CDMA Performance under Fading Channel

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Overview

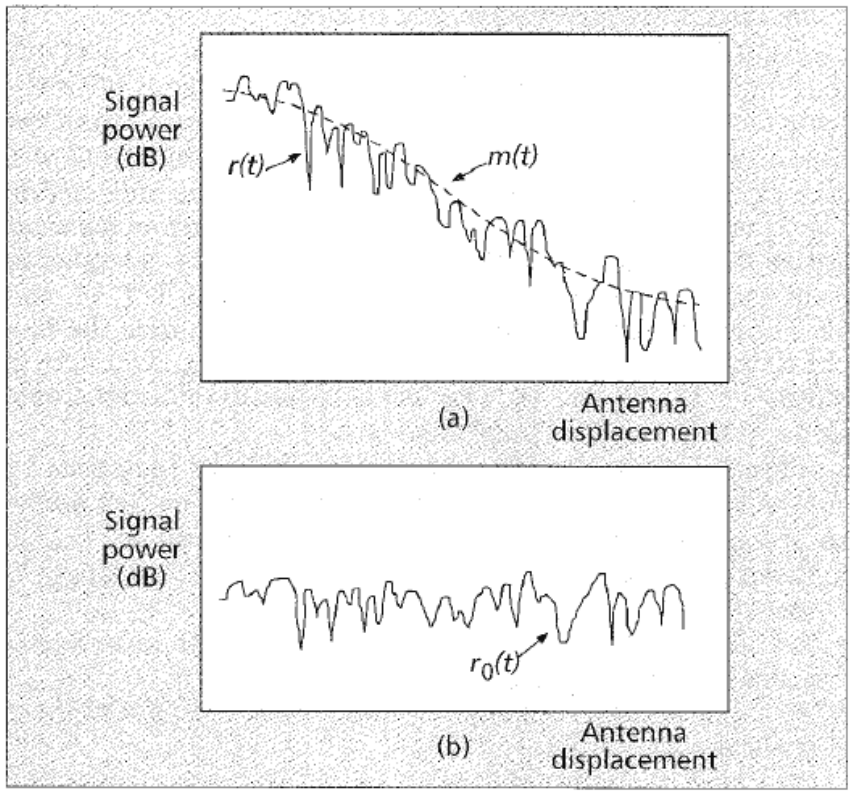
- Wireless channel fading characteristics
  - Large and small scale fading
  - Effects of multipath fading
- Comparative analysis of multiple access techniques
  - Fading
  - Capacity
  - ✓ Soft handoff in CDMA
  - ✓ Power control in CDMA

Wireless channel characteristics

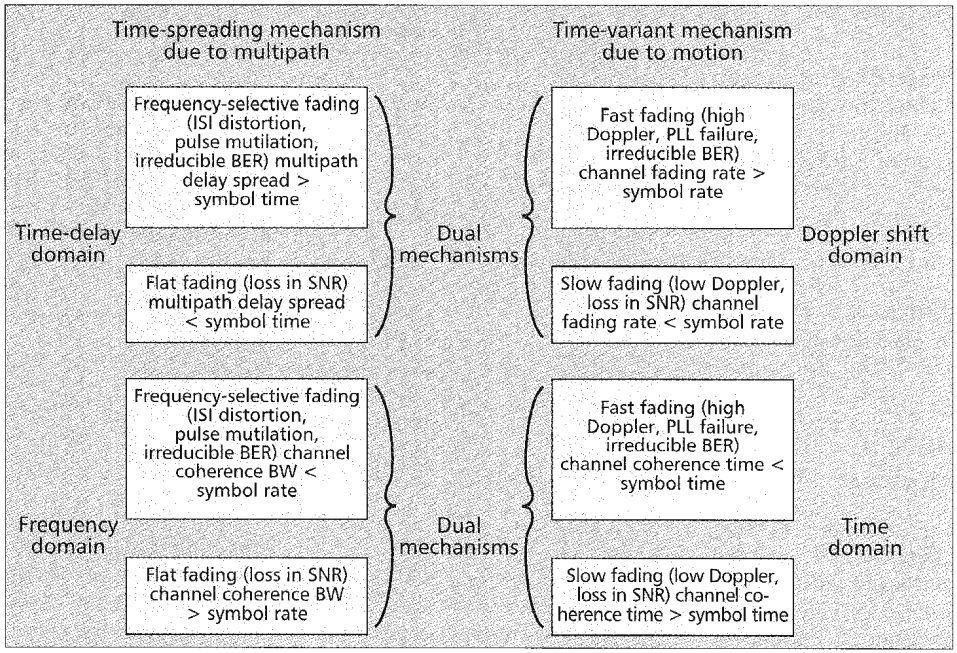
- Idealized Free space propagation follows inverse-square law
- Basic mechanisms of signal propagation
  - Reflection- reflection from smooth surface
  - Diffraction- signal reaches the receiver even when shadowed by an impenetrable obstruction
  - Scattering- reflected energy spreads out
- Coherence Bandwidth *BWch*
  - Range of frequencies over which channel response to all spectral components is same
- Coherence time *Tch*
  - Time duration over which the channel's response is invariant

Channel fading

- Fading- fluctuation in received signal's amplitude, phase and angle of arrival due to multipath reflective paths
- Large-scale fading
  - Average signal power attenuation due to motion over large areas
  - Described in terms of a mean-path loss (nth-power law) and a log-normally distributed variation about the mean
- Small scale fading
  - Results due to small changes in spatial separation between transmitter and receiver
  - Time-spreading of underlying digital pulses within the signal
  - Time-variant behavior of channel due to motion



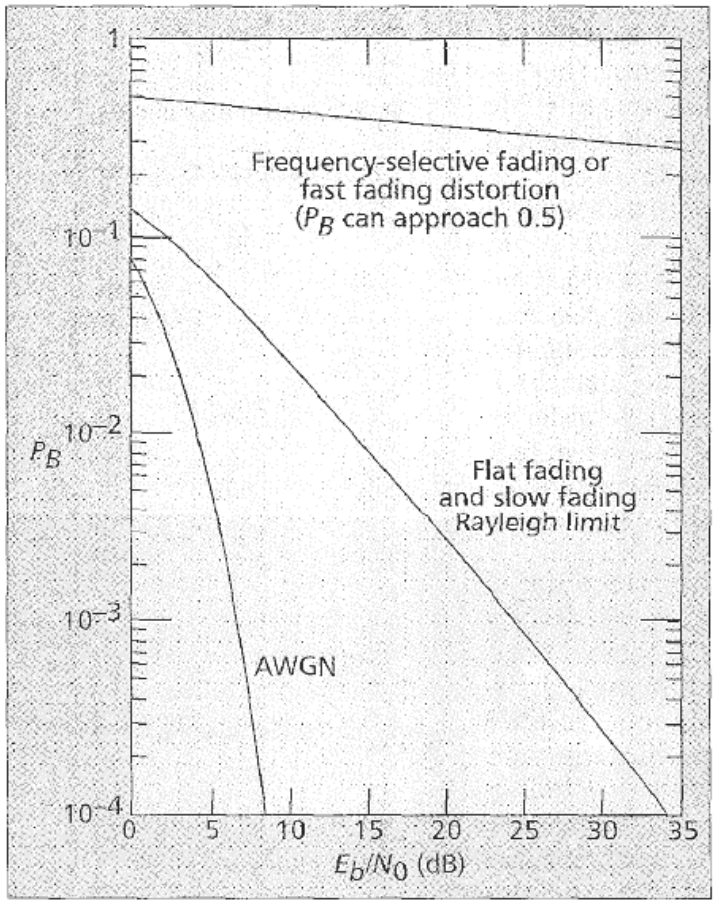
Small scale fading



- Time-spreading of underlying digital pulses within the signal
- Time-variant behavior of channel due to motion

Error performance analysis

- AWGN
- Rayleigh limit
- Frequency-selective or fast fading
- Mitigation of degradation and diversity



Multiple access techniques

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- Narrowband systems
  - FDMA- each user is assigned a frequency band
  - TDMA- each user is assigned a time slot
- Wideband systems
  - CDMA- Users are separated by codes and they use the wideband channel simultaneously

Comparative analysis: effect of fading

- TDMA And FDMA
  - Channel induced ISI caused by delay spread
  - Equalizer required for compensation
- TDMA
  - for a particular user time slot, the fading character of the channel may change several times during the time the symbol is propagating
- FDMA
  - Null in a particular frequency band would result in poor signal reception

Comparative analysis: effect of fading (contd…)

- CDMA
  - Rake receiver combines uncorrelated multipaths separated by more than a chip delay to achieve path diversity
  - Reduces signal distortion and increases signal energy
  - Since it is a wideband system, frequency selective fades occur in only a small fraction of the signal bandwidth at any instance of time
  - the fading rate is relatively slow or the channel coherence time is large as compared to the chip time in CDMA
  - the changes occur slowly enough that the receiver can readily adapt to them

Comparative analysis: capacity and frequency management

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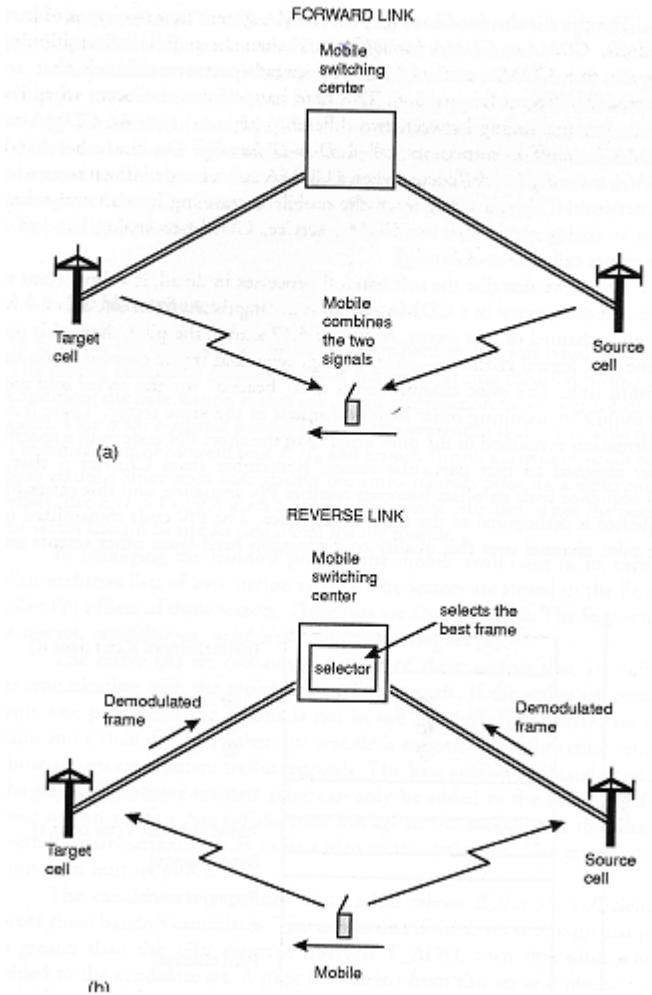
- Capacity
  - human voice activity cycle is 35%
  - When users assigned to the channel are not talking, all others on the channel benefit with less interference in a single CDMA radio channel
  - mutual interference reduces by 65%
  - channel capacity increases by three times
  - CDMA is the only technology that takes advantage of this phenomenon
- Frequency management
  - In FDMA and TDMA, the frequency management is always a critical task
  - Since there is only one common radio channel in CDMA, no frequency management is needed

Handoff

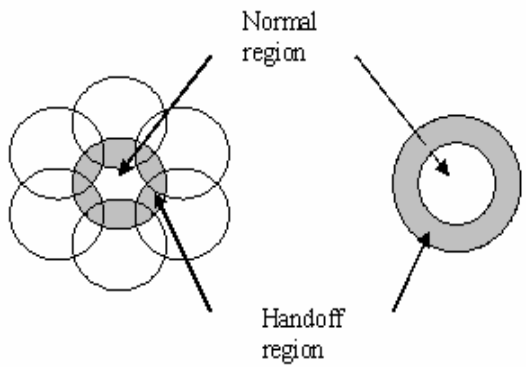
- Hard handoff
  - Handoff scheme which requires the mobile unit to break the communication with the current serving base station before establishing a new communication with the target base station , i.e., “break before make”
- Soft handoff
  - A handoff process in which the mobile unit can commence communication with a target base station without interrupting the communication with the current serving base station, i.e., “make before break”
- Advantage of soft handoff
  - provides enhanced communication quality and a smoother transition compared to the conventional hard handoff

Soft handoff process in CDMA

- Soft handoff
  - Forward link
  - Reverse link
- Softer handoff
  - Forward link
  - Reverse link
- Soft- softer handoff



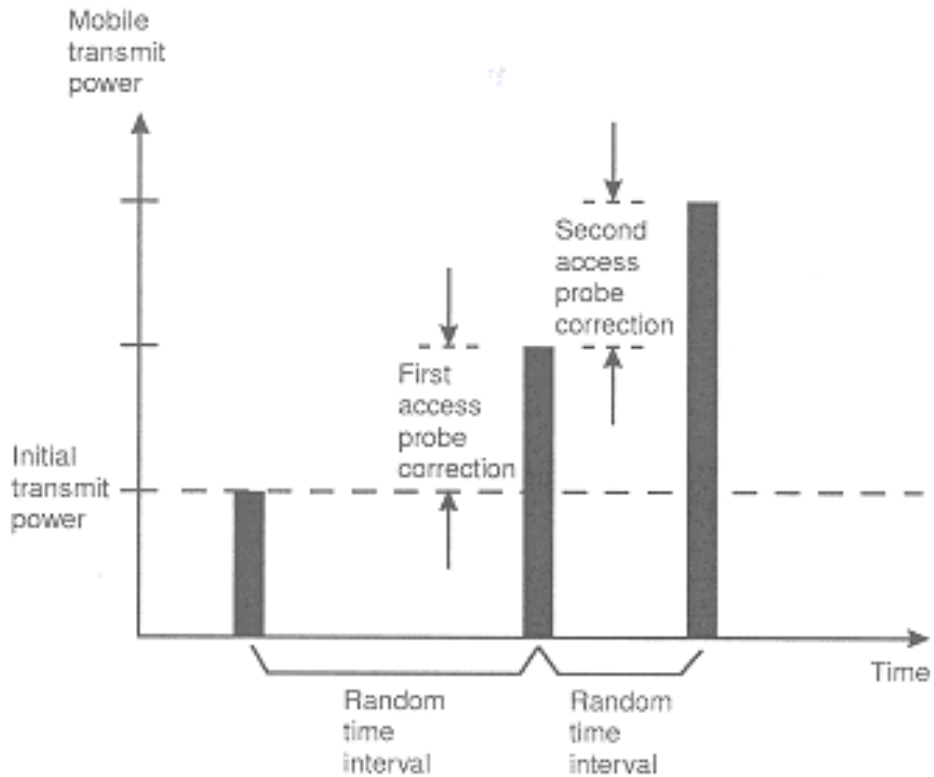
Effect of size of handoff region



- ‘a’ is the ratio of area of handoff region to the area of a cell
- the voice/data quality is better for larger ‘a’ because of the higher SIR from the diversity reception in the larger area
- the channel capacity in each cell is increased under the requirement of same voice/data quality when the value of ‘a’ becomes larger

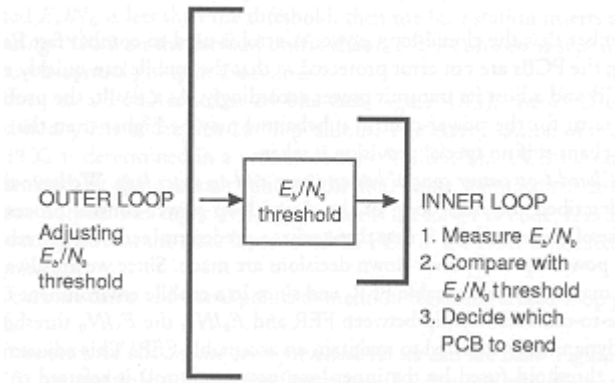
Power control

- Need
  - all users share the same RF band through the use of PN codes, each user looks like random noise to other users
  - The power of each individual user, therefore, must be carefully controlled so that no one user is unnecessarily interfering with others who are sharing the same band
- Access probes
  - Series of transmission of progressively higher power by mobile unit till acknowledgement from base station is received
  - Access probe correction

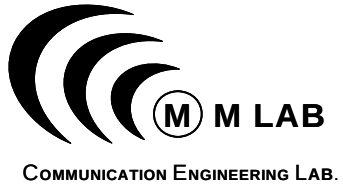


Open loop and closed loop power control

- Open loop power control
  - purely a mobile-controlled operation and does not involve the base station at all
  - Estimation of forward path loss from received power
  - Pt, initial = - Pr -73 + NOM_PWR + INIT_PWR
- Closed loop power control
  - Involves both mobile and base station
  - Compensates for fluctuations due to fast Rayleigh fading



Power control with soft handoff



- The mobile receives traffic channel frames from two or three base station during soft handoff
- If any one base station commands the mobile to power down, the mobile will power down
- Mobile will power up only if all of the base stations involved in soft handoff command the mobile to power up.

Conclusions

- Frequency selective fading and fast fading require mitigation of degradation as well as diversity
- CDMA outperforms FDMA and TDMA as regards to combating fading, capacity and frequency management due to usage of wideband channel and diversity techniques for signal reception
- Soft handoff
- Power control

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