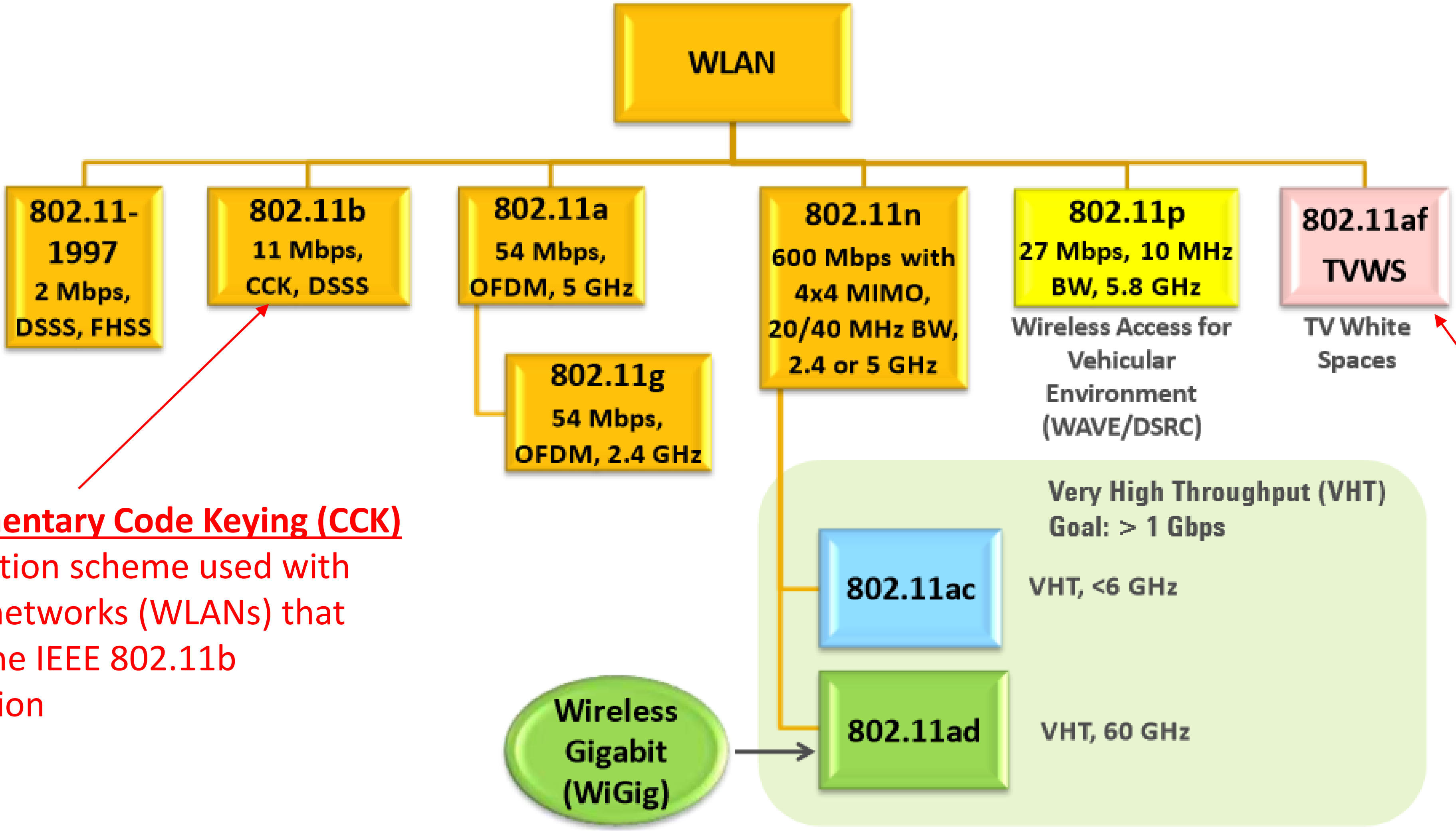
IEEE 802.11 PHYSICAL LAYER

ECE 3115 – WIRELESS COMMUNICATION TECHNOLOGIES

Wednesday, 08 November 2017

802.11 STANDARDS



Complementary Code Keying (CCK)

A modulation scheme used with wireless networks (WLANs) that employ the IEEE 802.11b specification

TV White Spaces

Frequencies allocated to a TV broadcasting service but not used locally

CATEGORIES OF 802.11 STANDARDS / 01

1. **IEEE 802.11:** The original IEEE 802.11 standard are 2 and 1 Mbps using the FHSS transmission scheme and the S-Band Industrial, Scientific, and Medical (ISM) frequency band (2.4 to 2.5 GHz).

   Under good transmission conditions, 2 Mbps is used; under less-than-ideal conditions, the lower speed of 1 Mbps is used.

1. **IEEE 802.11a** –Operates at a bit rate as high as 54 Mbps and uses the C-Band ISM (5.725 to 5.875 GHz).

   Uses OFDM, which allows data to be transmitted by sub-frequencies in parallel and provides greater resistance to interference and greater throughput.

   Has better support for video and conferencing applications.

CATEGORIES OF 802.11 STANDARDS / 02

1. **IEEE 802.11b** –Supports 5.5 Mbps and 11 Mbps, using the S-Band ISM.

   Uses DSSS transmission scheme.

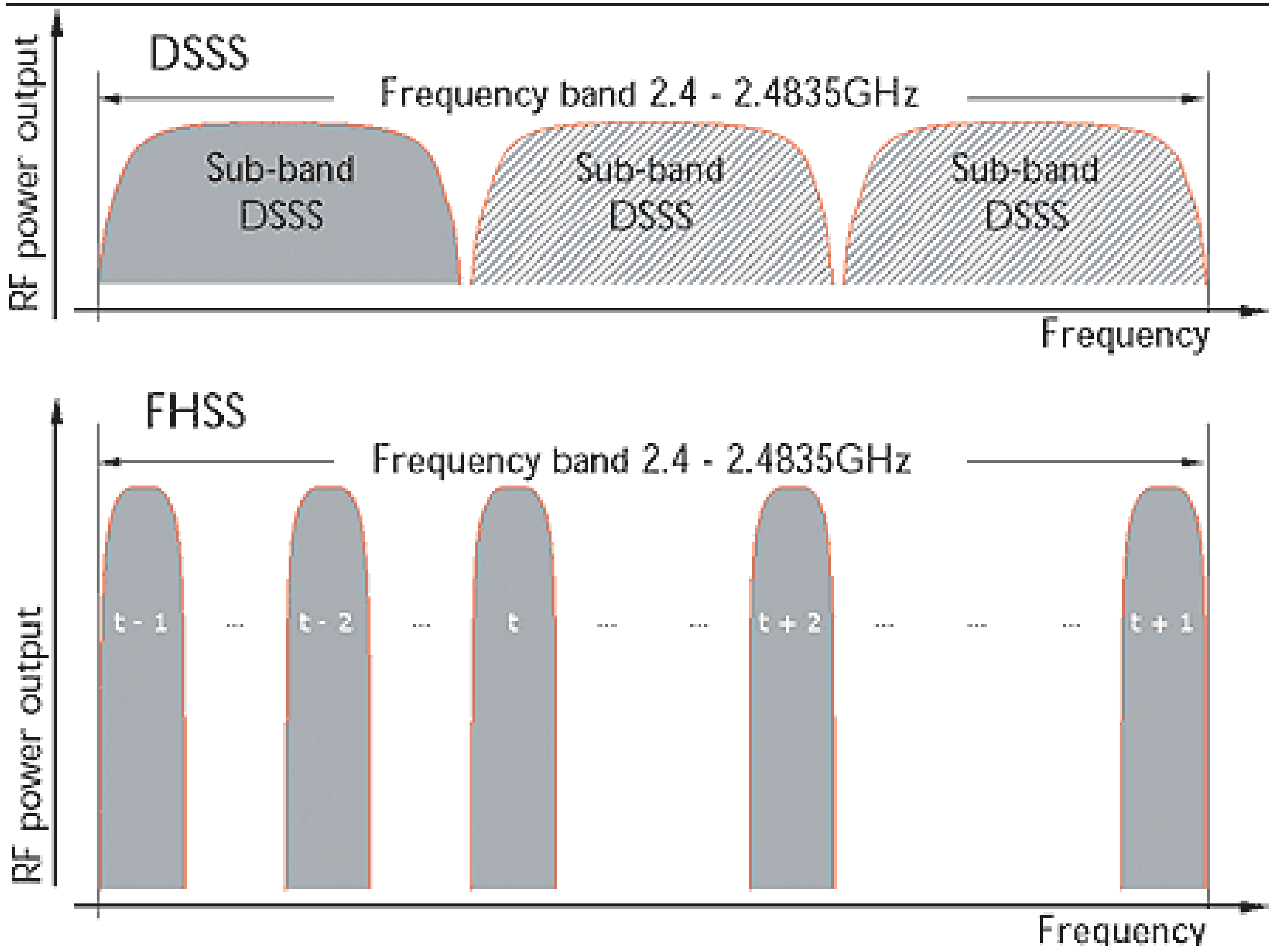
   11 Mbps bitrate is achievable in ideal conditions.

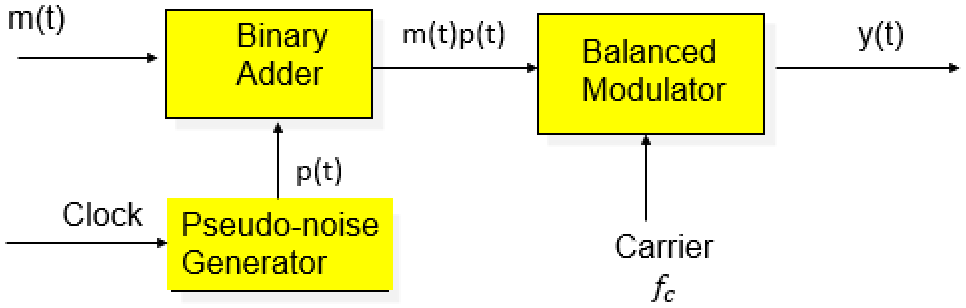
2. **IEEE 802.11g** - Operates at a bit rate as high as 54 Mbps,

   Uses the S-Band ISM and OFDM.

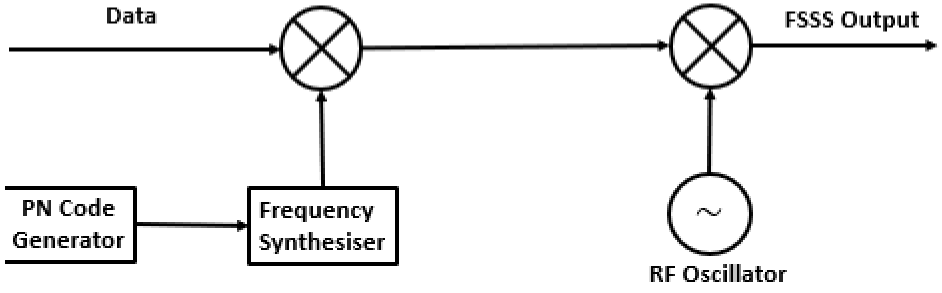
   Is backward-compatible with 802.11b

FREQUENCY USE BY IEEE 802.11 FHSS COMPARED TO DSSS





(a) Direct-Sequence Spread Spectrum (DSSS)

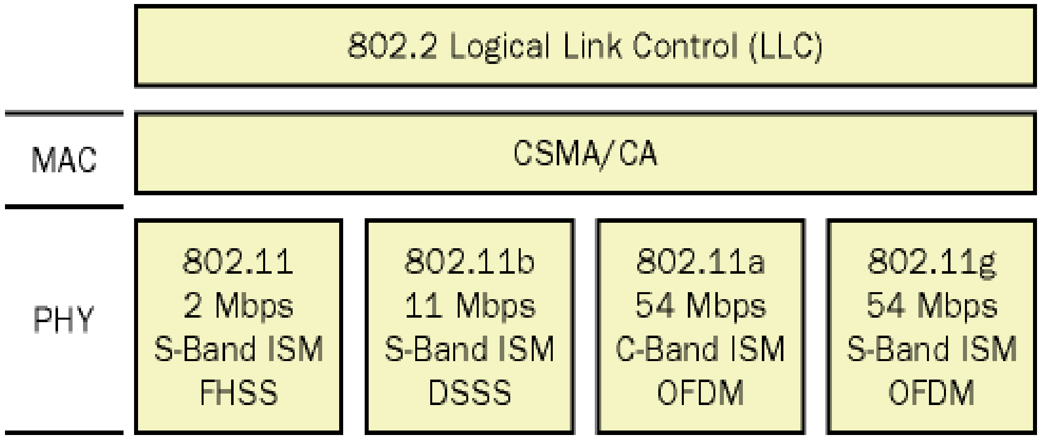


(b) Frequency Hopping Spread Spectrum (FHSS)

PHY FUNCTIONS

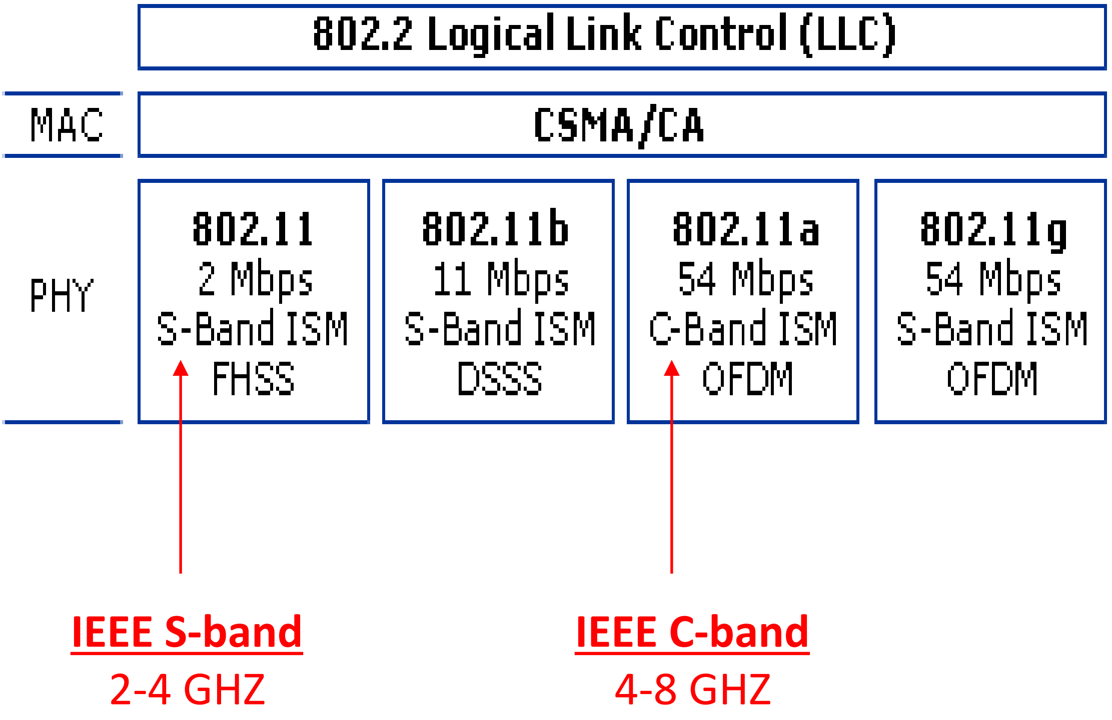
The functions of the IEEE 802.11 physical layer are:

1. Wireless transmission mechanism for the MAC
2. Assessing the state of the wireless medium and reporting it to the MAC
3. Creating Independence between MAC and PHY → enhancements
4. 802.11b, 802.11a, 802.11g PHYs use the same MAC.



IEEE 802.11 PHY SUBLAYER

1. **IEEE 802.11 physical (PHY)** layer defines a series of encoding and transmission schemes for wireless communications, the most prevalent of which are
   a) Frequency Hopping Spread Spectrum (FHSS),
   b) Direct Sequence Spread Spectrum (DSSS),
   c) Orthogonal Frequency-Division Multiplexing (OFDM) transmission schemes.
2. Figure shows the 802.11, 802.11b, 802.11a, and 802.11g standards that exist at the PHY layer.

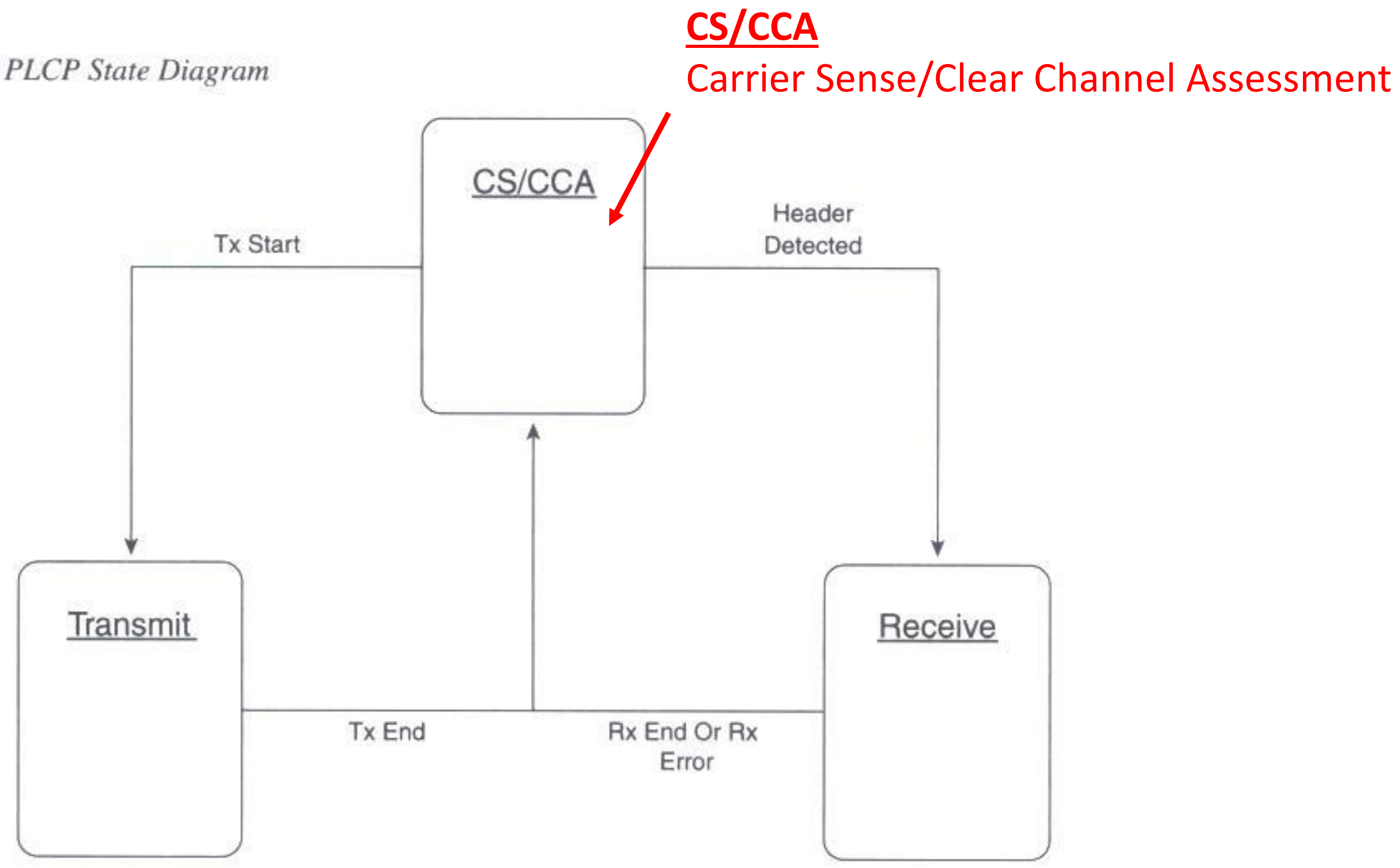


IEEE 802.11 PHY SUBLAYERS

- IEEE 802.11 has two sublayers, i.e
  - **Physical Layer Convergence Procedure (PLCP)** - a handshaking layer that enables MAC protocol data units (MPDUs) to be transferred between MAC stations over the PMD
  - **Physical Medium Dependent (PMD)** –interfaces directly with the wireless medium (that is, RF in the air) and provides modulation and demodulation of the frame transmissions.

PHYSICAL LAYER CONVERGENCE PROCEDURE (PLCP) FLOW-CHART

Figure 3-2 *PLCP State Diagram*



FURTHER READING

1. IEEE 802.11 Medium Access Control (MAC) - Clear Channel Assessment, Distributed Coordination Function, Hidden nodes
2. Understanding WiFi Carrier Sense

IEEE 802.11 FUNCTIONAL BUILDING BLOCKS

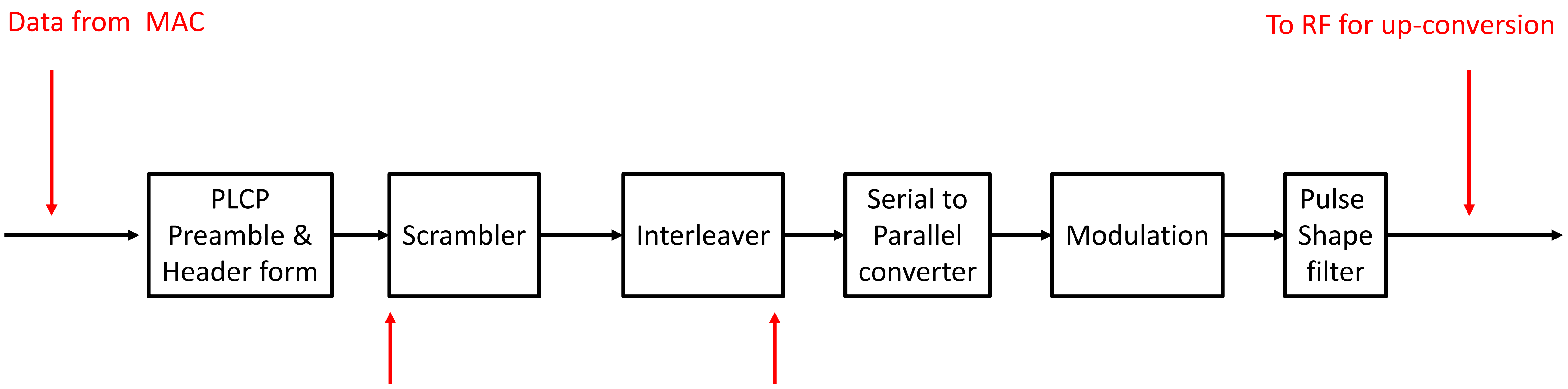
The PHY layer can be divided into the following functional building blocks as:

1. Scrambling
2. Coding
3. Interleaving
4. Symbol mapping and modulation

FURTHER READING

1. A perfect scrambler and descrambler for IEEE 802.11g wireless networks
2. Coding in 802.11 WLAN – PhD Thesis of the National University of Ireland Maynooth

PHY LAYER TRANSMITTER BLOCK



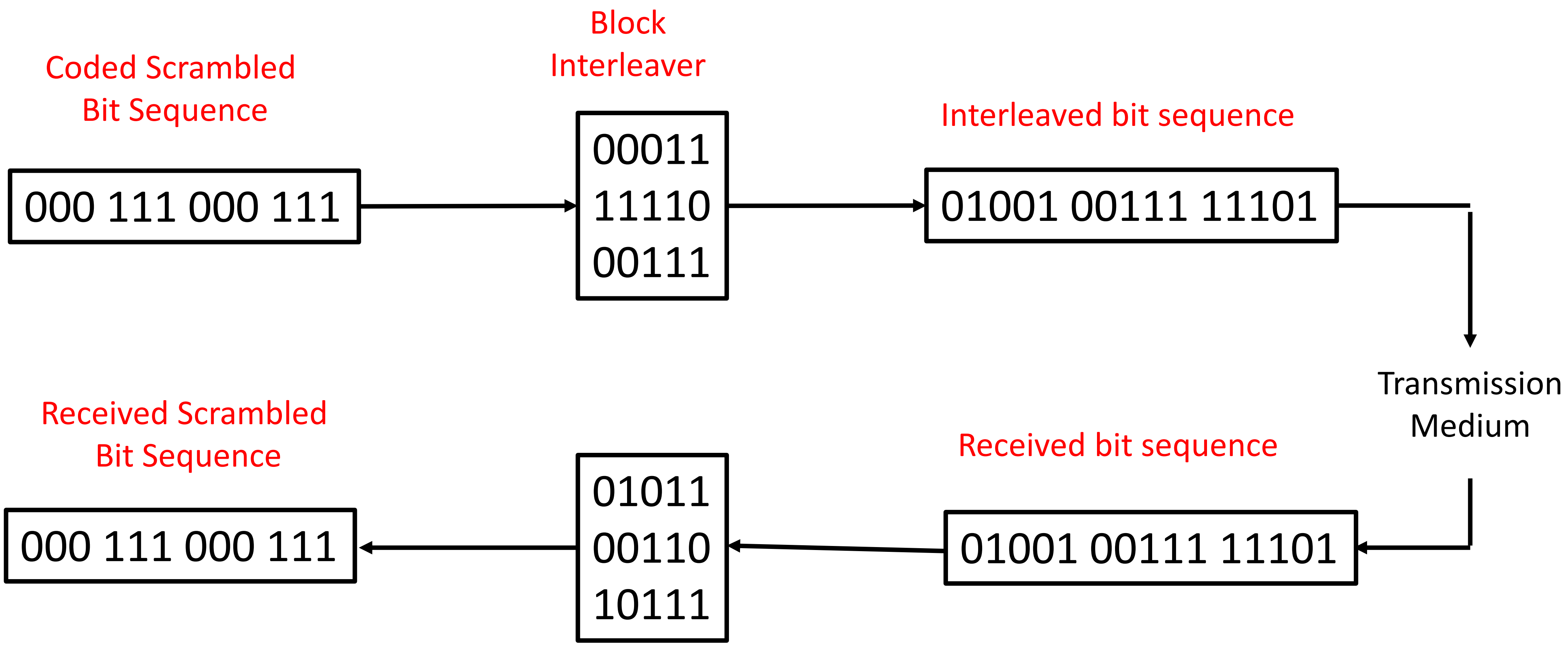
Scrambler

Transposes or inverts signals or otherwise encodes a message to make it unintelligible to an intended receiver.

Interleaver

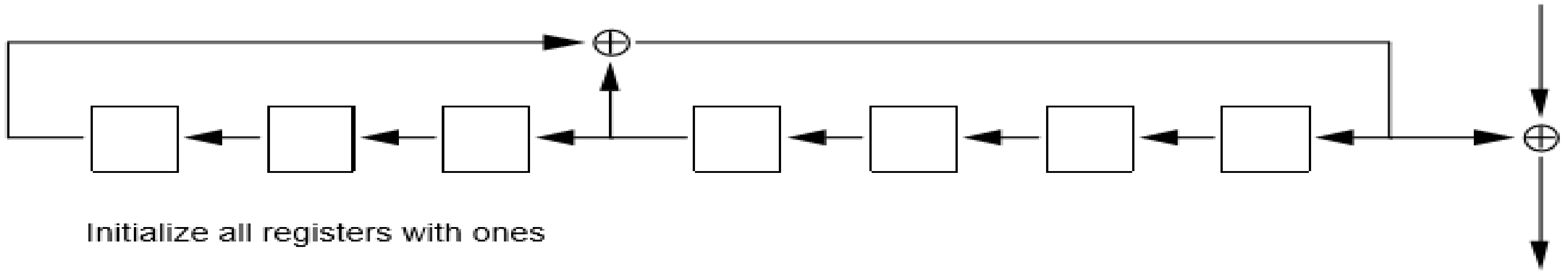
Supports error correction transposing the data so that the receiver can detect and correct errors.

INTERLEAVER

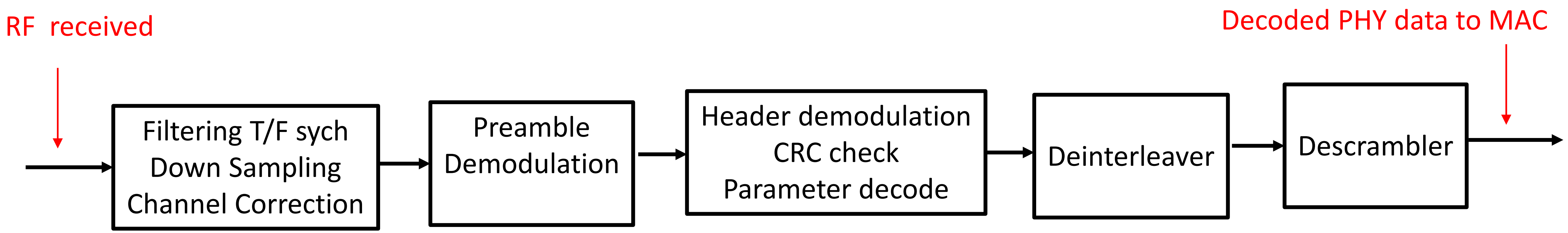


FH PHY SCRAMBLER

- Scrambling is applied just to PLCP_PDU, not to PLCP header
- Scrambling is performed by a bitwise XOR with LFSR sequence with 127 bit period, with $1+x^4+x^7$ feedback polynomial
- Same method is used for scrambling and descrambling



PHY LAYER RECEIVER BLOCK



IEEE 802.11 FREQUENCY HOPPING PHY

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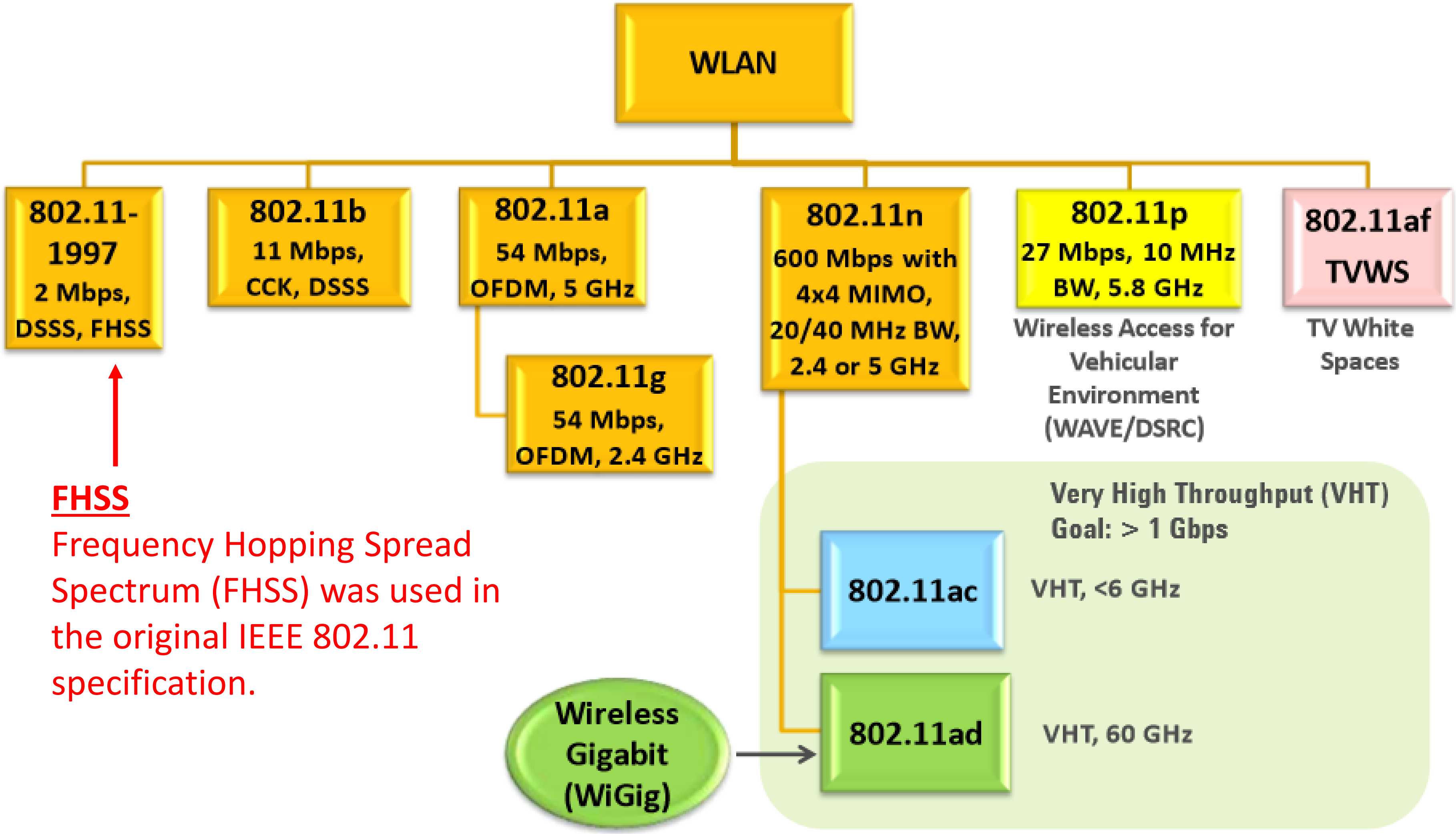
FHSS IN THE WLAN

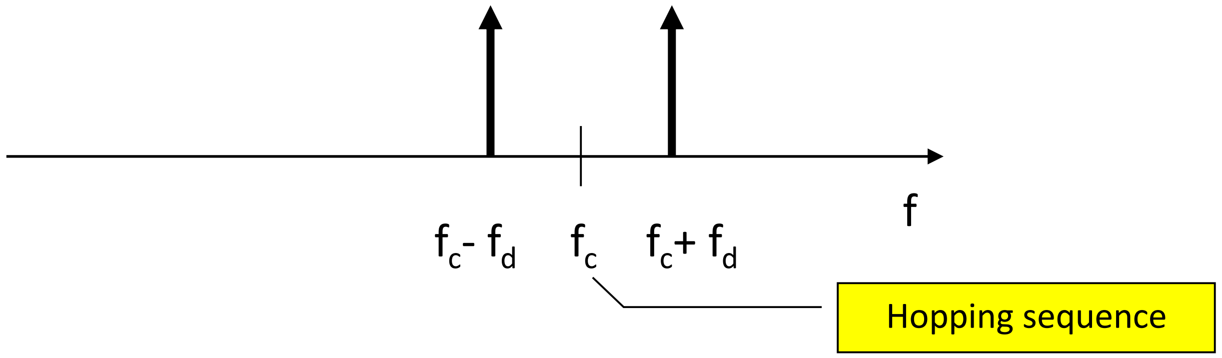


FHSS

Frequency Hopping Spread Spectrum (FHSS) was used in the original IEEE 802.11 specification.

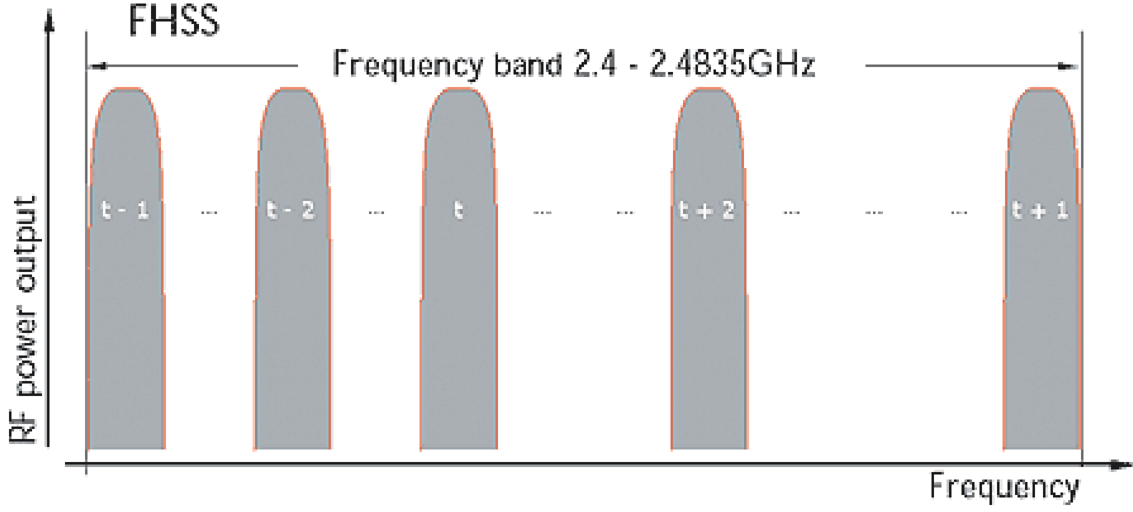
802.11 FHSS

- **IEEE 802.11 FHSS PMD sublayer** modulates the data stream by using FSK.
- **Advantage:**
  - Simple system
- **Disadvantages:**
  - Spectrally inefficient (no high data rates),
  - Interferences in the ISM band,
  - No mechanism to coordinate the hopping of adjacent APs (scalability)



FREQUENCY HOPPING IN IEEE 802.11

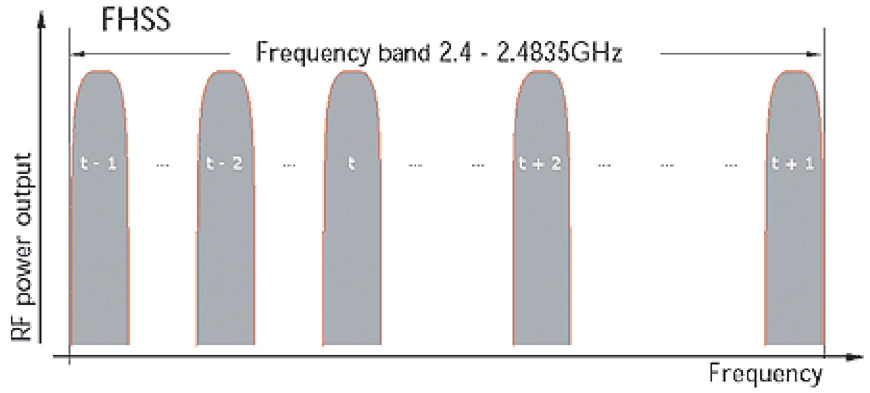
- **FHSS** works by modulating a data signal with a carrier signal that hops from frequency to frequency as a function of time over a wide band of frequencies.
- **In 802.11 FHSS**, the carrier frequency hops over the 2.4GHz frequency band between 2.4GHz and 2.483GHz.
- The signal stops long enough at each frequency to transmit data for an amount of time based on the dwell time set as a configuration parameter.



802.11 FHSS CHANNELS

- **802.11 Frequency Hopping (FH)** uses 79 nonoverlapping frequency channels with 1 MHz channel spacing.
- **FH** enables operation of up to 26 collocated networks, enabling therefore high aggregate throughput.
- **FH** is resistant to multipath fading through the inherent frequency diversity mechanism

79 channels each 1 MHz



REGULATORY REQUIREMENTS FOR IEEE 802.11 FHSS

North America

- Frequency band: 2400-2483.5 MHz
- At most 1 MHz bandwidth (at -20 dB re peak)
- At least 75 hopping channels, pseudorandom hopping pattern
- At most 1 W transmit power and 4 W EIRP (including antenna)

Europe

- Frequency band: 2400-2483.5 MHz
- At least 20 hopping channels
- At most 100 mW EIRP

Japan

- Frequency band: 2471-2497 MHz
- At least 10 hopping channels

ADVANTAGES & DISADVANTAGES OF FHSS OVER DSSS

1. **IEEE 802.11 FHSS provides the following advantages** (in comparison to DSSS):
    1. Greater tolerance of signal interference because of operation over wider (83.5MHz) bandwidth
    2. Capability to operate up to 10 collocated access points without significant interference
2. **IEEE 802.11 FHSS provides the following disadvantages** (in comparison to DSSS):
    a) Lowest potential data rates (2Mbps) from individual physical layers.
    b) Less range than direct sequence because of need for at least 18dB SNR at the receiver.
    c) Potential obsolescence as more companies continue to favour the higher-speed (802.11b) direct sequence products.

802.11 FHSS MODULATION OBJECTIVES

1. Achieving at least 1 Mbit/sec rate.
2. Use familiar, field proven, low cost technology - FSK – Constant Envelope- Saturated Amplifiers – Limiter-Discriminator detection.
3. Support multichannel operation -transmit signal shaping to reduce adjacent channel interference.
4. Use multiple rates - medium use optimization by taking advantage of short-range/good-propagation scenarios to increase rate.

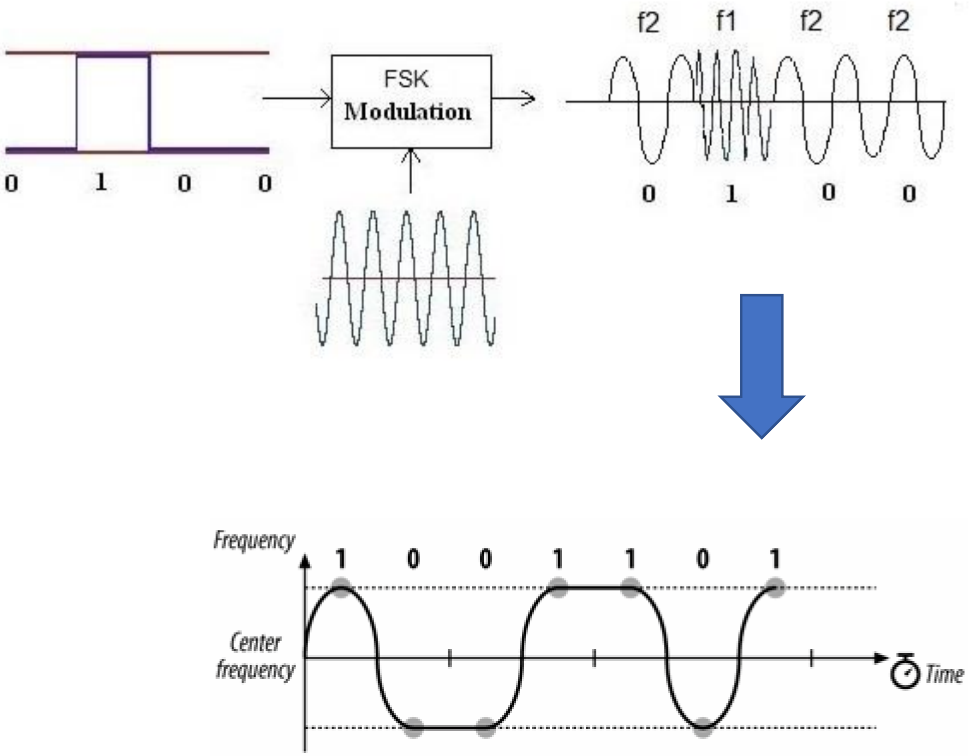
802.11 FHSS MODULATION

Gaussian shaped FSK (GFSK) at $F_{clk} = 1$ Msymbol/sec – NRZ data is filtered with BT=0.5 low-pass Gaussian filter (500 KHz bandwidth at 3 dB) and then FM modulates a carrier

1 or 2 Mbit/sec with multilevel GFSK

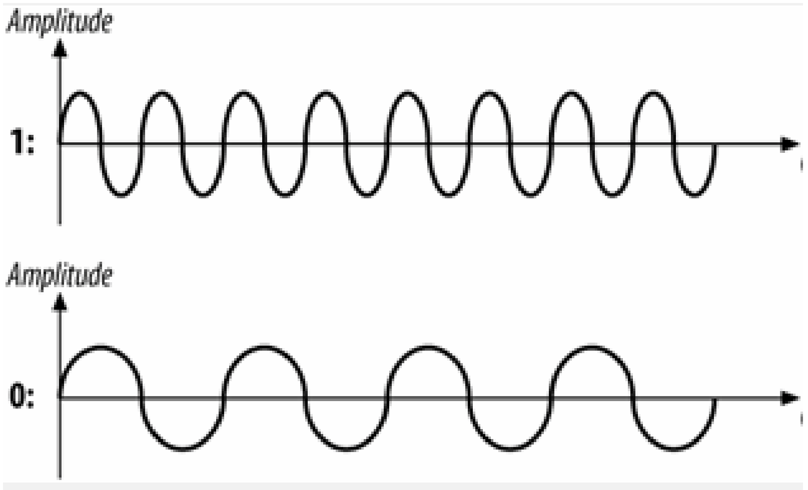
– 1 Mbit/sec: 2 level GFSK h2=0.34

– 2 Mbit/sec: 4 level GFSK h4=0.45h2=0.15



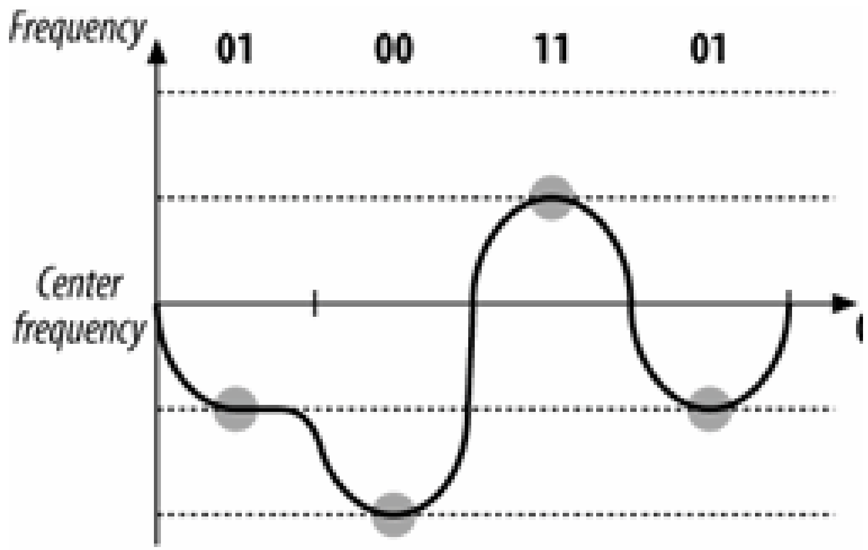
2-LEVEL GFSK

- **Gaussian in GFSK** refers to the shape of radio pulses; GFSK confines emissions to a relatively narrow spectral band and is thus appropriate for secondary uses.
- In 2-level GFSK (2GFSK), two different frequencies are used, depending on whether the data that will be transmitted is a 1 or a 0.
- To transmit a 1, the carrier frequency is increased by a certain deviation. Zero is encoded by decreasing the frequency by the same deviation.



4-LEVEL GFSK

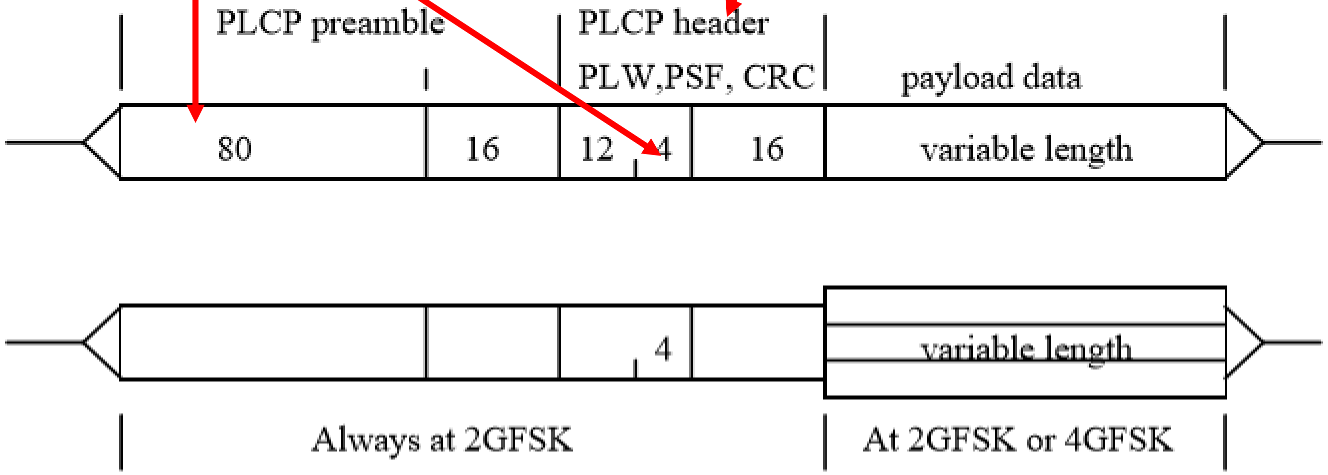
- **4-level GFSK (4GFSK)** uses the same basic approach as 2GFSK but with four symbols instead of two.
- **The four symbols (00, 01, 10, and 11)** each correspond to a discrete frequency, and therefore 4GFSK transmits twice as much data at the same symbol rate.



802.11 FHSS FRAME FORMAT

Preamble and Header
Always at a fixed rate of
1 Mbit/sec;

PHY header
Indicates payload rate
and length; CRC16
protected



Data
Variable speeds at 1 or 2
Mbit/sec

FHSS PLCP PREAMBLE

1. **FHSS PLCP preamble** starts with 80 bits of 0101 sync pattern, used to
   a) detect presence of signal
   b) resolve antenna diversity
   c) acquire symbol timing
2. **FHSS PLCP preamble** follows 16 bit Start Frame Delimiter (SFD) – the pattern is 0000 1100 1011 1101 (left bit transmitted first).
3. **SFD** provides symbol-level frame synchronization
4. **SFD** pattern is designed to optimize autocorrelation properties in conjunction with the 0101 pattern in front of it.

FH PHY SCRAMBLER

- Scrambling is applied just to Data, not to PLCP header
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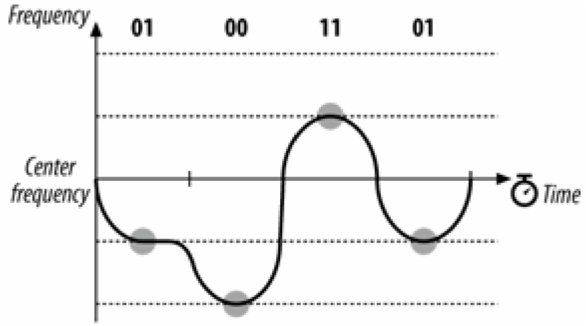
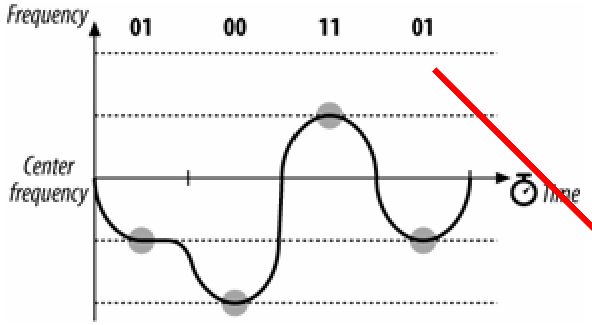
- The same method is used for scrambling and descrambling

BITS TO SYMBOL MAPPING

- 1 bit (with 2GFSK) or 2 bits with (4GFSK) are mapped to a symbol
- at 2 bits/symbol Gray coded mapping is used, as customary with multilevel modulations.
- 2GFSK and 4GFSK have same frequency deviation

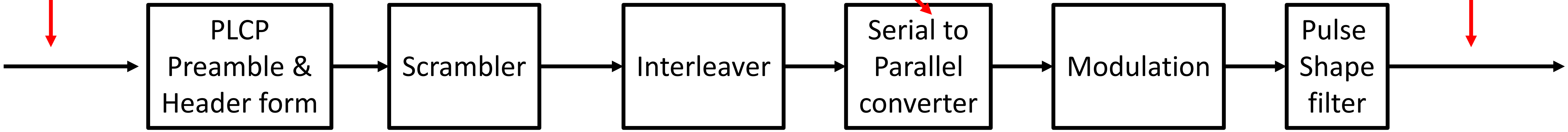


FUNCTION OF SERIAL-PARALLEL CONVERTER



Data from MAC

To RF for up-conversion



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REFERENCES

1. IEEE 802.11 Technical Tutorial
2. IEEE 802.11 – Physical Layer
3. IEEE 802.11 Wireless Local Area Networks – IEEE Communication Magazine
4. A Survey Of Quality Of Service In IEEE 802.11 Networks