Wireless Metropolitan Area Networks (WMANs)

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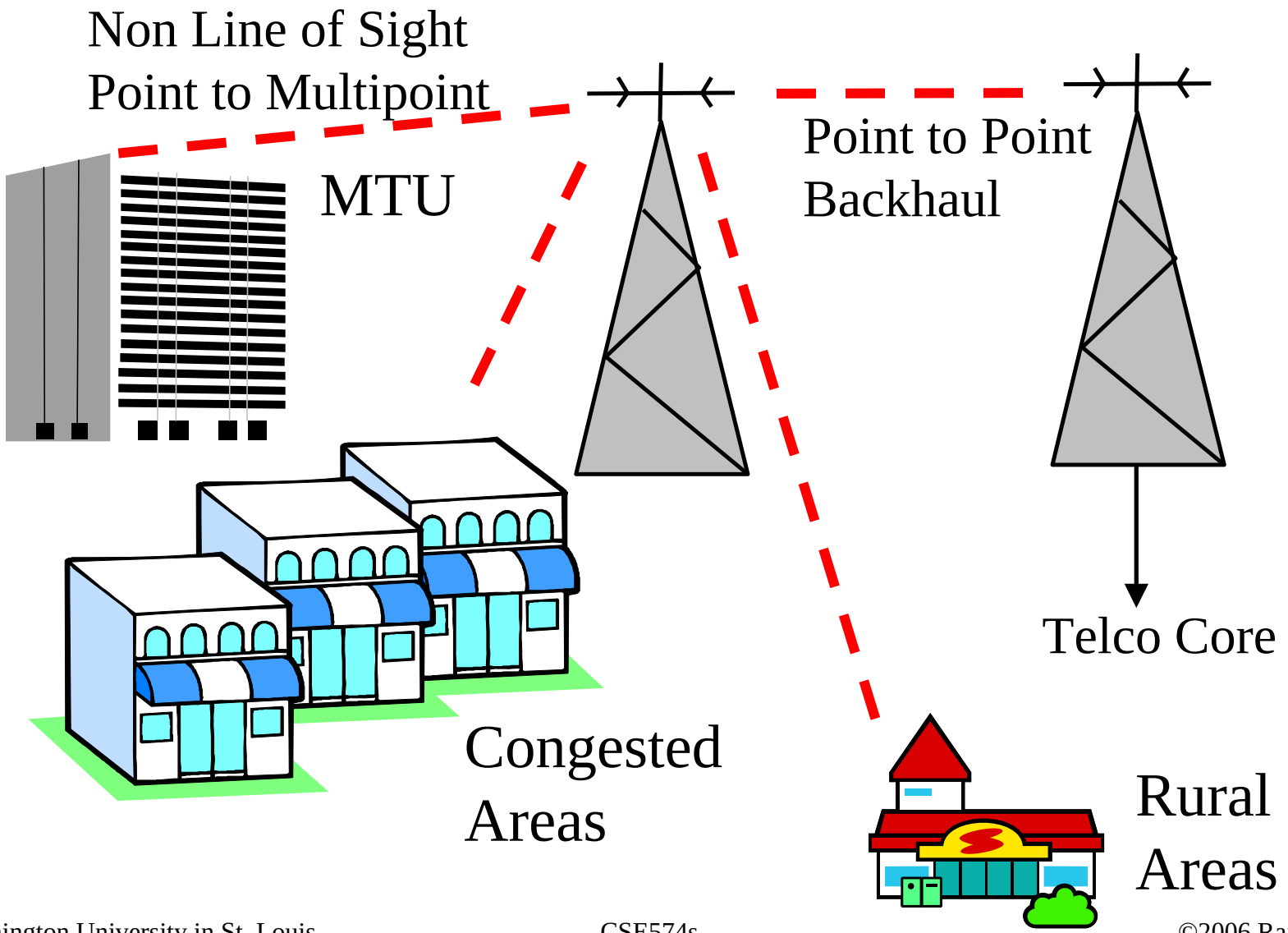
These slides are available on-line at:
http://www.cse.wustl.edu/~jain/cse574-06/

- IEEE 802.16 - WiMAX
- LMDS, MMDS
- IEEE 802.20 – Mobile Broadband Wireless Access
- IEEE 802.21 – Handover
- IEEE 802.22 – Wireless Regional Area Networks

Broadband Wireless Access



IEEE 802.16: Key Features

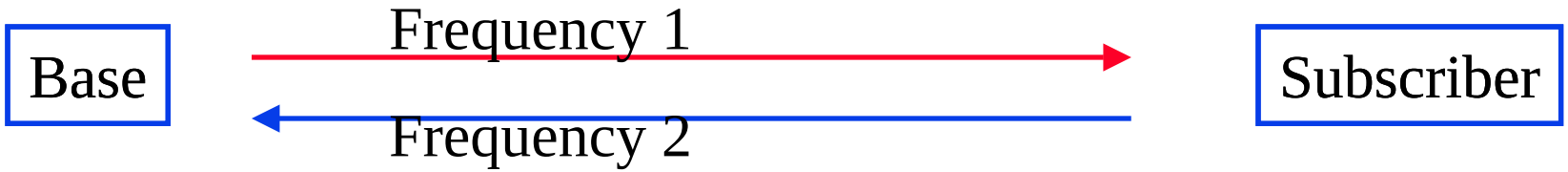
- Broadband Wireless Access
- Up to 50 km. Up to 70 Mbps.
- Data rate vs Distance trade off using adaptive modulation. 64QAM to BPSK
- Offers non-line of site (NLOS) operation
- 1.5 to 28 MHz channels
- Hundreds of simultaneous sessions per channel
- Delivers >1 Mbps per user
- Both Licensed and license-exempt spectrum
- QoS for voice, video, and T1/E1, continuous and bursty traffic
- Support Point-to-multipoint and Mesh network models

WiMAX

- A vendor organization for ensuring interoperability
- A WiMAX certified product will work with other WiMAX certified products
- Plugfests started November 2005
- 3rd WiMAX plug fest in France, March 2006.
- WiMAX forum lists certified base stations and subscriber stations from Aperto Networks, Redline Communications, and SEQUANS Communications
- More to come:
  - Outdoor subscriber stations similar to satellite dish by 2006 ≈$350
  - Indoor subscriber stations by 2006-2007 ≈ $250
  - Portable modems for laptops by 2007-2008 ≈ $100

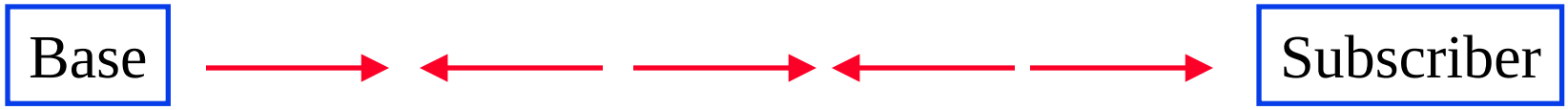
Duplexing Options

- Duplex = Bi-Directional Communication
- Full-Duplex = Both directions at the same time



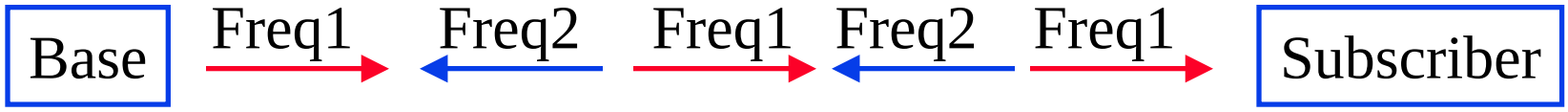
This is known as Frequency division duplexing (FDD)

- Half-duplex = One direction at a time



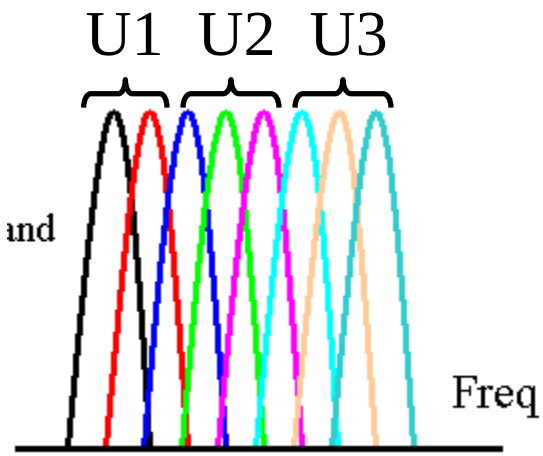
This is known as Time division duplex (TDD)

- Half-Duplex FDD (HFDD): Two frequencies. But either transmitter or receiver is on.



OFDMA

- Orthogonal Frequency Division Multiple Access
- A large number of subcarriers, e.g., 2048
- Each user has a subset of subcarriers
- OFDMA is a form of FDMA



IEEE 802.16 PHYs

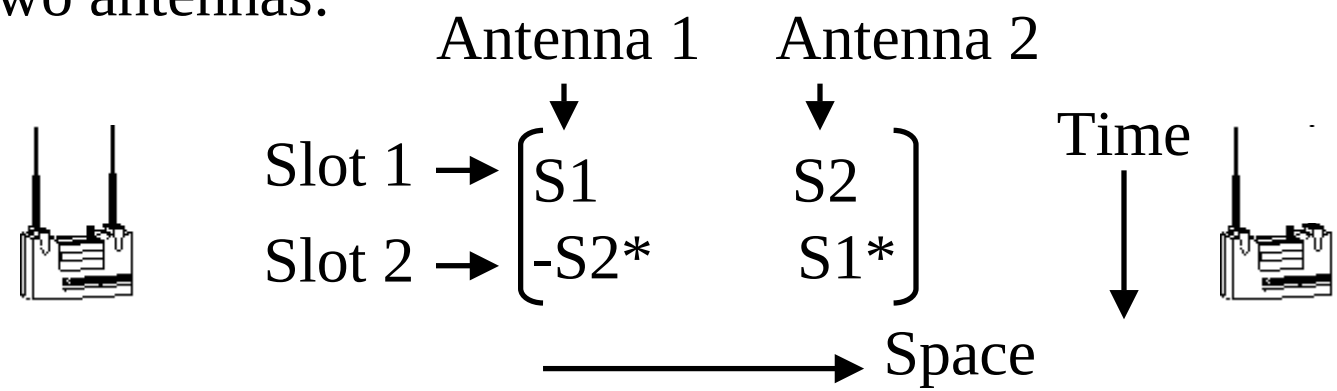
	Function	LOS	Freq. Band	Carrier	Duplexing
WirelessMAN SC	Pt-to-pt	LOS	10-66 GHz	Single	TDD, FDD
WirelessMAN SCa	Pt-to-pt	LOS	2-11 GHz Licensed	Single	TDD, FDD
WirelessMAN OFDM	Pt-to-mpt	NLOS	2-11 GHz Licensed	256	TDD, FDD
WirelessMAN OFDMA (16e)	Pt-to-mpt	NLOS	2-11 GHz Licensed	2048	TDD, FDD
WirelessHUMAN (High-speed Unlicensed)	Pt-to-mpt	NLOS	2-11 GHz License Exempt	1/256/ 2048	TDD Dynamic Freq. Sel.

IEEE 802.16 PHY: Other Features

- Adaptive Modulation and Coding
- Space Time Block Codes (STBC)
- Adaptive Antenna System

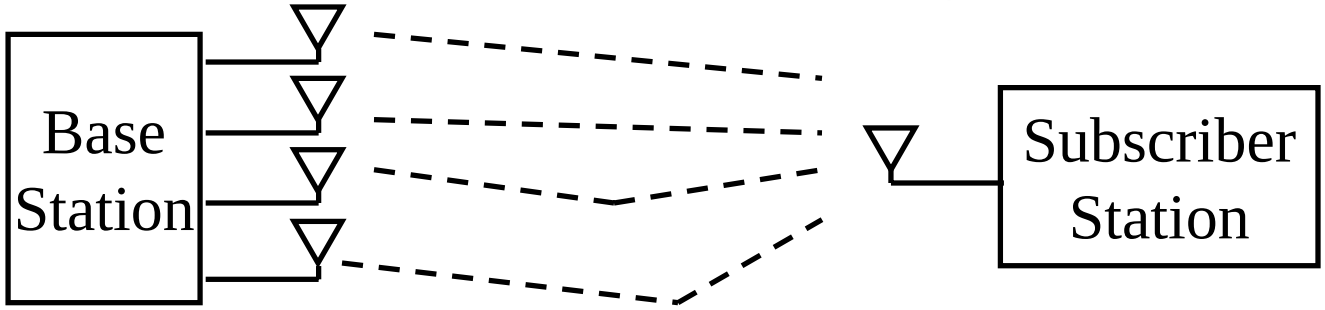
Space Time Block Codes (STBC)

- Invented 1998 by Vahid Tarokh.
- Transmit multiple redundant copies of the data 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:



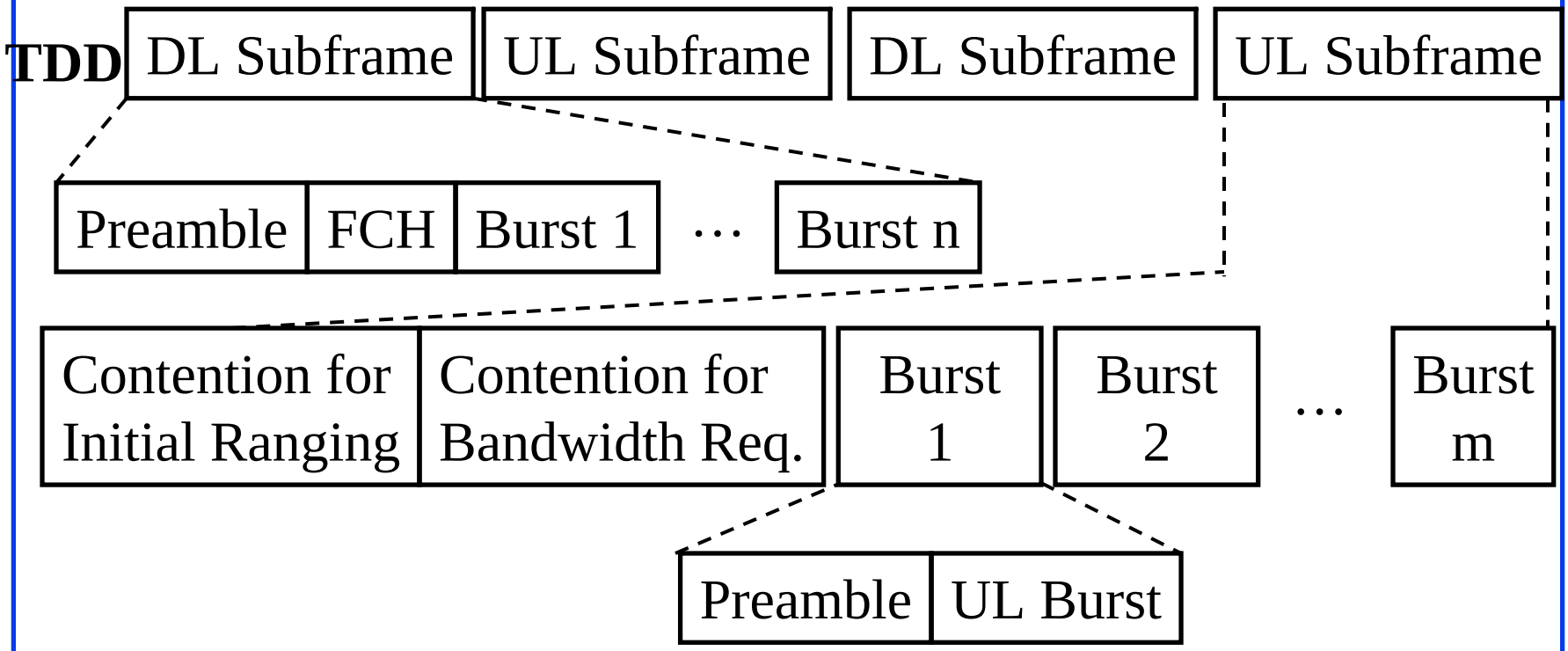
S1* is complex conjugate of S1 $\Rightarrow$ columns are orthogonal

Adaptive Antenna System (AAS)



- Multiple antennas are used to transmit a subset of OFDM subcarriers each
- Example: 4 Antennas. 192 data subcarriers plus 8 pilot subcarriers are divided into 4 groups of 50 subcarriers each. Each of the four antennas transmits one group.
- Receivers perform channel estimation on each beam
- Receivers feedback the channel information to transmitter
- Transmitters adjust the beam forming accordingly
- IEEE 802.16 has MAC messages and burst format required for AAS. Allows mixing non-AAS and AAS subscribers.

802.16 Frame Structure

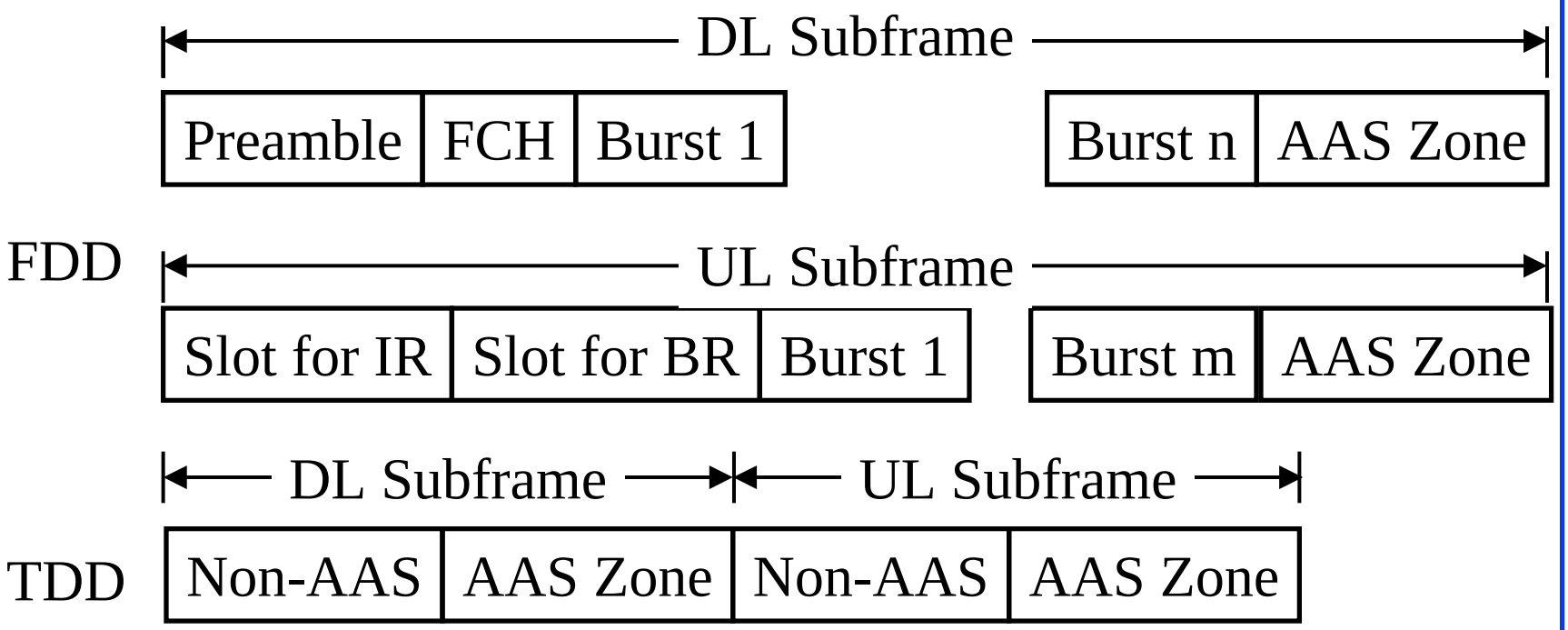


TDD = Time Division Duplexing FDD = Freq Div Duplexing

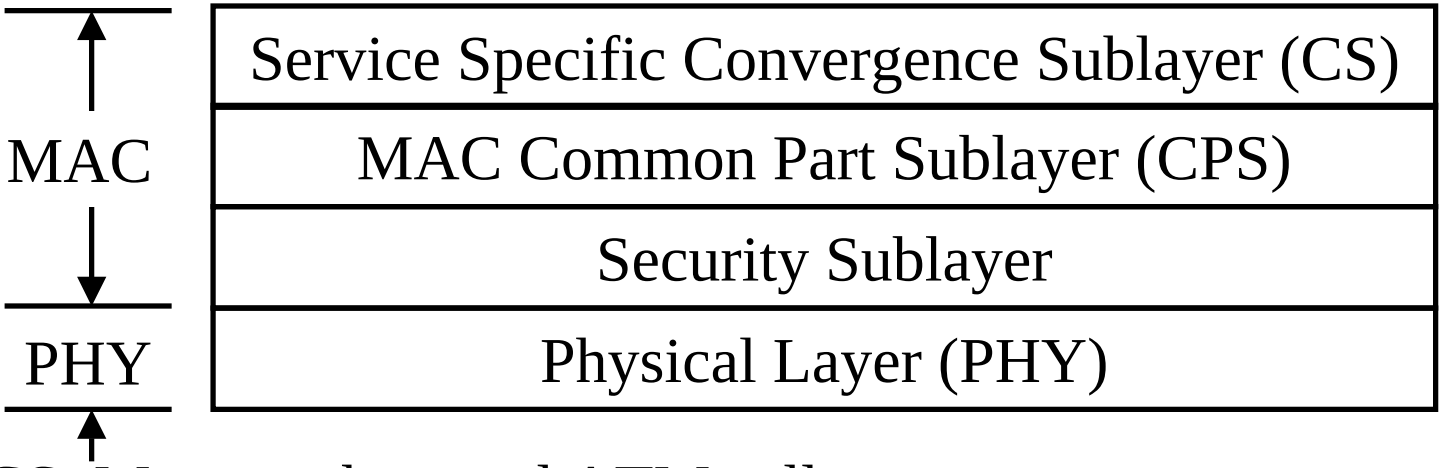
DL = Downlink (Base to subscriber) UL = Uplink

FCH = Frame control header: Burst Profile, Down-link map, Uplink map, DL channel descriptor, etc.

802.16 AAS Zone Structure



IEEE 802.16 Protocol Structure



- CS: Maps packets and ATM cells
- CPS:
  - Fragmentation and reassembly of large MAC SDUs
  - Packing and unpacking of several small MAC SDUs
  - QoS control, Scheduling and retransmission of MAC PDUs
  - Bandwidth request
  - Automatic repeat request (ARQ) using sliding windows

IEEE 802.16 – QoS Classes

Connection oriented: one or more unidirectional connections between subscriber and base

Four Service Classes:

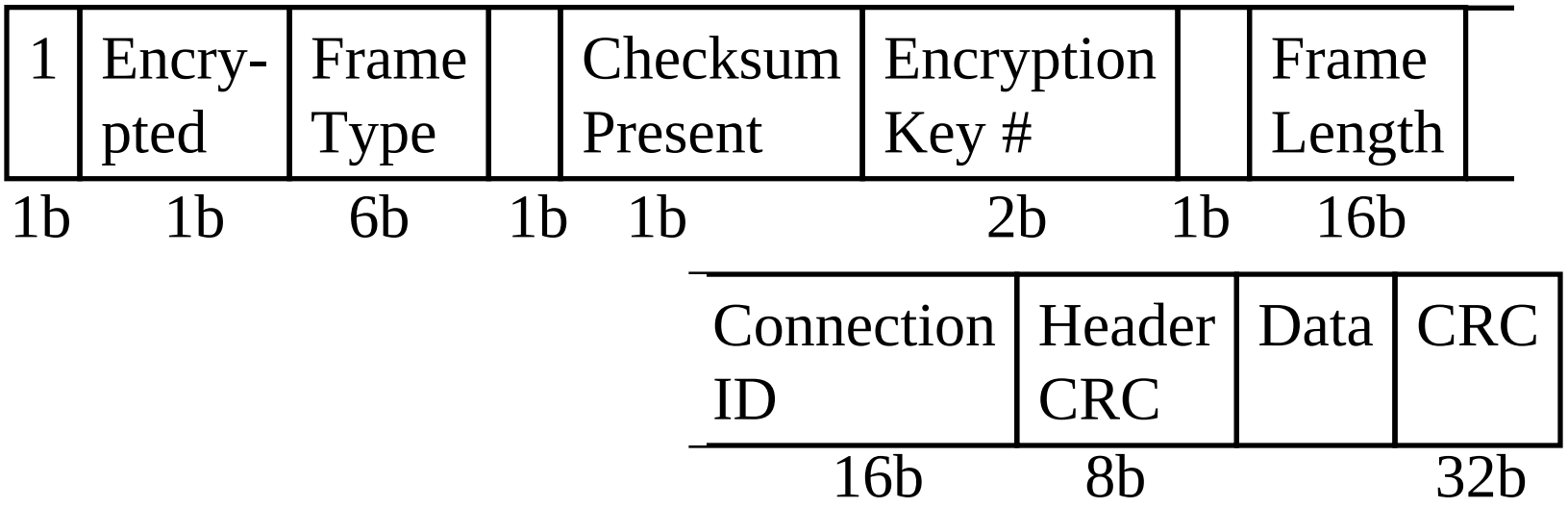
1. Unsolicited Grant Service (UGS):
   CBR traffic like voice
2. Real-Time Polling Services (rtPS):
   rtVBR like MPEG video
3. Non-Real-Time Polling Service (nrtPS):
   nrtVBR, e.g., FTP
4. Best Effort (BE)

Scheduling and Link Adaptation

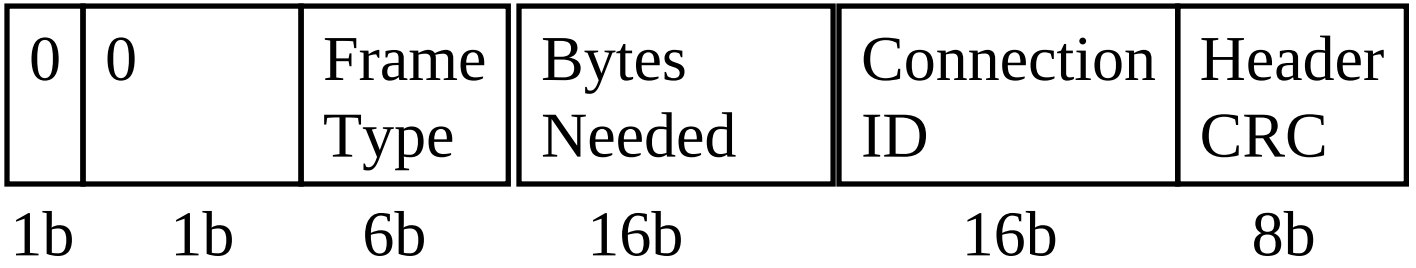
- Scheduling:
  - Base schedules usage of the air link among the subscribers
  - Packet schedulers at the base and subscribers give transmission opportunities to multiple connection queues
- Link Adaptation
  - Base determines the contents of the DL and UL portions of each frame
  - Base determines the appropriate burst profile (code rate, modulation level and so on) for each subscriber
  - Base determines the bandwidth requirements of the individual subscribers based on the service classes of the connections and on the status of the traffic queues at the base and subscriber.

802.16 MAC Frame Format

- **Generic Frame:**



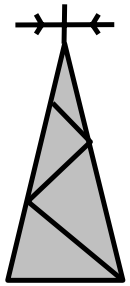
- **Bandwidth Request Frame:**



802.16 MAC Frame Format (Cont)

- Encrypted: 1 or 0
- Frame Type: 6 bits indicating fragmentation, packing
- CRC Indication: 1=> Header CRC is present
- Encryption Key #: which key is being used
- Frame Length: Total frame
- Connection ID
- Header CRC: Optional
- Frame CRC

Subscriber Initialization



Subscriber scans pre-set frequencies for base station

Subscriber finds base transmissions and synchronizes to it

Subscriber sends a ranging-request to BS at low power ←

Subscriber resends a ranging-request to BS at higher powers ←

Base sends ranging response giving management conn IDs →

Subscriber reports its PHY capabilities (modulation, coding, xDD) ←

Base accepts subscriber or rejects some PHY capabilities →

Base-Subscriber Authentication using X.509 Certificates ↔

IEEE 802.16 Standards

- **802.16-2001**: Air Interface for 10-66GHz (Obsolete)
- **802.16a-2003**: Amendment for 2-11GHz, Licensed and Licensed Exempt (Obsolete)
- **802.16c-2002**: 10-66 GHz Profiles, Coexistence and Interoperability (Obsolete)
- **802.16-2004**: Revision incorporating and obsolescing above 3. A.k.a. 802.16d
- **802.16f-2005**: Amendment for MIBs for fixed systems
- **802.16-2004/Cor1-2005**: Corrigendum to 802.16-2004
- **802.16e-2005**: Enhancements to support mobility
- **802.16/Conformance01-2003**: 10-66 GHz Protocol Implementation Conformance Statement (PICS)
- **802.16/Conformance02-2003**: 10-66 GHz Test Suite Structure and Test Purposes (TSS&TP)
- **802.16/Conformance03-2004**: 10-66 GHz Radio Conformance Tests
- **802.16.2-2001**: Coexistence for 10-66 GHz
- **802.16.2-2004**: Revision including 2-66 GHz

IEEE 802.16 Activities

- P802.16/Conformance04: <11 GHz
- P802.16g: Management Plane Procedures and Services
- P802.16j: Mobile MIB
- 802.16h: License-exempt channel coordination
- Mobile Multihop Relay (MMR) study group

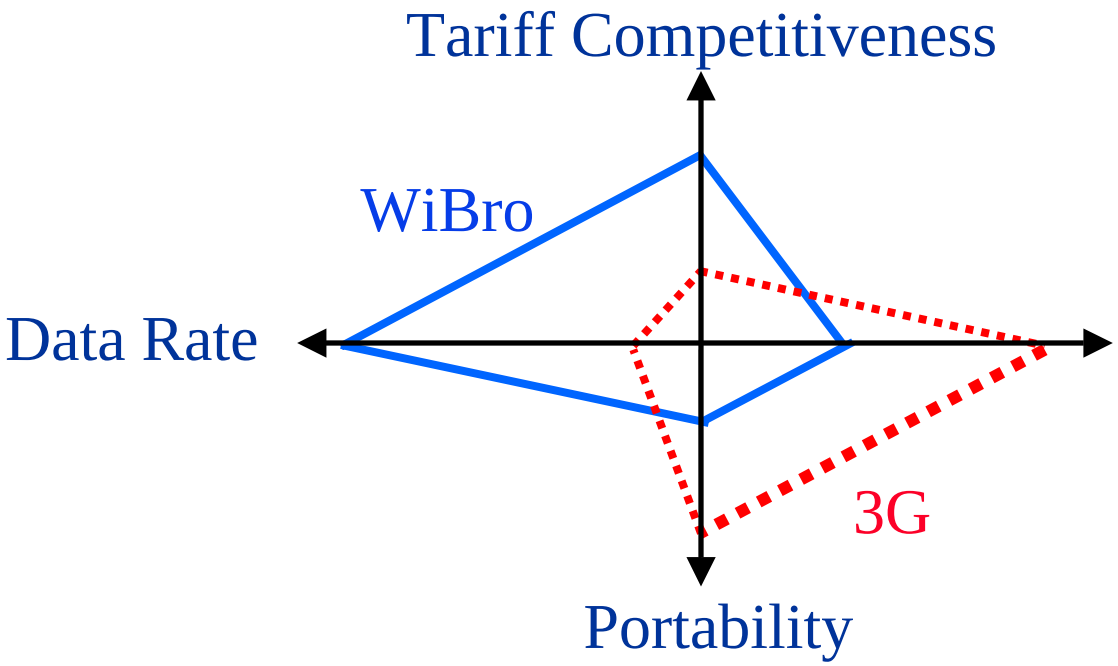
IEEE 802.11 vs 802.16

	802.11	802.16
Application	In-Building, Enterprise	Service providers => Carrier Class
Range	Optimized for 100m	Optimized for 7-10 km Up to 50 km
Range Spread	No near-far compensation	Handles users spread out over several kms
# Users	10's of users	Thousands of users
Coverage	Optimized for indoor	Optimized for outdoor. Adaptive modulation. Advanced Antenna
Bands	License exempt	License and license exempt bands Allows Cell Planning
Channels	Fixed 20 MHz Channel	1.5 MHz to 20 MHz Channels Size chosen by operator
Spectral Efficiency	2.7 bps/Hz ⇒54 Mbps in 20 MHz	3.8 bps/Hz ⇒ 75 Mbps in 20 MHz 5 bps/Hz ⇒ 100 Mbps in 20 MHz
Delay Spread	Designed to handle indoor multipath Delay spread of 0.8 \ms	Designed for longer multipaths. Multipath delay spread of 10\ms.
Duplexing	TDD only - Asymmetric	TDD/FDD/HFDD – Symmetric or asymmetric
MAC	Contention based. Distributed control.	Grant based. Centralized control.
QoS	No delay or throughput guarantees	Guarantees QoS
User Differentiation	All users receive same service	Different users can have different levels of service. T1 for businesses. Best effort for residential.
Security	WEP, WPA, WPA2	128-bit 3DES and 1024-bit RSA

WiBro

- Mobile broadband access standard for Korea
- A pre-standard version of 802.16e
  Will conform to 802.16e in the near future
- Standardized 1H04, Licenses issued 1H05, Service starts 1H06
- Up to 60 km/h mobility, 1km cells
- Spectral efficiency:
  Max: 6 bps/Hz/sector UL/ 2 bps/Hz/sector DL
  Avg: 2 bps/Hz/sector UP/ 1 bps/Hz/sector DL
- 10 MHz channel in 2.3 GHz band
- OFDMA with QPSK, QAM16, QAM64 modulation
- Per Subscriber Data rate:
  UL/DL = 3 Mpbs/1 Mbps (max) = 512 kbps/128 kbps (mobile)
- Handoff $\leq$ 150 ms

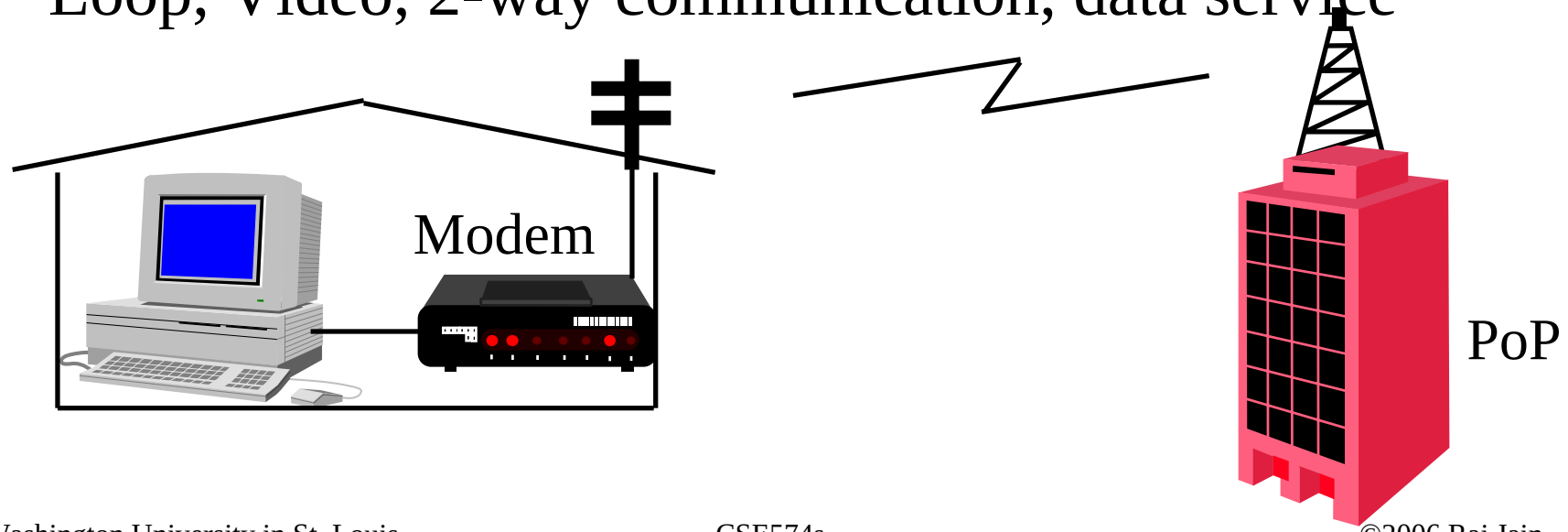
Wibro vs 3G



Source: KT

LMDS

- Local Multipoint Distribution Service (LMDS)
- Local ⇒ Within one cell. 2 to 5 miles range.
- Multipoint ⇒ Broadcast from base. Point-to-point from subscriber.
- Distribution ⇒ Multiple services = Wireless Local Loop, Video, 2-way communication, data service

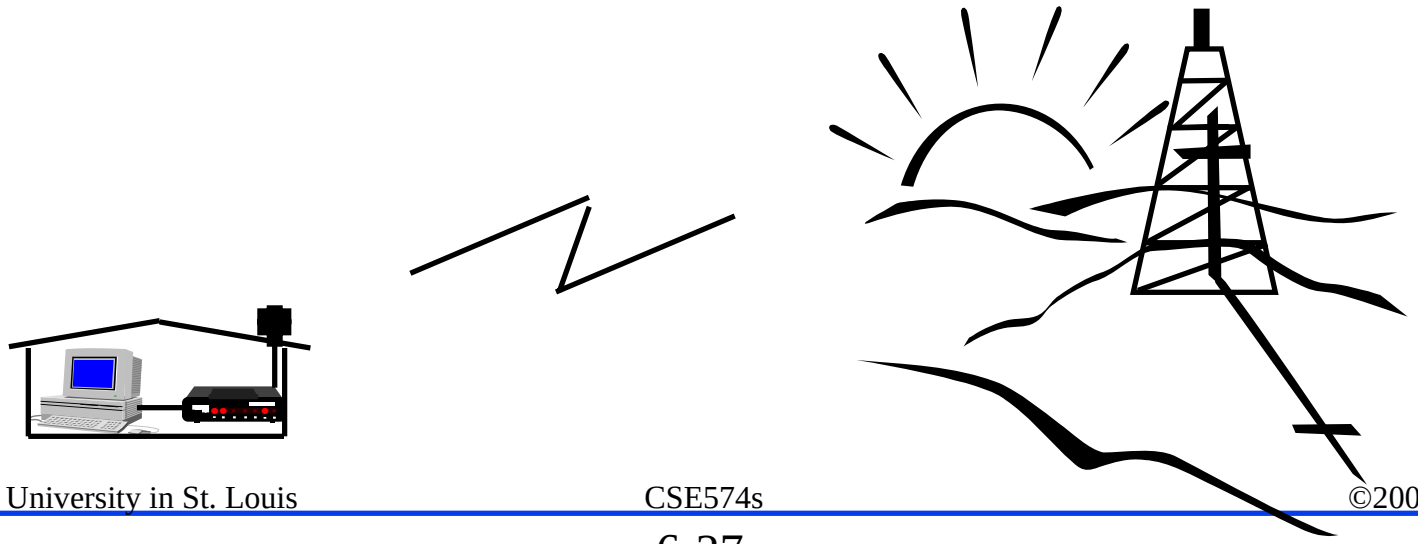


LMDS (Cont)

- 1.3 GHz around 28 GHz band (Ka Band)
  28 GHz $\Rightarrow$ Rain effects
- 1 Gbps downstream and 200 Mbps upstream
  Most commercial offerings T1/E1
- FCC auctioned LMDS spectrum in 1998.
  A Block: 27.5-28.35GHz, 29.10-29.25GHz
  B Block: 31.00-31.075 GHz, 32.225-32.300 GHz
- Using TDMA, FDMA, or CDMA
- CellularVision offers 49-channel cable TV service using LMDS in NYC.
- NextLink, Teligent, and Winstar offer ATM-based service
- Equipment too expensive and short distance (100m or less)

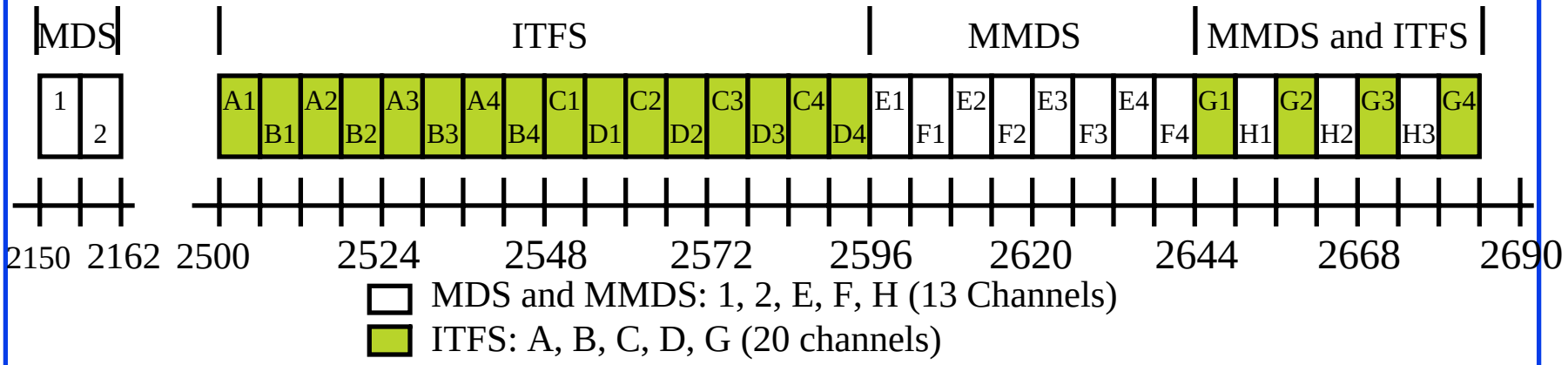
MMDS

- Multi-channel Multipoint Distribution Service (MMDS)
- 35-mile radius protected service areas or 3850 sq. miles per base
- Omni-directional or sectorized antennas on TV towers
- 99 data streams at 10 Mbps each
- Wireless cable for internet access in rural areas



MMDS (Cont)

- Multipoint Distribution Service (MDS), Multichannel Multipoint Distribution Service (MMDS), and Instructional Fixed Television Fixed Service (ITFS) have 33 TV channels of 6 MHz each
  ⇒ Over 1 Gbps using advanced coding
- 2.1, 2.5-2.7 GHz Band ⇒ Not affected by rain
- Line of sight. Alternative to DSL

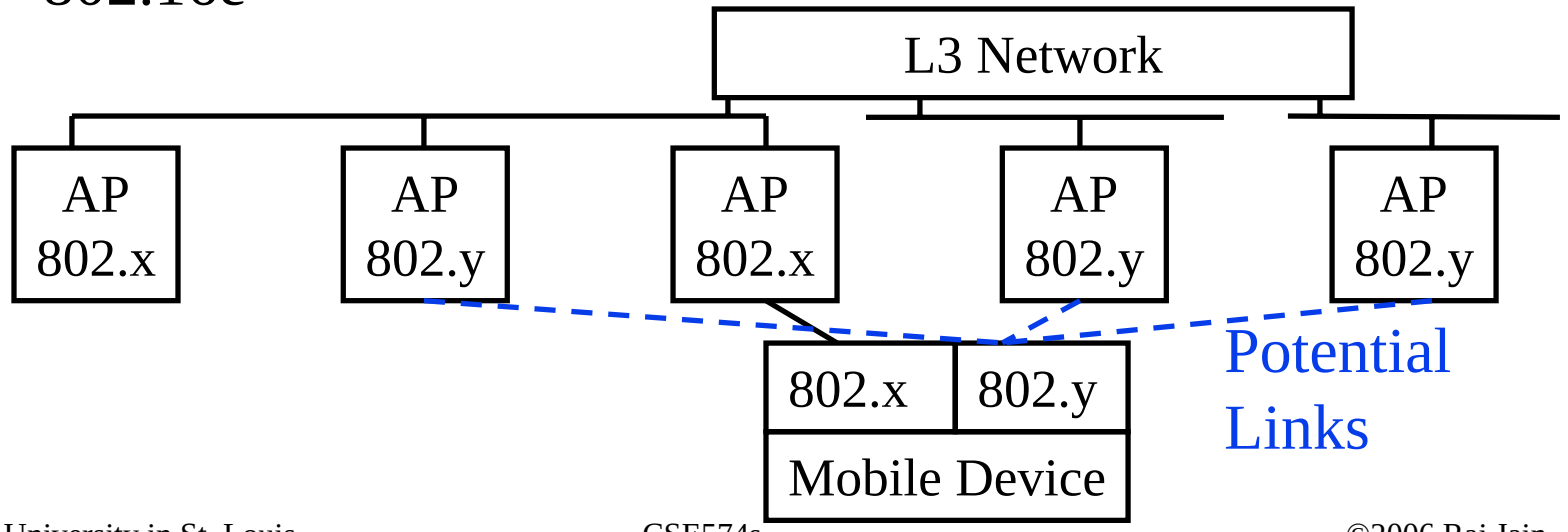


IEEE 802.20

- Mobile Broadband Wireless Access (MBWA)
- Optimized for IP data transport
- Licensed band below 3.5 GHz
- >1 Mbps data rate
- Vehicular mobility up to 250 Km/h
- Designed for green field wireless data providers
- Incumbent cellular providers with voice services may prefer 3G

IEEE 802.21

- Formed Nov 03
- Handoff between 802.3, .11,.15,.16, …
- Example Scenario:
  - Docked Laptop with 802.3, 802.11, and 802.16e
  - Laptop undocks and switches to 802.11
  - User moves outside the building, laptop switches to 802.16e



IEEE 802.22

- Wireless Regional Area Networks
- Unused TV channels – 56 MHz to 862 MHz
- Lower frequency ⇒ Longer distances
  ⇒ Good for sparsely populated rural areas
- Project started: Sept 2004
- Expected completion date: June 2007

Summary

1. IEEE 802.16 or WiMAX is designed for metro-wide access at high speed.
2. 802.16 MAC provides Strong QoS using per subscriber coding, resource allocation, and scheduling
3. 802.16 PHY uses OFDMA, Space time block codes, Adaptive antenna system
4. LMDS provides short distance service using 28 GHz while MMDS provides long distance service using 2 GHz.
5. 802.20 will provide mobility, 21 will provide handoff and 22 provides RAN using television frequencies.

Reading Assignment

- Read section 3.9 of Murthy and Manoj

Homework 6

Match the pairs:

1. OFDMA	1. Interoperability
2. WiMAX	2. Half-duplex
3. TDD	3. 66 GHz
4. WirelessHUMAN	4. UGS
5. STBC	5. Korea
6. CBR	6. License Exempt
7. AAS	7. Multiple Trans. Antenna
8. WiBro	8. Power Adjustment
9. Ranging	9. 2048 subcarriers
10. WirelessMAN SC	10. Zone

References

- Space Time Block Codes, http://en.wikipedia.org/wiki/Space-time_block_code
- Adaptive Antenna System, http://www.macltd.com/datafile_downloads/MAC%20Ltd%20-%20AAS%20for%20WiMAX.pdf

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