An overview to regulatory domains

Date: 2007-09-17

Authors:

Name	Affiliations	Address	Phone	email
Guido R. Hiertz	Philips	ComNets, Chair of Communication Networks, RWTH Aachen University, Kopernikusstr. 16, 52074 Aachen, Germany	+49-241-802-5829	hiertz@ieee.org
Dee Denteneer	Philips	Philips, HTC 37, 6515 AE Eindhoven, The Netherlands	+31-40-2749-743	dee.denteneer@philips.com

This version has been edited for publication as PDF file at ComNets, RWTH Aachen University.

Some animations may not be displayed correctly in PDF format.

Please see https://mentor.ieee.org/ for the original version in PowerPoint format.

Abstract

We provide an overview to regulatory domains, regulatory requirements and issues related in 802.11s.

Outline

- **This presentation reviews 802.11-2007 with respect to**
  - Regulatory Domains
  - Dynamic Frequency Selection (DFS)
  - Transmit Power Control (TPC)
  - And all the "other stuff"
    - That national regulatory bodies love so much …
      - Specific requirements on Carrier Sensing
      - Maximum transmission power level
      - Definition of transmission power
        - EIRP vs. peak output

What are regulatory domains?

- **It's all about the wireless medium itself**
  - Frequency bands
  - Licensed & unlicensed usage
  - Signal bandwidth
- **Countries are sovereign on spectrum regulation**
  - International agreements
  - 3 ITU regions
- **It's all about different rules**
  - Outdoor vs. indoor usage
  - Allowed maximum transmission power
    - How to measure the transmission power?
  - Primary and secondary users
  - Requirements on interference mitigation

Example on transmission power

- **Europe**
  - Power levels according to EIRP
  - 19 * 20MHz frequency channels
- **US**
  - Power as radio output
  - 24 * 20MHz frequency channels

Regulatory class	Frequency (MHz)		Europe		US	
	Lower	Upper	dBm	Behavior	dBm	Behavior
1	5170	5250	23	2, 3	16	1, 2
2	5250	5330	23	1, 3, 4	23	1
3	5490	5710	30	1, 3, 4	23	1
4	5735	5815	Not allowed		29	1
5	5815	5835	Not allowed		30	1

802.11 amendments affected

- **802.11a**
- **802.11b**
- **802.11g**
- **802.11h**
- **802.11j**
- **802.11n**
- **802.11p**
- **802.11y**

- **PHY amendments in 802.11 have country specific details**
  - Frequency band
    - 2.4, 3.65, 4.9 & 5 GHz
  - Tx Power
  - Channel spacing
    - 5, 10, 20 & 40MHz
  - CCA sensitivity
  - Maximum transmission duration
  - …

Regulatory elements in 802.11

9.8 Operation across regulatory domains

- **[…] The method for configuring individual stations is outside the scope of this standard. A station must be properly configured for operation in a particular regulatory domain prior to beginning normal operation. Particular care must be taken when operating in an IBSS configuration.**

- **Meaning**
  - The standard is not responsible for the operation of a device
  - The operator himself must ensure regulatory compliant configuration
  - The authors already foresaw that IBSS like networks will not be easy to handle …

Country information element

- **[…] (see 7.3.2.9) allows a STA to configure its PHY and MAC for operation when the regulatory triplet of Regulatory Extension Identifier, Regulatory Class, and Coverage Class fields is present. The regulatory triplet indicates both PHY and MAC configuration characteristics and operational characteristics. The First Channel Number field of subsequent subband triplet(s) is based on the dot11ChannelStartingFactor that is indicated by the Regulatory Class field.**

- **The country specific regulation targets MAC & PHY configuration**
  - MAC parameters may be maximum transmission duration
  - PHY may be output power and frequency band

Required mitigation technologies for secondary channel usage

DFS & TPC

- **Dynamic Frequency Selection**
  - Avoid interference by leaving a frequency channel of a primary user
  - Search for new frequency channel
- **Transmit Power Control**
  - Reduce transmission power and thereby emissions
  - Lower interference on primary user to an acceptable level

Dynamic Frequency Selection (DFS)

- **Currently required in 5GHz band in several countries**
  - Detect radar stations
- **5GHz band provides up to 30dBm signal strength**
  - May be limited to EIRP
  - Outdoor
- **Issues**
  - What to detect?
    - Signal pattern
    - Ignore noise
  - How to detect?
    - Measurements
  - Selection of new frequency channel

DFS in 802.11

- **Single logical entity decides**
  - Centralized approach
  - AP in BSS
  - "DFS owner" in IBSS
    - First device to set-up the network
    - When generating beacons, other STAs copy values from initiator
- **Strict hierarchy**
  - No distributed concept described

DFS: Current situation

- **Primary users complain about current implementation**
  - Existing devices do not reliably detect primary users
  - WLAN accused to interfere
- **Some regulatory bodies discuss further requirements**
  - Appropriateness of current scheme questioned
- **Discussion in Wi-Fi Alliance (WFA)**
  - WFA will reply to regulatory bodies
  - Defend existing frequency bands
  - Adopt technology to changing requirements

Transmit Power Control (TPC)

- **Currently required in 5GHz band in several countries**
  - Satellite uplink
- **Define maximum transmit power level**
  - May dynamically adopt level

- **Issues**
  - What to detect?
    - Signal pattern
    - Ignore noise
  - How to detect?
    - Measurements
  - Selection of maximum allowed transmit power
    - Impacts network topology

TPC in 802.11

- **Single logical entity decides**
  - Centralized approach
  - AP in BSS
  - Settings of initiator of IBSS determine maximum
- **Strict hierarchy**
  - Solely AP decicdes
  - IBSS settings cannot be changed during lifetime
    - Network would need to be restarted

TPC: Current situation

- **Link margin often not exploited**
  - Regulatory limits plus safety margin applied
- **TPC in IBSS is static**
  - No changes during lifetime
  - Conservative settings
- **No distributed solution available**
  - TPC impacts range and thus topology

11.8.2 Specification of regulatory and local maximum transmit power levels

- **[…] The regulatory and local maximum transmit powers may change in a STA during the life of a BSS. However, network stability should be considered when deciding how often or by how much these maximums are changed. The regulatory and local maximum transmit powers shall not change during the life of an IBSS.**

- **Transmit power influences**
  - Reception range
  - Interference to neighors
  - SINR @ receiver
    - Relates to usable Modulation and Coding Scheme (MCS)
- **Mesh networks depend on path selection**
  - Path selection depends on link metrics
    - Link metrics depend on link characteristics (speed, PER …)
- **Stability in a mesh network may be severely affected by changing transmission power**
- **The IBSS procedures may not be sufficient for 802.11s**

11.8.2 Specification of regulatory and local maximum transmit power levels

- **A STA shall determine a regulatory maximum transmit power for the current channel. The STA shall use the minimum of the following:**
  - Any regulatory maximum transmit power received in a Country element from the AP in its BSS or another STA in its IBSS and
  - Any regulatory maximum transmit power for the channel in the current regulatory domain known by the STA from other sources.

- **802.11 describes most simple (conservative) approach**
  - Always use lowest transmission power
    - Affects connectivity
    - Flexibility & dynamic changes in maximum transmit power may lead to unpredictable behaviors
  - To be discussed if IBSS like behavior is sufficient
    - Single transmission power threshold at the time the mesh was joined

802.11 hierarchical design

Strict hierarchy

- **Command & Order**
  - AP rules the Basic Service Set
    - Single administrative entity
    - In an IBSS, the DFS owner takes over the AP's role
  - STAs follow AP's instruction

802.11s design

No hierarchy

- **802.11s has no central coordination instance**
  - Distributed topology
    - Safe against single point of failure
    - Difficult to handle when global procedures must be enforced
  - Devices operate autonomously
- **Common behavior/protocols needed to achieve consistent operation**
  - Global instructions must be flooded to all devices

Impact on 802.11s

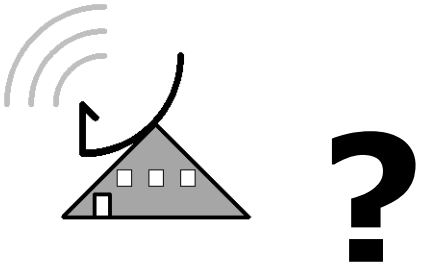
- **Mesh networks may cover large areas**
  - Message propagation takes time
    - Depends on traffic conditions
- **No single control entity**
- **Each MP has a different radio neighborhood!**
  - Radio conditions vary
  - A global optimum requires local compromises

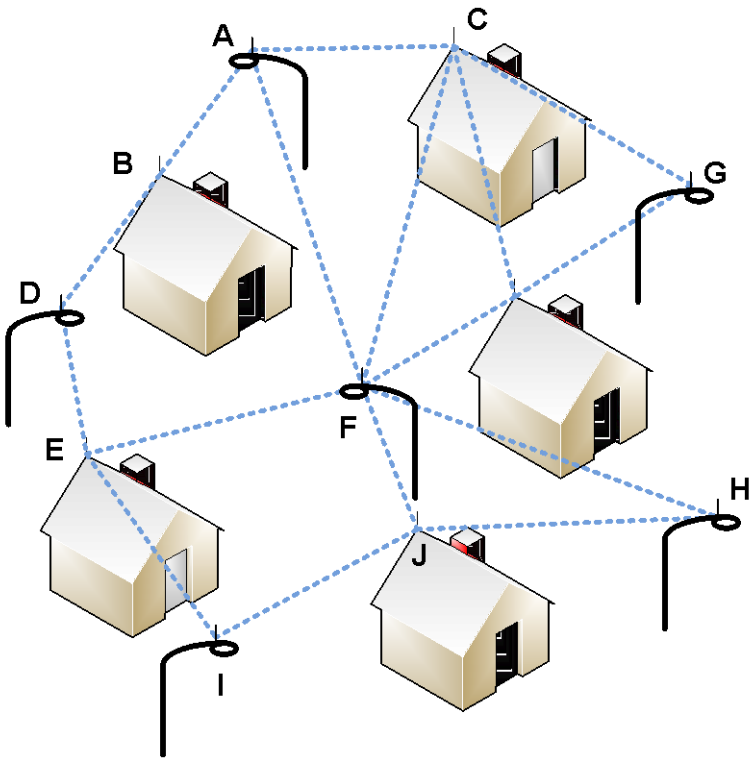
- **No two MPs have the same radio environment!**
  - Different location
  - Different WLAN chipsets
    - MAC, PHY, RF frontend
    - Tolerance in manufacturing
    - …

Example 1

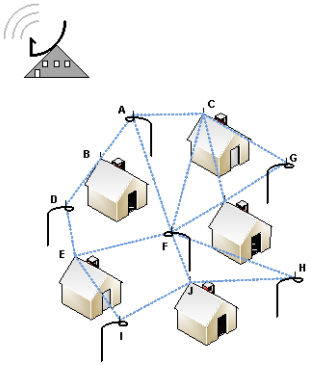
Mesh detects radar

- **MP A may detect radar**
  - A enforced to change frequency channel
- **What shall the Mesh do?**
  - Ignore A?
  - All MPs change frequency channel?
    - Assume single radio





"Radar story" continued



- **Assume MP A is the only one that interferes at the radar station**
  - Rest of Mesh could proceed to use the frequency channel
    - Radar operator will not complain
  - No need for others to switch
    - MP A disconnected
- **Can the Mesh trus A's report on radar detection?**
  - Other MPs may not be able to detect the radar due to a different location
  - A failure in MP A's report could be severe for the whole Mesh
    - Frequent switching
    - Stability?

Actions on radar detection

- **Assume total Mesh switches frequency channel**
  - Which new frequency channel to choose?
    - Is the Channel Graph switch protocol sufficient?
  - How to propagate in network?
    - What if MPs are in doze mode?
    - How long to wait before switch?
      - See next slides
    - How long does it take to propagate the message?
      - See next slides
    - Propagate as broadcast?
      - Possible according to D1.06
    - Propagate as unicast?
      - Possible according to D1.06
      - Whom to acknowledge?
- **Assume Mesh remains on frequency channel**
  - MP A must stop operation
  - MP A becomes excluded from network
  - What if MP A connects separate parts of the Mesh?
    - Mesh may partition
  - Is there sufficient time for MP A to say “goodbye”?
    - Peer links may be shut down

11.9.7.2 Selecting and advertising a new channel in a mesh

- **If an MP detects the need to switch the channel of a PHY (e.g., due to regulatory requirement for radar avoidance), the MP shall attempt to inform peer MPs to which a mesh link has been established on the PHY of the need to channel switch. Once the MP identifies the candidate channel to switch its PHY to, it creates a new candidate channel precedence indicator value by adding a pseudo-random number to the current channel precedence value. The random value shall be in the range 0 to 8191 inclusive. The random value shall be selected in a manner that minimizes the probability of MPs generating the same number, even when those MPs are subjected to the same initial conditions. It is important that designers recognize the need for statistical independence among the random number streams among MPs. The MP then executes the UCG switch procedure described in 11A.3.3.**

- **Is that description sufficient for TGs?**
  - "[…] shall attempt to inform […]" is more than vague
    - What about "[…] hopefully does inform […]"?
  - There is no mechanism to limit the rate of frequency channel changes
    - Different MPs may have different DFS requirements
      - Location and radar neighbors may differ
      - Different frequency channels may be available

11A.3.3 Channel graph switch protocol

- **[…] The MP first chooses a Mesh Channel Switch wait time in the range from 0 to 255, representing the time (in TUs) until the MP switches to the new channel. […]**

- **After announcement the MP will leave a frequency channel very quickly**
  - 255 * TU = 261,120µs = 0.26112s
- **Announcement needs to propagate in Mesh**
  - Duration [(Mean Backoff + Mesh Channel Switch Announcement Action Frame + SIFS + ACK) @ BPSK ½] = 253.5µs
    - Sufficient duration to inform whole Mesh?

Example 2

A typical IEEE meeting

Hi, I am from Britain.

Hi, I am from The Netherlands. Last time I was turned on, I connected to a Canadian AP.

1 Million Dollar question: Where is the meeting room?

Hi, I am from the Germany. When I went to doze state, I was connected to a Danish AP.

Japanese AP.

Hi, I am from the US. Last time I was turned on, I connected to a Mexican AP

Consequences for 802.11s

- **Regulatory domains need location information**
  - Administrator, user, operator provides input
    - A device cannot detect its environment without additional help
  - Ad hoc mesh networks may have entities that report different regulatory requirements
- **Currently, a single entity may bring down the whole mesh**
  - 802.11 uses minimum of several input values
  - A joining device may propagate new maximum transmit power levels
  - With different transmit power levels, available MCSs may change
  - Connectivity may change
    - Topology changes

Homework for TGs

Questions to 802.11 TGs (1)

- **Are we responsible?**
  - Shall TGs define means for DFS & TPC?
  - Is there a global 802.11 procedure or do we need to define specific 802.11s procedures?

- **Changing the term Mesh Point to Mesh Station may be sufficient to refer to 802.11 procedures for STAs**
- **Do we have requirements different than 802.11?**

Questions to 802.11 TGs (2)

- **Do we need to define a mandatory behavior for DFS & TPC?**
  - Stability is an important goal
    - Difficult to achieve
  - Mesh network should not be inherently likely to collapse due to regulatory requirements

- **The current 802.11 procedures for DFS & TPC for IBSSs are almost useless**
- **A mesh substantially differs from an IBSS**
  - Devices are not necessarily in mutual range

Questions to 802.11 TGs (3)

- **Shall TGs amend the 802.11 regulatory elements?**
  - Regulatory bodies deal with physical emissions to frequency channels
  - Regulatory bodies do not consider "logical" deployment concepts

- **There are no specific regulations for networks**
  - Regulatory bodies address the operator of devices
  - Mesh networks may consist of devices under control of several operators
    - Is it TGs' responsibility to consider such deployments?

Questions to 802.11 TGs (4)

- **How to propagate a single set of regulatory parameters throughout whole Mesh network?**
  - With different parameters, the network may become instable

- **Extremely important**
- **Solution may fit other TGs problems too**
  - EDCA parameter set propagation
    - Mesh wide AIFSN(AC), CWmin(AC), CWmax(AC), TXOP Limit(AC)
  - Short/Long retry counters settings
  - Synchronization
  - Mesh Channel Switch Announcement

References

- IEEE Std 802.11-2007
- IEEE P802.11s/D1.06