

CDMA CONCEPTS

Introduction To Cellular Communication

To provide wireless communication access to subscribers we need a pair of RF channels per active call. In a large city with several thousand subscribers number of channels required would be so large that they cannot be accommodated on one site. Also there is a limit to availability of spectrum. If an operators get a 5 MHz band, then he has only 25 channels to use with 25 channels loaded at one site he can offer cellular service to 2000 subscribers at most. To overcome this limitation, you have to create zones of coverage, which are called as cells.

Cellular Structure

Cells in cellular system are hexagons. The actual cell covered by a base station takes a very different shape depending upon the terrain obstructions and transmitting antenna characteristics. The cells are of different sizes and shapes to cover a densely populated area, smaller cells are used. Where a large cells cover a low subscriber density areas. On the highways and main roads cell size is optimised to cover larger length of the cell along the road. This is made possible by using directive antenna.

Code Division Multiplexing Access:-

The CDMA standard allows up to 61 simultaneous users in one 1.2288 MHz channel. By processing each voice packet with two PN codes. It is virtually impossible to monitor a CDMA conversation or fraudulently access ESNs, PINs or credit card numbers.

Though there are 64 Walsh codes available to differentiate call and theoretical limits are around 40 calls. The operational limitations and quality issues will reduce the maximum number of calls somewhat below this value.

Channelization Methods

- The band used in CDMA is 824 MHz to 894 MHz (50 MHz + 20 MHz separation)
- Frequency channel is divided into code channels
- 1.25 MHz of FDMA channel is divided into 64 code channels.

CDMA is a Code Division Multiple Access

- Spread spectrum technique
- Multiple users share the same frequency in one cell
- Same frequency in all the cells
- Takes advantage of Multipath
- Capacity is soft
- Operates under presence of interference

Spread Spectrum Technique

All of the modulation and demodulation techniques strive to achieve greater power and/or bandwidth efficiency in a stationary additive white Gaussian noise channel. Since bandwidth is a limited resource, one of the primary design objectives of all modulation schemes is to minimize the required transmission bandwidth. Spread spectrum techniques on the other hand employ a transmission bandwidth that is several orders of magnitude greater than the minimum required signal bandwidth. While this system is very bandwidth inefficient for a single user, the advantage of spread spectrum technique is that many users can simultaneously use the same bandwidth without significantly interfering with one another. In a multiple-user multiple access interference environment, spread spectrum systems becomes very bandwidth efficient.

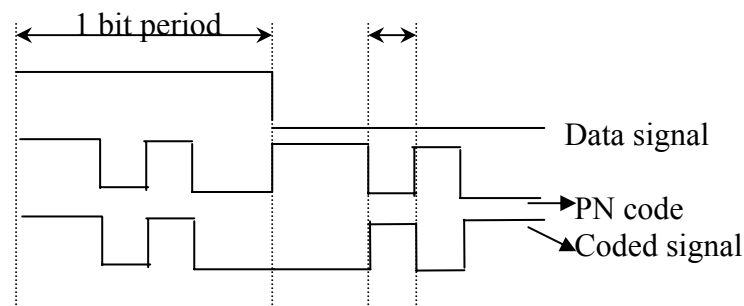
There are two types of spread spectrum techniques are used

- Direct Sequence
- Frequency Hopping.

Direct Sequence is adopted by CDMA

Direct Sequence Spread Spectrum

1 chip period



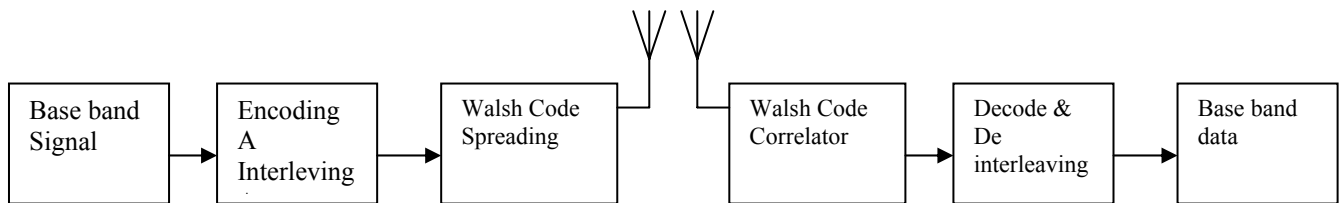
The base band data since is multiplied by a PN code, which is multiplication of each bit of base band data with the PN code, will result into a spread bandwidth but the spectral power density remains the same, because before spreading the energy was concentrated in a small bandwidth, now it is spread over a large bandwidth. Now when this spread signal is transmitted it is received at the receiver, with signal from other user of the same spectrum, which became noise for this noise, plus interference from other sources. The receiver in these systems will have a correlate, which use the replica of the PN code to extract the same information.

Advantages of Spread Spectrum

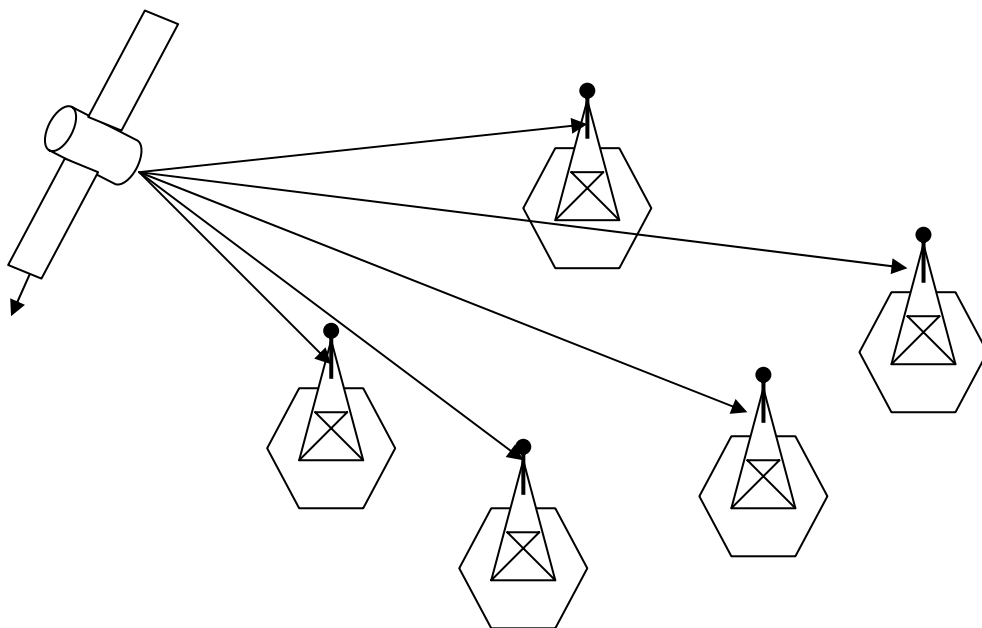
1. As the signal is spread over a large frequency band, the power spectral density is getting very small, so other communications systems do not suffer from this kind of communications. However the Gaussian Noise level is increasing.
2. Multiple accesses can be deal with, as large number of codes can be generated, which will permit a large number of users.

3. The maximal number of users is not spectrum or resource limited, like other access systems like FDMA, here they are only interference limited.
4. Security: without knowing the spreading code, it is nearly impossible to recover the transmitted data.
5. Fading rejection: as large bandwidth is used the system is less susceptible to distortions.

CDMA Concept



CDMA frequency Reuse



In CDMA timing plays an important role. All the base stations are synchronised with satellite time. The base stations will start their transmission with reference to the satellite clock. All the base stations will not transmit at the same instant. With reference to the satellite clock, each base station will offset it's timing by a certain offset. All base stations will have different offsets.

So even if transmission is occurring in a neighbouring cell using the same PN code, then though this come as an interference to the user in the existing cell but it will not effect the

receiver in decoding the right information. This is because, information is decoded by correlating the PN codes, since the neighbour base station is offset in time, it will not correlate with the code used in this cell.

CDMA Capacity

The factors deciding capacity are

- Processing Gain
- Signal to Noise Ratio
- Voice Activity Factor
- Frequency Reuse Efficiency

Capacity in CDMA is soft, CDMA has all users on each frequency and users are separated by code. This means CDMA operates in the presence of noise and interference. On top of this the neighbour cells use the same frequencies, which means no re-use. So CDMA capacity calculations should be very simple. No of code channels in a cell, multiplied by no of cells. But it is not that simple. Though the no of code channels available are 64, it may not be possible to use all at one time, since CDMA the frequency is same. Soft capacity means is that all code channels can be used at one time, but at the cost of quality.

Processing Gain:

$$P(\text{gain}) = 10\log(W/R)$$

W is Spread Rate

R is Data Rate

$$\text{For CDMA } P(\text{gain}) = 10\log(1228800/9600) \\ = 21\text{dB}$$

CDMA is spread spectrum technique. Each data bit is spread by a code sequence. This means energy per bit is also increased. This means, that we get some gain out of this. This gain is a factor of spreading rate and actual data rate.

On average, a typical transmission condition requires a signal to noise ratio of 7 dB for adequate voice quality.

Translated into a ratio, signal must be 5 times stronger than noise.

$$\text{Actual processing gain} = P(\text{gain}) - \text{SNR} \\ = 21 - 7 = 14\text{dB}$$

CDMA uses variable rate coder

The Voice Activity Factor of 0.4 is considered = -4dB.

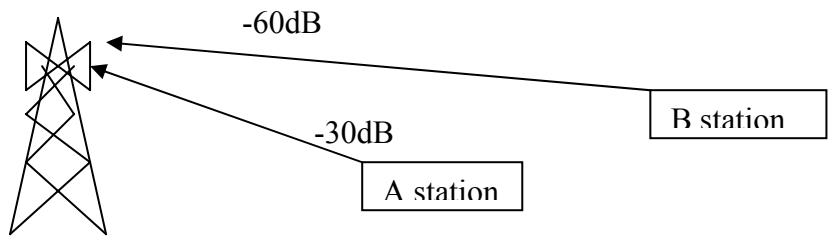
CDMA has 100% frequency reuse. Use of same frequency in surrounding cells causes some additional interference.

In CDMA frequency reuse efficiency is 0.67 (70% eff.) = -1.73dB

$$\text{Capacity (N)} = \frac{\text{Chann BW}}{\text{Data Rate}} \times \frac{1}{\text{Antilog SNR}} \times \frac{1}{\text{VAF}} \times \text{Fr}$$

Power Control

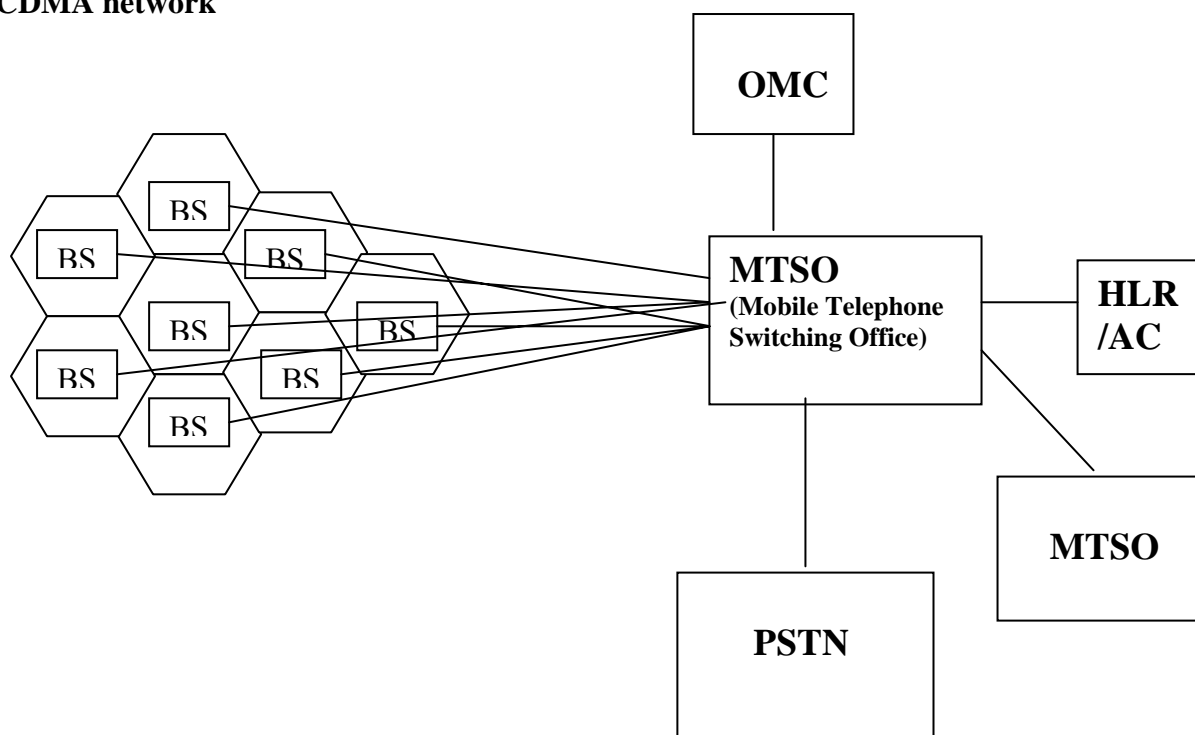
Far-end Near-end problem



- In this case, B is the signal, A is the noise.
- Both A and B are transmitting at constant power.
- Since A is near, it can be asked to transmit at low power.
- Since B is far, it can increase the power.

Base station will increase or decrease power levels based on the Path Loss.
Base station will command mobile also to increase or decrease power levels.

CDMA network



A Base Station is an essential element of the CDMA network. A base station covers a small geographical area called a cell. A cell could be omni directional or sectorial. Every base station will have one transmit antenna and two receive antennas for each cell. Two receive antenna are used per cell for the purpose of Space Diversity. In many implementation cases, there is a BSC (base station controller), which controls several base stations. Since the data rate of the mobile phone is either 8kbps or 13kbps, which is non-ISDN, but the switches that is the MSC's are generally do the switching at 64kbps, so there is a need of converting this mobile data rate to 64kbps, before it is switched. This is done by an element, which is the Transcoder. The Transcoder can be a separate element or it can be collocated within each base station or MSC.

All the base stations are connected to the MSC, which is the Mobile Switching Center. MSC is the entity, which manages the establishment, connection, maintenance and release of the calls within the network and also with the outside world.

MSC also has a database called HLR/AC, which is Home Location Register/Authentication Center; HLR is the database, which keeps all the subscriber database of the network. AC the Authentication Center is the security part of the HLR, which has certain algorithms to scrutinize the mobile phones.

The MSC is connected to the outside world i.e., the fixed line network. One MSC can also be connected to several other MSC's

OMC is the operation and Maintenance Center, which is not specified in the standards, but is an essential element of any cellular network. OMC monitors the health of the

network. All the alarm occurring at the individual base stations sites are forwarded to the OMC.

CDMA Identities

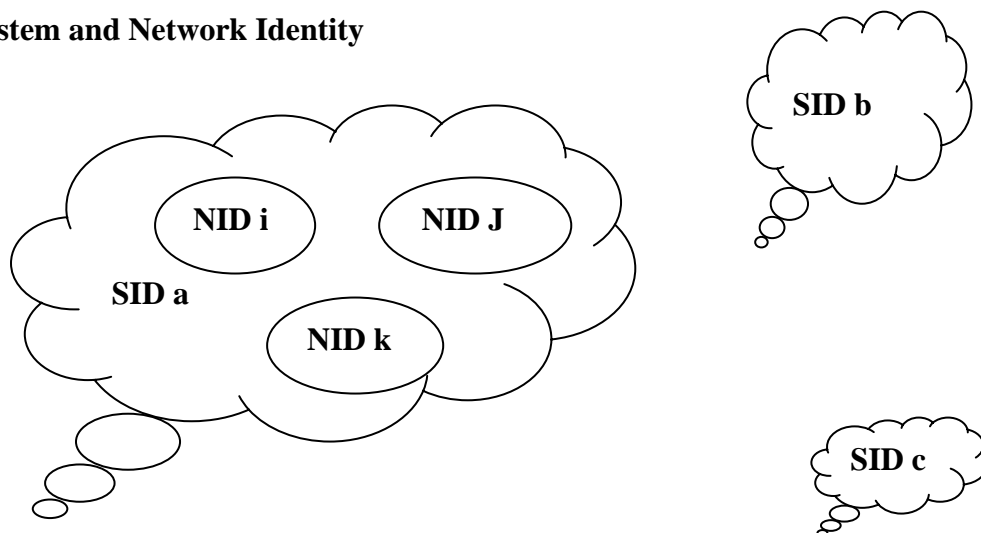
Network Identities:-

- SID (System Identity)
- NID (Network Identity)

Mobile Station Identities:-

- ESN (Electronic Serial Number)
- Permuted ESN
- IMSI (International Mobile Station Identity)
- IMSI_S
- IMSI_11_12
- Station Class Mark

System and Network Identity



A Base Station is a member of a cellular system and a network. A network is a subset of a system. Systems are installed with an identification called the System Identification (SID); networks with a system are given a Network Identification (NID). A network uniquely identified by pair of (SID, NID). The mobile station has list of one or more home (non-roaming) (SID, NID) pairs.

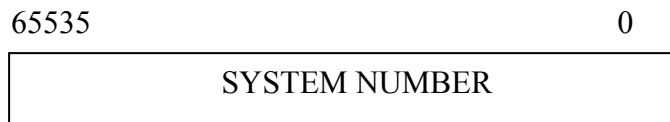
SID



BIT 14	BIT 13	COUNTRY
0	0	United States
0	1	Other Countries
1	0	Canada
1	1	Mexico

A 15-bit system identification indicator (SID) is stored in the mobile station and used to identify the mobile stations home system. The bit allocation of the system identification indicator is as shown above. The allocation of the international (INTL) codes (bits 14 and 13) is also in the table. Bits 12 through 0 will be assigned to each US system, by the FCC, for Non United States countries, these bits allocation will be done by the local regulating authorities.

NID



NID has a range of 0-65535 are reserved values. Value 65535 in a SID, NID pair is to indicate that the Mobile Station considers the entire SID (regardless of NID) as home.

Systems And Networks

The Mobile Station has a list of one or more home (non-roaming) (SID, NID) pairs. A mobile station is roaming of the base station broadcasted (SID, NID) pair does not match one of the mobile stations non-roaming (SID, NID) pairs.

The two types of roaming are defined:

A mobile station is a foreign NID roamer if the mobile station is roaming and there is some (SID, NID) pair in the mobile stations (SID, NID) list for which only SID matches.

A mobile station is a foreign SID roamer if the mobile station is roaming and there is some (SID, NID) pair in the mobile stations (SID, NID) list for which there is no matching SID.

Electronic Serial Number



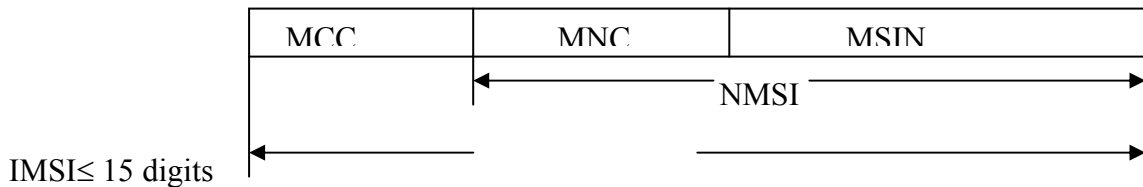
The ESN is a 32-bit binary number that uniquely identifies the mobile station to any CDMA cellular system. It must be factory set and not readily alterable in the field. Modification of the ESN will require a special facility not normally available to subscribers. The circuitry that provides the ESN must be isolated from fraudulent contact and tampering. Attempts to change the ESN circuitry must render the mobile station inoperative. At the time of issuance of initial type acceptance, the manufacturer shall be assigned a Manufacturers code (MFR) code within the eight most-significant bits (bit 31 through bit 24) of the 32-bit serial number. Bits 23 through 18 shall be reserved (initially zero). And each manufacturer shall uniquely assign bits 17 through 0. When a manufacturer has used substantially all possible combinations of serial numbers within bits 17 through 0, the manufacturer may submit notification to the FCC. The FCC will allocate the next sequential binary number within the reserve block (bits 23 through

Permuted ESN

CDMA is spread spectrum technique where multiple users access the system at the same instance in a cell, and of course on the same frequency. So discriminate the users on the reverse link (i.e., information coming from MS to the base station). We spread the information by using some codes, which are unique to mobile station in all CDMA cellular systems. This code has one element that is the ESN. But we don't use the ESN in the same format. But instead we use a Permuted ESN. An ESN us if 32-bit we change the position of the ESN. Similarly B1 of ESN becomes the second last MSB.

The reason why this is done, if there are two mobiles in a cell of the same make, and are having consecutive serial numbers, then for the base station receiver, it becomes difficult to decor relate these. So to prevent high correlation between long codes corresponding to successive ESNs we use permuted ESN's

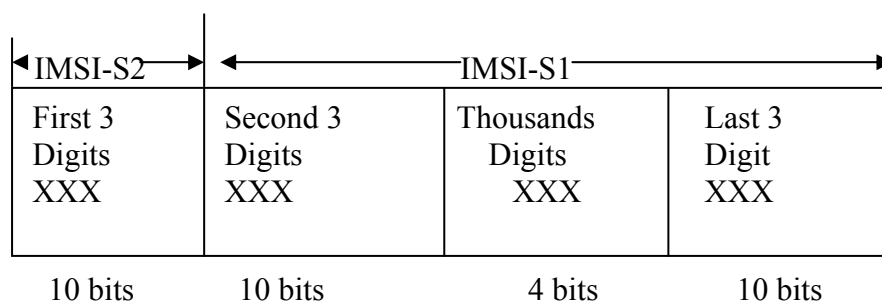
International Mobile Station Identity (IMSI)



- MMC: Mobile Country Code
- MNC: Mobile Network Code
- MSIN: Mobile Station Identification
- NMSI: National Mobile Station Identity

Mobile stations are identified by international mobile station identity (IMSI). The IMSI consists of up to 10 to 15 numerical characters (0-9). The first 3 digits of the IMSI is the mobile country code (MCC), the remaining digits are the national mobile station identity NMSI. The NMSI consists of the mobile Network code (MNC) and the mobile station identification number (MSIN). An IMSI which is 15 digits in length is called a class 0 IMSI (the NMSI is 12 digits in length). An IMSI, which is less than 15 digits in length, is called a class 1 IMSI (the NMSI is less than 12 digits in length). For CDMA operation, the same IMSI may be entered in multiple mobile stations. Individual systems may or may not allow these capabilities. The management of these capabilities is a function of the base station and system operator.

IMSI -S & IMSI - 11-12



The IMSI-S is a 10-digit (34-bit) binary number derived from IMSI. When the IMSI has ten or more digits, IMSI-S is equal to the last ten digits. When the IMSI has fewer than 10 digits, the least significant digits of IMSI_S are equal to the IMSI and zeros are added to the most significant side to obtain a total of ten digits. The 10 digit IMSI_S is doped into a 34 bit binary IMSI_S that consists of 10 and 24 bits parts called IMSI_S2 and IMSI_S1. IMSI_11_12 is equal to the 11 and 12th digits of the IMSI. When have fewer than 12 digits zeros are added to the most significant side to obtain a total length of 12 digits.

Station Class Mark

FUNCTION	BITS	SETTING
Reserved	7	Always 0
Dual mode	6	CDMA only dual mode
Slotted class	5	Non-slotted Slotted
IS-54 power class	4	Always 0
25 MHz Bandwidth	3	Always 1
Transmission	2	Continuous Discontinuous
Power class	1-0	Class 1 Class 2 Class 3 Reserved

Class of station information referred to as the station class mark must be stored in a mobile station. The least significant 5 bits of the dual mode SCM are used when operating in the analog mode; all bits are used when operating in the CDMA mode.

CDMA paradigm shift

Multiple users are on one frequency simultaneously.

A channel is defined by the correlative code in addition to the frequency.

The capacity limit is soft. Capacity can be increased with some degradation of the error rate or voice quality.

CDMA makes use of diversity

- Spatial diversity
- Frequency diversity
- Time diversity

Spatial diversity

- Multiple antennas at base station
- Multiple base stations for soft handoff.

It takes two forms:

The base station uses two receive antennas for greater immunity to fading. This is the classical version of spatial diversity.

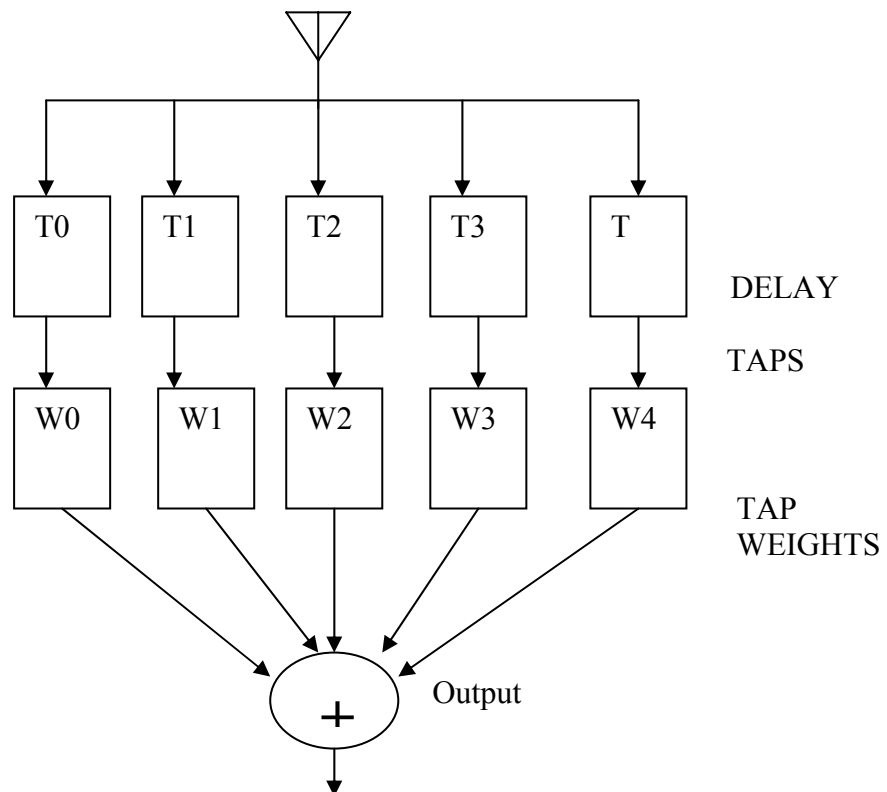
Multiple base stations simultaneously talk to the mobile during soft handoff.

During soft handoff, contact is made with two base stations simultaneously. The signals from the base to mobile are treated as Multipath signals and are coherently combined at the mobile unit. At the base stations, the signals are transmitted via the network to the mobile telephone switching office (MTSO) where a quality decision is made on a frame-by-frame basis, every 20msec.

Frequency diversity

It is inherent in spread spectrum systems. A fade of the signal is less likely than with narrow band systems. Fading is caused by Multipath and is a function of the time delays in the alternate paths. In the frequency domain, a fade appears as a notch filter that moves across a band. As the user moves, the frequency of the notch changes. The width of the notch is on the order of one over the difference in arrival time of two signals. For a 1-usec delay, the notch will be approximately 1 MHz wide. The CDMA system uses a 1.25 MHz bandwidth, so only those Multipaths of time less than 1-usec actually cause the signal to experience a deep fade. In many environments, the Multipath signals will arrive at the receiver after a much longer delay. This means that only a narrow portion of the signal is lost. This results in a power loss to a CDMA signal, but could result in the complete loss of an analog or TDMA signal.

Time diversity



It is a technique common to most digital transmission systems. Signals are spread in time by use of interleaving. Forward error correction is applied, along with maximal likelihood detection. The particular scheme used for CDMA is convolutional encoding in the transmitter with viterbi decoding soft decision points in the receiver CDMA takes advantage of the Multipath by using multiple receivers and assigning them to the strongest signals. The mobile receiver uses three receiving elements, and the base station uses four. This multiple correlator system is called a rake receiver. In addition to the separate correlators, searchers are also used to look for alternate Multipath and for neighbouring base station signals.

Reverse link power control

All mobiles are received at base station at equal power. There are two types of control

- Open Loop Power Control
- Closed Loop Power Control

Open loop power control is based on the similarity of the loss in the forward path to the loss in the reverse path (forward refers to the base to mobile link, while reverse refers to the mobile to base link). It sets the sum of transmit power and receive power to a constant, nominally -73 , if both powers are in dBm. A reduction in signal level at the receive antenna will result in an increase in signal power from the transmitter.

Closed loop power control is used to allow the power from the mobile unit to deviate from the nominal as set by open loop control. The base station monitors the power received from each mobile station and commands the mobile to either raise power or lower power by a fixed step of 1dB. This process is repeated 800 times per second, or every 1.25 μ sec. Because the power of the mobile is controlled to be not more than is needed to maintain the link at base station, less power is typically transmitted from the mobiles. In order to transmit enough power to maintain a link in the presence of fade, most of the time it is transmitting with excess power. CDMA is controlled and kept at low power.

Communication between BS and MS

Base station and mobile station speaking ideally should transmit and receive only traffic but apart from traffic, there are various other activities which takes place between a MS and BS. Like when the MS turns its first objective is to camp on to the right network. For this it needs the networks parameters to be broadcasted by the BS. And also to read the network parameters the MS needs to synchronize with the BS. A call cannot just started, first thing a mobile has to do initiate the call is access the network. This is required because cellular systems are blocking systems, in which no permanent or dedicated resources are allotted to mobile stations, mobile stations get dedicated resource only when they request. So mobile has to do some amount of access signalling with the network. After getting some dedicated resource also the call may not start immediately, mobile will have to authenticate itself, so this will involve some security related signalling. Then finally some amount of signalling will be required to do the call set-up. Another very important communication between BS and MS is paging. MS is mobile and is not having any permanent connection with the network. So whenever there is an incoming call, the BS will page the Mobile in different cells.

Codes

Walsh codes: - it is use to differentiate the channels in downlink (forward link). It is used to communicate from BS to Mobile.

This provides orthogonal encoding is that characterized by the following property when they are multiplexed:

- If they were encoded with the same code, the result is acknowledged by the receiving system.
- If they were encoded with different codes, the result is ignored by the receiving system.

Walsh codes are orthogonal mathematical codes. As such if two Walsh codes are correlated the result is intelligible only if these two codes are the same. As a result, when a Walsh encoded a PCS CDMA capable mobile terminal it appears as random noise to that terminal, unless that terminal uses the same code as the one encoding the incoming signal, receives signal.

Long code: - it is use to differentiate the channels in uplink (reverse link). It is used to communicate from mobile to BS. The long code is used to encrypt the content of the transmitted signal, and thus ensures privacy.

Short code: - this code is used to identify to the mobile, the antenna face, and the base station that the mobile is communicating with. This is also PN code.

Code Name	Description	Function
Long code mask	A random, 42 bit binary number, providing 16 trillion combinations of 0s and 1s.	Voice privacy
Walsh function	A 64-bit orthogonal code. Walsh functions are used to provide orthogonal channelization among all code CDMA forward channels (pilot, paging, sync, and traffic)	Channel formation, 0 to 63
Pilot channel PN code (short code)	A 15-bit code with 512 combinations that is unique to minicell face.	Time offset.

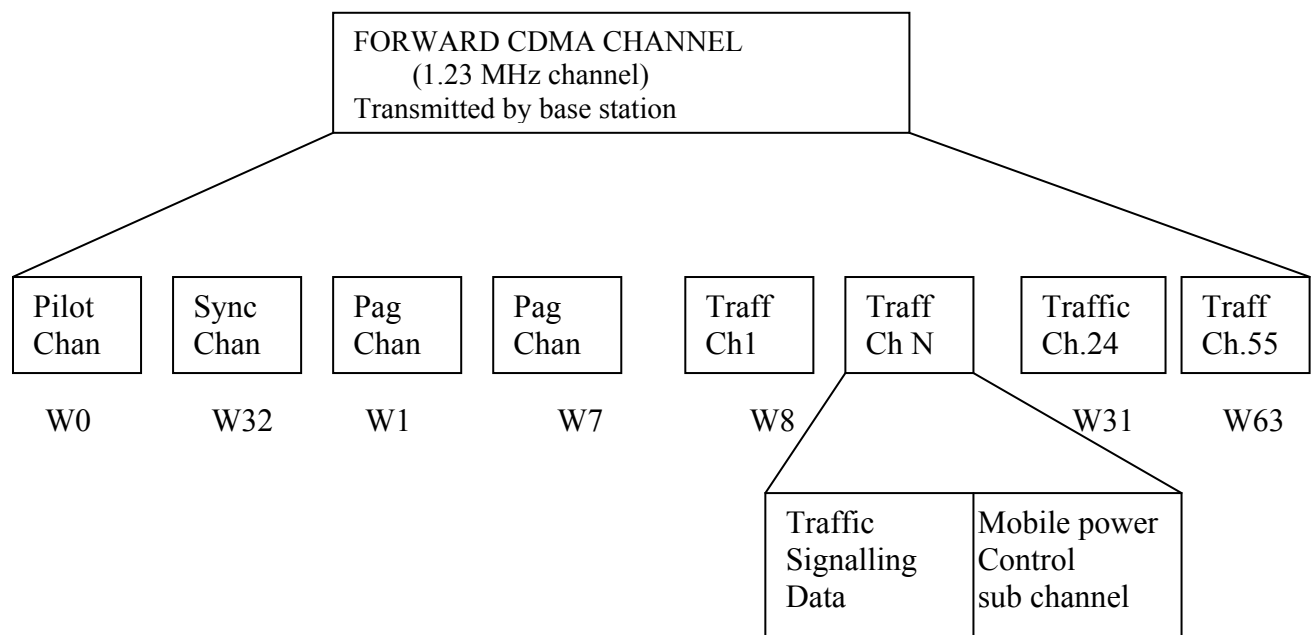
Channelization concept

CDMA is a duplex mobile communication technology; CDMA uses frequency division duplex to achieve duplex communication. With FDD, there are separate frequency channels for communication between mobile and base station and base station and mobile. In CDMA, the base station to mobile station transmission path is termed as

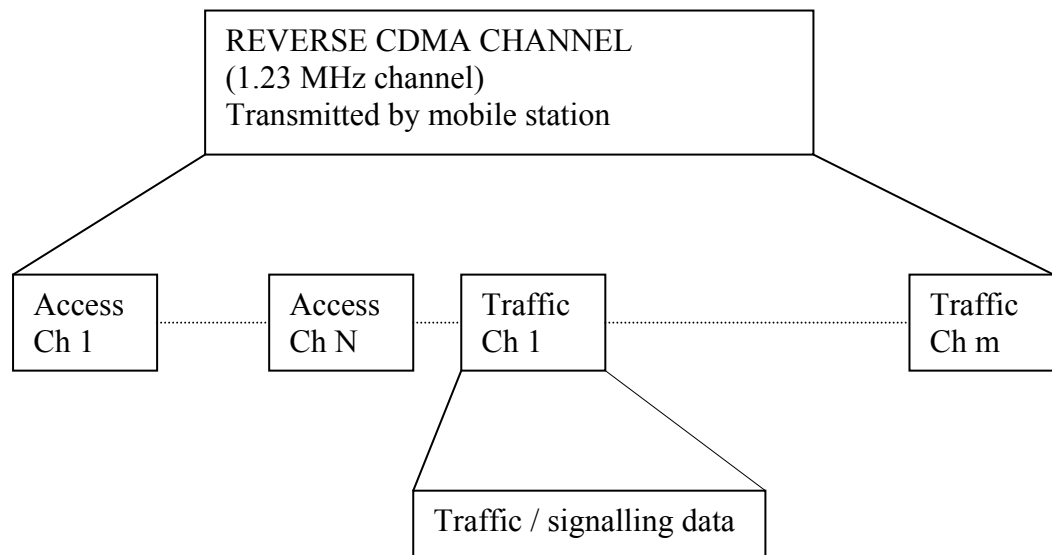
forward link. Whereas the mobile station to base station transmission path is termed as reverse link.

- FORWARD LINK: 869 MHz TO 894 MHz
- REVERSE LINK: 824 MHz TO 849 MHz

In CDMA channelization is done with spreading codes. The forward link the information is spread used Walsh codes. There are 64 Walsh codes. Each Walsh code is of bits. These 64 channels are divided into different function ones. Some Walsh codes are reserved for synch, paging etc and rest for traffic.



The reverse link, the communication requirements are divided into two categories, access and traffic. Access channels do the function of access signalling, whereas all other type of signalling communication is done on the traffic channel that has the major communication function is carrying traffic.



Forward link Traffic Channel

Vocoders: -

Convert voice to/from analog using data compression.

Convolutional Encoder: -

it uses half rate convolutional encoder and outputs two bits of encoded data for every input bit.

Whenever the information rate is lower than 9600 bps. Each code symbol at the 4800 bps rate shall be repeated 1 time. Each code symbol at the 2400 bps rate shall be repeated 3 times. Each code symbol at the 1200 bps data rate shall be repeated 7 times. For all the data rates this results in a constant modulation symbol rate of 19200 modulation symbols per second.

Interleaver: -

It is a process of permuting a sequence of symbols. It is a reordering procedure to achieve time diversity. CDMA uses block interleaving using 20ms blocks. Symbols are written in an input array are 384 symbols. Interleaved symbols are then read from the output array.

Data scrambler: -

Data scrambling is done to the traffic channels (and also paging channels). Data scrambling is performed on the modulations symbols output from the block interleaver at the 19200 sps rate. The data scrambling is performed by modulo-2 addition of the interleaver output symbol with the long code chip that is valid at the start of transmission.

Long code generator: -

A base stations digital transmission are referenced to a common CDMA system wide time scale that uses the GPS time scale, which is traceable to and synchronous with Universal Coordinated Time (UTC). GPS and UTC differ by an integer number of seconds, specifically the number of leap second corrections added to UTC. The start of CDMA system time is Jan 6, 1980 00:00:00:00 UTC, which coincides with the start of GPS time. System time keeps track of leap second corrections to UTC but does not use these corrections for physical adjustments to system time clock. The initial state of the long code is that state in which the output of the long code generator is the first 1 output following 41 consecutive zeros. This state of the register returns after 41.45 days. Decimator selects 1st bit output of every 64 chips and uses that for scrambling.

Power control Mux: -

Puncturing the data bits does closed loop power control. 1 bit is used for power control per 1.25 ms.

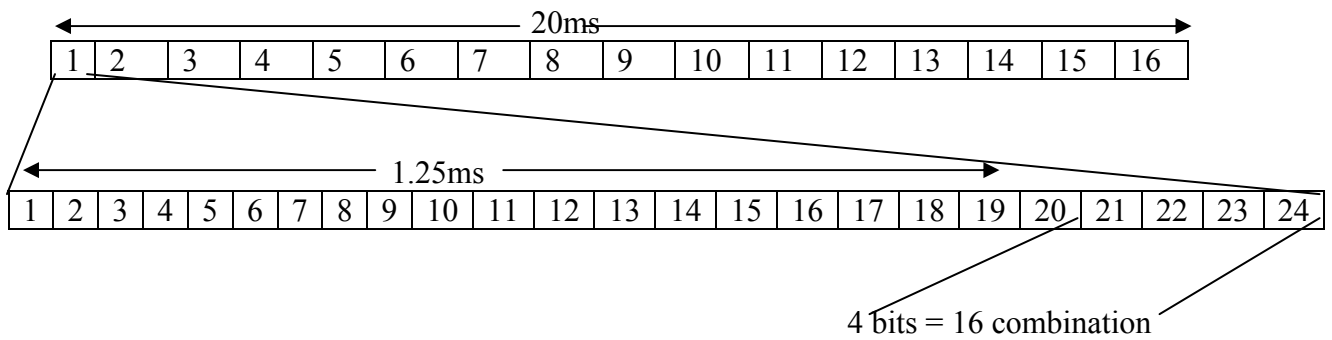
800 bits are multiplexed power second for power control. 0 indicates increase and 1 indicates decrease in power.

Power control bit puncturing: -

19.2 ksps: 384 symbols / 20ms frame.

Each 20 ms frame is divided into 16-power control group (1.25 ms each).

Each power control group will have 24 modulation symbols.



Walsh codes spread: -

Walsh codes are used to spread data. User is assigned a Walsh code. Data is spread using the assigned Walsh code.

For 0 data input the assigned Walsh code is output. For 1 data input the inverse of assigned Walsh code is output.

Spreading rate = data rate X Walsh chips on code

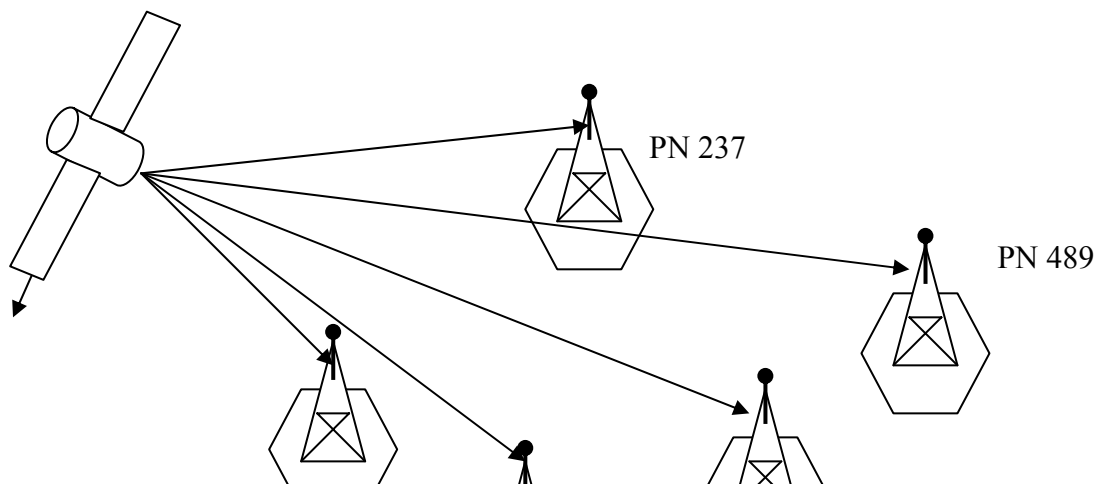
Short code (PN) spreading: -

Walsh coded data is scrambled with a PN code in both Q and I streams. PN code is generated at a rate of 1.2288 Mcps. PN code is generated with reference to system time. PN code is used for distinguishing base stations.

PN sequence codes are generated using 15 bit SFRs. PN sequence pattern repeats every 26.666 ms. 75 PN sequences repetition occur every 2 seconds. On every even second clock, MS will get PN sequence initial state.

PN Offsets: -

Each base stations will scramble PN sequence with data by some time offset. Time offsets are in intervals of 64 clock chips (52.08 usecs) from even second clock. 512 unique offsets are created (32768/64 chips = 512). Each base station is allotted an offset for PN sequence scrambling. It provides a cover to hide the 64 Walsh codes. Each base station is assigned a time offset in its short sequences. Time offsets allow mobiles to distinguish between adjacent cells. Also allows reuse of all Walsh codes in each cell.



Satellite

PN 0

PN 511

PN 120

Forward channels

- Traffic channel
- Pilot channel
- Sync channel
- Paging channel

Traffic channel

Forward traffic channel is used for the transmission of user and signalling information to a specific mobile station during a call. The maximum number of forward traffic channels that can be simultaneously supported by a given forward CDMA channel is equal to 63 minus the number of paging and sync channels. The data rate is selected on frame-by-frame basis.

The traffic channel frame is 20ms. The rates that are transmitted are 9600 bps, 4800 bps, 2400 bps and 1200 bps. Base station will reduce power for lower data rates.

Pilot channel

Uses Walsh code 0 all 64 bits are 0. All data into Walsh modulator is 0. Output of Walsh modulator is therefore all 0's. Pilot channel is just as the short codes. Pilot channel is an unmodulated spread spectrum signal that is used for synchronization by a mobile station operating within the coverage area of the base station. A pilot channel is transmitted at all times by the base station on each active forward channel. Each base station transmits a pilot signal having a different PN (timing) offset, pilot that discriminates cells.

Synchronization channel

Sync channel is defined as the code channel W32, transports synchronization message to the mobile station, used by the mobiles to acquire initial time synchronization. Sync channel will operate at a fixed rate of 1200 bps. A sync channel frame is of 26.666ms, uses the same PN offset as that of pilot. Mobile will normally not reuse sync channel until it powers on again.

Sync channel-Walsh spreading:- has a symbol rate of 4800 ksps. The spreading rate required is 1.2288 Mcps, this means 256 symbols are required per PN chip

(1228800/4800) for spreading. Walsh code (32) is repeated 4 times for spreading ($64 \times 4 = 256$), each sync channel symbol is repeated 256 times, then Xored.

Sync channel time alignment: -sync channel frame is of 26.667 ms. Sync channel super frame is formed by 3 frames; it is of 80ms (26.667×3), will have 384 mod symbols and 96 bits. Messages transmitted on the sync channel begin only at the start of a sync channel super frame.

Sync channel messages: -

- Base station protocol revision
- Min protocol revision supported
- SID, NID of cellular system
- Pilot PN offset of base station
- Long code state
- System time
- Leap seconds from start of system time
- Local time offset from system time
- Daylight savings time flag
- Paging channel data rate
- Channel number

Paging channel

The BS to transmit system overhead information and mobile station specific messages uses paging channel. It shall transmit information at fixed data rate of 9600 bps and frame is of 20ms. All paging channels in a given system (i.e. in the same SID) should transmit information at the same data rate.

Paging channel encoding and interleaving: -

For 4.8 kbps channels, symbol repetition is used after convolutional coding and for 9.6 kbps channel, only convolutional coding is used. Interleaving arrays are same as traffic channel.

Paging channel time alignment and frames: -

Paging channels use the same PN offset as pilot channel and is divided into 80ms slots. This each 80ms slot is composed of four paging channel frames, each of 20ms; this each 20ms frame is divided into 10ms long paging channel half frames. 80ms paging slots are grouped into cycles of 2048 slots; slots in this cycle are numbered as 0-2047 and will reoccur every 163.84sec. Mobiles will monitor the paging channel in slotted or non-slotted mode.

Paging channel messages:-

- System parameters
- Access parameters
- CDMA channel list
- Order
- Channel assignment
- Data burst
- Authentication

- SSD update
- Feature notification
- Extended system parameters
- Extended neighbour list
- Status request
- Service redirection
- General page
- Global service redirection
- TMSI assignment

Reverse Link Traffic Channel physical Layer

Reverse Error Protection

- Uses third-rate convolutional encoder.
- Outputs three bits for every input bit.

Reverse link modifications: -

Replace 8 kbps vocoder with a 13 kbps vocoder.

Effects: -

1. Provides toll quality speech
2. Uses a ½ rate encoder
3. Reduces processing gain 1.76 dB
4. Results in reduced capacity of smaller cell sizes

Interleaving

Mobile station shall interleave all code symbols on the reverse traffic channel prior to modulation and transmission. A block interleaver spanning 20ms is used. The output of symbol repetition block is 28.8 ksps = 576 syms/20ms. The interleaver is an array of 32 rows and 18 columns (i.e. 576 cells).

Data rates of 4800, 2400 and 1200 will also use 32 X 18 cells array and 576 symbols are input per 20ms in the 32 X 18 cells array the output of the interleaver will be row by row and will have different sequence for different data rates.

64-ary Modulation

Every 6 encoded voice data bits points to one of the 64 Walsh codes. It is not the channelization for the reverse link.

Long Code Spreading

Long code generator uses ESN in the user long code mask. ESN makes the long code unique for each mobile. It is used to provide unique channelizations in the reverse link with this method of channelization mobiles are uncorrelated but not orthogonal with each other.

Data Burst Randomiser

Interleaver output stream is gated with a time filter that allows transmission of certain interleaver output symbols and detection of others. The gating process operates by dividing the 20ms frames into 16 power control groups each of 1.25 ms.

For lower data rates, certain power control groups are gated on while other groups are gated off. During the gated off periods the mobile station shall bring down the output power by 20 dB thus reducing interference to other mobile stations operating on the same reverse CDMA frequency channel.

Short Sequence Spreading

Mobiles use same PN short codes. Extra $\frac{1}{2}$ chip delay is inserted into Q path to produce 0 QPSK modulation.

Allows simpler power amplifier since it reduces the dynamic range.

Reverse Link Channels:

- Traffic channel
- Access channel

Traffic Channel

Used for transmission of user and signalling information to the base station. The variable transmission rates of 9,6,4,8,2,4,1,2 kpbs. Data rate is selected on a frame-by-frame basis. These channels at the BS are discriminated by their unique long codes. All the data on reverse traffic channels is encoded, interleaved, and modulated by a 64 ary modulations and direct sequence spread prior to transmission.

Access Channel

The mobile station to initiate communication with the base station and to respond to paging channel messages uses access channel. And access channel transmission is a coded, interleaved, and modulated spread spectrum signal; these are uniquely identified by their long codes. Access channels transmission consists of an access channel preamble and the access channel message capsule. 32 access channels can be associated with 1 paging channel.

Access channel messages: -

- Registration message
- Order message
- Data burst message
- Origination message
- Page response message
- Authentication challenge response message

Advantages

Forward link (BS to mobile)	Reverse link (mobile to BS)
<ul style="list-style-type: none">• High power transmitter• Pilot channel• Added time diversity• Orthogonal code channels	<ul style="list-style-type: none">• Wide range power control• Diversity reception at base

Disadvantages

Forward link	Reverse link
<ul style="list-style-type: none">• Complexity Of Soft Handoff	<ul style="list-style-type: none">• Non-coherent demodulation• Limited power• Uncorrelated code channels

Multiplex option I

This provides transmission of primary traffic and signalling or secondary traffic. Signalling or secondary traffic can be multiplexed with the primary traffic on the same traffic channel. Signalling traffic may be transmitted via blank and burst or dim and burst method. It is same for forward and reverse link.

Signalling Traffic

Blank and burst signalling

This is sent at 9.6 kbps and steals one or more frames of primary traffic data, typically vocoded voice with signalling data.

Dim and burst signalling

It sends both primary traffic and signalling data in the same traffic frame using the 9.6 kbps transmission rate. Signalling data in this mode, shares the same frame of primary traffic.

When no primary traffic is not active, signalling is done using blank and burst example in the call set-up stage

When primary traffic is active signalling can be done with any of the two methods example measurement and handoff.

Signalling traffic cannot be sent on lower rates traffic frames like 4800, 2400, 1200 bps.

Forward Traffic Channel Signalling Messages

- Order message
- Authentication challenge message

- Alert with information message
- Data burst message
- Handoff direction message
- Analog handoff direction message
- In traffic system parameters message
- Neighbour list update message
- Send burst DTMF message
- Power control parameters message
- Retrieve parameters message
- Set parameters message
- SSD update message
- Flash information message
- Mobile station registered message

CDMA Turn On Process

Receives all pilot channels and chooses the strongest one and establish the frequency and PN time reference i.e., base station identity. Demodulates the sync channel and establish the system time. It determines the paging channel long code mask. Reads the paging channel and demodulate the paging channel by using long code mask derived from the pilot channel and PN offset is given in sync channel message and decodes the messages

When the call is initiated mobile transmits a special channel called the access channel, this access channel used a long code mask based on the access and paging channel numbers, base station identity and pilot PN offset. When call was completed base station answers access channel using the channel assignment message, mobile goes to traffic channel based on the channel assignment message information. Then base station begins to transmit and receive traffic channel.

CDMA Soft Handoff

When the mobile is entering new zone i.e., from base station to another base station then the mobile finds second pilot of sufficient power by sending pilot strength message to first base station. Base station notifies MTSO then MTSO requests new Walsh assignment from second base station. If available new Walsh channel information is relayed to first base station. This first base station orders soft handoff with new Walsh assignment then MTSO sends land link to second base station. Mobile receives power from two base stations and MTSO chooses better quality frame for every 20-ms. The power goes low at mobile station by the first BS and mobile sends pilot strength message then first BS transmission stops and frees up channel. Traffic channel continues on second base station.

CDMA system

The PCSC is equipped with switching and interface equipment and provides all the cellular network switching required to process calls to and from the cellular subscriber. The PCSC also provides cellular interface into PSTN call from and to the standard telephone network and calls from cellular subscriber to cellular subscriber pass through the PCSC.

Base station

The base station consists of a primary radio cabinet up to two optional growth cabinets (for adding up to three additional carriers for 3 sector applications) a power cabinet and an optional battery cabinet or an optional DC generator cabinet. The system can be installed indoors or outdoors.

Network Interfaces

The T1 network is digital transmission system using time division multiplexing to carry 24 DS0 channels. A DS0 channels digital signal of 64 kbps for a total on the T1 of 1.544 Mbps

Transmit /Receive Antenna

One transmit and two receive antenna are provided for each face of the cell site. For e.g. on a three sector cell site there would be 6 receive antennas and 3 transmit antennas.

Mobile Terminals

The cellular subscriber uses two categories of units:

Vehicle-mounted and transportable units (Class I)

Hand held units (Class III)

A variety of styles and options are available in each category. However, the basic functional operations of the vehicle-mounted units and the hand-held units are identical. The subscriber's unit contains a microprocessor and is continually performing operations and communicating with the cell site, even when not being used by the subscriber. The subscriber's unit performs these functions so that it can be ready to receive an incoming call or make a call.

Key parts in PCS switching Centre (PCSC)

PCS components

A PCSC has two components

1. A PCS Access Manager, that performs the mobility/management functions between base station and the Public switched Telephone Network
2. The 5ESS-2000-switch platform, that provides the network connectivity with other PCS switching centres, local carriers etc.

PCSC Diagram

Key parts – Access Manager

Components

The Access manager is composed of the Executive Cellular processor (ECP) and the Operation and maintenance Platform (OMP)

ECP

The ECP controls the operation of the AUTOPLEX® system 1000. The ECP is responsible for mobility management, call processing, system maintenance. Technician Interface and system integrity. In particular, the ECP maintains the database and the translation tables that contain the operating parameters of the cells connected to the switch.

OMP

Provides a computer platform dedicated to the support of all operation, administration and maintenance activities, including supporting remote data communication with the minicell site.

Access manager key features

The PCS Access manager provides

1. Wireless terminal mobility management including,
2. Home Location Register/Visitor Location Register paging
3. Autonomous registrations.
4. Subscriber management
5. Roaming support
6. Intelligent network support
7. Authentication and enciphering

The AM also supports stand-alone HLR capabilities.

AM capabilities

The PCS AM supports

1. The expected traffic loads (plus sparring) of the various call types up to engineered capacity of the platform. Depending upon these system traffic loads, some number of wireless call processing servers will be equipped (where each call processing server handles a specific engineered capacity)
2. The desired number of subscriber records (HLR). The HLR supports incremental growth up to the platform capacity.

Each Access Manager is sized to support the desired number of PCS Base stations.

Key features of 5ESS- 2000 switch

The 5ESS-200 Switching platforms

1. Provides the PCS switching function between PCS base stations and various networks
2. Supports both wireless and wired applications simultaneously.
3. Is a proven market leader
4. Provides multiple applications on the same switch
5. Provides increased switching capacity
6. Provides highest capacity
7. Co-exists with existing module or reduced foot print 5ESS equipment

Packet Pipe Trunk Group

The T1/E1 line carries all communications. Packet pipes carry voice communications between the switch and a minicell. Packet pipes are the result of multiplexing 64kB-wide, or 56 KB-wide band widths (DSOs) on a T1 span, going from the digital cellular switch (DCS) to the minicell site. The number of DSOs that can be accommodated in a Packet pipe depends on RF engineering considerations (processing gain, voice activity, intersector interference required service level). And on the minicell configuration. The packet pipe size for a given minicell is defined in the minicell translation tables

maintained by the ECP. Changes in minicell configuration may require changes in the packet pipe size.

PCS CDMA minicell site

The PCS CDMA minicell site contains that is designed to optimise performance for voice and data services at the 1.8 GHz to 2.0 GHz range. The minicell maintains maximum commonality with 800 MHz standards for CDMA.

Minicell diagram

Advantages of PCS CDMA minicells

Offers high capacity ten times capacity of analog cellular

Larger minicell radii three to four times that of GSM

Uses Multipath to enhance signal strength and combat fading

Offers good voice quality lower frame error rates with reduced fading, multiple base station communication, soft handoffs, and no recognizable noise or cross talk.

Imposes lower power requirements for mobiles longer battery life for handheld units

Provides a degree of built in privacy.

Performs the following functions the transmit and receive functions

On the transmit path:

- The PCSC has speech-handling circuitry to encode land-originated communications. Once encoded, communications destined to a given minicell are bundled into packet pipes assigned to that minicell and sent to the minicell site over a T1 line.
- The minicell site unbundled the packet pipes, provides channel encoding and bit interleaving to reduce communication errors, and provides long code encryption, Walsh function modulation, and signal spreading and carrier modulation.
- Bit interleaving is used to reduce the effects of RF fading and large interference bursts.

On the receive path:

- The minicell site provides carrier demodulation signal despreading, de-encryption, Walsh function demodulation, deinterleaving, channel decoding, and sends the resulting signal to the PCSC in a packet pipe over a T1 line.
- The PCSC converts the received signal into a voice communication and sends it over the PSTN

CDMA encoding process diagram

Encoding the Data

1. The forward traffic is encoded with the long mask code, and provided through multiplexing with a power control bit that will be used by the mobile to maintain its receive/transmit level.
2. The Walsh function is then applied to provide a cloaking of the channel within the RF noise outside the minicell. The pilot channel, by design, is always assigned the Walsh function W0.
3. The encoded signal is then provided with a phase shift to better transmit the bits.

Channel element encoding diagram

The call process steps: -

1. PSTN: phone call originates
2. Encode the digitised signal
3. Channel coding
4. Bit interleaving: duplicate the signal to rearrange the bits to limit burst errors
5. Encryption, long code scrambling: apply the users long code to provide secure transmission.
6. Signal spreading: Walsh function modulation
7. PN offset
8. Carrier modulation: prepare the encoded signal for transmission
9. Transmit to mobile terminal: the handset decodes the signal and encodes the mobile users voice
10. Mobile phone responds: receive signal from mobile terminal
11. Carrier demodulation
12. Signal dispreading
13. 64-bit orthogonal symbol demodulation
14. Decryption, long code unscrambling
15. Bit deinterleaving
16. Channel decoding
17. Decoding: convert voice data from vocoder to 64k digitised data
18. PSTN: the send and return sides of a call are completed.

CDMA Interferences

CDMA is based on the use of a spread spectrum form of modulation to encode a signal for its transmission and retrieval.

Noise sources

In spread spectrum technology, radio signals are spread across a single 1.23 MHz wide frequency band. Each subscriber is assigned PN codes. Signals that match the PN codes are decoded and processed. Signals that do not contain the code matches are treated as noise and ignored.

The predominant interference to CDMA users are other CDMA users. A CDMA signal experiences high level of interference dominated by the coded signals of other CDMA users. This takes two forms interference from other users in the same minicell and interference from adjacent cells. The total interference also includes background noise and other spurious signals.

Signal processing: receive

CDMA starts with an encoded narrowband signal; this is spread with the use of the PN codes to a bandwidth of 1.23 MHz.

Signal processing: receive

When the signal is received it is filtered and processed to recover the desired signal. A correlator that eliminates interference sources because they are uncorrelated with the desired signal does this processing. By using this method, a large number of CDMA calls may occupy the same frequency spectrum simultaneously.

Frame error rate:

The number of transmission errors, measured in terms of frame error rate (FER) increases with the number of calls. To overcome this problem, both the minicell site and mobile can increase power until neither the mobile nor the minicell site can power up further to decrease FER to an acceptable amount. This event gives a soft limit of calls of a particular minicell, and depends on:

- The noise floor naturally occurring and man made interference.
- Interference from calls on this minicell.
- Interference from calls on other cells.

Power per Walsh code

The power control bit is used during call processing to maintain the relative power of each individual active traffic channel, and power it up or down to maintain acceptable FER measurements by the mobile on the channel. This power is expressed in terms of digital gain units.

The following things occur in the transmit path: -

- The low bit rate digital voice packet from PSU2 (packet switch unit 2 in the 5ESS switch) is spread by a Walsh code in the minicell.
- The RF transmit carrier frequency is modulated by the spread signal.
- The direct sequence spread spectrum signal is transmitted.

The following things occur in the receive path: -

- The direct sequence spread spectrum signal is received.
- The signal is demodulated using the RF receive carrier frequency.
- The signal is despread using the same Walsh code.
- A bit detector restores the decoded signal to a reasonable representation of original speech pattern.

