WiMAX
Part I: PHY

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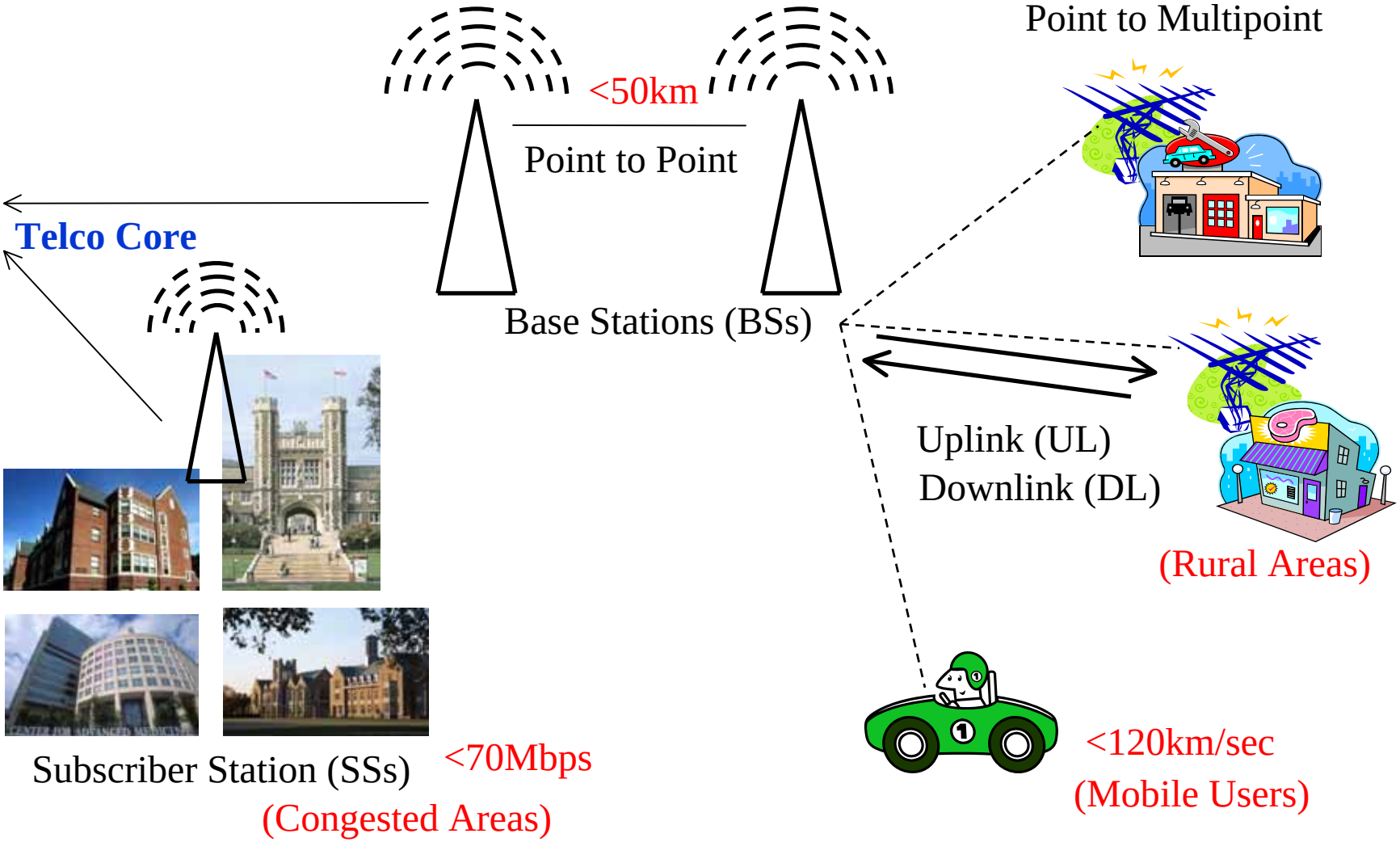
Audio/Video recordings of this lecture are available on-line at:
http://www.cse.wustl.edu/~jain/cse574-08/

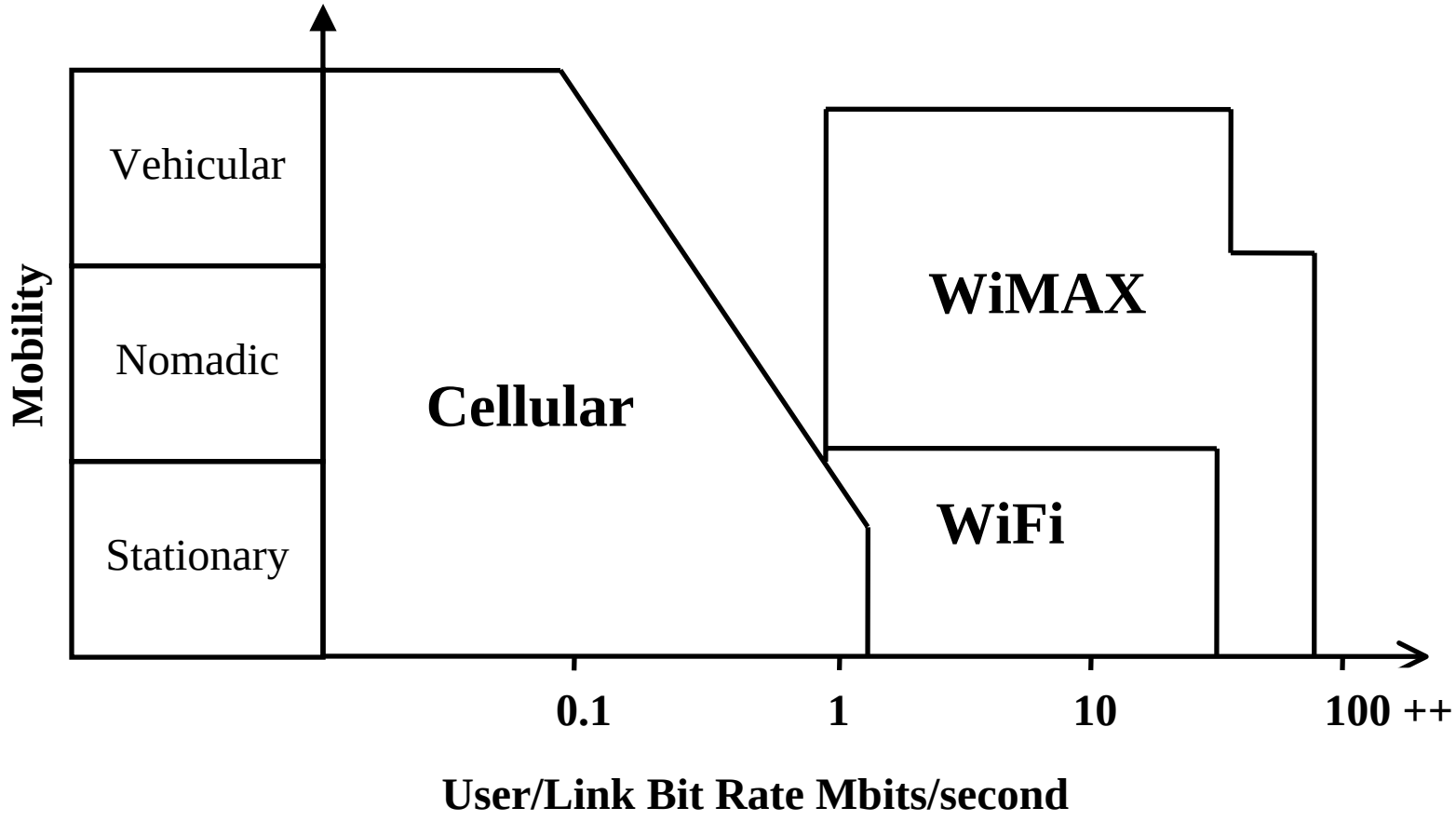
Overview

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

What is WiMAX?



Data rate vs. Mobility



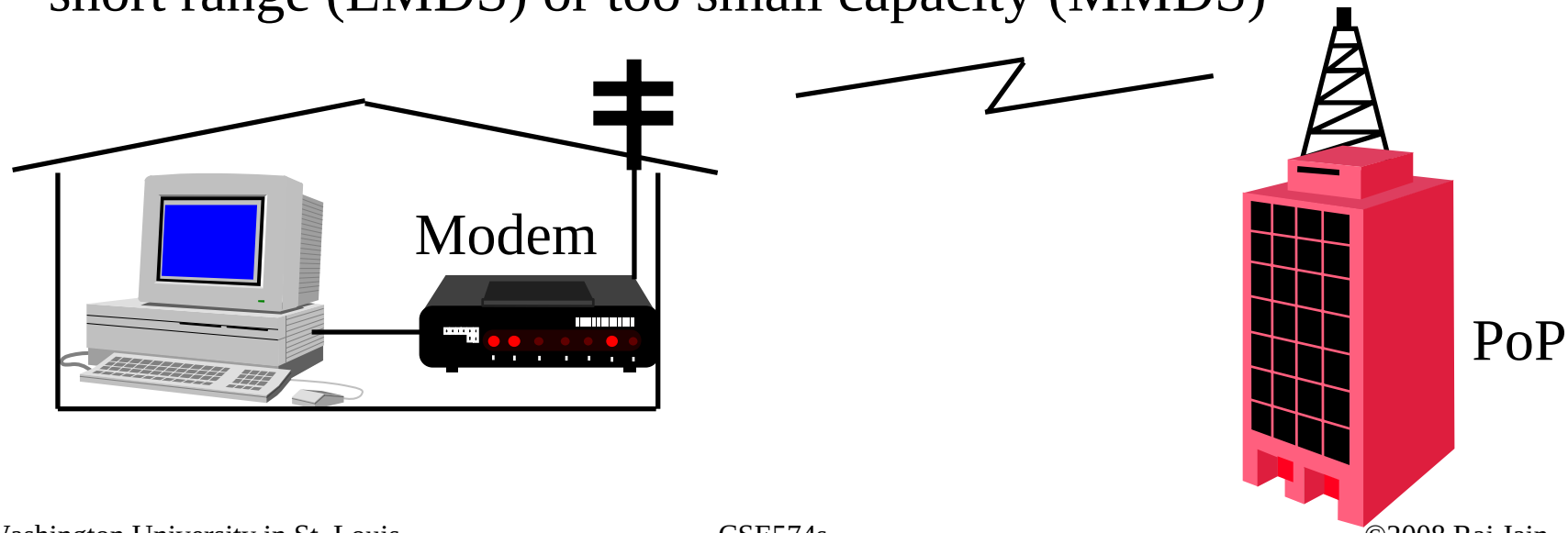
Key Features of WiMAX

- Works on many bands: 2.3 GHz, 2.5 GHz, 3.5 GHz, …
- Scalable Þ 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 Þ 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 ⇒ Rain effects
- Multi-channel Multipoint Distribution Services (1999-2001)
- 2.1, 2.5-2.7 GHz Band ⇒ Not affected by rain

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



WiMAX

- WiMAX ≠ 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. Worldwide.
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

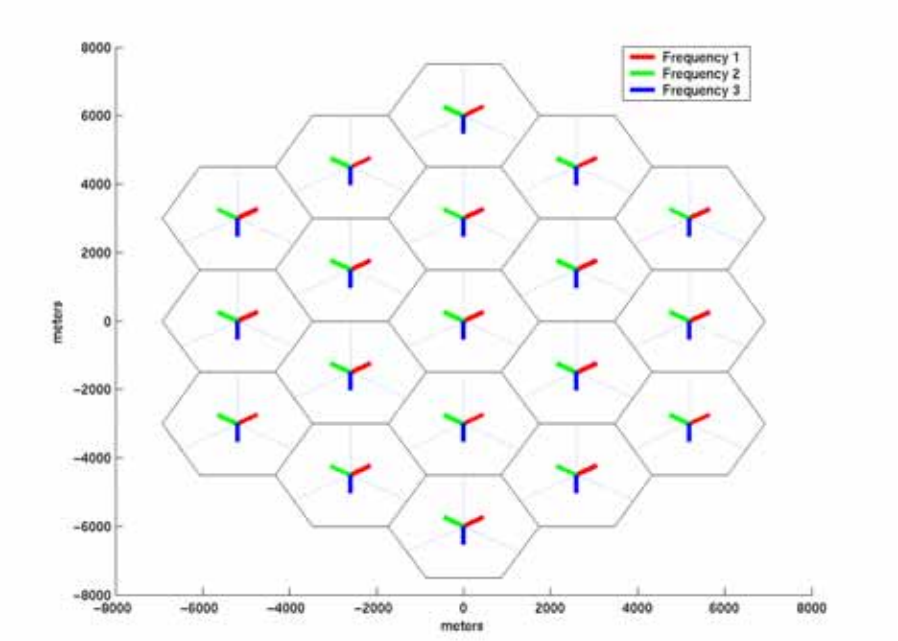
	Function	LOS	Freq. Band	Carrier	Duplexing
WirelessMAN SC	Pt-to-pt	LOS	10-66 GHz	Single	TDD, FDD
WirelessMAN SCa	Pt-to-pt	LOS	2-11 GHz Licensed	Single	TDD, FDD
WirelessMAN OFDM (16d)	Pt-to-mpt	NLOS	2-11 GHz Licensed	256	TDD, FDD
WirelessMAN OFDMA (16e)	Pt-to-mpt	NLOS	2-11 GHz Licensed	2048	TDD, FDD
WirelessHUMAN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

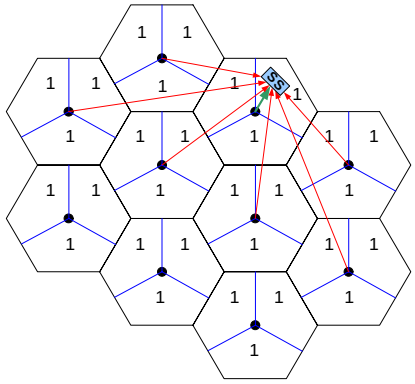
- NxSxK frequency reuse pattern
- N=Number of cells per cluster
- S= Number of sectors in a cell
- K = Number of frequency allocations per cell



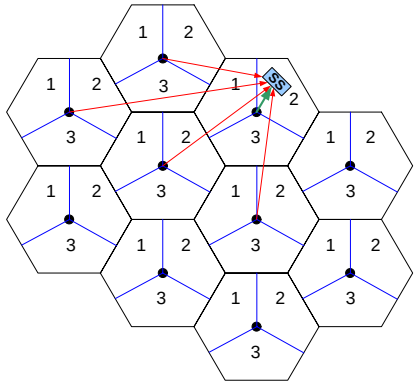
1X3X3

Frequency Reuse (Cont)

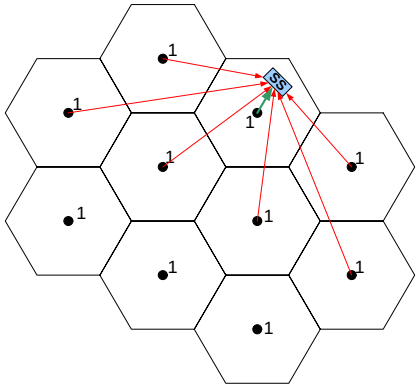
1x3x1



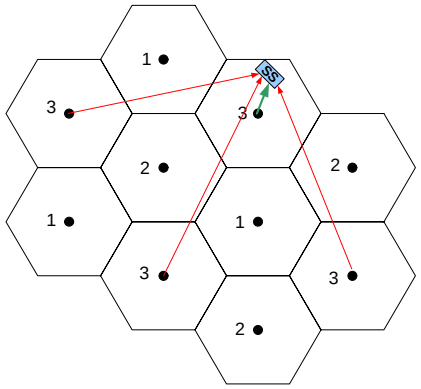
1x3x3



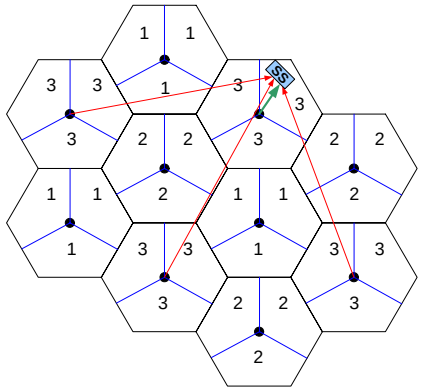
1x1x1



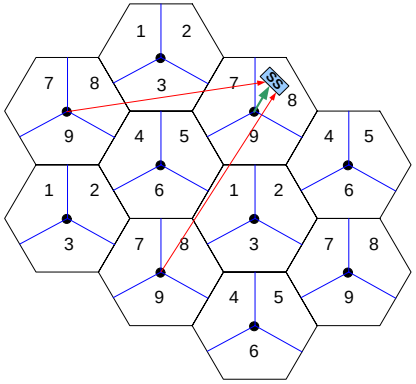
3x1x1



3x3x1

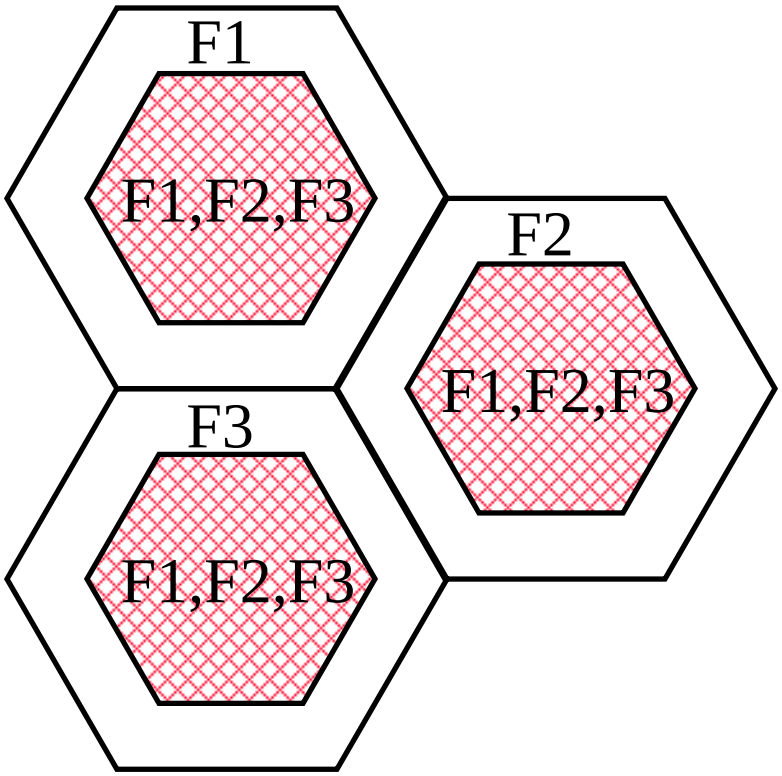


3x3x3



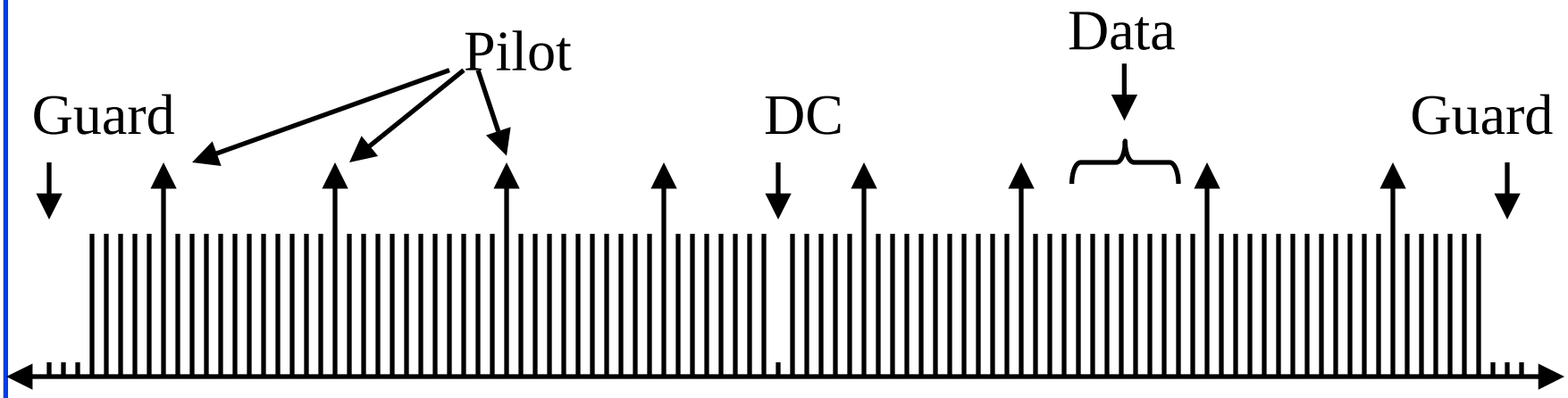
Fractional Frequency Reuse

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



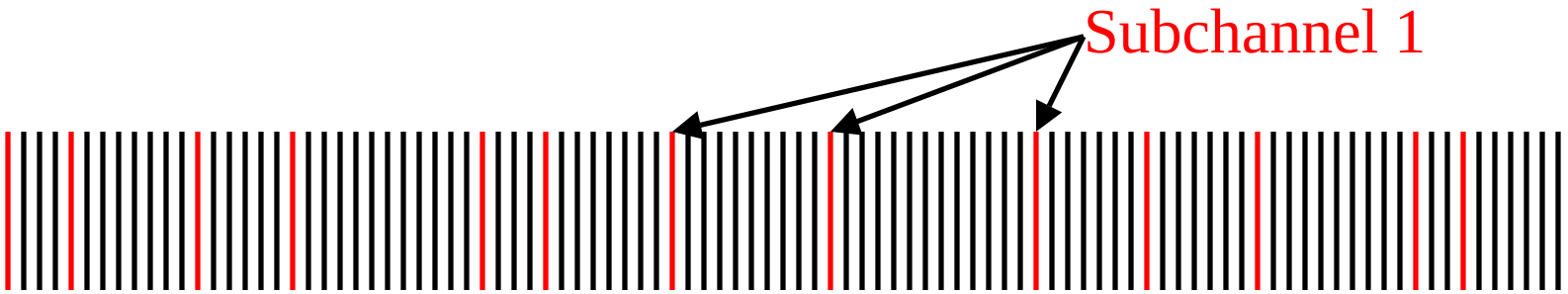
OFDM Subcarriers

- 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 ⇒ Frequency hopping
- All subcarriers are used ⇒ Full Usage of Subcarriers (FUSC) – Not in WiMAX Forum Profiles
- Partial Usage of Subcarriers (PUSC)
  - in WiMAX Forum profiles ⇒ commonly used

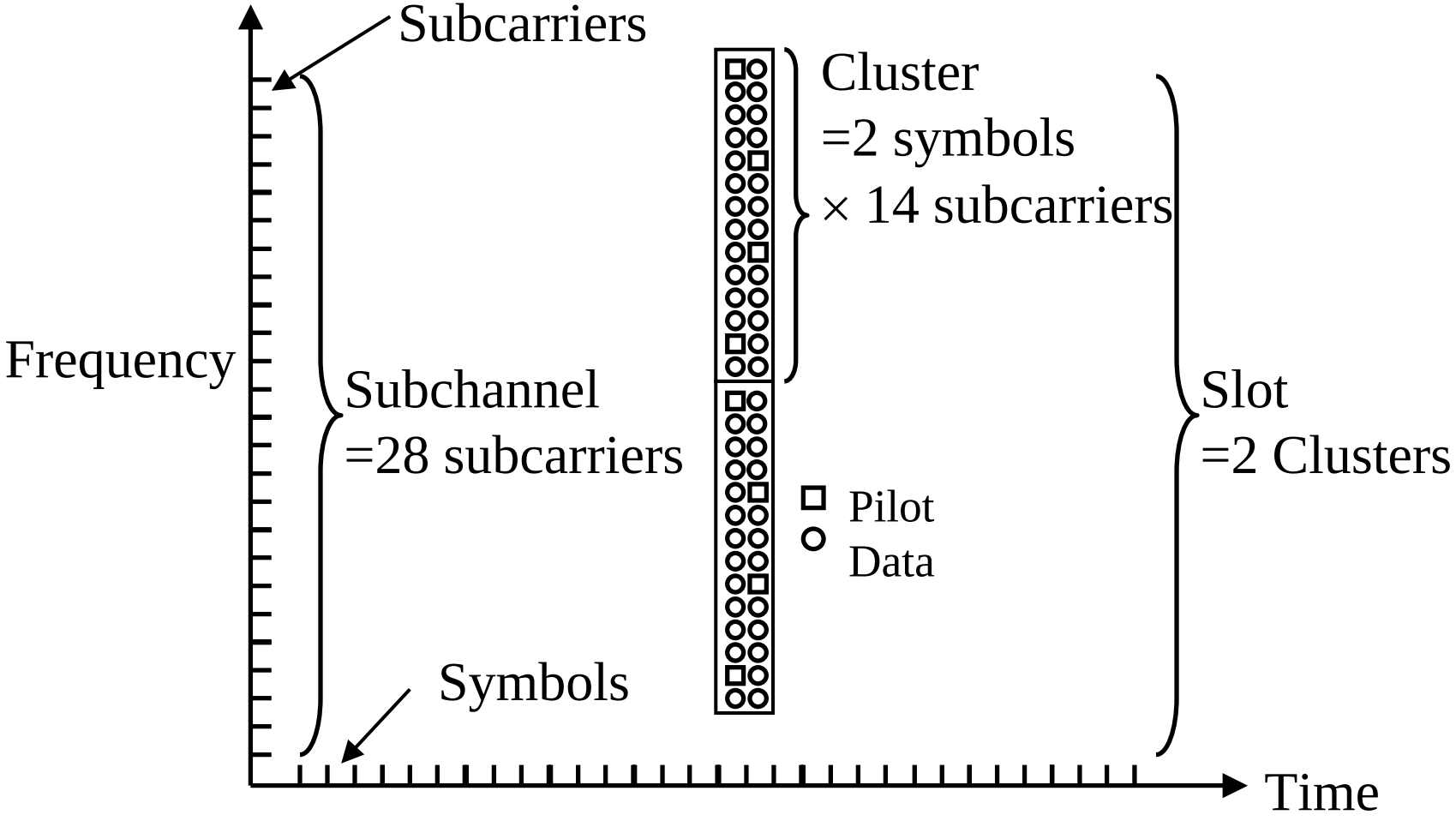
Downlink Partial Usage of Subcarriers

- Subcarriers are divided in to 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)

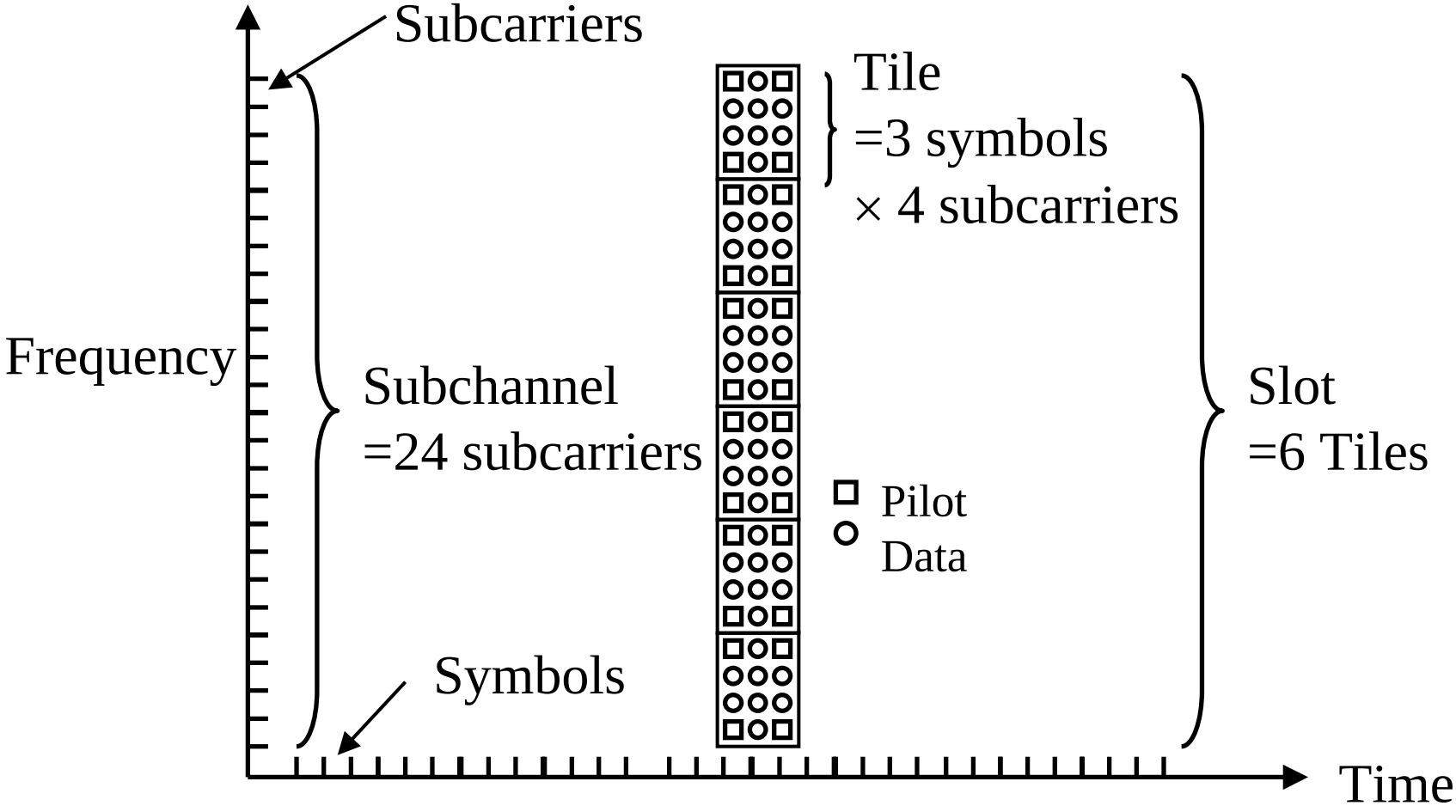
10 MHz = 1024 FFT = 840 subcarriers + 1 DC + 183 Guard

Total 30 subchannels = 30×28 = 840 subcarriers

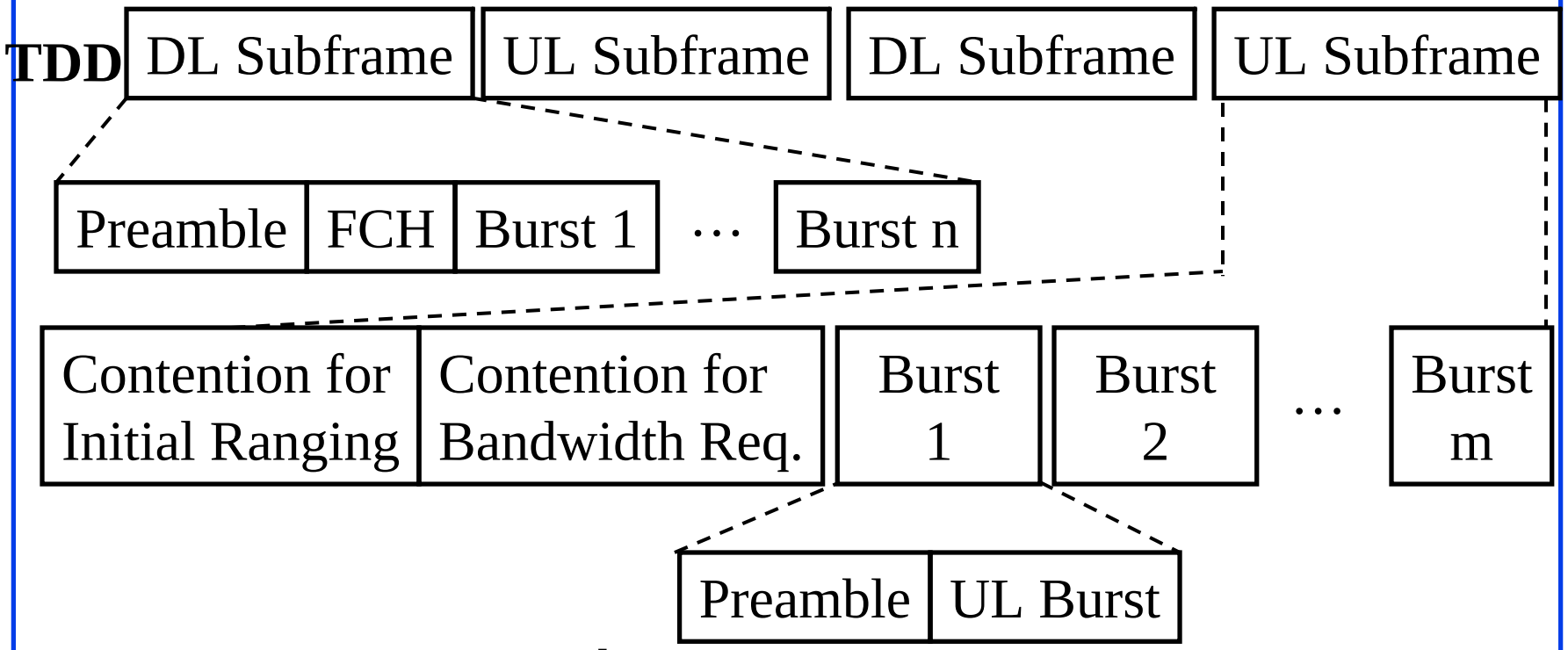


Symbols, Tiles, and Slots (PUSC UL)

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



802.16 Frame Structure

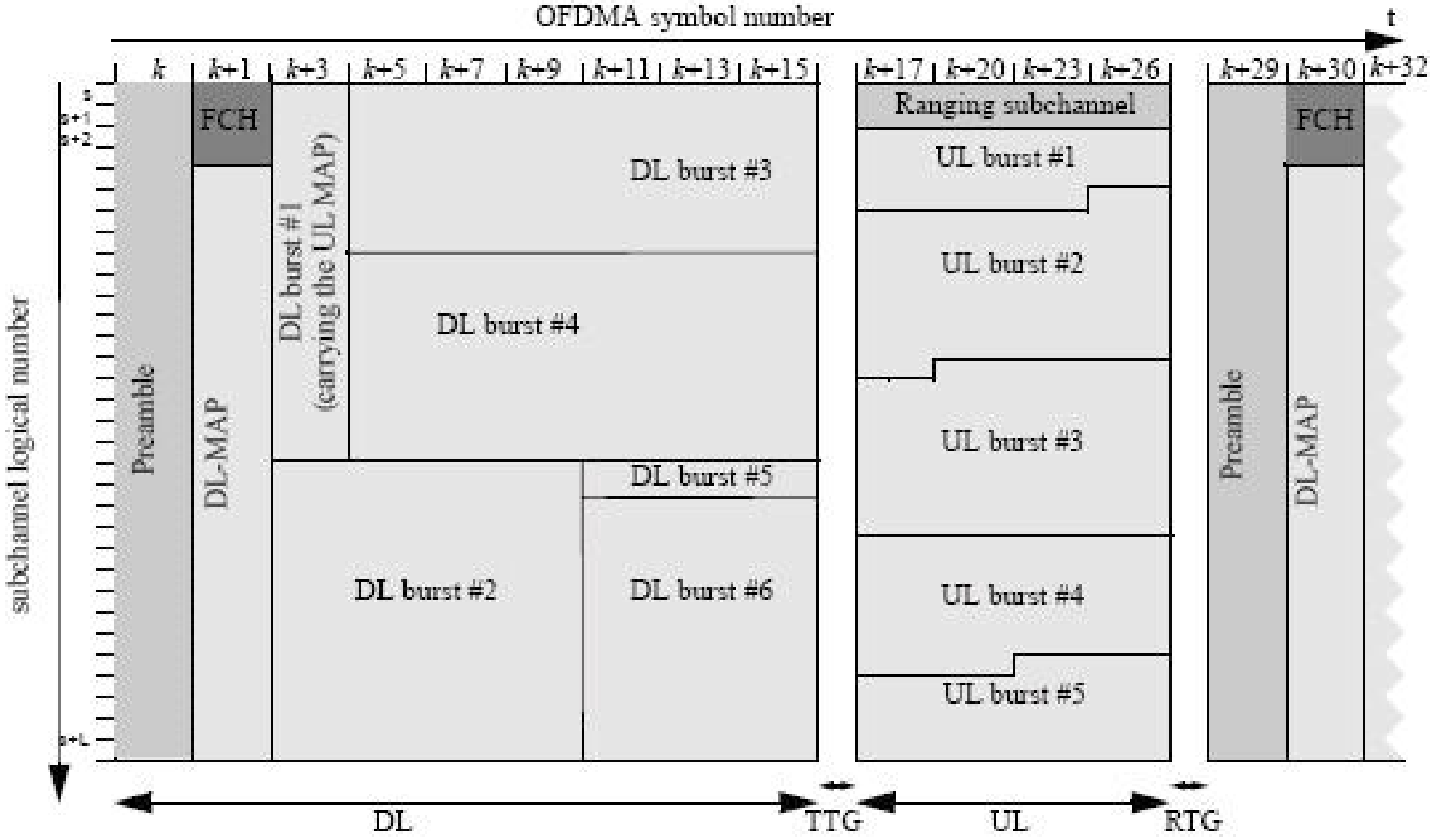


TDD = Time Division Duplexing
DL = Downlink (Base to subscriber)
FCH = Frame control header:

FDD = Freq Div Duplexing
UL = Uplink

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

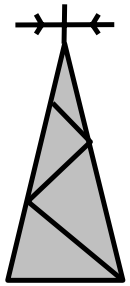
Mobile WiMAX Frame



Frame Structure

- **DL Preamble**: Time and frequency synchronization
- **Frame Control Header (FCH)**: MAPs lengths, modulation and coding, usable subcarriers
- **Downlink MAP**: Burst profile (time, frequency, modulation, coding) to each user
- **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)
  - **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 ←

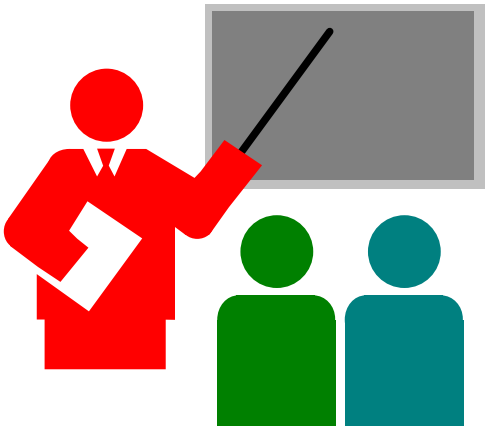
Base sends ranging response giving management conn IDs →

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. Stanwoood, 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.