Frequency Hopping Spread Spectrum subpart of the 802.11 Wireless LAN Standard

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802.11-FCC Meeting Objectives

To inform FCC about the 802.11 WLAN Standard and its status

To avoid situation in which 802.11 standard is not acceptable by FCC

To get better understanding of what FCC does permit, in order to produce a better standard

Collision Avoidance

The Physical layer (PHY) is able to provide Carrier Detect indication, when not transmitting.

Randomized Inter-Frame Space (IFS) for reducing collision probability

Exponential Backoff is used to stabilize the network when collisions occur

Virtual Carrier Sense mechanism

In radio network, some stations may not hear a transmission from a certain station and therefore collide with it

The RTS-CTS exchange contains timing information that signals other stations for how long the medium will be busy

Virtual Carier Sense mechanism is implemented in the MAC layer

Frequency Hopping Sp.Sp.

Operates according to FCC 15.247 ruling:

- max 1 MHz bandwidth at -20 dB PSD
- hopping over 79 frequencies in a pseudo-random manner
- max 1 Watt power and 36 dBm EIRP

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802.11 FHSS Modulation Objectives

- Achieving at least 1 Mbit/sec rate
 - Low cost/familiar technology FSK
 - Constant Envelope- Saturated Amplifiers
 - Limiter-Discriminator detection
 - Multichannel operation -shaping to reduce adjacent channel interference
- Multiple rates taking advantage of short range scenarios to increase rate

802.11 FHSS Modulation

Gaussian shaped FSK (GFSK)

1 Msymbol/sec

NRZ data is filtered with BT=0.5 Gaussian filter

1 or 2 Mbit/sec with multilevel GFSK

1 Mbit/sec: 2 level GFSK h,=0.34

2 Mbit/sec: 4 level GFSK h₁=0.45h₅=0.15

Preamble and Header always at 1 Mbit/sec; Data at 1 or

2 Mbit/sec

GFSK vs GMSK comparison

GMSK is a binary GFSK with h_2 =0.5

802.11 GFSK is $h_2=0.34$ due to both

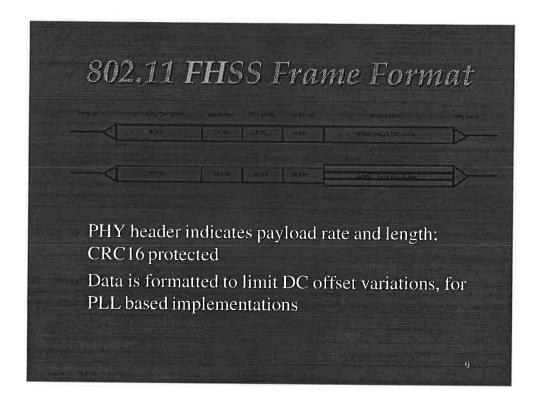
1 Mb/s objective

1 MHz 20 dB bandwidth 15.247 ruling

Results:

Sensitivity reduced by 4-5 dB

Increased first adjacent channel interference



FHSS Modulation Specifications Deviation: Upper bounded by FCC requirements Lower bounded to maintain sensitivity Shape accuracy: Zero crossing instants accuracy Level accuracy Center Frequency accuracy - 60 KHz

Parameter vs. Rate	1 Mb/s	2 Mb/s
Sensitivity	-80 dBm	-75 dBm
Desensitization		
@ 2 Mhz offset	30 dB	20 dB
@ 3 Mhz or more	40 dB	30 dB
Intermodulation	30 dB	25 dB
Protection		

CCA- Clear Channel Assessment

CCA is used to:

- Initiate frame reception
- Avoid transmitting when the channel is busy

CCA Sensitivity:

- -80 dBm for P_T<20 dBm, reduced by 0.5 dB for each dB of power increase
- Detection during 0101 pattern within 20 usec with 95% probability

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Frequency Hopping Sequences

Design Criteria:

Assured minimum hop distance for multipath diversity performance

Minimizing hits and adjacent channel hits between different hopping patterns

Minimizing consecutive hits between different hopping patterns

FCC 15.247 requirement: Pseudorandomly ordered frequency list

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Previous Hopping Sequences

Previous 802.11 hopping sequences were based on constant frequency increment (mod 79).

Had better worst case hit, adjacent hit and consecutive hit performance

Were rejected by FCC as insufficiently pseudorandom (due to constant frequency increment)

New Frequency Hopping Sequences

- Passed FCC approval for BreezeNet
- Predesigned computer generated pseudorandom list of 79 frequencies
- Minimum hop distance of 6 channels
- Additional hopping sequences derived from the base predesigned sequence.
- 78 hopping patterns organized in 3 sets of 26 patterns each.

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New Frequency Hopping Sequences- cont.

- Denote frequency as 2402+b[i], b[i] is the base sequence in range 0.. 78.
- k-th sequence is formed from the base sequence as 2402+(b[i]+k) mod 79
- Example:

Base seq:

2402, 2456, 2472, 2447, ...

30-th seq:

2432, 2407, 2423, 2477, ...

Hopping - Multiple AP's

Unspecified in the standard

System level optimization prefers networkwide hop synchronization

more efficient system - less collisions, less "air usage"

Folklore saya that FCC forbids this. If so, what is the rationale?

What is the truth?

Wish List

Synchronized hopping
Wider channels (Petition by Symbol
Technology

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