WirelessHUMAN™ Tutorial

802.16 Study Group on

Wireless High-Speed Unlicensed Metropolitan Area Networks

IEEE 802 Plenary Session

10 July 2000

6:30 - 8:00 pm

Outline

- Overview: Durga Satapathy
  - Details on Unlicensed Spectrum
  - Introduction to WirelessHUMAN
- Suitability of 802.16 MAC: Carl Eklund
- Suitability of 802.11 MAC: Tim Godfrey
- Suitability of 802.11a PHY: Naftali Chayat
- Discussion

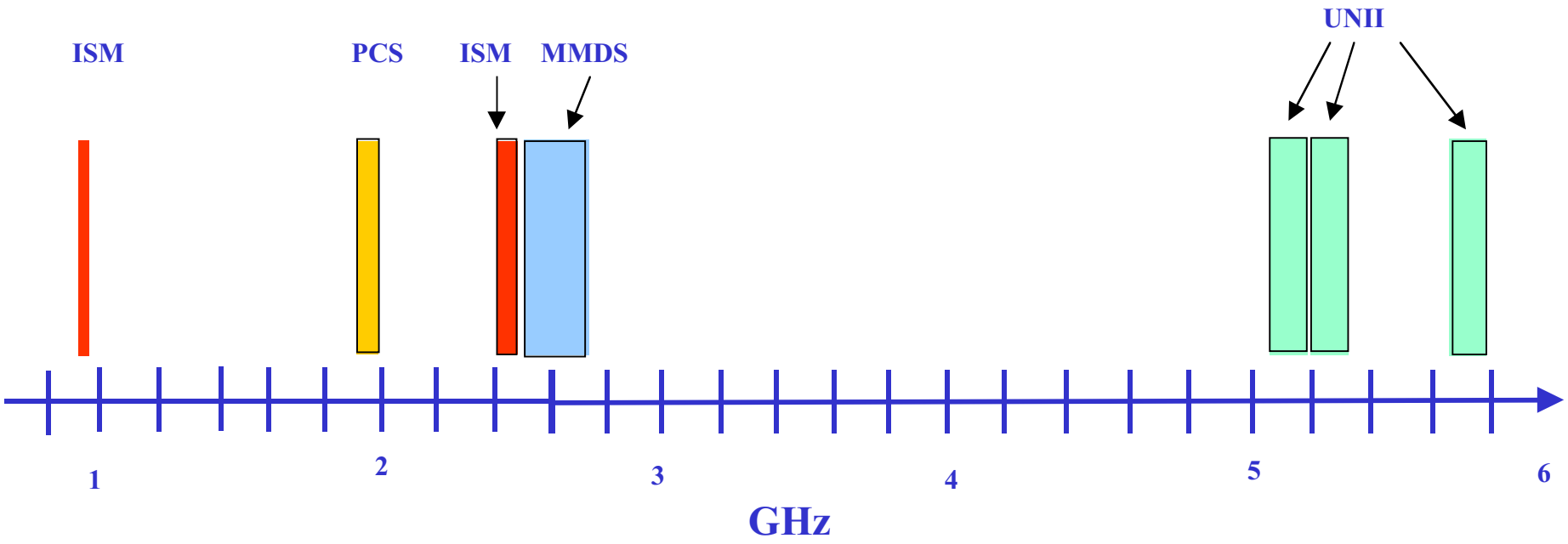
What is Unlicensed Spectrum?

- Any device may transmit in unlicensed spectrum without a license from the FCC
  - ***free*** radio spectrum
  - ***huge*** spectrum allocation
  - available ***nationwide***
- Unlicensed is subject to various rules and constraints, such as power limits.

Benefits

- Unlicensed can be used for both fixed and mobile services
  - Wireless Local Area Network
  - Wireless Private Branch Exchange
- Spectrum Sharing
- Allows experimentation and innovation

Spectrum View



ISM: Industry, Science & Medicine

PCS: Personal Communication Services

MMDS: Multi-channel Multipoint Distribution System

UNII: Unlicensed National Information Infrastructure

Unlicensed Bands	Spectrum	Typical Applications
ISM: Industry Science and Medicine 902-928 MHz, 2.4-2.4835 GHz & 5.725-5.85 GHz)	234.5 MHz	Cordless Phones, Wireless LANs (WLAN) and Wireless PBXs (WPBX)
UPCS: Unlicensed PCS Asynchronous:1910-1920, 2390-2400 MHz Isochronous: 1920-1930 MHz	 20 MHz 10 MHz	 WLAN WPBX
UNII: Unlicensed National Information Infrastructure UNII (5.15-5.25 GHz) UNII (5.25-5.35 GHz) UNII (5.725-5.825 GHz)	 100 MHz 100 MHz 100 MHz	 Indoor applications WLAN,WPBX Short outdoor links, campus applications Long outdoor links, Point-To-Point links
Millimeter Wave (59-64 GHz)	5 GHz	Home networking applications

Regulatory Approaches

- All unlicensed bands impose power limits
- ISM bands require spread spectrum modulation
- UPCS: Isochronous and asynchronous band, each with *Spectrum Etiquette* (rules regulating access and usage, e.g. Listen Before Talk (LBT))
- UNII bands & Mmwave bands: Minimal regulations e.g. power spectral density limits and emission limits

WirelessHUMAN Background

- The IEEE 802.16 WirelessHUMAN Study Group was approved at the March IEEE 802 Plenary meeting
- The charter is to investigate the feasibility of providing High-speed Unlicensed MAN access (focus on UNII bands)
- Significant interest from both academia and industry (manufacturers and service providers)
- First meeting held at IEEE 802.16 Session 7 with over 30 participants

What's Different?

- IEEE 802.11 – optimized for LANs primarily using ISM bands requiring spread-spectrum => not optimized for MAN access using 5-6 GHz (e.g. UNII bands)
- IEEE 802.15 - optimized for PANs (relatively small range) and focused on ISM bands
- IEEE 802.16.3 – optimized for licensed bands from 2 to 11 GHz
- The WirelessHUMAN Study Group addresses public network access in license exempt bands.
- The Study Group is investigating potential to reuse standardization efforts from 802.11/802.15/802.16

WirelessHUMAN™ System Characteristics

- Metropolitan Area Network
  - Need for Point-To-Multipoint Systems
  - Typically cellular; sectorized with frequency reuse
  - Typically needs backhaul architectures capable of reliable broadband transport
  - Connectivity to wired infrastructure/ core networks
- Services: voice, video & data
- Fixed/Nomadic Wireless Service Provider Application
- Operate in Unlicensed Frequency Bands (initial focus on outdoor UNII bands)
- Operation in presence of other unlicensed devices
- MAC/PHY efficiency to support MAN environment
- Cost and performance for residential/SOHO/SME/ customers
- QoS support (in-system & external interference)

Key Issues

- What are the existing regulations in the various unlicensed bands, and what unlicensed bands may be appropriate for WirelessHUMAN systems?
- What mechanisms for interference avoidance/suppression, resource sharing, and ensuring adequate performance exist in unlicensed bands?
- What are the unique system design issues/requirements of WirelessHUMAN systems from a MAC/PHY layer perspective? What elements can we utilize from existing work?

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IEEE 802.16.1 MAC protocol overview

Carl Eklund

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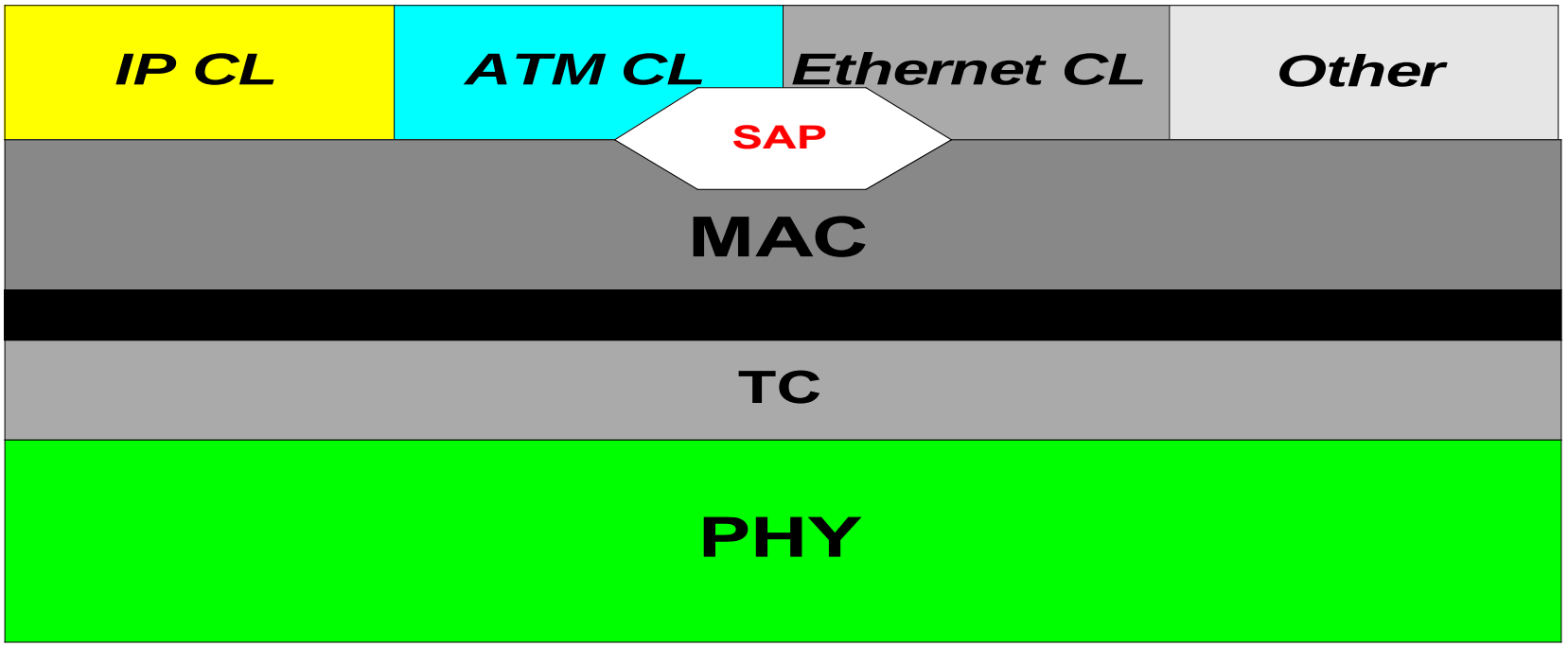
802.16.1 MAC protocol

- MAC protocol optimised for BWA
- Assumes point to multi-point network topology
- MAC protocol designed to be independent of the type of traffic transported
- Designed to support QoS for real-time traffic
- Core MAC developed through a 'clean sheet' approach
- MAC management leverages the extensive work done in cable modem standards
- Designed to allow for implementation of low cost LMDS equipment

Supported physical layer features

- Supports multiple PHYs. Currently two modes proposed for 802.16.1
- Subscriber level adaptive modulation
- Duplex schemes
  - FDD with TDM downlink and TDMA uplink
  - FSDD with TDMA in up- and downlink
  - (FSDD=frequency switched division duplex)
  - TDD with TDM downlink and TDMA uplink
- Physical layer details hidden from the MAC with help of a PHY specific transmission convergence layer

Protocol stack



MAC design

- MAC protocol is connection oriented
  - Flows uniquely distinguished by the connection identifier
  - Allows for leaner headers
- MAC layer is 'protocol agnostic'
- Data is transmitted in variable length PDUs
- Network protocol are interfaced via 'Network convergence layers'
- Convergence layer operations include
  - Assigning packet flows to connections
  - Mapping of network protocol parameters to MAC parameters
  - Payload header suppresession etc.
- Convergence layers for IPv4, IPv6, Ethernet and ATM under development

MAC services

- Unsolicited grant service
  - For providing ATM CBR like services e.g. T1/E1
- Unsolicited grant with activity detection service
  - For real time services which can have significant periods of inactivity e.g. VoIP
- Real time polling service
  - For rt-VBR like sevices e.g. video
- Non-RT polling service
- Best effort service

Request grant protocol

- Requests for upstream transmission opportunities are always made on a per connection basis
- Two modes for giving grants
  - Grant per connection: the BS specifies the connection that is granted BW
  - Grant per terminal: The BS gives a lump of BW to the terminal that fairly dirstibutes the BW to it's connections

Multiple Access Methods

- Polling
  - Terminals are polled either individually or in multicast polling groups
- BW stealing
  - The terminal uses a part of it's granted bandwidth to send a request
- Random access requests
  - BW requests are transmitted in RA slots
- Piggy back requests
  - More BW for the same connection can be requested through a piggyback field in the header

Conclusions

- A flexible and lean MAC protocol for PMP systems
- Supports QoS
- Not tied to a specific PHY layer design

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802.11 MAC applicability for WirelessHUMAN

Tim Godfrey

Intersil

July 9, 2000

Commonality with 802.11

- 802.11 has broad market acceptance, and a rapidly growing installed base.
- 802.11a WLAN devices will become available in 2001.
- Economies of scale will reduce the cost for 802.11a and WirelessHUMAN implementations if they use comparable technologies.

802.11a PHY Overview

- The 802.11a PHY is directly applicable to the Wireless HUMAN project.
  - 802.11a operates in the 5GHz UNII band.
  - 802.11a uses OFDM modulation with 52 subcarriers, providing excellent multipath performance.
  - 802.11a supports 8 data rates in the range of 6 to 54Mbps, which allows adaptation to various link conditions.

The 802.11A PHY

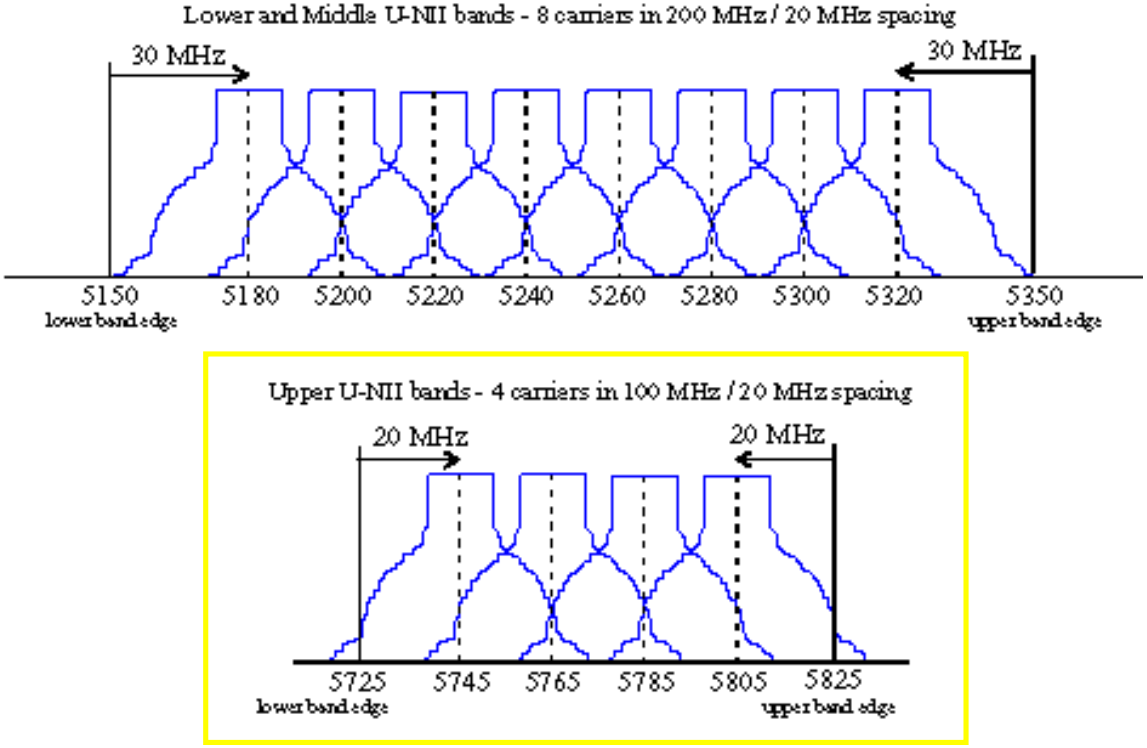


Figure 119—OFDM PHY frequency channel plan for the USA

Table 89—Transmit power levels for the USA

Frequency Band	Maximum Output Power with up to 6 dBi antenna gain
5.15 - 5.25 GHz	40 mW (2.5 mW/MHz)
5.25 - 5.35 GHz	200 mW (12.5 mW/MHz)
5.725 - 5.825 GHz	800 mW (50 mW/MHz)

Table 86—OFDM PHY major parameters of OFDM PHY

Information data rate	6, 9, 12, 18, 24, 36, 48 and 54 Mbit/s (6, 12 and 24 Mbit/s are mandatory)
Modulation	BPSK-OFDM QPSK-OFDM 16-QAM-OFDM 64-QAM-OFDM
Error Correcting Code	K=7 (64 states) Convolutional code
Coding rate	1/2, 2/3, 3/4
Number of subcarriers	52
OFDM symbol duration	4.0 μs
Guard interval	0.8 μs *(T_{GI})
Occupied Bandwidth	16.6 MHz

*Refer to subclause 17.3.2.4

Why is the 802.11 MAC appropriate for WirelessHUMAN?

- The 802.11 MAC was designed to support a relatively unreliable RF link operating in an unlicensed band.
- The protocol is extremely robust, and provides the level of reliability required by higher layer protocols.
- The MAC provides a level of indirection which enables nomadic users, and hand-off between access points, without affecting higher layer protocols.

What are potential problems with the 802.11 MAC for WirelessHUMAN?

- The 802.11 MAC we802.1ot dle0ignedC fornodPeJ!;MD,?

Improvements to the 802.11 MAC

- In September 1999, the MAC Enhancements study group was formed. Two PARs were generated.
- Enhancements related to Quality of Service, Security, Authentication, and other internal MAC functions are being developed by Task Group E. The Task Group will produce a supplement to the 802.11 standard.
- Enhancements related to the Inter Access Point Protocol are being developed by Task Group F. This protocol is outside the scope of 802 standards, so Task Group F will produce a Recommended Practices Document.

Scope and Purpose of Project 802.11E

- The PAR, approved in March 2000, defines the scope and purpose of the project:
  - Enhance the 802.11 Medium Access Control (MAC)
  - Improve and manage Quality of Service
  - Provide classes of service
  - Provide enhanced security and authentication mechanisms
  - Consider efficiency enhancements in the areas of the Distributed Coordination Function (DCF) and Point Coordination Function (PCF)

Why Enhance the 802.11 MAC?

- Demand for Quality of Service over wireless LAN
  - Voice over IP
  - Multimedia
  - Support for priorities and classes of service implemented in higher network layers.
- Need for improvements in privacy and authentication.
  - Weaknesses in existing WEP mechanism have been identified
  - Changes in regulations regarding export of encryption.
  - Desire to implement different authentication mechanisms in to correspond to differing security environments.

Why doesn't the existing Point Coordination Function provide adequate QoS?

- The PCF provides a Contention Free Period (CFP), where access to the medium is completely controlled by the Point Coordinator (PC).
  - The CFP begins with a beacon transmitted by the PC. The PC must contend for the medium using the DCF rules. Thus the beacon (and the CFP) may be delayed by other non-coordinated traffic.
  - There is no unacknowledged unicast service.
  - There is no standardized mechanism for controlling Point Coordinator bandwidth allocation policy.
  - Stations attempting to associate or reassociate in a Point Coordinated BSS must contend under DCF rules.

802.11E QoS Proposal Comparison

	Use 802.1d VLAN tags to indicate priority	Use SBM for admissi on control	Change DCF rules to provide priority	Fix existing problems with the PCF	Enhance the PCF	
A Polling Proposal for QoS TSA and Enrichnet - 061		✓			✓	
MAC Enhancements Joint Proposal AT&T, Lucent, Sharewave 071	✓	✓		✓	✓	
QoS Support in 802.11 WLAN Philips Research 110				✓		
802.11 PCF Enhancements and Contention Free Bursts NWN 113				✓	✓	
IEEE 802.11 Quality of Service Microsoft 028	✓	✓	✓			
Wireless LAN QoS Intel 036	✓	✓				

802.11E QoS Proposal Comparison

Proposals using enhancements to the PCF	PCF Enhancements						
	New types of polling	Extend CFP polling ordering rules	Mitigate the effects overlapping BSS on the same channel	Means to allow BW reservation without DCF Contention	Management interface for bandwidth allocation policy	New acknowledgement policies	Direct STA – STA transfers
A Polling Proposal for QoS TSA and Enrichnet - 061	✓	✓					?
MAC Enhancements Joint Proposal AT&T, Lucent, Sharewave 071	✓	✓	✓	✓	✓	✓	✓
802.11 PCF Enhancements and Contention Free Bursts NWN 113	✓	✓	✓				

802.11E CEPT Harmonization

- One of the enhancements planned for 802.11E is the addition of support for Dynamic Frequency Selection (DFS) and Transmit Power Control (TPC) to the 802.11 MAC.
  - Full implementation will require corresponding changes to the 802.11 PHYs.

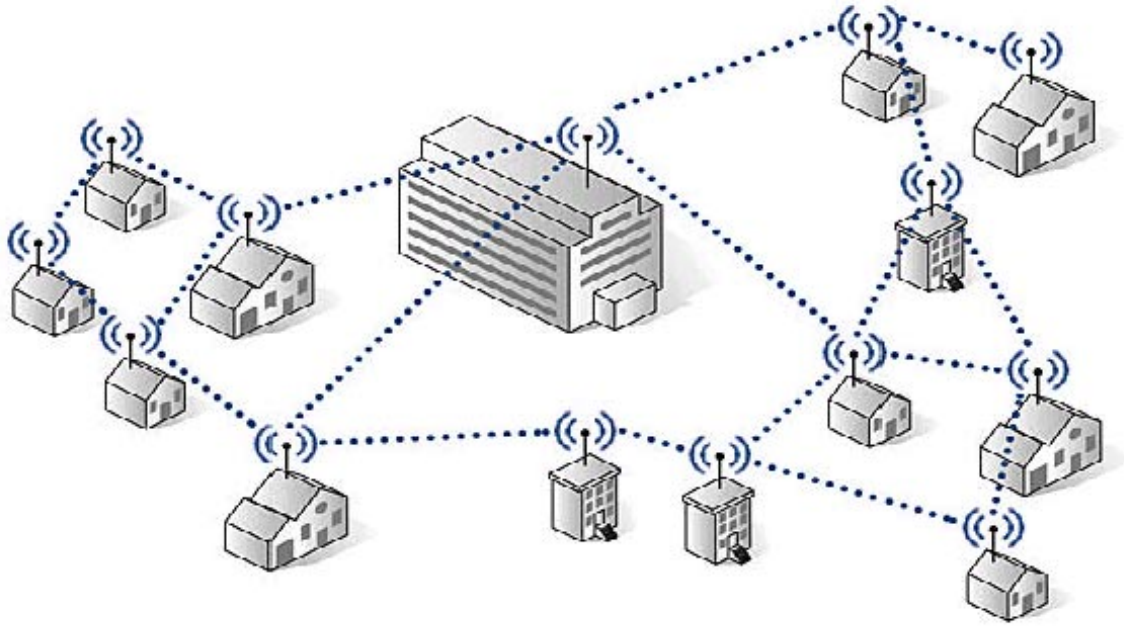
802.11E Security Enhancements

- The authentication mechanism will be extended to provide mutual authentication in both infrastructure and independent BSS's.
- Security enhancements will protect network traffic from eavesdropping to a reasonable level compatible with the state of the art.
- Security enhancements will allow for authentication of the source of each packet, to prevent link hijacking or undetected insertion of rogue packets into the link.
- Security enhancements will allow key distribution or derivation of per-link or per-session keys, and strongly protect keys and passwords from recovery by eavesdropper.

802.11E Project Timetable

- July 1999 – Study Group formed by 802.11
- November 1999 – MAC Enhancements PAR submitted
- March 2000 – PAR Approved, Task Group 802.11E formed
  - First set of proposals and papers on MAC Enhancements.
- May 2000 – First meeting of Task Group E
- July 2000 – 802 Plenary Meeting, La Jolla, CA
  - Continuation of presentation of papers and proposals
  - Refinement of Requirements and Evaluation Criteria
- September 2000 – Selection of proposals
- November 2000 – Target date for first letter ballot

WirelessHUMAN system architecture



From: 802.16hc-00/01
"**Requirements for WirelessHUMAN Systems**"

- A multi-hop network (wireless distribution system) is not directly supported by the 802.11 MAC.
  - Routing and forwarding could be handled at higher layers.
  - Such a system would make support QoS with 802.11E MAC enhancements much more difficult.

Conclusion

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802.11+ for Wireless HUMAN: potential benefits

Naftali Chayat, *BreezeCOM*

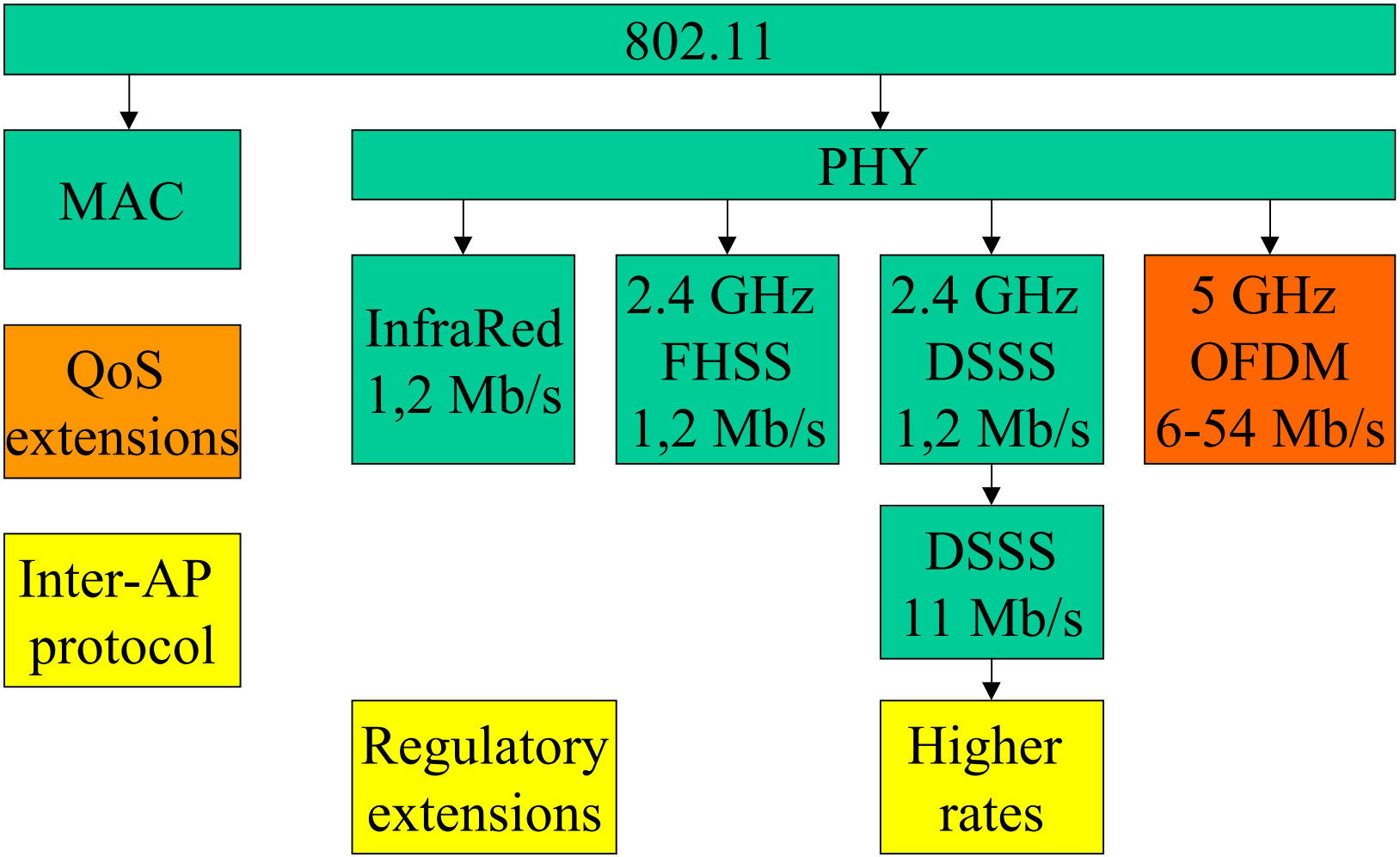
WirelessHUMAN Tutorial

July 2000, La Jolla

Presentation Overview

- Regulatory environment
- 802.11 and its activities relevant to Wireless HUMAN
  - 802.11a – High speed PHY for 5 GHz band
  - 802.11e – QoS++ extensions to 802.11 MAC
- 802.11a (and HIPERLAN/2)– Technical principles
- Conclusions

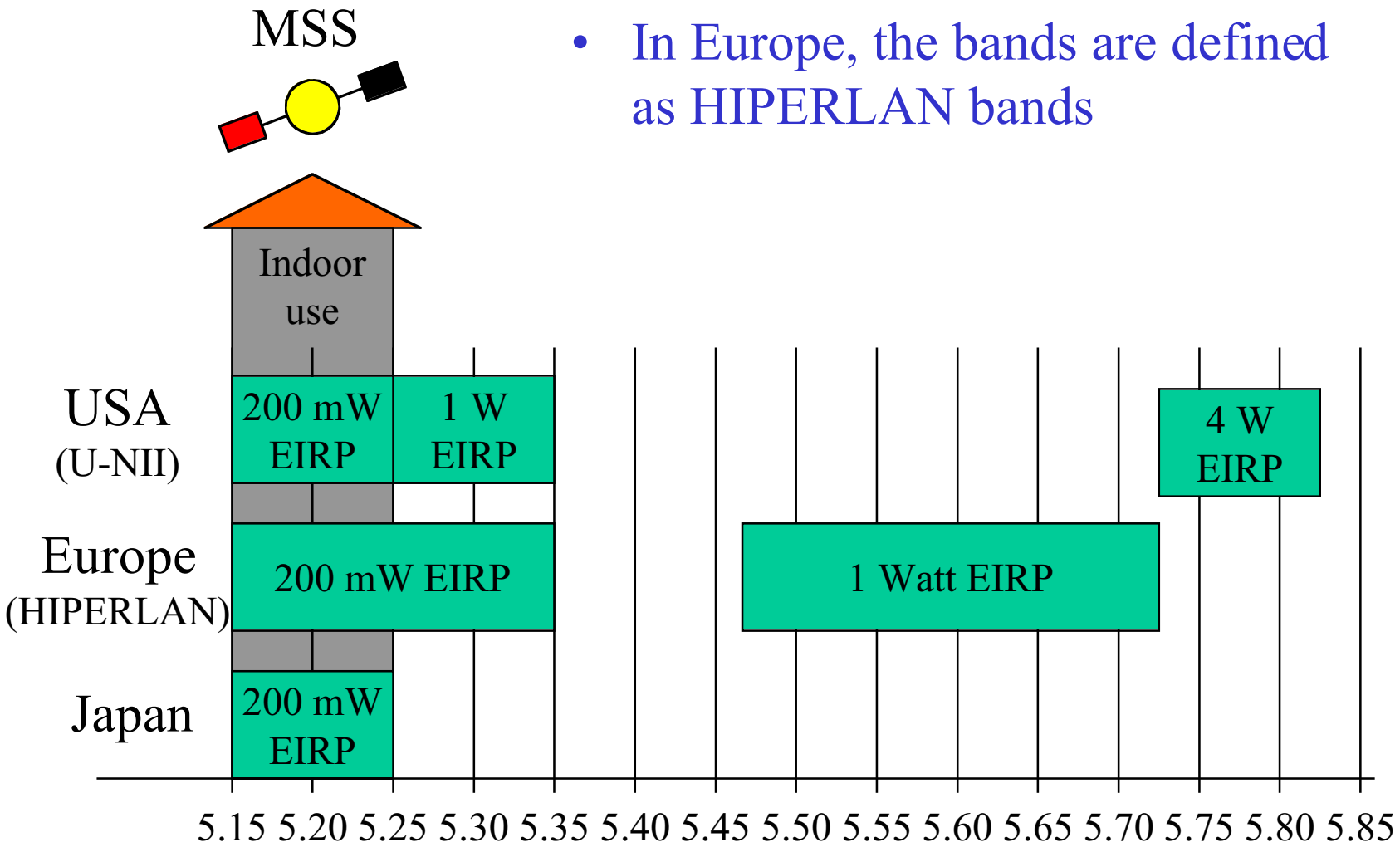
802.11 Standard's Structure



802.11a - 5 GHz OFDM PHY

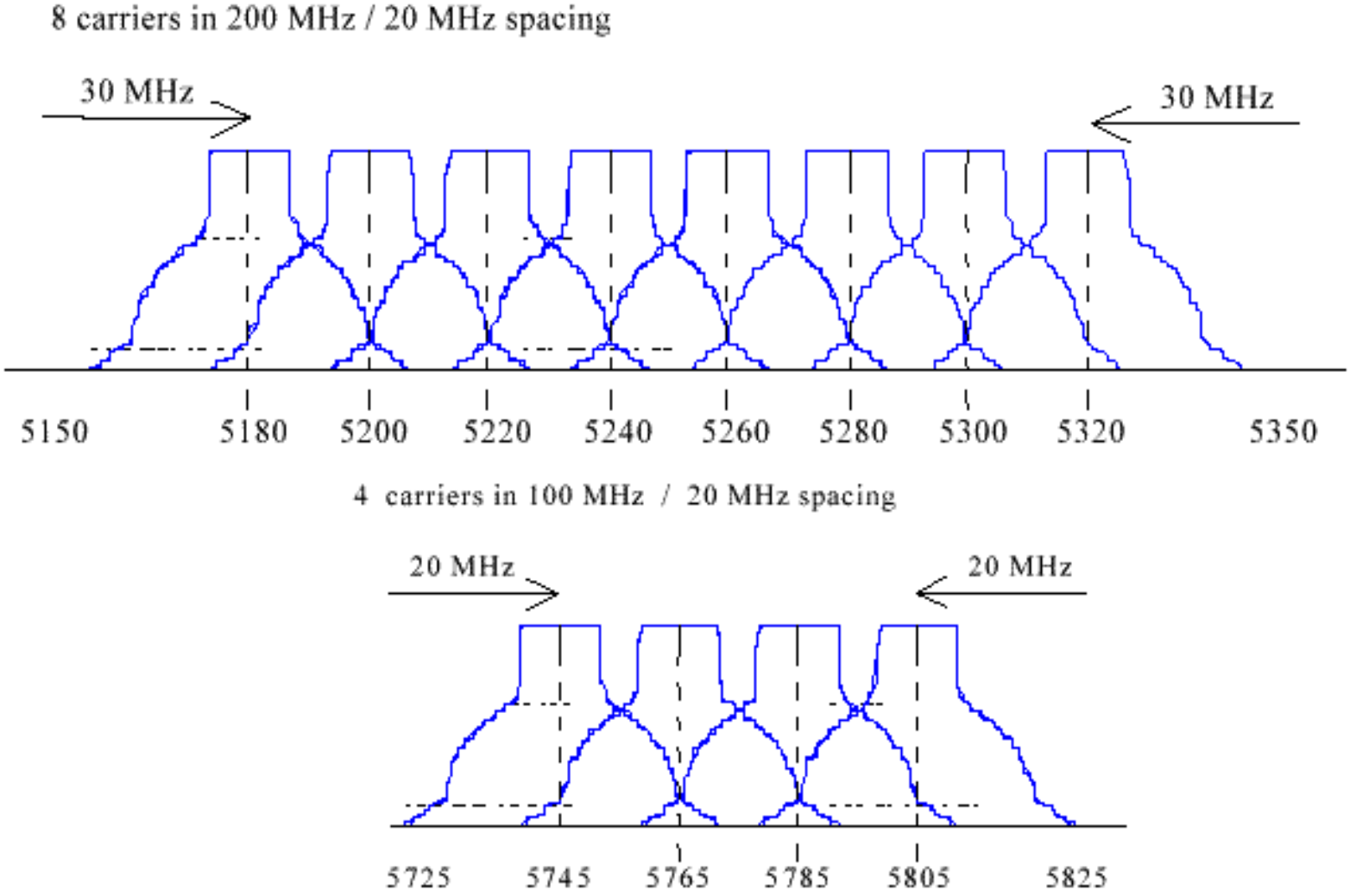
- Data rates 6-54 Mbit/s
  - Support of 6, 12 and 24 Mbit/s is mandatory
- 20 MHz channels spacing
  - 8 channels in lower+middle U-NII bands
  - 4 channels in upper U-NII bands
- OFDM modulation – multipath robustness
- Coordinated with ETSI HIPERLAN/2 and Japanese MMAC

5 GHz band – Regulatory Arena

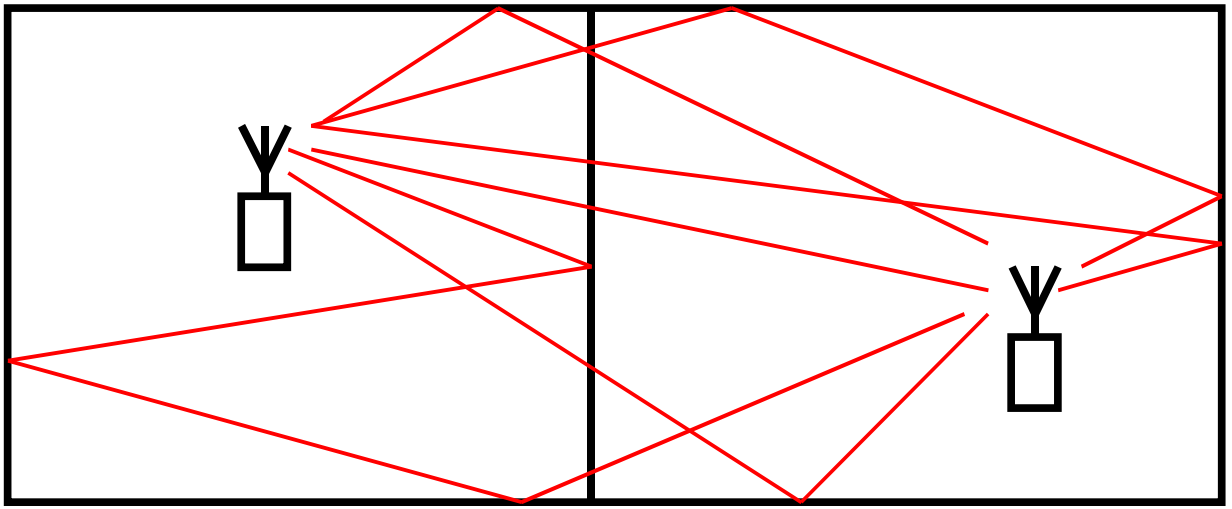


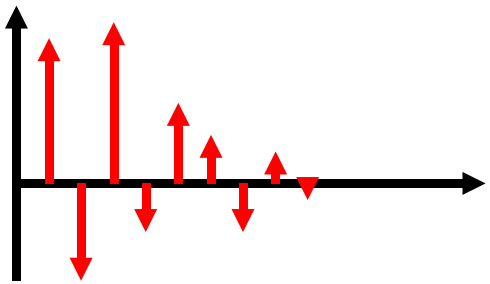
- In Europe, the bands are defined as HIPERLAN bands

Channelization in US

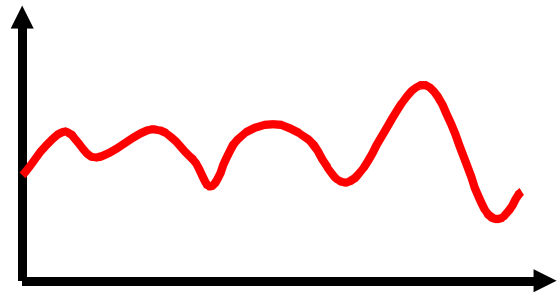


Multipath

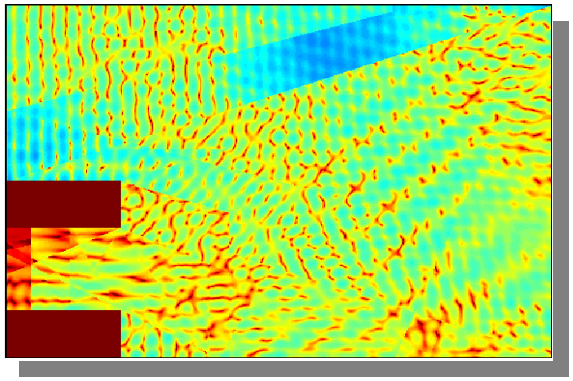




time



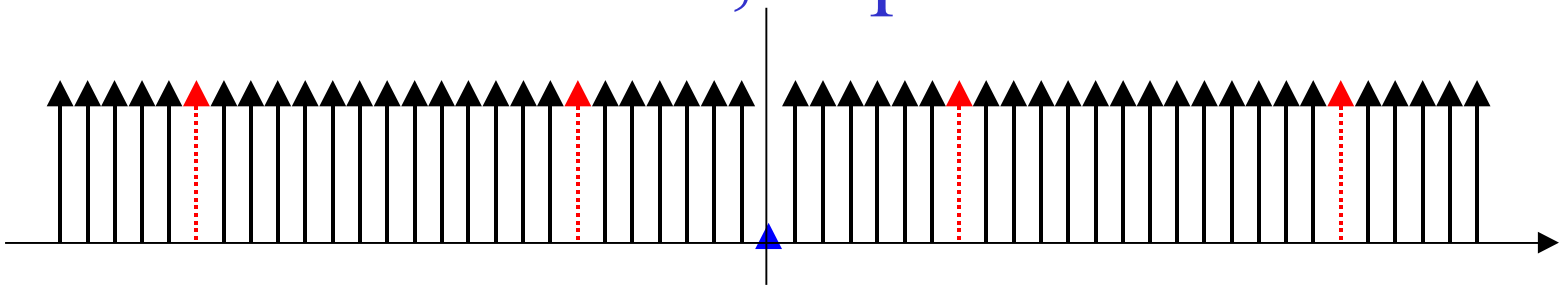
frequency



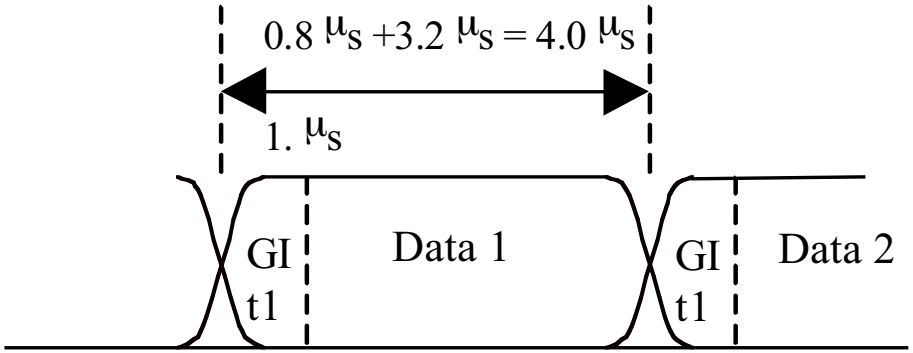
space

OFDM Modulation

- 48 data subcarriers, 4 pilot subcarriers

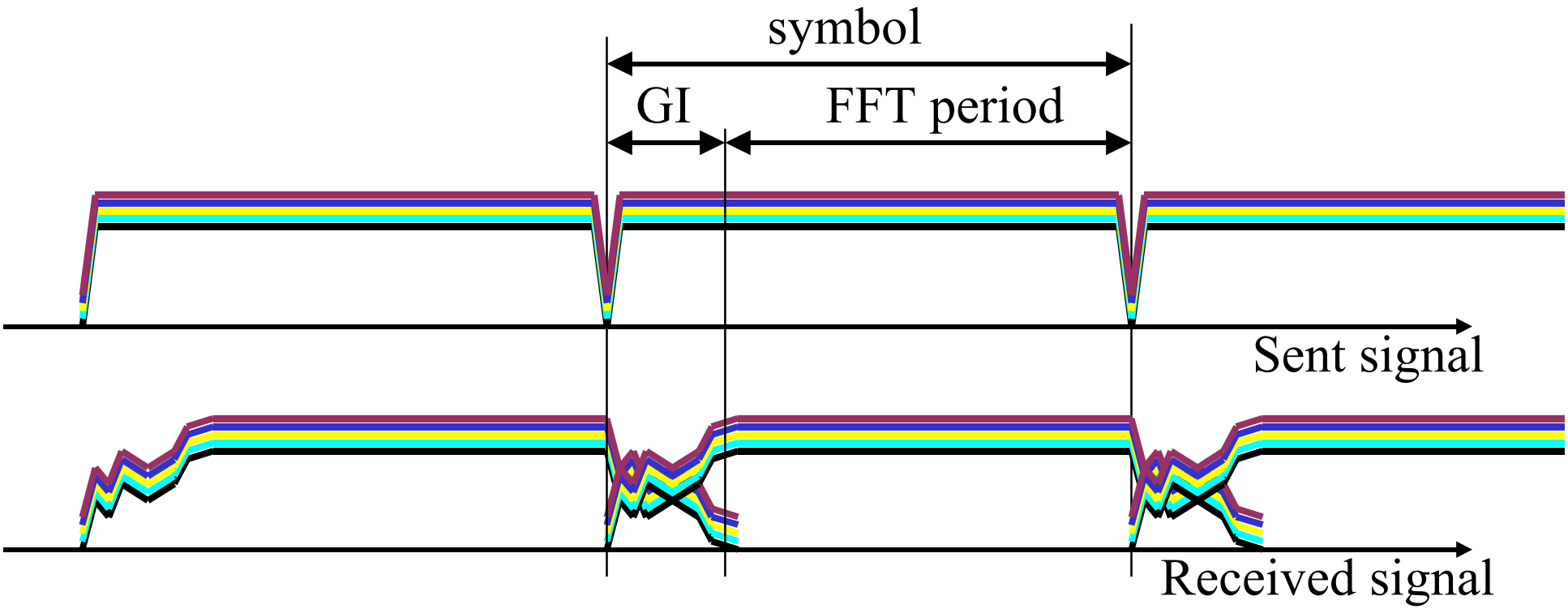


- 3.2 usec FFT, 0.8 usec Guard Interval



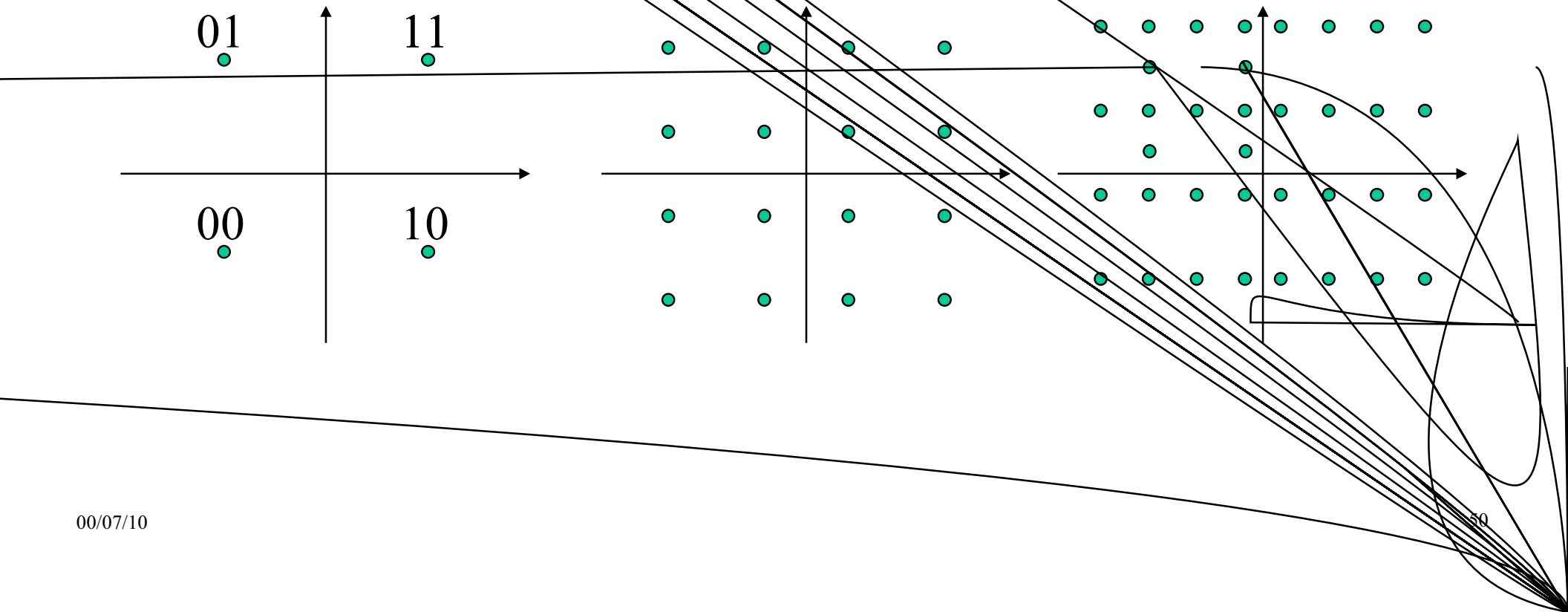
Guard time and Multipath

- The multipath corrupts the Guard Interval
- The FFT region remains undistorted



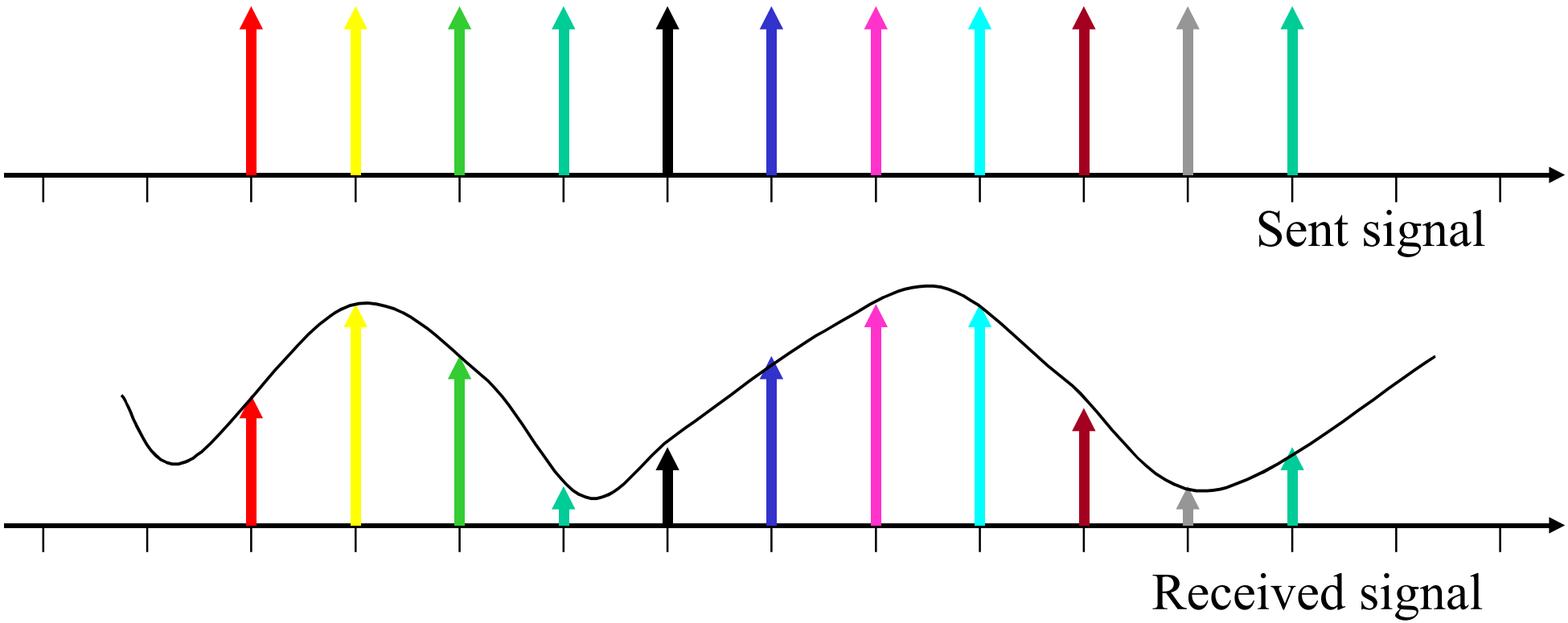
QAM constellations

- For multiple bits/symbol – QAM constellations
- Gray coding is typically used – neighbors differ by one data bit only



Multipath effect on OFDM

- Each subcarrier is scaled, but they still do not interfere with each other



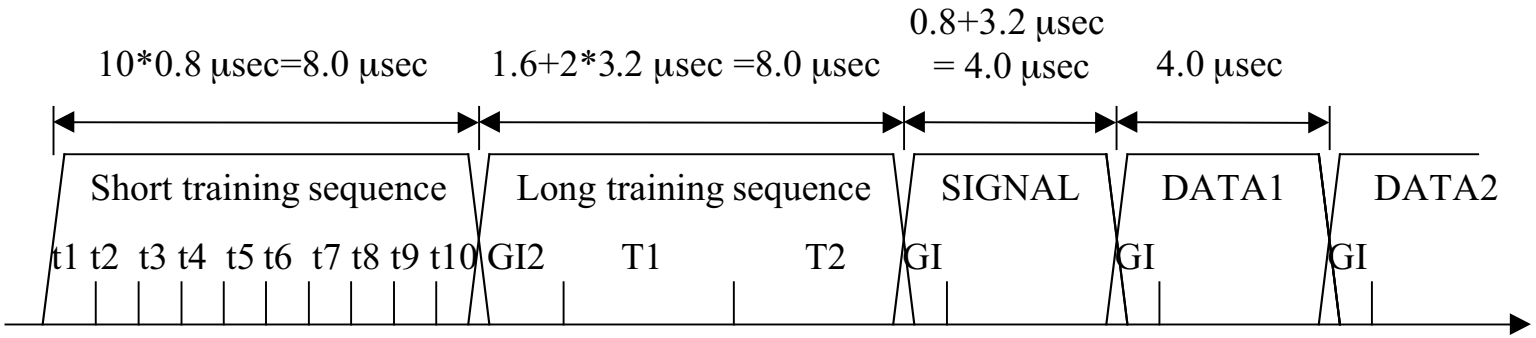
ECC, QAM and the Data Rates

Constellation	coding rate		
	1/2	2/3	3/4
BPSK	6 Mbit/s		9 Mbit/s
QPSK	12 Mbit/s		18 Mbit/s
16 QAM	24 Mbit/s		36 Mbit/s
64 QAM		48 Mbit/s	54 Mbit/s

- Industry standard convolutional code, K=7
  - R=1/2, rates R=2/3, 3/4 by puncturing
- Interleaving - adjacent coded bits are placed on nonadjacent frequencies
  - Interleaver span is one OFDM symbols

Preamble Structure

- Short sequences in the beginning
  - Signal Detection, AGC convergence, Diversity resolution, Timing estimation, Coarse frequency estimation
- Long sequences with Guard Interval
  - Fine frequency estimation, Channel Estimation



Signal detection
AGC convergence
Diversity selection
Coarse freq. offset estimate

Fine timing acquisition
Fine freq. offset estimation
Channel estimation

RATE and
LENGTH
Received at
6 Mbit/s

DATA is received at
RATE indicated in
the SIGNAL field

802.11a vs. HIPERLAN/2

- **Requirements are different**
- 802.11a supports the 802.11 MAC
  - Detecting signal arriving asynchronously
  - Listen Before Talk
  - RATE and LENGTH info in each packet
- H/2 air protocol is tightly controlled (WATM)
  - Scheduled transmissions
  - Receiver has a-priori synchronization knowledge
  - Rate and Length are known from the DLC

Common Parameters

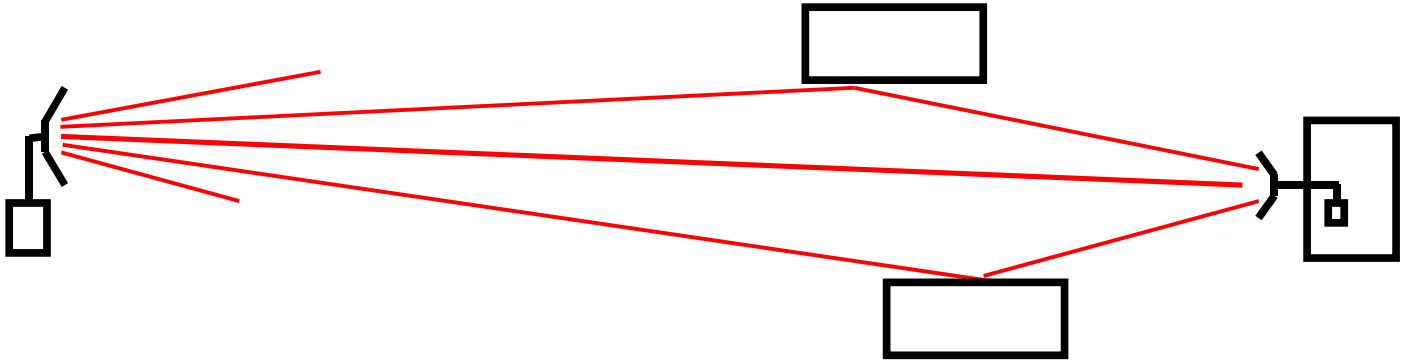
- OFDM modulation
  - BPSK, QPSK, 16QAM or 64QAM on each subcarrier
  - pilot assisted coherent detection
- 20 MHz channel spacing
- Number of subcarriers (48+4)
- Symbol duration (3.2+0.8 msec)
- Convolutional Coding, K=7, R=1/2
  - higher rates by puncturing
- One OFDM symbol interleaver span

802.11a and H/2 – Differences

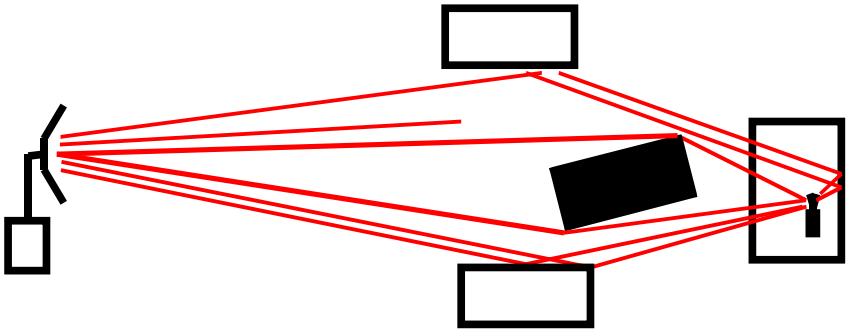
- Different preamble structure
  - H/2 has several preamble types
- Rates - 24 Mbit/s in 802.11a, 27 Mbit/s in H/2
  - accommodating 54 byte payloads in 4 OFDM symbols
- Rate and length signaling mechanism
  - In 802.11a rate and length are in SIGNAL field
  - In H/2 the rate and length are conveyed by MAC
- Some details of scrambling, CRC, puncturing

802.11a for W-HUMAN

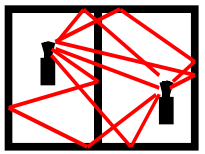
Multipath: W-HUMAN and 802.11 scenarios aren't that different!



Long range outdoor to outdoor directional antenna



Short range directional outdoor to omni indoor antenna



Indoor omni to indoor omni antenna

802.11 Task Group E - QoS

- 802.11 is working on improving its ability to handle QoS-demanding traffic
- Some other PHY related issues discussed
  - Dynamic Frequency Seleciton, Power Control

- 802.11e becomes “Local Area Access”

Some personal conclusions

- 802.11a is a robust, high speed, multirate PHY
- Minor extensions to 802.11e will make it applicable to outdoor MAN operation
- 802.11a PHY + 802.11e QoS enabled MAC are an excellent candidate for W-HUMAN in U-NII band
- Cooperate rather than coexist!!

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