



Wireless Multiaccess Using Code Division Multiple Access

Zartash Afzal Uzmi
LUMS, Lahore. Pakistan
April 25, 2003



Outline

- Cellular systems
 - Cellular concept
 - Frequency reuse
- Multiaccess techniques
 - Static Multiaccess (FDMA, TDMA)
 - Dynamic Multiaccess and CDMA
- Code division multiple access (CDMA)
 - Transmitter
 - Channel
 - Receiver



Outline

- Cellular systems
 - Cellular concept
 - Frequency reuse
- Multiaccess techniques
 - Static Multiaccess (FDMA, TDMA)
 - Dynamic Multiaccess and CDMA
- Code division multiple access (CDMA)
 - Transmitter
 - Channel
 - Receiver



Wireless Systems

- Wireless systems are inherently different from wireline systems
 - Bandwidth is limited
 - Transmitted power is limited
- Power and bandwidth constraints limit the service areas to the vicinity of base stations



A Single Base Station System

- All users communicate with this single entity
- Not practical
 - Client perspective
 - Far users need to transmit high powers
 - Reduced battery life
 - System perspective
 - Single point of failure
 - Base station perspective
 - Transmission at high powers → not permitted
 - Required bandwidth in an area becomes enormous



Cellular Concept

- A large geographical area is divided into smaller areas called cells
- Many low power transmitters are placed within cells at approx their centers
- “Cellularization” is flexible
 - Cell size can be changed based on demand
- Cell size (and shape) is primarily controlled by
 - Power transmitted by the base station
 - Terrain within the region of the cell
 - Presence of man-made features, e.g., buildings



Cellular Concept

- Each active user “belongs” to a cell
- Other base stations neglect the signal from the users who don’t belong to this cell
- Can users move from one cell to another?
 - Yes, when the link with the new base station becomes more reliable
 - Handoff
 - New base station starts and old base station ceases to interpret signals from the user undergoing handoff
 - Creates challenges that are unique to cellular systems



What Do Base Stations Do?

- Provide a mediation point
 - Every user communicates with the base station
 - Two users don't communicate directly. Why?
- Provide connectivity to the PSTN
 - Base stations are connected to MTSO that provides connectivity between the wireless and wireline networks
 - MTSO can provide simple interfacing
 - MTSO can also perform complex protocol translation functions (WAP to HTTP, for example)



Frequency Reuse

- Same set of frequencies can be used in different cells that are sufficiently apart
 - Interference prohibits reusing frequencies in cells that are fairly close
 - A “cluster” defines the set of cells in which frequency is not reused
- For FDMA systems, cluster size is 3 to 7
- CDMA systems use single cell clusters
 - Frequency reused in every cell



Outline

- Cellular systems
 - Cellular concept
 - Frequency reuse
- Multiaccess techniques
 - Static Multiaccess (FDMA, TDMA)
 - Dynamic Multiaccess and CDMA
- Code division multiple access (CDMA)
 - Transmitter
 - Channel
 - Receiver



Multiaccess Systems

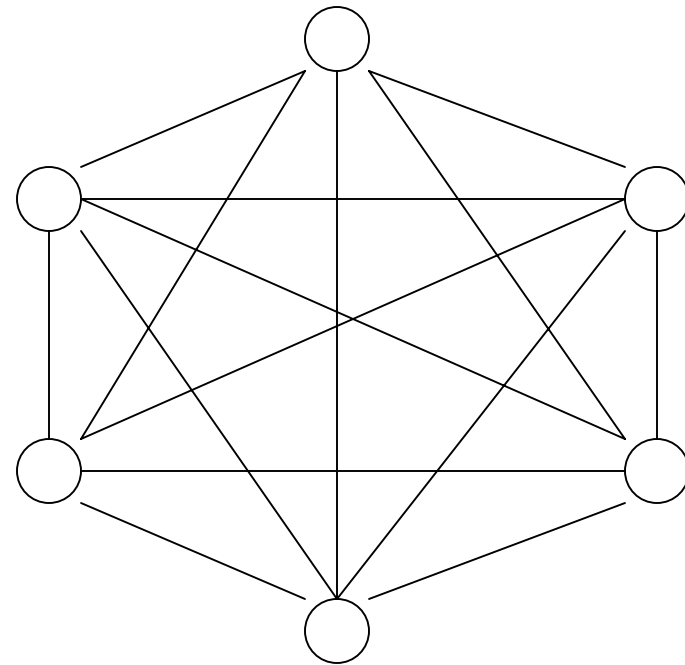
- Two communication paradigms
 - Point to point
 - Two entities communicate over isolated link
 - Multipoint to multipoint
 - More than two entities communicate simultaneously
- Sharing of links is desirable
 - Examples include LAN and cellular systems
 - Direct communication (Multiuser system)
 - LAN environment
 - Indirect communication (Multiaccess system)
 - Communication through an entity – e.g., Base station

Why Link Sharing Is Needed?

N nodes or stations
With no link sharing:

Wireline:
Need $N(N-1)/2$ links

Wireless:
Users too far off to
communicate





Multuser System

- Direct communication between users
- Links are shared
- A sharing protocol is used
 - ALOHA, slotted ALOHA, CSMA/CD, etc.
- Why users communicate directly?
 - End stations have high processing power
 - An entity is still needed to talk to external stations
 - A bridge or a router
- User stations typically filter the data
 - Every user receives data from every other user



Multiaccess System

- Indirect connection between users
 - A mediating entity is used – a base station
- Links are still shared
- A media access protocol is used
- End stations (usually cell phones) have low processing powers
- User handsets only receive what they are supposed to receive – no need of filtering as in the case of ethernet LAN stations



Two Problems

- How to identify the source and the destination
 - Addressing solves the identification problem
- How to share the communication channel
 - Use the MAC protocols
- Multiuser systems (MAC and addressing in either direction of communication)
 - Links are typically symmetric, e.g., LANs
- Multiaccess systems
 - Downlink uses multiplexing to provide addressing
 - Based on frequency (FDM), time (TDM) or code (CDM)
 - Uplink uses multiaccess to provide channel sharing
 - FDMA, TDMA, and CDMA



Uplink Channel Sharing

- Uplink sharing is provided by the multiaccess protocols:
 - Static Multiaccess
 - Dynamic Multiaccess
 - Demand assigned multiple access
 - Random Multiaccess
- Choice of a particular protocol depends upon the traffic characteristics



Static Multiaccess

- Channel's capacity is divided into fixed portions
- One portion is allocated to each user
 - May combine portions and allocate to one user
- Portions can be made on the basis of
 - Frequency
 - Time
 - Code
- There are no shared resources
 - If the user doesn't use the allocated portion, that portion just goes unused and hence wasted
- Works better with predictable traffic and predictable set of users that doesn't change much over time



Multiaccess Examples

- FDMA
 - AMPS system – 30kHz per channel – 800 to 900MHz band
 - Different frequencies, same time
- TDMA
 - First US digital standard (IS-54)
 - GSM
 - Different times, same frequency
- CDMA
 - 2nd US digital standard (IS-95)
 - Technology for the 3rd generation systems
 - Same time, same frequency



Dynamic Multiaccess

- Traffic from users is bursty
 - Transmission rates varying significantly
- Set of active users change
- Desirable to assign portions dynamically
 - Demand assigned multiple access (DAMA)
 - Random Multiaccess



DAMA

- Two channel paradigm
 - Data channel
 - Divided into as many portions as the number of active users
 - Request channel
 - Users send requests for the allocation of a portion in the data channel
 - Static – divided into as many chunks as the total number of users – active or inactive
 - Multiaccess problem shifted from the data channel to the request channel
 - Random Multiaccess in the request channel



Random Multiaccess

- When request channel in DAMA uses static multiaccess
 - What if total number of users is much larger than the number of active users?
 - What if the data is too bursty such that the control overhead of DAMA is unacceptable?
 - Solution: allow random multiaccess in DAMA request channel
- Random Multiaccess used in the data channel
 - Users transmit simultaneously at the same frequency
 - Possible collisions and retransmissions
 - CDMA can provide inherent random multiaccess
 - Without requiring retransmissions!!!

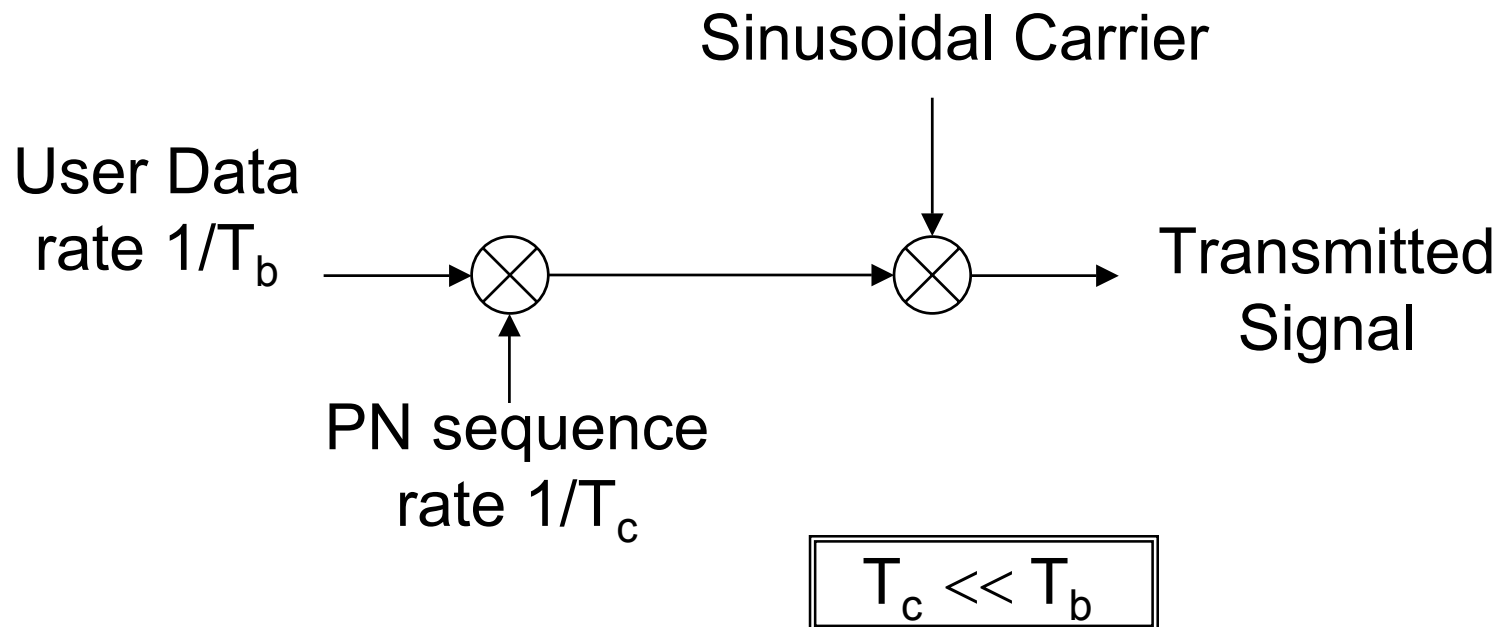


Outline

- Cellular systems
 - Cellular concept
 - Frequency reuse
- Multiaccess techniques
 - Static Multiaccess (FDMA, TDMA)
 - Dynamic Multiaccess and CDMA
- **Code division multiple access (CDMA)**
 - Transmitter
 - Channel
 - Receiver

DS-CDMA Transmitter

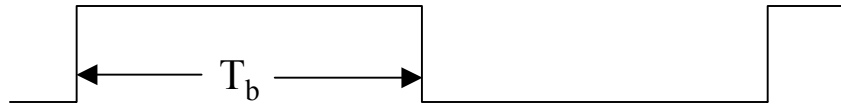
A simplified DS-CDMA Transmitter



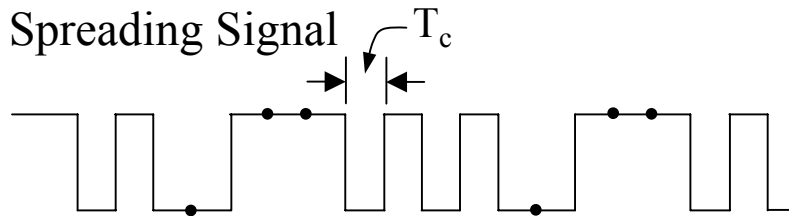
DS-CDMA Signal

Time domain

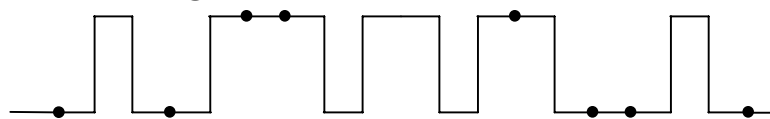
Original Data Signal



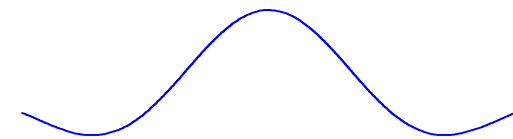
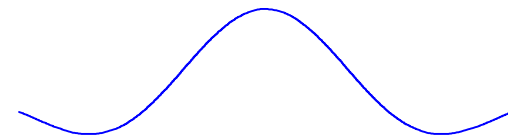
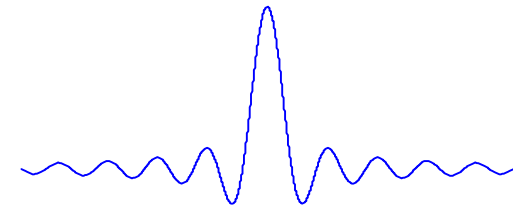
Spreading Signal



Product signal



Frequency domain



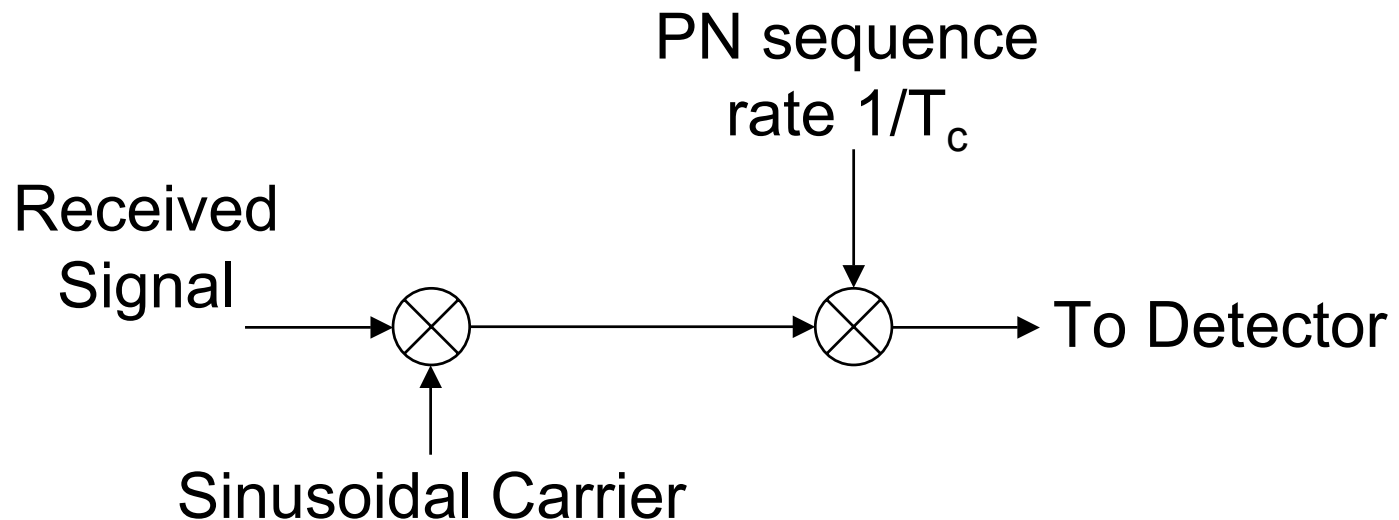


DS-CDMA

- Each user has a unique spreading code
- Spreading gain
 - Ratio of the signal bandwidth after spreading and the original signal bandwidth
- Processing gain
 - Number of chips periods over which detection is carried out at the receiver
- Base station receives sum of all the signals from various users
- Base station transmits sum of signals intended for various users

DS-CDMA Receiver

A simplified DS-CDMA Receiver



PN sequence “exactly” matches the one in transmitter



Interference in CDMA

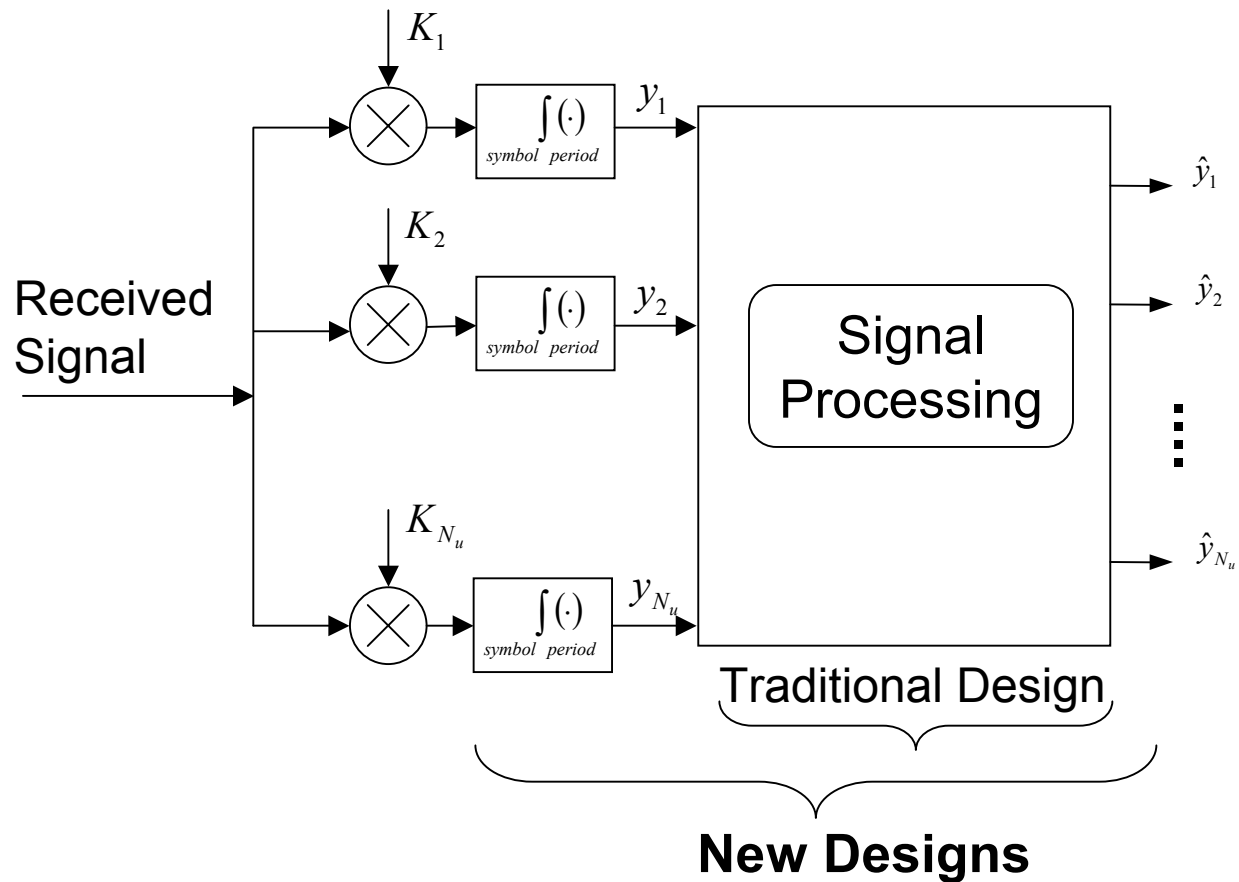
- Users transmit simultaneously and at the same frequency
- In “usual” random multiaccess, a collision will require retransmission
- In CDMA, signal from users can still be detected even if they “collide”
- For each user, signal from every other user is interference (MAI) – generally regarded as gaussian noise. Is it a good idea?



Advanced CDMA Receivers

- Multiuser detectors
 - Use of filters to eliminate MAI
 - Use knowledge of spreading sequences to iteratively subtract the interference
 - Beamformers
 - Enhance signals coming from one direction while suppressing signals coming from other directions

Advanced CDMA Receivers





What Does CDMA Do To...?

- Narrowband interference
 - Addressed by spreading
- Gaussian noise
 - No effect
- Multipath and delayed ISI
 - Addressed by autocorrelation properties
- MAI
 - Addressed by crosscorrelation properties