

# Wireless Access Networks: Recent Developments, Issues and Trends

**Raj Jain**

Professor of Computer Science and Engineering  
Washington University in Saint Louis  
Saint Louis, MO 63130 USA

[Jain@cse.wustl.edu](mailto:Jain@cse.wustl.edu)

Invited talk at Broadband Access Communication Technologies  
III Conference, Photonics West, San Jose, January 28, 2009

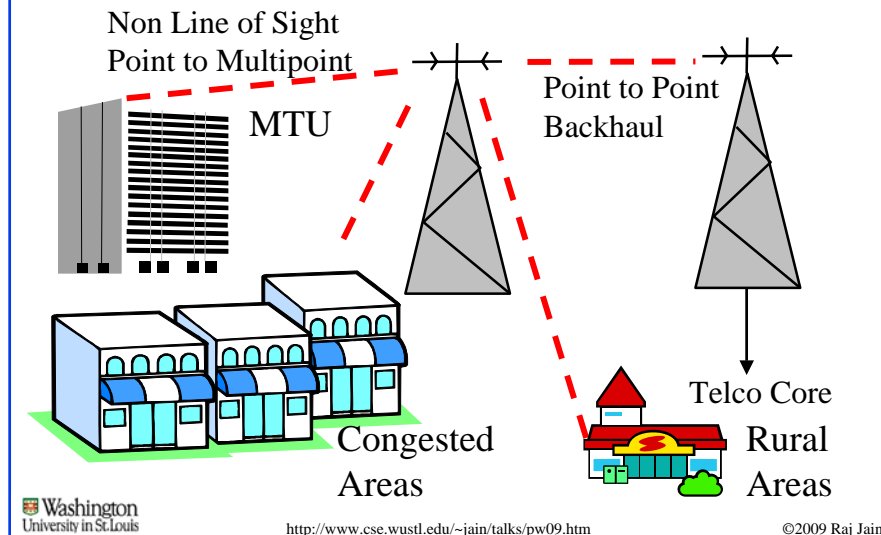
These slides are available on-line at

<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



3

## 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

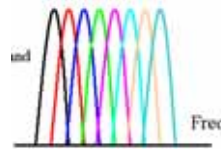
4

# 1. OFDM

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

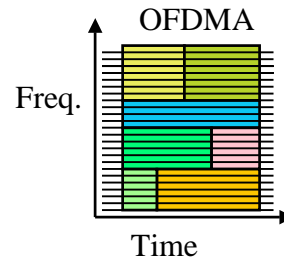
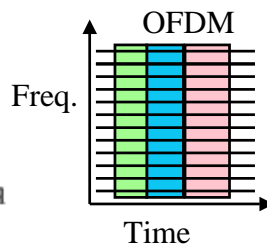
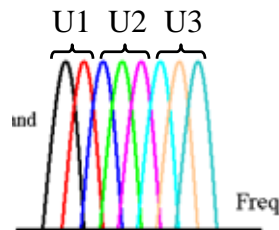


- Frequency band is divided into 256 or more sub-bands.  
Orthogonal ⇒ Peak of one at null of others
- Each carrier is modulated with a BPSK, QPSK, 16-QAM, 64-QAM etc depending on the noise (Frequency selective fading)
- Used in 802.11a/g, 802.16, Digital Video Broadcast handheld (DVB-H)
- Easy to implement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



# OFDMA

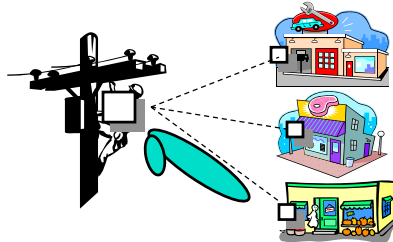
- Orthogonal Frequency Division Multiple Access
- Each user has a subset of subcarriers for a few slots
- OFDM systems use TDMA
- OFDMA allows Time+Freq DMA ⇒ 2D Scheduling



## Scalable OFDMA (SOFDMA)

- ❑ OFDM symbol duration =  $f(\text{subcarrier spacing})$
  - ❑ 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  $\mu\text{s}$
    - ⇒ Keep subcarrier spacing 10.94 kHz
    - ⇒ Number of subcarriers  $\propto$  Frequency bandwidth
- This is known as scalable OFDMA

## 2. Beamforming

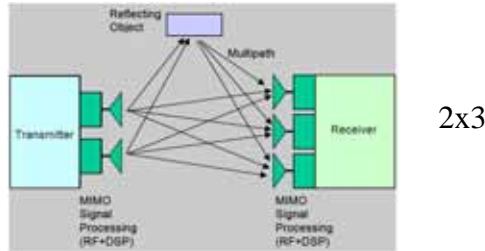


- ❑ Phased Antenna Arrays:
  - Receive the same signal using multiple antennas
- ❑ By phase-shifting various received signals and then summing  $\Rightarrow$  Focus on a narrow directional beam
- ❑ Digital Signal Processing (DSP) is used for signal processing  $\Rightarrow$  Self-aligning

### 3. MIMO



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



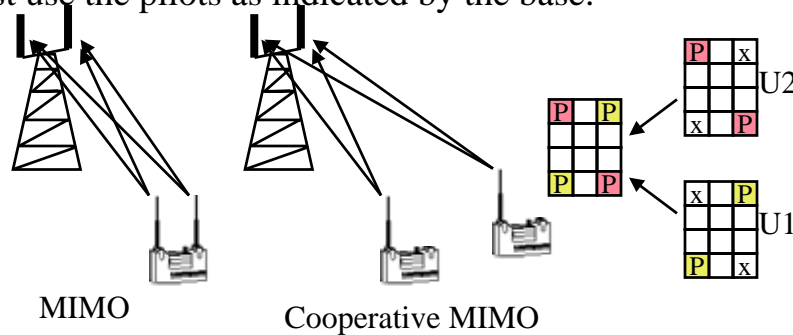
2x3

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

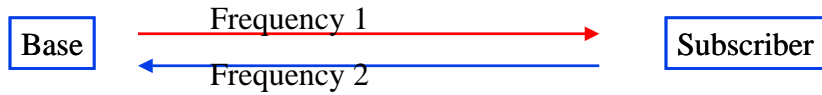
- ❑ Two subscribers with one antenna each can transmit at the same frequency at the same time
- ❑ The users do not really need to know each other. They just use the pilots as indicated by the base.





## 6. Time Division Duplexing (TDD)

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

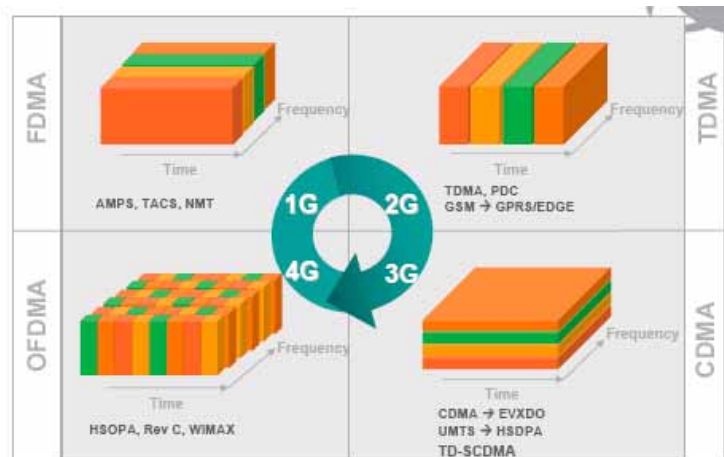


- Time division duplex (TDD): Half-duplex

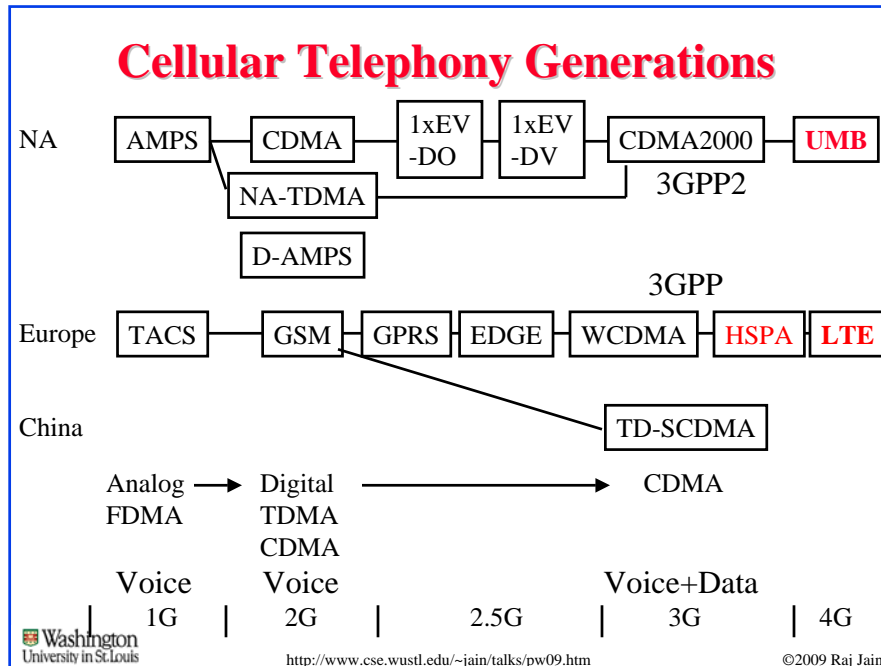


- Most WiMAX deployments will use TDD.
  - Allows more flexible sharing of DL/UL data rate
  - Does not require paired spectrum
  - Easy channel estimation  $\Rightarrow$  Simpler transceiver design
  - Con: All neighboring BS should time synchronize

## Multiple Access Methods



Source: Nortel



16

## 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)

Washington University in St. Louis | <http://www.cse.wustl.edu/~jain/talks/pw09.htm> | ©2009 Raj Jain

19

## 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](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