Background and Overview of the Wireless LAN

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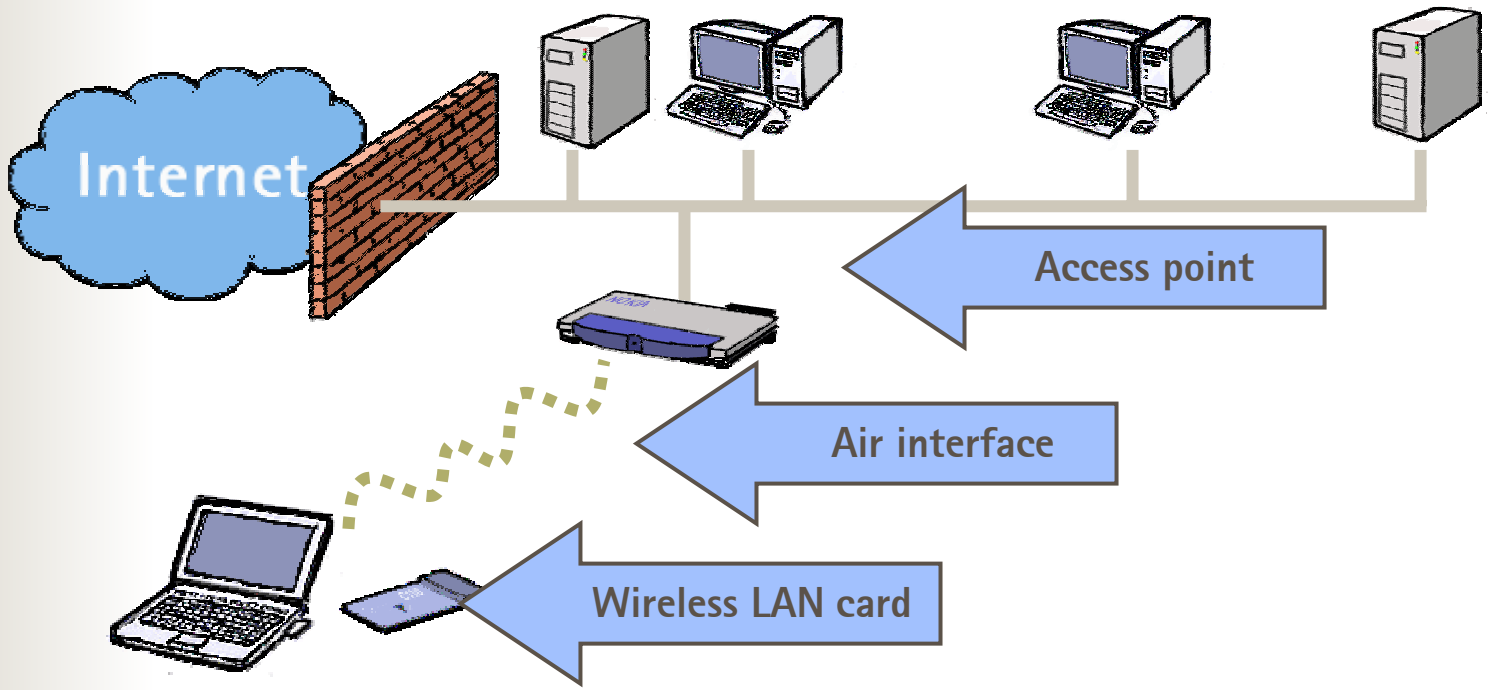
What is Wireless Local Area Network

- *It provides all the features and benefits of traditional LAN technologies without the limitations of wires or cables.*
- *Wireless LAN (local area network) is a mobile extension of the traditional wired LAN*
- *Wireless LAN is transparent to the user*



Benefits of wireless LAN

- Flexibility & Mobility
  - User can move around freely with wireless connection
- Installation
  - Less cabling
  - Wireless LAN can easily be moved to other location
  - Can be used where wire is not possible
- Cost of ownership
  - Installation costs may be lower
  - Saves when the LAN needs moving
- Scalability
  - Ad hoc networks
  - From one cell to multiple cell networks

Disadvantage of Wireless LAN

- Distance limits & wall/objects attenuation
- Security must be addressed
- Performance
- Problems with narrowband interference
- Relatively expensive

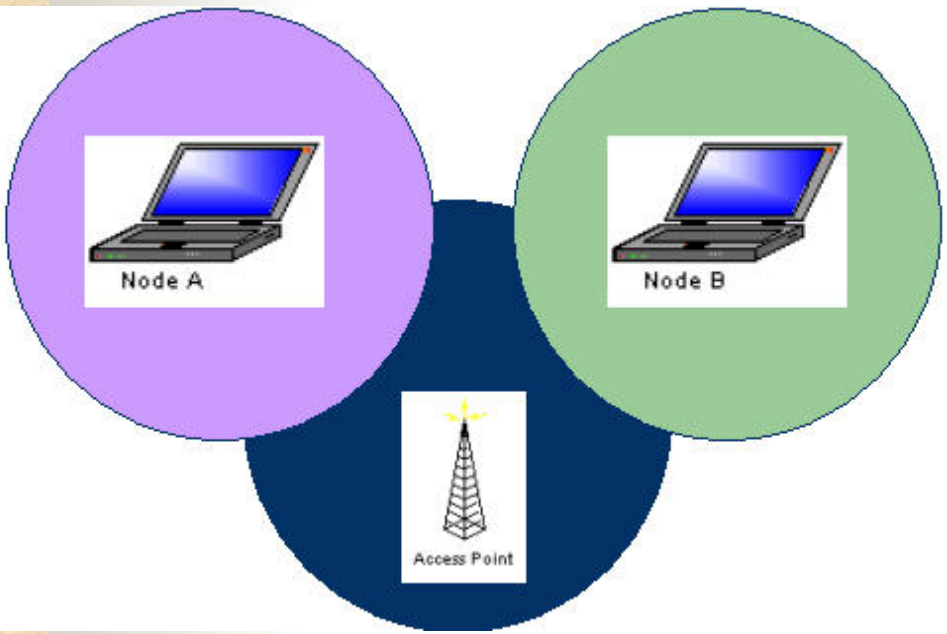
Security Problem

- Signals are sent by radio broadcast, it is easier to be listened
- Even if using the WEP (Wired Equivalent Privacy defined in 802.11 standard) to encrypt the signal/contents, it still can be cracked.

Hidden Node Problem (1/2)

- Reasons:

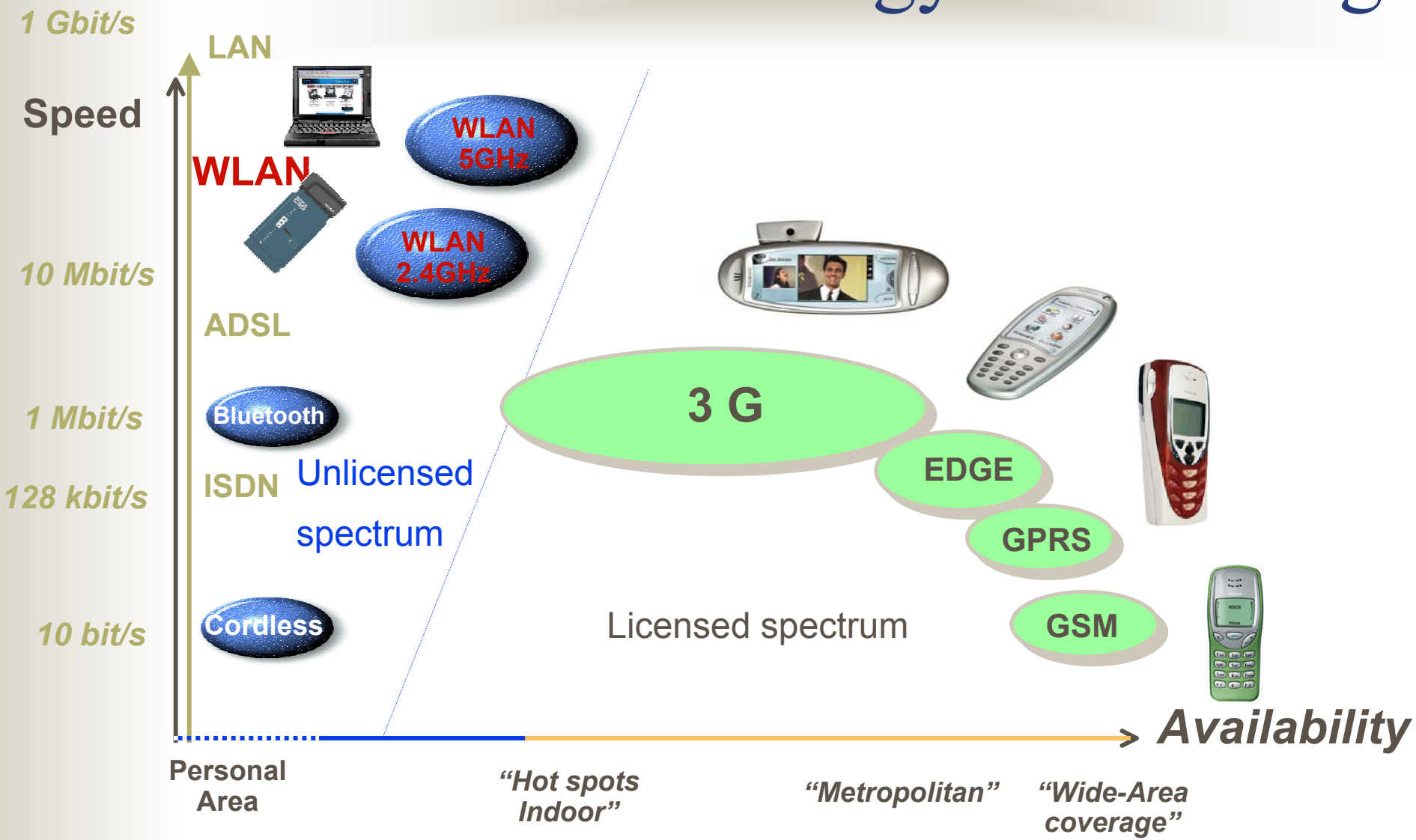
Two mobile nodes are located too far away to hear each other, but close enough to an Access Point located between them, If they both start to send signals simultaneously, they disturb each others transmission and the Access Point can not receive the signals properly.



Hidden Node Problem (2/2)

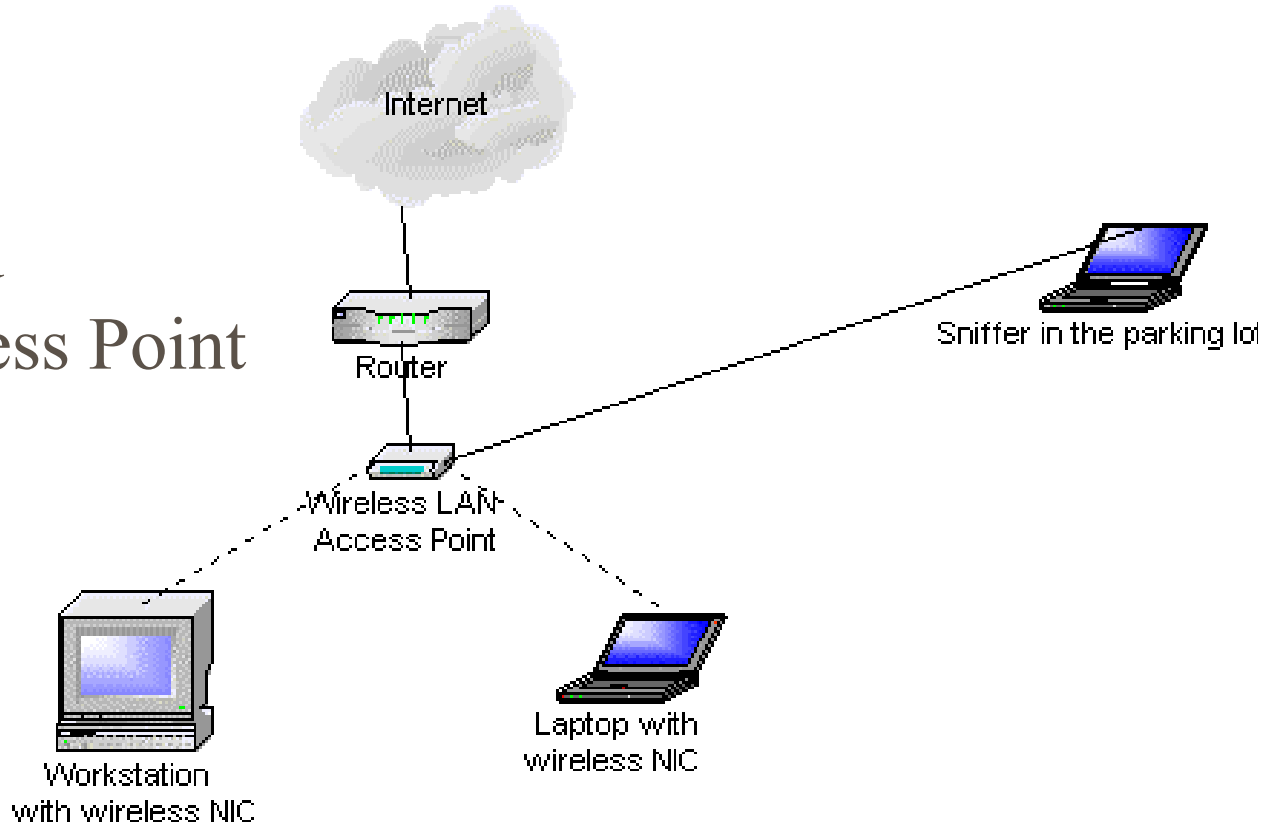
- This can disrupt 40% or more of the communications in a highly loaded Wireless LAN environment
- The use of CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) and ACK sequences helps the prevent the disruptions caused by this problem.

Wireless LAN Technology Positioning



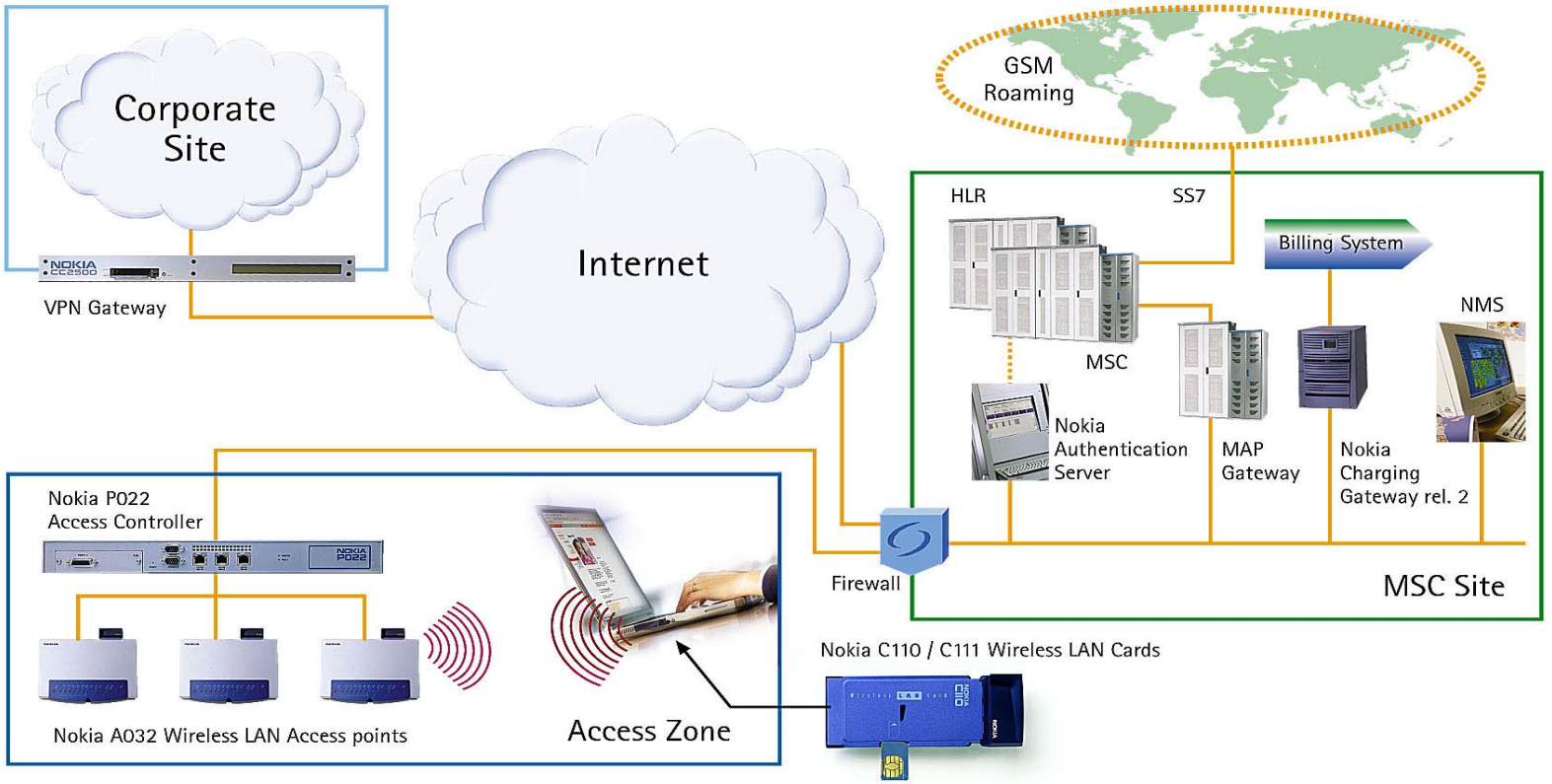
Wireless LAN Architecture Components

- Wireless LAN Card
- Wireless LAN Access Point
- Router



Operator WLAN Architecture

- Nokia solution



Wireless LAN Components
- Wireless LAN Card

- For the end user:
  - PC cards
  - "Interface between the user and the network“
- For the network connection:
  - Different types of access points
  - "An access point is like a bridge which enables users to communicate with the wired network"

Wireless LAN Components

- Wireless LAN Access Point

- Gateway to wired network
- It is a wireless hub that controls a wireless LAN, it is equivalent to wired hub
- It is a wireless network police manager
- Network management tool
- It offers the seamless roaming between different access points, so that the users will always feel that network access is transparent.

Nokia Access Point product – A032

Wireless LAN Components

- Wireless LAN Router

- *The wireless LAN router can be as a gateway between the wireless or fixed LAN access zone and the operator's IP core network or the public Internet.*
- *It has the other functions:*
  - *Authentication of the users,*
  - *Monitors network usage in real time,*
  - *Collects accounting information for billing purposes.*

Nokia P022 Access Controller

Narrowband Technology

- A narrowband radio system transmits and receives user information on a specific radio frequency. It keeps the radio signal frequency as narrow as possible in transmitting the information.
- Undesirable crosstalk between communications channels is avoided by carefully coordinating users on different channel frequencies.
- In a radio system, privacy and non-interference are accomplished by using separate radio frequencies. The radio receiver filters out all radio signals except those on its designated frequency.
- The drawback is that end users must obtain the FCC license for each site for different frequency.

Spread Spectrum Technology

- Most wireless LAN systems use spread spectrum.
- Wideband radio frequency technology was originally developed by the military for use in reliable, secure, mission-critical communications systems.
- Principles:
  - produces a signal that is louder and thus easier to detect, the receiver knows the parameters of the spread spectrum signal being broadcast.
  - If the receiver is not tuned to the correct frequency, a spread spectrum signal is received as background noise.
- Pro & Cons:
  - reliability, integrity, and security.
  - more bandwidth is consumed than in narrowband transmission.

Spread Spectrum Technology Family

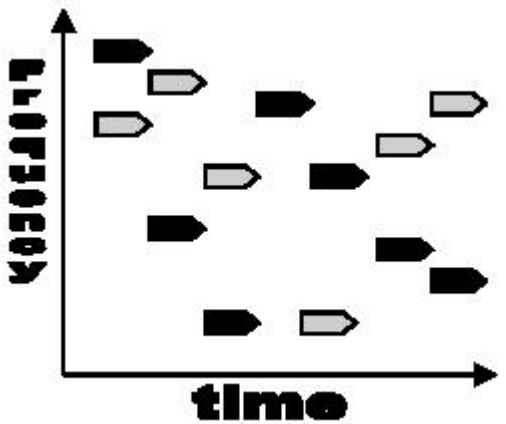
- FHSS - Frequency Hopping Spread Spectrum
- DSSS - Direct Sequence Spread Spectrum

Frequency Hopping Spread Spectrum (FHSS) Technology (1/2)

- 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

and Frequency Shift Keying methods

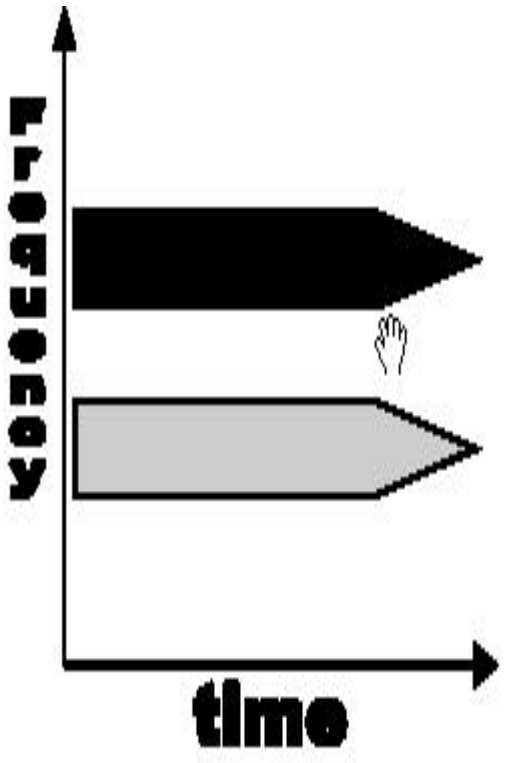


Frequency Hopping Spread Spectrum (FHSS) Technology (2/2)

- Hopping pattern is known to both transmitter & receiver.
- In order to properly receive the signal, the receiver must be set to the same hopping code and listen to the incoming signal at the right time and correct frequency.
- The net effect is to maintain a single logical channel if synchronizing sender and receiver properly.
- Frequency hopping offers a current maximum data rate of 3 Mbit/s.
- Unintended receiver see FHSS to be short time impulse noise.

Direct Sequence Spread Spectrum (DSSS) Technology (1/2)

- Most widely recognized technology for spread spectrum.
- This method generates a redundant bit pattern for each bit to be transmitted. This bit pattern is called a chip.
- The longer the chip, the greater the probability that the original data can be recovered, and the more bandwidth required.



Direct Sequence Spread Spectrum (DSSS) Technology (2/2)

- Even if one or more bits in the chip are damaged during transmission, it can be recovered the original data by using statistical techniques without the necessary for retransmission.
- To an unintended receiver, DSSS signals are received as low-power wideband noise.
- In the IEEE 802.11b standard, the normal data rates using DSSS are 1, 2, 5.5, and 11 Mbit/s.

Wireless LAN Standards

There are 3 different standardizing organizations:

1. IEEE (Institute of Electrical and Electronics Engineers Inc.)
   - IEEE 802.11 for Wireless LAN
   - Standards for both 2.4 GHz and 5 GHz band
   - Most widely used Wireless LAN standard
2. ETSI (European Telecommunication Standards Institute)
   - ETSI HiperLAN 1 and 2
   - Standards only for 5 GHz band
3. MMAC (Mobil Multimedia Access Communications)

Wireless Standard - 802.11

- It was the first published WLAN standard.
- It defines a network operating at the 2.4 GHz unlicensed frequency.
- The maximum throughput is between 1Mbps and 2 Mbps.
- It defines these two techniques as frequency hopping or direct sequence spread modulation.
- 802.11 is slowly becoming obsolete as the standard 802.11b become more popular.

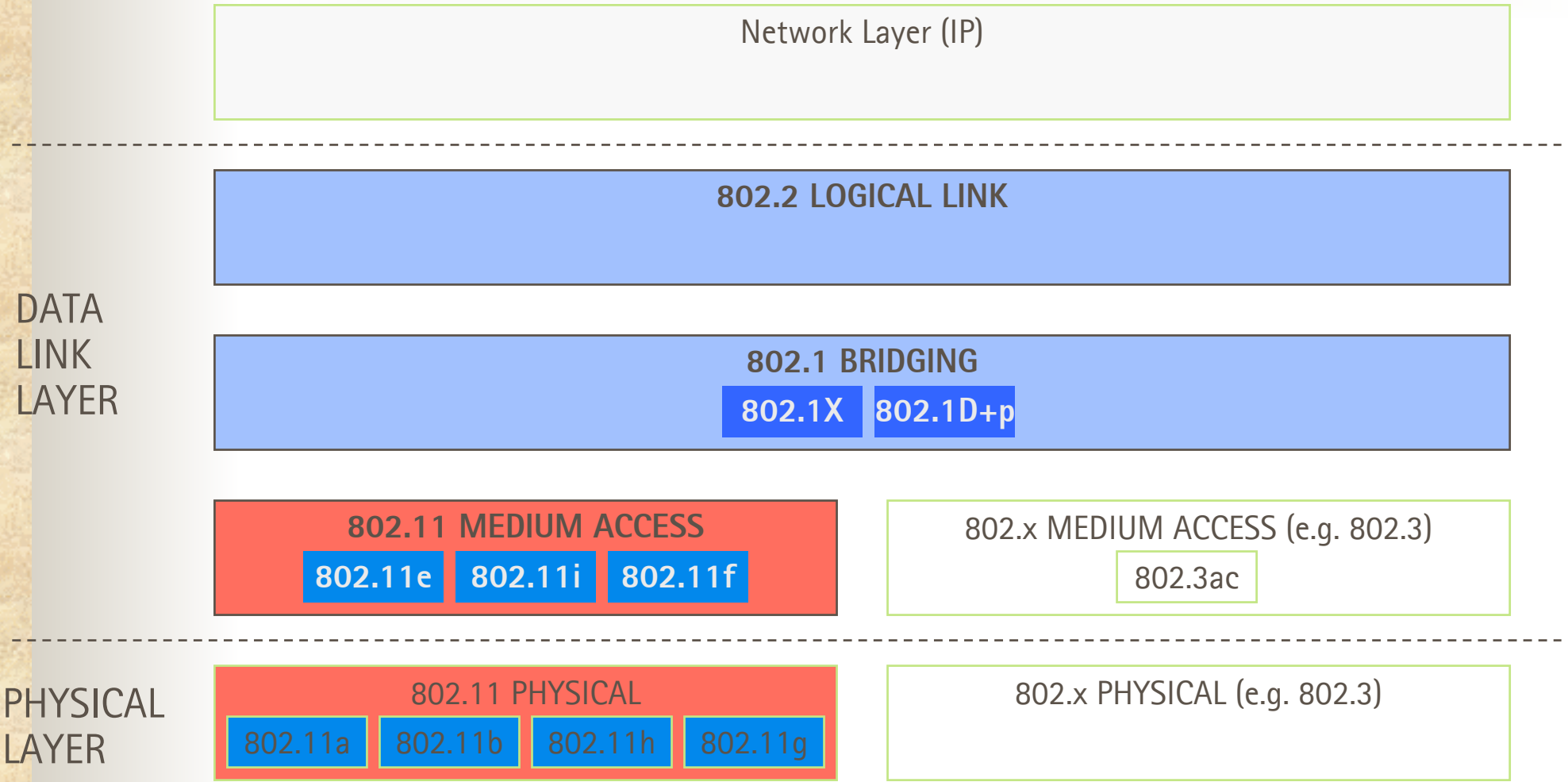
Wireless Standard
- 802.11b (aka Wi-Fi)

- IEEE 802.11b is the most widespread WLAN-standard. Another name is of 802.11b is Wi-Fi.
- It was published in late 1999 as a supplement to 802.11.
- It operates in the 2.4 GHz band, but data rates can be at 11Mbps high.
- It does not support frequency hopping, but it specifies the direct sequence spread modulation.

Wireless Standard
- 802.11a

- It was amended as a supplement to 802.11 in 2000 .
- It operates in the 5GHz band instead of the 2.4GHz. There is less interference in 5GHz band.
- It uses ODFM method (Orthogonal Frequency Division Multiplexing) for data transmission up to 54Mbps.
- 802.11a had trouble getting approved for use in Europe because of overlapping frequencies with some military channels. However it become more popular and more products are coming out because of the advanced technologies.
- 802.11a is not compatible with 802.11b.
- It is the reduced working distance by using the 5GHz frequency. The 54Mbps connection usually needs a line of sight between the Access Point and the Network Interface Card (NIC).

Positioning IEEE802.11 protocols in Physical and Data Link layer



IEEE 802.11a PHY

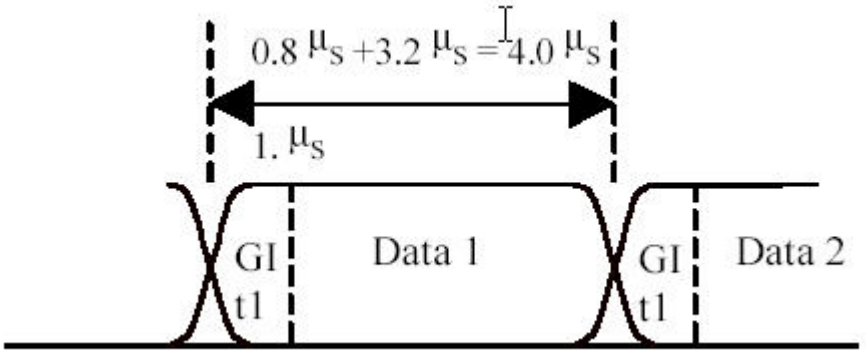
-Main Parameter

Data Rate:	6, 9, 12, 18, 24, 36, 48, 54 Mbit/s
Modulation	BPSK, QPSK, 16-QAM, 64-QAM
Code Rate	½, 9/16, 2/3, ¾
Number of Subscarriers	52
Number of Pilot Tones	4
OFDM symbol duration	4 μ sec
Guard Interval	800η sec, 400η sec (optional)
Subscriber Spacing	312.5kHz
Signal Bandwidth	16.66MHz
Channel Spacing	20 MHz

IEEE 802.11a PHY

-OFDM Frame Structure

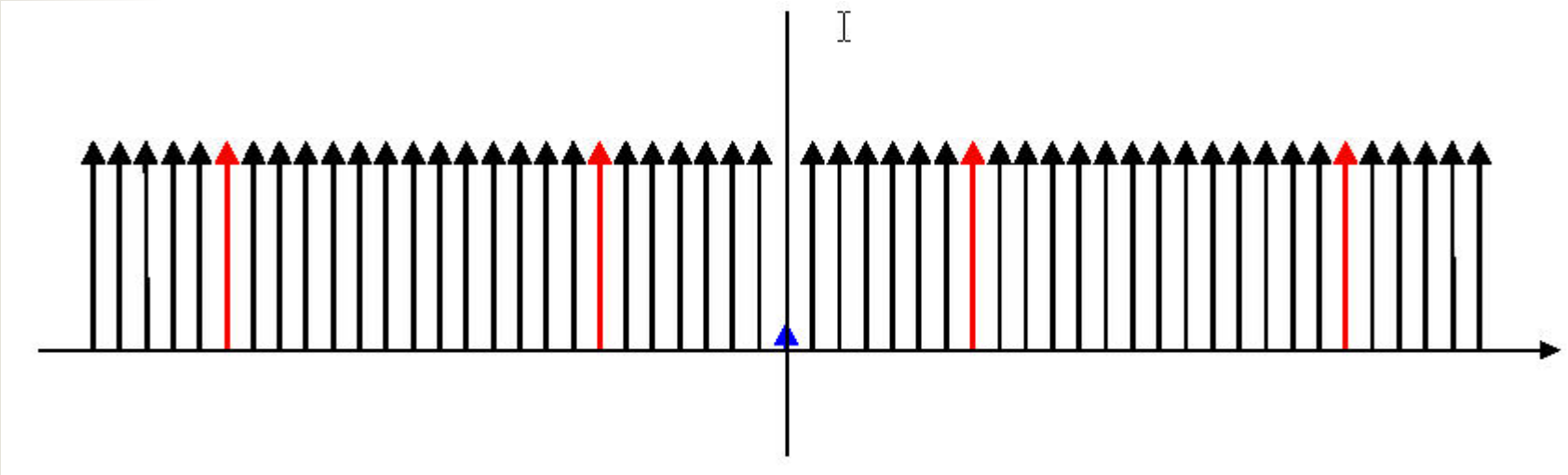
- Carrier spacing is 312.5 KHz
- Fourier transform performed over 3.2 microseconds
- 0.8 microsecond Guard Interval for ISI rejection



IEEE 802.11a PHY

- Data and Pilot subcarriers

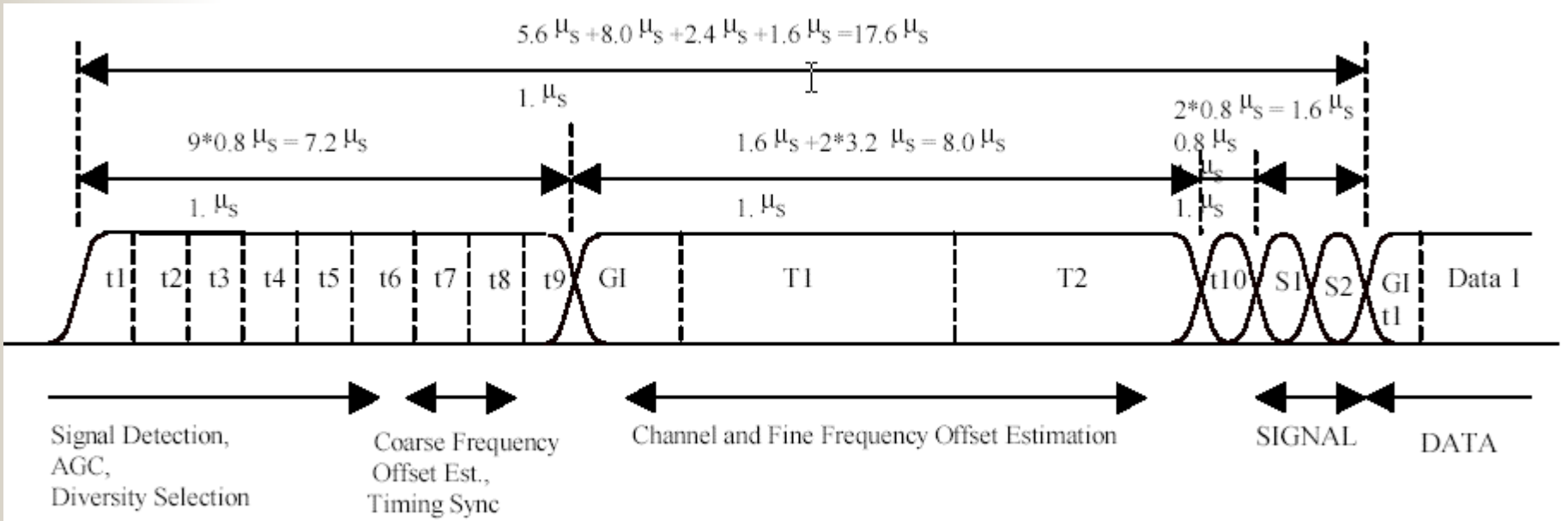
- 52 non zero subcarriers
  - 48 data subcarriers
  - 4 carrier pilot subcarriers
- Center frequency subcarrier not used



IEEE 802.11a PHY

- Preamble Structure

- Nine repetitions of short sequence in the beginning
  - Signal Detection, AGC convergence, Diversity resolution, Timing estimation, Coarse frequency estimation
- Two repetitions of long sequence with Guard Interval
  - Fine frequency estimation, Channel Estimation



Medium Access Control Sub-Layer

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

MAC for WLAN standards

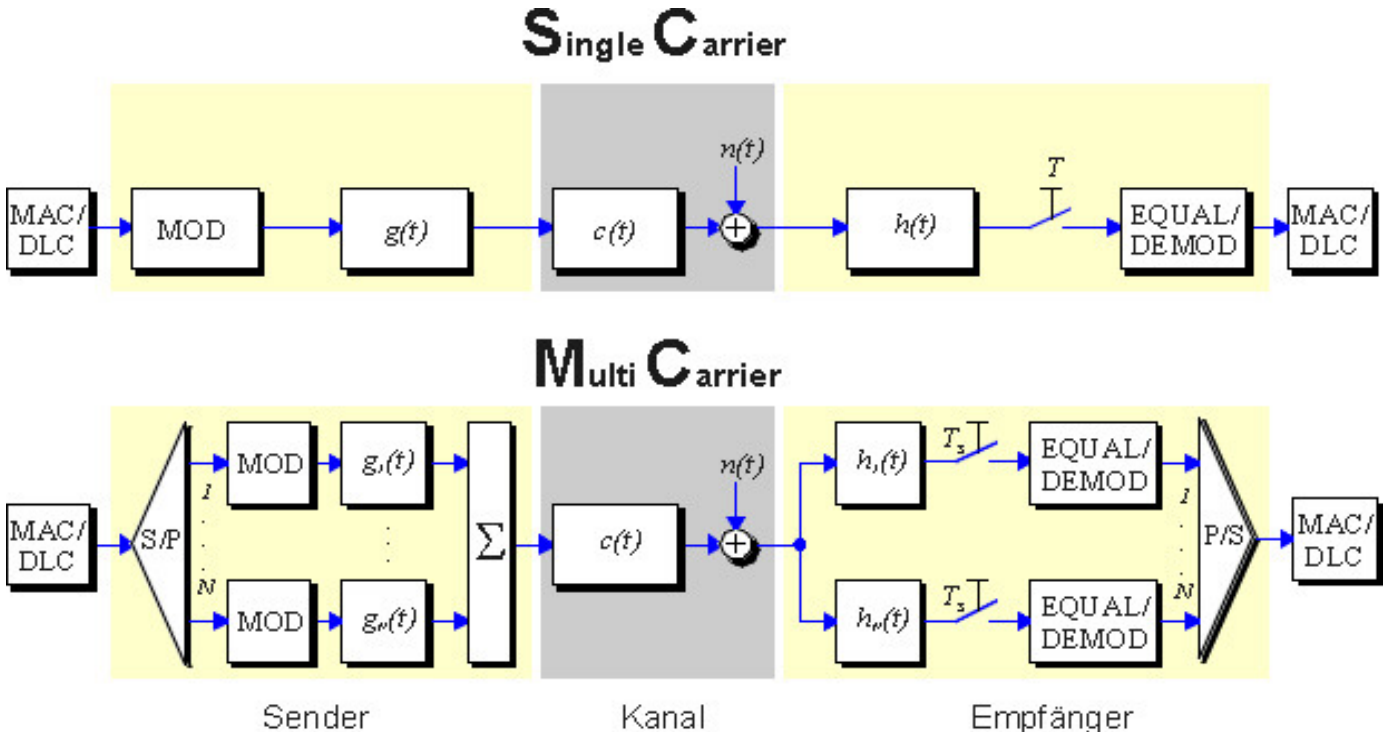
- IEEE 802.11a uses a distributed MAC based on CSMA/CA (Carrier Sense MultiAccess with Collision Avoidance)
- HiperLAN/2 (from ETSI) uses a central and scheduled MAC based wireless asynchronous transfer mode (ATM)
- MMAC supports both of them.

IEEE 802.11 Media Access Control (MAC) Sub-Layer

- 802.11 specification of MAC(Media Access Control) has similarities to 802.3 Ethernet wired line standard
- CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) protocol is used for 802.11
  - Uses carrier-sense, multiple access, collision avoidance methods.
  - Avoids collisions instead of detecting a collision like the algorithm in 802.3
  - Collision avoidance is used because it is difficult to detect collisions in radio transmission network

OFDM –Single Carrier vs. Multi Carrier

- In standard singlecarrier communication systems for high data rates, the effects of multipath propagation increases the equalization costs due to short symbol durations and relative long channel delay times.
- As an example, if we want to use a singlecarrier technique for bit rates of 20 mbps or more, the symbol duration is about 50 ns. Measured indoor channels cause echo delay times of more than 500 ns. In case of QPSK, the viterbi equalizer needs more than 1.000.000 internal states.

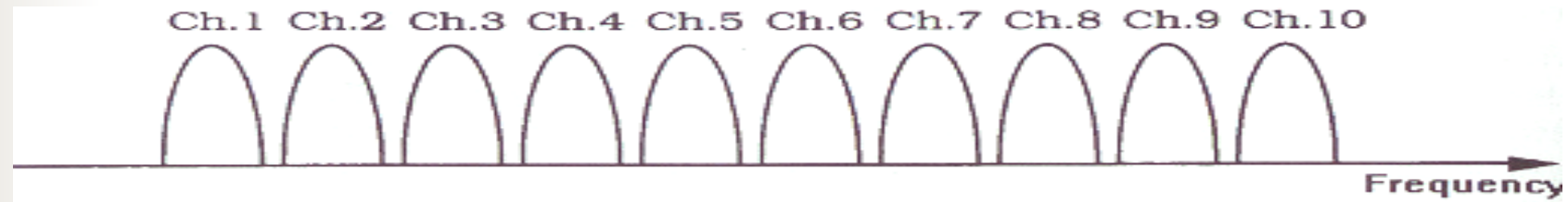


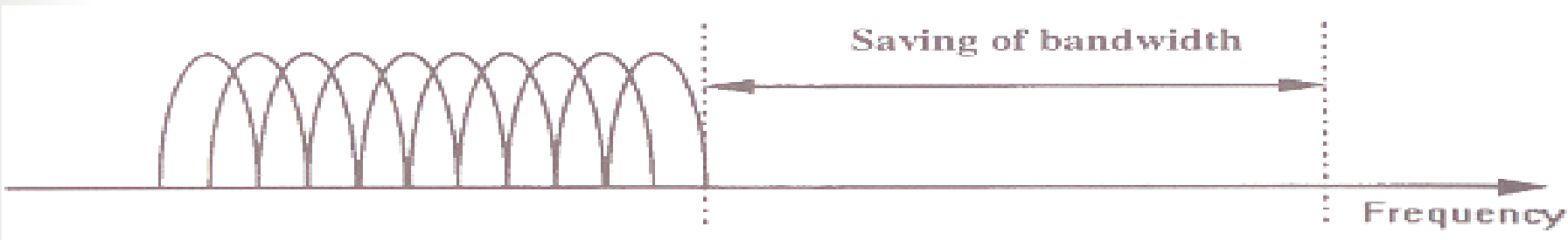
What is OFDM

- Orthogonal Frequency Division Multiplexing
- Takes a large data stream and breaks it into smaller ones and transmits them in parallel over sub channels
- Has ability to do error checking
- Drastically cuts down on retransmission of packets

From FDM to OFDM

- FDM splits into *N* sub channels and leaves guard bands
- OFDM transmits in parallel with orthogonal overlapping channels (almost a 50% savings)



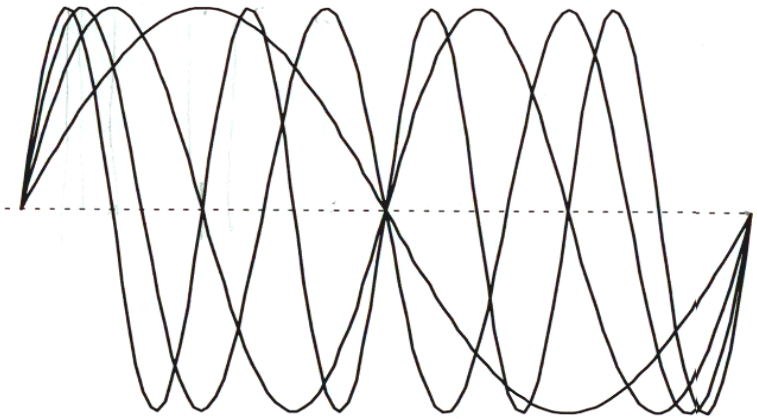


What Does It Mean To Be Orthogonal? 1/2

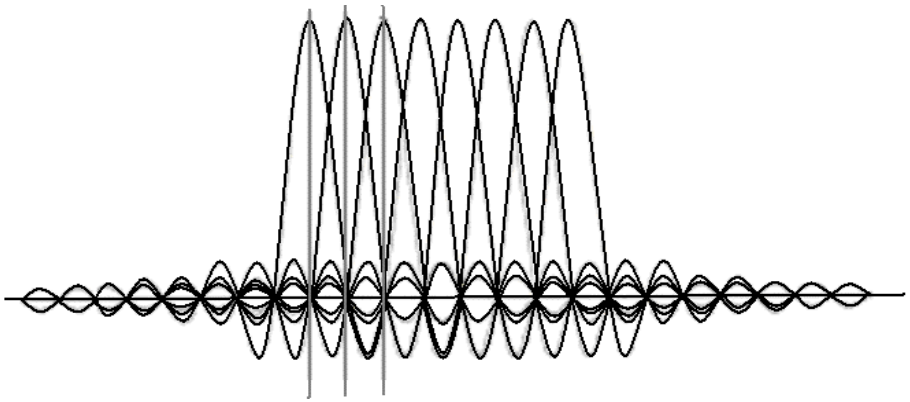
- These sub-carriers are orthogonal which means every sub-carrier can be separated out at the receiver without interference from other sub-carriers.
  - This is made possible due to the mathematical property of orthogonal waveforms, which ensures that the integral of the product of any two sub-carriers is zero.
- By dividing up the frequency band into a large number of narrow-band carriers, wireless channel impairments are significantly reduced.
  - The most important of such impairments is the fading phenomenon which results from the multiple reception of a single transmit signal at the receiver antenna. This results in the degradation of specific frequencies across the channel.

What Does It Mean To Be Orthogonal? 2/2

- Fading impacts a very limited number of the sub-carriers.
- Most of the narrow-band sub-carriers, along with the information modulated into the waveform, are communicated over the channel in a reliable manner.
- OFDM provides for superior link quality and robustness of communication over the wireless channel.



Four subcarriers in one OFDM symbol



OFDM in Wireless LAN

- IEEE 802.11a/HiperLAN2 and MMAC Wireless LAN OFDM in the new 5GHz band is comprised of 802.11a, HiperLAN2, and WLAN standards.

- IEEE selected OFDM as the basis for the new 802.11a 5GHz standard targeting a range of data rates up to 54 Mbps in July 1998.
- ETSI BRAN is now working on three extensions for OFDM in the HiperLAN standard:
  - (i) HiperLAN2, a wireless indoor LAN with a QoS provision;
  - (ii) HiperLink, a wireless indoor backbone;
  - (iii) HiperAccess, an outdoor, fixed wireless network providing access to a wired infrastructure.
- In Japan, consumer electronics companies and service providers are cooperating in the MMAC project to define new wireless standards similar to those of IEEE and ETSI BRAN.

- All three standards bodies are working in close cooperation to make sure that differences among the various OFDM standards are kept to a minimum, enabling the manufacturing of devices and equipment that can be used worldwide.

Single Carrier vs. OFDM Comparison

- Single carrier systems are fairly robust to frequency offset errors and are more appropriate for mobile environment. that experience large frequency offset errors. And the performance of single carrier system is degraded as a result of NSR loss caused by timing errors.
- OFDM systems are fairly robust to timing errors compared to single carrier system. And their performance is similar affected by the loss in SNR caused by frequency offset errors. Intuitively, this is easily understood from the fact that the OFDM symbol duration is N times longer than its single carrier counterpart operating at the same data rate.

- In terms of fading, the performances of the two system are similar.
- The complexity of the equalizer for single carrier system is much greater than OFDM system.

Abbreviation

- AGC: Automatic Gain Control
- BPSK: Binary Phase Shift Keying
- FHSS: Frequency Hopping Spread Spectrum
- MAC: Medium Access Control
- SNR: Signal-to-Noise Ratio
- OFDM: Orthogonal Frequency Division Multiplexing
- QAM: Quadrature Amplitude Modulation
- QPSK: Quadrature Phase Shift Keying

References

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[19]: csci.mrs.umn.edu/UMMCSciWiki/pub/ Main/RodneyKohout/802.11.ppt

Question

- General description for OFDM.