

WiMAX

Part I: PHY

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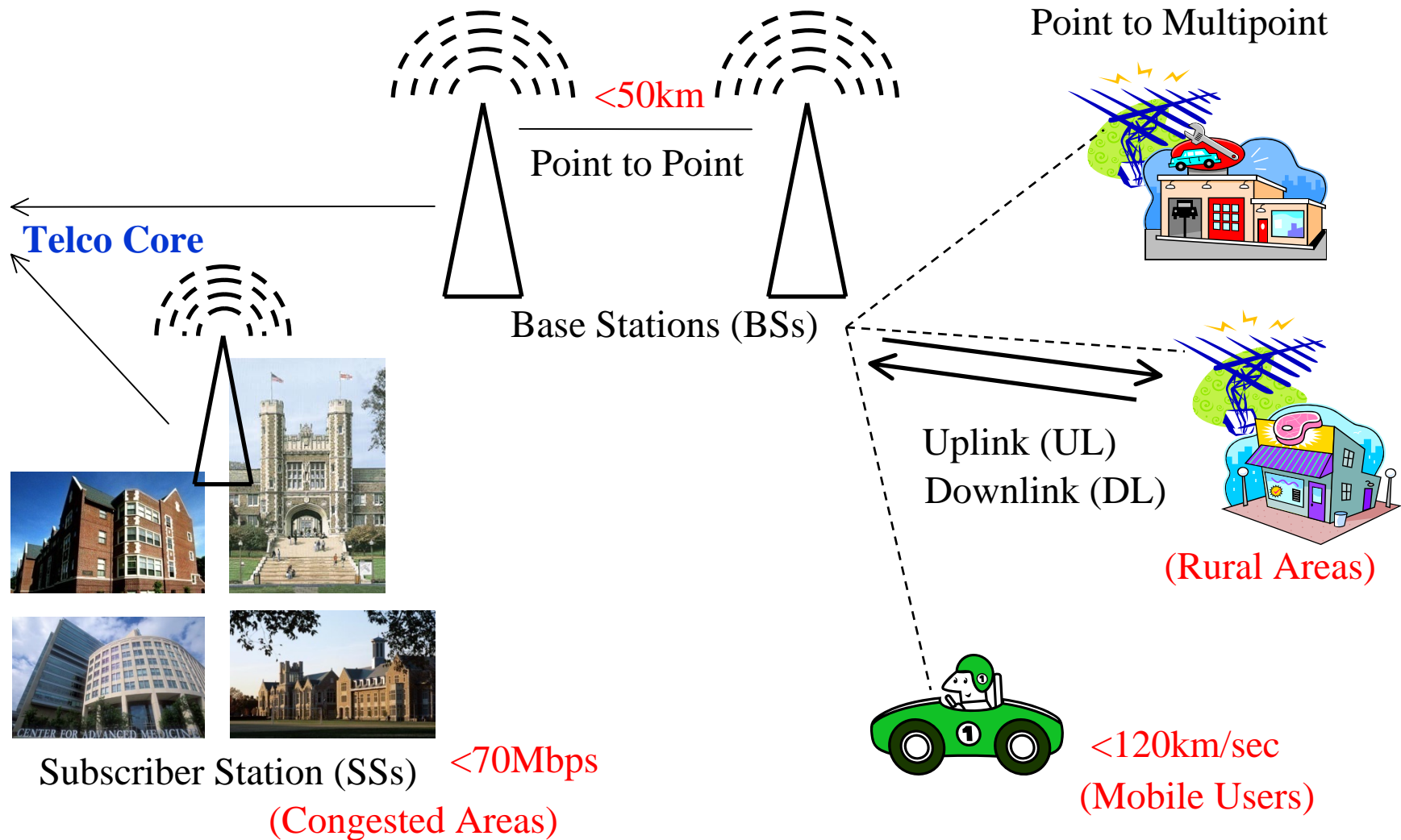
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<http://www.cse.wustl.edu/~jain/cse574-10/>

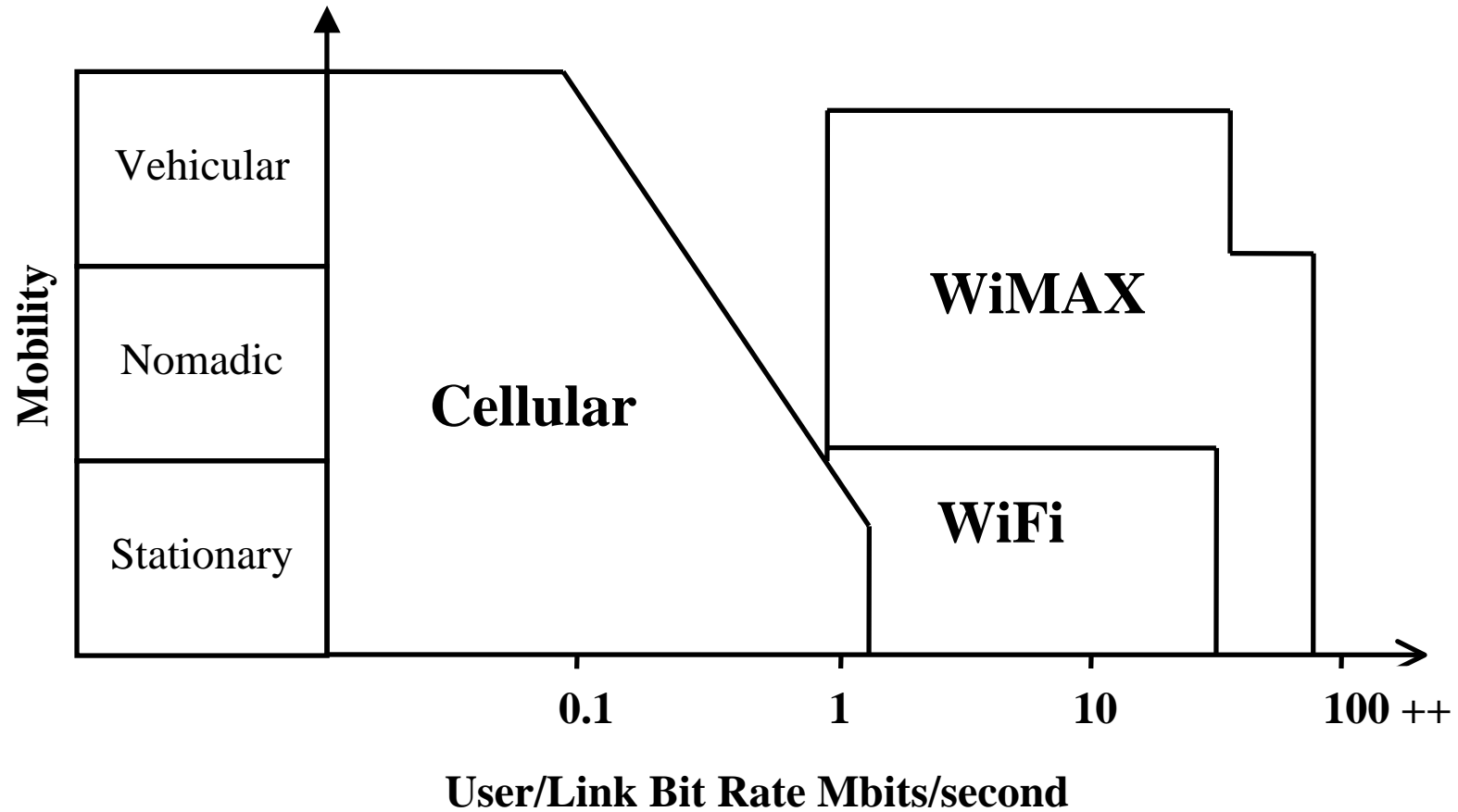


- ❑ What is WiMAX
- ❑ Previous Broadband Wireless Access: LMDS, MMDS
- ❑ WiMAX PHY Layer
- ❑ Frequency Reuse
- ❑ Subchannelization
- ❑ Frame structure

What is WiMAX?



Data rate vs. Mobility



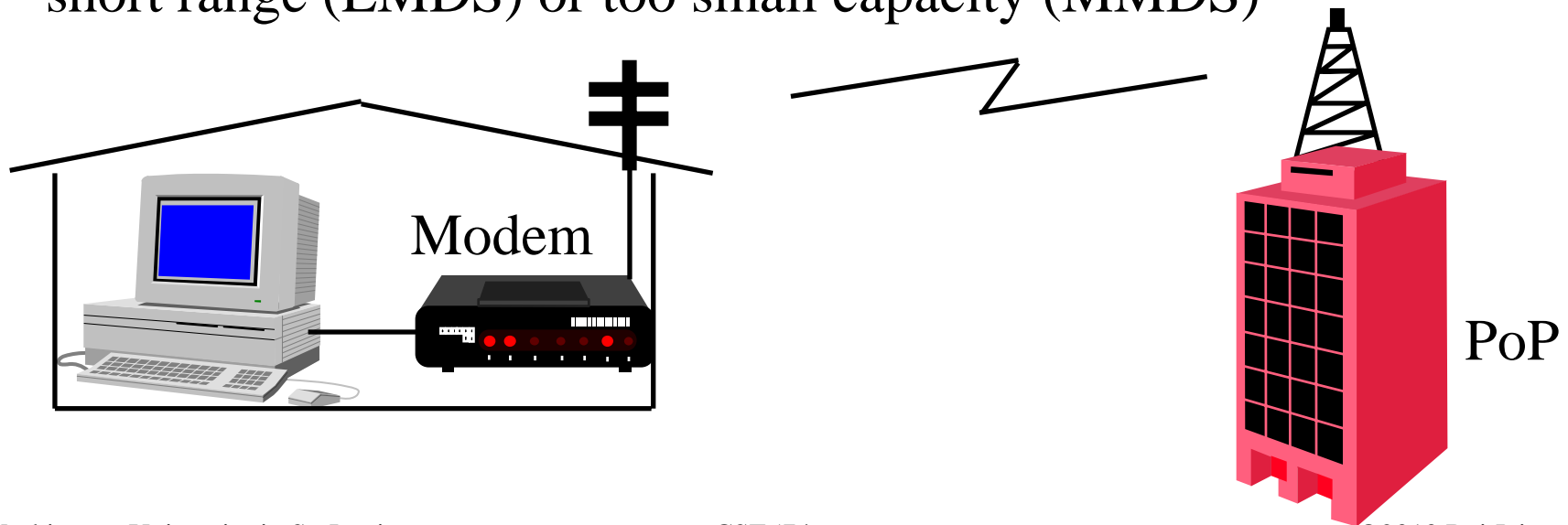
Key Features of WiMAX

- ❑ Works on many bands: 2.3 GHz, 2.5 GHz, 3.5 GHz, ...
- ❑ Scalable \Rightarrow Can use any available spectrum width: 1.25 MHz to 28 MHz
- ❑ Strong security
- ❑ Open technology like WiFi
- ❑ Reach and mobility like Cellular but much higher data rates
 - High data rate, up to 70Mbps
 - Long distance, up to 50kms
 - Mobility, up to 120 to 150 km/hour
- ❑ Data rate vs Distance trade off using adaptive modulation. 64QAM to BPSK
- ❑ Offers non-line of site (NLOS) operation
- ❑ Strong QoS \Rightarrow Guaranteed services for data, voice, and video

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)



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>

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)	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

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

IEEE 802.16 PHYs

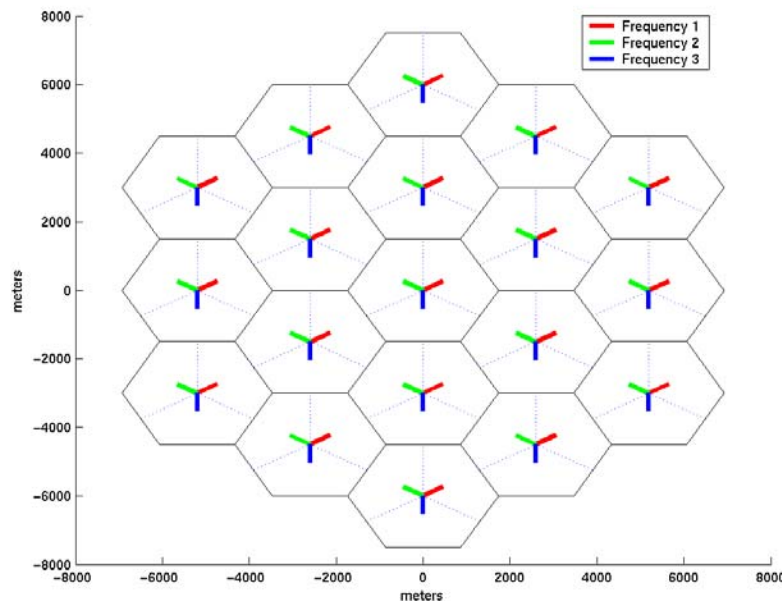
	Function	LOS	Freq. Band	Carrier	Duplexing
WirelessMAN SC	Pt-to-pt	LOS	10-66 GHz	Single	TDD, FDD
WirelessMAN SCa	Pt-to-pt	LOS	2-11 GHz Licensed	Single	TDD, FDD
WirelessMAN OFDM (16d)	Pt-to-mpt	NLOS	2-11 GHz Licensed	256	TDD, FDD
WirelessMAN OFDMA (16e)	Pt-to-mpt	NLOS	2-11 GHz Licensed	2048	TDD, FDD
WirelessHUMAN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

IEEE 802.16 PHY: Features

- ❑ Features discussed previously:
 - Scalable OFDMA
 - TDD and FDD
 - Adaptive Modulation and Coding
 - Space Time Block Codes (STBC)
 - Adaptive Antenna System
- ❑ Other Features:
 - Subchannelization and permutation
 - Slots, tiles, and clusters, bursts

Frequency Reuse

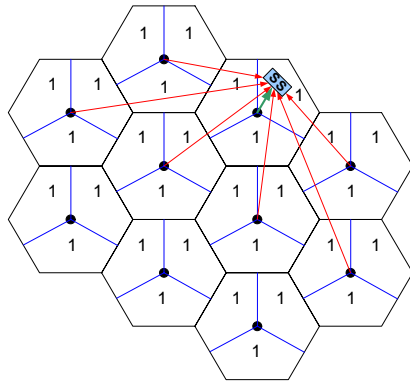
- $N \times S \times K$ frequency reuse pattern
- N = Number of cells per cluster
- S = Number of sectors in a cell
- K = Number of frequency allocations per cell



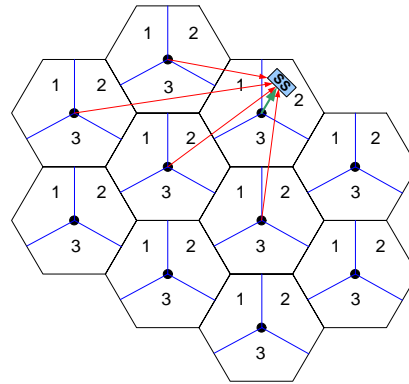
1X3X3

Frequency Reuse (Cont)

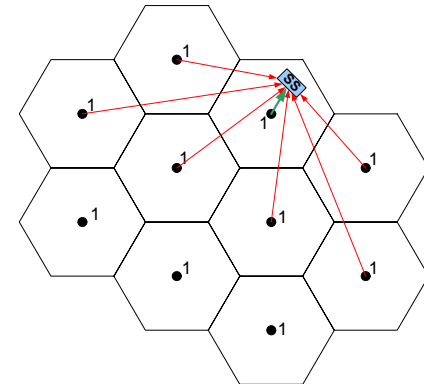
1x3x1



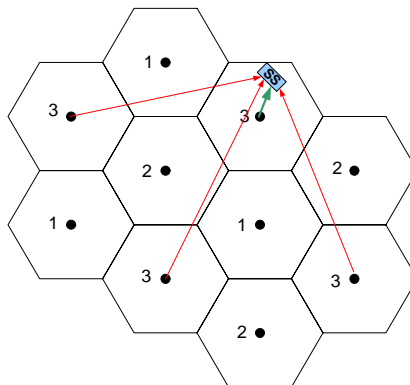
1x3x3



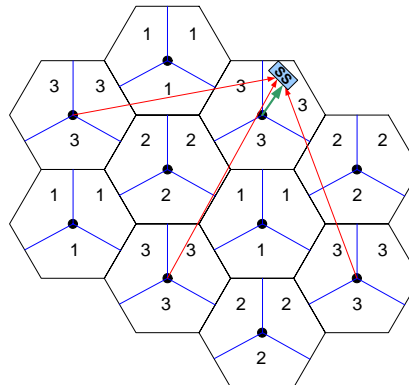
1x1x1



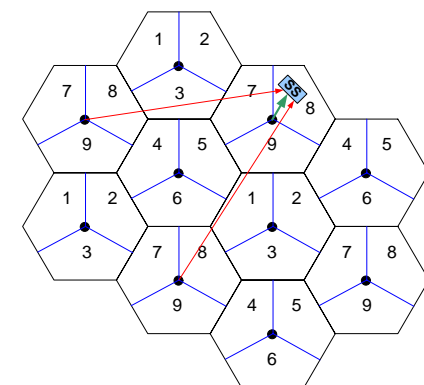
3x1x1



3x3x1

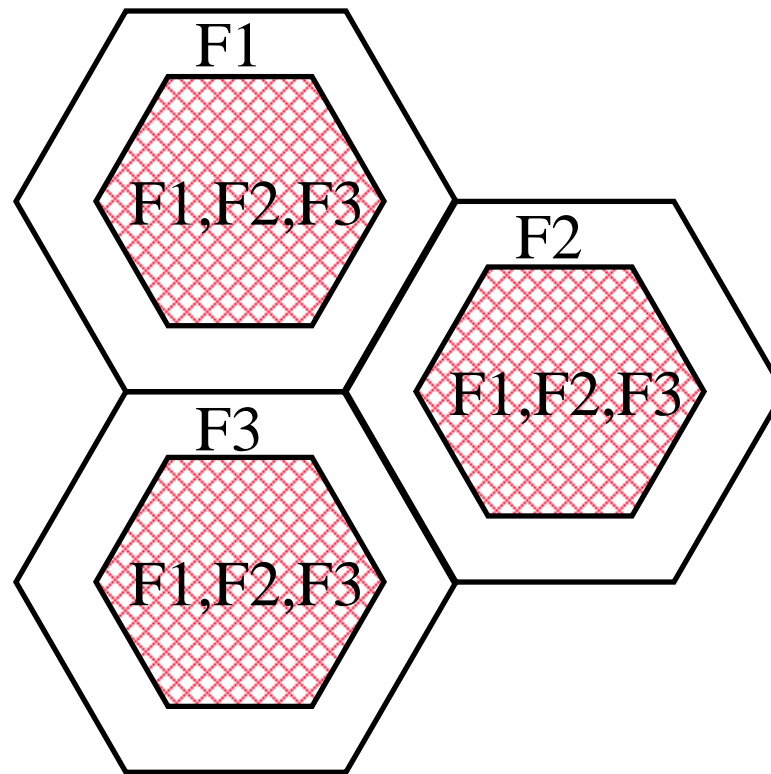


3x3x3



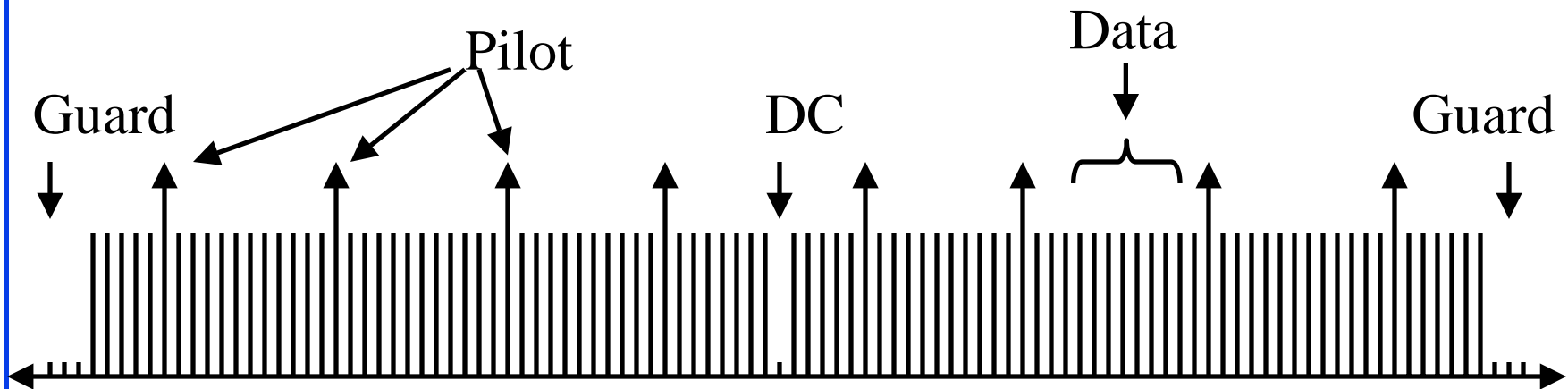
Fractional Frequency Reuse

- ❑ Users close to the BS use all frequency subchannels
- ❑ Users at the cell boundary use only a fraction of available subchannels



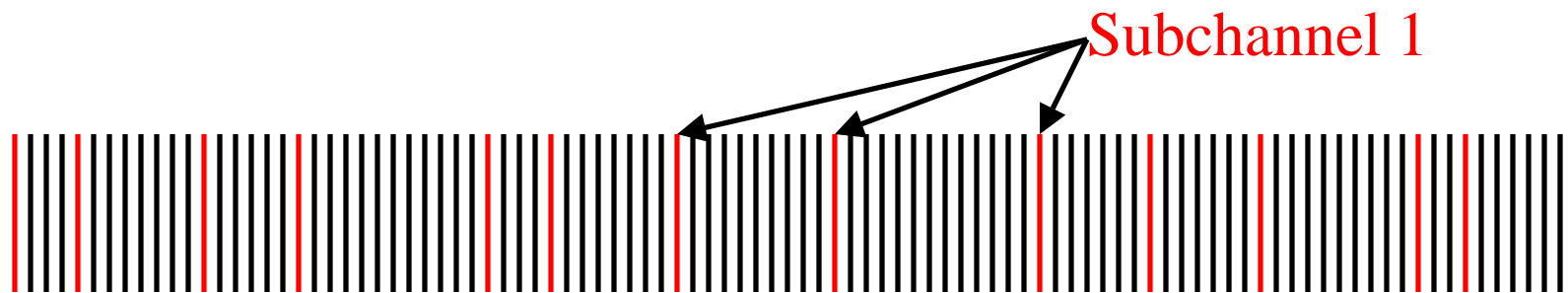
OFDM Subcarriers

- ❑ Data subcarriers
- ❑ Pilot Subcarriers: Used for channel estimation
- ❑ Guard subcarriers: At the edges. No power
- ❑ DC subcarrier: At the center for frequency band. No power.



Subchannelization

- ❑ Subchannel = Group of subcarriers
- ❑ Each user is given one or more subchannel.
- ❑ Subcarriers of a subchannel can be contiguous or distributed



- ❑ Contiguous
 - ⇒ Subchannels allocated based on use's SINR
 - ⇒ Band AMC ⇒ Not suitable for mobile applications

Subcarrier Permutations

- ❑ Subcarriers are randomly assigned to a channel and changed every symbol time \Rightarrow Frequency hopping
- ❑ All subcarriers are used \Rightarrow Full Usage of Subcarriers (FUSC) – Not in WiMAX Forum Profiles
- ❑ Partial Usage of Subcarriers (PUSC)
 - in WiMAX Forum profiles \Rightarrow commonly used

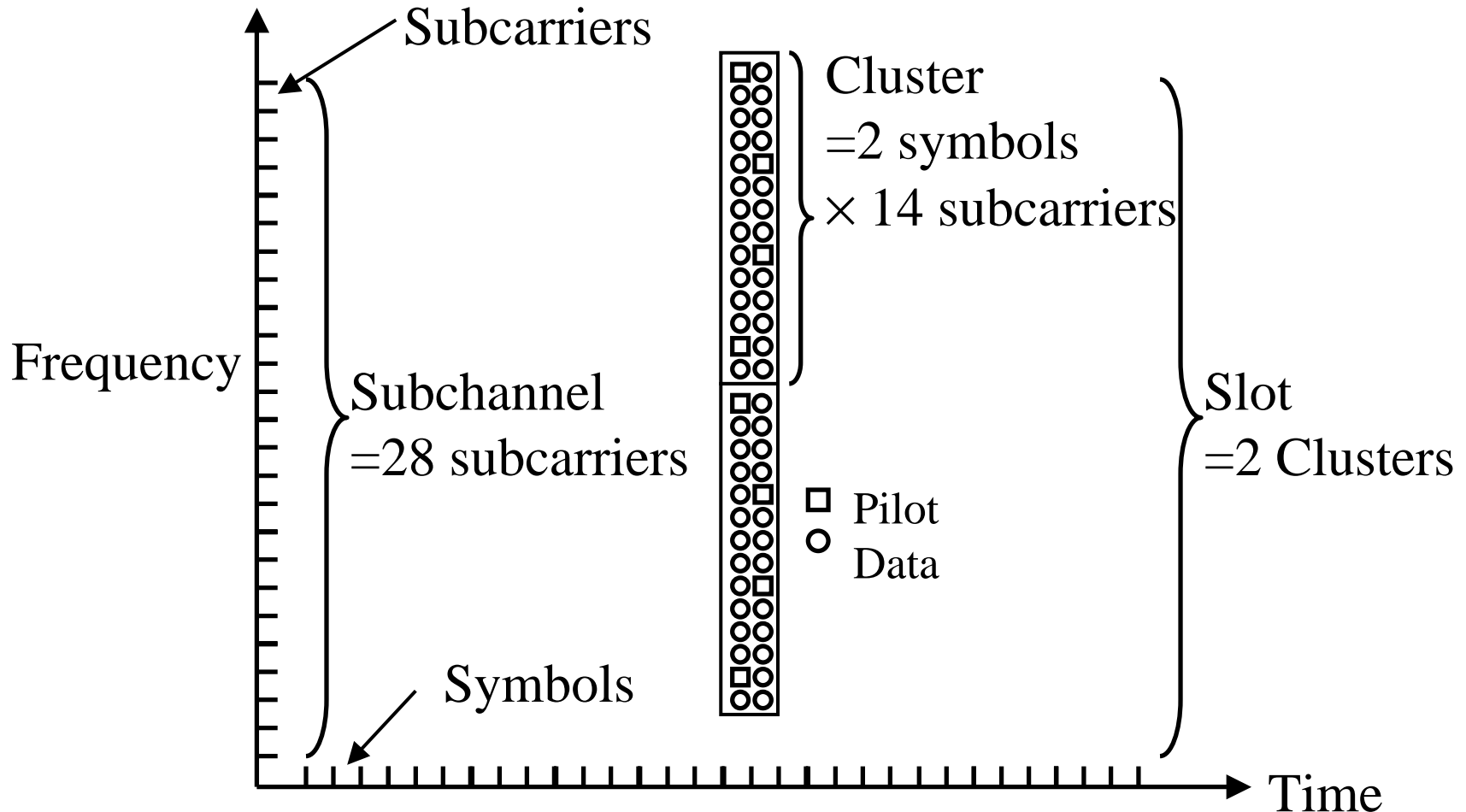
Downlink Partial Usage of Subcarriers

- ❑ Subcarriers are divided into 6 groups and only some groups may be used in a sector or cell
- ❑ Data and pilots are arranged in clusters of 14 subcarriers over 2 symbols = 24 data + 4 pilot
- ❑ Clusters are renumbered using a pseudo random numbering scheme
- ❑ The clusters are then divided into 6 groups (segments 0 through 5)
- ❑ Subchannel = Two clusters from the same group
- ❑ It is possible to allocate some subset of groups to each transmitter in a cell, e.g., 2 groups per sector

Symbols, Clusters, and Slots (PUSC DL)

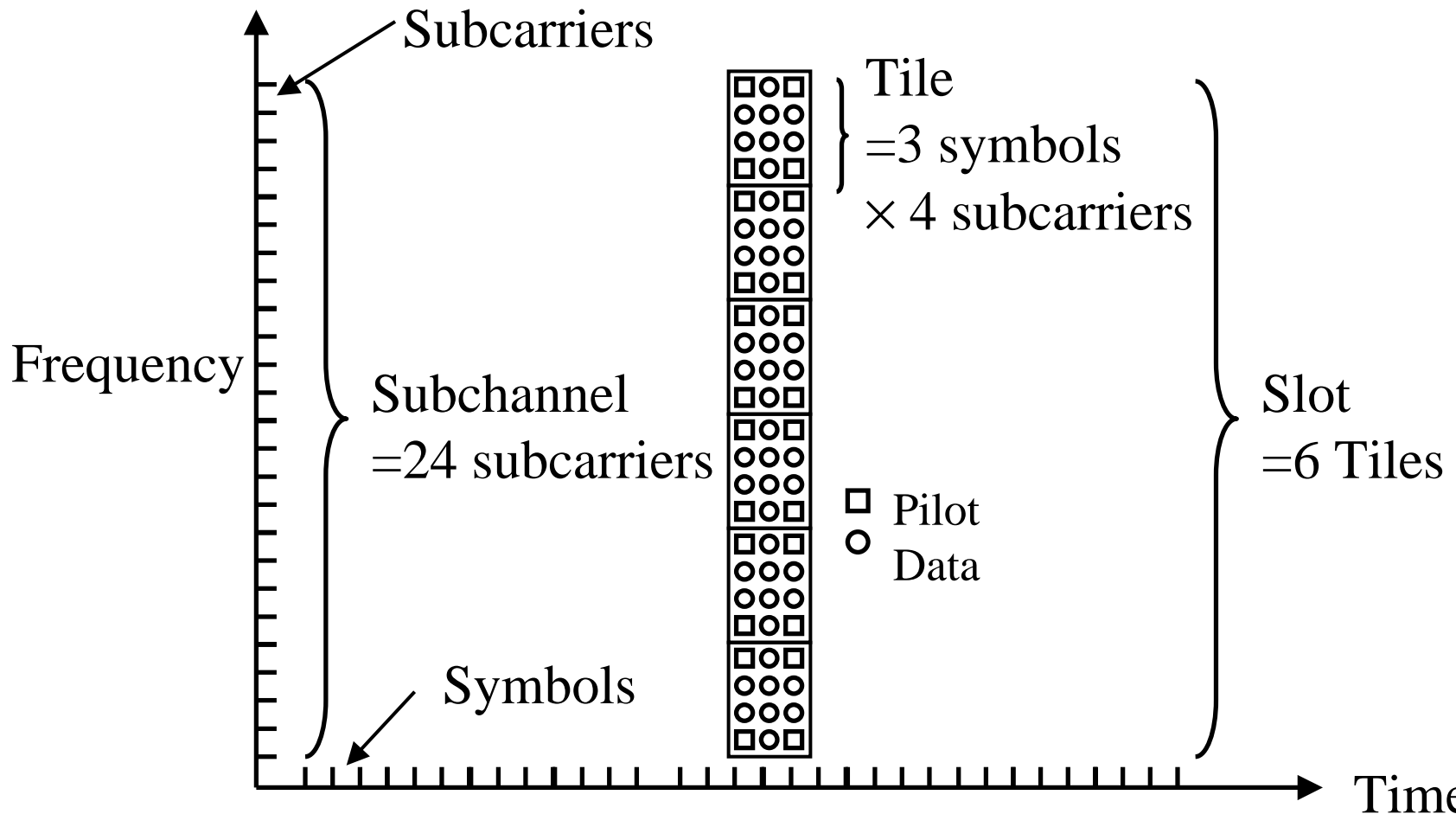
10 MHz = 1024 FFT = 840 subcarriers + 1 DC + 183 Guard

Total 30 subchannels = $30 \times 28 = 840$ subcarriers

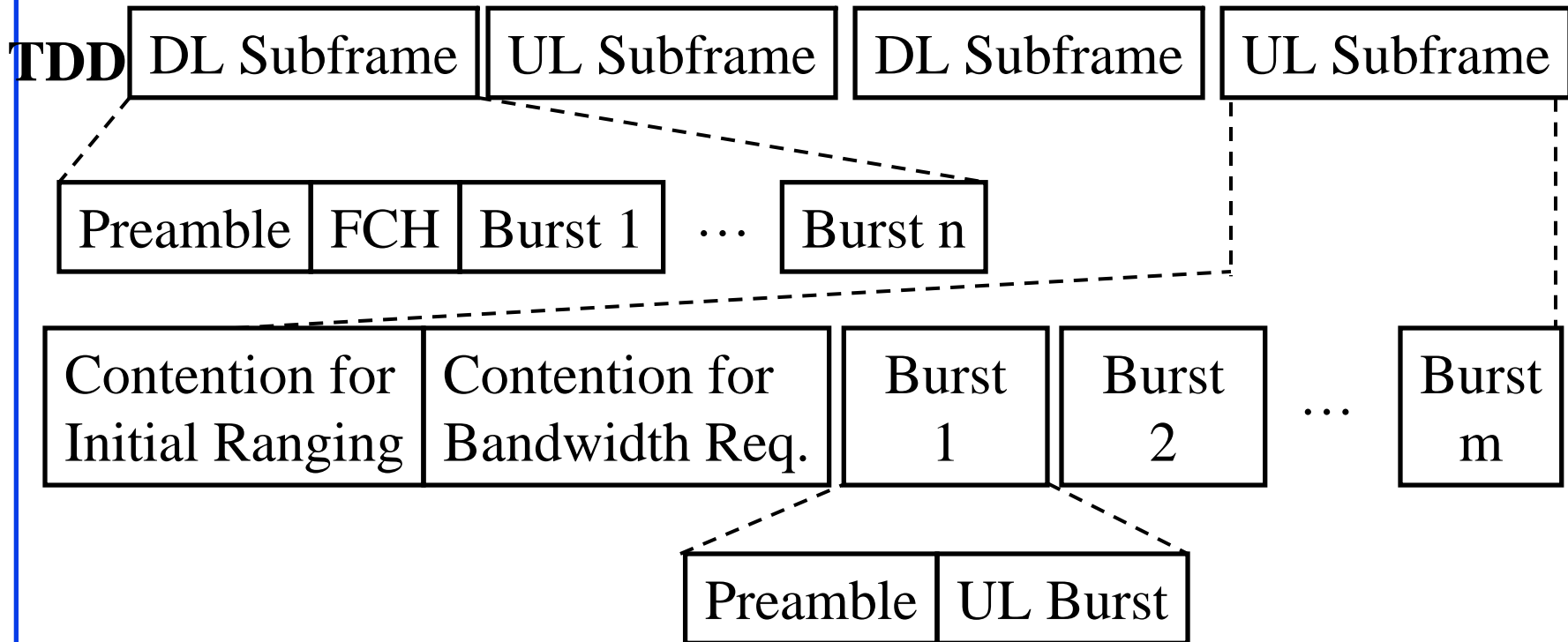


Symbols, Tiles, and Slots (PUSC UL)

- 10 MHz = 1024 FFT = 840 subcarriers + 1 DC + 183 Guard
Total 35 subchannels = 35X24 = 840 subcarriers



802.16 Frame Structure



TDD = Time Division Duplexing

DL = Downlink (Base to subscriber)

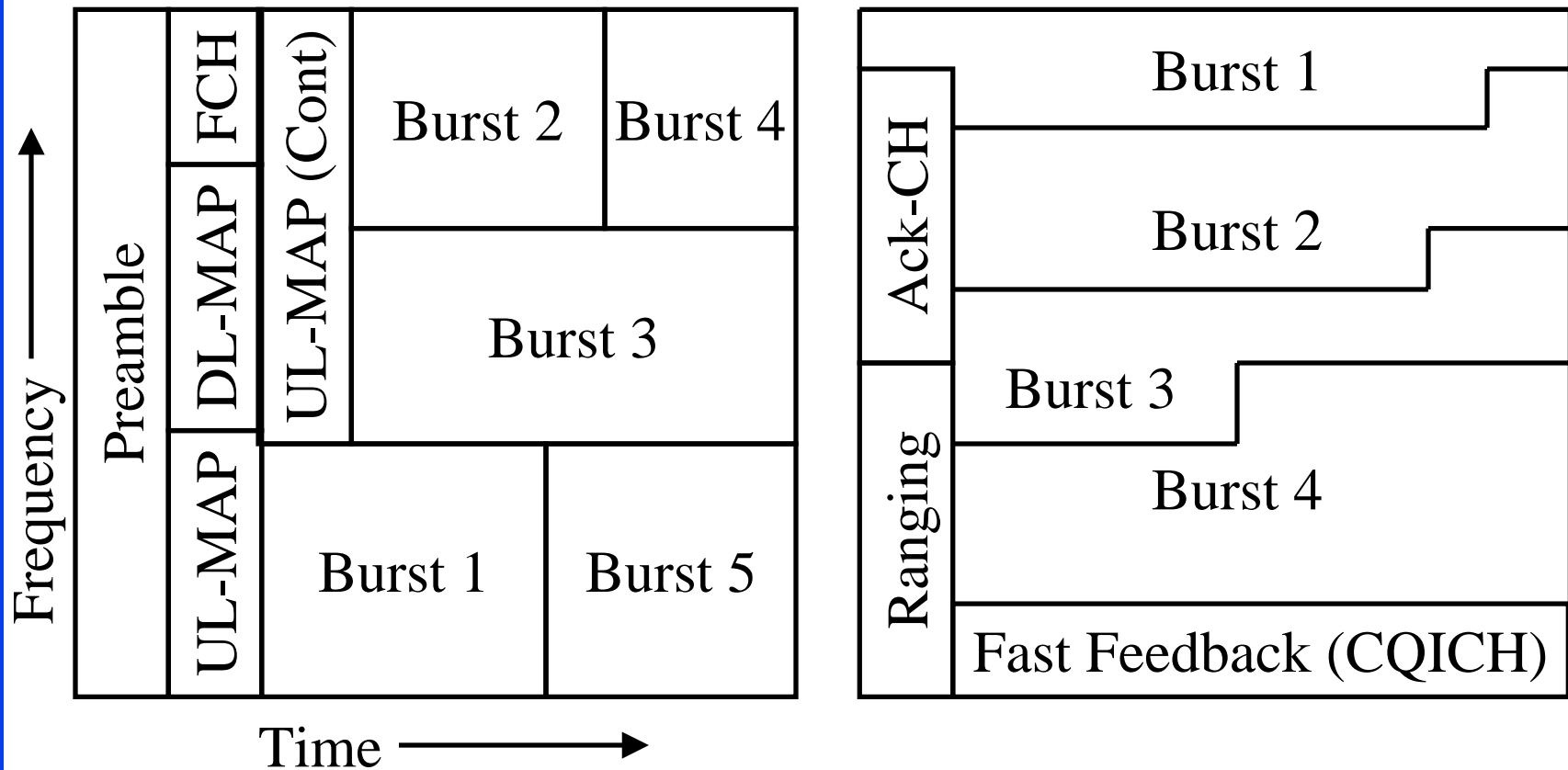
FCH = Frame control header:

FDD = Freq Div Duplexing

UL = Uplink

Burst Profile, Down-link map, Uplink map, DL channel descriptor, etc.

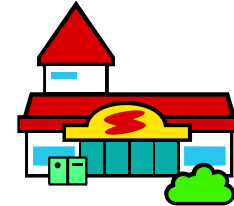
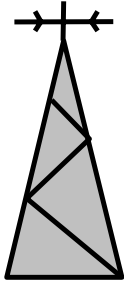
Mobile WiMAX Frame



Frame Structure

- ❑ **DL Preamble:** Time and frequency synchronization
- ❑ **Frame Control Header (FCH):** MAPs lengths, modulation and coding, usable subcarriers
- ❑ **Downlink MAP:** Burst profile (time, freq., modulation, coding)
- ❑ **Uplink MAP:** Burst profile for transmission from each user.
MAPs can be compressed
- ❑ **Contention-based region:** Ranging, bandwidth request, best-effort data
- ❑ **Ranging Channel:**
 - Closed loop frequency, time, and power adjustments
 - Channel quality indicator channel (CQICH)
CINR measurement
 - **Ack Channel:** subscriber stations
- ❑ Initially, 5 ms frames only.

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

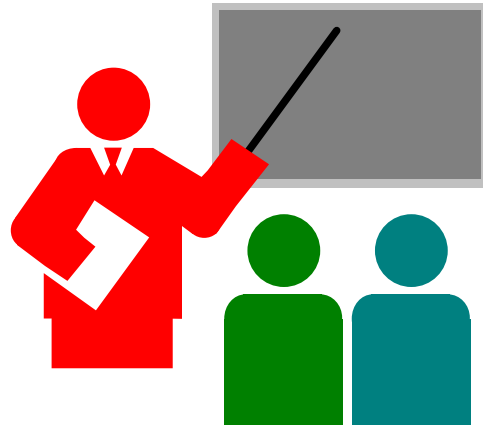
Base sends ranging response giving management conn IDs

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

Base accepts subscriber or rejects some PHY capabilities

Base-Subscriber Authentication using X.509 Certificates

Summary



- ❑ WiMAX supports non-line of sight using scalable OFDMA
- ❑ Any band any bandwidth
- ❑ Sophisticated frequency reuse
- ❑ 2D frame structure

References: Books

1. Cal Eklund, Roger B. Marks, Subbu Ponnuswamy, Kenneth L. Stanwood, Noco J.M. van Waes, "**WirelessMAN: Inside the IEEE 802.16 Standard for Wireless Metropolitan Area Networks**," IEEE, May-06, ISBN:0738148423.
2. Jeffrey G. Andrews, Arunabha Ghosh, Rias Muhamed, "**Fundamentals of WiMAX: Understanding Broadband Wireless Networking**," Prentice-Hall, ISBN:0132225522.
3. Loutfi Nuaymi, "**WiMAX: Technology for Broadband Wireless Access**," Wiley, Mar-07, 310 pp., ISBN:0470028087.

Note: These are the best 3 of 12+ books on WiMAX.

Reading List

- ❑ J. Thiel, “Metropolitan and Regional Wireless Networking: 802.16, 802.20 and 802.22,”
<http://www.cse.wustl.edu/~jain/cse574-06/wimax.htm>
- ❑ M. Wood, “An Analysis of the Design and Implementation of QoS over IEEE 802.16,”
http://www.cse.wustl.edu/~jain/cse574-06/wimax_qos.htm

Related Wikipedia Pages

- ❑ <http://en.wikipedia.org/wiki/WiMAX>
- ❑ http://en.wikipedia.org/wiki/IEEE_802.16
- ❑ http://en.wikipedia.org/wiki/Orthogonal_frequency-division_multiple_access
- ❑ http://en.wikipedia.org/wiki/Orthogonal_frequency-division_multiplexing
- ❑ http://en.wikipedia.org/wiki/Symbol_rate
- ❑ <http://en.wikipedia.org/wiki/WiBro>
- ❑ http://en.wikipedia.org/wiki/WiMAX_MIMO
- ❑ http://en.wikipedia.org/wiki/Wireless_broadband
- ❑ http://en.wikipedia.org/wiki/Wireless_local_loop

Related Wikipedia Pages (Cont)

- ❑ http://en.wikipedia.org/wiki/Local_Multipoint_Distribution_Service
- ❑ http://en.wikipedia.org/wiki/Multichannel_Multipoint_Distribution_Service
- ❑ http://en.wikipedia.org/wiki/Cellular_network
- ❑ http://en.wikipedia.org/wiki/Cellular_network#Frequency_reuse
- ❑ <http://en.wikipedia.org/wiki/Xohm>
- ❑ <http://en.wikipedia.org/wiki/Clearwire>
- ❑ http://en.wikipedia.org/wiki/List_of_deployed_WiMAX_networks

List of Acronyms

- ❑ AAS Adaptive Antenna System
- ❑ APAC Asia Pacific
- ❑ BS Base Station
- ❑ BTC Block Turbo Codes
- ❑ CC Convolutional Coding
- ❑ RS-CC Reed-Solomon Convolutional Codes
- ❑ CINR Carrier to Interference and Noise Ratio
- ❑ CQICH Channel quality indicator channel
- ❑ CTC Convolutional Turbo Codes
- ❑ DC Direct Current
- ❑ DIUC Downlink Interval Usage Code
- ❑ DL Downlink
- ❑ GHz Giga Hertz
- ❑ IEEE Institution of Electrical and Electronics Engineers
- ❑ LMDS Local Multipoint Distribution Service

List of Acronyms (Cont)

- ❑ MAC Media Access Control
- ❑ MAP Media Access Profile?
- ❑ MCS Modulation and Coding scheme
- ❑ MHz Mega Hertz
- ❑ MIB Management Information Base
- ❑ MIMO Multiple Input Multiple Output
- ❑ MMR Mobile Multihop Relay
- ❑ OFDM Orthogonal Frequency Division Multiplexing
- ❑ OFDMA Orthogonal Frequency Division Multiple Access
- ❑ PCMCIA Personal Computer Memory Card International Association
- ❑ PHY Physical Layer
- ❑ PUSC Partial Usage of Subcarriers
- ❑ QAM Quadrature Amplitude Modulation
- ❑ RSSI Received Signal Strength Indicator
- ❑ SINR Signal to Interference and Noise Ratio
- ❑ STBC Space Time Block Codes