Overview of Mobile WiMAX Technology

Esmael Dinan, Ph.D.
Clearwire

April 17, 2009

Outline

- Part 1: Introduction to Mobile WiMAX
- Part 2: Mobile WiMAX Architecture
- Part 3: MAC Layer Technical Features
- Part 4: Physical Layer Technical Features
- Part 5: Mobile WiMAX Network Performance

Part 1:

Introduction to Mobile WiMAX

WiMAX Networks Phases

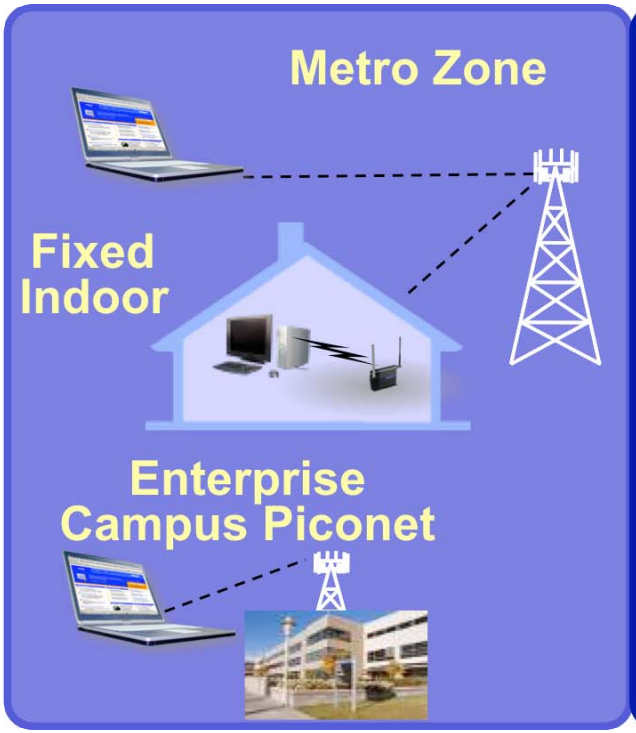
802.16-2004

Access Service

Data Overlay w/ Voice - 2005

- 2.5, 3.5, 5.8 GHz - Lic& UnLic
- Low cost network
- Backhaul focus

802.16e



Portable Service

Cell Data Overlay Network - 2006

- Freq < 3.5G Licensed
- Low/Mid cost networks
- Notebook focus

802.16e

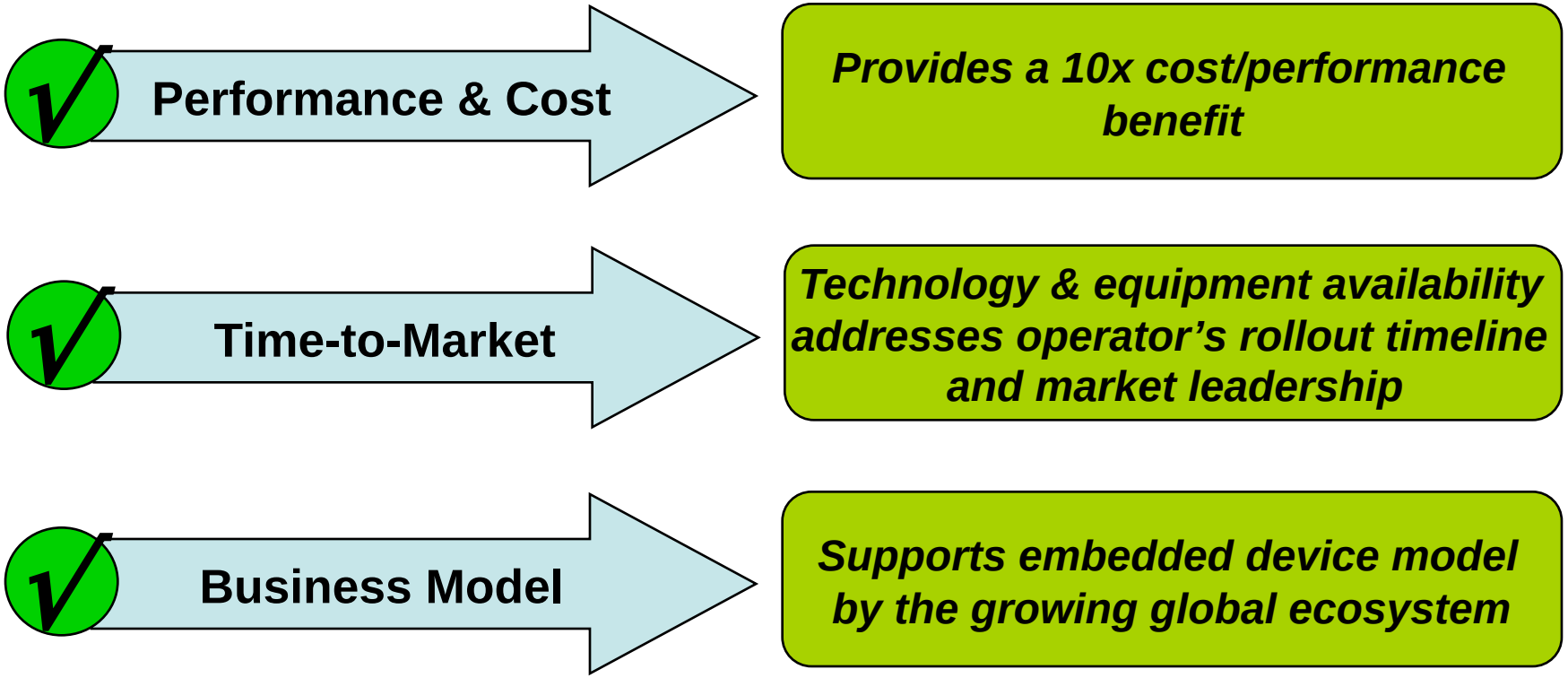
Mobile Service

Dense Cell Overlay Network
Mobile Triple Play - 2007+

- Freq < 2.5 GHz Licensed
- Mid cost networks
- Handheld & Notebook

WiMAX Technology for Wireless Operators

- **Why do operators choose WiMAX?**



WiMAX Technical Flexibility

- Global harmonization in 2.5GHz and 3.5 GHz
- Provides wireless mobile access and wireless backhaul
- Quality of Service built in
  - Efficient QoS for voice, video (multimedia), business and consumer classes
- Very high level of Flexibility and Scalability
  - Flexible duplexing schemes (TDD, FDD, and Half Duplex FDD)
  - Flexible channel sizes (1.25 to 20MHz)
  - Flexible spectrum allocation (Licensed and unlicensed)
  - Flexible mobility management by implementing different handoff schemes
- Favorable technical features
  - OFDMA for increasing bandwidth efficiency and interference mitigation
  - High throughput at longer ranges (using Multiple antenna)
    - 40 Mbps for fixed, 15 Mbps for mobile per channel
  - Efficient sleep and idle mode (for regional mobility, and power saving)
  - Uplink power control combined with sub-channelization to lower MS transmit power

WiMAX is not equal to 802.16d or 802.16e

Develop core network architecture, and RAN design for 802.16 air interface

Define a harmonized carrier requirement

Contributes Conformance Test Specs to IEEE802.16 standards

Multi-company process to develop System Profiles, PICS, Test Suite Structure and Test Protocols

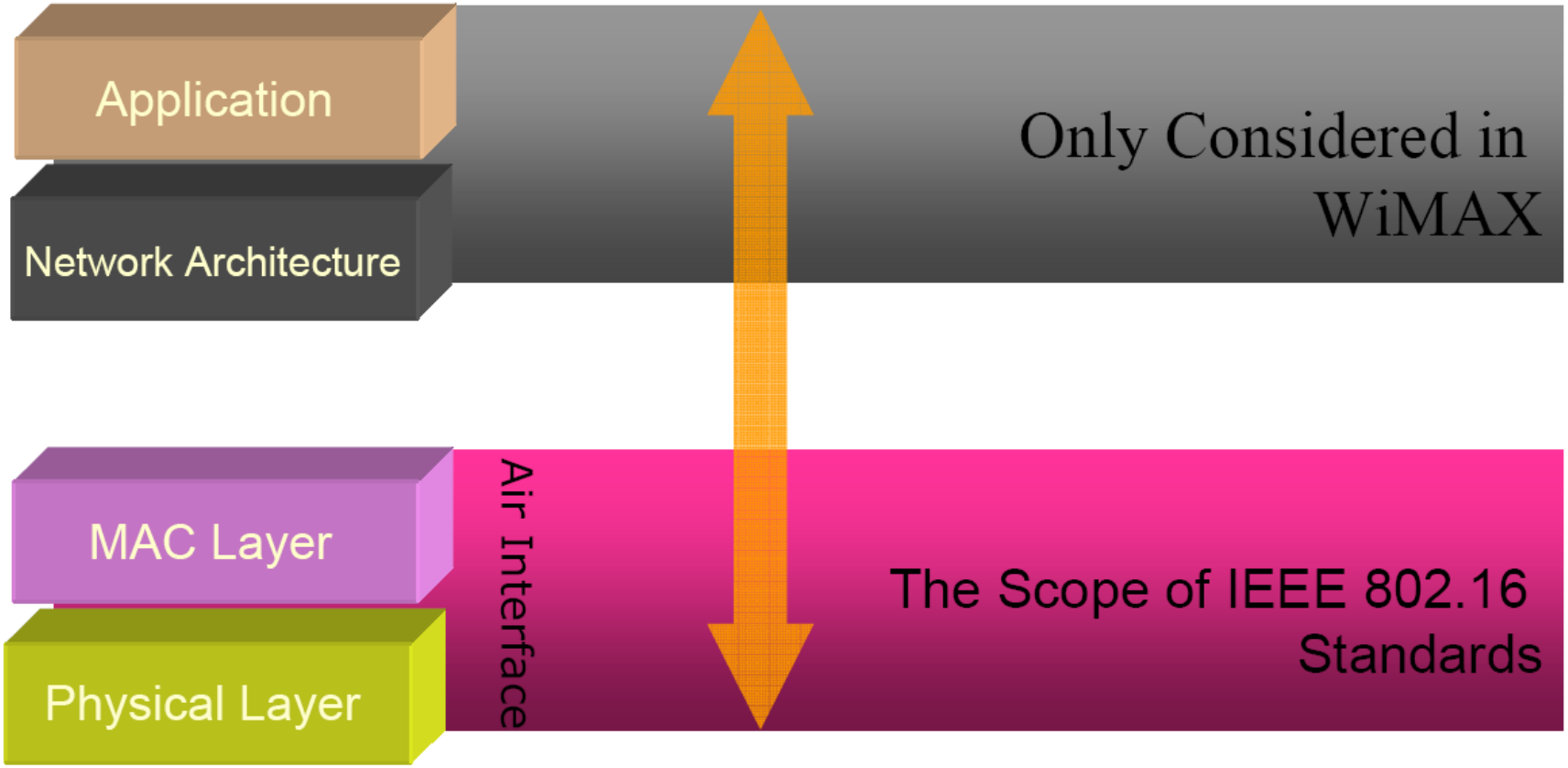
What is WiMAX Forum?

A non-profit organization formed to promote and certify conformance, compatibility and interoperability of products based on IEEE 802.16 standards

WiMAX ≠ IEEE802.16

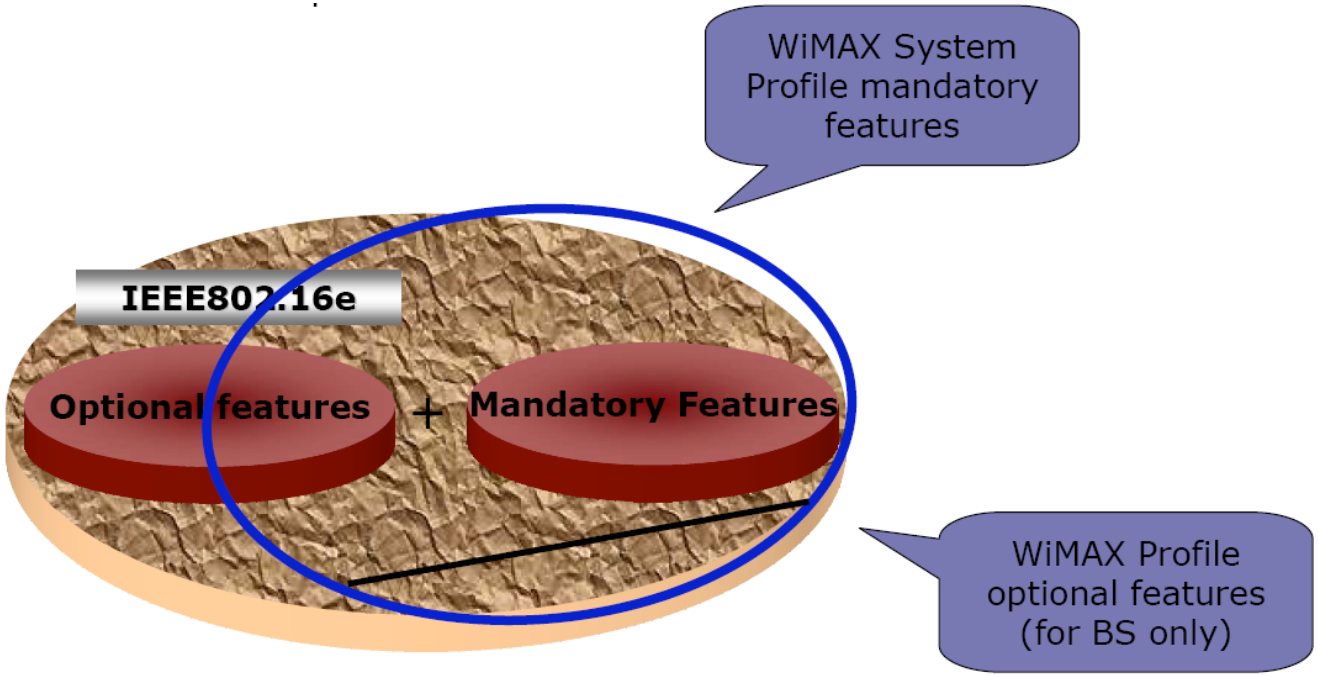
IEEE802.16 develops the technology specification
WiMAX ensures conformance, and interoperability of 802.16 products and develops the network architecture for IEEE802.16

Scope of IEEE 802.16 / WiMAX



WiMAX System Profile

- IEEE802.16 Standard includes several mandatory, as well as optional features
- System Profile, is a list of mandatory and optional features chosen from IEEE802.16 draft, the WiMAX vendors must implement to be WiMAX certified and interoperable.

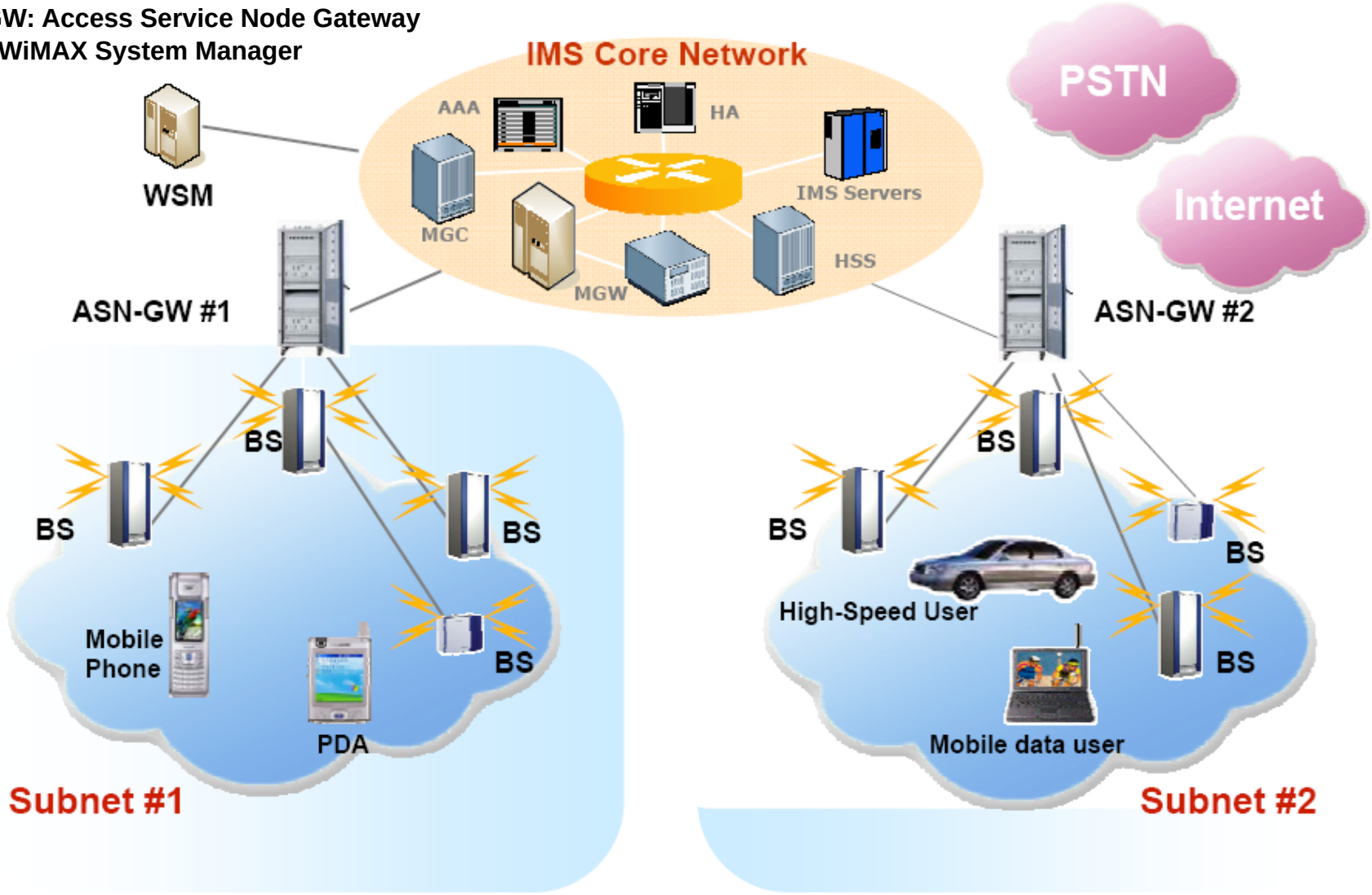


Part 2:

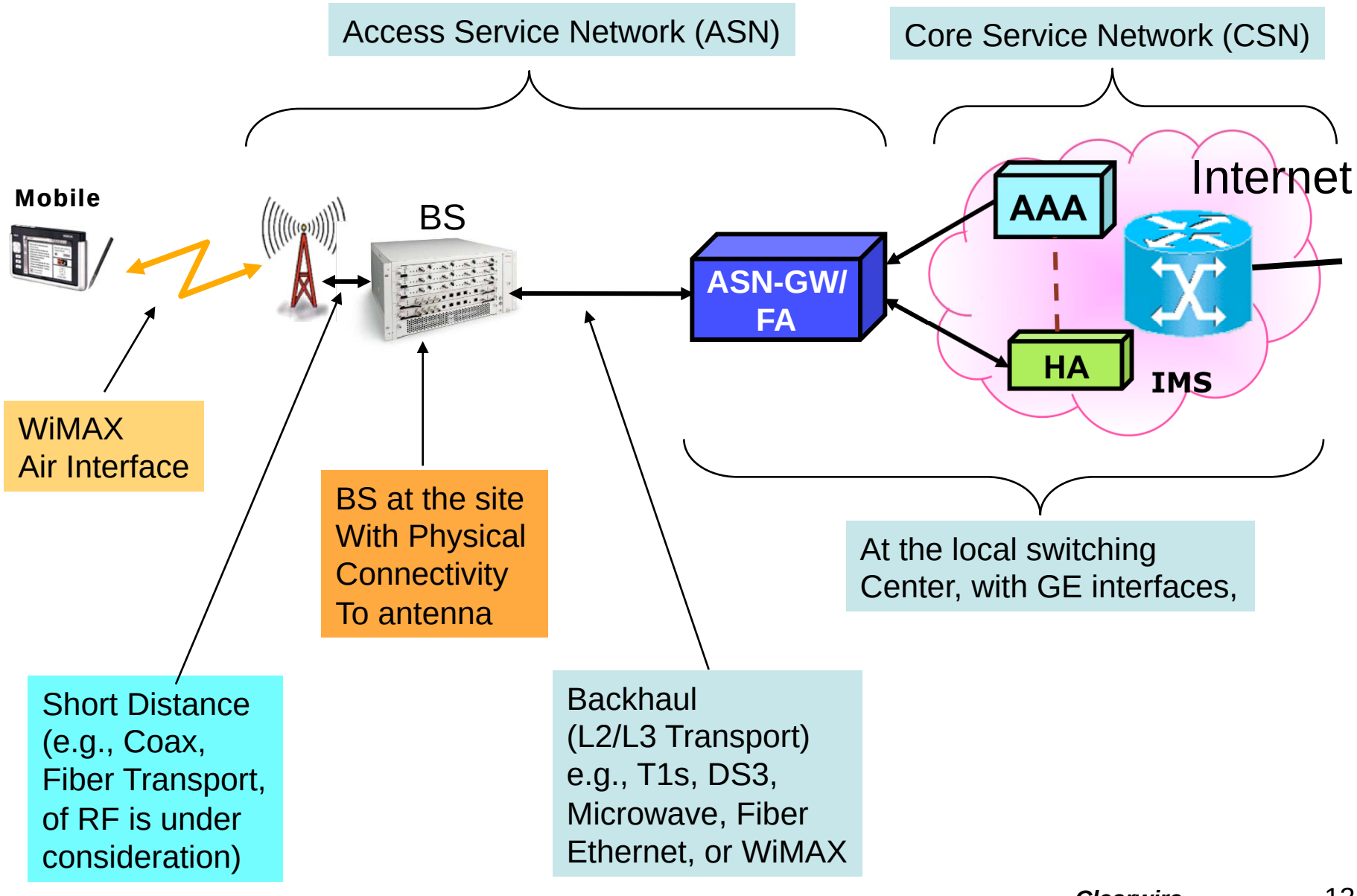
WiMAX Architecture

Mobile WiMAX Network Diagram

BS: Base Station
ASN-GW: Access Service Node Gateway
WSM: WiMAX System Manager



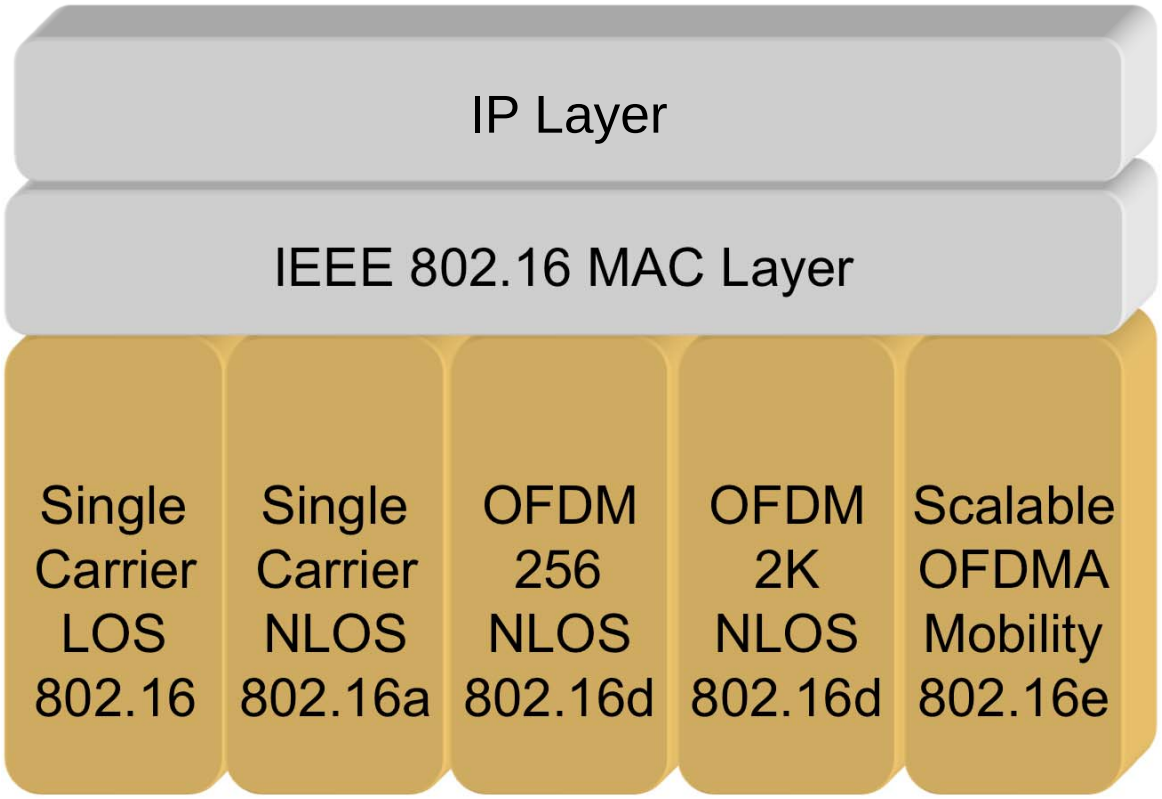
Network Nodes



Part 3:

MAC Layer Technical Features

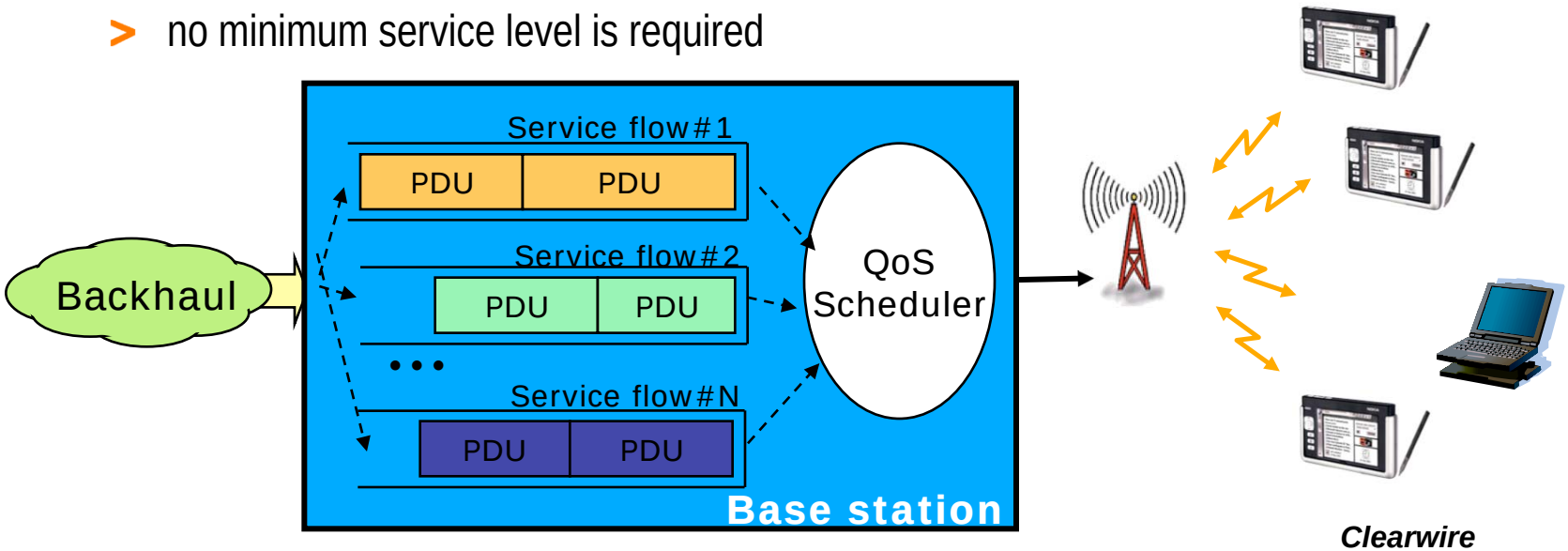
IEEE 802.16 Protocol Layer Structure



Single MAC layer supporting multiple PHY layers

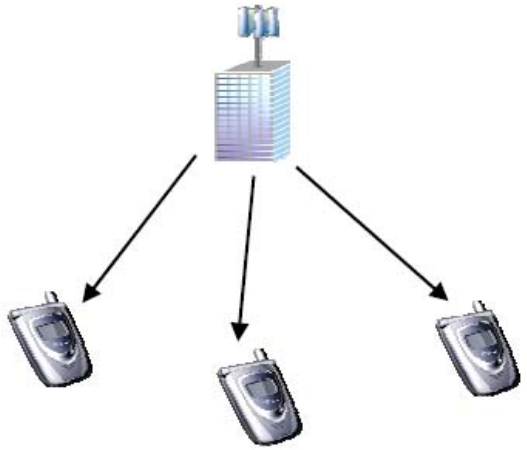
802.16 MAC- QoS of Service Flow

- CBR/UGS: Constant Bit Rate/Unsolicited Grant Service
  - to support real time constant bit rate (CBR) such as T1
- rtPS: real-time Polling Service
  - to support real time variable size data packets on a periodic basis: MPEG video.
- ErtPS: Extended Real-time Poling Service
  - to support real time variable bit rate in an unsolicited manner and has less request/Grant overhead than rtPS, VOIP services with silence suppression
- nrtPS: Non-real-time Polling Service
  - to support non-real-time variable size data packets: FTP
- BE: Best Effort
  - no minimum service level is required



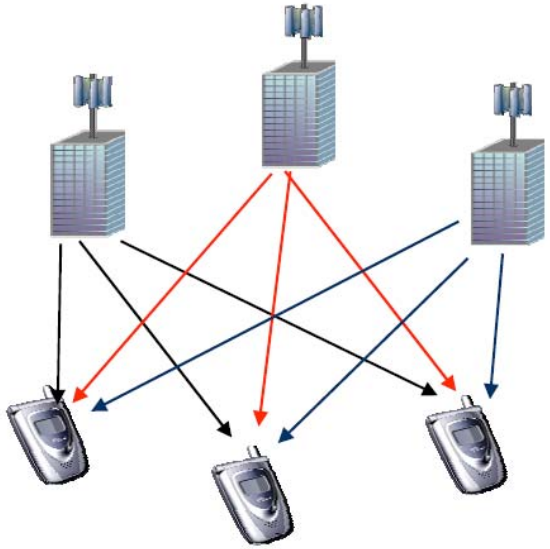
802.16 Multicast Broadcast Service (MBS)

- Broadcast :
  - unidirectional service in which data is transmitted from a single source to all user terminals in the associated service area.
- Multicast:
  - unidirectional service in which data is transmitted from a single source to multiple user terminals that are subscribed to the service.



- Each MBS connection is associated to specific QoS parameters and security Parameters

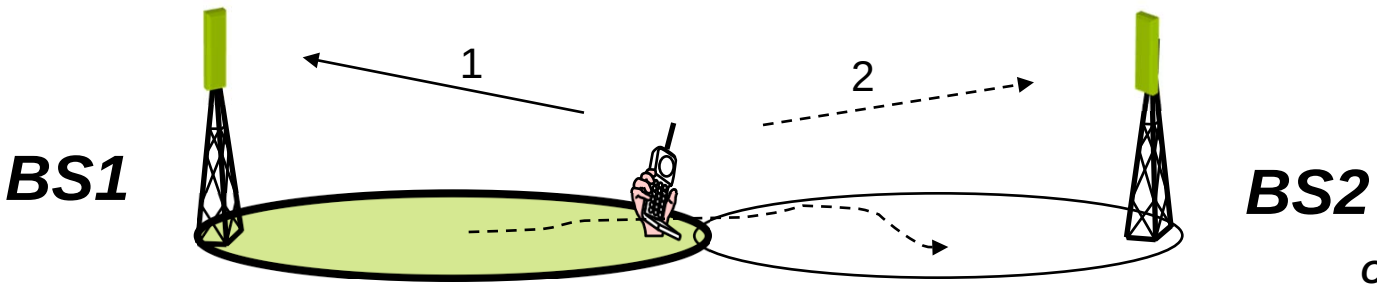
- Two types of MBS access
  - Single-BS MBS: SS registered to only one BS for MBS.
  - Multi-BS MBS: More than one BS participate in transmitting multicast/broadcast data from Service Flow(s).



WiMAX Hard Handoff and Optimized Hard Handoff

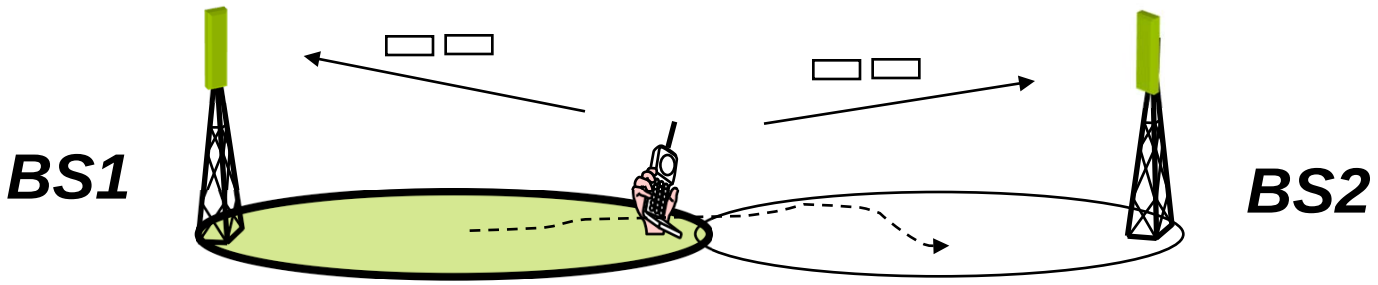
- **Hard Handoff: Break Before Make**
  - High handoff latency
  - High probability of packet drops
  - Hard Handoff Processes
    - Cell Reselection -> HO Decision and Initiation -> Synchronization to target BS downlink -> Ranging -> Termination of service -> HO cancellation

- **Optimized Hard Handoff**
  - Avoiding the complexity of FBSS while the HO latency (outage) is below 50 ms for full mobility.
  - Data latency can be covered by buffers at the MS for 50 msec.



IEEE 802.16 Handoff: FBSS and MDHO

- Fast Base Station Switching (FBSS): A FBSS handover begins with a decision for an MS to receive/transmit data from/ to the Anchor BS (serving BS) that may change within the Diversity Set.
  - > Diversity Set Selection/Update through scanning the neighboring BSs by MS
  - > Anchor BS Selection/Update – monitoring the signal strength of BSs in diversity set.
- Macro Diversity Handover (MDHO) Decision: MDHO begins with a decision for an MS to transmit to and receive from multiple BSs at the same time (similar to soft handoff).



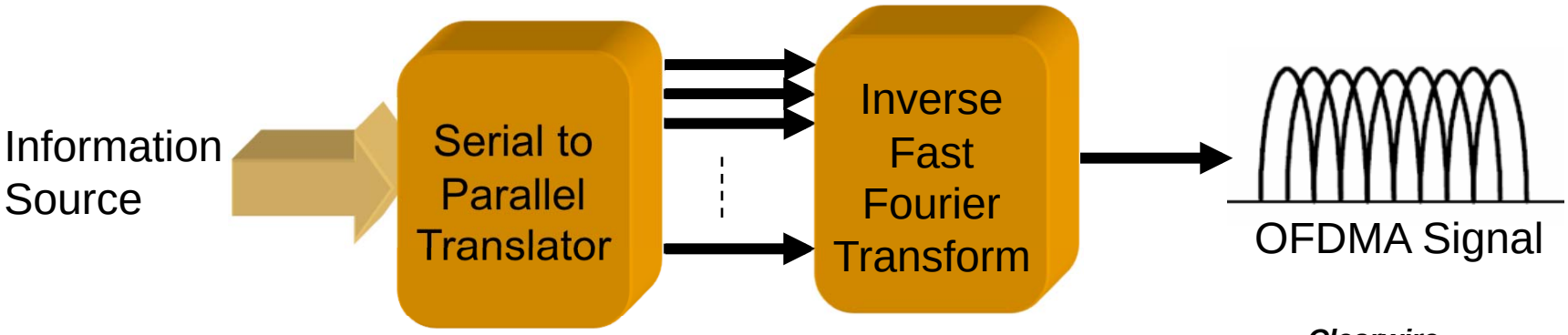
Mobile establishes connection to both base stations

Part 4:

Physical Layer Technical Features

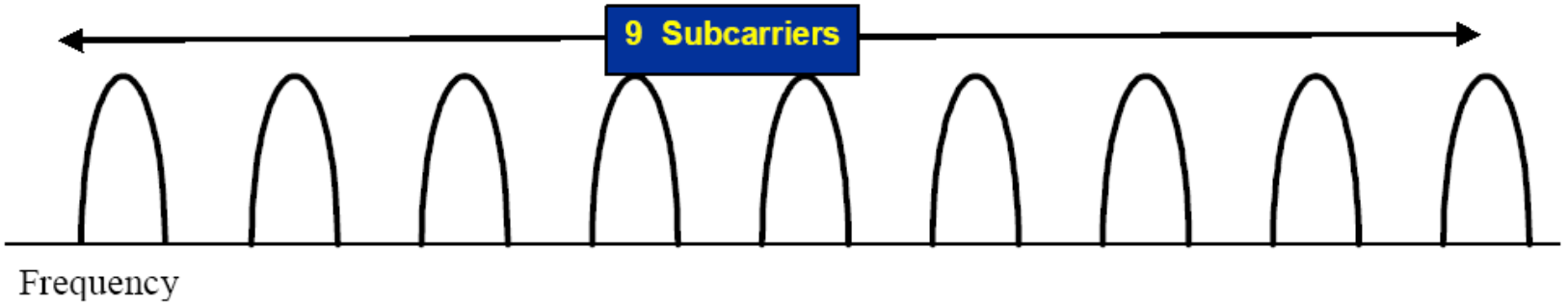
OFDM: A Solution for ISI Channels

- Conversion of a high-data rate stream into several low-rate streams.
- Parallel streams are modulated onto orthogonal carriers.
- Data symbols modulated on these carriers can be recovered without mutual interference.
- Overlap of the modulated carriers in the frequency domain - different from FDM.
- Block of ‘N’ symbols are grouped and sent in parallel
- No interference among the data symbols sent in a block

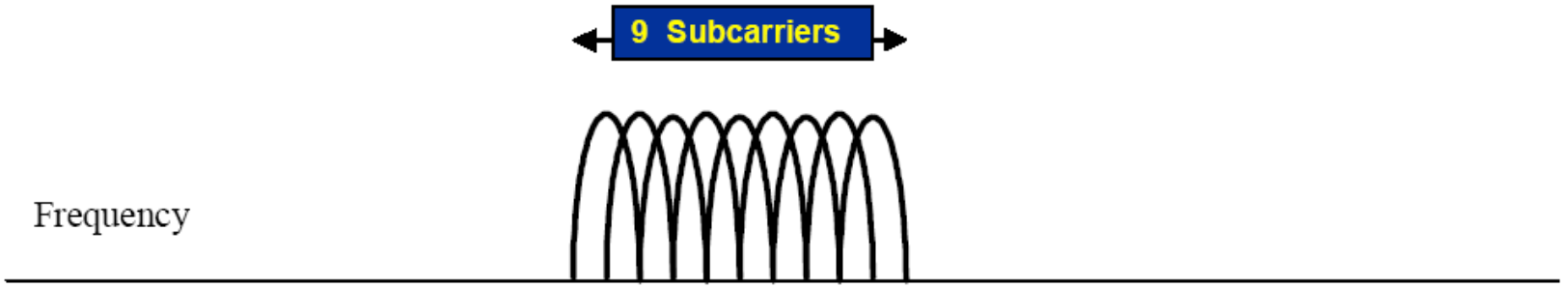


FDM and OFDM

- FDM with Nine Sub-carriers Using Filters



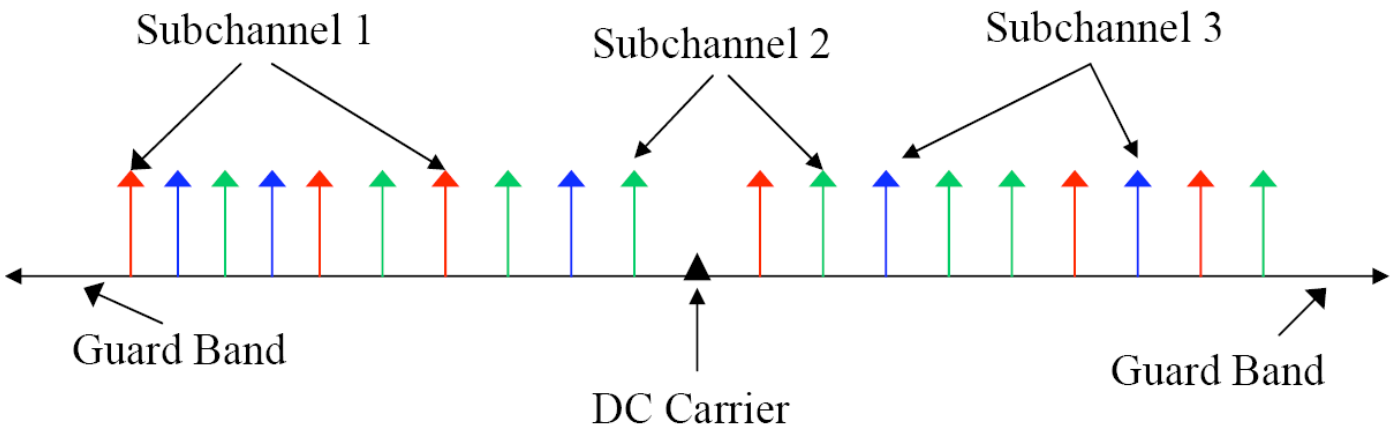
- OFDM with Nine Sub-carriers



Adaptive MCS: Each tone is modulated and coded independently depending on CINR, e.g. QPSK ½, 16-QAM 2/3, 64-QAM 5/6

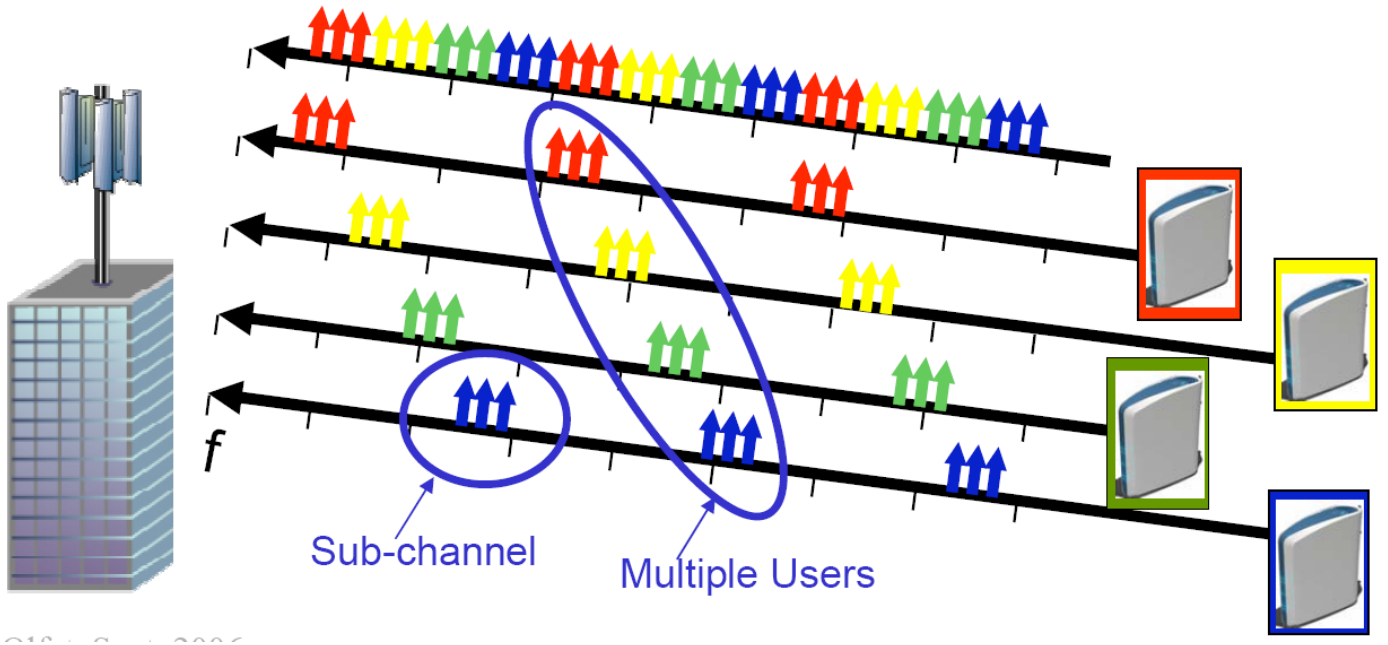
OFDMA Signal

- OFDMA (Orthogonal Frequency Division Multiple Access): The same as OFDM, except, the tones are divided into several sub-channels (sub-channelization), and then each sub-channel is assigned to one or more users.
- Supports Multiple Access
- Different sub-channels can use different coding and modulation type



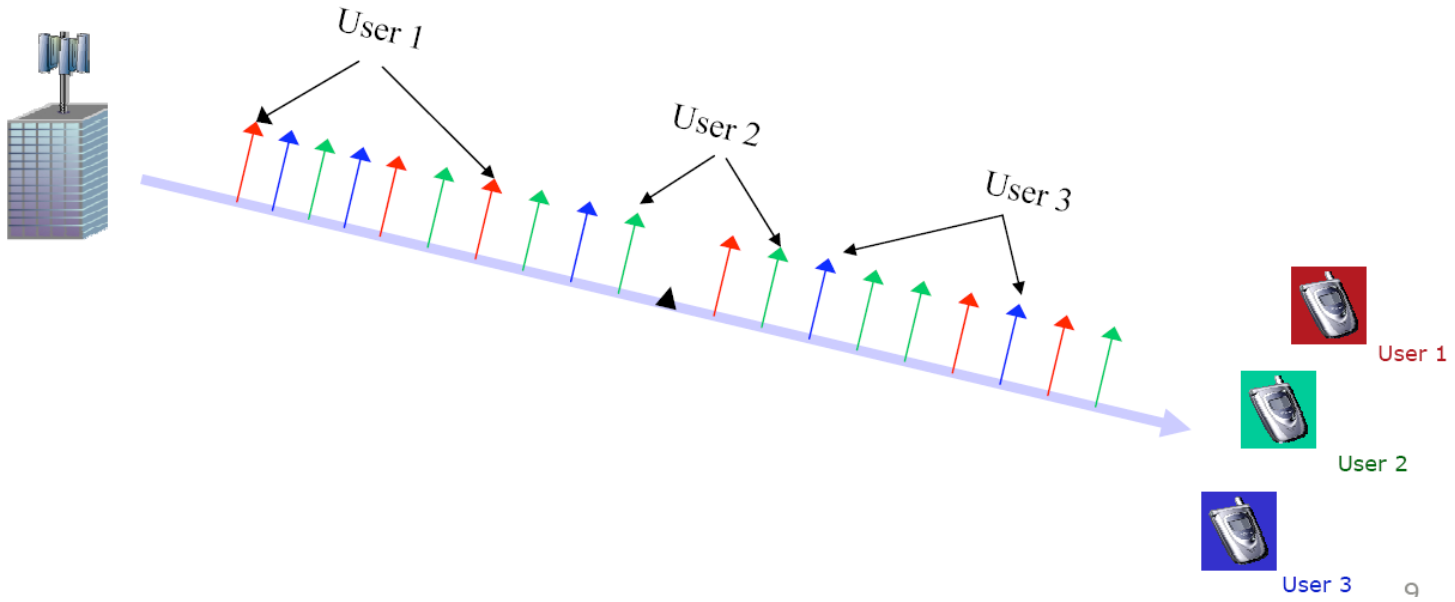
OFDMA in UL

- Each user transmits its signal in a group of sub-channels not all of the tones.
- The user, inserts zero energy on other tones
- The Base Station receives a superposition of all of these signals



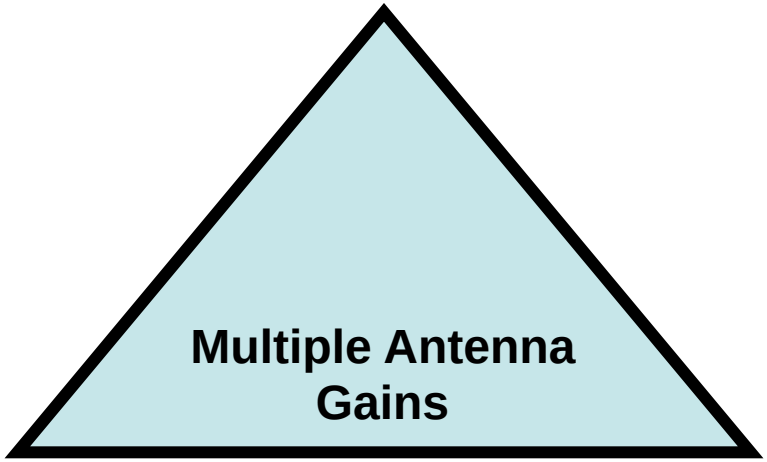
OFDMA in DL

- For each user, the base station inserts the signal aimed to that user into a separate group of sub-channels.
- The base station transmits in all tones
- Each user receives all of the tones, but decodes and demodulates those sub-channels that belong to it



Potential Multiple Antenna Advantages

Beamforming Array Gain
(Antenna gain and SNR improvement)

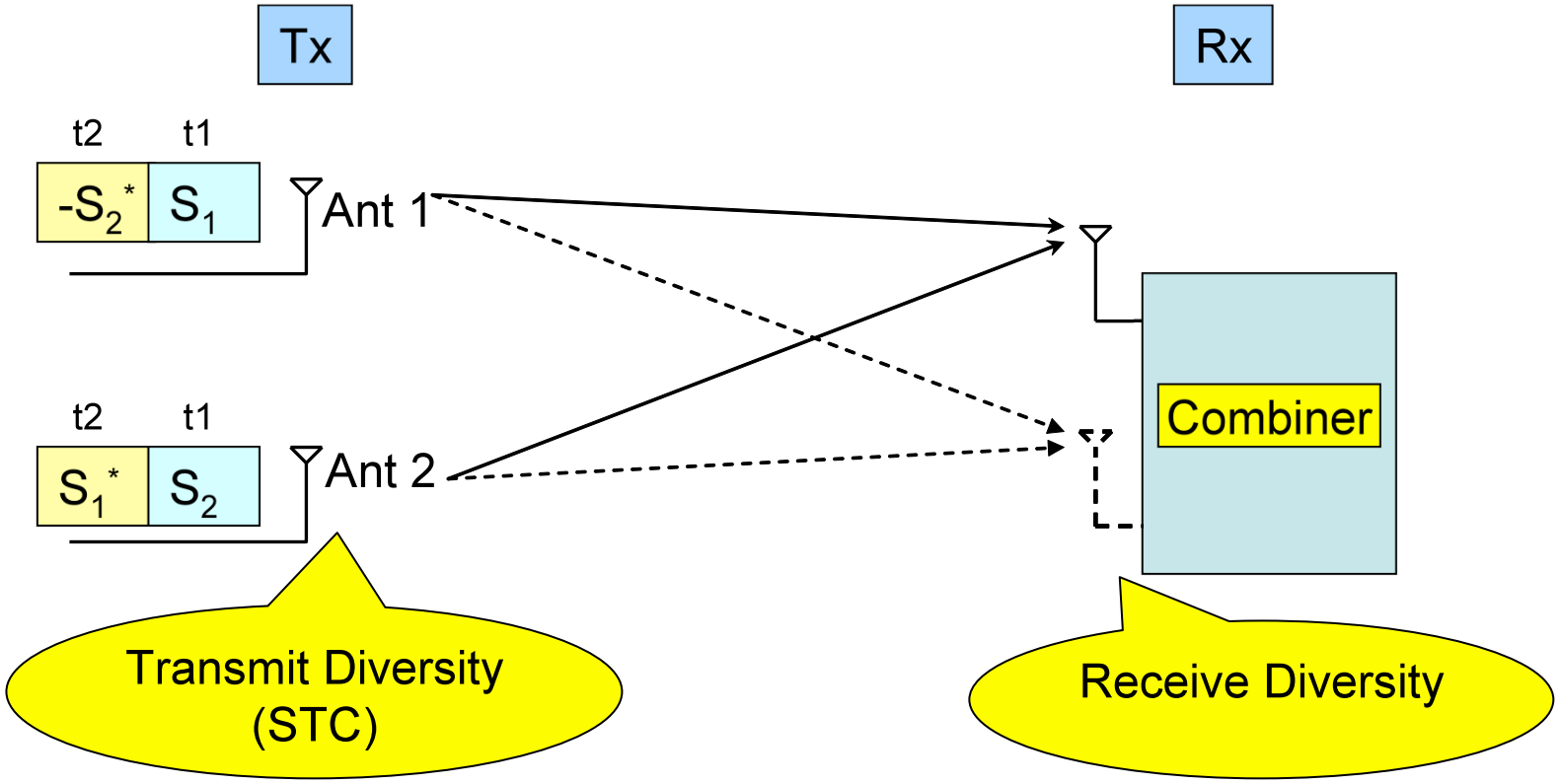


Diversity and Coding gain
MIMO - Space Time Coding
(link reliability enhancement)

Multiplexing gain
MIMO – Spatial Multiplexing
(Capacity Improvement)

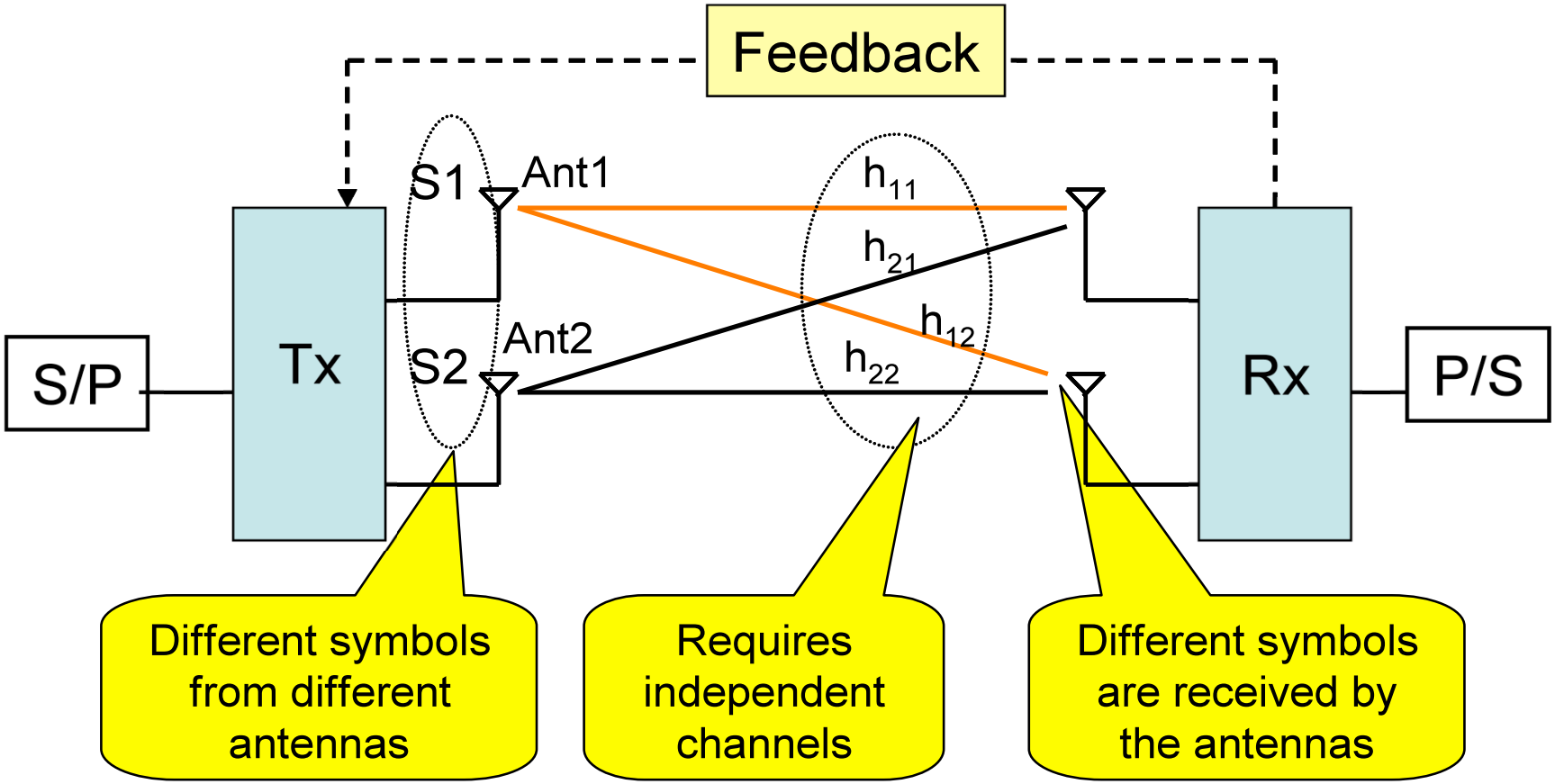
MIMO: Multiple Input Multiple Output

MIMO-A 2x2 (Space Time Coding – STC)



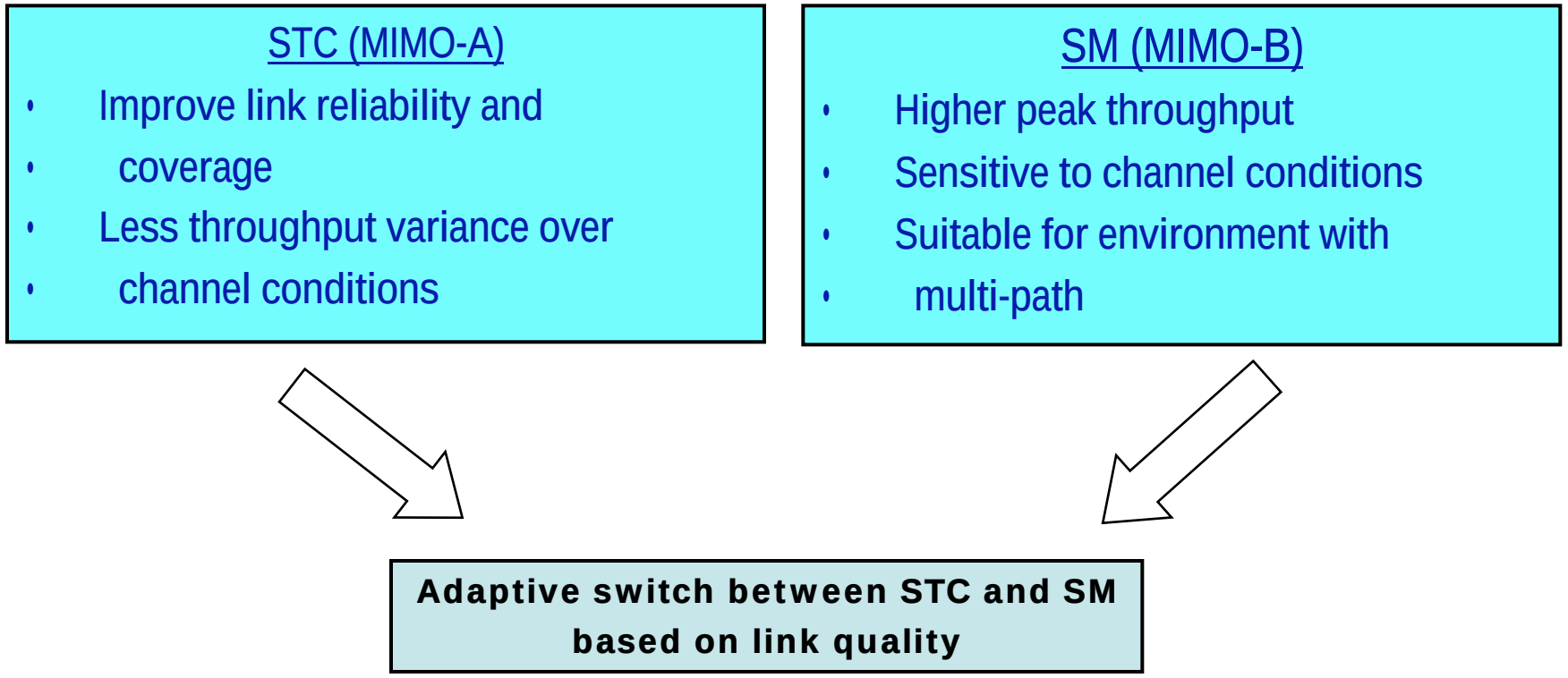
- **2 transmit antenna and two receive antenna**
- **Combine Transmit diversity and Receive diversity**
- **Combat multi-path and increase coverage**

MIMO-B: Spatial Multiplexing (SM)



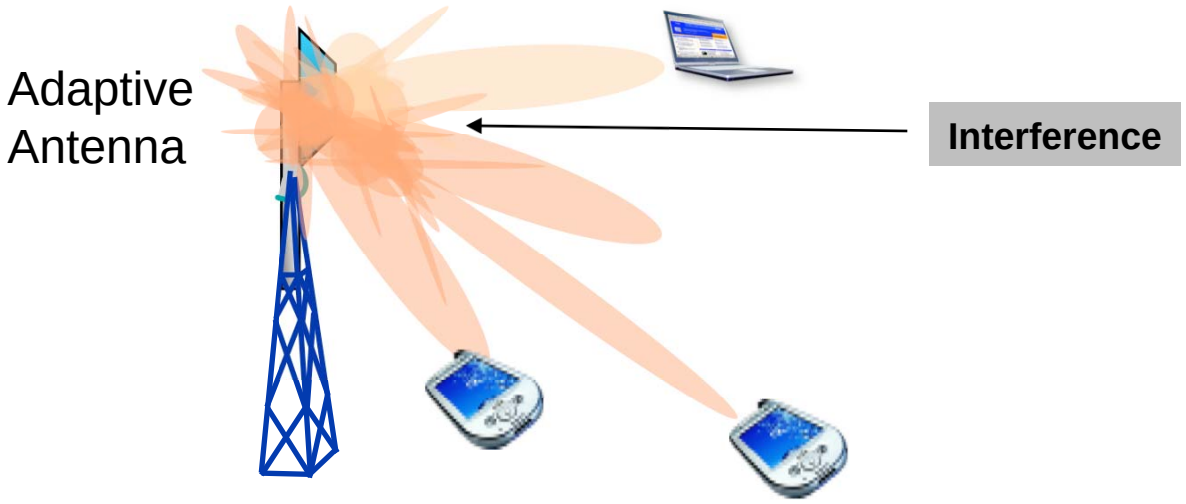
- **2 transmit antenna and two receive antenna**
- **MIMO Matrix B defined in 806.16e**
- **Make use of multipath and increase throughput**

MIMO Spatial Multiplexing (SM) vs. STC Encoding



Beamforming

- Beamforming, Adaptive Antenna, Smart Antenna
- A smart antenna system consists of several antenna elements, whose signals are processed adaptively in order to exploit the spatial dimension of the mobile radio channel.
- Beamforming provides higher antenna gain, and interference rejection capability
- Improvement in coverage and capacity
  - > E.g. 8 antenna elements: 12 dB increase in antenna gain



Part 5:

WiMAX Network Performance

Air Interface Configuration

- WiMAX Capacity depends on various system configuration parameters, coverage design, and subscriber locations
- Here is we consider the following parameters, which considers 10 MHz carriers using TDD technology

Parameter	Value
System Channel Bandwidth	10 MHz
FTT Size (N_FFT)	1024
Sub-carrier Frequency Spacing	10.94 kHz
Useful Symbol Time (Tb = 1/f)	91.4 micros
Guard Time (Tg = Tb/8)	11.4 micros
OFDMA Symbol Duration (Ts = Tb + Tg)	102.9 micros
Number of OFDMA Symbols/Frame	47
Frame Duration	5 ms
DL/UL Ratio	29/18

Maximum Throughput Using 2x2 MIMO

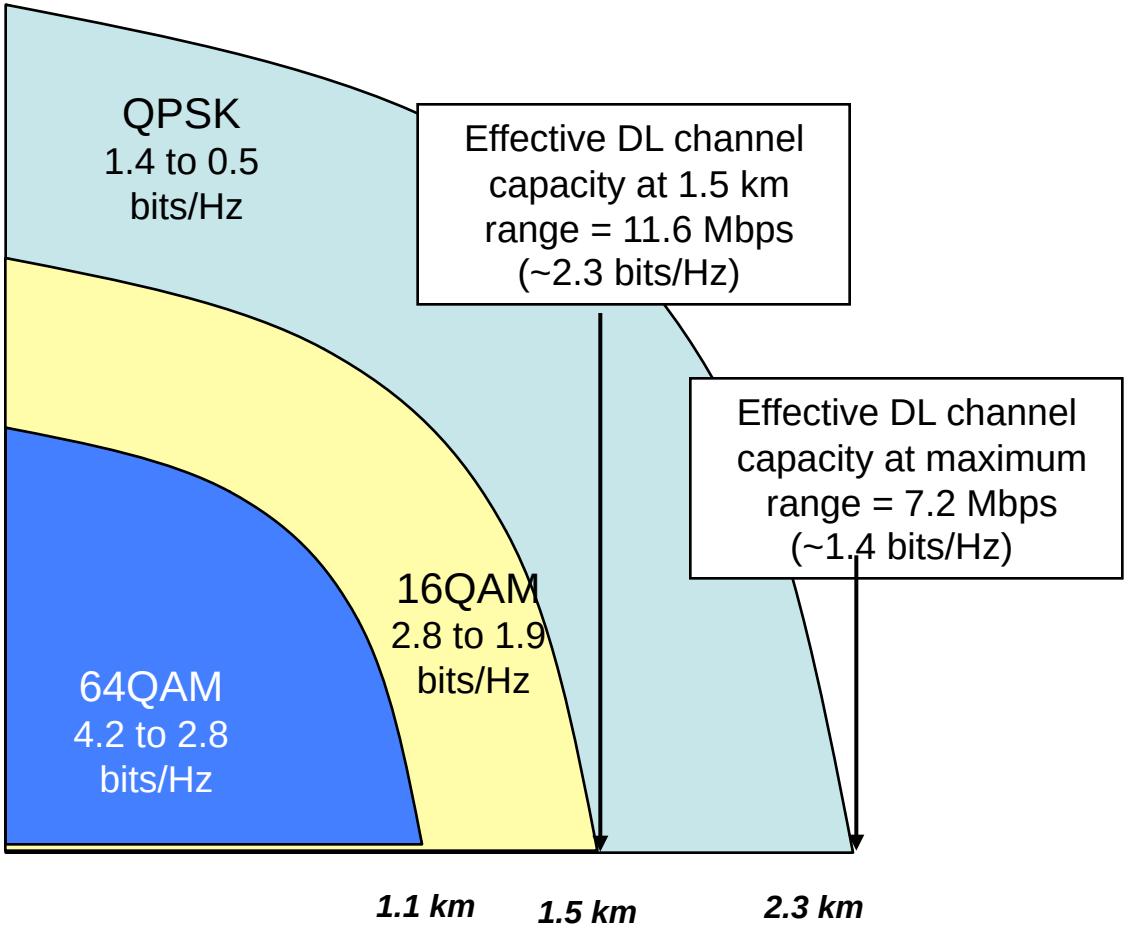
Max Throughput: Basic Configuration without 2x2 MIMO

Modulation	Coding	Downlink	Uplink
16 QAM	3/4 CTC		5.040 Mbps
64 QAM	5/6 CTC	17.28 Mbps	

Max Throughput: with 2x2 MIMO Configuration

	Antenna	DL	UL
User Peak Rate (Mbps)	SIMO (1x2)	17.28 Mbps	5.04 Mbps
User Peak Rate (Mbps)	MIMO (2x2)	34.56 Mbps	5.04 Mbps
Sector Peak Rate (Mbps)	SIMO (1x2)	17.28 Mbps	5.04 Mbps
Sector Peak Rate (Mbps)	MIMO (2x2)	34.56 Mbps	10.08 Mbps

Example: WiMAX traffic throughput and coverage

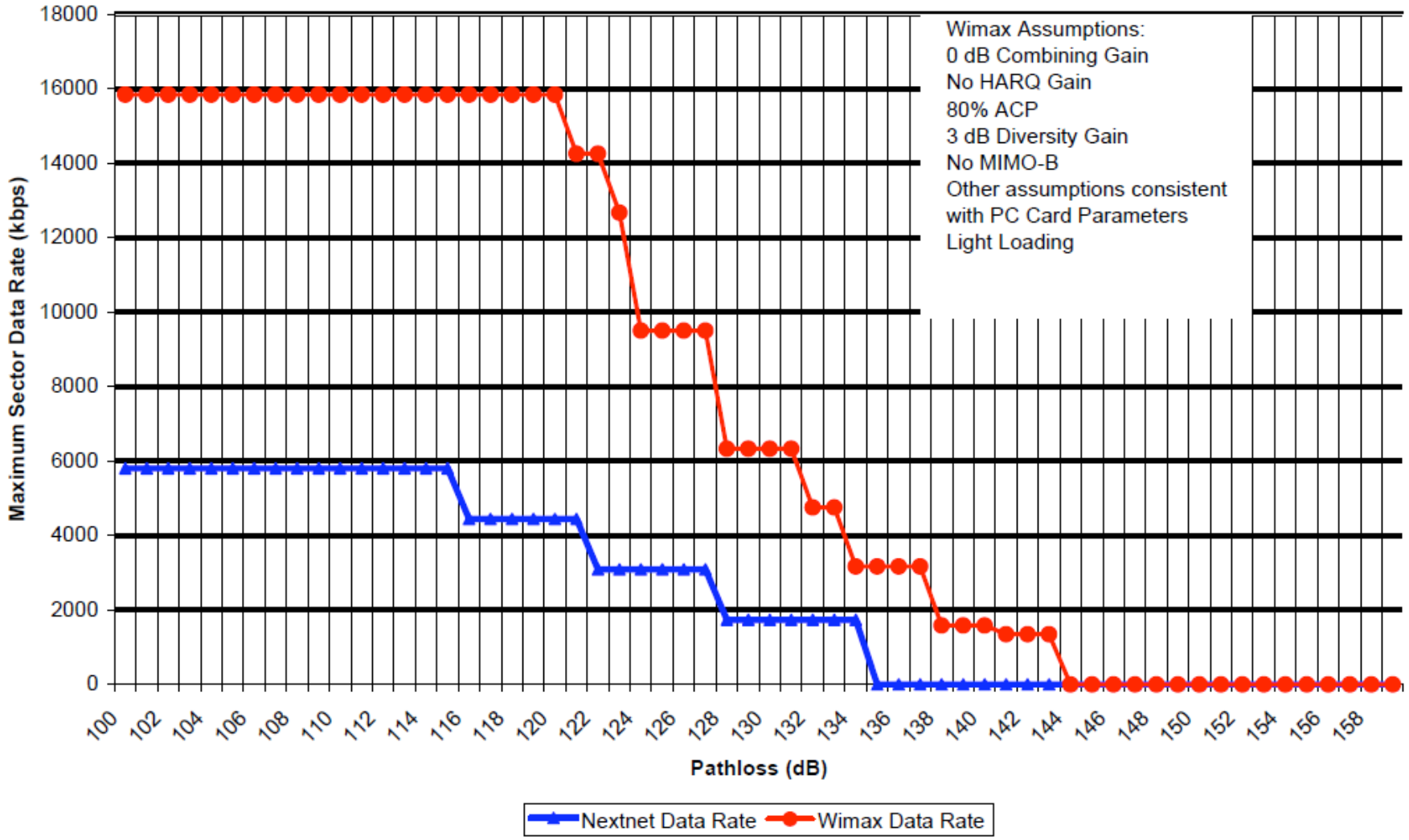


Non-LOS Range for Terrain Category B, 2.5 GHz, 5 MHz BW, TDD, 142 dB Link Budget

1.0 km 1.3km 2.0 km

Non-LOS Range for Terrain Category B, 2.5 GHz, 10 MHz BW, TDD, 139 dB Link Budget

Test Results



Average Network Throughput

- Average Sector throughput is lower than maximum sector throughput depending on
  - Coverage quality: better coverage provides higher capacity
  - Subscriber locations: if subscribers are closer to the site, throughput is higher, and subscribers at the cell edge experience lower throughput.
- Average sector throughput could reach half of the max throughput in a well designed network
- For a detailed WiMAX technology description and network simulation resuls please refer to WiMAX Forum:
  - www.WiMAXforum.org then select the white papers.

Backup Slides

Outline

This presentation provides a summary of the IEEE 802.16e / Mobile WiMAX technology and WiMAX Network Performance

Abstract:

In this presentation, we will provide an overview of the technical aspects of Mobile WiMAX features and capabilities. Mobile WiMAX is one of the 4G wireless technologies promising tens of megabits per second of wireless capacity to mobile users. The scalable architecture, low cost deployment, network efficiency and open eco-system make mobile WiMAX one of the leading solutions in wireless industry. We will review network architecture, then turn our focus to WiMAX air interface and orthogonal frequency division multiple access (OFDMA) technologies. We will learn about how WiMAX advanced features such as adaptive antenna systems (AAS), QoS, interference management, adaptive modulation and coding can significantly improve customer experience. At the end, we will review network performance data and challenges in design and implementation of the network.

Acronyms

PICS	Protocol Implementation Conformance Specification
AMC	Adaptive Coding & Modulation
HSS	Home Subscriber Server
I-WLAN	Intelligent Wireless Local Area Networking
SAE	System Architecture Evolution
MBMS	Multimedia Broadcast/Multicast Service
AES	Advanced Encryption Standard
PHSI	payload header suppression Index
ECRTP	Extended Compressed RTP
UGS	unsolicited grant service
OTA	Over-The-Air
TTG	Transmit/Receive Transition Gap
RTG	Receive/Transmit Transition Gap
MMSE	minimum mean-square-error