無線通訊協定

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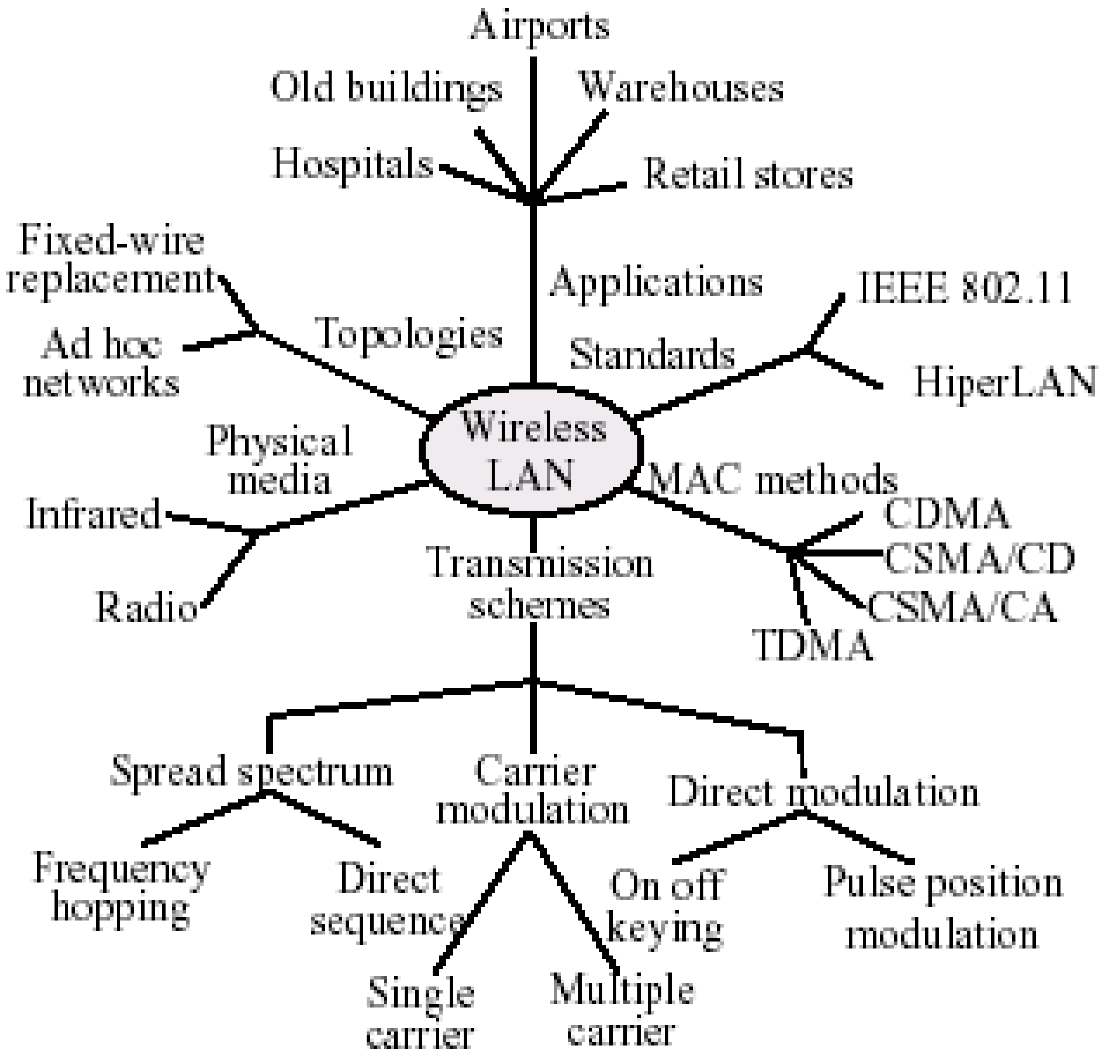
Outline

1. 802.11 Architecture and Overview
2. Baseband Infrared (IR) Physical Layer Specification
3. Direct Sequence Spread Spectrum (DSSS) Physical Layer Specification
4. Orthogonal Frequency Division Multiplexing (OFDM) Physical Layer Specification
5. IEEE 802.11g Extended Rate PHY (ERP) Specification
6. Frequency Hopping Spread Spectrum PHY of the 802.11 Wireless LAN Standard
7. IEEE 802.11 Wireless LAN MAC Standard

1. 802.11 Architecture and Overview

Technology Tree for Wireless LAN

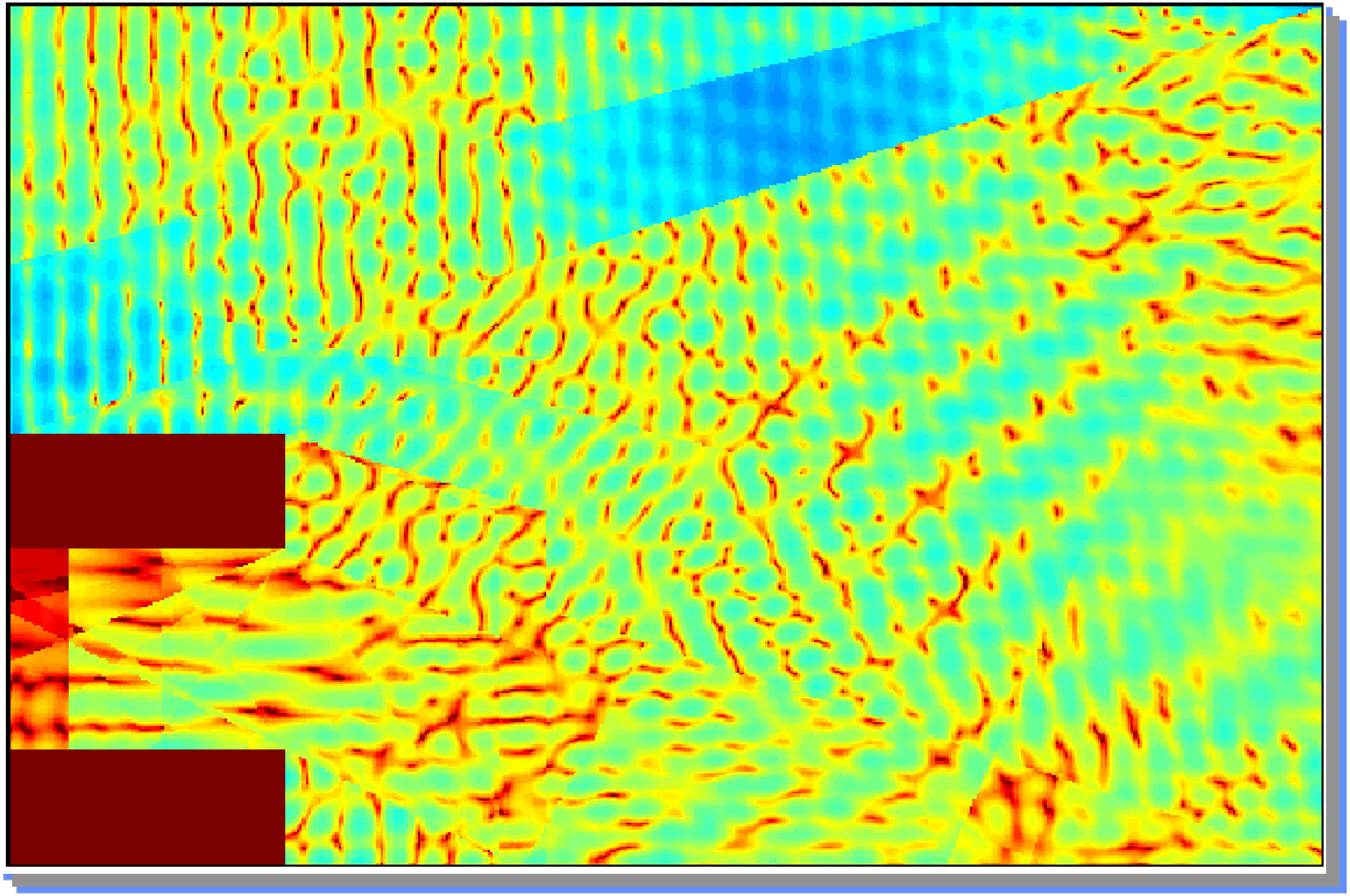


HomeRF
Bluetooth
Zigbee

What is unique about wireless?

- Difficult media
  - interference and noise
  - quality varies over space and time
  - shared with unwanted 802.11 devices
  - shared with non-802 devices (unlicensed spectrum: microwave ovens, bluetooth, Zigbee, etc.,)
- Full connectivity cannot be assumed
  - Hidden node problem
- Multiple international regulatory requirements

Medium Variations



Uniqueness of Wireless (continued)

- Mobility
  - variation in link reliability
  - battery usage: requires power management
  - want seamless connections

power control ???

- Security
  - no physical boundaries
  - overlapping LANs

Requirements

- Single MAC to support multiple PHYs.
  - Support single and multiple channel PHYs.
  - Different PHYs have different medium sense characteristics.
- Should allow overlap of multiple networks in the same area and channel space.
- Need to be Robust for Interference?
  - ISM band (Industry, Science and Medicine)
    - 13.56 MHz, 27.55 MHz, 303 MHz, 315 MHz, 404 MHz, 433 MHz, 868 MHz (Europe), 915 MHz (North America), 2.45 GHz, 5.2 GHz (North America), 5.3 GHz, and 5.7 GHz (North America)
    - Microwave, other non-802.11 interferers.
    - Co-channel interference.
- Need mechanisms to deal with Hidden Nodes?
- Need provisions for Time Bounded Services (real-time service).

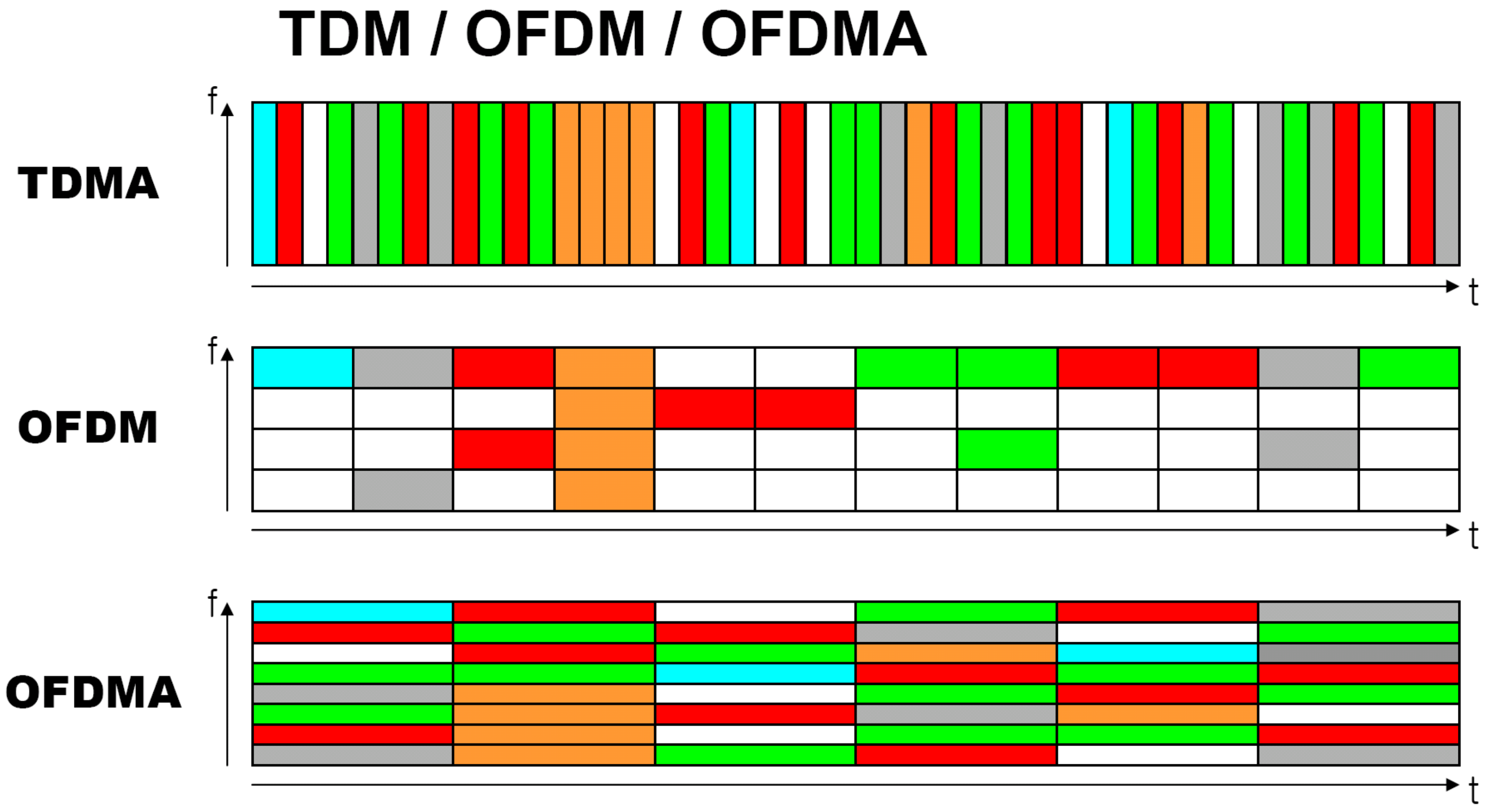
Architecture Overview

- **One MAC supporting multiple PHYs**
  - **Frequency Hopping Spread Spectrum**
  - **Direct Sequence Spread Spectrum**
  - **Infrared**
  - **Orthogonal Frequency Division Multiplexing**
  - **Orthogonal Frequency Division Multiple Access (OFDMA)**

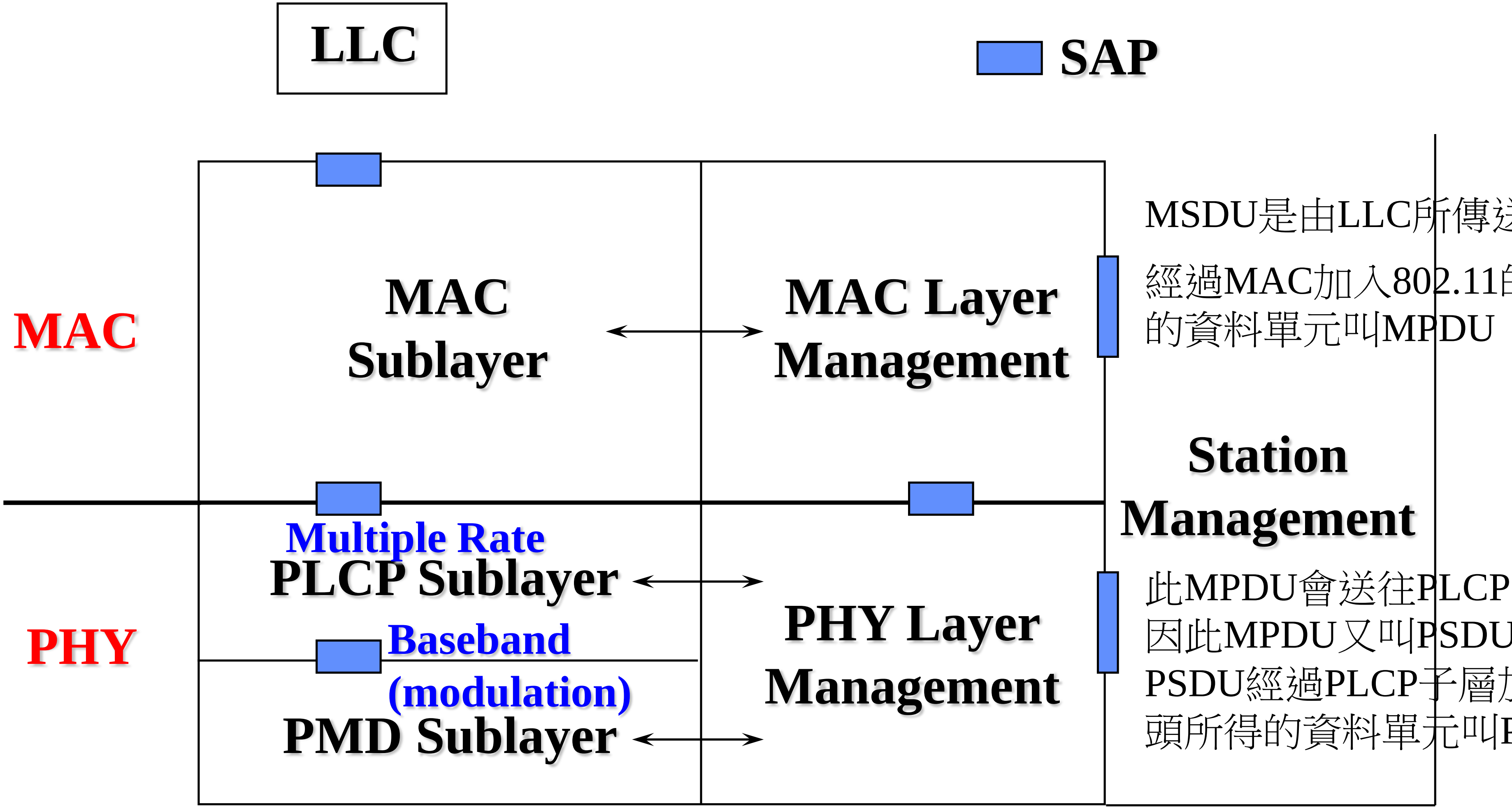
- **Two configurations**
  - **Independent (ad hoc) and Infrastructure**
  - Hybrid configuration has being studied (802.11s)

- **CSMA/CA (collision avoidance) with optional Point Coordination Function (PCF)**

TDMA/OFDM/OFDMA



802.11 Protocol Entities



LLC

SAP

MAC

PHY

MAC Sublayer

MAC Layer Management

Multiple Rate

PLCP Sublayer

Baseband

(modulation)

PMD Sublayer

PHY Layer Management

Station Management

MSDU是由LLC所傳送

經過MAC加入802.11的

的資料單元叫MPDU

此MPDU會送往PLCP

因此MPDU又叫PSDU

PSDU經過PLCP子層加

頭所得的資料單元叫P

802.11 Protocol Architecture

- MAC Entity
  - basic access mechanism
  - fragmentation/defragmentation
  - encryption/decryption
- MAC Layer Management Entity
  - synchronization
  - power management
  - roaming
  - MAC Management Information Base (MIB)
- Physical Layer Convergence Protocol (PLCP)
  - PHY-specific, supports common PHY SAP
  - provides Clear Channel Assessment signal (carrier sense)

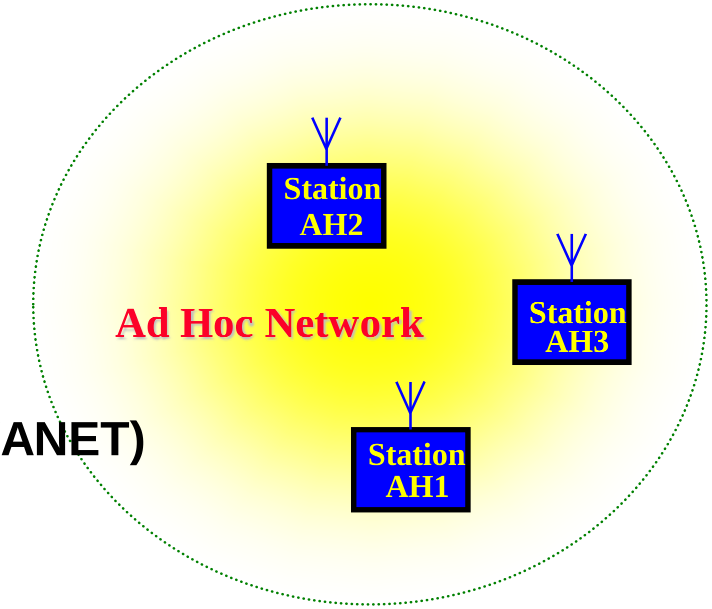
802.11 Protocol Architecture (cont.)

- Physical Medium Dependent Sublayer (PMD)
  - modulation and encoding (baseband)
- PHY Layer Management
  - channel tuning (channel switching delay : 224us in 802.11b)
  - PHY MIB
- Station Management
  - interacts with both MAC Management and PHY Management

802.11 Configurations - Independent

- Independent
  - one Basic Service Set (BSS)
  - Ad Hoc network
  - direct communication
  - limited coverage area

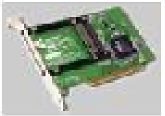
- Research topics
  - Multi-Hop Routing (IETF MANET; VANET)
  - Multicasting
  - Multi-channel Access
  - Security
  - QoS ...

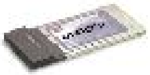


Mobile Station : STA

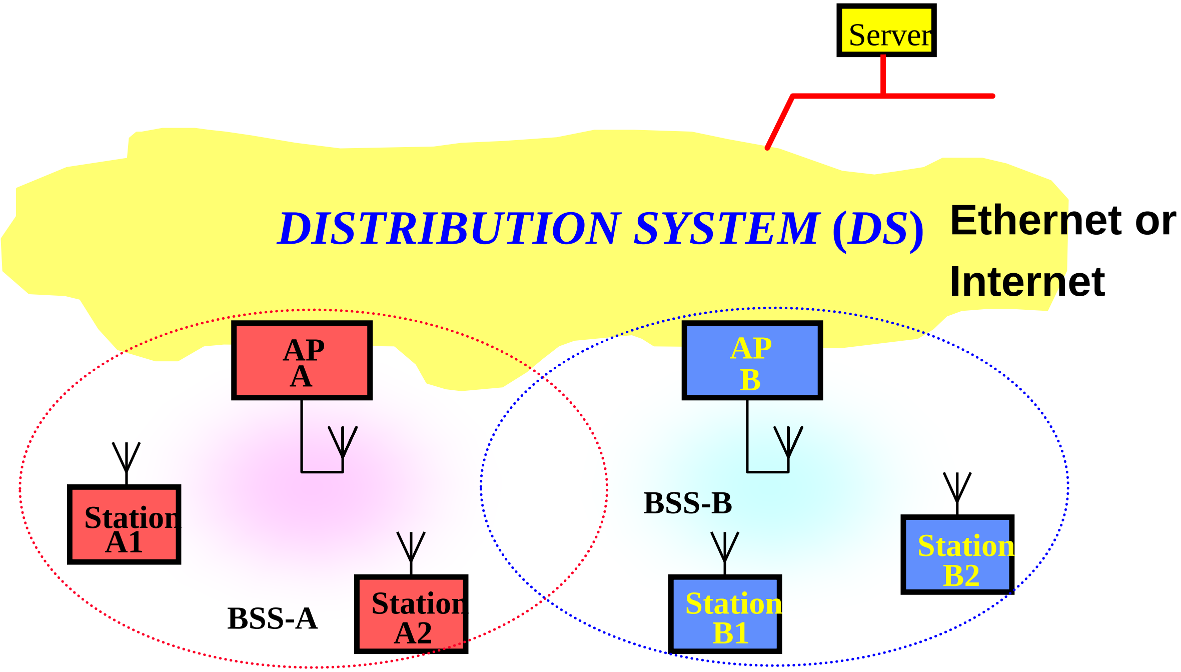
Commercial Products : WLAN Cards

- **One piece**
- **Two pieces**





802.11 Configurations - Infrastructure

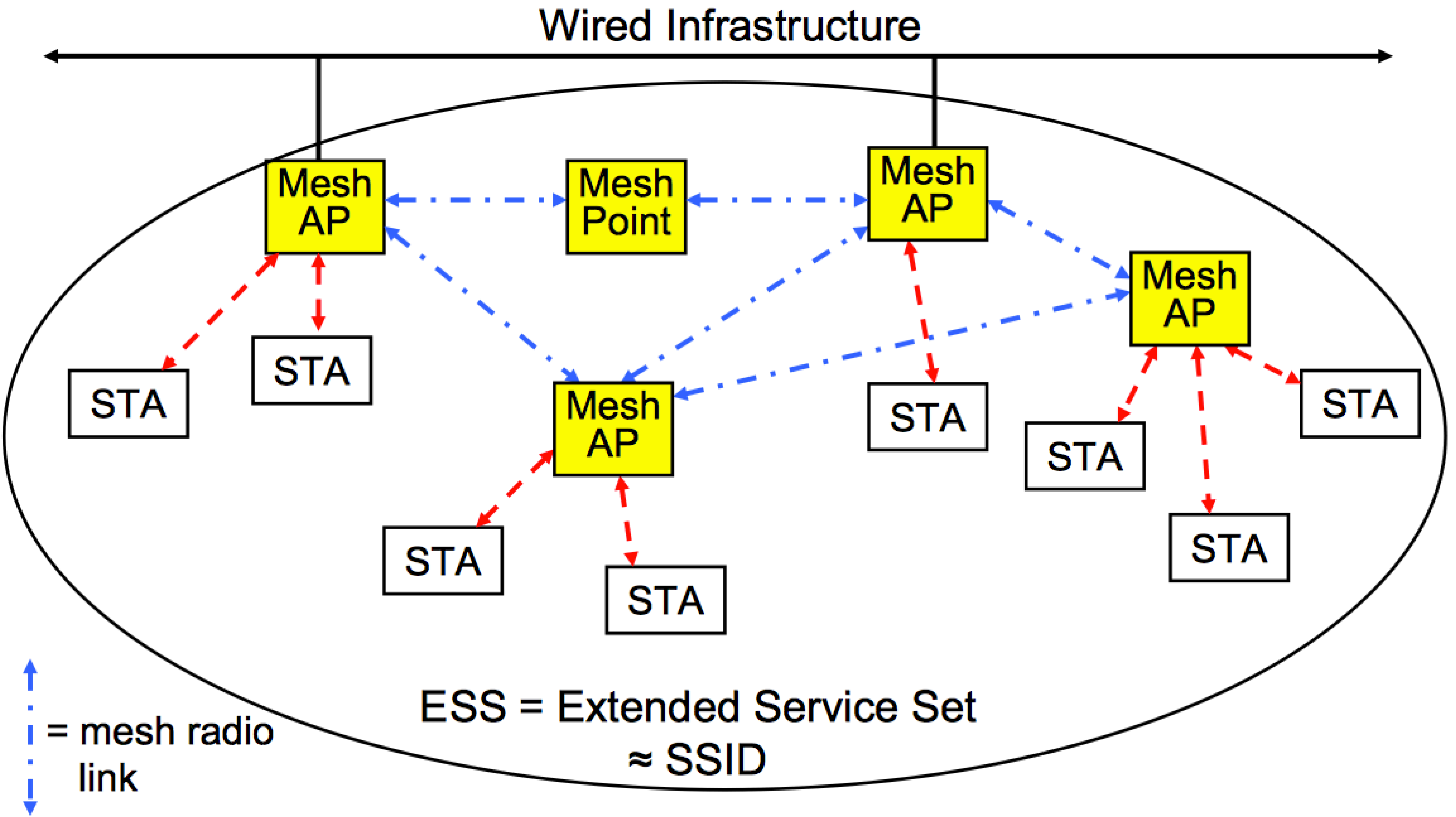


- Infrastructure
  - Access Points (AP) and stations (STA)
- Distribution System interconnects Multiple Cells via Access Points to form a single Network.
  - extends wireless coverage area
- Wireless bridge application

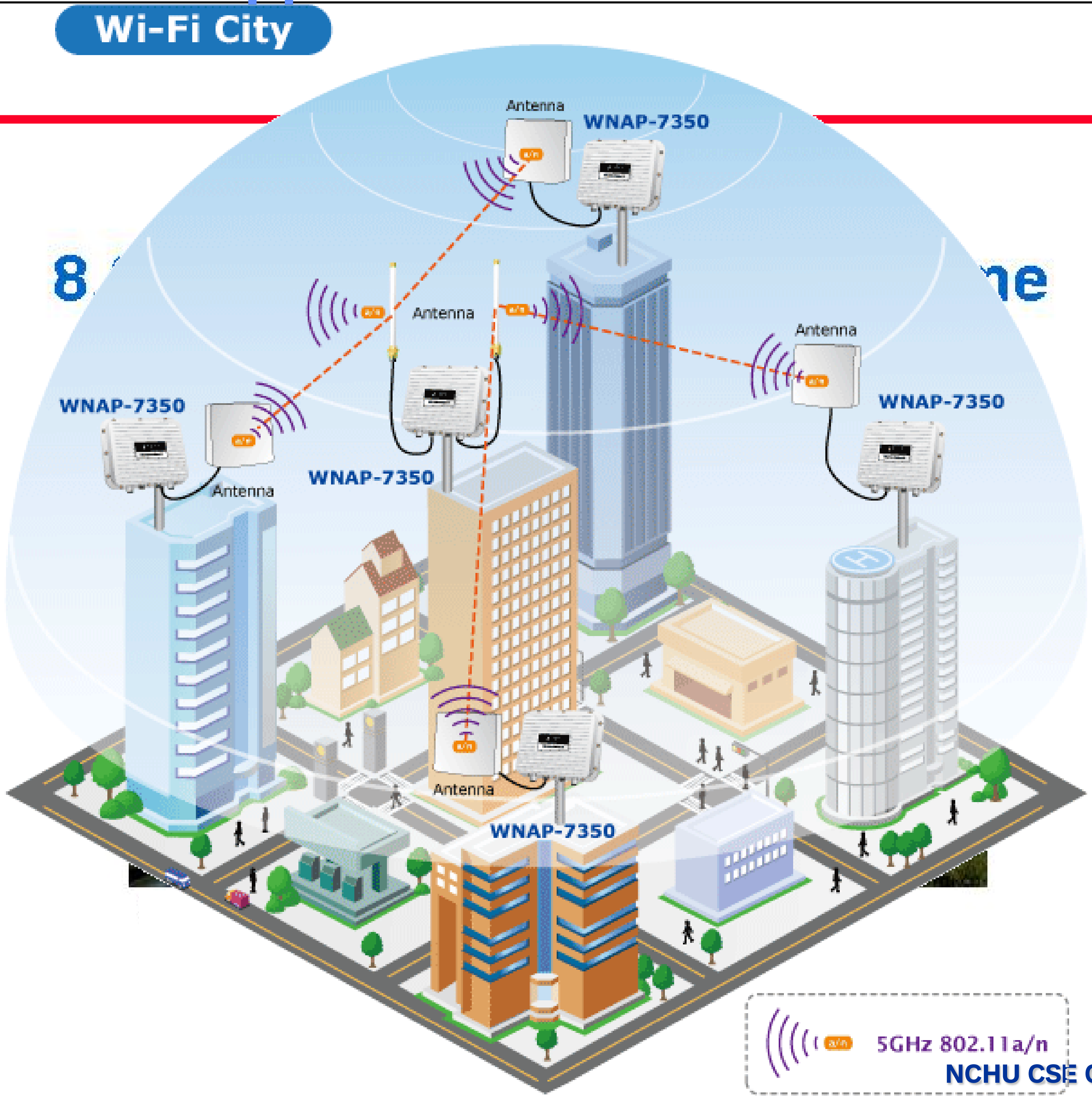
Commercial Products : AP

Access Points

Wireless Bridging



Outdoor Application



Outdoor Application - Antenna

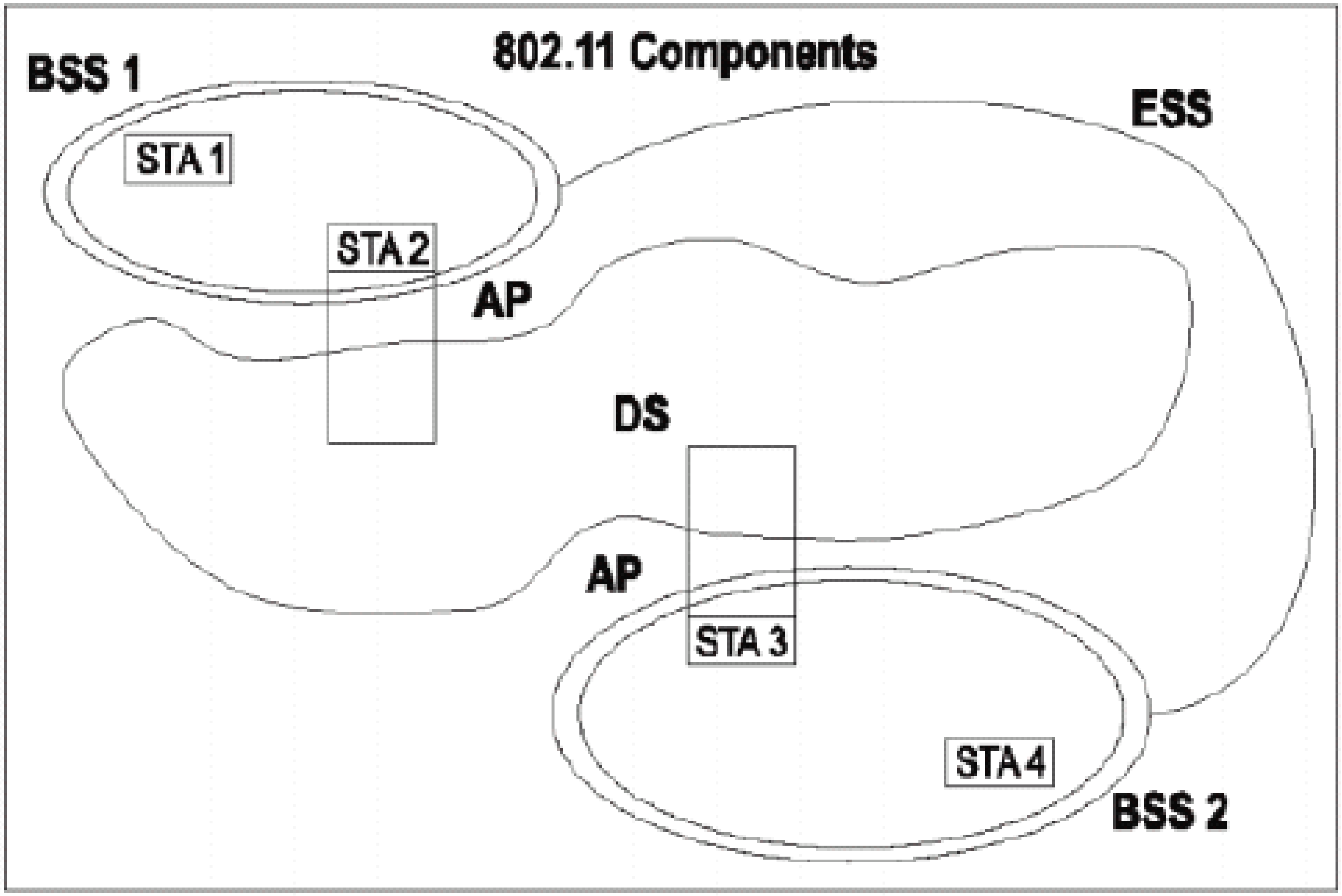
Antennas

Directional Antenna

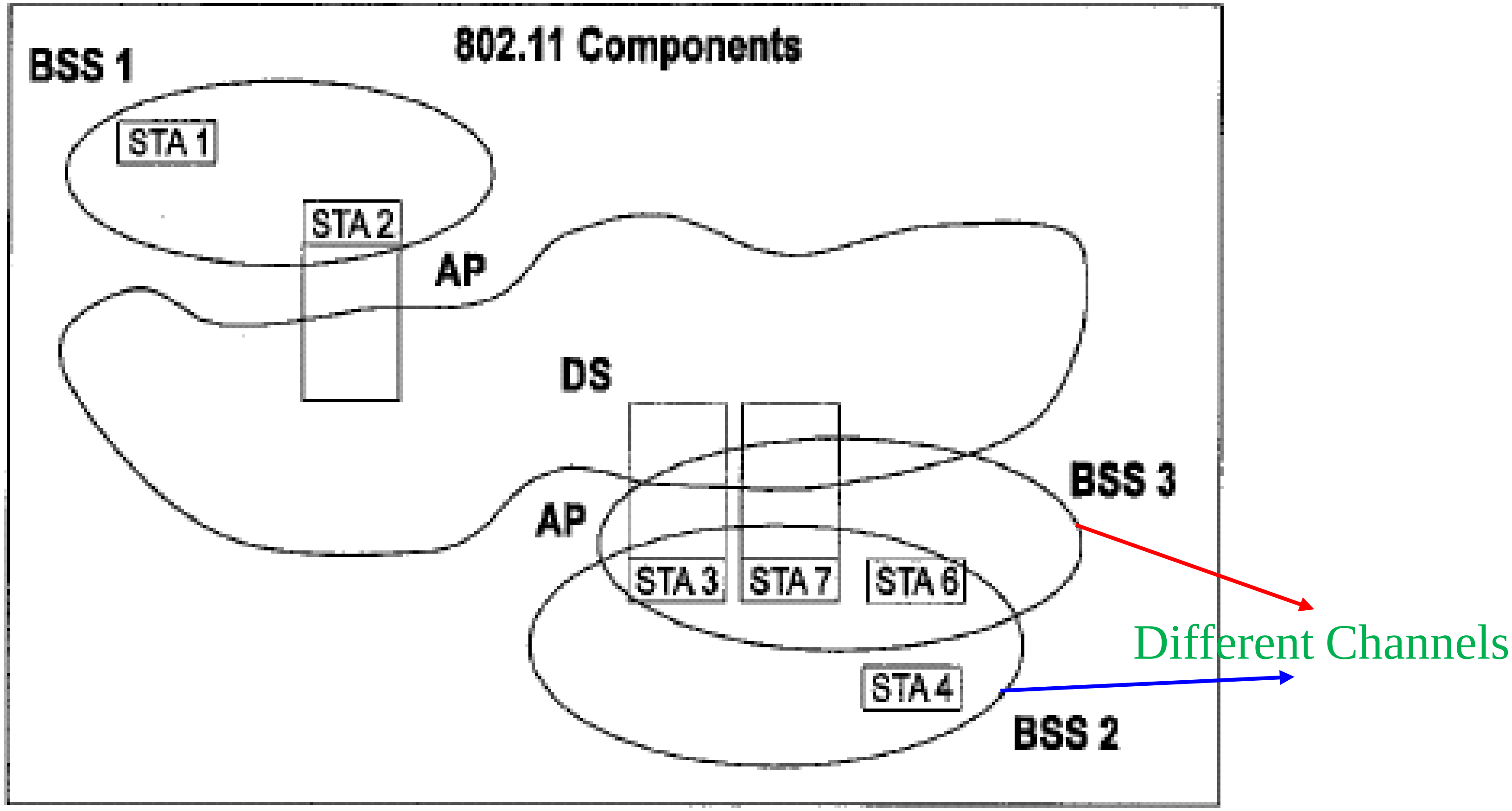
Distribution System

- Used to interconnect wireless cells
  - multiple BSS connected together form an ESS (Extended Service Set)
  - Allows mobile stations to access fixed resources
- Not part of 802.11 standard
  - could be bridged IEEE LANs, wireless, other networks
  - Only Distribution System Services are defined

BSS vs ESS

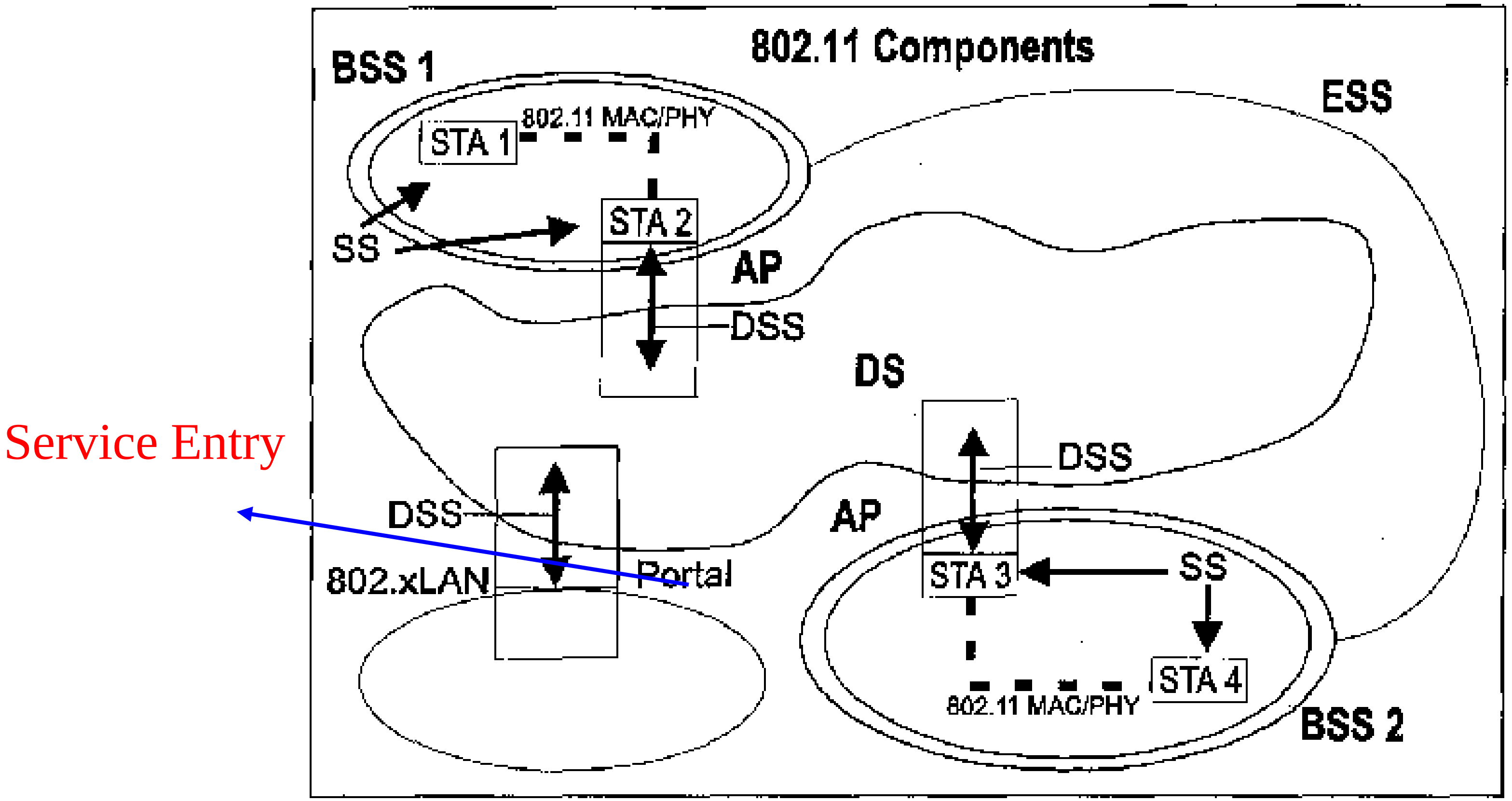


Collocated Coverage Areas



DS : Distribution System

Complete Architecture



DSS : Distribution System Service

Access Points

- Stations select an AP and Associate with it
- Support roaming
  - IAPP (Inter Access Point Protocol) IEEE 802.11f (Layer 2)
  - Mobile IP (Layer 3; IETF)
- Provide other functions
  - time synchronization (beaconing)
  - power management support (if any)
  - point coordination function (PCF) (if any)
- Traffic typically (but not always) flows through AP
  - direct communication possible (Ad-Hoc)

Access Points

- In an Infrastructure BSS, all mobile stations communicate with the AP
  - quoted from "IEEE 802.11 Handbook", Bob O'Hara and Al Petrick
  - Disadvantage :
    - » bandwidth is consumed twice than directional communication between STAs
    - » more contentions and more collisions
  - Advantage :
    - » easily solve hidden terminal problem
    - » provide power saving function
    - » meet the AAA (authentication, authorized, accounting) architecture
    - » provide per flow bandwidth control, QoS guarantee (IEEE 802.11e)

802.11 Defines the Airwaves IF

- The airwaves interface between stations (including that between station and AP) is standardized
  - PHY and MAC
- No exposed MAC/PHY interface specified
- No exposed interface to Distribution System
  - only required DS services are defined
- Internals of Distribution System not defined

MAC Services

- Asynchronous MSDU Data Delivery
  - provided to LLC (2304 octets maximum)
- Time Bounded Services
  - optional point coordination function (PCF)
  - Existing in commercial products ?
    - » Bandwidth is not enough for supporting real-time service
    - » Not necessary, CSMA/CA works well (likes Ethernet history)
    - » IEEE 802.11e enhances QoS
- Security Services
  - confidentiality, authentication, access control
- Management Services
  - scanning, joining, roaming, power management

MAC Functionality

- Independent and Infrastructure configuration support
  - Each BSS has a unique 48 bit address
  - Each ESS has a variable length address
- CSMA with collision avoidance (CSMA/CA)
  - MAC level acknowledgment (positive acknowledgement)
  - allows for RTS/CTS exchanges
    - » hidden node protection 41%
    - » virtual carrier sense
    - » bandwidth saving
  - MSDU fragmentation
  - Point Coordination Function option
    - » AP polling

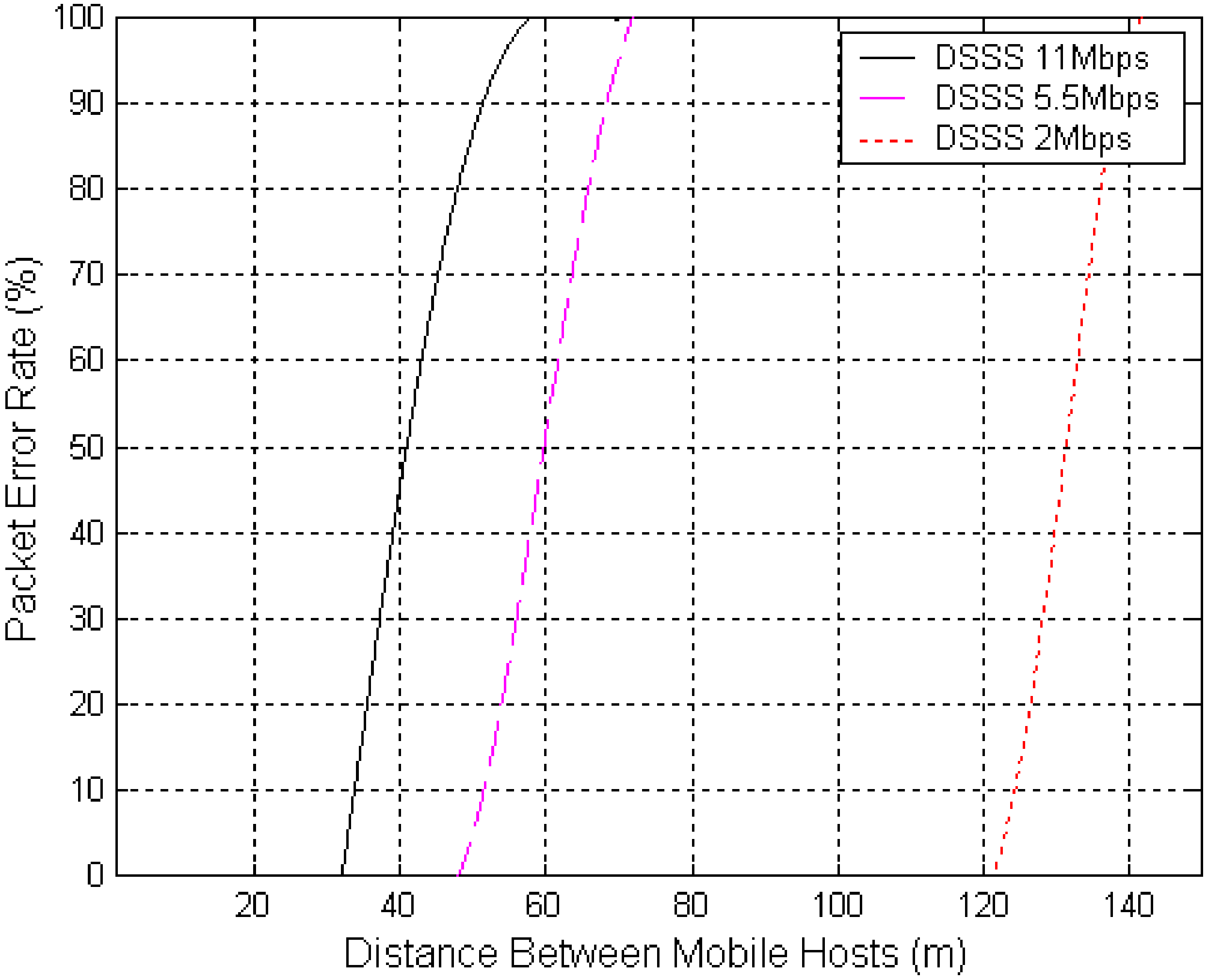
MAC Functionality (continued)

- Roaming support within an ESS
  - station scans for APs, association handshakes
- Power management support
  - stations may power themselves down
  - AP buffering, distributed approach for IBSS
- Authentication and privacy
  - Optional support of Wired Equivalent Privacy (WEP)
  - Key exchange
  - Authentication handshakes defined
  - IEEE 802.1x spec. enhances authentication control (EAP)
  - IEEE 802.11i enhances security (IEEE 802.11i over IEEE 802.1x)

PHY Layer Services

- PHY_DATA transfers
  - multiple rates (1, 2, 5.5, 11Mbps)
  - extended rates (22, 33 or 6, 9, 12, 19, 24, 36, 48, 54Mbps)
  - The algorithm for performing rate switching is beyond the scope of the standard. (p6, 802.11b)
    - » Question : how to decide the proper data rate ?
- Clear Channel Assessment (CCA)
  - carrier sense
  - detect start frame delimiter
- PHY Management
  - channel tuning

Data Rate vs. Range



Four PHYs

- Frequency Hopping Spread Spectrum (FHSS)
  - 2.4 GHz band, 1 and 2 Mbps transmission
    - » 2GFSK, 4GFSK
    - » 2.5 hops/sec over 79 1MHz channels (North America)
- Direct Sequence Spread Spectrum (DSSS)
  - 2.4 GHz band, 1 and 2 Mbps transmission
    - » 11 chip Barker sequence
    - » DBPSK, DQPSK (Differential Binary/Quadrature Phase Shift Keying)
  - 2.4 GHz band, 5.5 and 11 Mbps transmission
    - » CCK (Complementary Code Keying), PBCC (Packet Binary Convolutional Code)
    - » CCK : DQPSK(5.5Mbps, 11Mbps)
    - » PBCC : BPSK(5.5Mbps), QPSK(11Mbps) (optional)
    - » Sep. 1999 (802.11b)
  - 2.4 GHz band, 22 and 33 Mbps transmission
    - » PBCC-22, PBCC-33

Four PHYs

- Baseband IR (Infrared)
  - Diffuse infrared
  - 1 and 2 Mbps transmission, 16-PPM and 4-PPM
    - PPM : Pulse Position Modulation
- Orthogonal Frequency Division Multiplexing (OFDM)
  - 2.4 GHz band (IEEE 802.11g DSSS-OFDM, OFDM)
  - 5 GHz band (IEEE 802.11a)
    - Similar ETSI HIPERLAN/II PHY Spec.
  - 6, 9, 12, 18, 24, 36, 48 and 54 Mbps
    - BPSK(6,9Mbps), QPSK(12,18Mbps), 16-QAM(24,36Mbps), 64-QAM(48,54Mbps)
    - Convolutional Code with coding rates ½,2/3,¾.
    - 20MHz/64 subcarriers per channel
      - 52 subcarriers occupy 16.6MHz
      - 12 additional subcarriers are used to normalized the average power of OFDM symbol
    - Mandatory : 6, 12, 24 Mbps
    - Extended (turbo mode 5-UP protocol): 72/108Mbps (proposed by Atheros Corp.)

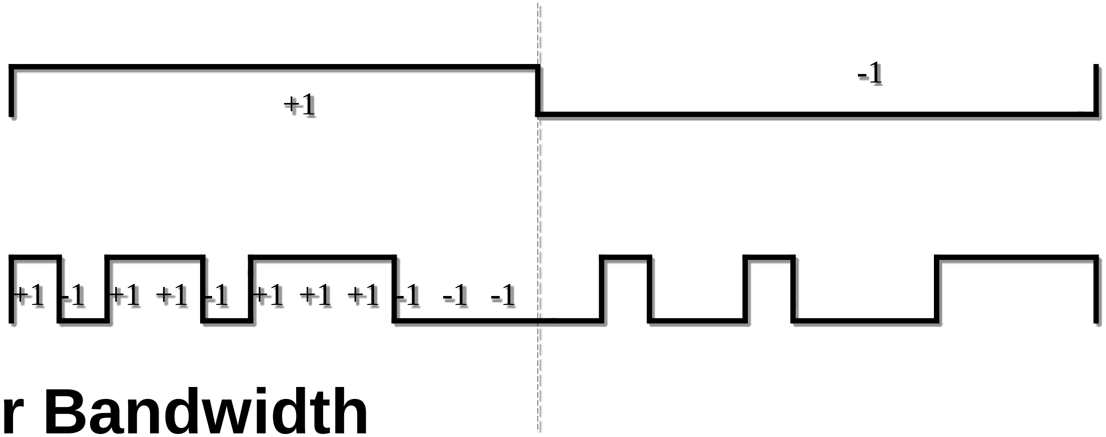
Unlicensed Operation RF Bands

- 902MHz
  - 26MHz BW (902-928MHz)
  - Crowded and Worldwide limited
  - IEEE 802.11 WLAN, IEEE 802.15.4 LR-WPAN, coreless phone, .etc.,
- 2.4GHz
  - 83.5MHz BW (2400-2483.5MHz)
  - Available worldwide
  - IEEE 802.11(b/g) WLAN, Bluetooth, IEEE 802.15.4 LR-WPAN and IEEE 802.15.6 WBAN, etc.,
- 5.1GHz
  - 300MHz (three 100MHz segments)
  - Unlicensed NII
  - 802.11a WLAN
    - » OFDM / 6,12,18,24,36,48,54Mbps / BPSK,QPSK,16-QAM, 64-QAM
  - HiperLAN I and HiperLAN II
    - » 23.5Mbps/GMSK and 6-54Mbps/BPSK,QPSK,16-QAM, 64-QAM

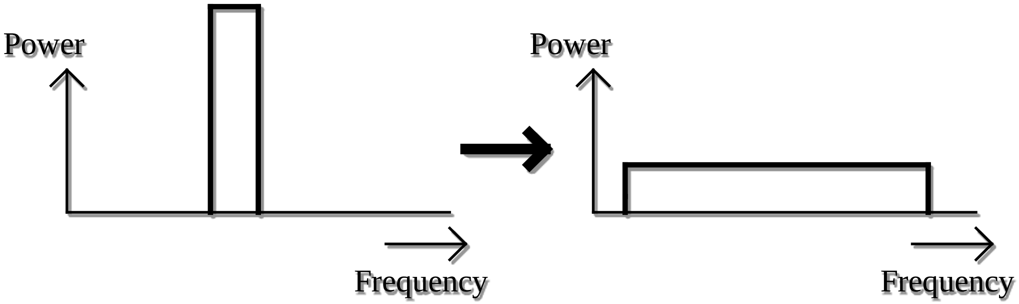
3. Direct Sequence Spread Spectrum (DSSS) Physical Layer Specification

What is DSSS?

- Signal symbol is spread with a sequence

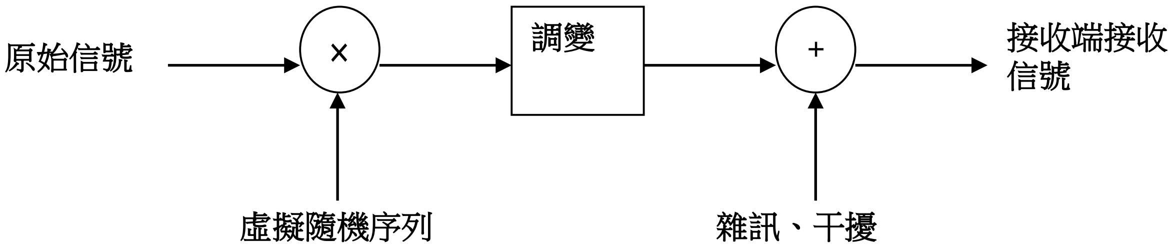


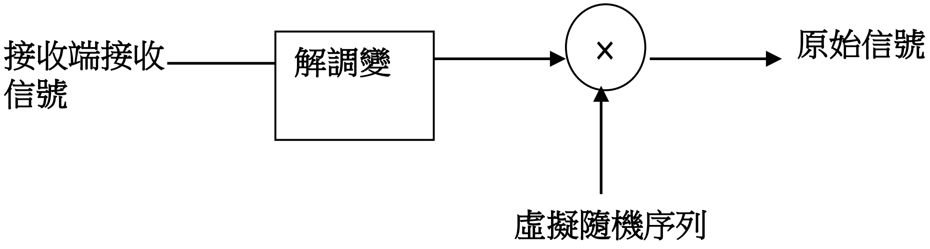
- Wider Bandwidth
- Less power density



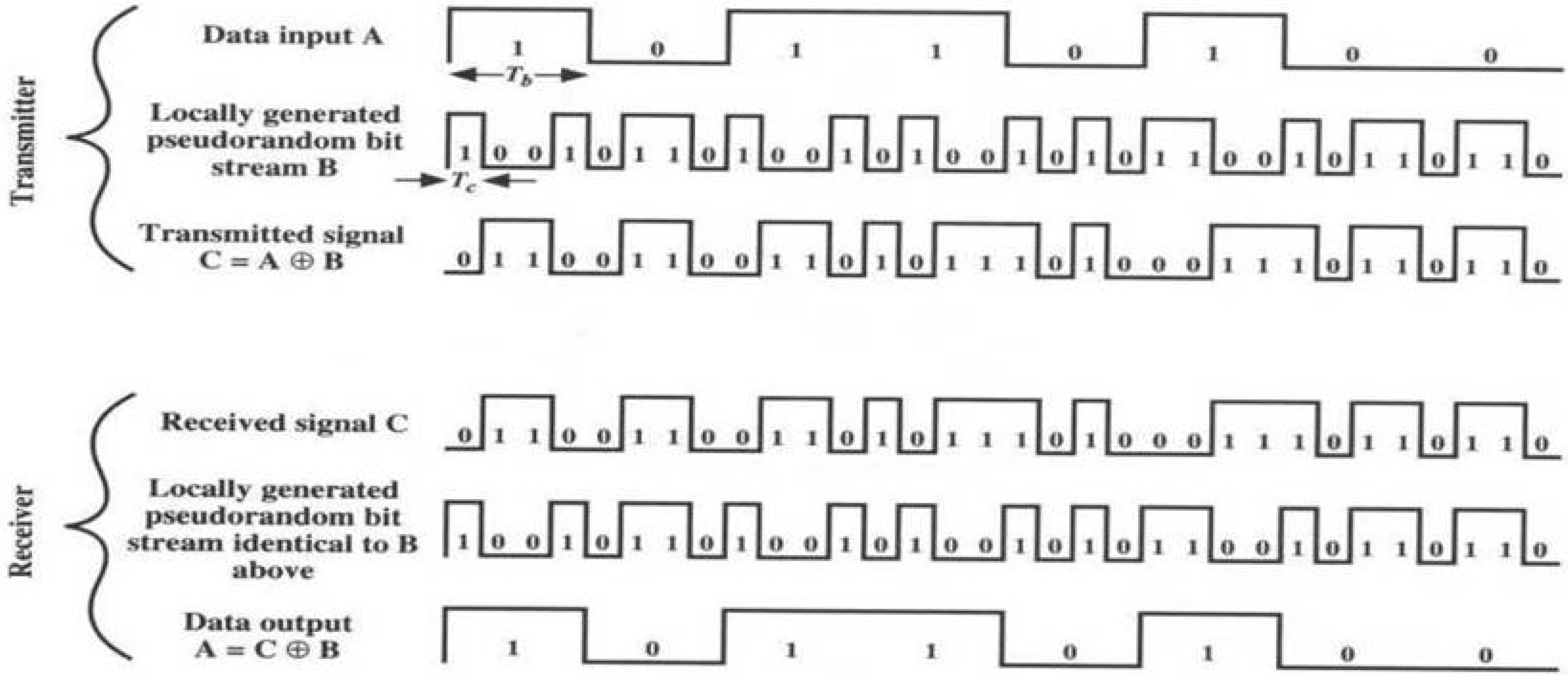
展頻技術-直接序列展頻

- 直接序列展頻技術（Direct Sequence Spread Spectrum：DSSS）是將原始信號乘上一虛擬隨機序列，再經過調變後送出去，當然在環境中會受到雜訊及干擾的影響，在接收端，會將接收到的信號經過解調變後，再乘上原本的虛擬隨機序列，最後就會將原始信號還原 。



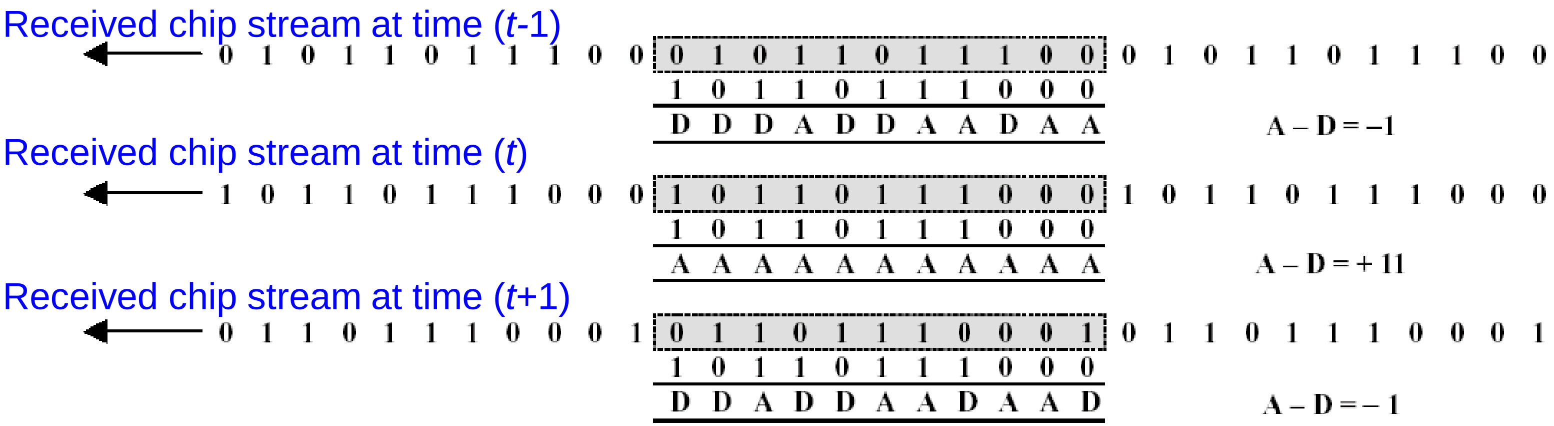


DSSS


Transmitter
Data input A
1 0 1 1 0 1 0 0
T_b
Locally generated pseudorandom bit stream B
1 0 0 1 0 1 1 0 1 0 0 1 0 1 0 0 1 0 1 0 1 1 0 0 1 0 1 1 0 1 1 0
T_c
Transmitted signal C = A ⊕ B
0 1 1 0 0 1 1 0 0 1 1 0 1 0 1 1 1 0 1 0 0 0 1 1 1 0 1 1 0 1 1 0
Receiver
Received signal C
0 1 1 0 0 1 1 0 0 1 1 0 1 0 1 1 1 0 1 0 0 0 1 1 1 0 1 1 0 1 1 0
Locally generated pseudorandom bit stream identical to B above
1 0 0 1 0 1 1 0 1 0 0 1 0 1 0 0 1 0 1 0 1 1 0 0 1 0 1 1 0 1 1 0
Data output A = C ⊕ B
1 0 1 1 0 1 0 0

11 Chip BARKER Sequence

- Good autocorrelation properties
- Minimal sequence allowed by FCC
- Coding gain 10.4 dB



Received chip stream at time (*t*-1)

← 0 1 0 1 1 0 1 1 1 0 0 | 0 1 0 1 1 0 1 1 1 0 0 | 0 1 0 1 1 0 1 1 1 0 0

1 0 1 1 0 1 1 1 0 0 0

D D D A D D A A D A A   A – D = –1

Received chip stream at time (*t*)

← 1 0 1 1 0 1 1 1 0 0 0 | 1 0 1 1 0 1 1 1 0 0 0 | 1 0 1 1 0 1 1 1 0 0 0

1 0 1 1 0 1 1 1 0 0 0

A A A A A A A A A A A   A – D = + 11

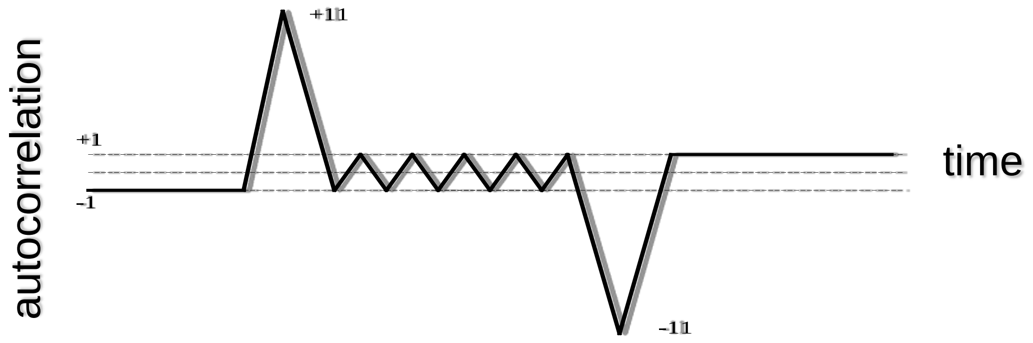
Received chip stream at time (*t*+1)

← 0 1 1 0 1 1 1 0 0 0 1 | 0 1 1 0 1 1 1 0 0 0 1 | 0 1 1 0 1 1 1 0 0 0 1

1 0 1 1 0 1 1 1 0 0 0

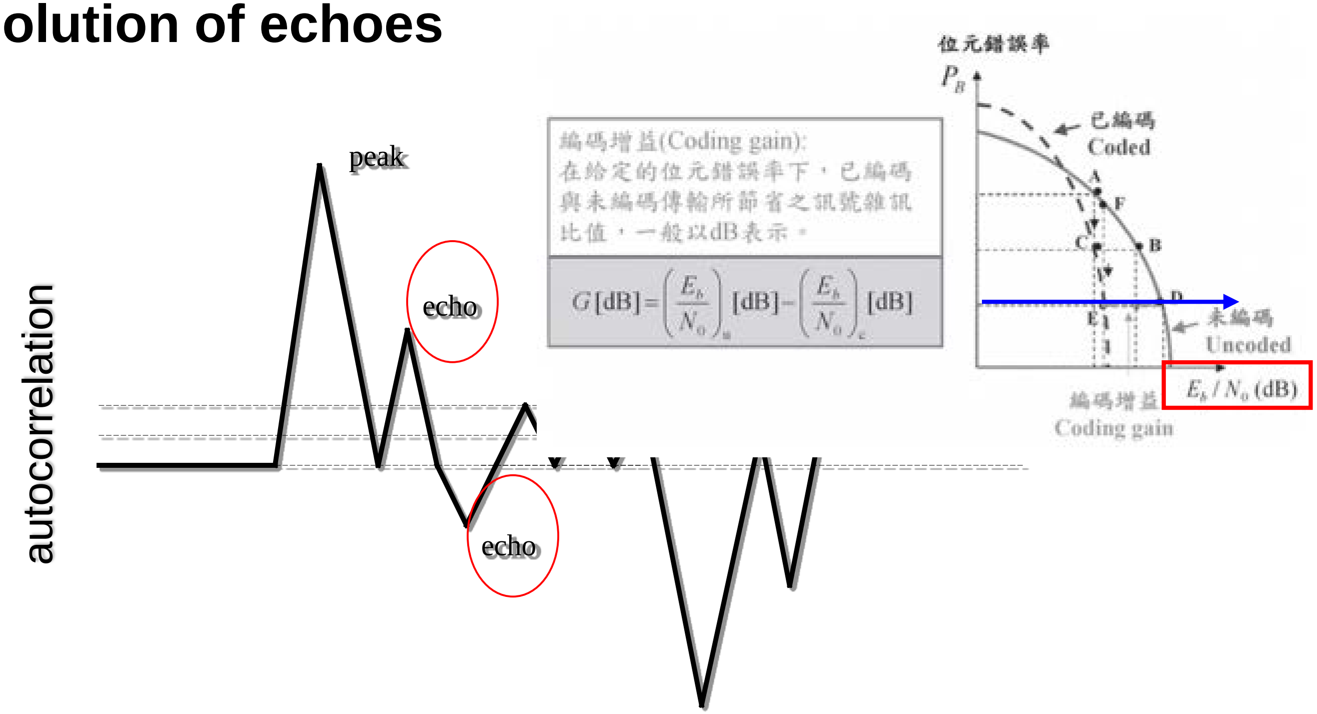
D D A D D A A D A A D   A – D = – 1

11-chip Barker sequence



DSSS Benefits

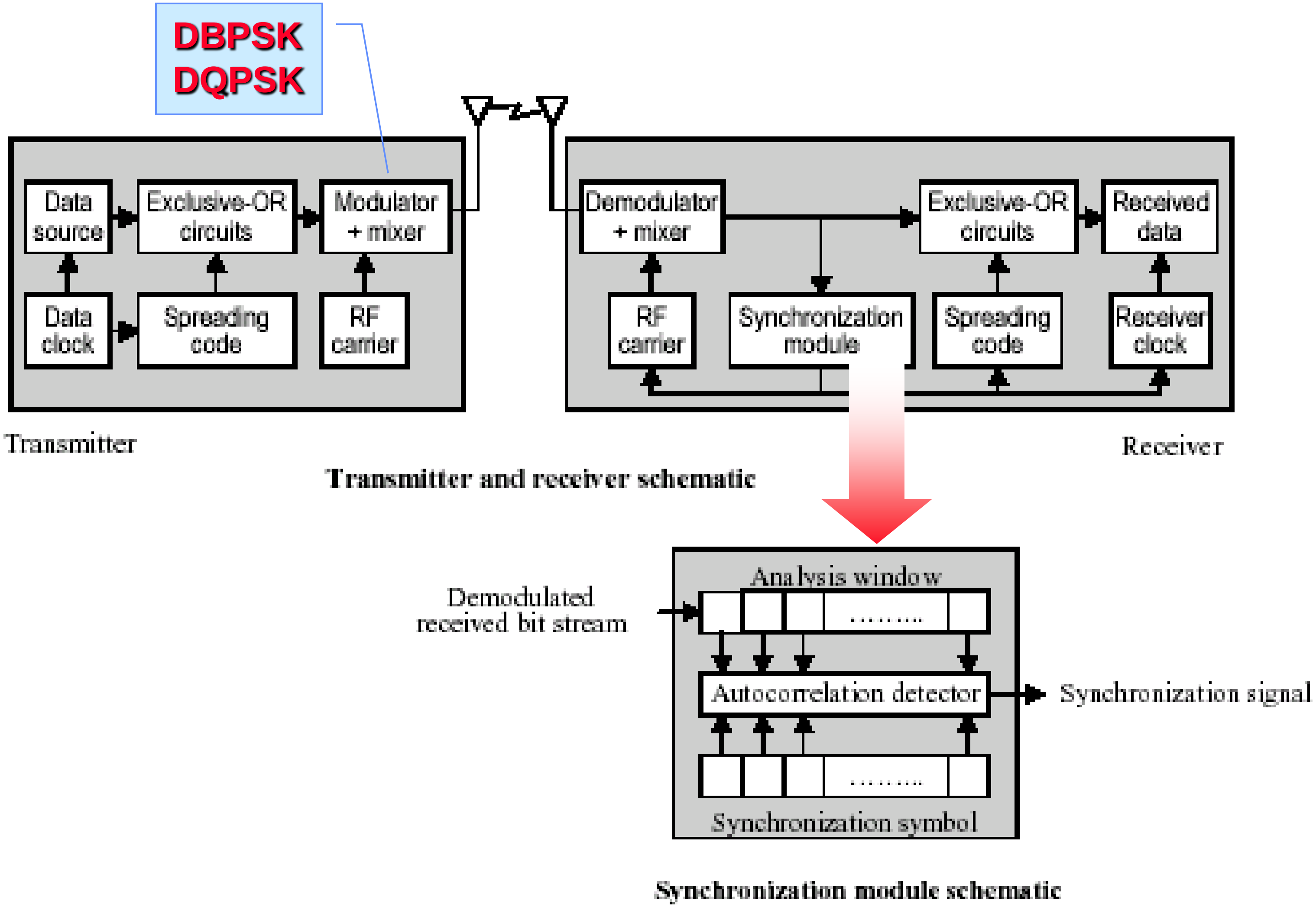
- **10 dB coding gain:**
  - **Robust against interferers and noise (10 dB suppression)**
- **Robust against time delay spread**
  - **Resolution of echoes**



編碼增益(Coding gain):
在給定的位元錯誤率下，已編碼與未編碼傳輸所節省之訊號雜訊比值，一般以dB表示。

$$G[\mathrm{dB}] = \left(\frac{E_b}{N_0}\right)_u [\mathrm{dB}] - \left(\frac{E_b}{N_0}\right)_c [\mathrm{dB}]$$

DSSS Hardware Block Diagram



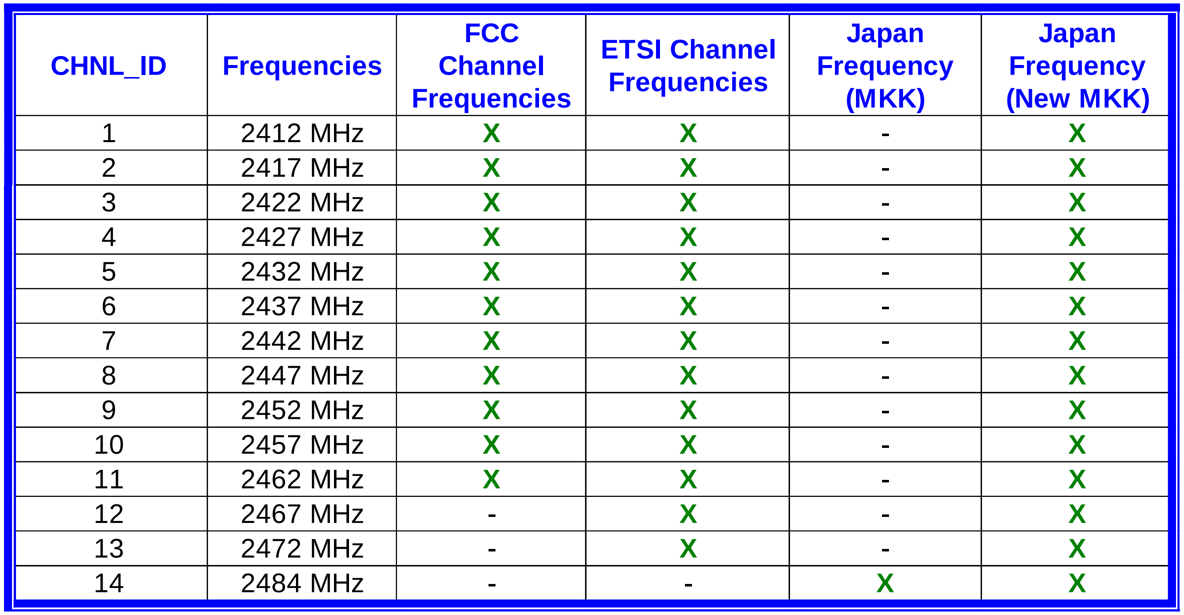
Transmitter and receiver schematic

Synchronization module schematic

IEEE 802.11 DSSS PHY characteristics

- 2.4 GHz ISM band (FCC 15.247)
- 1 and 2 Mb/s datarate
  - DBPSK and DQPSK modulation
  - Chipping rate 11 MHz with 11 chip Barker sequence
- 5.5 and 11Mbps (802.11b)
  - CCK (QPSK, DQPSK modulations – mandatory)
  - PBCC (BPSK, QPSK modulations – optional)
- 22 and 33Mbps (802.11g)
  - PBCC-22, PBCC-33 modulation (TI proposal – optional)
- Multiple channels in 2.4 to 2.4835 GHz band

DSSS Channels



CHNL_ID	Frequencies	FCC Channel Frequencies	ETSI Channel Frequencies	Japan Frequency (MKK)	Japan Frequency (New MKK)
1	2412 MHz	X	X	-	X
2	2417 MHz	X	X	-	X
3	2422 MHz	X	X	-	X
4	2427 MHz	X	X	-	X
5	2432 MHz	X	X	-	X
6	2437 MHz	X	X	-	X
7	2442 MHz	X	X	-	X
8	2447 MHz	X	X	-	X
9	2452 MHz	X	X	-	X
10	2457 MHz	X	X	-	X
11	2462 MHz	X	X	-	X
12	2467 MHz	-	X	-	X
13	2472 MHz	-	X	-	X
14	2484 MHz	-	-	X	X

Table 1, DSSS PHY Frequency Channel Plan

- **FCC(US), IC(Canada) and ETSI(Europe) : 2.4GHz - 2.4835GHz**
- **Japan : 2.471GHz - 2.497GHz (MKK : channel 14; new MKK : channels 1-14)**
- **France : 2.4465GHz - 2.4835GHz (channels 10, 11, 12, 13)**
- **Spain : 2.445GHz - 2.475GHz (channels 10, 11)**
- **Adjacent cells using different channels : ≥ 30MHz (25MHz in 802.11b)**
- FCC pushes the unused unlicensed TV broadcasting band 3.65GHz-3.70GHz as WLAN band.

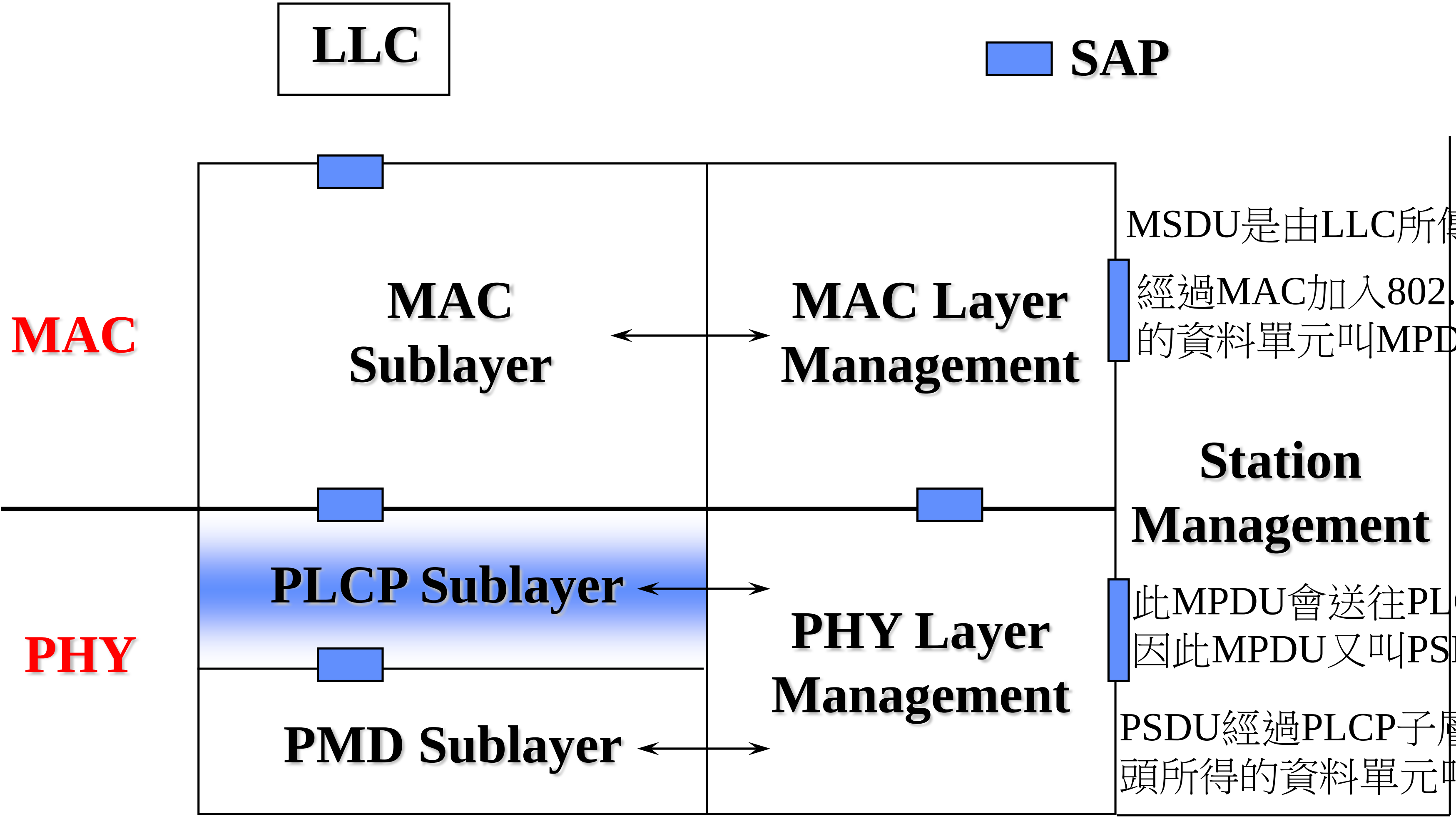
IEEE 802.11 PHY Terminology in Spec.(s)

- 1 Mbps : Basic Rate (BR)
- 2 Mbps : Extended Rate (ER)
- 5.5/11 Mbps : High Rate (HR)
- 22~33/6~54 Mbps : Extended Rate PHY (ERP)
- 150 Mbps : Multi-Input Multi-Output (MIMO); 11n
- 500Mbps : IEEE 802.11ac

PLCP Frame Formats in IEEE 802.11b

- Two different preamble and header formats
  - Long PLCP PPDU format (Mandatory in 802.11b)
    - 144-bit preamble : 1Mbps DBPSK
    - 48-bit header : 1Mbps DBPSK
    - Spend 192us
    - PSDU : 1, 2, 5.5, 11Mbps
    - Compatible with 1 and 2 Mbps
  - Short PLCP PPDU format (Optional in 802.11b)
    - Minimize overhead, maximize data throughput
    - 72-bit preamble : 1Mbps DBPSK
    - 48-bit header : 2Mbps DQPSK
    - Spend 96us
    - PSDU : 2, 5.5, 11 Mbps

PLCP (PHY Convergence) Sublayer



MSDU是由LLC所傳送過來

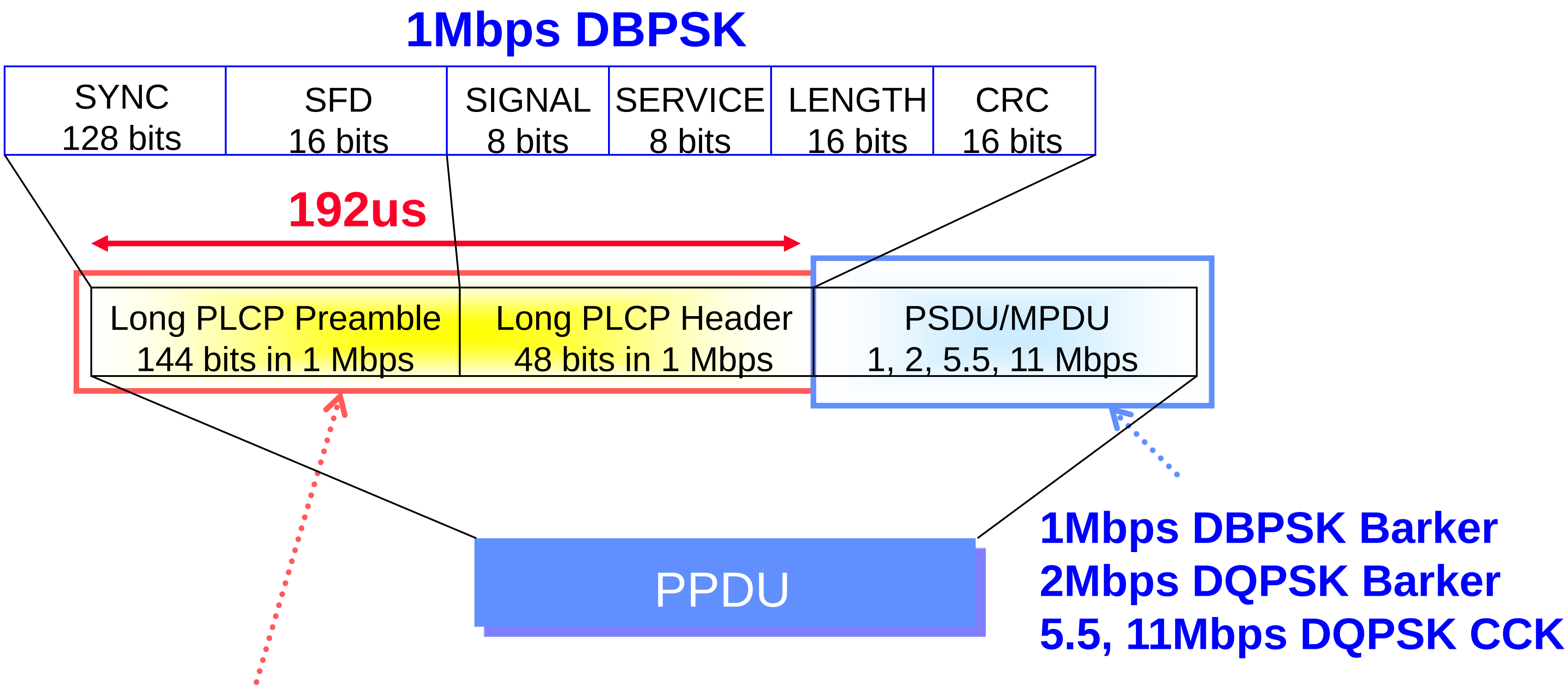
經過MAC加入802.11的協定
的資料單元叫MPDU

此MPDU會送往PLCP 實體
因此MPDU又叫PSDU

PSDU經過PLCP子層加入80
頭所得的資料單元叫PPDU。

Long PLCP Frame Format

- **Mandatory in 802.11b**



1Mbps DBPSK

SYNC	SFD	SIGNAL	SERVICE	LENGTH	CRC
128 bits	16 bits	8 bits	8 bits	16 bits	16 bits

192us

Long PLCP Preamble	Long PLCP Header	PSDU/MPDU
144 bits in 1 Mbps	48 bits in 1 Mbps	1, 2, 5.5, 11 Mbps

PPDU

1Mbps DBPSK Barker
2Mbps DQPSK Barker
5.5, 11Mbps DQPSK CCK

Preamble and Header always at 1Mb/s DBPSK Barker

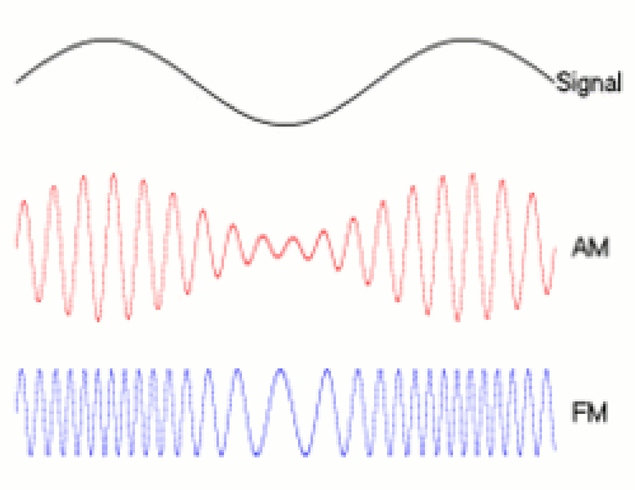
Modulation

- **Modulation** is the process of varying one or more properties of a periodic waveform, called the *carrier signal*, with a modulating signal that typically contains information to be transmitted.
- Most radio systems in the 20th century used frequency modulation (FM) or amplitude modulation (AM) to make the carrier carry the radio broadcast.

Modulation

- Modulation is a process of conveying message signal, for example, a digital bit stream or an analog audio signal, inside another signal that can be physically transmitted.

- Modulation of a sine waveform transforms a narrow frequency range baseband message signal into a moderate to high frequency range passband signal, one that can pass through a filter.



Digital Modulation Methods

- Digital modulation methods can be considered as digital-to-analog conversion and the corresponding demodulation or detection as analog-to-digital conversion.

- The changes in the carrier signal are chosen from a finite number of M alternative symbols (the *modulation alphabet*).

Example

- A telephone line is designed for transferring audible sounds, for example, tones, and not digital bits (zeros and ones).
- Computers may, however, communicate over a telephone line by means of modems, which are representing the digital bits by tones, called symbols.
- If there are four alternative symbols (corresponding to a musical instrument that can generate four different tones, one at a time), the first symbol may represent the bit sequence 00, the second 01, the third 10 and the fourth 11.

Example

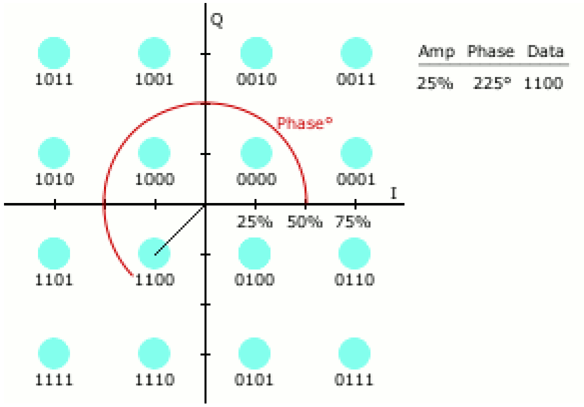
- If the modem plays a melody consisting of 1000 tones per second, the symbol rate is 1000 symbols/second, or baud.
- Since each tone (i.e., symbol) represents a message consisting of two digital bits in this example, the bit rate is twice the symbol rate, i.e. 2000 bits per second.
  - This is similar to the technique used by dial-up modems as opposed to DSLmodems.

Fundamental Digital Modulation Methods

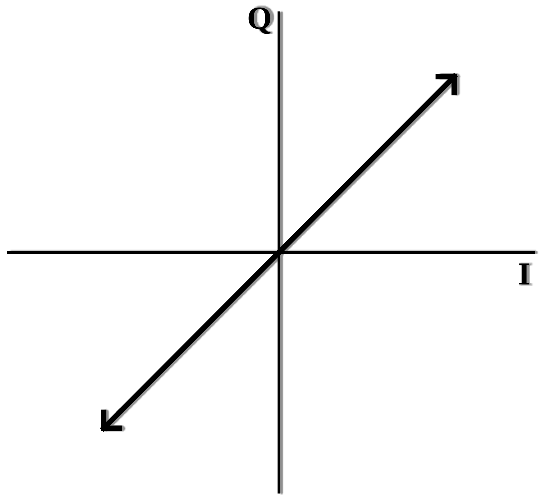
- The most fundamental digital modulation techniques are based on keying:
  - PSK (phase-shift keying): a finite number of phases are used.
  - FSK (frequency-shift keying): a finite number of frequencies are used.
  - ASK (amplitude-shift keying): a finite number of amplitudes are used.
  - QAM (quadrature amplitude modulation): a finite number of at least two phases and at least two amplitudes are used.

QAM

- An in-phase signal (or **I**, with one example being a cosine waveform) and a quadrature phase signal (or **Q**, with an example being a sine wave) are amplitude modulated with a finite number of amplitudes and then summed.
- It can be seen as a two-channel system, each channel using ASK. The resulting signal is equivalent to a combination of PSK and ASK.



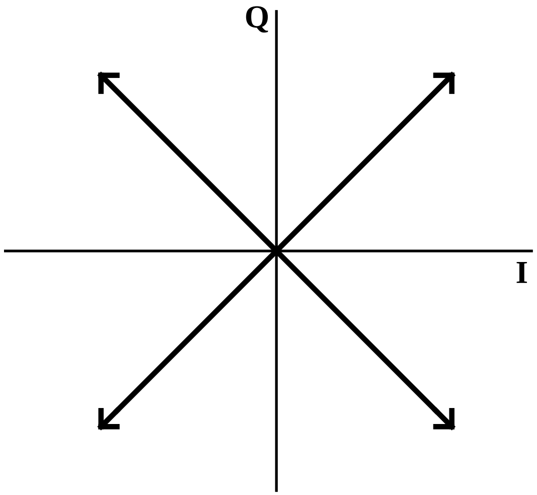
DBPSK Modulation



Bit Input	Phase Change (+jω)
0	0
1	π

Table 1, 1 Mb/s DBPSK Encoding Table.

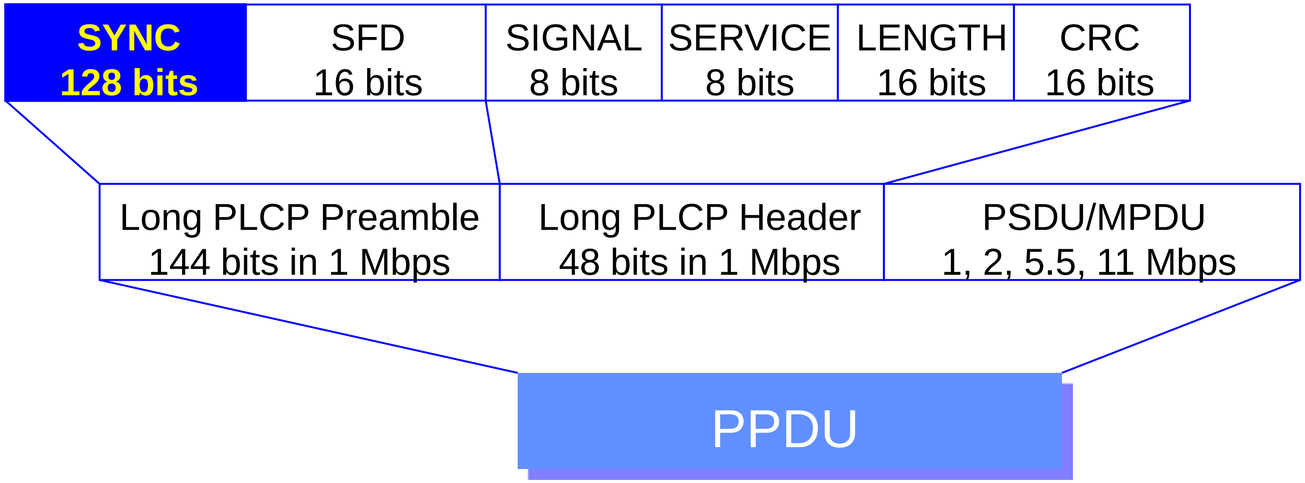
DQPSK Modulation



Dibit pattern (d0,d1) d0 is first in time	Phase Change (+jω)
00	0
01	π/2
11	π
10	3π/2 (-π/2)

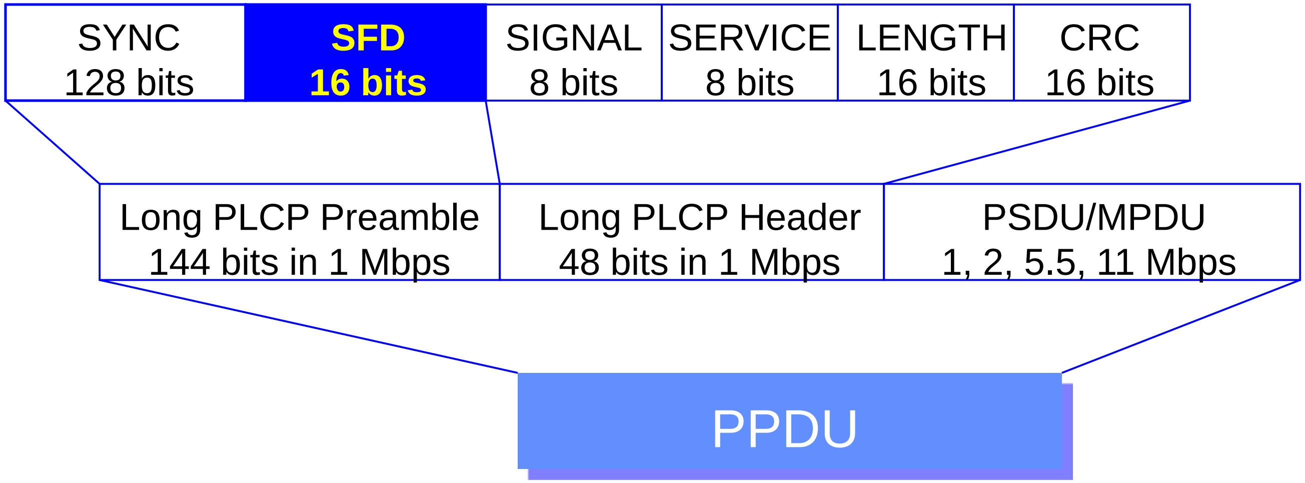
Table 1, 2 Mb/s DQPSK Encoding Table

PLCP synchronization



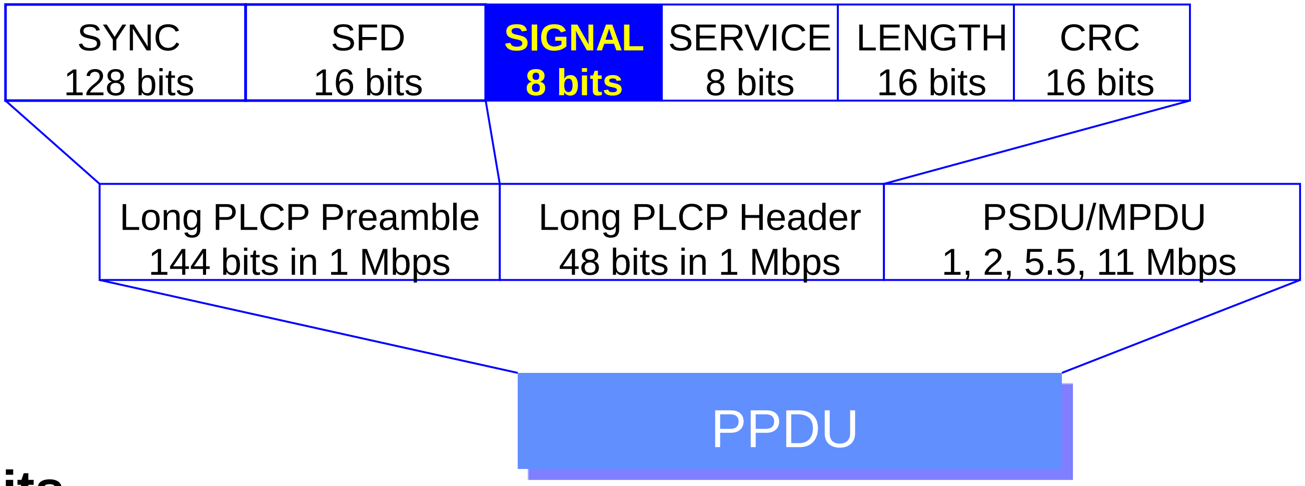
- **128 one bits (‘1’)**
- **scrambled by scrambler**
- **Used for receiver to clock on to the signal and to correlate to the PN (Pseudo Noise) code**

Start Frame Delimiter



- **16 bit field (hF3A0)**
- **used for**
  - **bit synchronization**

Signal Field



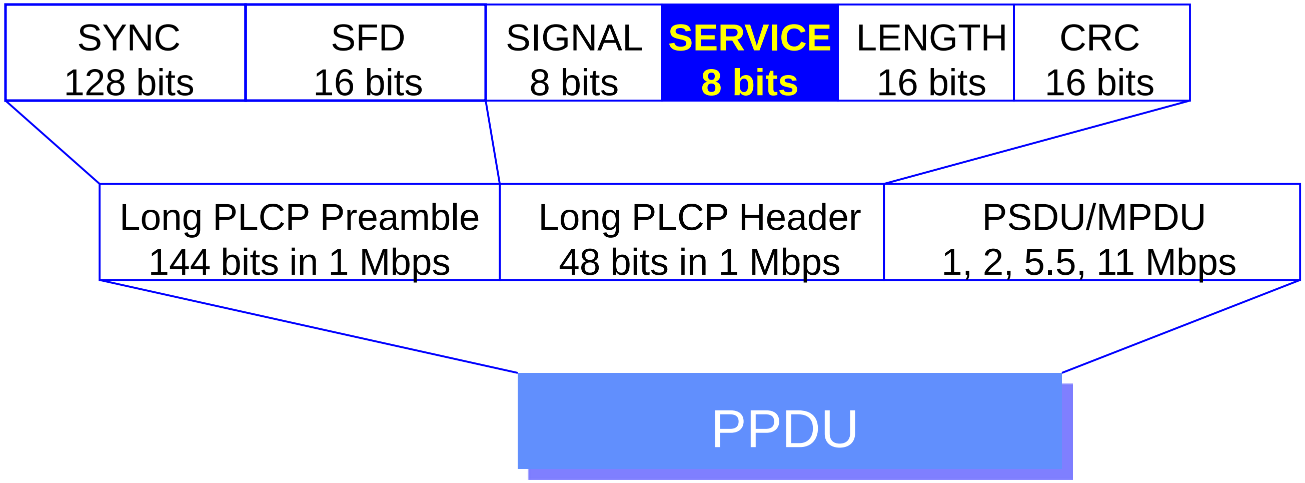
SYNC 128 bits | SFD 16 bits | **SIGNAL 8 bits** | SERVICE 8 bits | LENGTH 16 bits | CRC 16 bits

Long PLCP Preamble 144 bits in 1 Mbps | Long PLCP Header 48 bits in 1 Mbps | PSDU/MPDU 1, 2, 5.5, 11 Mbps

PPDU

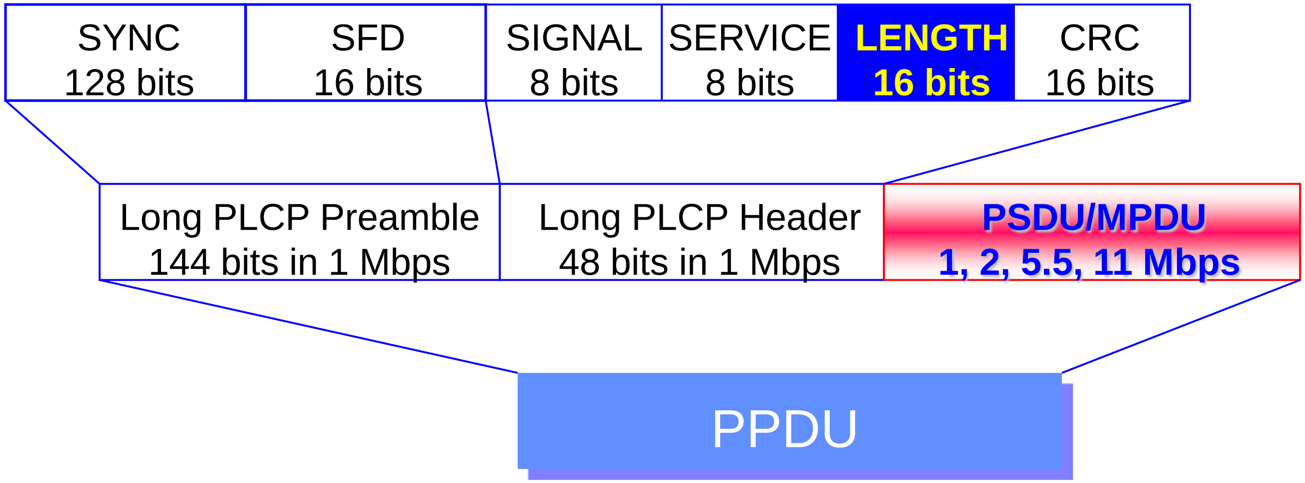
- **8 bits**
- **Rate indication**
  - **h0A 1Mb/s DBPSK**
  - **h14 2Mb/s DQPSK**
  - **h37 5.5Mb/s CCK or PBCC**
  - **h6E 11Mbps CCK or PBCC**
- **Other values reserved for future use (100 kb/s quantities)**

Service Field



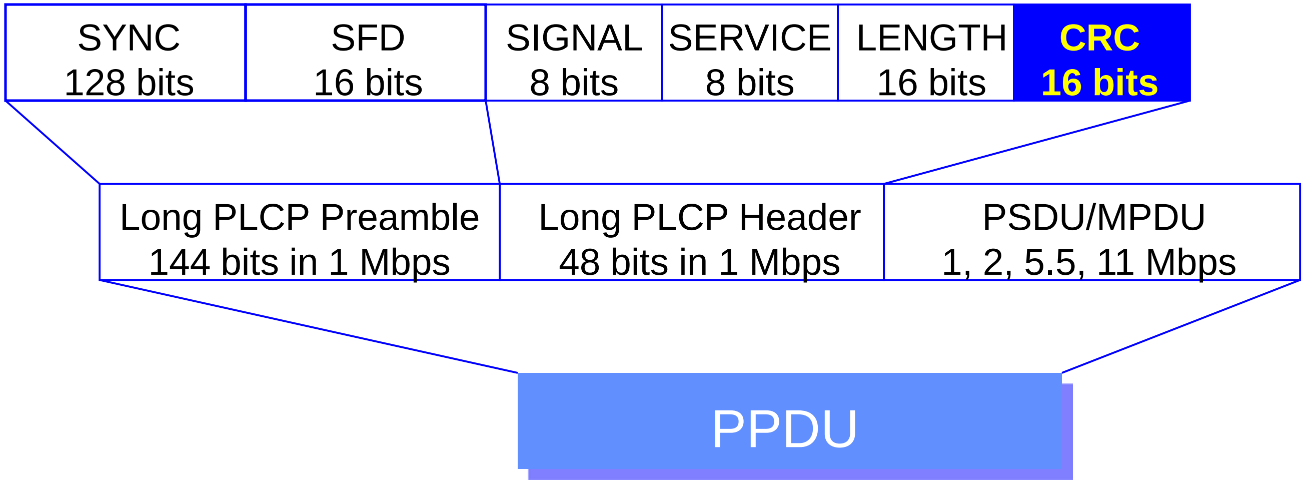
- **Reserved for future use**
  - **Bit 2 : locked clock bit**
    - » **Indicate transmit freq. (mixer) & symbol clocks (baseband) derived from same oscillator**
    - » **optional in 802.11b and mandatory in 802.11g**
  - **Bit 3 : modulation selection**
    - » **0 : CCK / 1 : PBCC**
  - **Bit 7 : length extension bit (in the case datarate > 8Mbps)**
- **h00 signifies 802.11 compliant**

Length Field



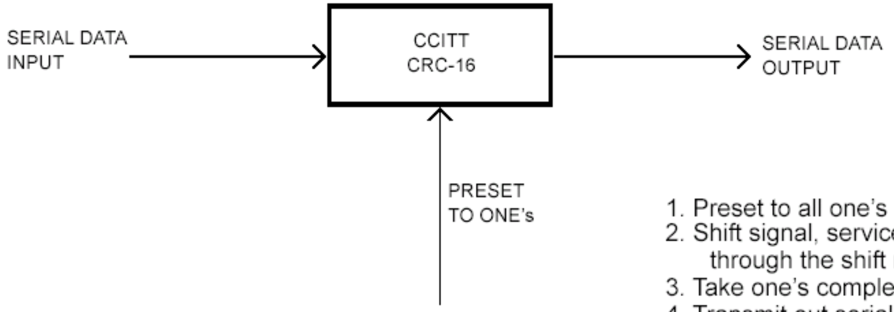
- **Indicates number of micosceonds to be transmitted in PSDU/MPDU**
  - **Decided by Length and datarate (in TXvector)**
- **Used for**
  - **End of frame detection**
  - **Perform Virtual Carrier Sense (for those with lower datarate)**
  - **MPDU CRC sync**

CRC field



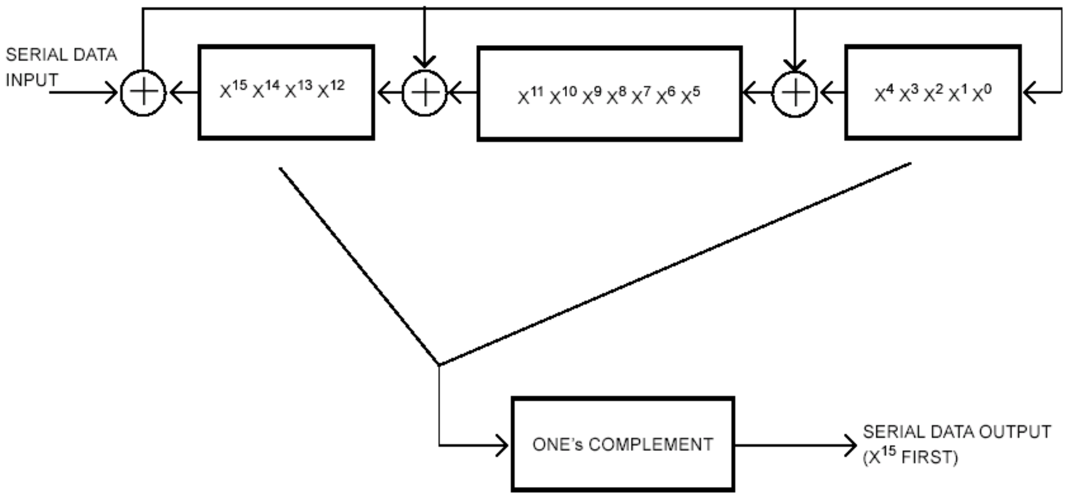
- **CCITT CRC-16**
- **Protects Signal, Service and Length Field**

CRC Implementation



1. Preset to all one's
2. Shift signal, service length fields through the shift register
3. Take one's complement of the remainder
4. Transmit out serial X^{15} first

CCITT CRC-16 POLYNOMIAL: $G(x) = X^{16} + X^{12} + X^{5} + 1$


SERIAL DATA
INPUT
$X^{15}\ X^{14}\ X^{13}\ X^{12}$
$X^{11}\ X^{10}\ X^{9}\ X^{8}\ X^{7}\ X^{6}\ X^{5}$
$X^{4}\ X^{3}\ X^{2}\ X^{1}\ X^{0}$
ONE's COMPLEMENT
SERIAL DATA OUTPUT
(X^{15} FIRST)

Data	CRC Registers msb lsb
	1111111111111111
0	1110111111011111
1	1101111110111110
0	1010111101011101
1	0101111010111010
0	1011110101110100
0	0110101011001001
0	1101010110010010
0	1011101100000101
0	0110011000101011
0	1100110001010110
0	1000100010001101
0	0000000100111011
0	0000001001110110
0	0000010011101100
0	0000100111011000
0	0001001110110000
0	0010011101100000
0	0100111011000000
0	1001110110000000
0	0010101100100001
0	0101011001000010
0	1010110010000100
1	0101100100001000
1	1010001000110001
0	0101010001000011
0	1010100010000110
0	0100000100101101
0	1000001001011010
0	0001010010010101
0	0010100100101010
0	0101001001010100
0	1010010010101000