Frequency Hopping Spread Spectrum subpart of the 802.11 Wireless LAN Standard

FCC - 802.11 meeting, Jan. 5, 1996

Naftali Chayat
Chief Scientist

1

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

2

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

3

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

4

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

5

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

6

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_2=0.34
  - 2 Mbit/sec: 4 level GFSK h_4=0.45h_2=0.15
  - Preamble and Header always at 1 Mbit/sec; Data at 1 or 2 Mbit/sec

7

GFSK vs GMSK comparison

- GMSK is popular with cellular telephony
- 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

8

802.11 FHSS Frame Format

PHY header indicates payload rate and length; CRC16 protected

Data is formatted to limit DC offset variations, for PLL based implementations

9

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

10

Receiver Performance

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 Protection	30 dB	25 dB

11

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

12

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

13

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)

14

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.

15

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, ...

16

Hopping - Multiple AP's

- Unspecified in the standard
- System level optimization prefers network-wide 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