# Wireless Access Networks: Recent Developments, Issues and Trends

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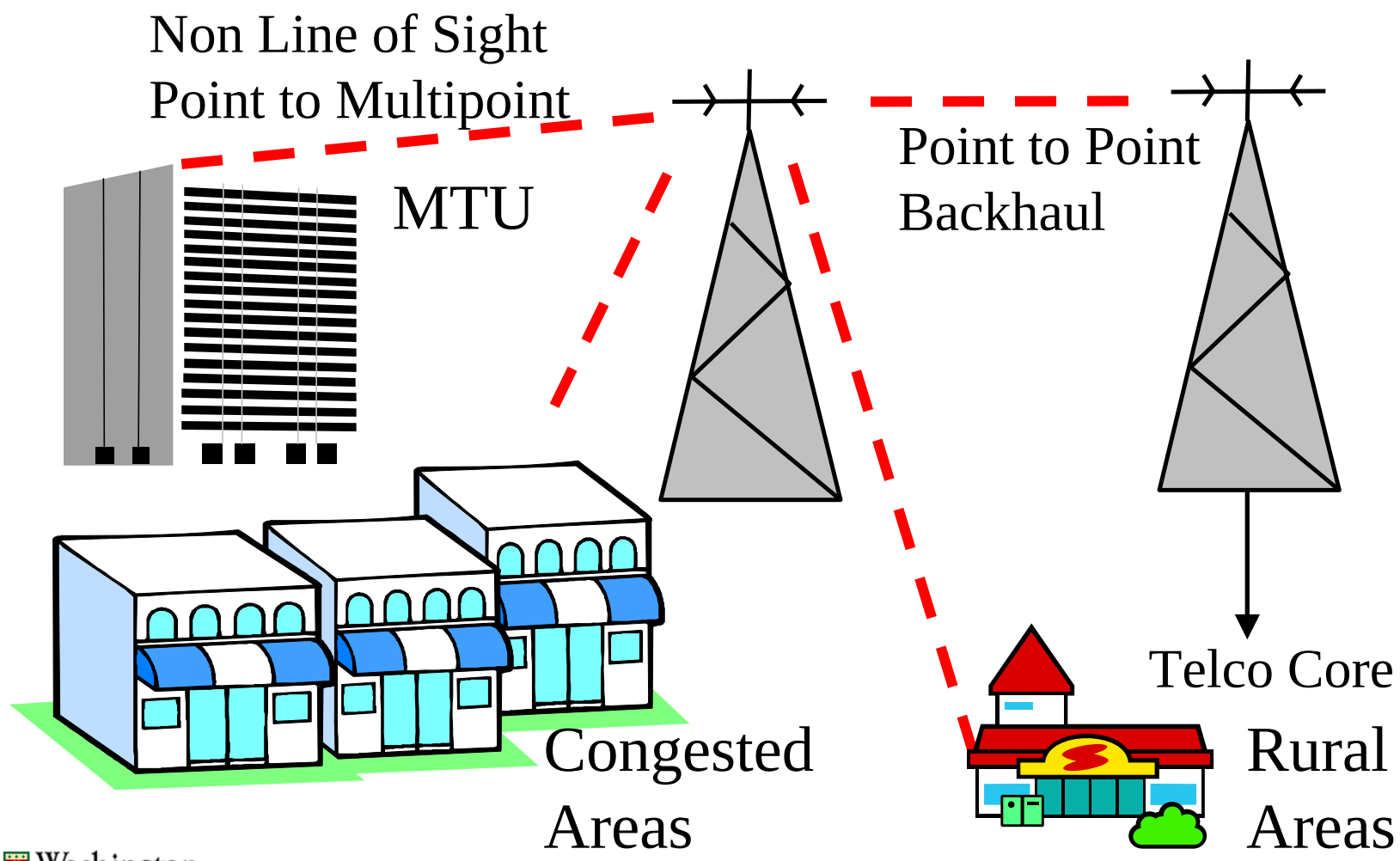
These slides are available on-line at
http://www.cse.wustl.edu/~jain/talks/pw09.htm


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



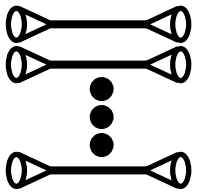
# Six WiMAX Foundation Technologies

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

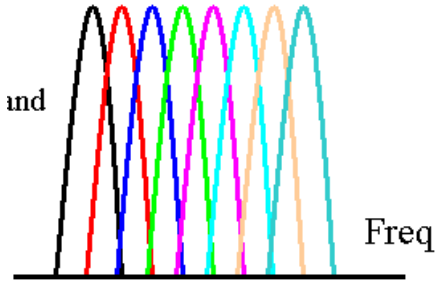
Note: All of these have also become the foundations of all competing wireless broadband access

# 1. OFDM

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

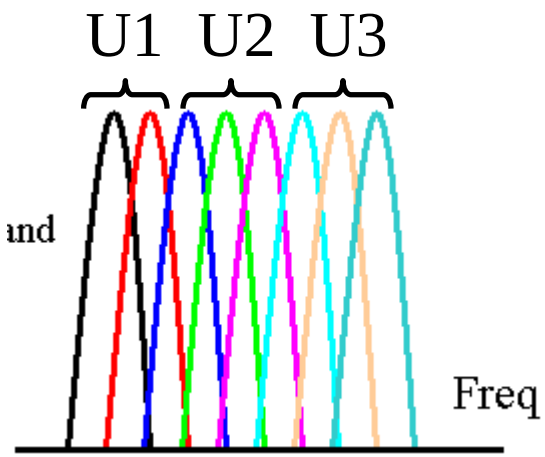


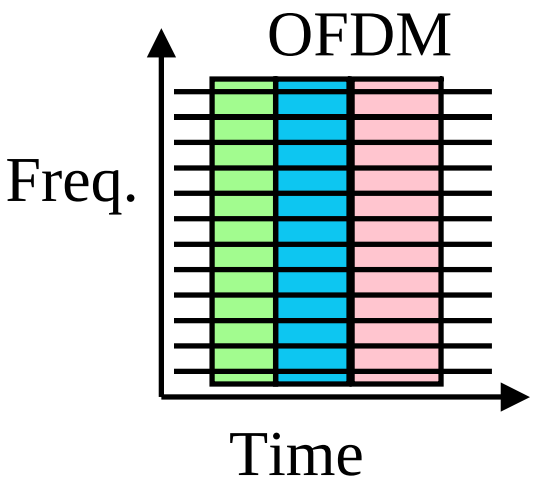
- Frequency band is divided into 256 or more sub-bands.
  Orthogonal ⇒ Peak of one at null of others
- Each carrier is modulated with a BPSK, QPSK, 16-QAM, 64-QAM etc depending on the noise (Frequency selective fading)
- Used in 802.11a/g, 802.16,
  Digital Video Broadcast handheld (DVB-H)
- Easy to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

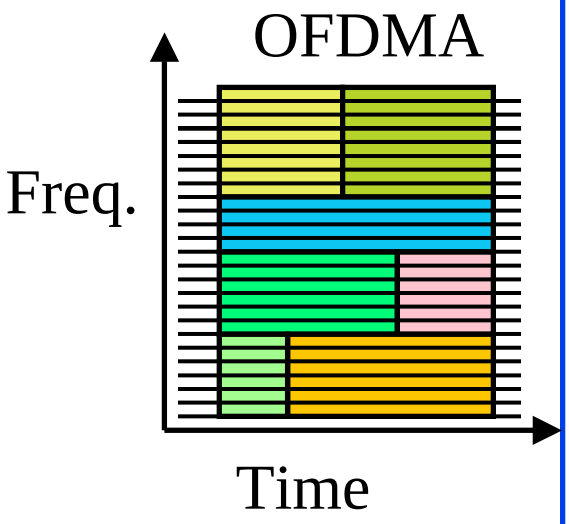


# OFDMA

- 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 ⇒ 2D Scheduling



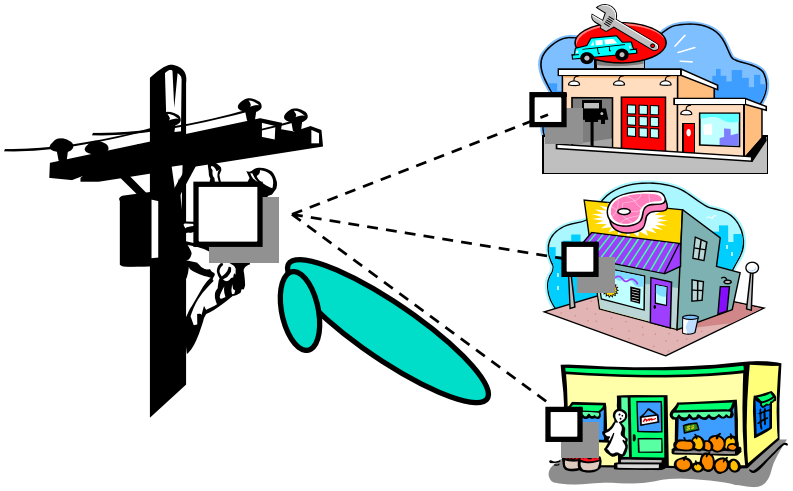



# Scalable OFDMA (SOFDMA)

- 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
  $\Rightarrow$ Keep symbol duration constant at 102.9 us
  $\Rightarrow$ Keep subcarrier spacing 10.94 kHz
  $\Rightarrow$ Number of subcarriers $\propto$ Frequency bandwidth
  This is known as scalable OFDMA

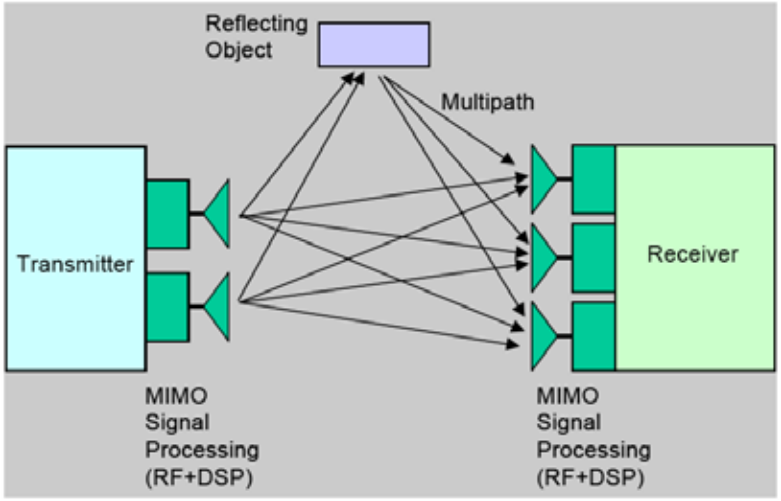
# 2. Beamforming



- 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
  $\Rightarrow$ Simultaneous reception or transmission of multiple streams



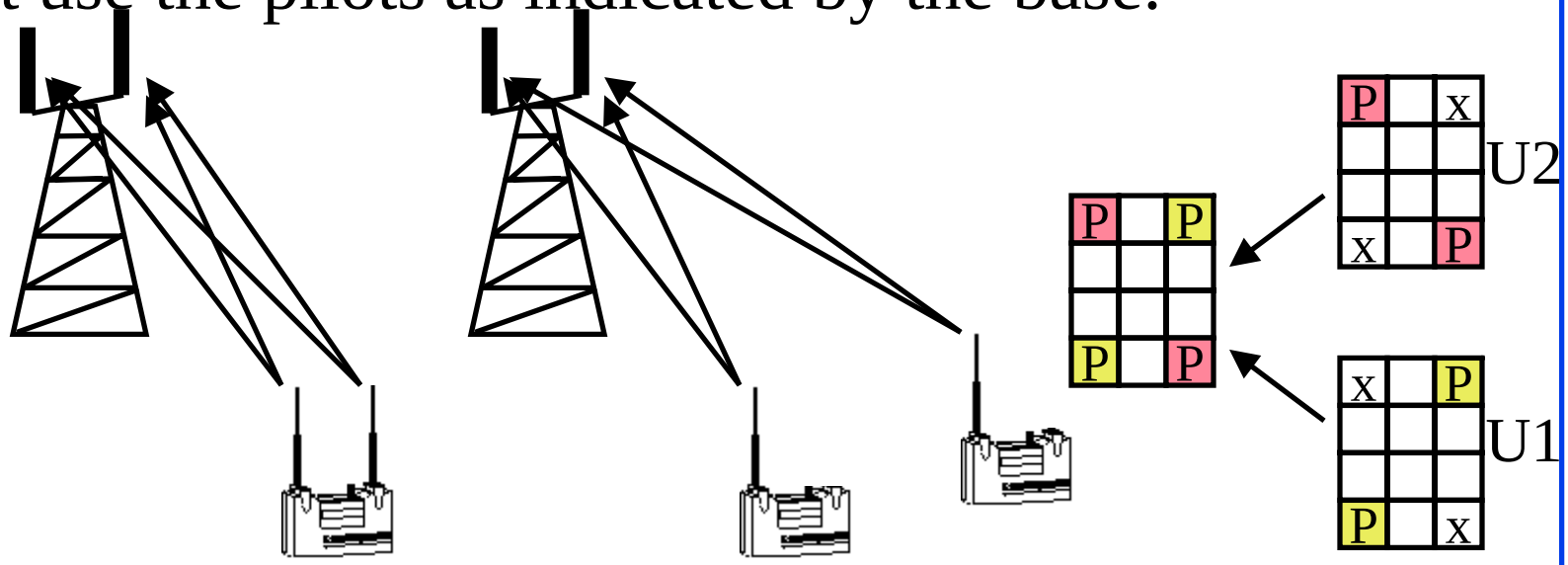

2x3

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 |

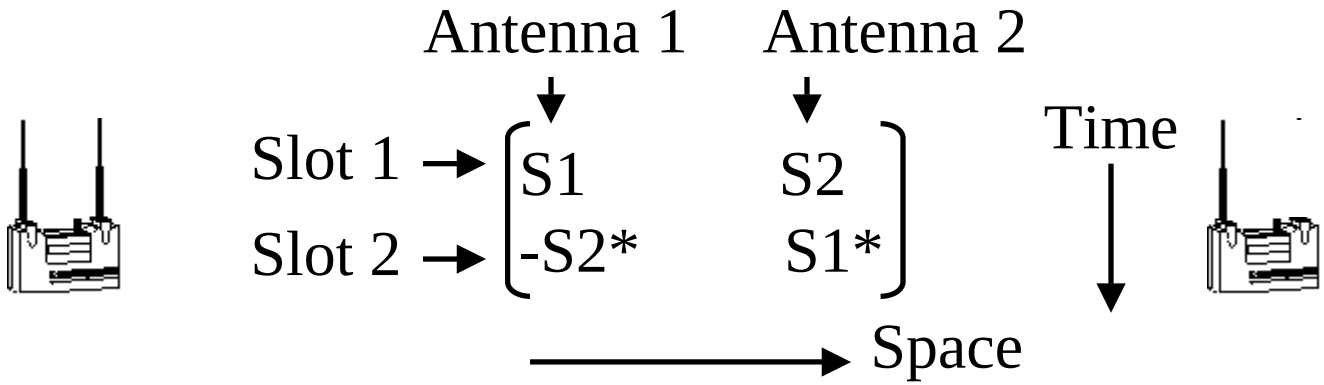
# Cooperative MIMO

- 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.



# 4. Space Time Block Codes (STBC)

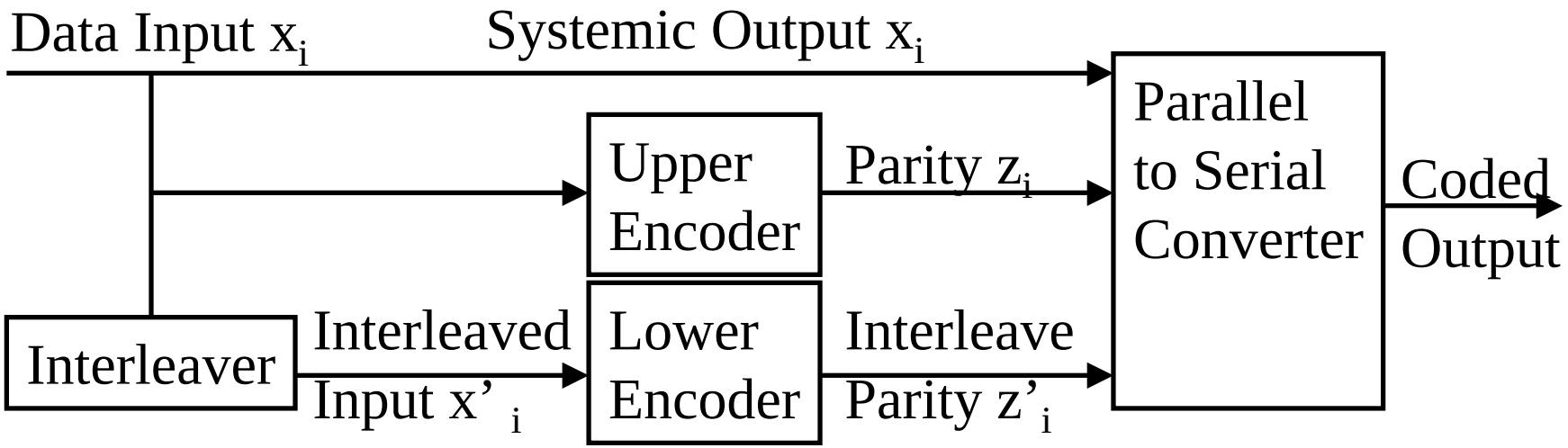
- Invented 1998 by Vahid Tarokh.
- Transmit multiple redundant copies from multiple antennas
- Precisely coordinate distribution of symbols in space and time.
- Receiver combines multiple copies of the received signals optimally to overcome multipath.
- Example: Two antennas:




S1* is complex conjugate of S1 ⇒ columns are orthogonal

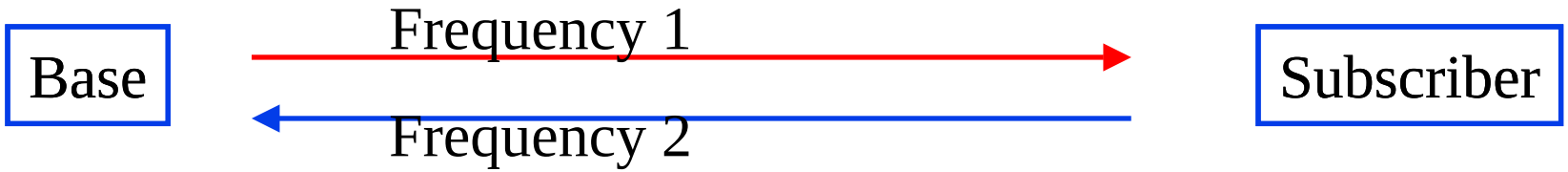
# 5. Turbo Codes

- 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

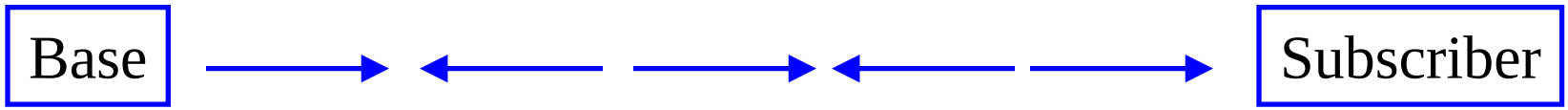


# 6. Time Division Duplexing (TDD)

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

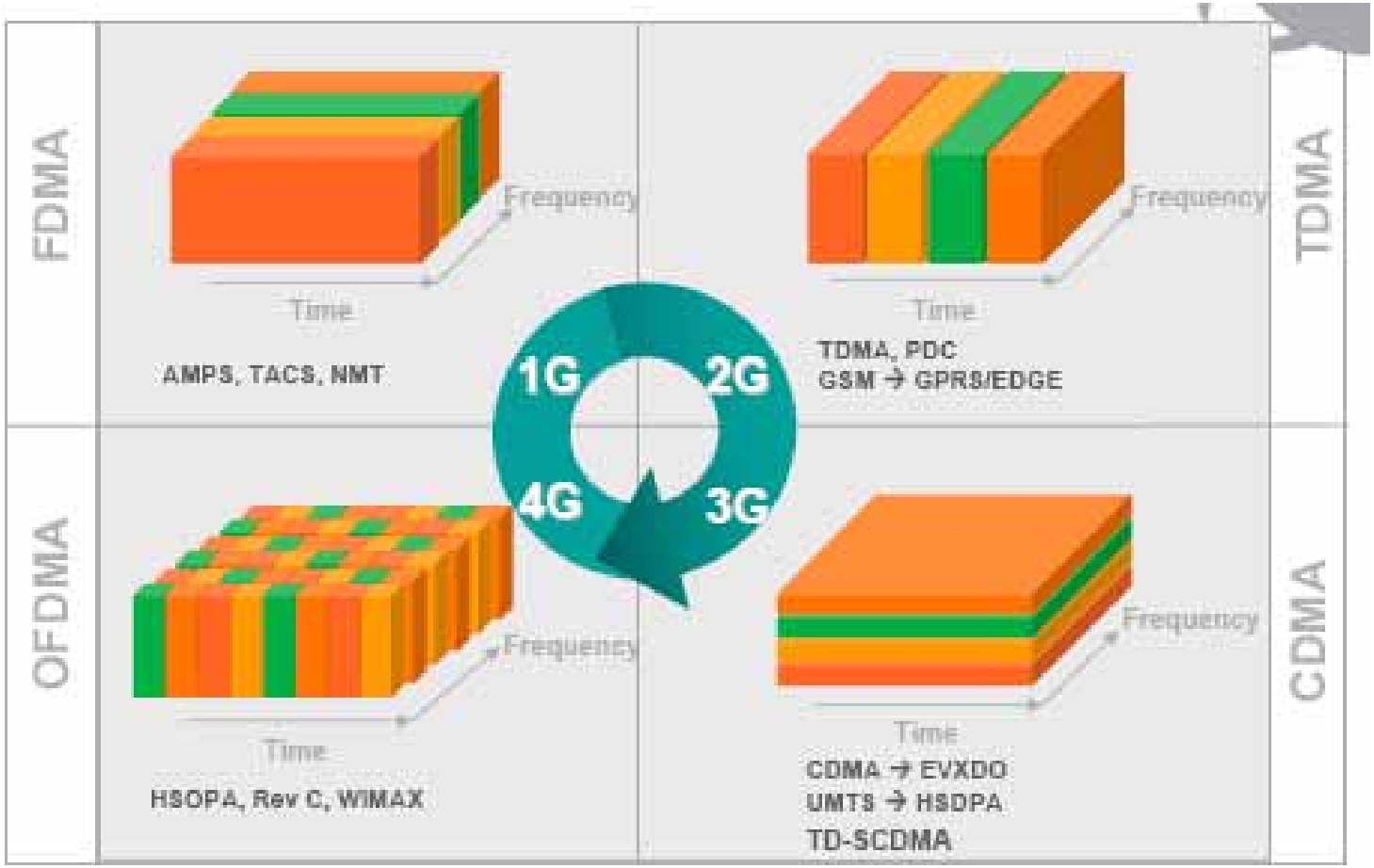



- Time division duplex (TDD): Half-duplex



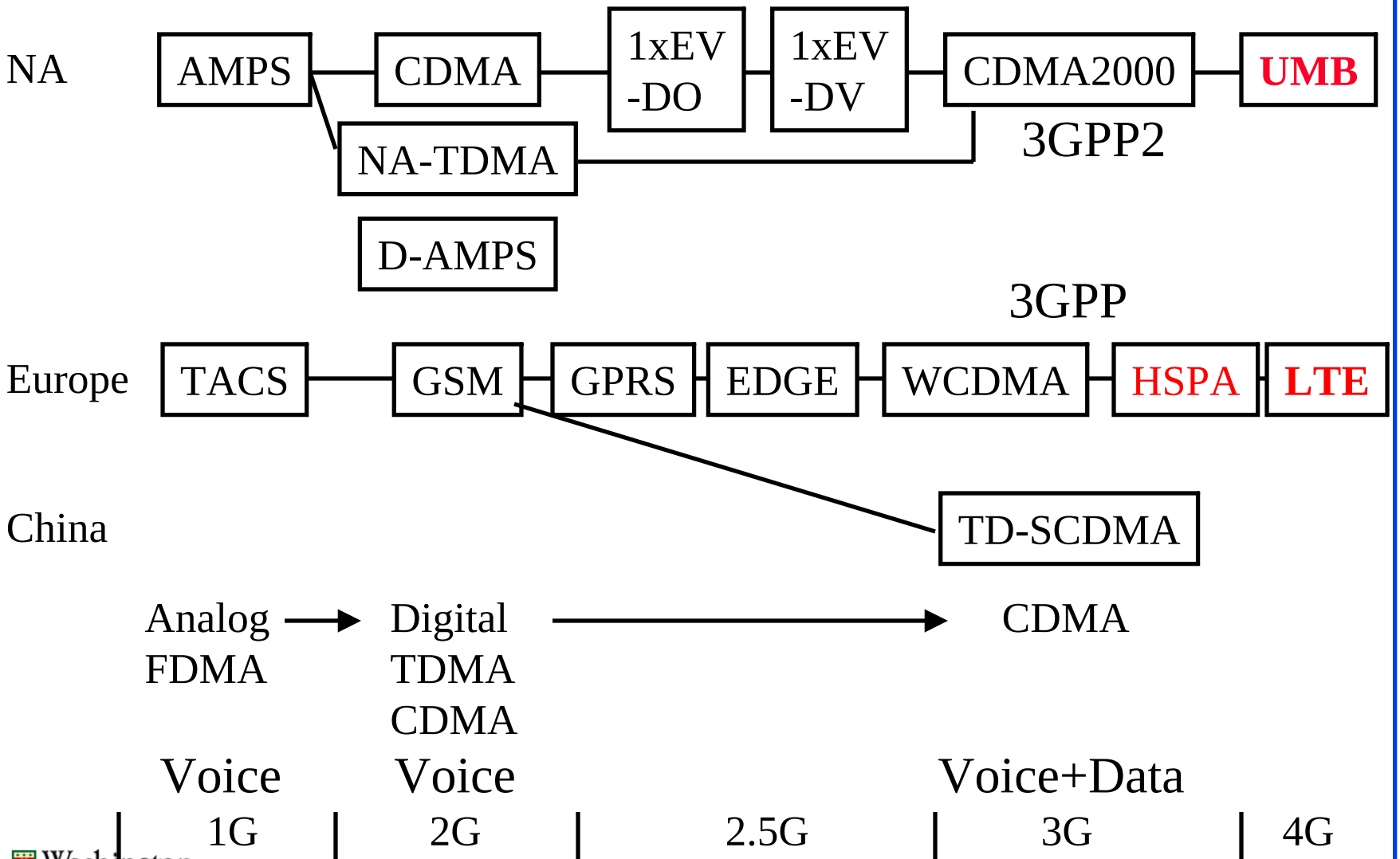

- Most WiMAX deployments will use TDD.
  - Allows more flexible sharing of DL/UL data rate
  - Does not require paired spectrum
  - Easy channel estimation ⇒ Simpler transceiver design
  - Con: All neighboring BS should time synchronize

# 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

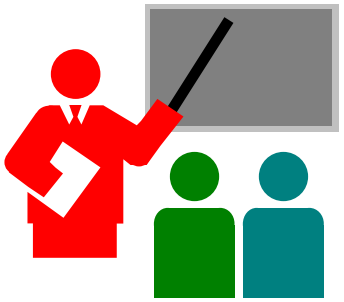
# 700 MHz

- 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