

Broadband Wireless Access

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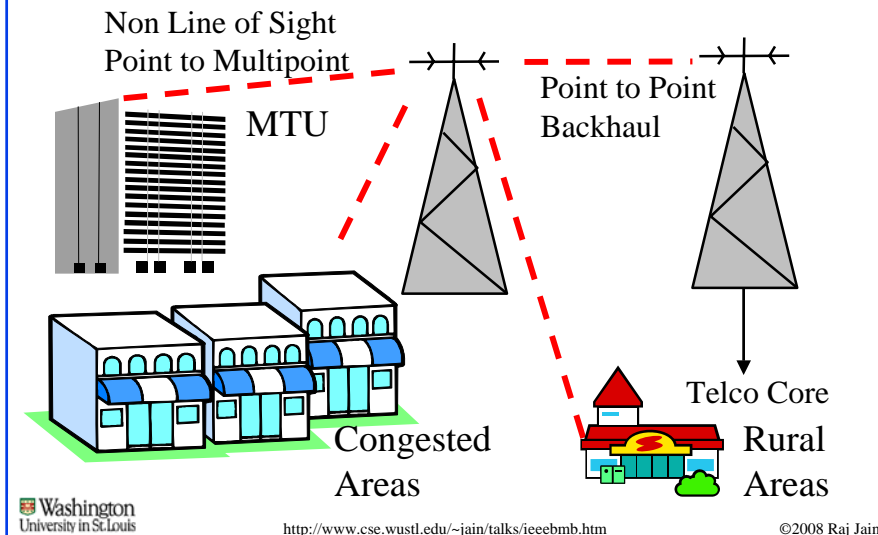
A talk given at IEEE Mumbai Section, December 15, 2008

Audio/video recordings of the presentation are available on-line at
<http://www.cse.wustl.edu/~jain/talks/ieeebmb.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



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IEEE 802.16: Key Features

- Broadband Wireless Access
- Up to 50 km or Up to 70 Mbps.
- Data rate vs Distance trade off w adaptive modulation.
64QAM to BPSK
- Offers non-line of site (NLOS) operation
- 1.5 to 28 MHz channels
- Hundreds of simultaneous sessions per channel
- Both Licensed and license-exempt spectrum
- Centralized scheduler
- QoS for voice, video, T1/E1, and bursty traffic
- Robust Security

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WiMAX

- ❑ WiMAX \neq IEEE 802.16
- ❑ Worldwide Interoperability for Microwave Access
- ❑ 420+ members including Semiconductor companies, equipment vendors, integrators, service providers. Like Wi-Fi Alliance
- ❑ Narrows down the list of options in IEEE 802.16
- ❑ Plugfests started November 2005
- ❑ WiMAX forum lists certified base stations and subscriber stations from many vendors
- ❑ <http://www.wimaxforum.org>

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)

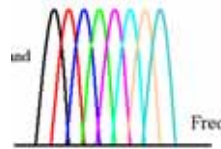
Note: All of these have also become the foundations of all competing wireless broadband access

1. OFDM

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

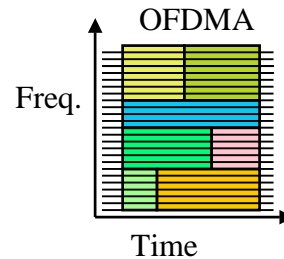
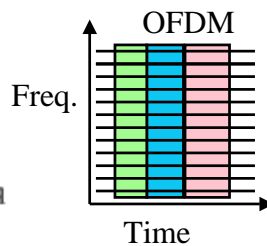
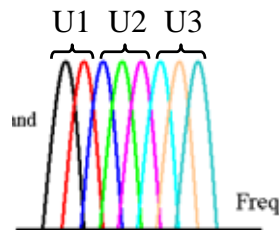


- Frequency band is divided into 256 or more sub-bands.
 Orthogonal ⇒ Peak of one at null of others
- Each carrier is modulated with a BPSK, QPSK, 16-QAM, 64-QAM etc depending on the noise (Frequency selective fading)
- Used in 802.11a/g, 802.16, Digital Video Broadcast handheld (DVB-H)
- Easy to implement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



OFDMA

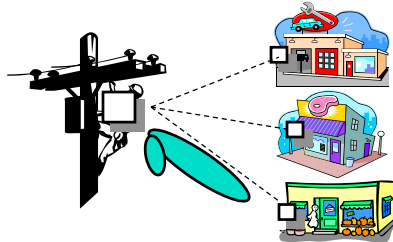
- Orthogonal Frequency Division Multiple Access
- Each user has a subset of subcarriers for a few slots
- OFDM systems use TDMA
- OFDMA allows Time+Freq DMA ⇒ 2D Scheduling



Scalable OFDMA (SOFDMA)

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

2. Beamforming

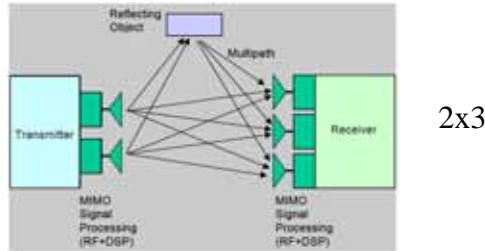


- ❑ Phased Antenna Arrays:
 - Receive the same signal using multiple antennas
- ❑ By phase-shifting various received signals and then summing \Rightarrow Focus on a narrow directional beam
- ❑ Digital Signal Processing (DSP) is used for signal processing \Rightarrow Self-aligning

3. MIMO



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



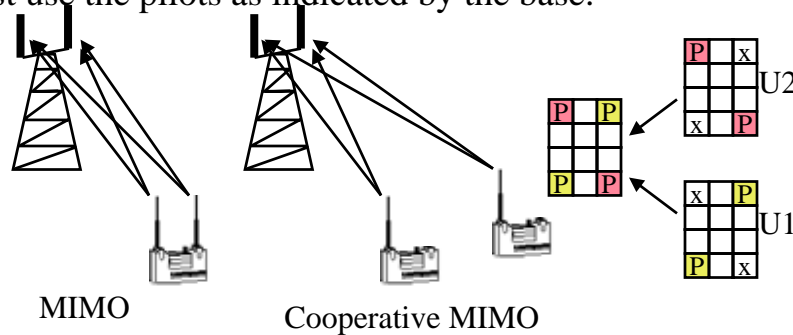
2x3

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

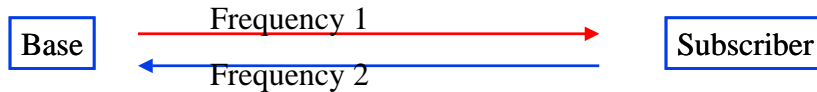
Cooperative MIMO

- 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

Status of WiMAX

- WiBro service started in **Korea** in June 2006
- More than 200 operators have announced plans for WiMAX
 - About half are trialing or have launched pre-WiMAX
 - Two dozen networks in trial or deployed in APAC
 - 15 in Western Europe
- **Sprint-Nextel in 2.3/2.5 GHz**
 - Equipment by Intel, Motorola, Samsung, Nokia, and LG
 - \$3B for radio network over 3 yrs to cover 200M population
 - Initial deployment in Washington DC and Chicago
- Intel has a multi-band WiMAX/WiFi chipset
- **M-Taiwan**

Sample WiMAX Subscriber Stations



Alvarion



Airspan



Axxcelera



Siemens



Aperto



Redline

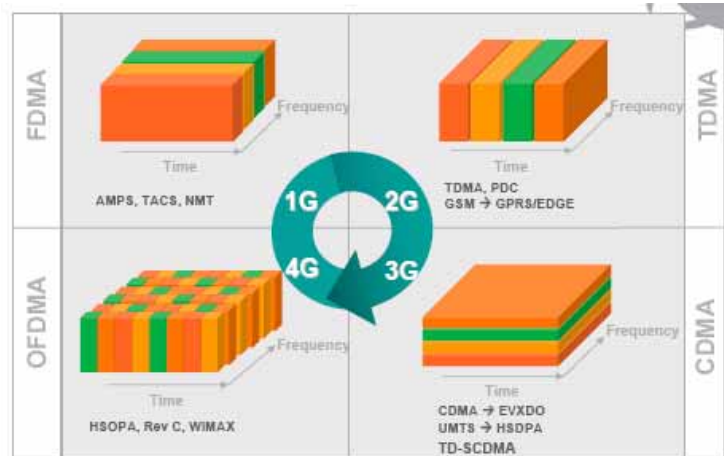


SR Telecom

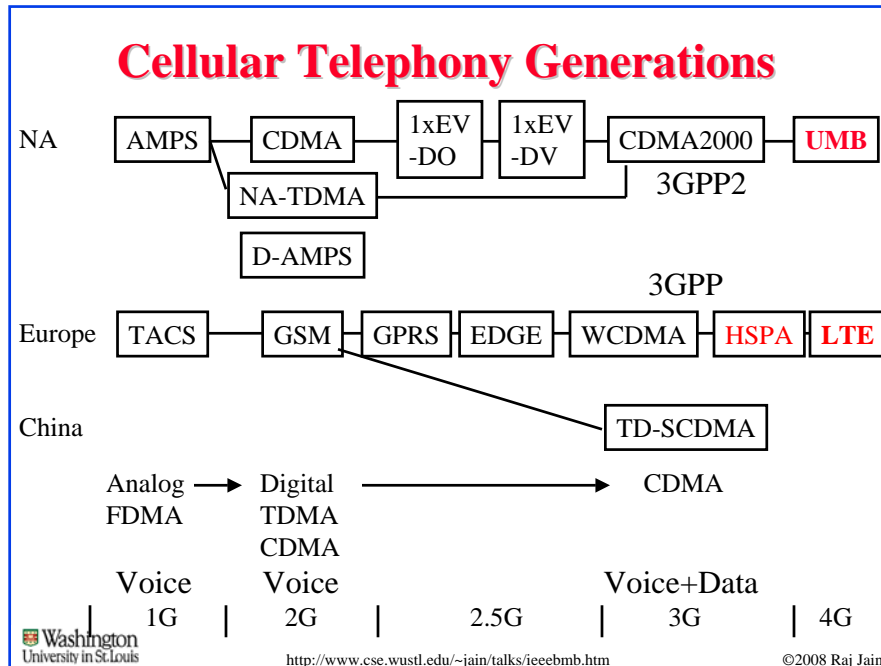


Telsima

Multiple Access Methods



Source: Nortel



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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)

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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