WLAN Standard Technology

Requirements - Applications, Service, Deployment

Functionality

PHY Layer

Data Link Layer

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Requirements - Applications

- Data communication applications
  - Bandwidth! Always, the more the better
  - Statistical multiplexing supported
  - Minimize connection setup time
  - Minimize retransmissions
- New applications
  - Interactive applications need QoS
  - Bandwidth! Always, the more the better
  - Must work & coexist with datacom applications
  - Minimize connection setup time

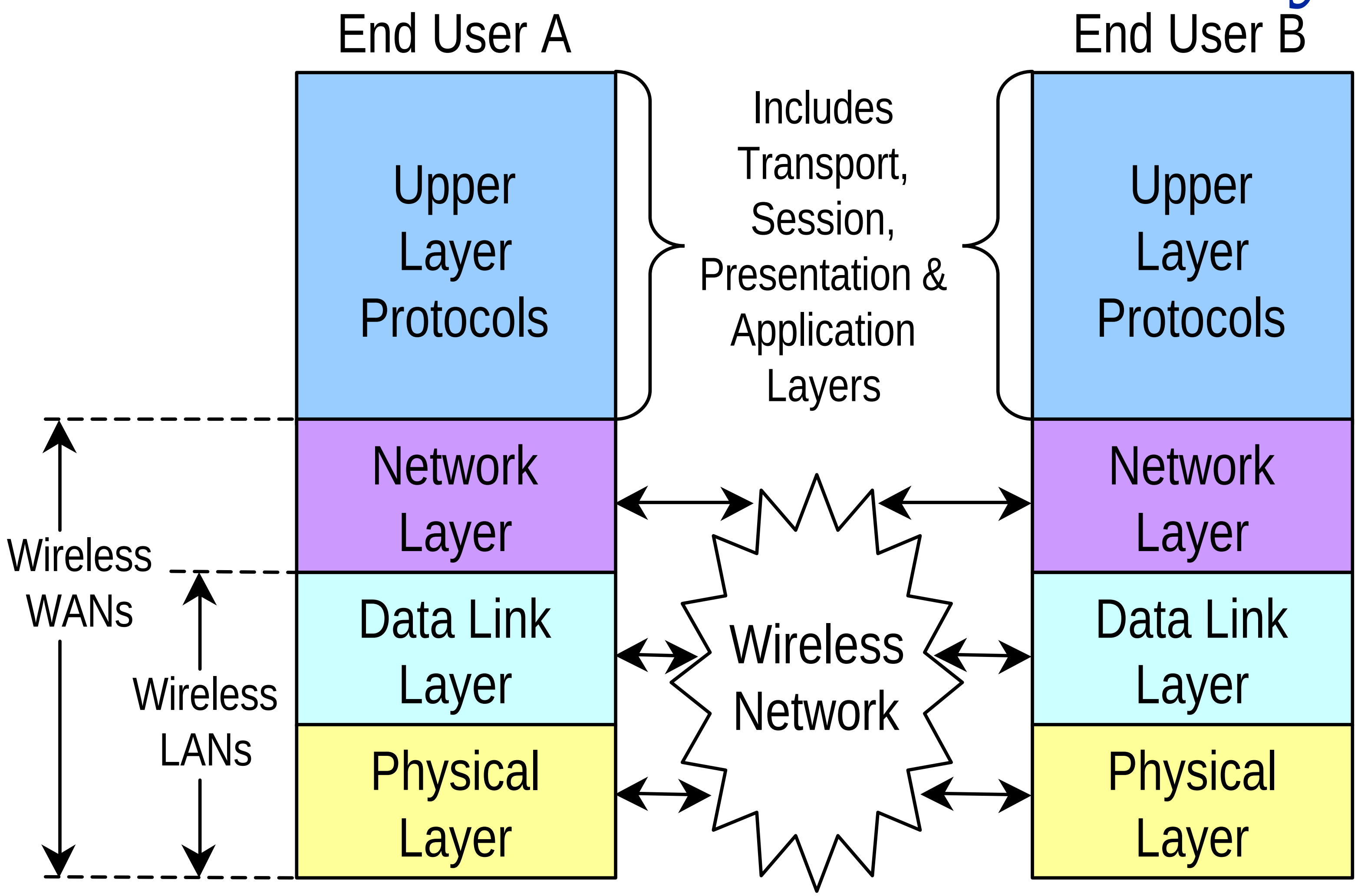
Requirements - Service

- Mobility implies service negotiation
  - Authentication
  - Operator identification, roaming
  - Bearer capabilities
- Wireless & Internet imply security
- New applications & new devices would benefit if interoperation with WAN is supported
- Interoperable products

Requirements - Deployment

- Easy to install & operate
  - Especially in indoor environments
- Scalable in cost & performance with respect to coverage & number of users
- Transparent or flexible in how to connect to fixed network & higher layers
- Available on all markets

Wireless LANs Functionality



Wireless LANs & MANs fulfil Data Link & Physical Layer functionality while wireless WANs also include functions at the Network Layer

Defining the Different Layers

- Physical layer
  - Provides the transmission of bits through a communication over the medium or channel by defining electrical, mechanical & procedural specs
- Data link layer
  - Ensures error control & synchronization between two entities
  - Includes Medium Access Control (MAC) & Logical Link Control (LLC)
- Network layer
  - Provides the routing of packets through routers from source to destination
  - Protocols such as IP operate at this layer

Physical (PHY) Layer

WLAN PHY Technology Types

- Narrowband
- Spread Spectrum modulation
  - Frequency-Hopping Spread Spectrum (FHSS)
  - Direct-Sequence Spread Spectrum (DSSS)
- Infrared (IR)

Narrowband Radio Technology

- User information is transmitted & received on a specific radio frequency
- Radio signal frequency is kept as narrow as possible
  - This allows the ability to just pass the information
- Undesirable crosstalk between communication channels is avoided by carefully coordinating different users on different channel frequencies

Narrowband Radio Technology

- Private telephone line is much like a radio frequency
  - Each home in neighborhood has its own private phone line
    - People in one home cannot listen to calls made to other homes
- In a radio system
  - Privacy & noninterference are accomplished by the use of separate radio frequencies
  - Radio receiver filters out all radio signals except the one on its designated frequency
- Drawback
  - End user must obtain an FCC license for each site where it is employed

Spread Spectrum

Technology

FHSS - Frequency Hopping Spread Spectrum

DSSS - Direct Sequence Spread Spectrum

Origins

- Wideband RF technology developed by the military
  - Used for reliable, secure, mission-critical communication
  - Systems are designed to trade off bandwidth efficiency for reliability, integrity & security
    - More bandwidth is consumed than in the narrowband case
    - Tradeoff produces louder & easier to detect signals, provided the receiver knows the parameters of the spread-spectrum signal being broadcast
  - If a receiver is not tuned into the right frequency, a spread-spectrum signal looks like background noise

Technology

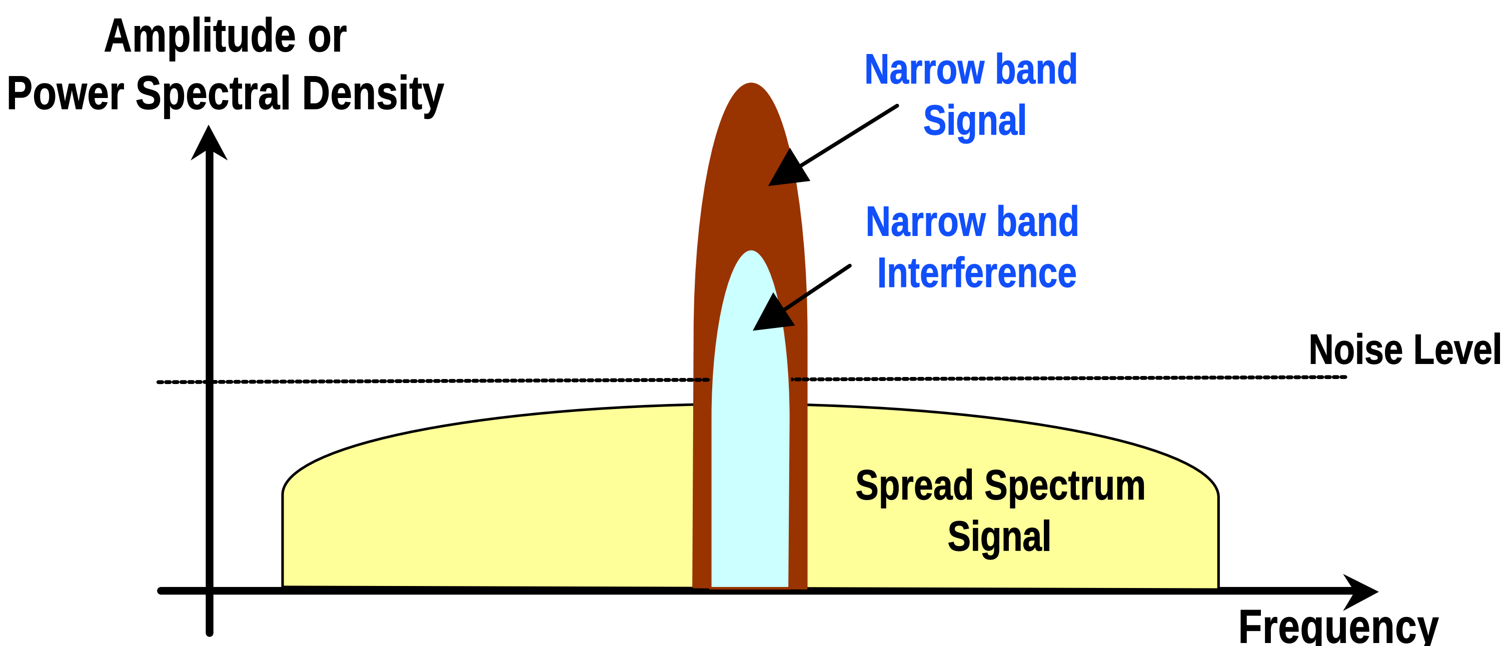
- Physical layer function
- Spread spectrum is a modulation technique or method of transmission where the
  - Radio transceiver prepares the digital signal within the NIC for transmission over the airwaves
  - The transmitted signal occupies a bandwidth considerably greater than the minimum necessary to send the information
  - Some function other than the information being sent is employed to determine the resulting modulated bandwidth

Spread Spectrum Modulation

- Spreads a signal’s power over a wider band of frequencies
- Process gain - sacrificing bandwidth to gain signal-to-noise performance
  - Contradicts the desire to conserve frequency bandwidth
  - Spreading process makes the data signal much less susceptible to electrical noise than conventional radio modulation techniques
- Narrow bandwidth transmission & electrical noise
  - Interfere with a small portion of the spread spectrum signal
  - Result in much less interference & fewer errors when the receiver demodulates the signal

Spread Spectrum Modulation

- Frequency spectrum of a data-signal is spread using a code uncorrelated with that signal
  - Codes used for spreading have low cross-correlation values and are unique to every user
  - Sacrifices bandwidth to gain signal-to-noise performance



Spread Spectrum Advantages

- Low power spectral density
  - Spreading the signal over a large frequency-band makes the power spectral density very small
    - However, the Gaussian noise level increases
- Interference limited operation
  - In all situations the whole frequency-spectrum is used
  - Spread spectrum reduces multi-path effects
- Privacy is kept due to unknown random codes
  - Applied codes are unknown to a hostile user
- Random access possibilities
  - Users can start their transmission at any arbitrary time

How Does SS Work?

- Receivers should be assigned different codes
  - It will address them away from other receivers with different codes
- Codes with low cross correlation properties should be chosen to minimize interference between groups of receivers
- Selective addressing and Code Division Multiple Access (CDMA) are implemented via these codings

How Does SS Work?

- Power spectrum spreads out with spreading the intelligence of a signal over several MHz of spectrum
  - It makes the detection of the none-coded signals very difficult
- By increasing the bandwidth Signal/Noise may be decreased without decreased BER performance

C = W log2 (1+ S/N)
C = Channel capacity in bits
W = Bandwidth in Hertz
S = Signal Power
N = Noise Power

Types

- Spread spectrum modulators use one of two methods to spread signal over a wider area
  - Frequency Hopping
  - Direct Sequence

FHSS
Frequency Hopping Spread Spectrum

- It works very much like its name implies
  - Frequency hopping
    - Data signal is modulated with a narrowband carrier signal that hops from frequency to frequency as a function of time over a wide band of frequencies
    - Relies on frequency diversity to combat interference
      - This is accomplished by multiple frequencies, code selection & FSK
  - E.g., A FH radio will hop the carrier frequency over the 2.4GHz frequency band between 2.4GHz & 2.483GHz
    - If the radio encounters interference on one frequency, the radio will retransmit the signal on a subsequent hop on another frequency

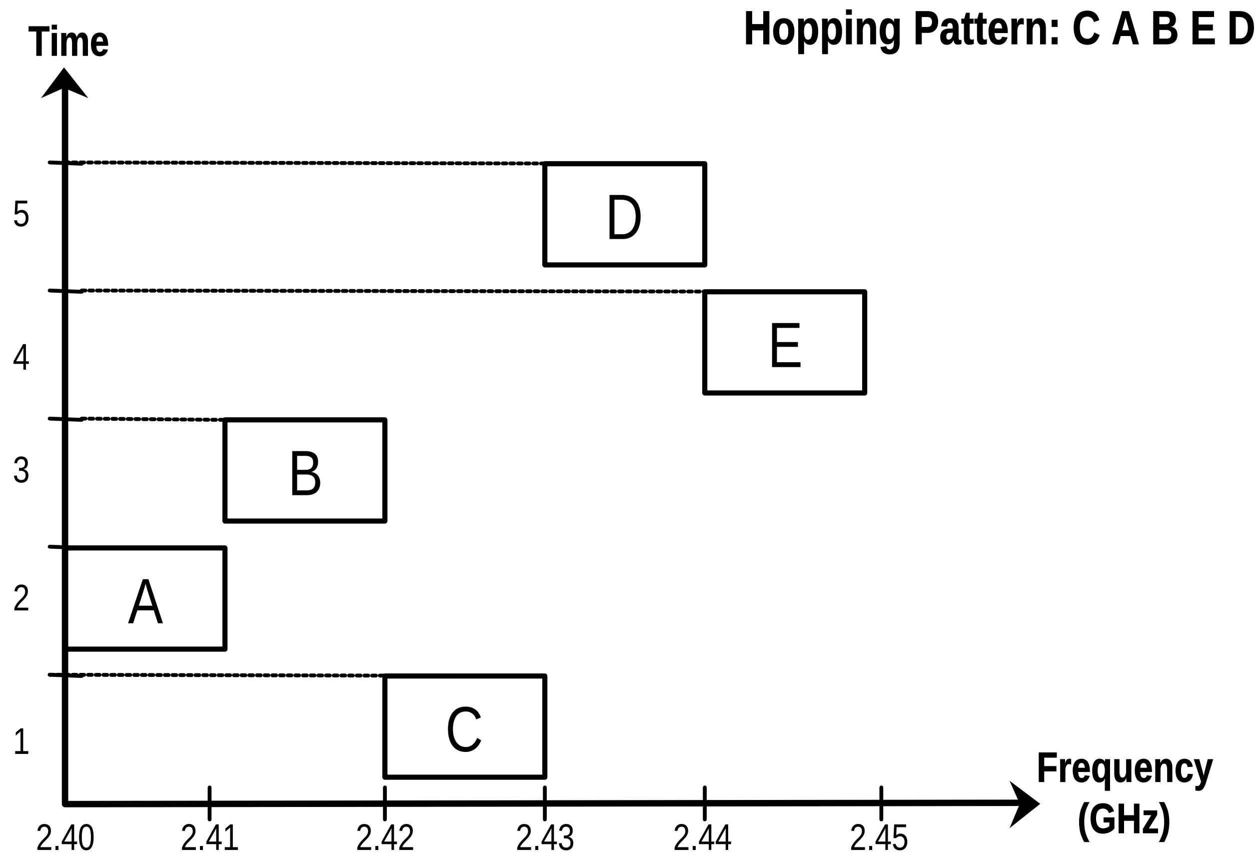
FHSS Technology

- Hopping code determines the frequencies the radio will transmit and in which order
  - Hopping pattern is known to both transmitter & receiver
    - To properly receive the signal the receiver must be set to the same hopping code & listen to the incoming signal at the right time & correct frequency
  - If properly synchronized the net effect is to maintain a single logical channel
- Unintended receiver see FHSS to be short-duration impulse noise

FHSS Technology

- FHSS system must hop its whole information signal over a band of frequencies of the ISM band in use
  - Does not interfere with primary user
- Because of the nature of its modulation technique frequency hopping can achieve up to 2Mbps data rates
  - Faster data rates are susceptible to huge number of errors
- Frequency hopping technique reduces interference
  - An interfering signal from a narrowband system will affect the spread spectrum signal only if both are transmitting at the same frequency at the same time
  - Aggregate interference will be very low, resulting in little or no bit errors

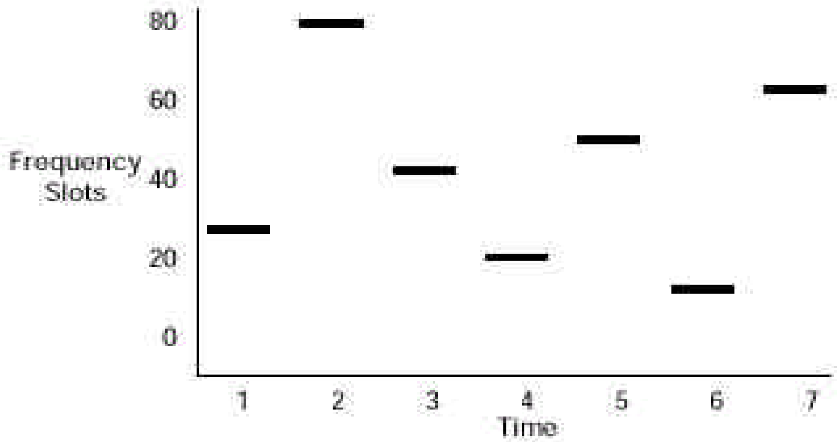
FH Example



With FHSS, the Carrier Frequency Changes Periodically - The incoming digital stream is shifted in frequency by an amount determined by a code that spreads the signal power over a wide bandwidth

FHSS Example for One Channel

- 7 frequency slots exist in the band
  - System send the information signal in frequency slot 24 for the first time slot, then frequency slot 78 for the second time slot, then frequency slot 42 for the third time slot, and so on
- Users wishing to receive signals must tune receiver to particular frequency slot
  - To receiver channel number 1 must tune its receiver to frequency slot 24 for first time slot, frequency slot 78 for the second time slot, then frequency slot 42 for the third time slot, and so on



Different FH Pattern

- Each channel is a different frequency hopping pattern
  - Channels are distinguished between channel 1 & channel 2 by having a different frequency hopping pattern
  - Receiver of channel 2 must hop his receiver according to the channel 2 FH pattern
  - This is not a different frequency as in Frequency Division Multiplexing - it is a different Frequency Hopping Pattern
    - In FDM each channel simply stays on one frequency slot for the duration of the transmission

Different FH Pattern

- It is possible to have operating radios use spread spectrum within the same frequency band & not interfere
  - Such that they use a different hopping pattern
  - While one radio is transmitting at one particular frequency the other radio is using a different frequency
    - A set of hopping codes that never use the same frequencies at the same time are considered *orthogonal*

FHSS Products

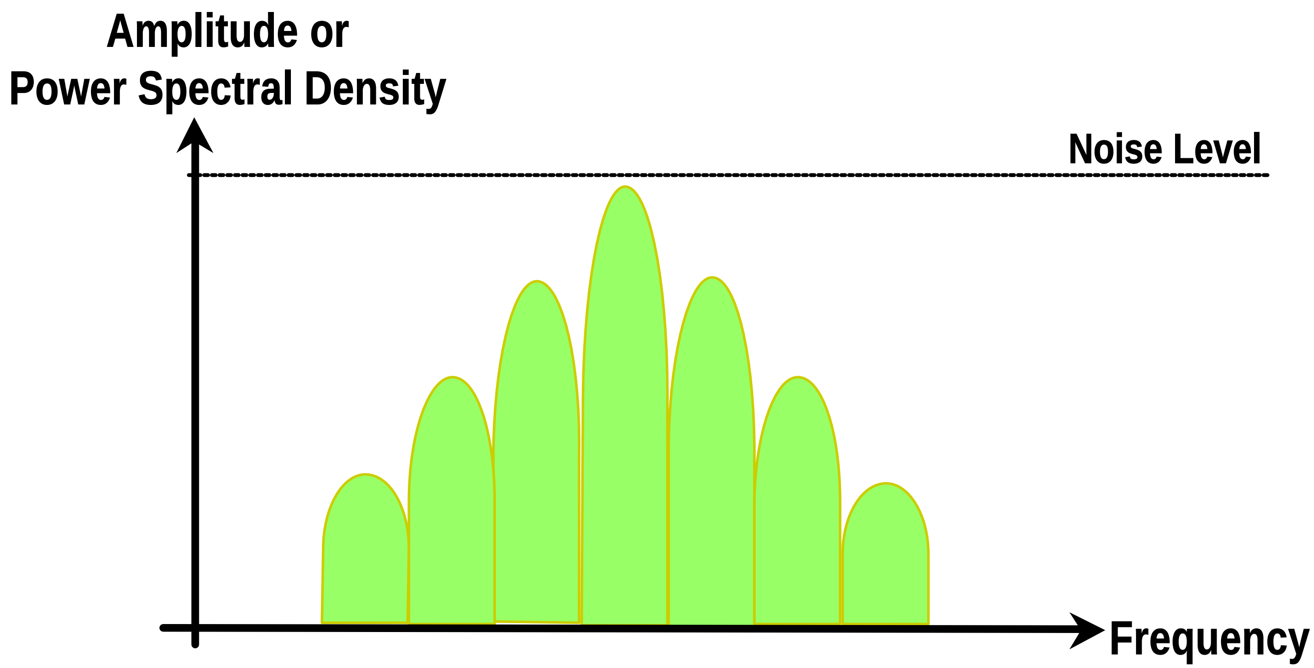
- The FHSS transmitter is a pseudo-noise PN code controlled frequency synthesizer
  - The instantaneous frequency output of the transmitter jumps from one value to another based on the pseudo-random input from the code generator
  - Varying the instantaneous frequency results in an output spectrum that is effectively spread over the range of frequencies generated

DSSS

- Direct Sequence Spread Spectrum
- Most widely recognized form of spread spectrum
- The DSSS process is performed by effectively multiplying an RF carrier and a pseudo-noise (PN) digital signal
  - First, the PN code is modulated onto the information signal using one of several modulation techniques (eg. BPSK, QPSK, etc.)
  - Then, a doubly balanced mixer is used to multiply the RF carrier and PN modulated information signal
  - This process causes the RF signal to be replaced with a very wide bandwidth signal with the spectral equivalent of a noise signal

DSSS

- The signals generated with this technique appear as noise in the frequency domain
  - The wide bandwidth provided by the PN code allows the signal power to drop below the noise threshold without loss of information



DSSS

Direct Sequence Spread Spectrum

- Combines a data signal at the sending station with a higher data rate bit sequence
  - High processing gain increases the signal's resistance to interference
- A chipping code is assigned to represent logic 1 and 0 data bits
  - As the data stream is transmitted, the corresponding code is actually sent

Chipping Code: 0 = 11101100011
1 = 00010011100

Data Stream: 101

Transmitted Sequence:

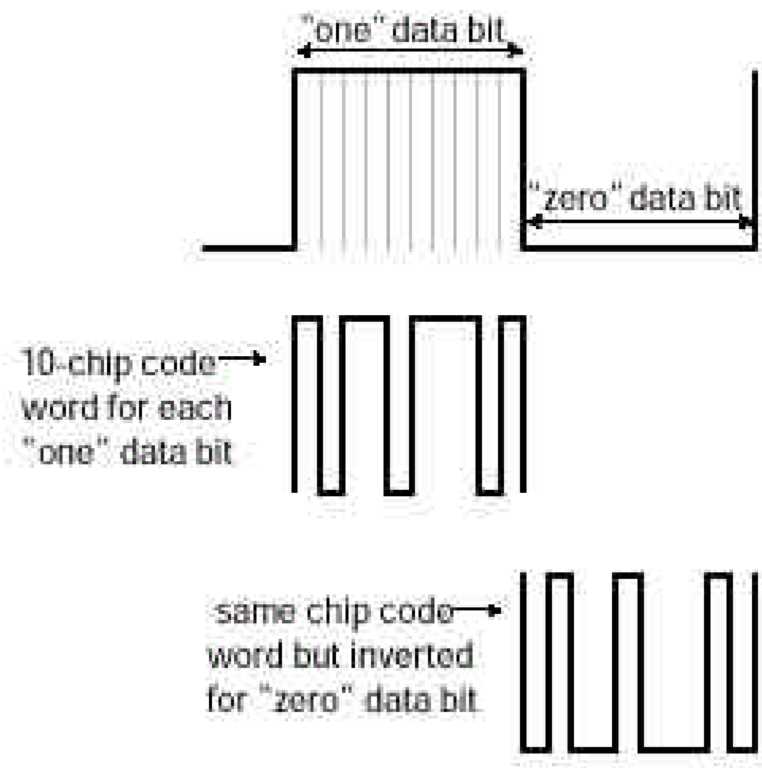
00010011100	11101100011	00010011100
1	0	1

Example: DSSS sends a specific string of bits for each data bit sent - The transmission of a data bit equal to 1 would result in the sequence 00010011100 being sent

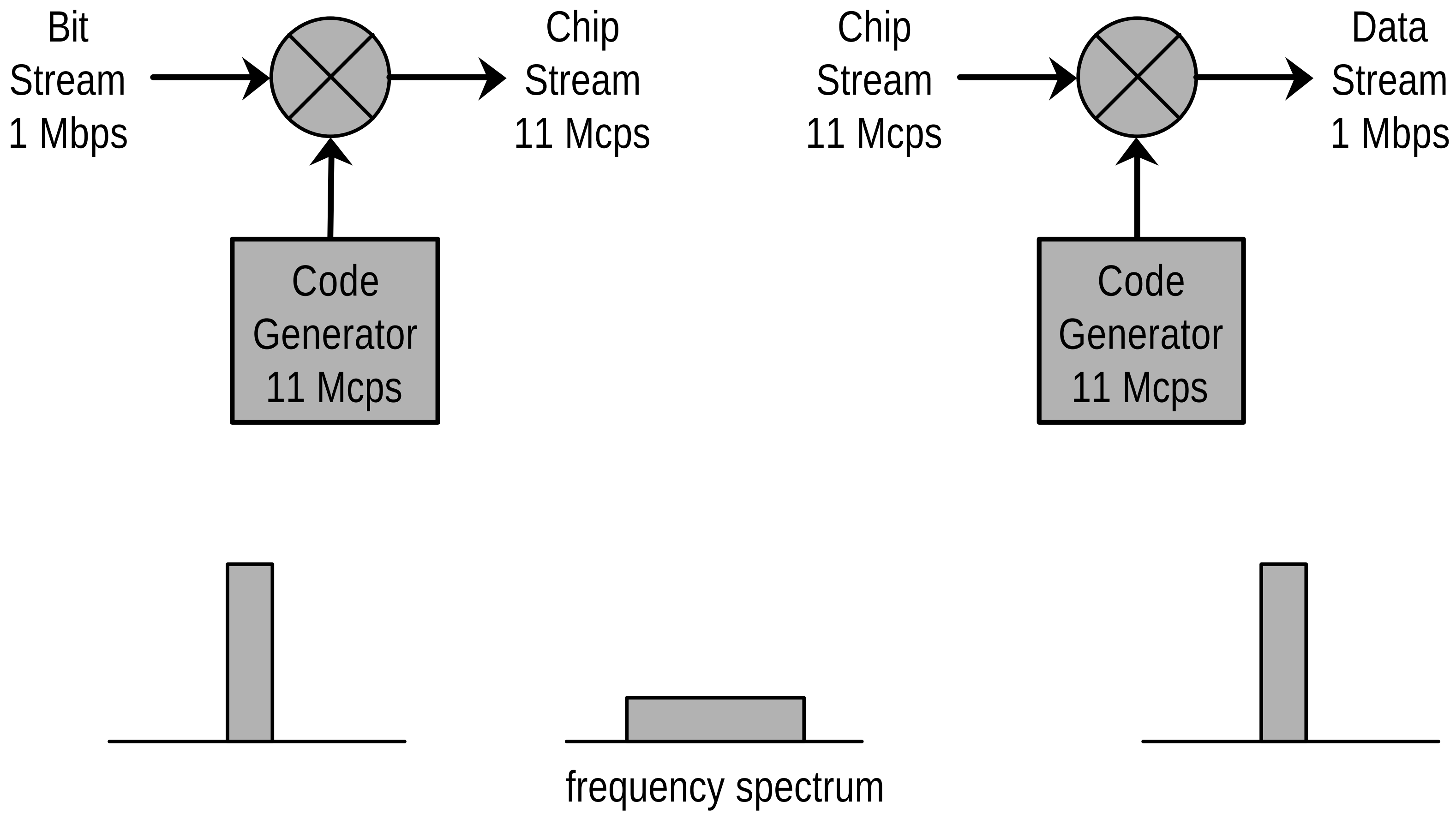
DSSS Technology

- Generates redundant bit pattern for each bit to be transmitted
  - This bit pattern is called chip/chipping code (processing gain)
  - Longer the chip
    - Greater is the probability that the original data will be recovered
    - More is the bandwidth that is required
  - If one or more bits are damaged during transmission
    - Statistical techniques embedded in the radio can recover the original data without the need for retransmission
- Unintended receivers
  - View DSSS as a low-power wideband noise & is ignored or rejected by most narrowband receivers

DSSS Technology



DSSS


Bit Stream 1 Mbps
Chip Stream 11 Mcps
Chip Stream 11 Mcps
Data Stream 1 Mbps
Code Generator 11 Mcps
Code Generator 11 Mcps
frequency spectrum

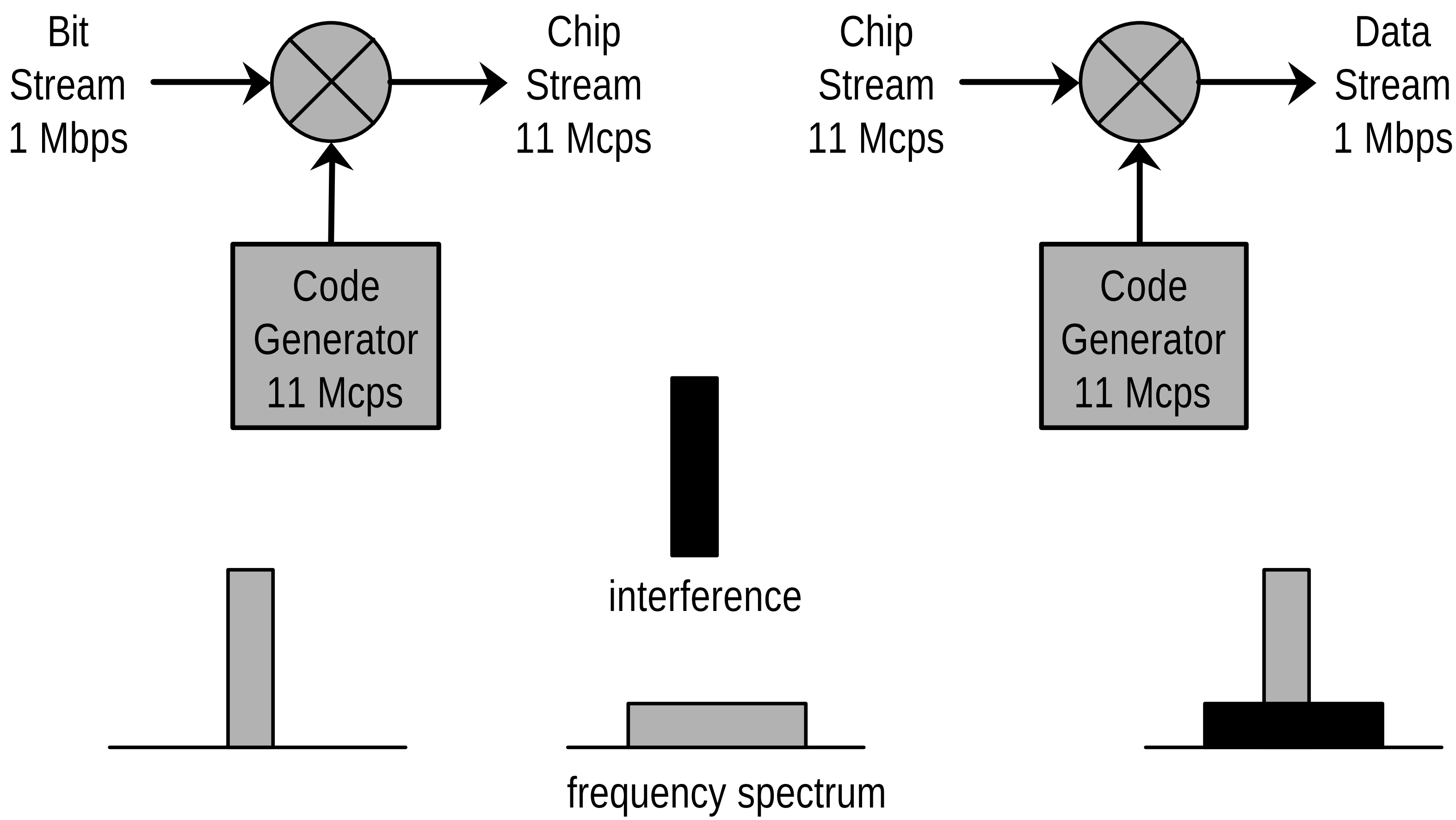
DSSS Operation

- Input data stream
  - Runs at 1Mbps
  - Multiplied by a chip stream running 11 times faster at 11 Mcps
- A chip is exactly like a bit - zero or one,
  - Called chip only to be distinguished from a bit
  - More chips exist than do bits
- When the bit stream is multiplied, its frequency spectrum becomes spread out
  - Occupies about 11 times as much bandwidth, spectral energy is 11 times lower
  - Since it is so low it does not interfere with the the primary user

DSSS Operation

- With more DSSS systems occupying the band, the overall noise level (interference) rises
  - Causes degradation in performance
  - Causes primary user to increase a bit
    - Increased interference to DSSS users are expected to become a problem long before the primary user notices any interference
- At the receiver
  - Input chip stream is multiplied by the same coded chip stream that was used at the transmitter
  - Two codes are synchronized
    - Original bit stream is correlated
    - Any interference on the air when it goes through the correlator becomes spread out

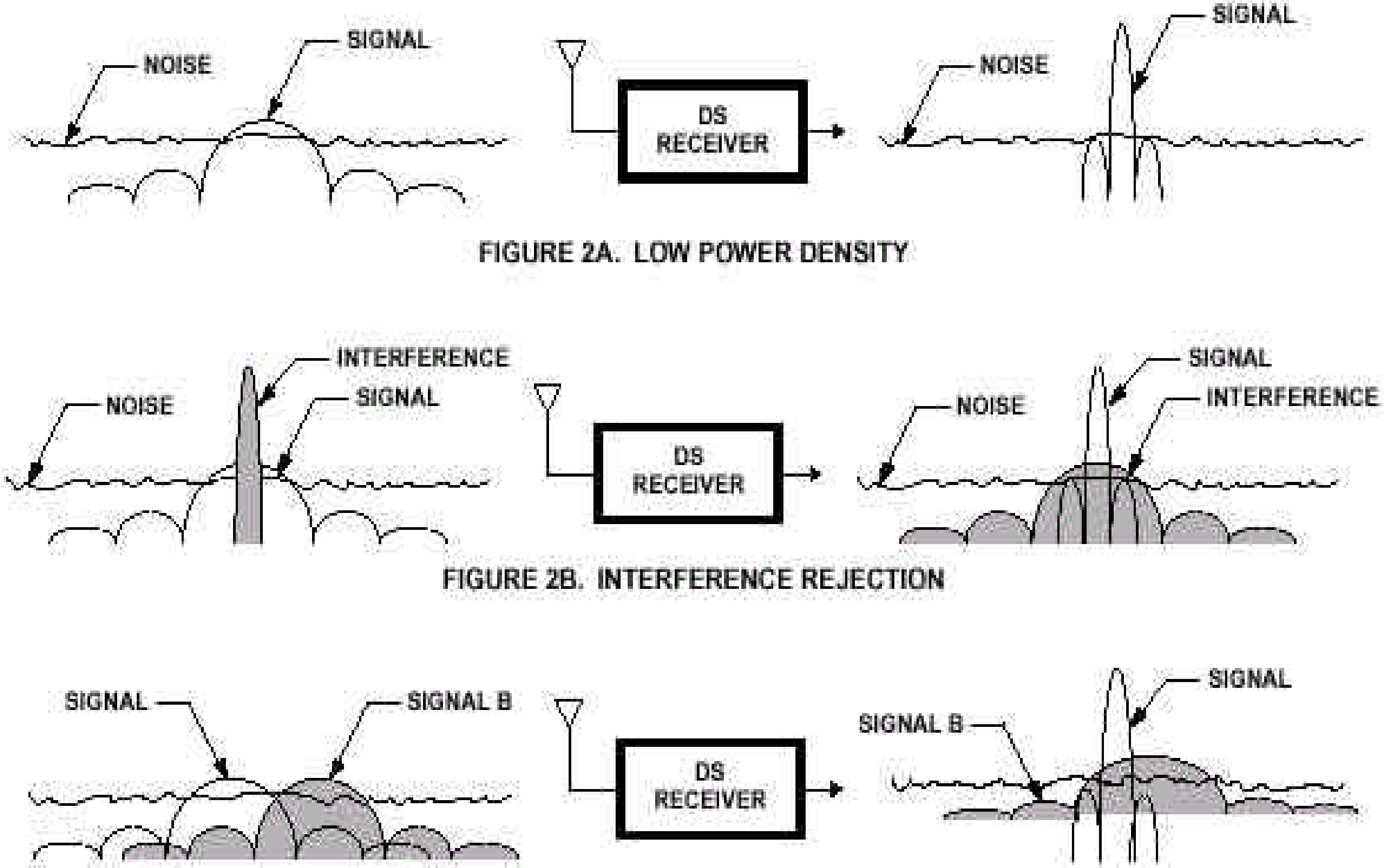
DSSS With Interference



Interference in DSSS

- Amount of interference energy is reduced by the spreading factor
  - Anti-jamming effect makes DSSS technology useful for defense applications
  - DSSS continues to operate at stated throughput
- As more interference is introduced in the channel
  - Noise level increases until even though it is spread out by the correlator, it still becomes too much for the DSSS system to operate
  - DSSS system stops working and throughput declines to zero

DSSS Properties



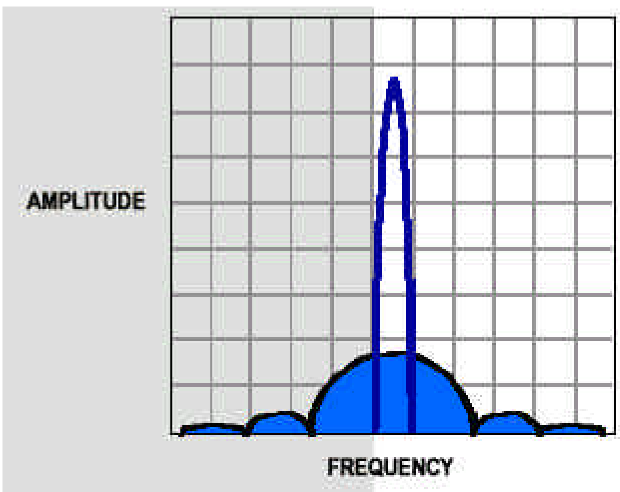
Source: Intersil

Processing Gain Information

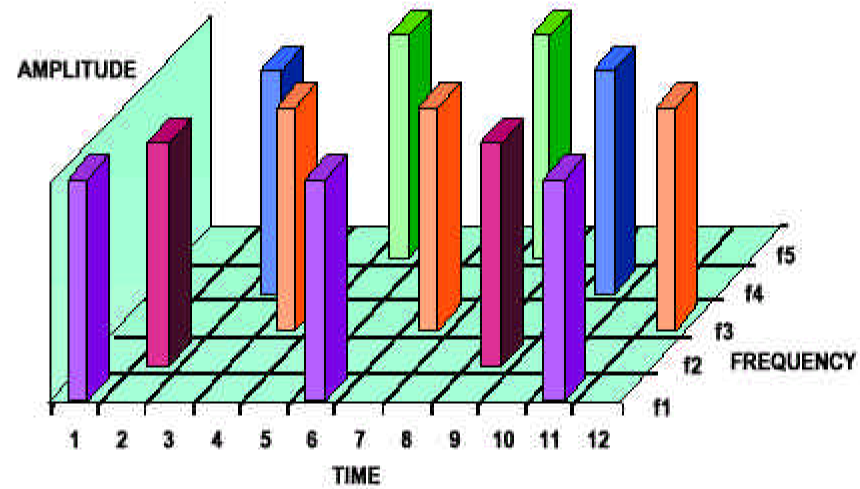
- Minimum linear processing gain allowed by the FCC is 10
- Most commercial products operate under 20
- IEEE 802.11 Working Group has set its minimum processing gain requirements at 11

Spread Spectrum Summary

- Transmission bandwidth is greater than the information data rate
- Code signal spreads the original signal
- Spread and de-spread codes are the same



Direct Sequence Spread Spectrum



Frequency Hopping Spread Spectrum

Source: Compaq

DSSS vs. FHSS Comparison

Direct Sequence (DS)	Frequency Hopping (FH)
Higher Throughput	Interference immunity
Wider Range	Echo resistant
Upgradeable to higher speeds at 2.4GHz	Less expensive than DS systems
	Simpler installation
	More extensive product selection, more vendors

- FHSS degrades gradually, DSSS degrades drastically!
- DSSS can achieve much higher data rates than FHSS's 2Mbps
- FHSS can have up to 10 or 15 channels, while DSSS can have up to 2 or 3 channels

DSSS vs. FHSS Comparison

- Instantaneous data rates of DSSS can be larger than FHSS
  - In FHSS the maximum bandwidth of the signal is specified to 1MHz at the 2.4GHz band
    - Realistic data rates are limited to 1 or 2 Mbps
  - With DSSS, the rule is to spread by at least a factor of 11
    - Theoretically it is possible to use the whole 80 MHz band & provide a data rate in the order of 6 or 7 Mbps
    - Circuitry would be required to run at a very high rate of 66 or 77 Mbps in order to generate the chip stream necessary to support the 6 or 7 Mbps bit rate
    - This high rate would be very expensive & not seen in the industry at this time

Infrared (IR) Technology

- IR systems use very high frequencies, just below visible light in the electromagnetic spectrum to carry data
- IR cannot penetrate opaque objects and uses
  - Directed (line-of-sight) technology
    - Inexpensive directed systems
      - Provide very limited range - 3ft
      - Used for personal area networks & occasionally in wireless LAN
    - High performance directed IR
      - Impractical for mobile users & used only to implement fixed subnetworks
  - Diffuse (or reflective) IR technology
    - Line-of-sight is not required & cells are limited to individual rooms
- Little used in commercial wireless LANs

Non-Interoperable PHYs

- DSSS radio cannot interoperate with a FHSS radio
- FHSS radio cannot interoperate with a DSSS radio
- Neither a FHSS nor DSSS radio can interoperate with IR
- The 3 types of PHY layers are due to legacy issues

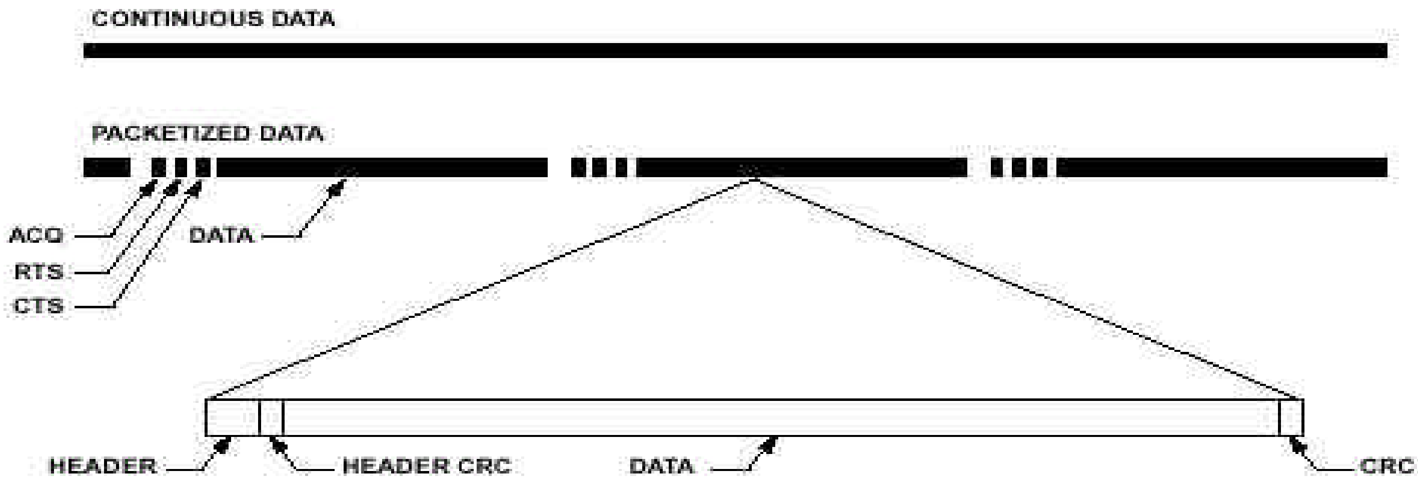
Radio Waves

- Referred to as radio carriers because they simply perform the function of delivering energy to a remote receiver
- Data being transmitted is superimposed on the radio carrier so that it can be extracted at the receiving end
  - Modulation of the carrier by information being transmitted
  - The radio signal occupies more than a single frequency, since the frequency or bit rate of the modulating information adds to the carrier

Radio Waves

- Multiple radio carriers exist in same space at same time
  - No interference between radio waves if they are transmitted on different radio frequencies
- Data extraction
  - Radio receiver tunes in one radio frequency rejecting all other frequencies

Packetized Communications



Source: Intersil

- Packet radio or packet communications
  - Breaking up of a large block of data into small "packets" is a common technique in communications
    - Insures error free communication even with interruptions
    - Packet communications is a term used where the communication medium is not well controlled & can be interrupted
    - There are numerous reasons why a radio communications link may be interrupted, such as the microwave oven

Packetized Data

- If the medium is corrupted intermittently, a large block of data will never make it through without errors
- In the packet technique
  - Block of data is broken into small packets that each have some error detection bits added
  - If an error is detected, a retransmission of the small packet that was corrupted will not burden the network
  - This packet communications technique has short control packets that check to see if the medium is clear, the other end is ready to receive and, to request a retransmission if a packet did not get through correctly
  - All of this requires some overhead expense that reduces the net system throughput

Packetized Data

- Packet length can be optimized
  - This minimizes overhead while insuring the greatest throughput & data integrity
  - When continuous data is packetized, the instantaneous rate must increase since the time allowed for data transmission is reduced
  - This allows time for the packet protocol interchange, packet headers and other overhead

Data Link Layer

Medium Access Control (MAC)

Logical Link Control (LLC)

Data Link Layer

- Provides a reliable, efficient communication protocol between machines physically connected machines communicating over a channel
- Functions
  - Provide services to the network layer
  - Framing
    - Determines the grouping of the physical layer bits into frames
  - Error control (detection and correction)
    - Deals with transmission errors
  - Flow control
    - Regulates the flow of frames so that the slow receivers are not swamped by fast senders

Medium Access Control Sub-layer

- Sub-layer of the data link layer
- Determines priority & allocation to access the channel

MAC Protocol Alternatives

- Random access
  - ALOHA, CSMA (with CD)
- Ordered access
  - Token bus, token ring
- Deterministic access
  - FDMA, TDMA, CDMA
- Combinations
  - FDMA/TDMA, CDMA/TDMA, TDMA/CSMA

Logical Link Control (LLC) Sub-layer

- Sub-layer above the MAC
- Framing/Frame construction takes place here
  - LLC inserts certain fields in the frame such as source address & destination address at the head end of the frame & error handling bits at the end of the frame

It is Not Like a Wired Network?

- Carrier sense
  - In a wired network
    - Means listening to the medium which is the network cable
  - In a wireless network
    - Defining the cable is not straightforward
    - Issue of hidden nodes
      - Is everyone in the Basic Service Area? Or is everyone in the Extended Service Area? Or is it some other set of nodes?

Two MAC Layer Bridging Protocols Within 802.11

- Spanning tree bridges
  - Construct tables of which LAN segment nodes are at any point anytime and age them out if they haven't heard from them
  - Each bridge broadcasts its identity and the identity of other bridges it knows
  - The tree is continuously updated as bridges come and go
  - More popular & more used
- Source routing bridges
  - Rely more on source node which keep a table of where the other nodes are & constructs a network topology
  - Includes the route the packet is to take in the header
  - Heavy load on the nodes resources

What Does the MAC Do?

- Provide access control functions for shared medium PHYs in support of the LLC layer
- MAC layer provides these primary functions
  - Addressing - Accessing the wireless medium
  - Access coordination - Joining the network
  - Frame check sequence generation and checking - Providing authentication and privacy
- MAC layer performs the addressing and recognition of frames in support of the LLC

What Does the MAC Do?

- Accessing the wireless medium
  - CSMA/CA
    - Contention based protocol similar to IEEE 802.3 Ethernet
    - 802.11 specification refers to this mode as distributed coordination function (DCF)
  - Priority based access
    - Contention free access protocol
    - Usable on infrastructure network configurations containing a controller called a point coordinator with the access points
    - 802.11 specification refers to this mode as point coordination function (PCF)

Multiple Access

- Basic access method for IEEE 802.11 is the DCF which uses CSMA/CA
  - Station listens for users
  - If the channel is idle, the station may transmit
  - However if it is busy, each station waits until transmission stops, and then enters into a random back off procedure
    - Prevents multiple stations from seizing the medium immediately after completion of the preceding transmission

How do WLANs Work?

- Electromagnetic waves (radio or IR)
  - Communicate information from one point to another without replying on a physical connection
- Configuration
  - Access points (Transceiver devices)
    - Connect the wired network from a fixed location using standard cabling
    - Receives, buffers & transmits data between wireless LAN & the wired network infrastructure
    - Supports small group of users
    - Functions within a range of 100 to several hundred feet

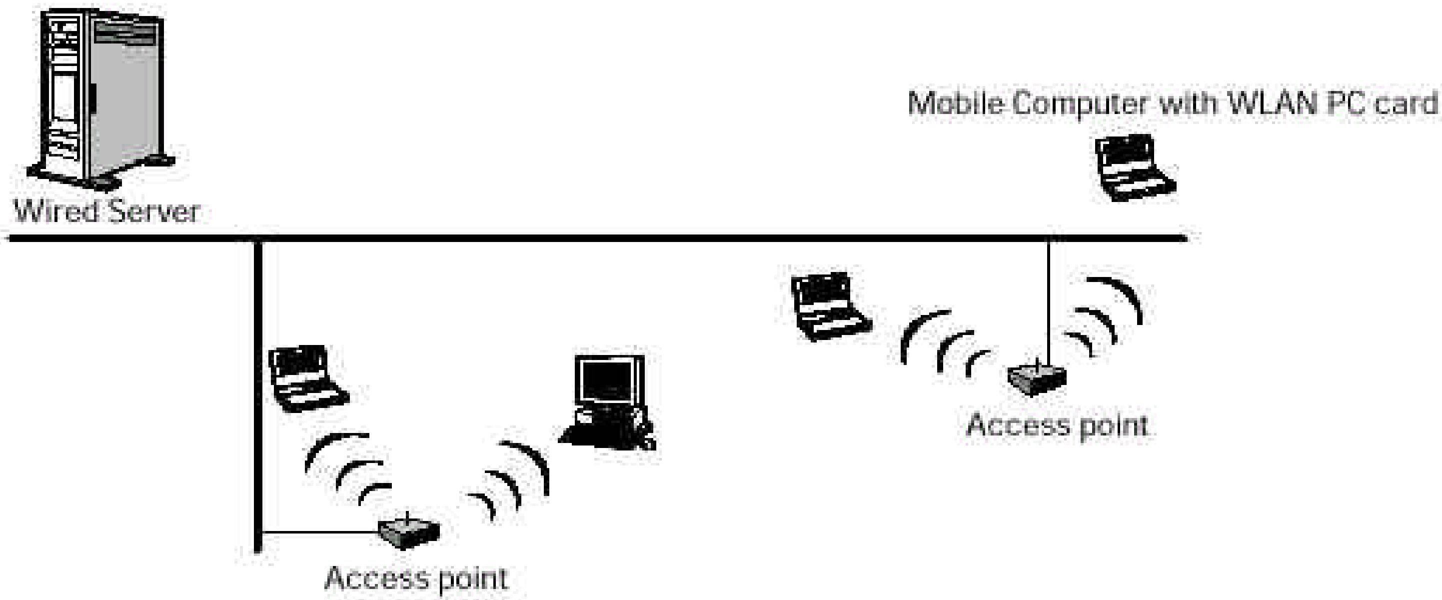
How do WLANs Work?

- Adapters
  - Implemented as PC cards in notebook PCs
  - Provide an interface between the client network operating system (NOS) & the airwaves via an antenna
    - Nature of the wireless connection is transparent to the NOS

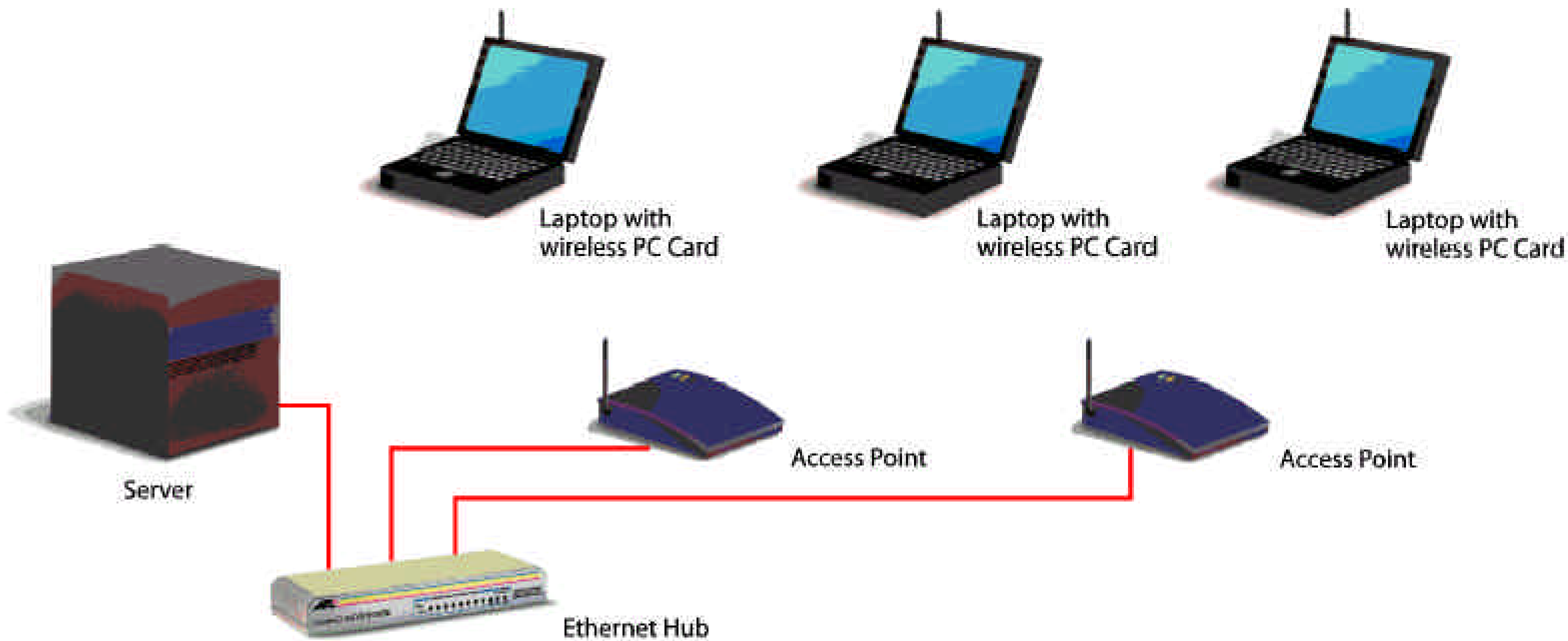
WLAN Configurations

- Wireless peer-to-peer network
- Clients & access points
- Multiple access points & roaming
- Use of an extension point
- Use of directional antennas

Typical WLAN Configuration



Wireless LAN Configuration



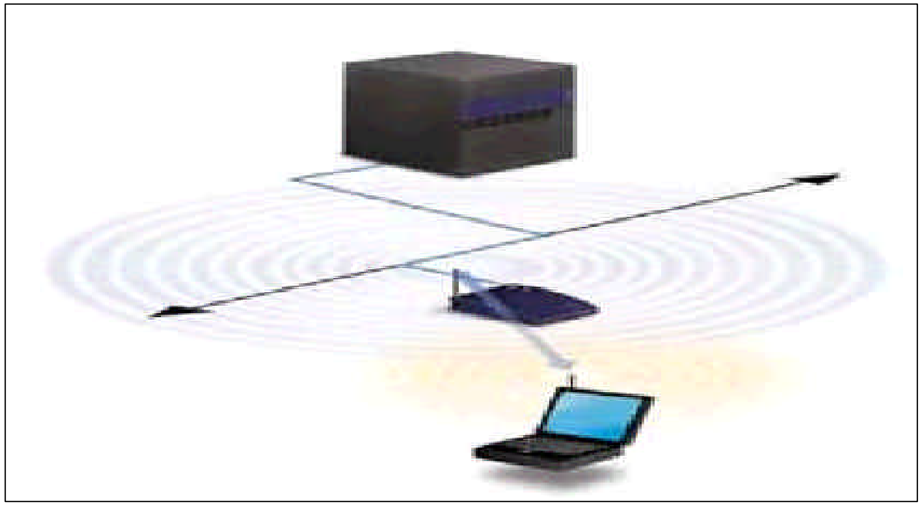
Source: *Proxim*

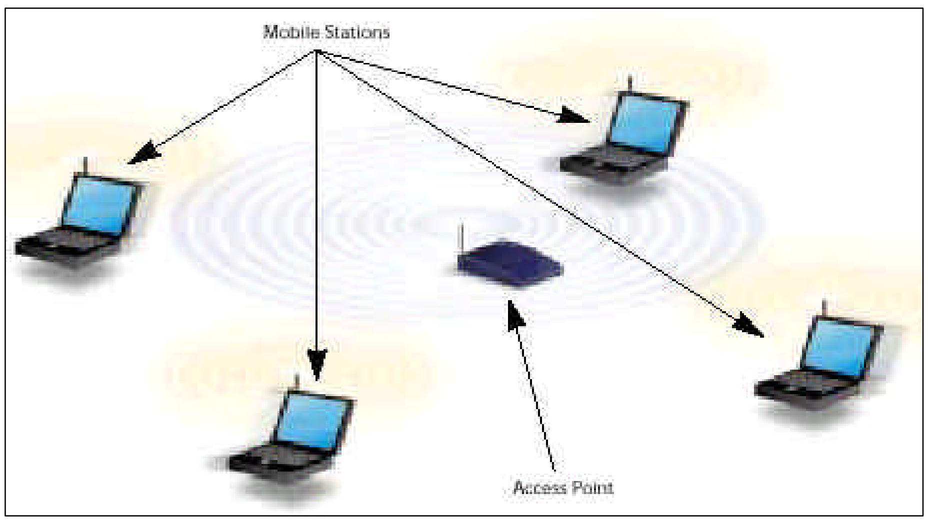
Wireless Peer-to-Peer Network

- Direct communication between devices
- Ad-Hoc Network

Source: *Proxim*

Clients and Access Points



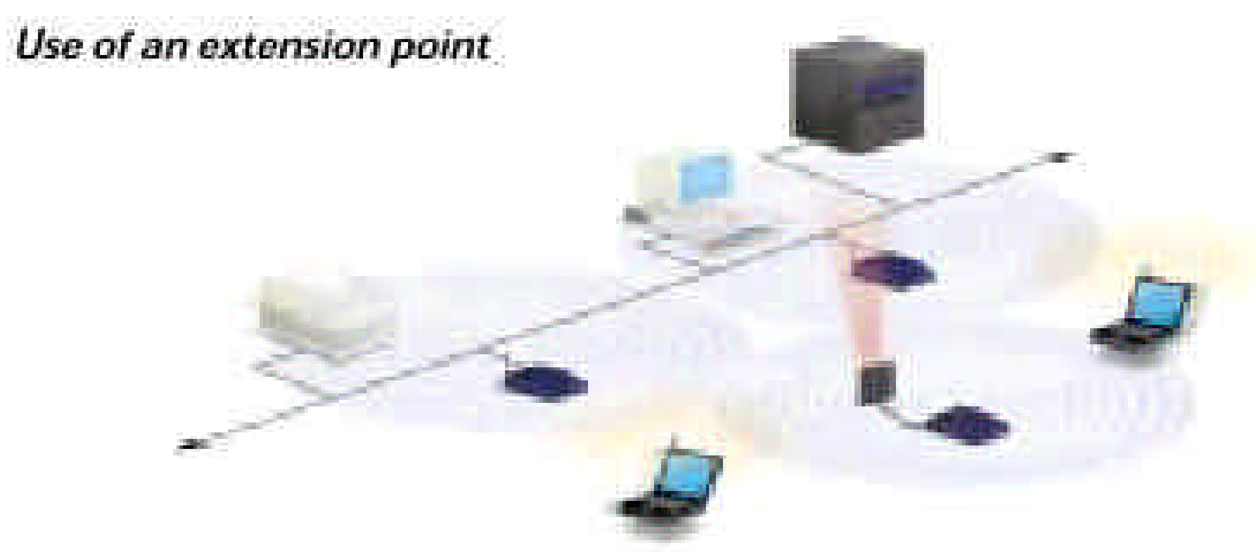


Source: *Proxim*

Multiple Access Points & Roaming

Source: *Proxim*

Extension Point



Source: *Proxim*

Emerging WLAN Standards

- HiperLAN & HiperLAN2
- IEEE 802.11 a and b WLAN standards
- Both standards cover the PHY and MAC layers of the OSI network reference model

Interoperability

What is Interoperability?

- It is a key principle upon which modern communication networks are built
- Core concept of network interoperability
  - Simple in concept, but complex in execution
  - Ability of equipment from different manufacturers to work together as each piece was intended to
- Interoperability is made possible by 'Industry Standards'
  - 10BaseT Ethernet card from one firm should be interoperable with the 10BaseT hub built by another firm since they are built to the same spec 802.3 10BaseT standard

Why Do We Need It?

- Why is it a pervasive concern?
  - So many boxes, cables, software options, configurations
  - There are several wireless standards
    - Wireless LAN standards
      - IEEE 802.11
      - Wireless LAN Interoperability Forum's OpenAir
      - ETSI BRAN HiperLAN2
    - HomeRF
    - Bluetooth

Standards-Based Interoperability is of Critical Importance

- Standards encourage the development of a variety of new products
  - Increasing the range of choices available
  - Customers have a large range of products to choose from
    - Extending the standard without creating incompatibilities can be a key product differentiation
- More products means increased competition
  - Lower prices, wider choice of product-specific features beyond standards requirement

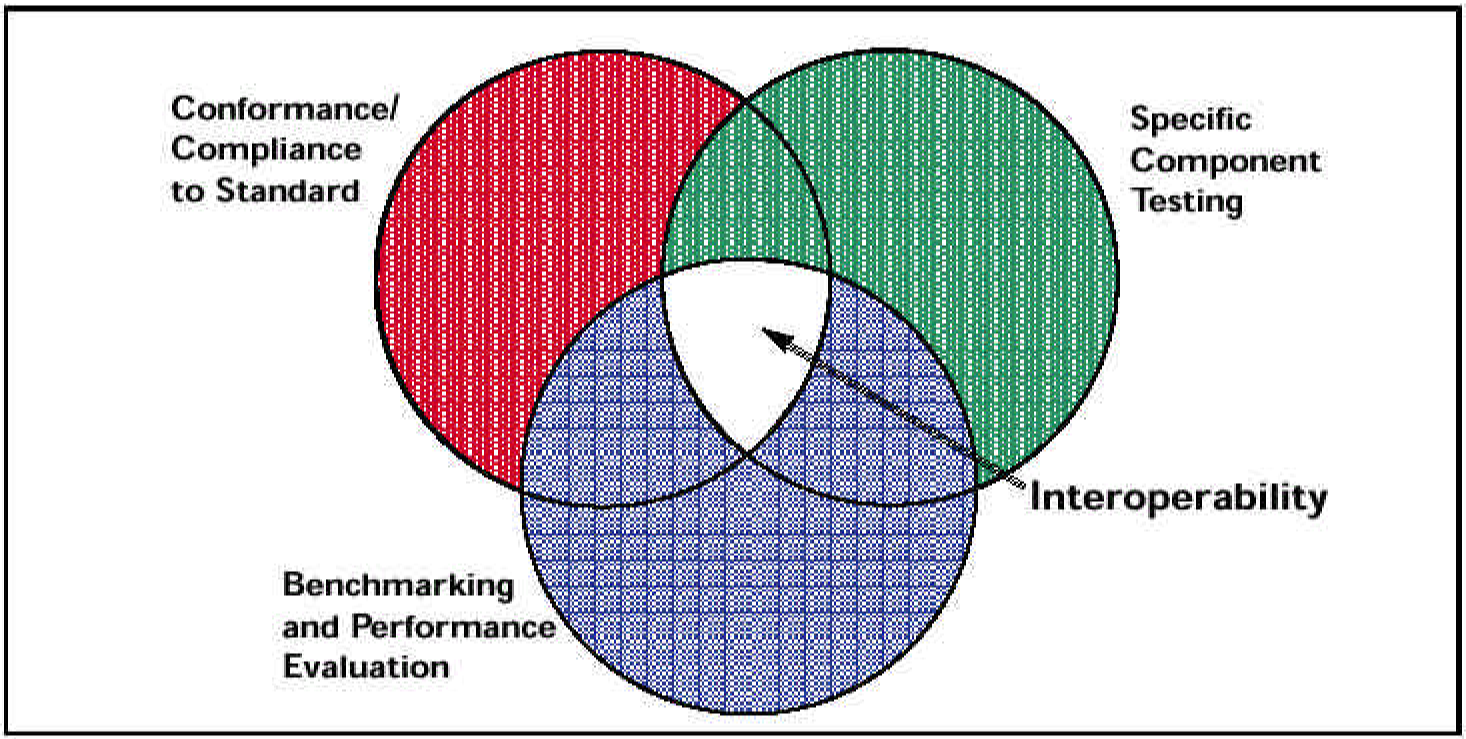
Standards-Based Interoperability is of Critical Importance

- Standards can provide new technologies the foothold needed in an emerging market
  - For example
    - WLANs seem interesting & suitable for an array of applications
    - Standards such as IEEE 802.11 & HiperLAN2 ensure WLANs enjoy rapid growth, see expanding opportunities & fulfil the needs of users

Addressing the Key Concerns

- Concern
  - Does the product really comply with a given standard
- Specialized testing procedures to verify functionality at a number of levels
  - Conformance or compliance to a standard must be verified
    - Test to verify the interface at which standards define interoperability
  - Interoperability between 2 specific components must be tested
    - Accomplished with specialized software suites which exercise the 2 components working together
  - Benchmarking & performance evaluation
    - After interoperability, highest performance is the next requirement

Elements of Interoperability



Source: WLI Forum

Understanding WLAN Interoperability

- Process of WLAN interoperability is similar to wired LANs
- Involves
  - Documentation of test procedures with software suites which verify interoperability
- Factors to consider - PHY Layer
  - Implementations must match meeting local regulations for the particular band being used
    - Involves bandwidth, antenna, power-output limitations
  - Matching PHY layer protocols
    - Such as the use of a particular spread-spectrum modulation technique

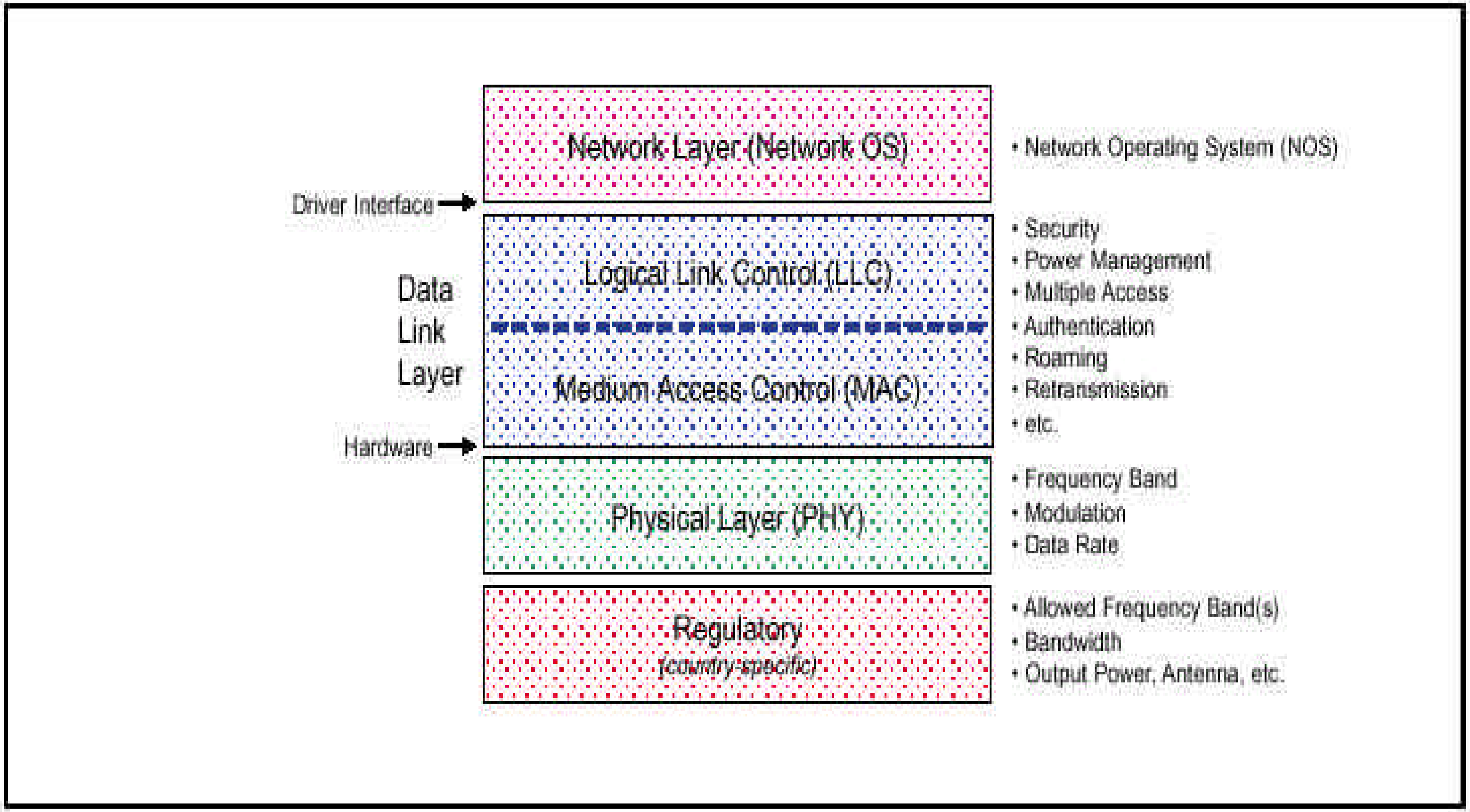
Understanding WLAN Interoperability

- Factors to consider - MAC Layer
  - Support for security, power saving "sleep" modes, automatic retransmission in the event of of an error (ARQ) & others
    - Possible that not all manufacturers will support every feature in a given MAC spec
- Factors to consider - Driver Interfaces
  - Each product must support a set of driver interfaces to specific network operating systems
    - Includes Win9x/NT, Netware and others

Understanding WLAN Interoperability

- Some items can simply not be tested
  - Because they are not part of a standard
    - E.g., Inter-access-point interoperability is not part of the 802.11 standard as each manufacturer defines its own protocol for handoff & load balancing
  - Higher level network functions can be verified with tools that are not specific to PHY layer
- Wireless interoperability needs to be achieved for the whole protocol stack
  - Real applications do not care about the protocol stack

Layers of Reality - Features Supported At Each Protocol Layer



Source: WLI Forum

UNH - IOL

- University of New Hampshire - InterOperability Lab
  - Well known for its work in verifying interoperability between classes of networking devices
- UNH has defined PHY layer tests for DS & FH PHYs
- UNH has a wide range of tests designed to address specific MAC-level features
  - Due to the range of possible combinations MAC-level testing can be both time-consuming & complex

UNH - IOL

- UNH has defined PHY layer tests for DS & FH PHYs
  - Point-to-point interoperability test
    - Verifies that an access point can communicate to a station
  - Packet error test
    - Generates multicast traffic between an AP & multiple STAs
  - Fair access test
    - Generates traffic between an AP & multiple STAs verifying that the STAs are receiving the same amount of traffic
  - Fail over test
    - Makes sure STAs can associate with another AP in event of a failure of the AP currently being used
  - Large network configuration test
    - Examines error rates in WLAN configurations typical of real installations (multiple AP & multiple STAs)

WLIF

- Wireless LAN Interoperability Forum
- Defines a set of procedural tests for verifying interoperability with minimum special software
  - Such tests can be performed under carefully controlled conditions
- Publishes the certified interoperable product information to help customers make more informed purchasing decisions

Additional Tests

- For net throughput and effective range
- Performance-oriented LAN benchmarks
  - Programs which generate synthetic workload for a given class of applications
- Diagnostic tools
  - Such as SNMP or other network management tools
  - Help isolate more subtle interoperability problems
  - Tuning a given installation for maximum throughput, reliability & operation management

Bluetooth (BT)

- Short-range wireless data transmission technology
  - Personal Area Networks (PANs)
  - Provide a simple module that will allow a wide variety of electronic devices to exchange data electronically over short ranges
- Low-cost, low power consumption methods of transmitting data without using wires
- By 2003, BT market could be worth $5 billion (SG Cowen)
- Bluetooth SIG is a huge industry following
  - Ericsson, Nokia, IBM, Intel, Toshiba, Motorola, Lucent, 3Com
  - 2000+ members today

Key Characteristics & Capabilities of BT

- Transmits sound and data
- Used worldwide (standard technology)
- Ad hoc connection
- Open environment, but prevents external reception
- Compact, & able to be installed in a variety of devices
- Extremely low power consumption
- Open industry standard
- Low cost

Issue Between BT & IEEE 802.11

- Coexistence of 802.11 high speed DSSS & BT radios
  - Both radios located in a mixed environment
- Both share common spectrum in the 2.45 GHz ISM band
- Both are largely targeted at the business user & will come in close proximity to each other within enterprise settings
  - The advent of 11Mbps data rates 802.11 DSSS radios
    - Can provide a mobile extension to wired networks in large enterprises & SOHO applications
  - BT will become an important asset for mobile worker & business traveler servicing a number of applications
    - Downloading email to a laptop via cellular phone, synchronizing palmtop devices, accessing local printers