread by the Walsh code for the particular channel assignment

**Paging channel processing block diagram**




- Data scrambling is performed after the block interleaver
- The 1.2288 MHz PN sequence is applied to a decimator, which keeps only the first chip out of every sixty-four consecutive PN chips
- The symbol rate from the decimator is 19.2 ksps
- The data scrambling is performed by modulo-2 addition of the interleaver output with the decimator output symbol
- Majorly done for Data Encryption making call more secure

# Long PN Sequence

- The long code provides limited privacy
- The long PN sequence is uniquely assigned to each user is a periodic long code with $2^{42}$-1period chips
- The long code is specified by the following characteristic polynomial:

$$p(x) = x^{42} + x^{35} + x^{33} + x^{31} + x^{27} + x^{26} + x^{25} + x^{22} + x^{21} + x^{19} + x^{18} + x^{17} + x^{16} + x^{10} + x^{7} + x^{6} + x^{5} + x^{3} + x^{2} + x^{1} + 1$$

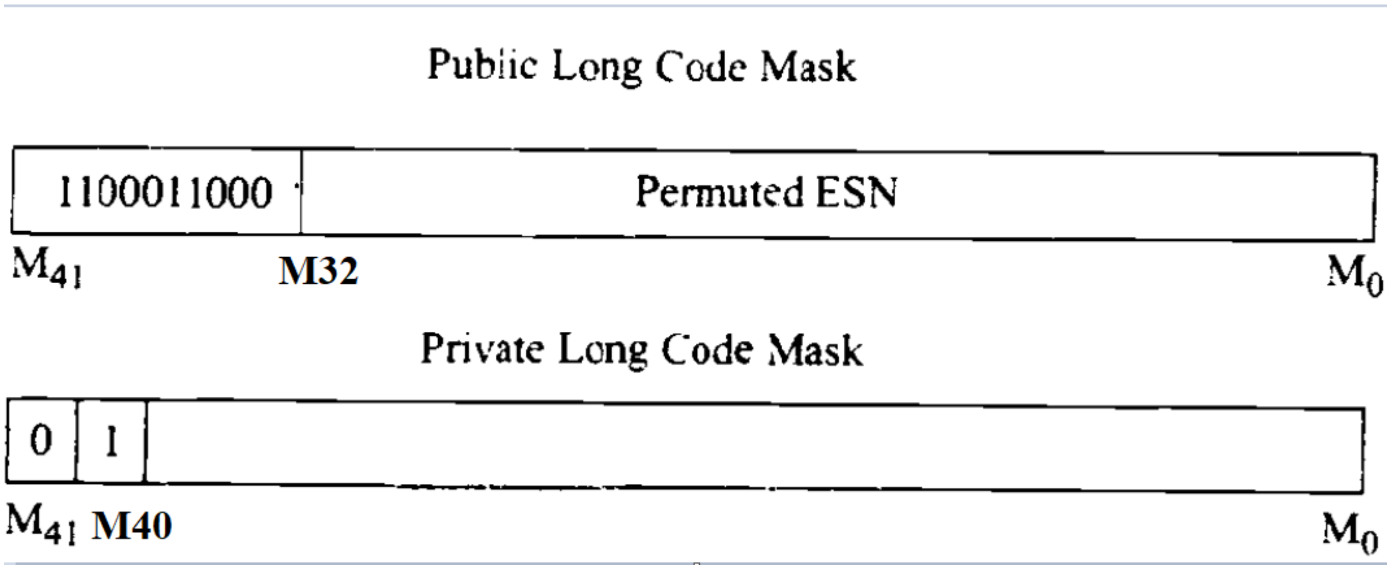
- **Each PN chip of the long code is generated by the modulo-2 inner product of a 42 bit mask and the 42 bit state vector of the sequence generator**
- Two types of masks are used in the long code generator:
- **A public mask for the mobile station's electronic serial number (ESN) and a private mask for the mobile station identification number (MIN)**
- All CDMA calls are initiated using the public mask
- Transition to the private mask is carried out after authentication is performed

# Long PN Sequence (Contd..)

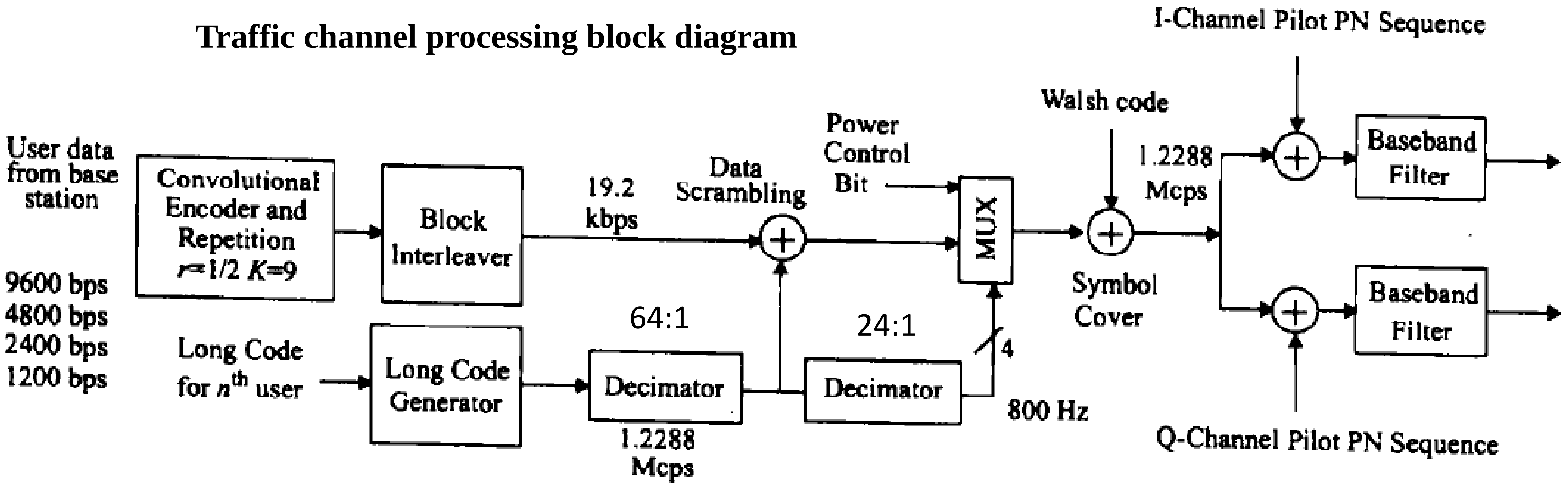
- The public long code is specified as follows: M41 through M32 is set to 1100011000, and M31 through M0 is set to a permutation of the mobile station's ESN bits
- The permutation is specified as follows:

Permuted ESN = ($E_0$, $E_{31}$, $E_{22}$, $E_{13}$, $E_4$, $E_{26}$, $E_{17}$, $E_8$, $E_{30}$, $E_{21}$, $E_{12}$, $E_3$, $E_{25}$, $E_{16}$, $E_7$, $E_{29}$, $E_{20}$, $E_{11}$, $E_2$, $E_{24}$, $E_{15}$, $E_6$, $E_{28}$, $E_{19}$, $E_{10}$, $E_1$, $E_{23}$, $E_{14}$, $E_5$, $E_{27}$, $E_{18}$, $E_9$)

- The private long code mask is specified so M41 and M40 are set to '01'. And M39 through M0 are set by a private procedure

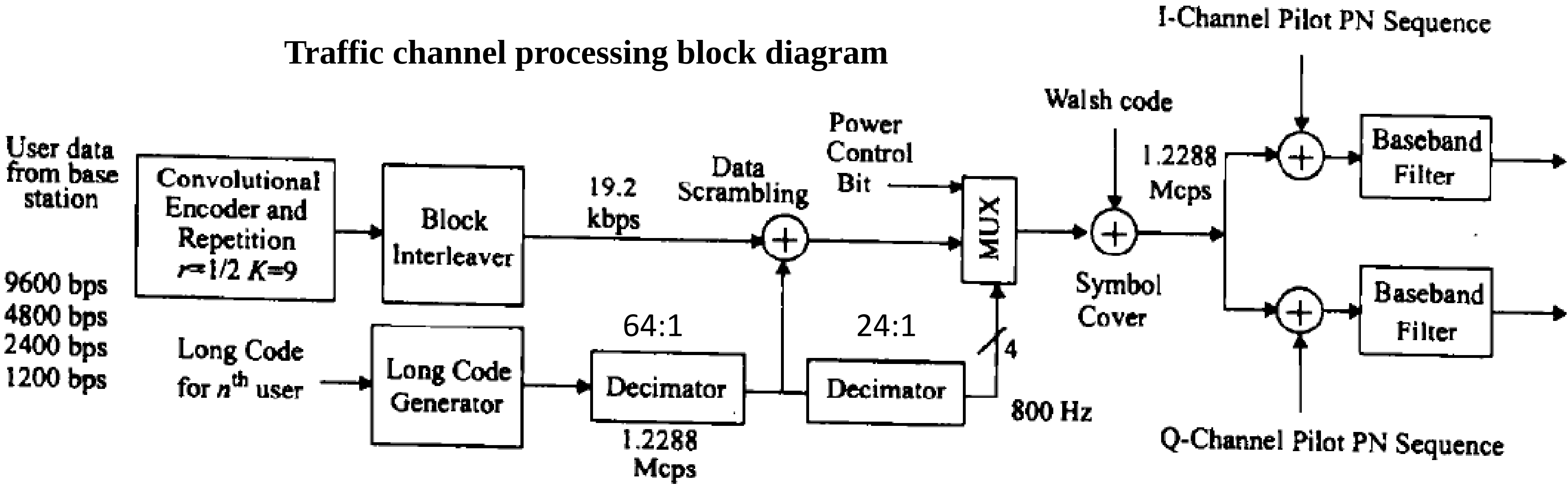


# IS-95 CDMA Forward Channel




- Speech coded voice or user data are encoded using a half-rate convolutional encoder with constraint length 9
- The speech encoder exploits pauses and gaps in speech, and reduces its output from 9600 bps to 1200 bps during silent periods
- In order to keep a constant baseband symbol rate of 19.2 kbps, whenever the user rate is less than 9600 bps, each symbol from the convolution encoder is repeated before block interleaving
- The repetition results in a constant coded rate of 19,200 symbols per second for all possible information data rates
- After convolution coding and repetition, symbols are sent to a 20 ms block interleaver, which is a 24 by 16 array
- Data scrambling is performed after the block interleaver

# IS-95 CDMA Forward Channel




- Power control commands are sent to each subscriber unit on the forward control sub channel which instruct the mobile to raise or lower its transmitted power in 1 dB steps
- If the received signal is low, a ‘0’ is transmitted over the power control sub channel, thereby instructing the mobile station to increase its mean output power level
- If the mobile's power is high, a ‘1’ is transmitted to indicate that the mobile station should decrease its power level
- The power control bit corresponds to two modulation symbols on the forward traffic channel
- Power control bits are inserted after data scrambling
- The power control bit is sent in one of 16 possible locations coded by the 4 bit output of the second decimator

# Power control

- In CDMA, ‘near-far’ problem is very significant
  - As users transmit at the same time and frequency, a user close to the base station may drown the signal of a user far away from the station
- To overcome this problem, power control is used
- Power control reduces the battery power consumption making the CDMA phone somewhat smaller than their TDMA counterparts
- **Open-loop power control**
  - Uses a transmit power that is inversely proportional to the received signal strength from the base station
  - Base station transmits at a known power level which the mobile measures to estimate the path loss
  - This technique works under the assumption that path loss in both the directions is the same
    - However it is not very accurate as forward and reverse channels are separated in frequency

# Power control (Contd..)

- **Closed-loop power control**
  - Signal-to-Interference ratio is measured at the receiver (BS) and compared to a target SIR value
  - A power control bit is transmitted on the forward link
  - This bit instructs the mobile to either increase or decrease the power by 1 dB
  - This type of power control requires a bi-directional link
  - This technique is applied in traffic channel wherein power control bits are inserted periodically to downlink data instructing MS to adjust power levels
  - This power control type is further divided into
    - **Inner loop (or fast power control)**
    - **Outer loop (or slow power control)**

| **Inner loop** | **Outer loop** |
|---|---|
| • Measures received SIR<br>• Controls transmit power<br>• Commands sent several times per frame (hence fast power control) | • Measures packet error rate<br>• Changes target SIR for inner loop<br>• Directly modifies transmit power based on frame error rate<br>• Commands sent once per frame (hence slow power control) |

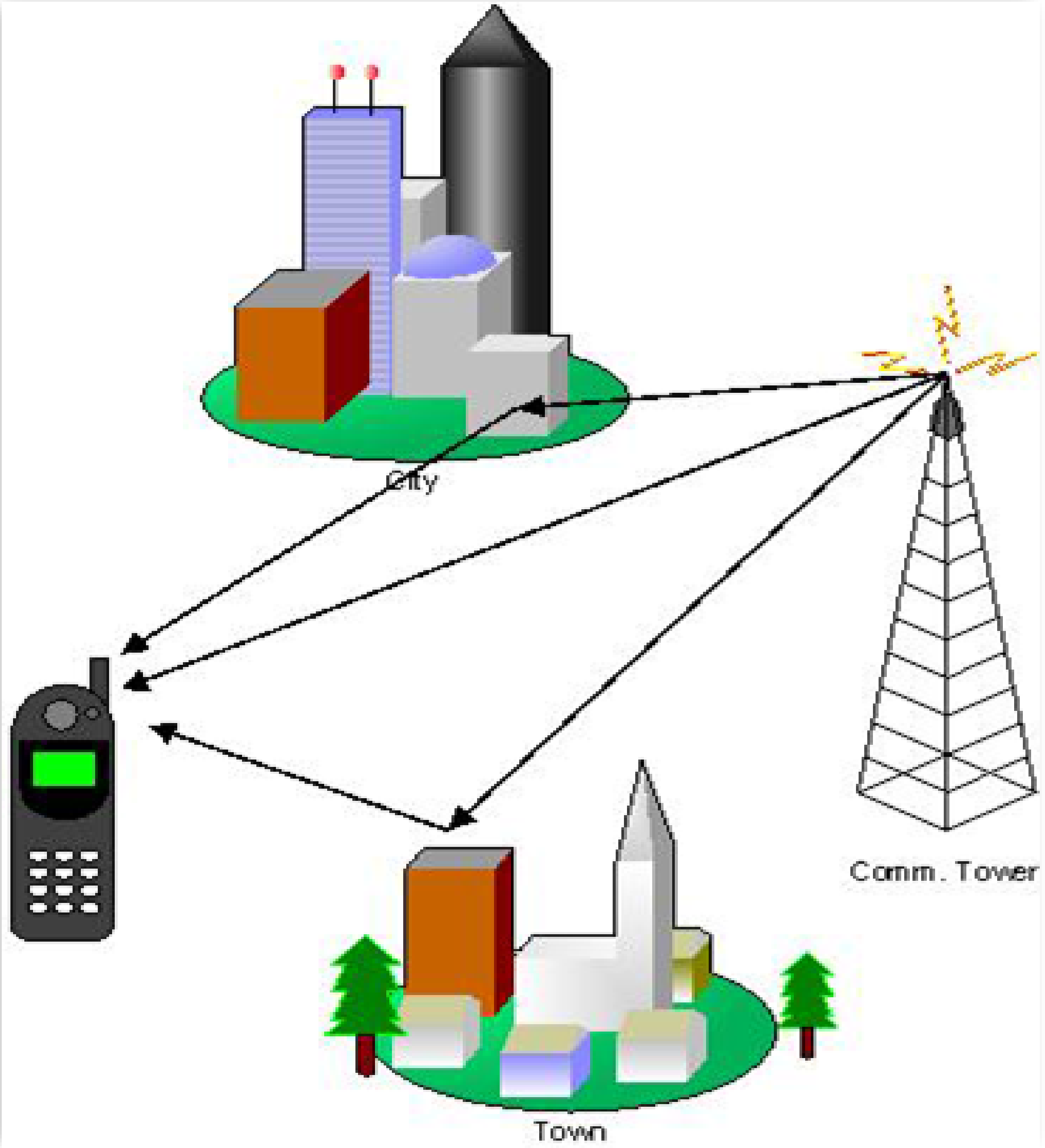
# IS-95 CDMA Reverse Channel

- Fundamentally different from the forward channels
- Uses OQPSK for power efficiency
- 824 to 849 MHz range
- No spreading of the data using orthogonal codes
- Two types of logical channels: The **access channels** and the **reverse traffic channels**
  - MS transmits control information such as call origination, registration, security messages and response to a page using the access channels with data rate **4.8 kbps**
  - The reverse traffic channel supports voice data at two rates, RS1 and RS2

# Use of 'Rake Receivers' in CDMA systems

❖**Rake Receiver**

- When the signal travels from transmit end to the receive end, it will go through multiple paths
- This results into multiple versions of the transmit signals received at the receiver
- Each of these signals will have different attenuations and path delays leading to multipath fading of the received signal
- Rake Receiver is used to oppose the characteristics of multipath fading



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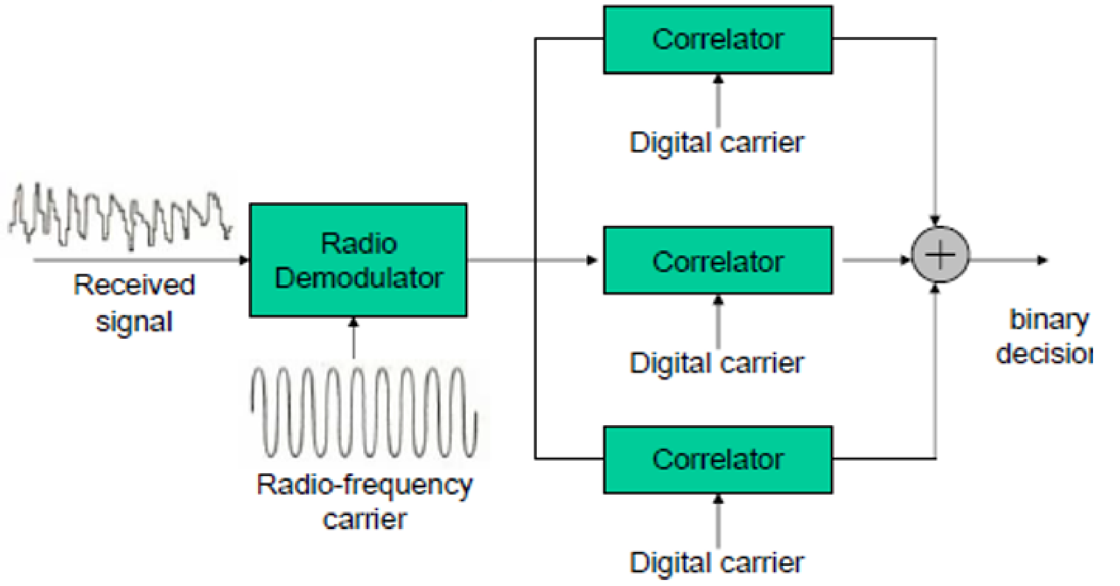
- Rake Receiver is used to oppose the characteristics of multipath fading
- After the demodulation, chip stream is fed to the correlators, each providing different amount of delay
- The Correlators are used by the rake receiver to find which multipath component is strongest
    - The signal is correlated with a locally generated copy of the signal waveform
    - If, however, the signal is distorted by the channel, the receiver should correlate the incoming signal by a copy of the expected received signal, rather than by a copy of transmitted waveform
- This can be done by weighing each correlator and choosing the best among them
- To yield better performance, the weighted coefficients of the correlators need to be considered
- When multipath signals are sent through the correlator one signal may be corrupted because of fading and it will not be the same case for other signals
- The corrupted will not be considered during the weighting process



# Soft handoff in IS 95

- Soft handoff is different from the traditional hard-handoff process
- With hard handoff, a definite decision is made on whether to hand off or not
- With soft handoff, a conditional decision is made on whether to hand off
- Depending on the changes in pilot signal strength from the two or more base stations involved, a hard decision will eventually be made to communicate with only one
- This normally happens after it is evident that the signal from one base station is considerably stronger than those from the others
- In the interim period, the user has simultaneous traffic channel communication with all candidate base stations
- It is desirable to implement soft handoff in power-controlled CDMA systems
- A system with power control attempts to dynamically adjust transmitter power while in operation
- **Power control is closely related to soft handoff**
- IS-95 uses both power control and soft handoff as an interference reduction mechanism

# Soft handoff in IS 95

## ❑Benefits

- Less transmit power from the mobile results in longer battery life and longer talk time
- In a soft handoff, if a mobile receives an up power control bit from one base station and a down control bit from the second base station, the mobile decreases it transmit power
- The mobile obeys the power down command since a good communications link must have existed to warrant the command from the second base station

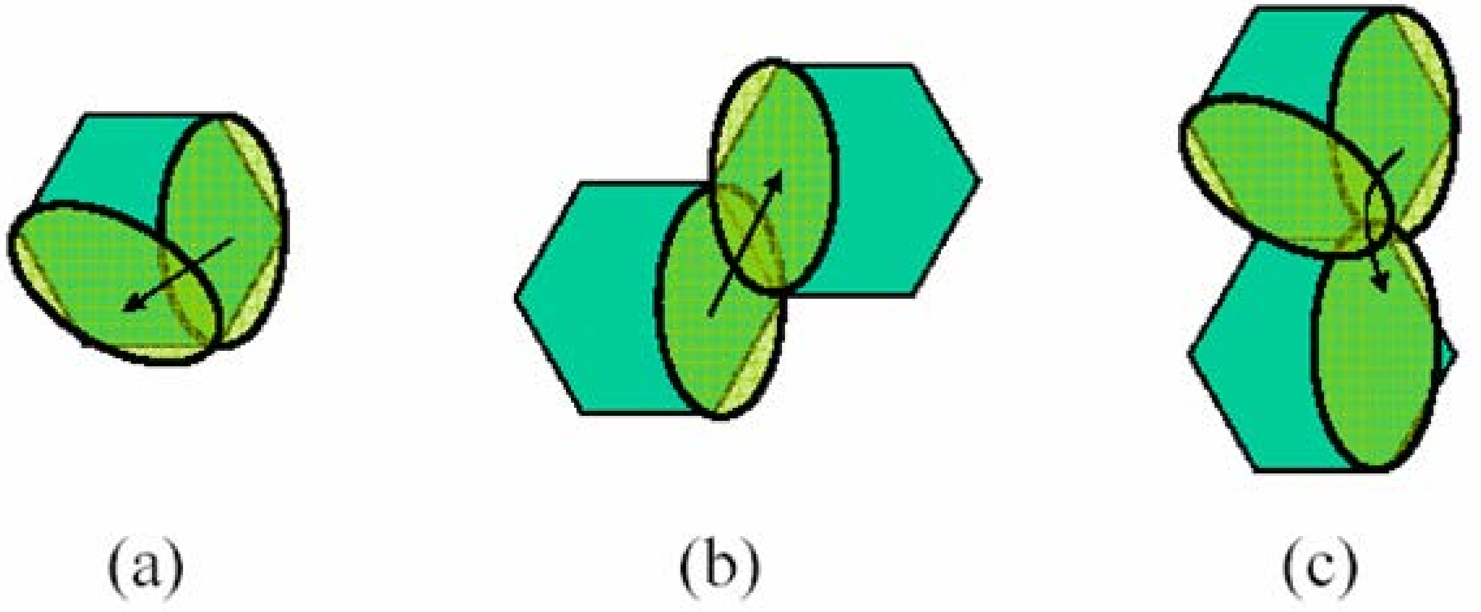
# Soft handoff in IS 95

**IS-95 specifies three basic types of soft handoff**

(a) Softer: handoff between two sectors of same cell

(b) Soft: handoff between sectors of adjacent cells

(c) Soft-softer: candidates for handoff include two sectors from the same cell and a sector from adjacent cell



(a) Softer (b) soft and (c) soft-softer handoff

# Steps for soft handoff

- The mobile detects a pilot signal from a new cell and informs primary base station A
- A communications path from base station B to the original frame selector is established
- The frame selector selects frames from both stream
- The mobile detects that base station A’s pilot is failing and requests that this path be dropped
- The path from original base station A to the frame selector is dropped
- Base station B gives base station A its assigned Walsh code
- Base station A gives the mobile the Walsh code of B as part of the HDM
- Now the mobile can listen to base station B
- Base station A gives the user’s long-code mask to base station B
- Now B can listen to the mobile
- Both base stations A and B receive forward link power control information back from the mobile and act accordingly
- The mobile receives independent puncture bits from both A and B
- If directions conflict, the mobile decreases power; otherwise the mobile obeys directions

# How IS-95 Works

- When a phone is turned on, it scans one of the forward channels to find a base station identifier
    - Camps on the strongest signal
- The phone sends out an encrypted pass key and gains access to the network
- It can then send and receive calls
    - It is assigned a 1.25 MHz wide frequency to operate on
- It listens for pages on the forward channel to let it know it has a call incoming
- This is all very similar to how GSM operates so far