WiMAX

A Short e-Course

Course Objectives and Structure

- IEEE 802.16 Standard and the WiMAX Network Architecture
- Key Concepts of WiMAX/IEEE 802.16 Physical Layer
- Key Concepts of WiMAX/IEEE 802.16 MAC Layer

Summary and Review

Course Objectives & Structure

Learning Objectives

- Differentiate the WiMAX architecture from other, more traditional architectures used for mobile communications
- Identify the different end-to-end network architectures that the WiMAX technology can be used for
- Evaluate the strengths, opportunities, and challenges offered by the physical layer of WiMAX
- Evaluate the strengths, opportunities, and challenges offered by the MAC layer of WiMAX

Recall Lesson Plan

Course Objectives and Structure

- **IEEE 802.16 Standard and the WiMAX Network Architecture**
- Key Concepts of WiMAX/IEEE 802.16 Physical Layer
- Key Concepts of WiMAX/IEEE 802.16 MAC Layer

Summary and Review

Legend:

Already completed

Just ahead

Yet to come

Lesson 1:

WiMAX Architecture

Learning Objectives

- Differentiate the WiMAX architecture from other, more traditional architectures used for mobile communications
- Identify the different end-to-end network architectures that the WiMAX technology can be used for

Spectrum: World-Wide Regulatory Environment

FPLMTS

IMT-2000

UMTS

3G, 4G, etc

What is the degree of consistency in the sense of
(1) meaning and (2) spectrum allocations,
and/or implementation of these concepts around the world?

It should then be no surprise that the same holds for WiMAX!

World-Wide Spectrum Allocations for WiMAX

- In short: There is ***none***!
- Complete answer is more complex, as usual!
- In addition to the usual complexities related to multi-band operations, such as exist in GSM or UMTS, there are two "types" of bands usable for WiMAX:
  - Unlicensed bands
  - Licensed bands

To License or Not to License!

Issue	Licensed Band	Unlicensed Band
Right to Use	1. Exclusive usage rights within license area 2. Complete interference protection from others	1. No interference protection from others and must make sure not to interfere with others
Cost	1. The license may be expensive 2. Less cell sites required due to higher transmitted power limits	1. No license fee. 2. More cell sites required. 3. BTSs may be less expensive.
Deployment Issues	1. Not readily available – any spectrum purchase attempt requires long term planning 2. Once it is available, the interference protection ensures a lot more flexibility in terms of design and deployment	1. Readily available 2. Must plan around existing users of this band; complex design process 3. Low power limit necessitates more intensive deployment 4. Unsuitable for critical or premium service offering

Target Spectrum Bands

Based on the global spectrum band availability, the following frequency bands are currently being targeted:

- Unlicensed band:
  - 5.8 GHz: This includes the 5150-5350 MHz (U-NII Low and U-NII Middle) and 5725-5825 MHz (U-NII High) band. The U-NII High band has higher power limit (4 W EIRP typically) and is more attractive
- Licensed bands
  - 3.5 GHz: This includes the band within 3400-3600 MHz
  - 2.5 GHz: This includes the 2500-2690 MHz band; 2305-2320 and 2335-2350 MHz are also available in North America
  - Sub 1 GHz: This includes the 700-800 MHz bands currently used for analog TV transmission, some channels from which may be freed up with a move to digital TV transmissions

Global Spectrum Availability Issue vis-à-vis WiMAX Capabilities

WiMAX's approach to meeting varying global regulatory requirements is its **flexibility**

- Supports FDD and TDD duplexing modes
- Supports various frequency bands
- Supports various channel bandwidths

WiMAX versus IEEE 802.16

- While "WiMAX" is a widely recognized term, standardization has proven to be a very desirable feature
- The IEEE has been working hard at developing numerous standards for communications in general, wireless communications systems in particular

IEEE 802 Working Group 802.16 (1)

- 802.16 is a group of broadband wireless communications standards for metropolitan area networks (MANs)
- The original 802.16 standard, published in December 2001, specified fixed point-to-multipoint broadband wireless systems operating in the 10-66 GHz licensed spectrum
- An amendment, 802.16a, approved in January 2003, specified non-line-of-sight extensions in the 2-11 GHz spectrum, delivering up to 70 Mbps at distances up to 30 miles
- Officially called the WirelessMAN™ specification, 802.16 standards are expected to enable multimedia applications with wireless connection and, with a range of up to 30 miles, provide a viable last mile technology

IEEE 802 Working Group 802.16 (2) – contd.

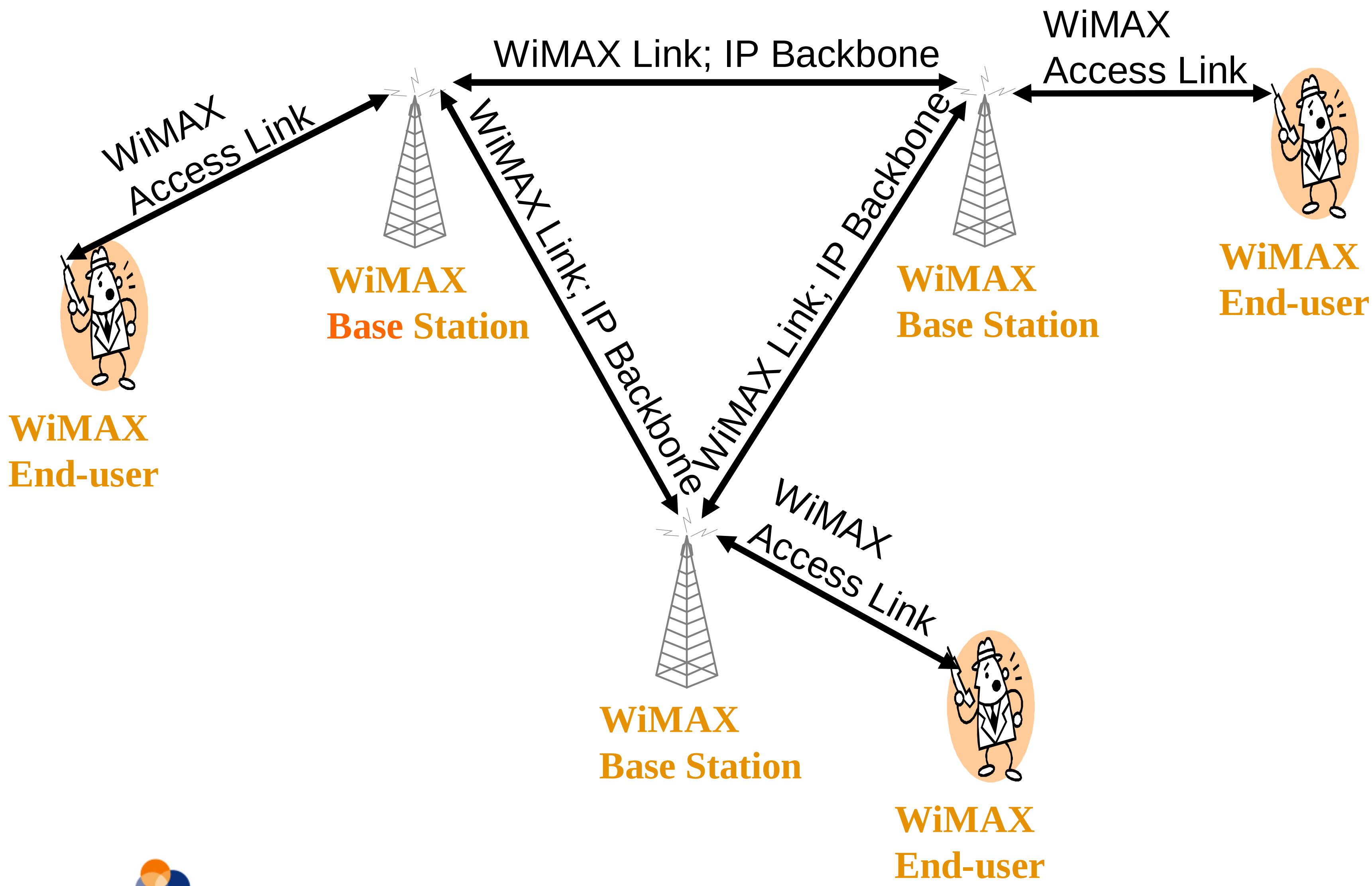
- 802.16 standards provide a wireless alternative to expensive T1 links connecting offices to each other and the Internet
- Although the original standard provides only for fixed wireless connections, the most recent amendment, IEEE 802.16e, enables connections for mobile devices
- 802.16e was approved by the IEEE on Dec 7, 2005 and was published in March 2006
- A coalition of wireless industry companies, including Intel, Proxim and Nokia, banded together in April 2001 to form WiMAX, an 802.16 advocacy group

  The organization's purpose is to actively promote and certify compatibility and interoperability of devices based on the 802.16 specs., and to develop such devices for the marketplace

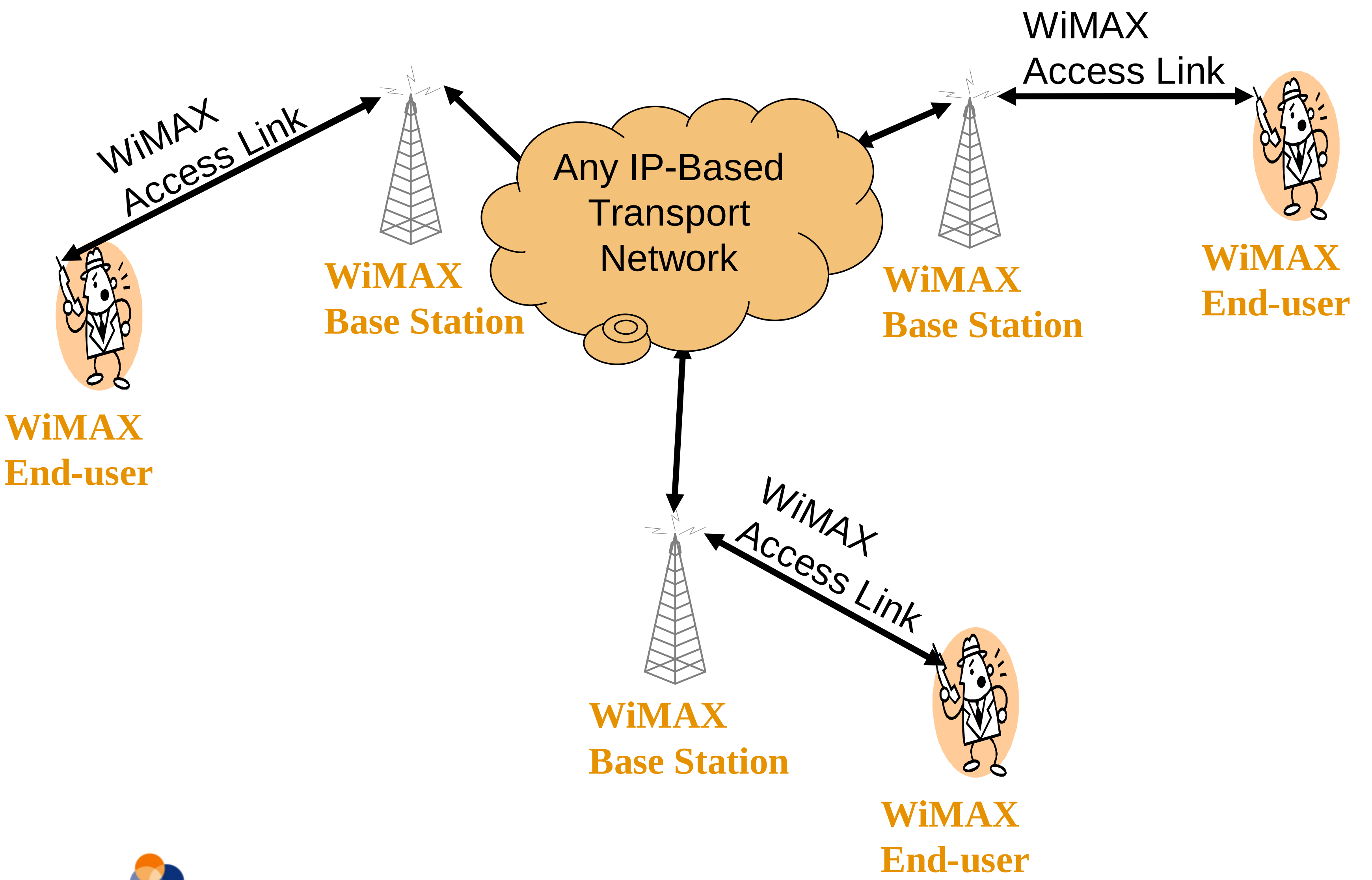
IEEE 802.16 Network Architecture

- Unlike "traditional" wireless networks, such as GSM or UMTS, WiMAX ***does not*** address any of the interconnect issues
- Moreover, it only "exists" at
  1. The physical layer and
  2. The link layer, the MAC in particular
- Typical expected architectures/applications/implementations are discussed next, followed by the protocol architecture

WiMAX as PTP Fixed Wireless (Thus Transport)



WiMAX as Wireless Access Only



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Summary and Review

Lesson 2

The Physical Layer

Learning Objectives:

Evaluate the strengths, opportunities, and challenges offered by the physical layer of WiMAX

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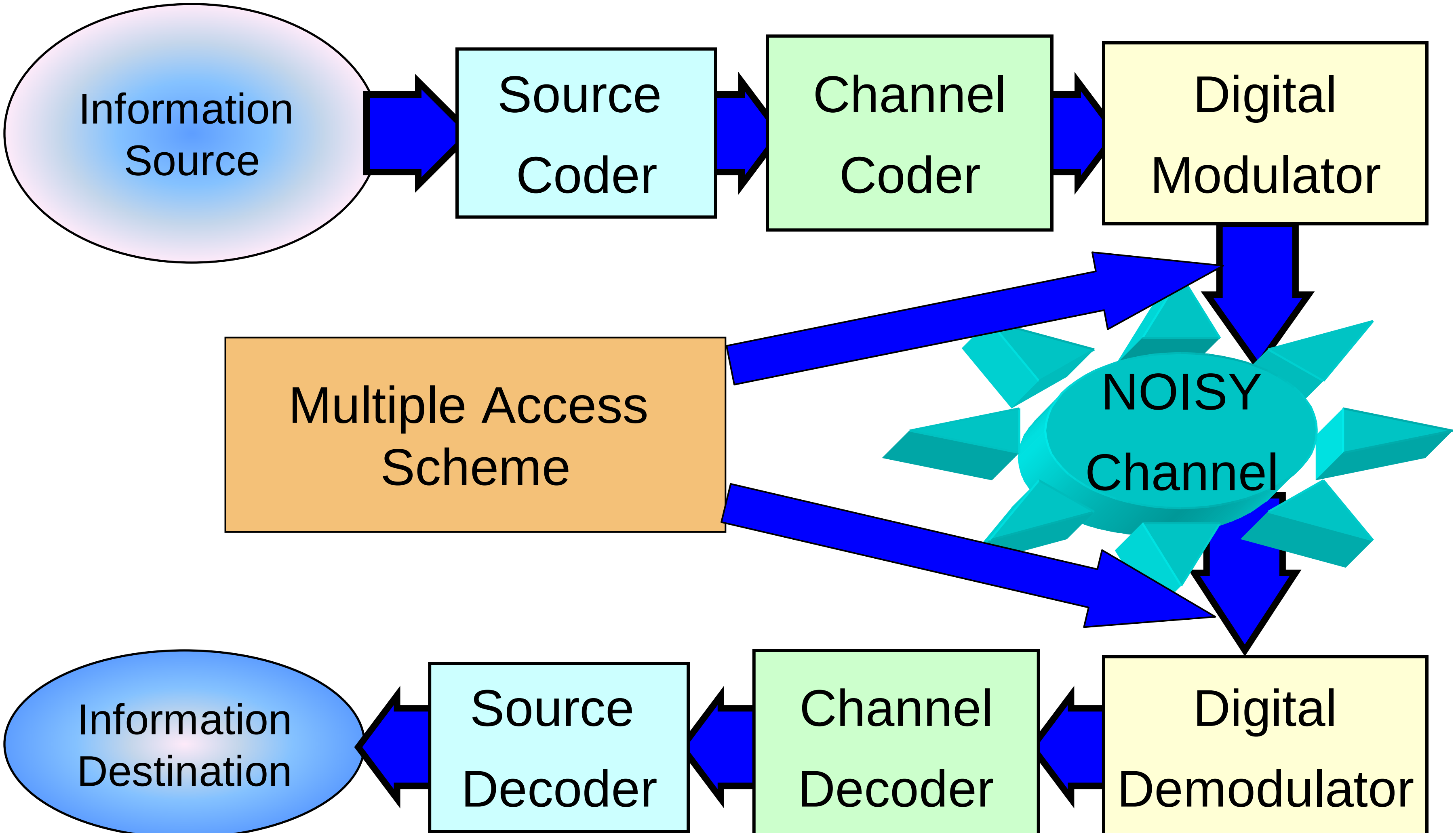
WiMAX: The Air Interface

- Indeed, when people talk about "wireless network", what they usually mean is the air interface portion of it and often just the physical layer!
- What are the challenges on the air interface?
- ***Our challenge***:
  - Conceptually the problems are ***easy***
  - However, "the devil is in the details" and that deeper consideration is what is ***hard!***
  - We will review the issues at hand and then briefly discuss the WiMAX approach to their solution

Basic Block Diagram of a Digital Communication System (1)



“Noise” in a Multipath Environment

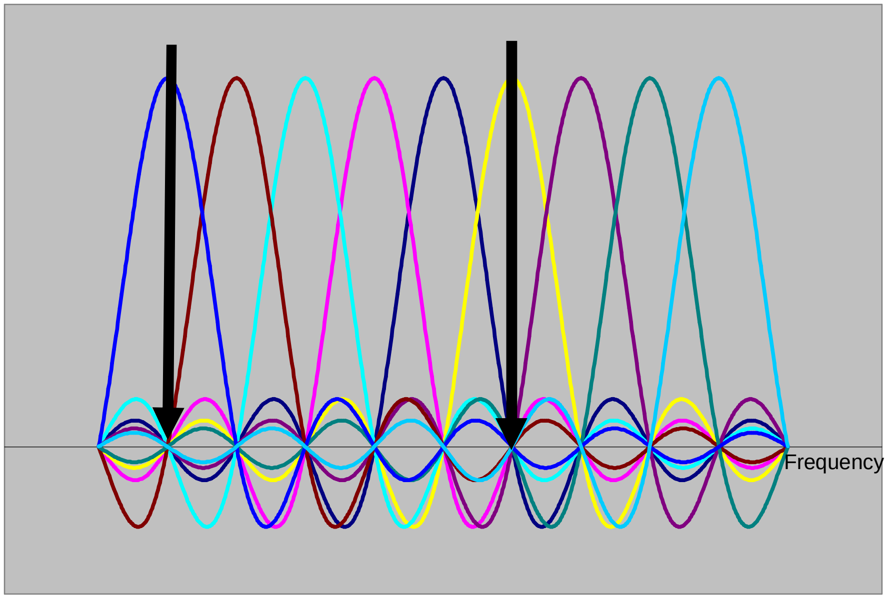
- What “type” of noise is the most difficult to overcome in a radio environment such as the ones typically found in our applications?
  A. Adjacent channel interference
  B. Co-channel interference
  C. Inter-symbol interference
  D. Additive, white, Gaussian noise
- How is the said noise dealt with in
  - TDMA systems, for example in GSM
  - CDMA systems, for example in UMTS/WCDMA?

- TDMA: Eliminate it, as best as possible!
- CDMA: Don’t try to combat it; Instead,

take advantage of it!

Orthogonal Frequency Division Multiplexing (OFDM)

- Spectrum is divided into multiple small-bandwidth sub-carriers
- Subcarriers are tightly packed
  - Orthogonality is achieved by ensuring that the center frequency of a sub-carrier falls on the impulse response nulls of all other sub-carriers



OFDM Fundamental Advantages (1)

OFDM handles multipath environment well

- Results from low-bandwidth sub-carriers
- Lower sub-carrier data rate results in longer symbol duration
- Long symbol duration is better able to handle Inter Symbol Interference (ISI) resulting from multipath signals, i.e., from frequency selective fading
- Guard interval in symbol period allows “area” of ISI
  - Also known as cyclic extension
  - Guard time intervals of 1/4, 1/8, 1/16, and 1/32 allowed
    - Long guard time interval can be used in environments with relatively high delay spread, depending upon channel bandwidth

OFDM Fundamental Advantages (2)

- Fast Fourier Transform (FFT) size is equivalent to the number of sub-carriers
  - 802.16-2004 allows FFT size ranging from 128 to 2048
- Orthogonal Frequency Division Multiple Access (OFDMA): Allows subcarriers to be assigned to different users for simultaneous transmissions
- Scalable OFDMA
  - FFT size scaled according to channel bandwidth, to keep sub-carrier bandwidth constant

OFDM Inherent Difficulties

Potential problems with OFDM

- Peak-to-mean Power Ratio
- Time and Frequency Synchronization
- Effects of Frequency Selective Channel Fading

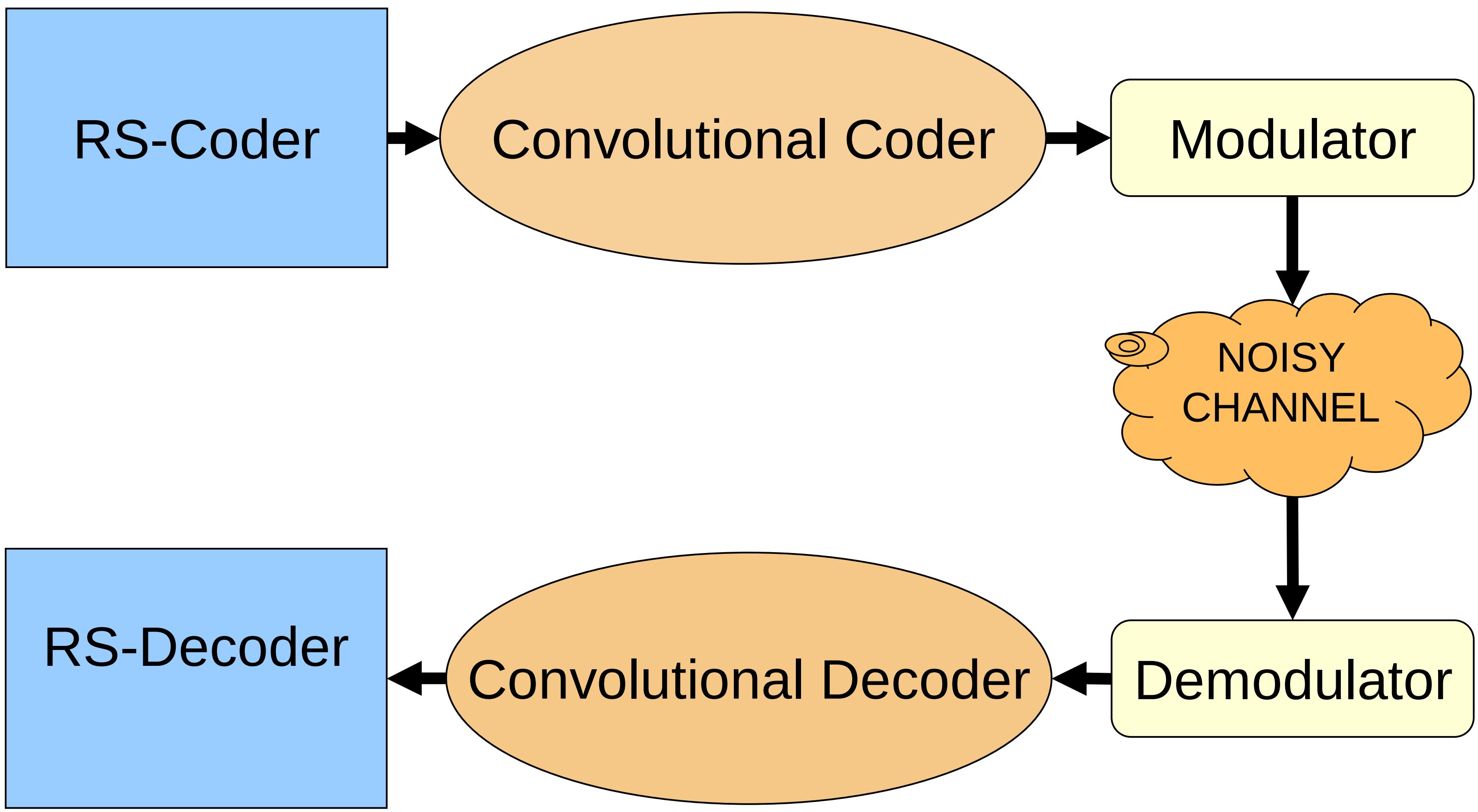
Key Attributes of the Physical Layer of 802.16 (1)

- Channel Coding
  - Convolutional coding
  - Concatenated Reed-Solomon Convolutional Coding
  - Optional channel coding techniques:
    - Turbo Codes
    - Low Density Parity Check (LDPC) codes
- Modulation
  - BPSK, with rate ½ code
  - QPSK, with rate ½ code
  - QPSK, with rate ¾ code
  - 16QAM, with rate ½ code
  - 16QAM, with rate ¾ code
  - 64QAM, with rate ½ code
  - 64QAM, with rate ¾ code

Key Attributes of the Physical Layer of 802.16 (2)

- In the case of OFDM/OFDMA operation, the "channel" consists of the following number of subcarriers, which get individually modulated using the FFT of the same size
  - 2048
  - 1024
  - 512
  - 128
- How many and which subcarriers are used for which user constitutes a significant portion of the complexity of the system!
  - **There is a fair amount of flexibility, thus complexity, depending on the frequency band and on vendor implementation, as to how to make these allocations!**

A Moment of Reflection: RS Outer Code with CC Inner Code



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Summary and Review

Lesson 3

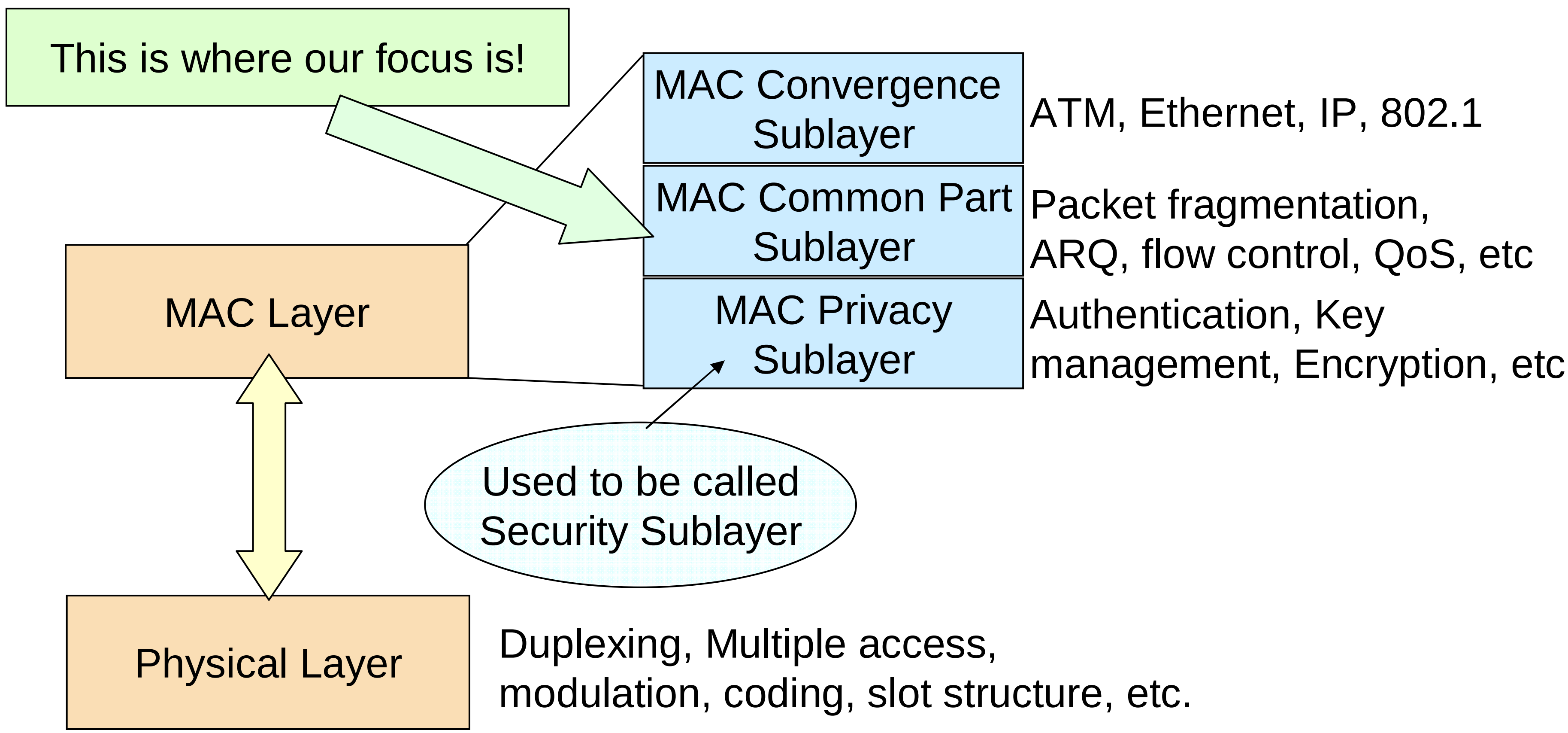
The MAC Layer

Learning Objectives:

Evaluate the strengths, opportunities, and challenges offered by the MAC layer of WiMAX

WiMAX Protocol Stack

- It is **VERY SIMPLE**!

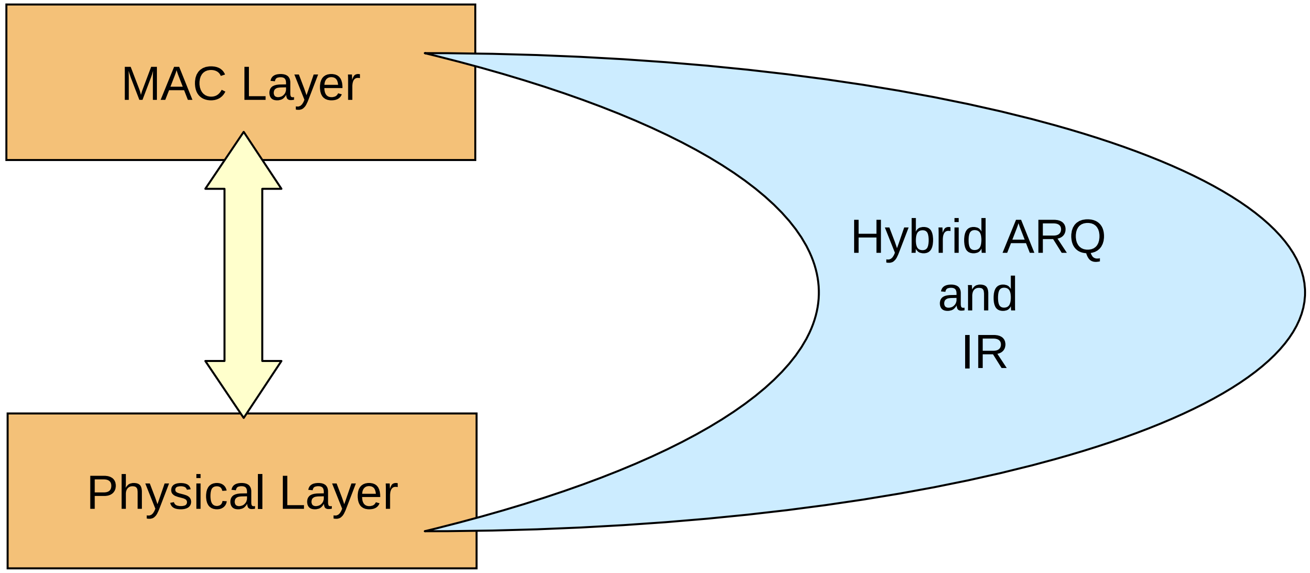


Key MAC Layer Functions

- WiMAX/IEEE 802.16 MAC layer is mostly responsible for:
  - Constructing MAC PDU’s according to one of several formats
  - MAC PDU transmission scheduling and associated resource (“bandwidth”) allocations
  - Idle mode processes, including
    - Cell selection
    - Paging structures
    - Location area updates
  - QoS service classes
  - Sleep mode processes
  - MAC layer handover procedures
  - MAC multicast and broadcast services

WiMAX Protocol Stack: Revisited

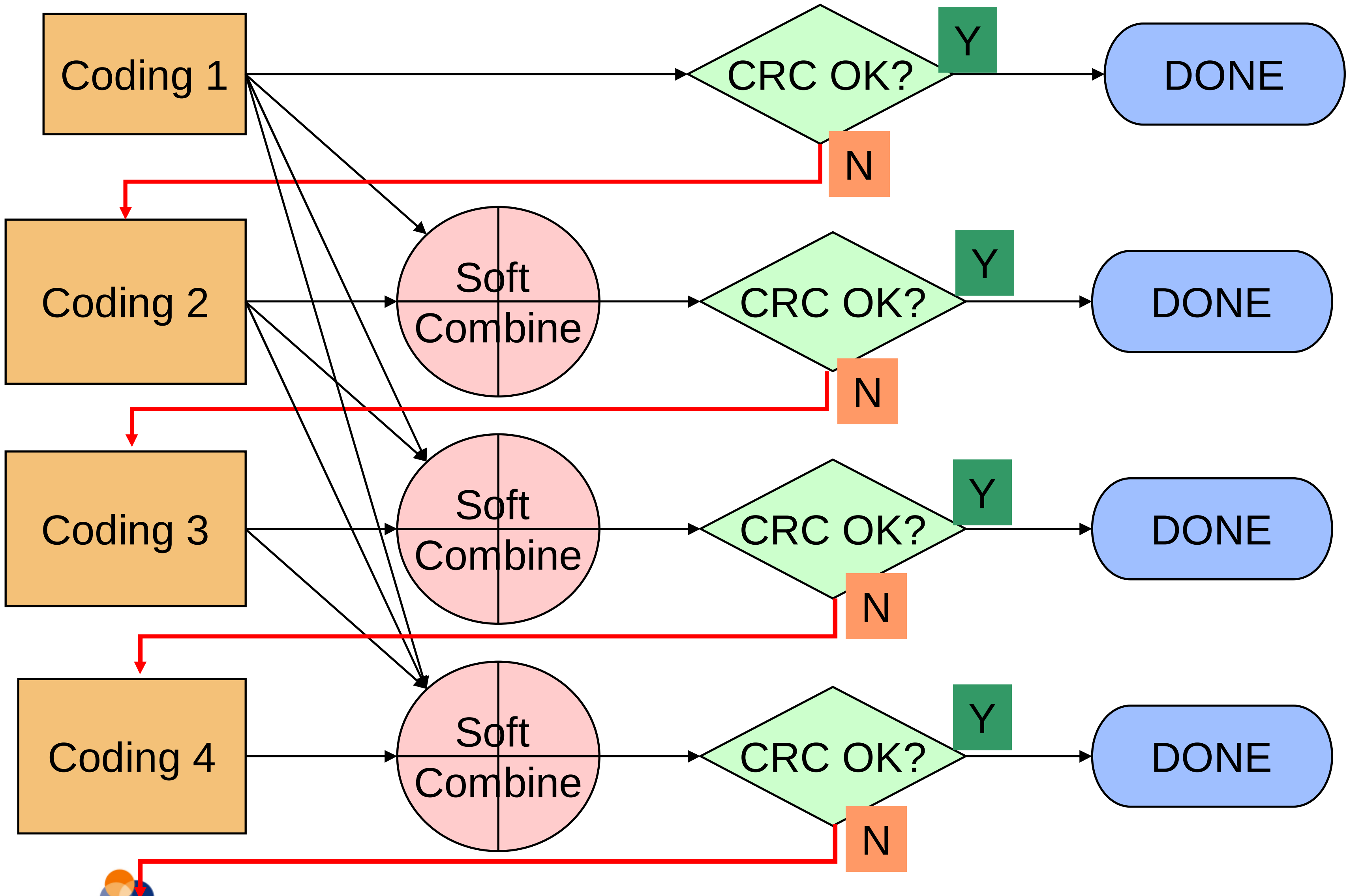
- Key limitation of the "divide and conquer" approach
- Equally key feature of WiMAX (and also available in EDGE, UMTS, and cdma2000)



A One Slide Introduction

- What does Hybrid ARQ mean?
- What is Incremental Redundancy (IR)?
- ***Question:*** If the channel is bad enough to the extent that ***each*** and ***every*** packet that is transmitted and/or retransmitted is received in error, is there any hope of getting the correct version of the packet without ever having a correctly received packet?
- ***Answer:*** That is a self contradicting statement, so obviously the answer is ***No -- but is it?***

Hybrid ARQ and IR at Its Core



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Summary and Review

Summary and Review

Summary and Review

- The WiMAX technology can serve both the “interconnect” and “last mile” needs of an operator
- It is based on an all-IP network architecture, which brings both pluses and minuses
- It is defined only at the physical and the MAC layers, making it simple and interoperable, but potentially causing interoperability issues
- On the physical layer, it takes advantages of OFDM and OFDMA
- Similarly, the physical layer takes advantage of the latest knowledge of error correcting codes, promising higher than ever throughputs
- The throughputs will also be enhanced by a much more sophisticated MAC layer, including hybrid ARQ and Incremental Redundancy

Review Questions

- What can you say about the frequency band(s) that WiMAX is defined in?
- In IS-95, a CDMA system, the channel size is 1.25 MHz. In UMTS, another CDMA system, the channel size is 5 MHz. What is the channel size in WiMAX?
- If an operator provides just the air interface in a WiMAX system, is ensuring end-to-end QoS parameters entirely in the operator's hands? Why or why not?
- Name the most fundamental aspect of the access technique used in WiMAX. How does it differ from the access techniques used in, for example (i) GSM and (ii) UMTS?
- How does WiMAX solve the ISI problem?

Review Questions (contd.)

- Can the question: "What is the raw transmission rate in a WiMAX system?" be answered? If so, what is the answer, if not why not?
- Can you summarize the main aspects of the error control coding scheme used in WiMAX and its advantages/disadvantages?
- Name all the layers of the WiMAX protocol stack
- In WiMAX, the MAC layer is subdivided into sublayers. Name them.
- One of the most important functions of the MAC layer is the implementation of Hybrid ARQ. Why is that so important? If the benefit is so great, what is the "cost" of using/implementing it?

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