

ECE6604
PERSONAL & MOBILE COMMUNICATIONS

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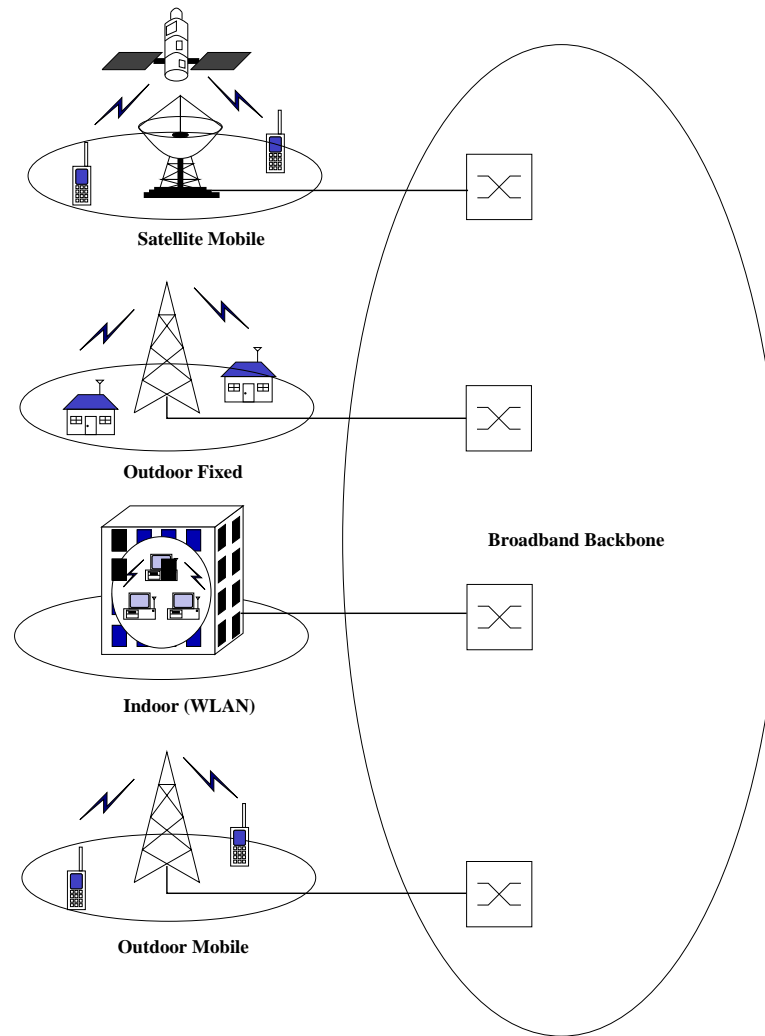
TENTATIVE TOPICAL OUTLINE

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.

WIRELESS LANs (WiFi)

- **IEEE 802.11 – Direct Sequence Spread Spectrum (1-and-2 Mb/s, 2.4GHz)**
- **IEEE 802.11b – Complimentary Code Keying (CCK) (5.5-and-11 Mb/s, 2.4GHz)**
- **IEEE 802.11g/a – Orthogonal Frequency Division Multiplexing (OFDM) (6-to-54 Mb/s, 2.4/5GHz)**
- **IEEE 802.11e – MAC enhancements for Quality of Service (QoS)**
- **IEEE 802.11i – Security**
- **IEEE 802.11n – MIMO physical layer**

WIRELESS PANs

- **IEEE Std 802.15.1-2002 - 1Mb/s WPAN/Bluetooth v1.x derivative work**
- **P802.15.2- Recommended Practice for Coexistence in Unlicensed Bands**
- **P802.15.3 - 20+ Mb/s High Rate WPAN for Multimedia and Digital Imaging**
- **P802.15.3a - 110+ Mb/s Higher Rate Alternative PHY for 802.15.3 - ultra wide band (UWB)**
- **P802.15.4 - 200 kb/s max for interactive toys, sensor and automation needs**
- **Applications include (mobile) ad hoc networks, sensor networks**

WIRELESS MANs (WiMax)

- IEEE 802.16 addresses the "first-mile/last-mile" connection in wireless MANs.
 - focuses on the efficient use of bandwidth between 10 and 66 GHz (the 2 to 11 GHz region with point-to-point (PMP) and optional Mesh (ad hoc) topologies)
 - defines a medium access control (MAC) layer that supports multiple physical layer specifications customized for the frequency band of use.
- IEEE 802.16e - mobility extension of IEEE802.16.
- Alternatives to Wireless MANS
 - Digital Subscriber Line (DSL)
 - Cable (coaxial)
 - Satellite
 - 3G cellular with high speed downlink packet access HSDPA (8-10 Mb/s)
 - Fiber
 - Power Line Communications

WIRELESS REGIONAL AREA NETWORKS (WRANs)

- IEEE 802.22 provides wide area radio access using *Cognitive Radio*
 - Coexistence in (6, 7, 8 MHz) unused DTV bands on a non-interfering basis.
 - Air interface based on IEEE802.16e with modifications for spectrum coexistence.
- Essential elements include
 - Spectrum sensing to detect incumbent signals (DTV and wireless microphone).
 - Dynamic spectrum management to transmit in unused DTV channels.
 - Transmit power control to limit interference.

A BRIEF HISTORY OF CELLULAR RADIO

First Generation - Now Extinct

- **1970s — development of computer technology and development of radio technology for 800/900 MHz mobile communications.**
- **1976 — World Administrative Radio Conference (WARC) allocates spectrum for cellular radio.**
- **1979 — Nippon Telephone and Telegraph (NTT) introduces the first cellular system in Japan.**
- **1981 — Nordic Mobile Telephone (NMT) 900 system introduced by Ericsson Radio Systems AB and deployed in Scandanvia.**
- **1984 — Advanced Mobile Telephone Service (AMPS) introduced by AT&T in North America.**

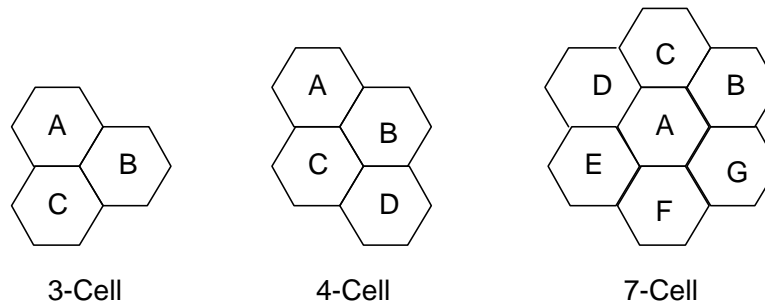
Second Generation - GSM and IS-95A/B still in use

- **1982 — Conference of European Postal and Telecommunications Administrations (CEPT) established Groupe Special Mobile (GSM) with a mandate to define future Pan-European cellular radio standards.**
- **1990 — Interim Standard IS-54 (USDC) adopted by TIA.**
- **1990 — Interim Standard IS-19B (NAMPS) adopted by TIA.**
- **1992 — Phase I GSM system is operational (September 1).**
- **1993 — Interim Standard IS-95A (CDMA) adopted by TIA.**
- **1994 — Interim Standard IS-136 adopted by TIA.**
- **1995-7 — PCS licenses issued in North America.**
- **1997-8 — North American PCS operators deploy, GSM, IS-54, IS-95**
- **1998 — IS-95B standard is approved.**
- **1999 — IS-54 sees deployment in major North American markets; IS-95 is deployed in the North America, Korea, Hong Kong, Israel; GSM is deployed in 110 countries.**

Third Generation

- 1998 — A group called 3GPP (Third Generation Partnership Project) is created to produce a common 3G standard based on WCDMA.
- 1999 — The group 3GPP2 is created to harmonize the use of multi-carrier cdma2000
- 2000 — South-Korean Telecom (SKT) launches cdma2000-1X network (DL/UL: 153 kbps)
- 2001 — NTT DoCoMo deploys commercial UMTS network in Japan
- 2002 — cdma2000 1xEV-DO (UL: 153 kbps, DL: 2.4 Mb/s)
- 2003 — WCDMA (UL/DL: 384 kbps)
- 2006 — HSDPA (UL: 384 kbps, DL: 7.2 Mbps)
- 2007 — cdma2000 1xEV-DO Rev A (UL: 1.8 Mbps, DL: 3.1 Mbps)
- 2008 — HSUPA (UL: 5.8 Mbps, DL: 7.2 Mbps), cdma2000 1xEV-DO Rev B (UL: 27 Mbps, DL: 73 Mbps)
- future — HSPA+ (UL: 10 Mbps, DL: 40 Mbps), LTE (UL: 50 Mbps, DL: 100 Mbps), cdma2000 1xEV-DO Rev B (UL: 100 Mbps, DL: 250 Mbps)

FREQUENCY RE-USE AND THE CELLULAR CONCEPT



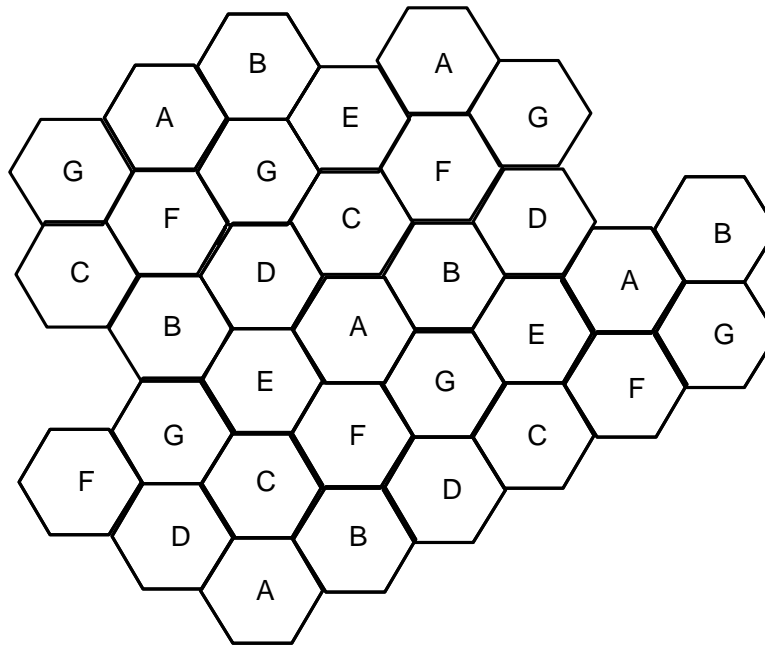
Commonly used hexagonal cellular reuse clusters.

- Tessellating hexagonal cluster sizes, N , satisfy

$$N = i^2 + ij + j^2$$

where i, j are non-negative integers and $i \geq j$.

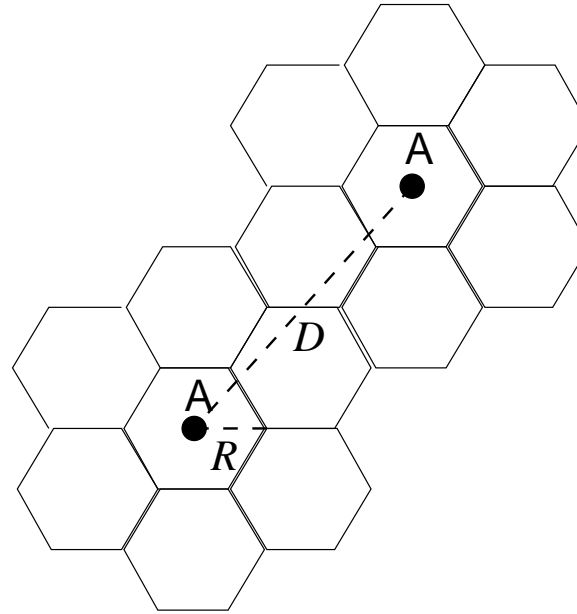
– hence $N = 1, 3, 4, 7, 9, 12, \dots$



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 Ω_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

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