Wireless Access Networks: Recent Developments, Issues and Trends

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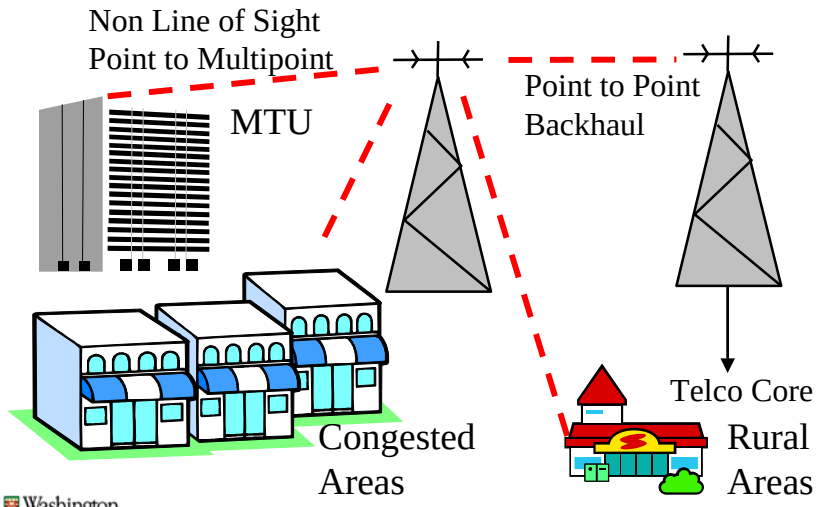
http://www.cse.wustl.edu/~jain/talks/pw09.htm

1. IEEE 802.16: Key Features
2. Six WiMAX Foundation Technologies
3. Cellular Telephony Generations
4. 4G: IMT-Advanced
5. 700 MHz

Broadband Wireless Access



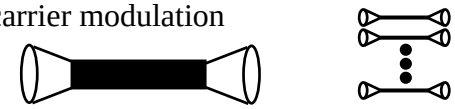
Six WiMAX Foundation Technologies

1. OFDM, OFDMA, Scalable OFDMA (SOFDMA)
2. Beamforming
3. MIMO
4. Space Time Block Codes (STBC)
5. Turbo Codes
6. Time Division Duplexing (TDD)

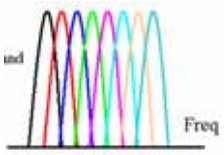
Note: All of these have also become the foundations of all competing wireless broadband access

1. OFDM

- Orthogonal Frequency Division Multiplexing
- Ten 100 kHz channels are better than one 1 MHz Channel
  $\Rightarrow$ Multi-carrier modulation

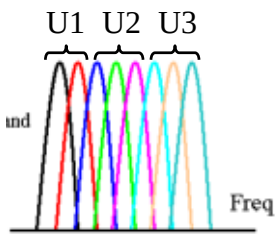


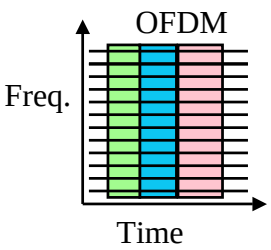
- Frequency band is divided into 256 or more sub-bands.
  Orthogonal $\Rightarrow$ Peak of one at null of others
- Each carrier is modulated with a BPSK, QPSK, 16-QAM, 64-QAM etc depending on the noise (Frequency selective fading)
- Used in 802.11a/g, 802.16,
  Digital Video Broadcast handheld (DVB-H)
- Easy to implement using FFT/IFFT

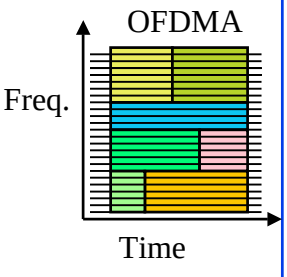


OFDMA

- Orthogonal Frequency Division Multiple Access
- Each user has a subset of subcarriers for a few slots
- OFDM systems use TDMA
- OFDMA allows Time+Freq DMA $\Rightarrow$ 2D Scheduling



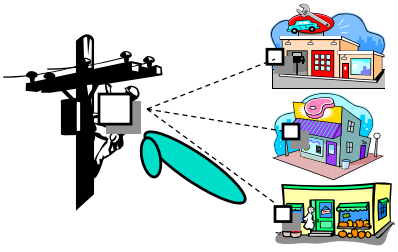




Scalable OFDMA (SOFDMA)

- OFDM symbol duration = f(subcarrier spacing)
- Subcarrier spacing = Frequency bandwidth/Number of subcarriers
- Frequency bandwidth=1.25 MHz, 3.5 MHz, 5 MHz, 10 MHz, 20 MHz, etc.
- Symbol duration affects higher layer operation
  ⇒ Keep symbol duration constant at 102.9 us
  ⇒ Keep subcarrier spacing 10.94 kHz
  ⇒ Number of subcarriers ∝ Frequency bandwidth
  This is known as scalable OFDMA

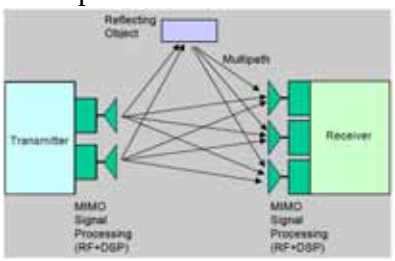
2. Beamforming



- Phased Antenna Arrays:
  Receive the same signal using multiple antennas
- By phase-shifting various received signals and then summing ⇒ Focus on a narrow directional beam
- Digital Signal Processing (DSP) is used for signal processing ⇒ Self-aligning

3. MIMO

- Multiple Input Multiple Output
- RF chain for each antenna
  ⇒ Simultaneous reception or transmission of multiple streams



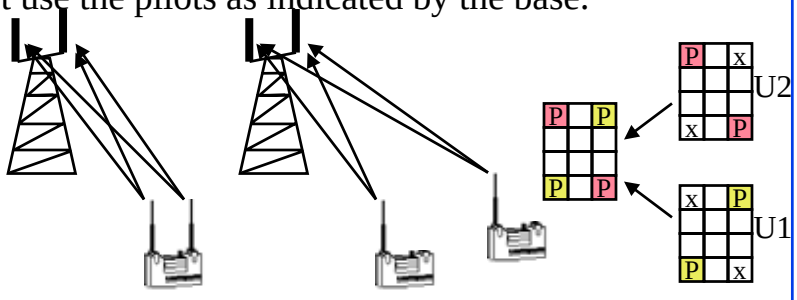
2x3

802.16e at 2.5 GHz, 10 MHz TDD, D:U=2:1

T:R	1x1	1x2	2x2	2x4	4x2	4x4
b/Hz	1.2	1.8	2.8	4.4	3.7	5.1

Cooperative MIMO

- Two subscribers with one antenna each can transmit at the same frequency at the same time
- The users do not really need to know each other. They just use the pilots as indicated by the base.

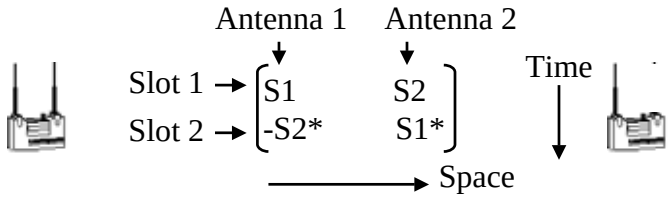


MIMO

Cooperative MIMO

4. Space Time Block Codes (STBC)

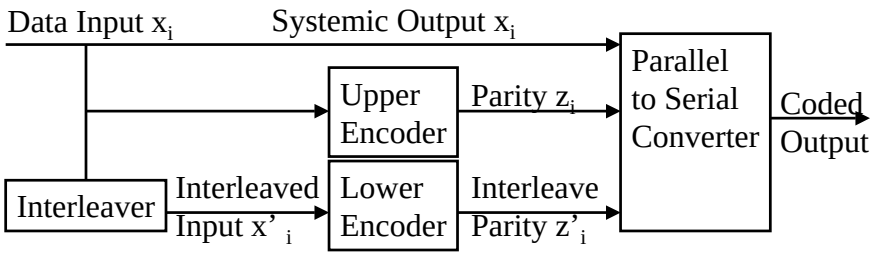
- Invented 1998 by Vahid Tarokh.
- Transmit multiple redundant copies from multiple antennas
- Precisely coordinate distribution of symbols in space and time.
- Receiver combines multiple copies of the received signals optimally to overcome multipath.
- Example: Two antennas:



S1* is complex conjugate of S1 ⇒ columns are orthogonal

5. Turbo Codes

- Normal FEC codes: 3dB below the Shannon limit
- Turbo Codes: 0.5dB below Shannon limit
  Developed by French coding theorists in 1993
- Use two coders with an interleaver
- Interleaver rearranges bits in a prescribed but irregular manner



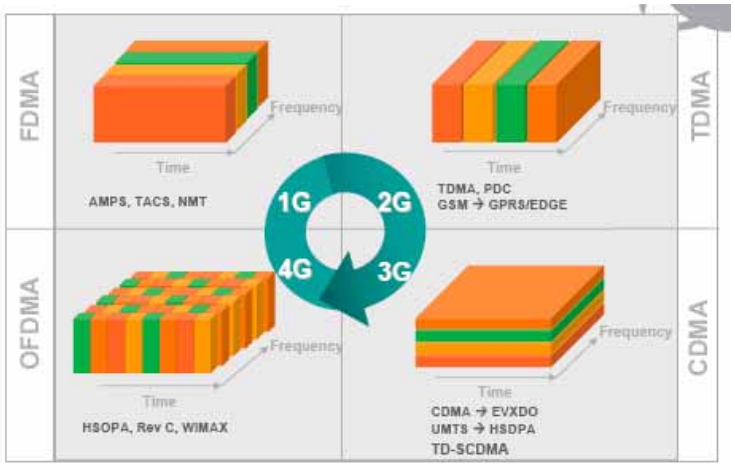
6. Time Division Duplexing (TDD)

- Duplex = Bi-Directional Communication
- Frequency division duplexing (FDD) (Full-Duplex)

- Time division duplex (TDD): Half-duplex

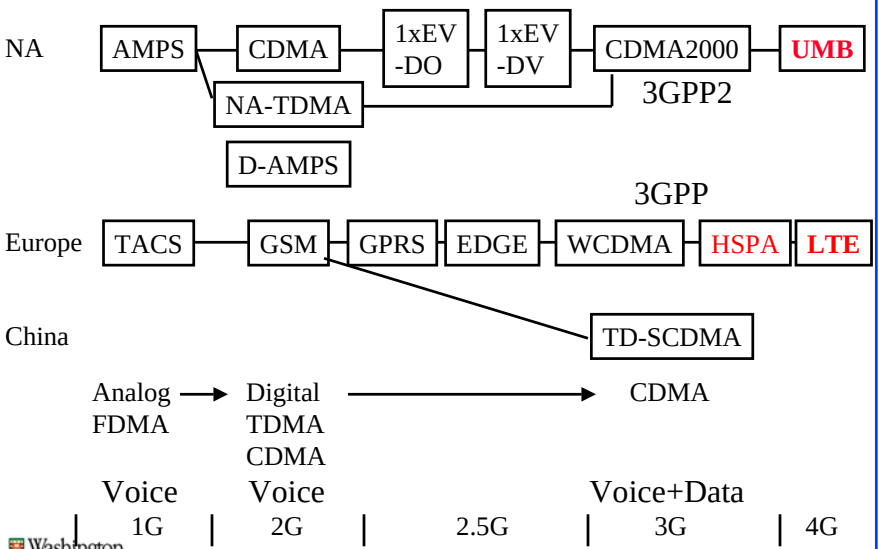
- Most WiMAX deployments will use TDD.
  - Allows more flexible sharing of DL/UL data rate
  - Does not require paired spectrum
  - Easy channel estimation ⇒ Simpler transceiver design
  - Con: All neighboring BS should time synchronize

Multiple Access Methods



Source: Nortel

Cellular Telephony Generations



4G: IMT-Advanced

- International Mobile Telecommunications – Advanced or 4G
- Wireless broadband access to be standardized around 2010 and deployed around 2015
- 1 Gbps for nomadic/fixed and 100 Mbps for high mobility (150 km/h)
- Requirements will be set in 2008
- Set of 4G technologies will be selected by 2010

Ref: ITU-R M.1645, "Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000" (2003)

IEEE 802.16m

- Peak data rate:
  - Downlink (BS->MS) > 6.5 bps/Hz,
    Uplink (MS->BS) > 2.8 bps/Hz
    After PHY overhead
  - 20 MHz => 130 Mbps
- Mobility: Optimized for 0-15 km/h, marginal degradation 15-120 km/h, maintain connection 120-350 km/h
- 3 dB improvement in link budget over 16e
- Optimized for cell sizes of up to 5km. Graceful degradation in spectral efficiency for 5-30km. Functional for 30-100 km.

Ref: Draft IEEE 802.16m requirements, June 8, 2007,
http://ieee802.org/16/tgm/docs/80216m-07_002r2.pdf

700 MHz

- February 19, 2009: TV vacates 700-MHz
- FCC just approved 700 MHz for broadband access
- 108 MHz total available
  - 60 MHz available by Auction in January 16, 2008
  - 24 MHz for Public Safety
  - 24 MHz already owned by Access Spectrum, Aloa Partners, Pegasus Comm, Qualcomm,Verizon, DirecTV, Echostar, Google, Intel, Skype, and Yahoo!
- **Open Access**: Open applications, Open devices, Open services, and open networks
- **White spaces**: Unused spectrum between 54 and 698 MHz. (Channel 2 through 51)

Effect of Frequency

- Higher Frequencies have higher attenuation,
  e.g., 18 GHz has 20 dB/m more than 1.8 GHz
- Higher frequencies need smaller antenna
  Antenna $\geq$ Wavelength/2, 800 MHz $\Rightarrow$ 6"
- Higher frequencies are affected more by weather
  Higher than 10 GHz affected by rainfall
  60 GHz affected by absorption of oxygen molecules
- Higher frequencies have more bandwidth and higher data rate
- Higher frequencies allow more frequency reuse
  They attenuate close to cell boundaries. Low frequencies propagate far.
- Mobility $\Rightarrow$ Below 10 GHz

Summary

1. Wireless is the major source of carrier revenue
   $\Rightarrow$ Significant growth in **mobile data** applications
2. CDMA is past. **OFDMA** is taking over.
3. WiMAX allows indoor, non-line of sight operation using TDD, OFDMA, MIMO, centralized scheduling, QoS
4. IMT-Advanced race is on:
   - Next generation of 3G LTE and UMB are evolving.
     Taking the best of WiMAX: OFDMA, MIMO
   - Next generation WiMAX 802.16m will run at 100+ Mbps
5. **700 MHz** will significantly increase the reach and capacity