HiperLAN & HiperLAN2

High Performance Radio LAN

Backgrounder

- ETSI (European Telecommunications Standards Institute)
  - Developing HiperLAN standards as part of an effort called BRAN (Broadband Radio Access Network)
  - Effort includes 4 standards
    - HiperLAN1
    - HiperLAN2
    - HiperLink
      - Designed for indoor radio backbones
    - HiperAccess
      - Designed for fixed outdoor use to provide access to a wired infrastructure

Backgrounder

- Both HiperLAN standards are approved standards for European spectrum
- HiperLAN2 has a key advantage over IEEE 802.11a
  - 802.11a products may not be usable in Europe

End User Applications

- Office
  - HiperLAN2 benefits companies with a flexible workforce
  - Employees can transfer their laptop computers from one project to another
  - Allows continuous exchange of large amounts of information between project members and the company server
  - It is also possible to connect several desktop computers & video projectors via HiperLAN2

End User Applications

- Construction
  - With HiperLAN2 installed, workers on a construction site can use laptops to collect blue prints, order materials & communicate with experts
  - By sending short video sequences via the integrated camera to an expert in real time, a problem can be looked at, discussed & solved , using the high quality audio function
  - The broadcast function also means that everyone working on site can be contacted with any information and that creates a more efficient on-site operation

End User Applications

- Home
  - Domestic electronics like TVs, cameras, stereo equipment & PCs can all be interconnected by HiperLAN2 using small H2 modules which automatically establish connectivity
  - HiperLAN2 allows multimedia equipment to be intelligently controlled from any computing device in the home without the need for network cables

End User Applications

- Airport
  - HiperLAN2 enables travelers and employees to work while on the move
    - Gives them access to the company network, Internet & the ability to make and receive multimedia calls
  - Aircraft Engineers
    - Using customized software can gain access to information from databases & get in touch with experts on site

End User Applications

- University
  - HiperLAN2 benefits both students and lecturers, allowing wireless access to the university Internet
  - Covering the entire campus, students can access information, such as videotaped lectures and remote supervision transmitted by their lecturer
  - Two-way communication can take place between students and lecturers through laptops

5GHz vs. 2.4GHz

The Better Spectrum Band for Wireless LANs

- 2.4GHz Band
  - Most LANs operate in this unlicensed band
  - Several limitations
    - Only 80MHz wide
    - Mandates use of spread spectrum technology
    - WLAN users must not interfere with primary license holders
- 5GHz Band
  - Developed after recognition the limitations of 2.4GHz band
  - Licensing authorities around the world have allocated large blocks of spectrum in the 5GHz band
  - Broad blocks of spectrum & lenient operating rules enable high-speed operation by large numbers of users

HiperLAN1

- Next generation, high-speed wireless LAN technology
- Standard is complete
  - Leading wireless LAN vendor Proxim is now delivering products based on it
- Offers the fastest route to market for a high-speed wireless LAN technology while minimizing the complexity of the radio technology

HiperLAN1

- Uses Gaussian Minimum Shift Keying (GMSK)
  - Well understood
  - Broadly used in GSM (Global System for Mobile Communications) cellular networks & CDPD
- Throughput up to 25Mbps

HiperLAN2

- Most sophisticated (& technically challenging) wireless LAN technology so far defined
  - Uses a new type of radio technology called Orthogonal Frequency Division Multiplexing (OFDM)
- Spec will be completed in year 2000
  - Products will not appear till 2001
- Is not the only standard deployed in this class
  - HiperLAN1 products will precede HiperLAN2
  - IEEE 802.11a will offer comparable performance
    - IEEE 802.11a & HiperLAN2 have the same PHY layer
      - Allows sharing components & cost reduction

HiperLAN2 Global Forum

- Launched in September 1999
  - Founded by Bosch, Dell, Ericsson, Nokia, Telia & TI
  - Strong industry backing
    - Alcatel, Cambridge Silicon Radio, Canon, Lucent, Intersil, Panasonic, Mitsubishi, Motorola, National Semiconductor, NTT, Philips, Samsung, Siemens, Sony, Silicon Wave, Toshiba
- Mission
  - Drive the adoption of HiperLAN2 as the global broadband wireless technology in 5GHz band
  - Providing untethered connectivity for mobile devices in corporate, public & home environments
- www.hiperlan2.com

Compelling Features of HiperLAN2

- Mobility
- High speed transmission
  - Raw over-the-air rate is 54Mbps at the PHY layer
  - Sustained throughput for applications is 20Mbps
- QoS
  - Connection-oriented network
    - Data is transmitted on connections between the MT (mobile terminal) and the AP that have been established prior to the transmission
    - Straight forward to implement QoS support
  - Important for applications like video & voice

HiperLAN2 Architecture

- Network and application independence
  - HiperLAN2 protocol stack has a flexible architecture for easy adaptation & integration with a variety of fixed network
  - Provides connections to multiple network infrastructures
  - Includes Ethernet, IP, ATM, PPP, 3G cellular networks
- Automatic frequency management
  - Like cellular networks such as GSM there is no need for manual frequency planning
  - APs have a built-in support for automatically selecting appropriate radio channels for transmission within each AP's coverage area
  - Simplifies deployment

HiperLAN2 Architecture

- Security
  - Authentication & Encryption
    - AP & MT can authenticate each other to ensure authorized network access
    - Authentication relies on supporting functions such as directory service
    - Encryption protects the user traffic on an established connection against eaves-dropping & man-in-middle attacks

HiperLAN2 Architecture

- Power save
  - MT may at anytime request the AP to enter a low power state and provide a sleep period
  - At the expiration of the negotiated sleep period the MT searches for any wake up indication from the AP
  - In the absence of a wake up indication the MT reverts back to its low power state for the next sleep period
  - The AP defers any pending data to an MT until the corresponding sleep period expires
  - Different sleep periods are supported to allow either short latency requirement or low power requirement

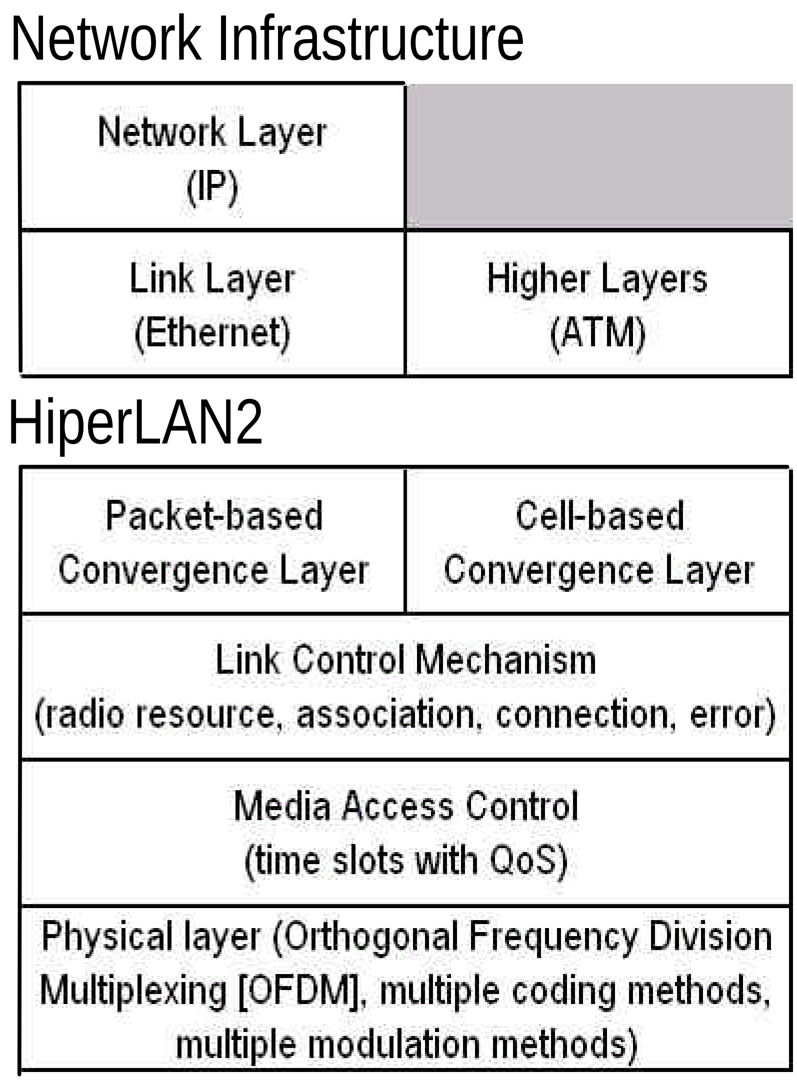
HiperLAN2 Technology

- Connects mobile terminals to access points
  - To bridge traffic to wired networks
- Also allows mobile nodes to communicate directly with each other
- Seamless extension to other networks
  - Wired network nodes see HiperLAN2 nodes as other network nodes
  - All common networking protocols at layer 3 (IP, IPX & AppleTalk) will operate over HiperLAN2
    - Permits network-based applications to operate

Network Topology

- HiperLAN2 defines a PHY layer & a Data-link layer
- Above these layers is a Convergence layer
  - Accepts packets or cells from existing networking systems & formats them for delivery over the wireless medium

HiperLAN2 Protocols



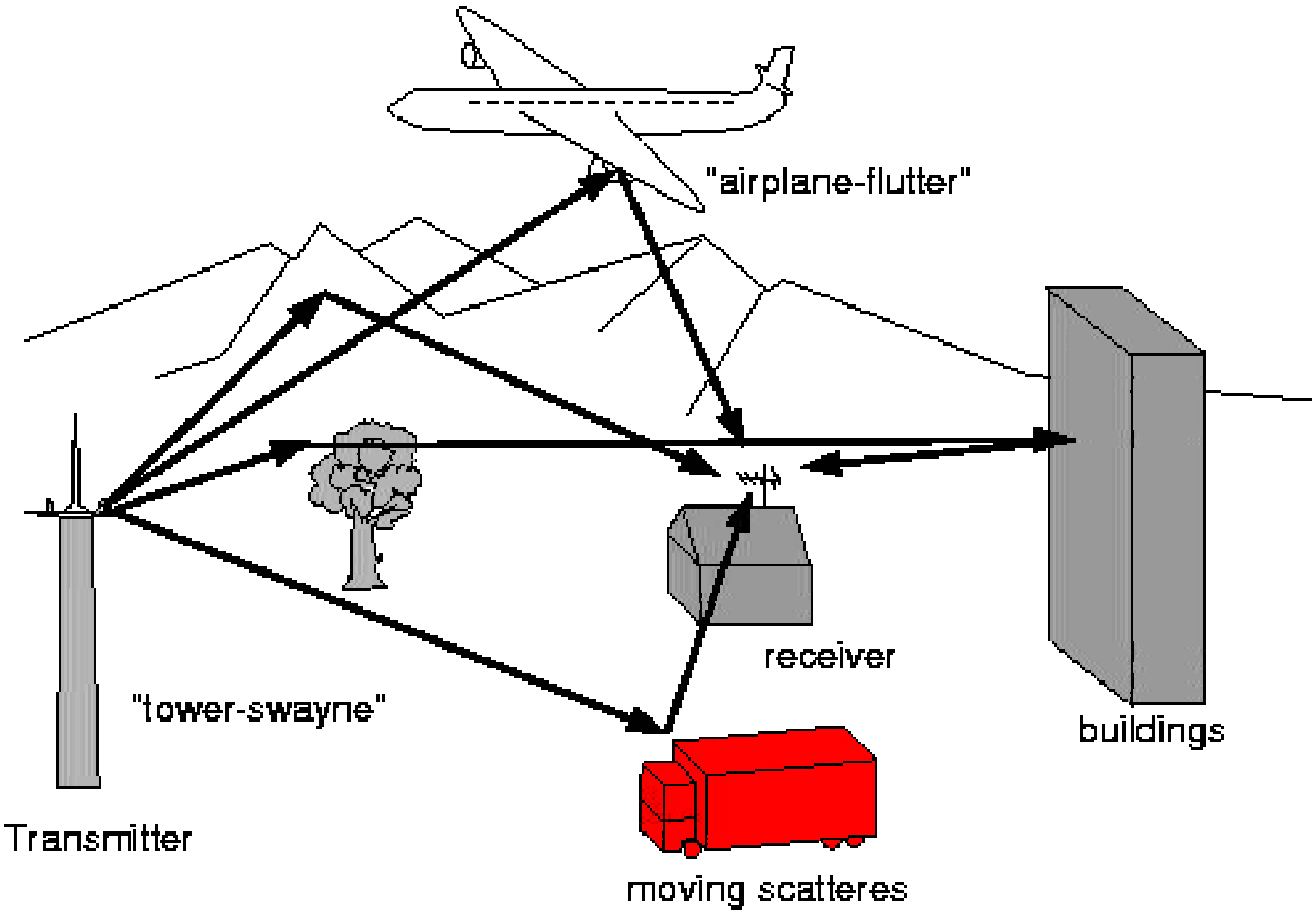
Orthogonal Frequency Division Multiplexing - OFDM

- First time being used as a WLAN standard
  - Used in wireless broadcast application for European Digital Audio Broadcast (DAB)
  - Discrete Multitone (DMT) for ADSL (Asymmetric Digital Subscriber Lines)
- Extremely effective in a time-dispersive environments
  - Signals can take many paths to reach their destinations
  - Results in variable time delays
  - At high data rates these time delays can reach a significant proportion of the transmitted symbol (a modulated waveform)
    - Results in one symbol interfering with the next
    - OFDM is the answer to this "intersymbol interference"

Introducing OFDM Technology

- Allows transmission over high data rates over extremely hostile channels at comparable low complexity
- Issue - data transmission over multipath channels
  - Different from satellite communication where there is one single direct path from transmitter to receiver
  - In the classical terrestrial broadcasting scenario we have to deal with a multipath channel
    - The transmitted signal arrives at the receiver in various paths of different length
    - Since multiple versions of the signal interfere with each other (inter symbol interference (ISI)) it becomes very hard to extract the original information

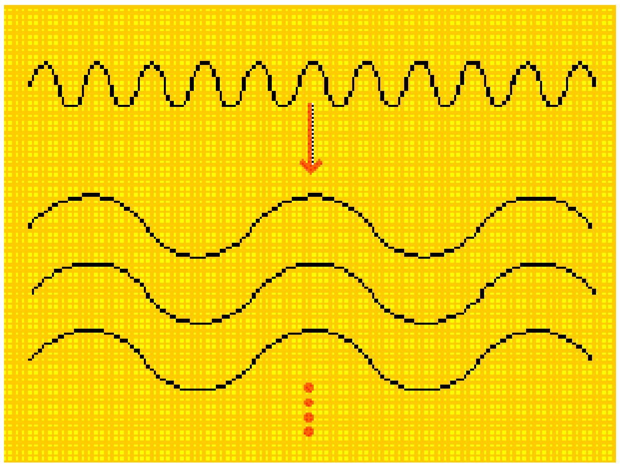
Multipath Transmission in a Broadcasting Application



OFDM - Technology

- Special method of multi-carrier modulation
  - Like all wireless transmission schemes, OFDM encodes data onto a radio frequency (RF) signal
  - OFDM transmits multiple high data rate signals concurrently on different frequencies
  - The channel spectrum is passed into a number of independent non-selective frequency sub-channels
    - These subchannels are used for one transmission link between the AP and MTs

OFDM



Single high-frequency carrier is replaced by multiple subcarriers, each operating at a significantly lower frequency

- Division of a single high-frequency radio channel into multiple subcarriers
  - Data is transmitted in parallel bit streams on them
    - Each one of these bit streams is modulated on a separate subcarrier
  - Aggregate throughput is the same but the data rate on each subcarrier is much lower
    - Makes each symbol longer
    - Practically eliminates the effect of the variable time delays

OFDM & Synchronization

- HiperLAN2 products will cost more than lower-speed alternatives
  - OFDM demands extremely linear power amplifiers
    - Increase the cost of the radio
- Spectral allocation for Europe
  - HiperLAN2 channels will be spaced 20MHz apart
    - Total of 19 channels
  - Each channel will be divided into 52 subcarriers
    - 48 data carriers & 4 as pilots to provide synchronization
  - Synchronization enables coherent in-phase demodulation
    - Through DSP, subchannels are divided through mathematical processing rather than in the analog domain

OFDM in Practice

- OFDM is efficiently realized by using effective signal processing, fast-fourier transforms (FFT) in the transmitter & receiver
  - Significantly reduces the amount of hardware required compared to earlier FDM-systems
- OFDM requires a properly designed system
  - Specially important is the design of frequency synchronization & power amplifier back-off in the receiver

Advantages of OFDM

- OFDM results in a very efficient use of bandwidth
  - Provides robust communications in the presence of noise, intentional or unintentional interference & reflected signals that degrade radio communications
  - Conventional single carrier transmission schemes like AM/FM send only one signal at a time using one RF
- Lesser utilization of hardware
  - Effective signal processing, FFT

Advantages of OFDM

- Increased spectral efficiency
  - That is, more bps/Hz than conventional transmission schemes
  - Spectrally efficient because the spectrum can be made to look like a rectangular window
    - Because the subcarriers are packed maximally close together
    - All frequencies are utilized similarly
- Robustness against the adverse effects of multipath propagation with respect to intersymbol interference
- OFDM is less sensitive to timing errors
  - A timing error is simply translated to a phase offset in the frequency domain

OFDM Compared to Other PHY Technologies

- The 3 RF technologies available to solve the challenge of increasing the speed of wireless data/Internet networking
  - Narrow band microwave
  - Spread spectrum
    - Frequency Hopping Spread Spectrum
    - Direct Sequence Spread Spectrum
  - OFDM

OFDM Compared to Narrowband Microwave

- Narrow band systems
  - Power to transmit the data is increased to overcome the noise
    - This improves the performance of the transmission, but interferes with other signals that are being sent by other users of the band, causing data errors for others
  - Sensitive to multipath interference
    - In this your own signal is reflected off another object and arrives late at the destination, scrambling the original signal
    - This requires on-going tuning and adjustment using specific hardware which means an increased system cost

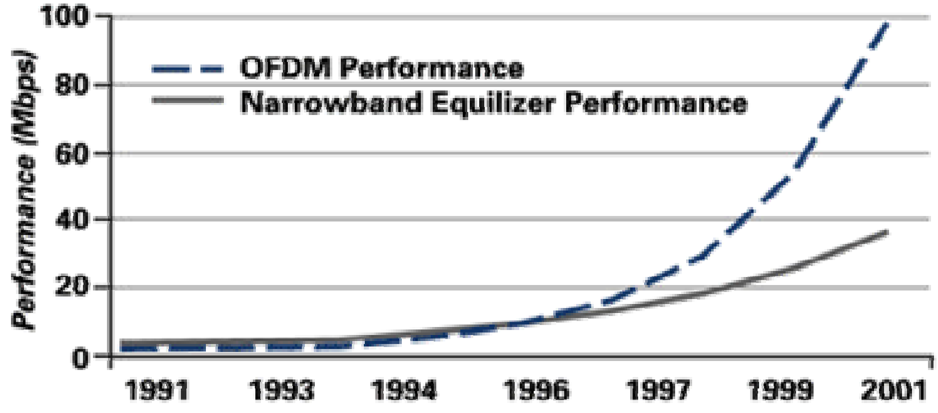
OFDM Compared to Spread Spectrum

- Spread spectrum technology
  - Uses much more bandwidth than is absolutely required to send signals, but this allows it to overcome noise & multipath problems
  - As the amount of data increases, the bandwidth required rises
    - The best systems to date deliver 11 Mbps and use 22MHz of spectrum.
    - That translates to less than 44 Mbps maximum if one used the entire 2.4 GHz license-exempt band
    - The best possible speed achievable is approximately 15 Mbps in 22 MHz, which means that spread spectrum technology is approaching its limits in speed

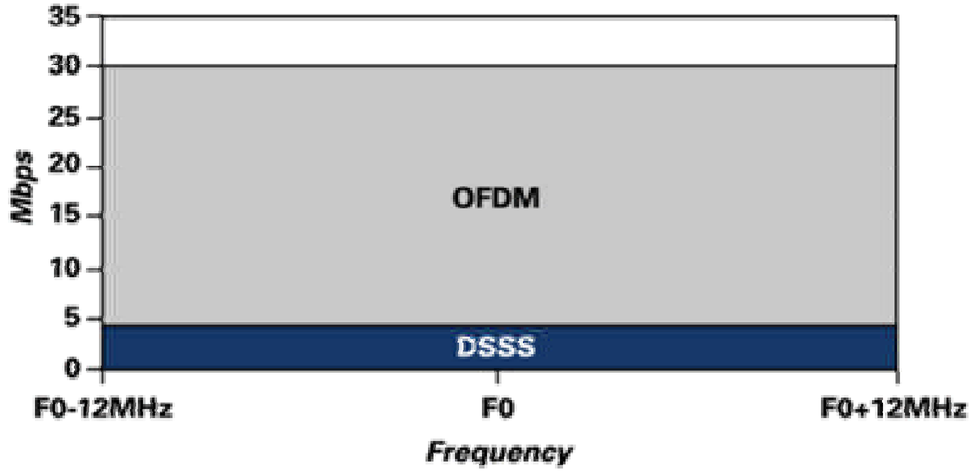
OFDM Compared to Other PHY Technologies

- OFDM technology
  - Breaks one high-speed data signal into tens or hundreds of lower speed signals, which are all transmitted in parallel
    - This creates a system highly tolerant to noise and multipath &, at the same time, is very efficient in its use of bandwidth
  - Noise and multipath immunity allow for wide-area, multipoint coverage, and the efficient use of bandwidth allows for many more high-speed channels within a frequency band
- Therefore, the main difficulties in narrow band and spread spectrum are overcome by OFDM

OFDM Compared to Other PHY Technologies



OFDM
vs.
Narrowband



OFDM
vs.
DSSS

Source: Wi-LAN

OFDM is Gaining Popularity

- OFDM is a very efficient technology, but it was proven to be difficult to implement until now
  - Recent advances in DSPs now permit OFDM systems to be cost-effectively constructed creating a renewed interest
- The digital audio and terrestrial digital video broadcasting standards are based on OFDM
- In 1998, the IEEE 802.11a approved the use OFDM
  - For its high-speed (6 to 54 Mbps) extension to the 802.11 WLAN standard
- ETSI is using OFDM for the ETSI BRAN HiperLAN2 standard

Advantages of Wideband OFDM (W-OFDM)

- Great performance against multipath, through a simple division by the channel frequency response
- Enhanced equalization of radio distortions, through a division by the channel frequency response that includes the radio distortion
- Easy inclusion and optimal exploitation of forward error correcting codes, like Reed-Solomon, ensuring the integrity of transmitted data
  - This includes the ability to recover the symbols, even if some carriers are totally absent
- Less sensitive to carrier offset

Advantages of W-OFDM

- More amenable to erasures of errors in the forward error corrector
  - Improves the bit error rate performance by over an order of magnitude
  - The positions of the errors can easily be determined from the estimated channel frequency response
- The whitening process reduces the peak to average ratio, thus reducing linearity requirement of the power amplifiers
- The group delay of the frequency response can be used to deliver an estimate of the propagation time between the transmitter and receiver

PHY Layer

Includes Data Encoding & Subchannel Modulation Type

- OFDM does not fully describe the PHY layer
- Encoding involves serial sequencing of data & FEC
  - Lower speed wireless LANs do not employ FEC
  - HiperLAN2 provides multiple levels
    - Each capable of protecting against a certain % of bit errors
- HiperLAN2 employs multiple types of modulation
  - Dynamic adaptation of the FEC & modulation to varying conditions
  - Allows data transmission at
    - Higher data rates with a strong signal relative to noise
    - Lower throughputs under adverse conditions

H2 - Data-link Layer

- Data-link layer constitutes the logical link between an AP and the MTs
  - Data-link sub layers include MAC protocol, Error Control (EC) protocol, Radio-Link Control (RLC) protocol
- Data-link layer in HiperLAN2 is connection-oriented differentiating it from other wireless LANs
  - Before a mobile terminal transmits data the Data-link layer communicates with the AP in the signaling plane to set-up a temporary connection
    - This allows the negotiation of QoS parameters like bandwidth & delay requirements
    - Assures that other terminals will not interfere with subsequent transmissions

H2 - Data-link Layer

- HiperLAN2 contrasts with MTs conforming to IEEE 802.11 std.
  - IEEE 802.11
    - They communicate when the radio channel becomes available
    - May experience packet collisions from other terminals
    - IEEE 802.11 does provide separate mechanism for synchronous applications like voice

H2 - QoS

- QoS parameters include
  - Bandwidth, bit error rate, latency, jitter
- HiperLAN2 implements QoS through time slots
  - Original request by a mobile terminal made to send data uses specific time slots allocated for random access
  - Collisions from other mobile terminals can occur in this random-access channel
    - Since messages are brief, this is not a problem

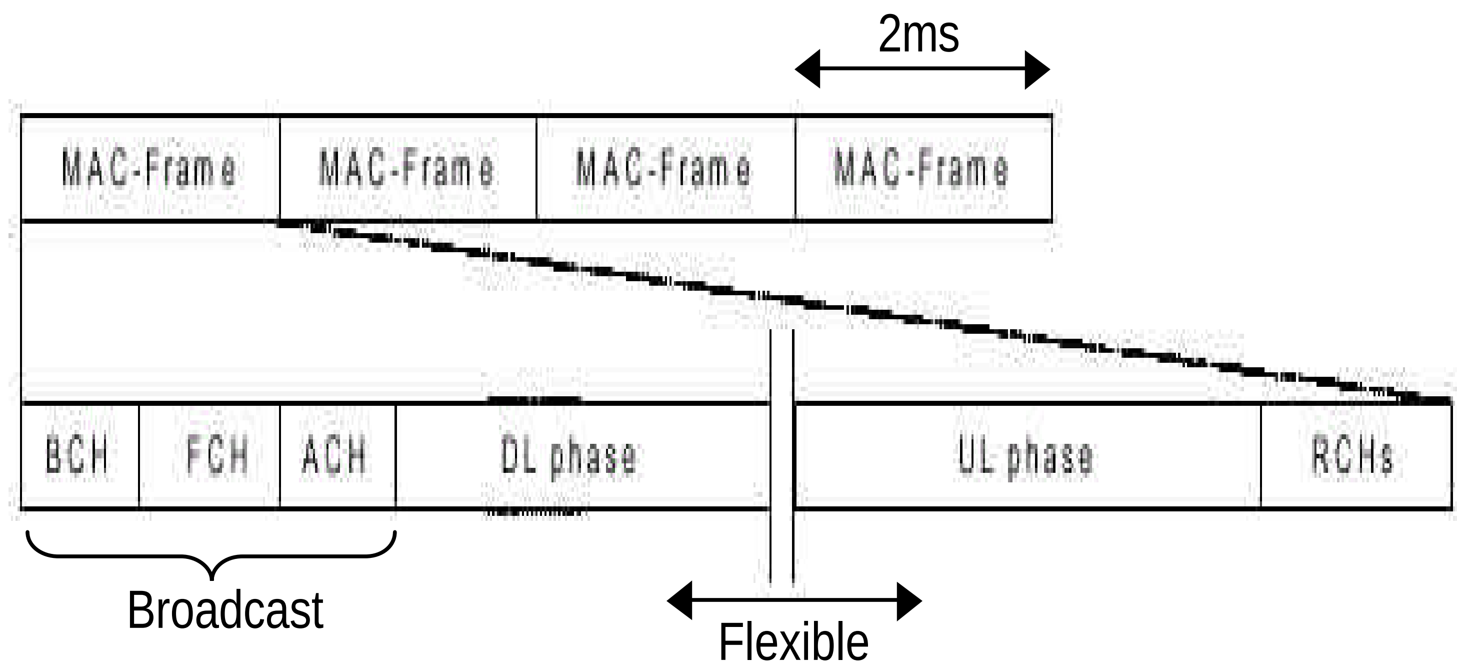
H2 - Data-Link Layer

- Transport channels
  - Access point grants access by allocating specific time slots for a specific duration
  - Mobile terminal then sends data without interruption from other mobile terminals operating on that frequency
  - Control channel provides feedback to the sender
    - Indicates whether data was received in error & if it needs to be retransmitted

H2 - MAC Protocol

- MAC protocol
  - Used for access to the medium with the resulting transmission of data onto that medium
  - Control is centralized to the AP which informs the MTs
    - It is at this point that the MAC frame is allowed to transmit data
- MAC frame in H2
  - Air interface is time-division duplex (TDD) & dynamic time-division multiple access (TDMA)
    - Time slotted structure of the medium allows for simultaneous communication in both downlink and uplink within the same time frame
  - MAC frame forms the interface between Data link & PHY layer

H2 - Frame Structure



- Centrally controlled TDMA/TDM with TDD
- Packet sizes 54 bytes (data) & 9 bytes (control)

H2 - Error Control Protocol

- Selective repeat (SR) ARQ is the Error Control (EC) mechanism
  - Increases reliability over the radio link
  - Detects bit errors and and retransmits U-PDU(s) if such errors occur

H2 - Convergence Layer (CL)

- Exists above the Data-link layer & has 2 main functions
  - Adaptive service requests
    - Responds to service requests from higher layers to the service offered by the data link layer
  - To convert the higher layer packets (SDUs) with variable or possibly fixed size that is used within the data link layer
    - Formats data (padding, segmentation & reassembly function)
- Generic architecture of the CL makes HiperLAN2 suitable for a diversity of fixed networks
  - E.g., Ethernet, IP, ATM, UMTS, etc.
- 2 different types of defined CLs: packet-based (Ethernet) & cell-based (ATM) communication

H2 - Radio Network Functions

- H2 standard defines measurement & signaling to support a number of radio network functions
  - Dynamic frequency selection
  - Link adaptation
  - Antennas
  - Handover
  - Power Control

HiperLAN2 - AFA

- Comes with Automatic Frequency Allocation (AFA)
  - To provide continuous coverage access points need to have overlapping coverage areas
  - Coverage extends 30m indoors & 150m in unobstructed environments
  - APs monitor the HiperLAN radio channels & automatically selects an unused channel
    - Eliminates the need for frequency planning
    - Makes deployment relatively straightforward

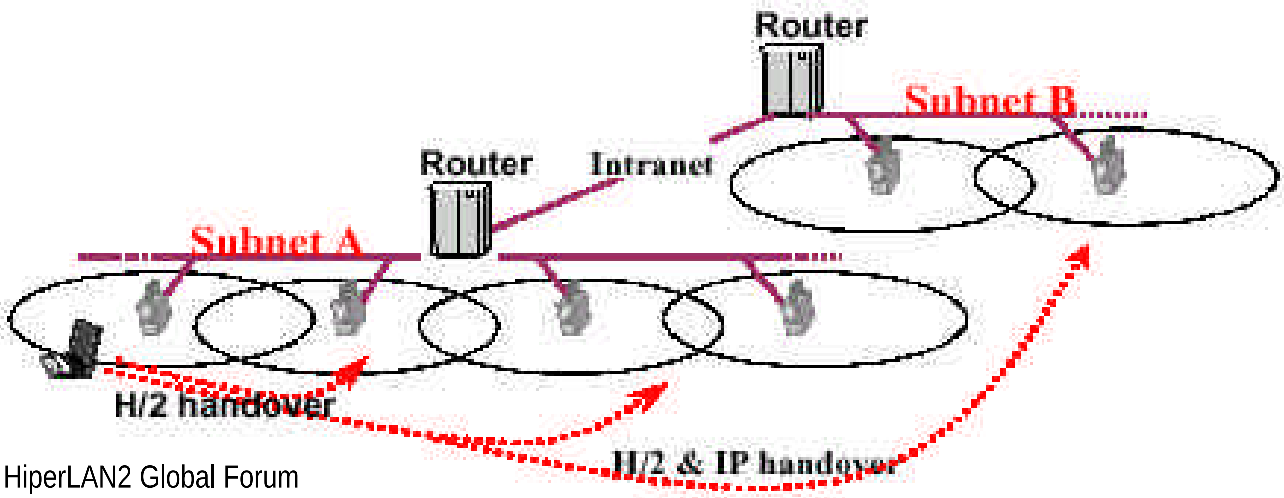
HiperLAN2 - Roaming

- Mobile terminal roams from coverage area of one AP to another
  - Initiates handoff to the new access point after detecting a better signal on another radio channel
  - New AP obtains details of the mobile terminal's connection from old AP
    - Allows communication to continue smoothly

HiperLAN2 - Security Mechanism

- Mobile terminal creates a secure communication session (association) with the AP
  - First using Diffie Hellman key exchange to negotiate a secret session key
  - Then mutual authentication process via a secret key or public hey if a PKI is available
  - Data traffic is encrypted using DES or Triple DES
- Communication over HiperLAN2 should be as secure as wired LANs

H2 - Example Applications



Source: HiperLAN2 Global Forum

- Corporate LAN
  - Example of a corporate network built around ethernet LAN and IP routers
  - A H2 network is used as the last segment between the MTs and the network/LAN
  - The H2 network supports mobility within the same LAN/subnet
  - Moving between subnets implies IP mobility which must be taken care of on a layer above H2

H2 - Example Applications

- Hot spots
  - H2 networks can be deployed at hot spot areas, enabling an easy way of offering remote access and Internet services to business people
    - E.g. airports, hotels, etc.
  - An access server to which the H2 network is connected can route a connection request for a point-to-point connection (PPP) over a tunnel either to to the corporate network (via a preferred ISP) or perhaps to an ISP for Internet access

H2 - Example Applications

- Access to 3 rd generation cellular network
  - HiperLAN/2 can be used as an alternative access technology to a 3 rd generation cellular network
  - One may think of the possibility to cover hot spots and city areas with HiperLAN/2 and the wide area with W-CDMA technology
    - In this way, a user can benefit from a high-performance network wherever it is feasible to deploy HiperLAN/2 and use W-CDMA elsewhere
    - The core network sees to that the user is automatically and seamlessly handed over between the two types of access networks as the user moves between them

H2 - Example Applications

- Home network
  - The use of this technology in a home environment to create a wireless infrastructure for home devices
    - E.g. home PCs, VCRs, cameras, printers, etc.
  - The high throughput and QoS features of HiperLAN/2 support the transmission of video streams in conjunction with the datacom applications
  - The AP may in this case include an "uplink" to the public network - "Residential Gateway"
    - E.g. ADSL or cable modem

HiperLAN2 - Features Summary

- PHY layer
  - OFDM modulation, variable bit rate
  - FEC error control
- Data-link layer
  - QoS via dynamic fixed time slots (within MAC)
  - ARQ (within EC)
  - Dynamic frequency selection
  - Power control
  - Cellular handover
  - Public & private key encryption
- Convergence layer
  - Supports both cell & packet based networks

HiperLAN2 - Summary

- Lots of bandwidth, up to 54Mbps
- QoS
- Plug & play radio network
- Service negotiation
- Security, authentication & encryption
- Spectrum availability
- Scalable
- Generic architecture supporting Ethernet, Firewire, ATM, PPP, 3G, etc.
- Considerably cheap

IEEE 802.11 vs. HiperLAN2

Comparison - 802.11 vs. HiperLAN2

Characteristic	802.11	802.11b	802.11a	HiperLAN2
Spectrum	2.4 GHz	2.4 GHz	2.4 GHz	5 GHz
Maximum physical rate (apprx.)	2 Mbps	11 Mbps	54 Mbps	54 Mbps
Maximum data rate, layer 3 (approx.)	1.2 Mbps	5 Mbps	32 Mbps	32 Mbps
Medium access control/Media sharing	Carrier sense - CSMA/CA	CSMA/CA		Central resource control/TDMA/TDD
Connectivity	Connection-less	Connection-less	Connection-less	Connection-oriented
Multicast	Yes	Yes	Yes	Yes
QoS support	PCF	PCF	PCF	ATM/802.1p/RSVP/DiffServ (full control)
Frequency selection	Frequency-hopping or DSSS	DSSS	Single carrier	Single carrier with Dynamic Frequency Selection
Authentication	No	No	No	NAI/IEEE address/X.509
Encryption	40-bit RC4	40-bit RC4	40-bit RC4	DES, Triple-DES
Handover support	No	No	No	No
Fixed network support	Ethernet	Ethernet	Ethernet	Ethernet, IP, ATM, UMTS, Firewire, PPP
Management	802.11 MIB	802.11 MIB	802.11 MIB	HiperLAN/2 MIB
Radio link quality control	No	No	No	Link adaptation

PCF - Point Control Function; Concept defined in 802.11 to allow certain time slots being allocated for real-time