

Wireless Access Networks: Recent Developments, Issues and Trends



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<http://www.cse.wustl.edu/~jain/talks/accnet.htm>



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1. Trends
2. WiMAX
3. Recent developments in wireless PHY
4. Competition
5. Upcoming Technologies



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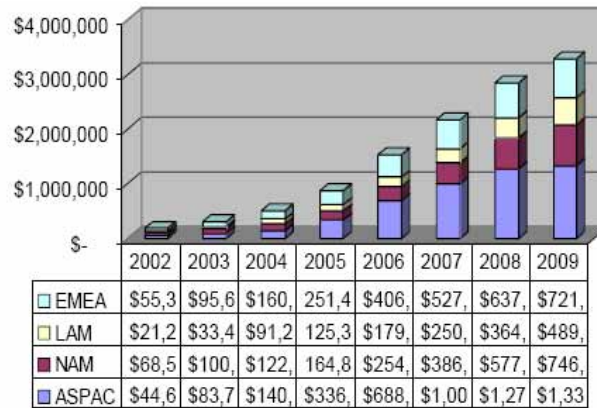
Telecom Revenue

	Revenue in Billions						Annual Growth
	2003	2004	2005	2006	2007	2008	
Video	0.2	0.3	.05	1.0	1.6	2.5	65.7%
Consumer Broadband	2.8	3.5	4.0	4.2	4.6	4.8	11.4%
Consumer long distance	20.7	18.2	16.0	13.6	11.3	9.2	-15.0%
Business local	26.3	26.7	26.4	26.1	25.8	25.5	-0.6%
Business long distance	26.1	24.5	23.0	21.3	19.7	18.2	-7.0%
Business data	44.8	45.6	46.6	47.1	46.8	45.4	0.3%
Consumer local	46.9	42.2	39.0	36.2	34.0	32.3	-7.25%
Wireless	91.5	108.7	119.2	132.8	144.5	153.6	10.9%
Total	260.7	271.5	277.0	285.0	291.3	294.9	2.5%

Source: Instat/MDR (Business Week, Feb 28, 2005)

- ❑ Long distance is disappearing.
 - ❑ 48% of global Telco revenues coming from wireless
 - ❑ 26% of wireless revenues coming from data (vs. voice)
- Third broadband pipe (along with Cable modem, DSL)

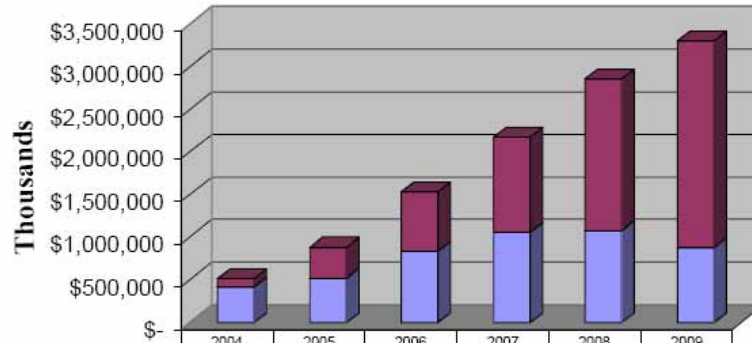
Broadband Market by Regions



- ❑ ASPAC and EMEA leading the growth

Source: Skylight Research

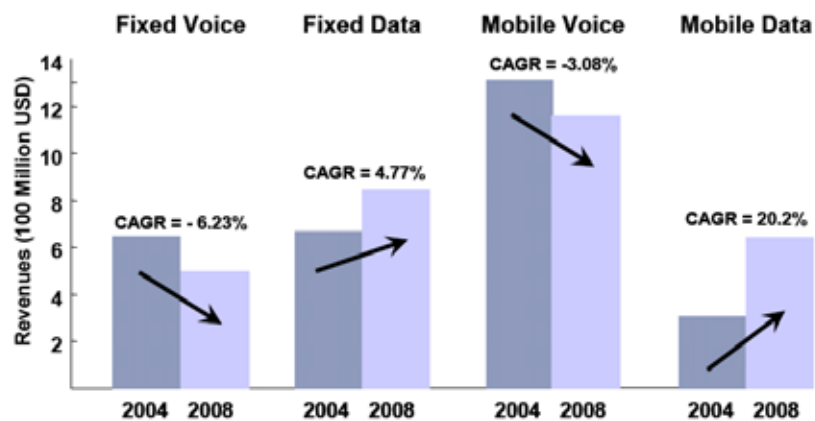
Personal Broadband: Fixed vs. Mobile



Source: Skylight Research

- Mobile broadband is growing

Voice and Data Revenues (Korea)



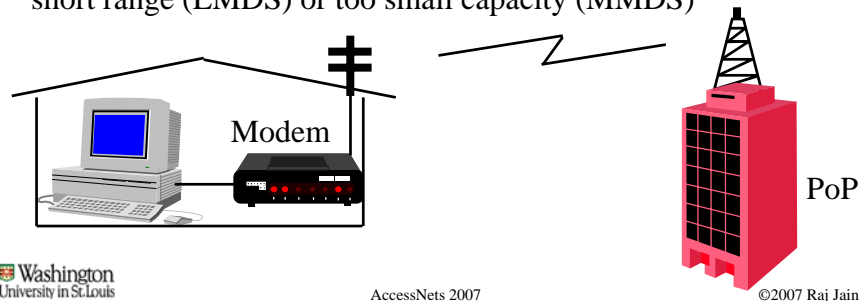
Source: KISDI 2004

- Future growth is in data services

Prior Attempts: LMDS & MMDS

- ❑ Local Multipoint Distribution Service (1998)
- ❑ 1.3 GHz around 28 GHz band (Ka Band)
28 GHz \Rightarrow Rain effects
- ❑ Multi-channel Multipoint Distribution Services (1999-2001)
- ❑ 2.1, 2.5-2.7 GHz Band \Rightarrow Not affected by rain

Issues: Equipment too expensive, Roof top **LoS** antennas, short range (LMDS) or too small capacity (MMDS)



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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>

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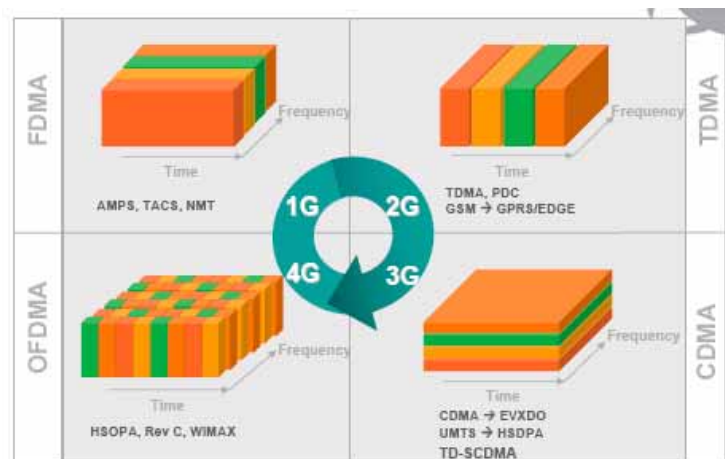
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Six WiMAX Foundation Technologies

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

Multiple Access Methods



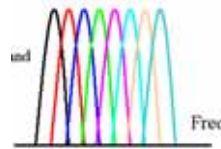
Source: Nortel

1. OFDM

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

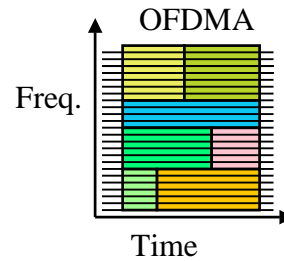
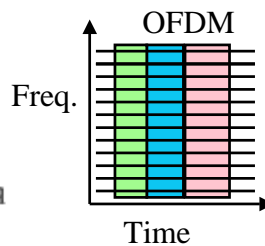
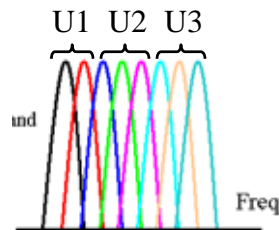


- Frequency band is divided into 256 or more sub-bands.
Orthogonal ⇒ Peak of one at null of others
- Each carrier is modulated with a BPSK, QPSK, 16-QAM, 64-QAM etc depending on the noise (Frequency selective fading)
- Used in 802.11a/g, 802.16, Digital Video Broadcast handheld (DVB-H)
- Easy to implement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



OFDMA

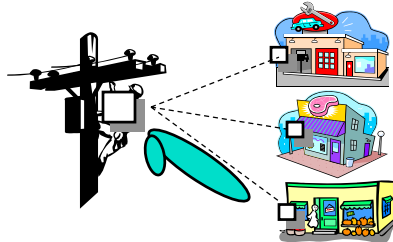
- Orthogonal Frequency Division Multiple Access
- Each user has a subset of subcarriers for a few slots
- OFDM systems use TDMA
- OFDMA allows Time+Freq DMA ⇒ 2D Scheduling



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

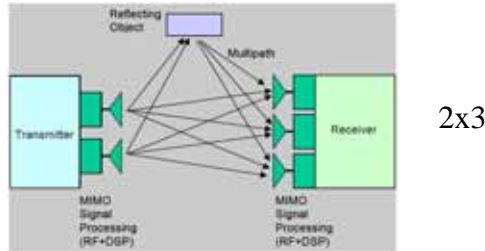


- ❑ Phased Antenna Arrays:
 - Receive the same signal using multiple antennas
- ❑ By phase-shifting various received signals and then summing \Rightarrow Focus on a narrow directional beam
- ❑ Digital Signal Processing (DSP) is used for signal processing \Rightarrow Self-aligning

3. MIMO



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



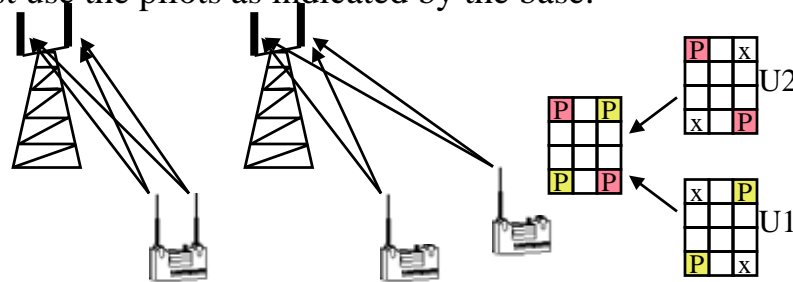
2x3

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.

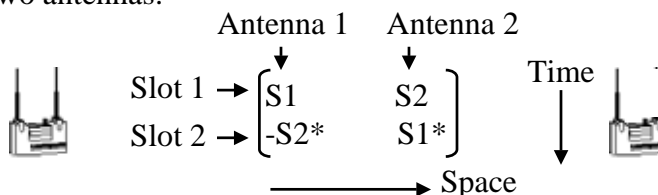


MIMO

Cooperative MIMO

4. Space Time Block Codes (STBC)

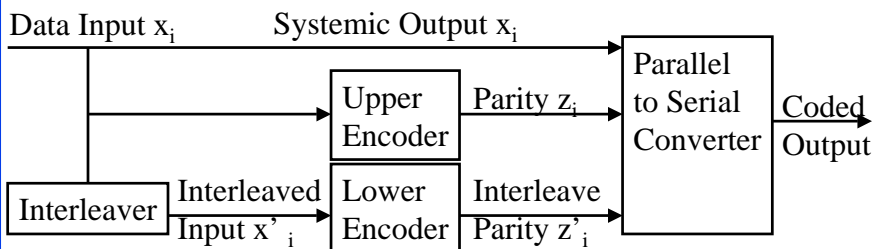
- ❑ Invented 1998 by Vahid Tarokh.
- ❑ Transmit multiple redundant copies from multiple antennas
- ❑ Precisely coordinate distribution of symbols in space and time.
- ❑ Receiver combines multiple copies of the received signals optimally to overcome multipath.
- ❑ Example: Two antennas:



$S1^*$ is complex conjugate of $S1 \Rightarrow$ columns are orthogonal

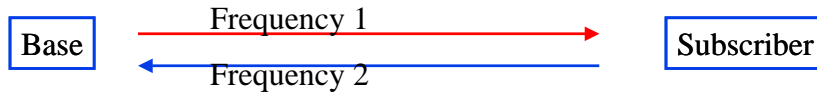
5. Turbo Codes

- ❑ 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

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 will sample a multi-band WiMAX/WiFi chipset in late 2007
- **M-Taiwan**

Sample WiMAX Subscriber Stations



Alvarion



Airspan



Axxcelera



Siemens



Aperto



Redline



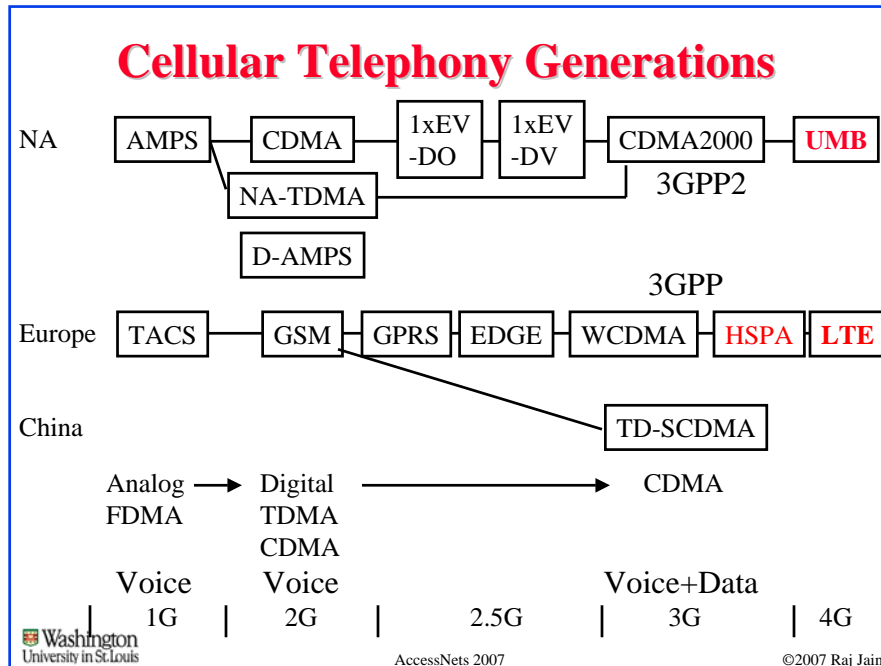
SR Telecom



Telsima

Other Broadband Access Technologies

- ❑ IEEE 802.11
- ❑ High Speed Downlink Packet Access (HSDPA),
High Speed uplink packet access (HSUPA),
High speed packet access (HSPA)
- ❑ Evolution data optimized (EV-DO)
- ❑ Long Term Evolution (3GPP)
- ❑ Ultra Mobile Broadband (3GPP2)
- ❑ IEEE 802.20 (Mobile Broadband), IEEE 802.22
(Regional Area Networks)



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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)

Summary



1. Wireless is the major source of carrier revenue
 ⇒ 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

Spectrum Options

Designation	Frequency GHz	Bandwidth MHz	Notes
3.5 GHz	3.4-3.6; 3.3-3.4; 3.6-3.8	200 Total. 2×(5 to 56)	In 77 Countries. Not in US. Considering 3.65-3.70 for unlicensed
2.5 GHz	2.495-2.690	194 Total. 16.5+6 paired.	In USA.
2.3 GHz	2.305-2.320; 2.345-2.360	2×5 paired. 2×5 unpaired.	US, Kr, Au, Nz
2.4 GHz	2.405-2.4835	80 Total	Lic exempt. World-wide.
5 GHz	5.250-5.350; 5.725-5.825	200 MHz	Worldwide.
700 MHz	0.698-0.746; 0.747-0.792	30+48	US
Adv W. Serv.	1.710-1.755; 2.110-2.155	2×45 paired	Used for 3G