ECE6604
PERSONAL & MOBILE COMMUNICATIONS

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TENTATIVE TOPICAL OUTLINE

1. INTRODUCTION TO CELLULAR RADIO SYSTEMS
2. MULTIPATH-FADING CHANNEL MODELLING AND SIMULATION
3. SHADOWING AND PATH LOSS
4. CO-CHANNEL INTERFERENCE AND OUTAGE
5. SINGLE- AND MULTI-CARRIER MODULATION TECHNIQUES AND THEIR POWER SPECTRUM
6. DIGITAL SIGNALING ON FLAT FADING CHANNELS
7. MULTI-ANTENNA TECHNIQUES
8. ADVANCED TOPICS
   • SPREAD SPECTRUM TECHNIQUES
   • MULTICARRIER TECHNIQUES
   • CELLULAR ARCHITECTURES AND RESOURCE MANAGEMENT
1.0 INTRODUCTION
WIRELESS INFRASTRUCTURE

1. Satellite Systems
2. Cellular Land Mobile Radio Systems
3. Fixed Wireless Access and Broadcast Networks
4. Wireless Local and Personal Area Networks
5. Sensor Networks
Types of Wireless Systems.
IEEE802 Family of Standards

• IEEE801.11b/a/g/n is a success
  – Femtocells integrate WiFi with 3G cellular.
    * Frees up cellular capacity and reduces BS power consumption.
    * Handheld power drain due to WLAN searching.
    * Fast WLAN-to-cellular handoff is needed.

• IEEE802.16-2009 has a slow start
  – 3.5M subscribers worldwide
  – 400K WiMax and 50M 3G subscribers added in 1Q 2009.
  – Competing solutions ADSL, Satellite, Cable, 3G cellular,
    Licensed proprietary systems, Power line communications.

• IEEE802.15 sees moderate success
  – Bluetooth widely deployed, but slow start (1994?)
    * The HYPE: you can get gigabits anywhere and everywhere!!
    * The REALITY: but only over very short distances (< 5 m)
IEEE 802.22 WRAN

- IEEE 802.22 is an unlicensed regional area network (WRAN) using TV band white space, based on cognitive radio (spectrum sensing and dynamic spectrum access).
  - Coexistence in (6, 7, 8 MHz) unused DTV bands on a non-interfering basis.
  - Provide broadband access to rural areas where the population density is low and a large number of vacant TV channels exist.
    * Coverage range is 33 km based on 4W Customer Premise Equipment (CPE) EIRP.
  - FCC Compliant: TV band white space is identified by using geo-location/database supplemented by spectrum sensing.
  - Closest relative among the IEEE 802 family is IEEE 802.16.
    * IEEE 802.16 does not include spectral sensing.
    * Coverage range of IEEE 802.16 is significantly smaller.
3G & 4G Cellular Technologies

- Cellular operators are heavily invested in 3G infrastructures.
  - 2Q 2009: 494M CDMA2000 and 410M WCDMA subscribers
  - 4B GSM and WCDMA subscribers

- LTE: OFDMA considered revolutionary by cellular operators. Deployment is some years away.
  - Develop LTE (4G) in parallel with evolved 3G.

- Evolved HSPA (HSPA+) is evolutionary
  - Can achieve the data rates as LTE in 5 MHz with HSPA+
    - Receiver diversity
    - Equalization and Interference cancellation
    - MIMO (2 x 2)
    - High-order signal constellations (64 QAM)
  - As of August 2009 there were 12 HSPA+ networks in the world running at 21 Mbps (DL). More are expected.
Commonly used hexagonal cellular reuse clusters.

- Tessellating hexagonal cluster sizes, $N$, satisfy
  \[ N = i^2 + ij + j^2 \]
  where $i$, $j$ are non-negative integers and $i \geq j$.
- hence $N = 1, 3, 4, 7, 9, 12,\ldots$
Cellular layout using seven-cell reuse clusters.

- Real cells are not hexagonal.

- Frequency reuse introduces co-channel interference and adjacent channel interference.
CO-CHANNEL REUSE FACTOR

Frequency reuse distance for 7-cell clusters.

- For hexagonal cells, the co-channel reuse factor is

\[
\frac{D}{R} = \sqrt{3N}
\]
RADIO PROPAGATION MECHANISMS

- Radio propagation is by three mechanisms
  - Reflections off objects larger than a wavelength
  - Diffraction around the edges of objects
  - Scattering by objects smaller than a wavelength

- A mobile radio environment is characterized by three nearly independent propagation factors
  - Path loss attenuation with distance.
  - Shadowing caused by large obstructions such as buildings, hills and valleys.
  - Multipath-fading caused by the combination of multipath propagation and transmitter and/or receiver movement.
FREE SPACE PROPAGATION

• The received signal power decays with the square of the path length in free space. The received envelope power is

\[ \mu_{\Omega_p} = \Omega_t G_T G_R \left( \frac{\lambda_c}{4\pi d} \right)^2 \]

where \( \Omega_t \) is the transmitted power, \( G_T \) and \( G_R \) are the transmitter and receiver antenna gains, and \( d \) is the radio path length.

• For free space propagation the path loss is

\[
L_p (\text{dB}) = 10\log_{10} \left\{ \frac{\Omega_t G_T G_R}{\mu_{\Omega_p}} \right\} \\
= -10\log_{10} \left\{ \left( \frac{\lambda_c}{4\pi d} \right)^2 \right\} \\
= -10\log_{10} \left\{ \left( \frac{c/f_c}{4\pi d} \right)^2 \right\} \\
= 20\log_{10} f_c + 20\log_{10} d - 147.55 \text{ dB} \]