IEEE P802.19
Wireless Coexistence

Proposal of decision-making algorithm

Date: 2011-07-13

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Abstract

The document proposes a coexistence decision making algorithm in management services for CM to provide necessary reconfiguration commands to TVBD network or devices. It may also apply in information service with some modifications for TVBD network or devices to make its own coexistence decision.

Introduction

Coexistence decision making algorithm is focused on providing necessary reconfiguration commands for a TVBD network or devices. In short we will use the term network for TVBD network or device. According to current system any change in the environment can trigger the decision making algorithm. Therefore it is important to select which network to optimize. Flowchart of coexistence decision making algorithm is provided below:

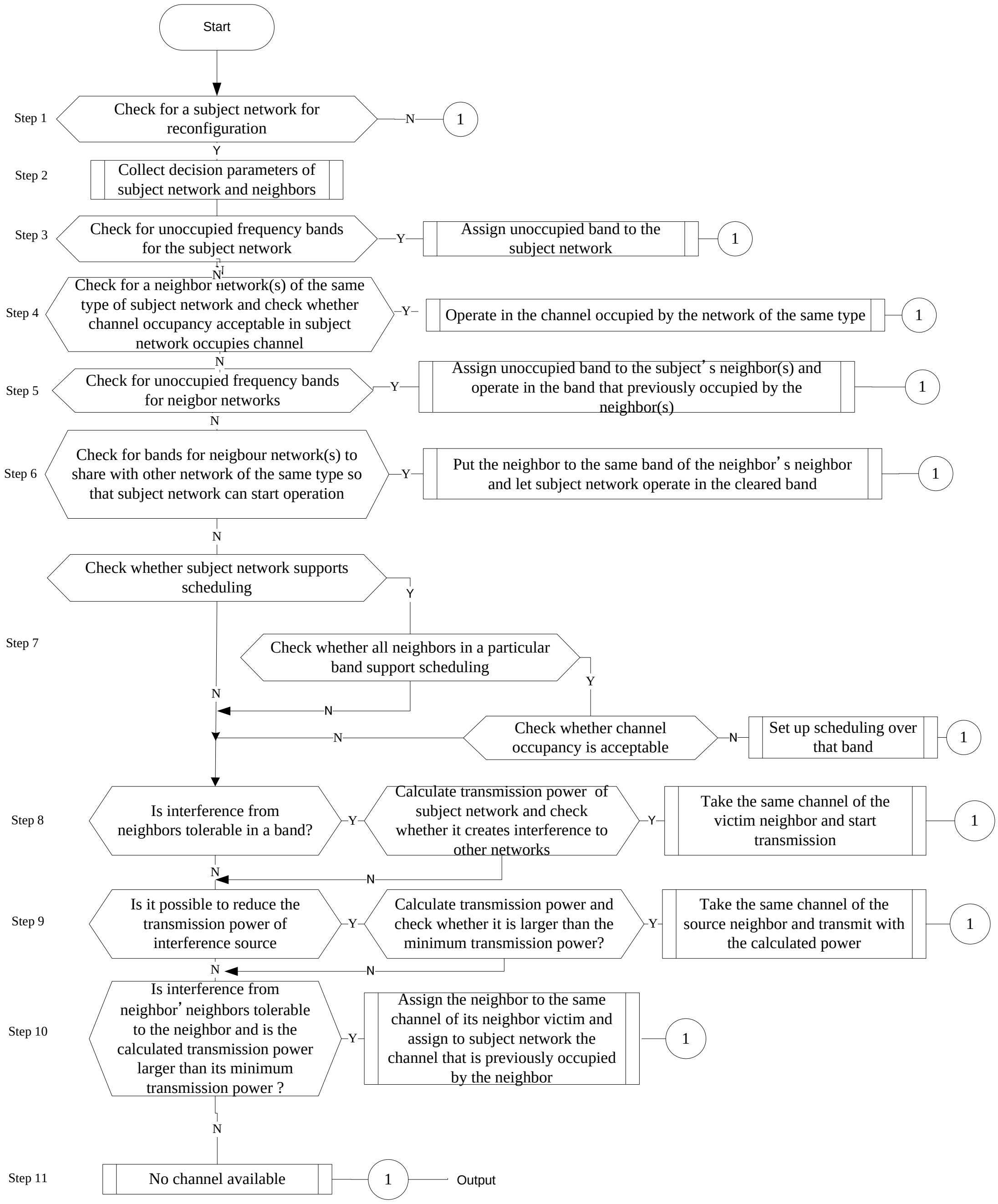

Figure 1 Coexistence Decision making algorithm flowchart

General decision making levels

There are totally 3 levels for decision making as shown in Figure 2. The first level decision making only impacts the subject network. The second level decision making impact both the subject network and some of its neighbors. The third level decision impact the subject network, its neighbors and the neighbors' neighbors. Considering the possible protocol overhead, only 3 levels are limited. In general, we follow one rule: affect as few as possible networks so that any decision may not trigger a big decision making propagation.

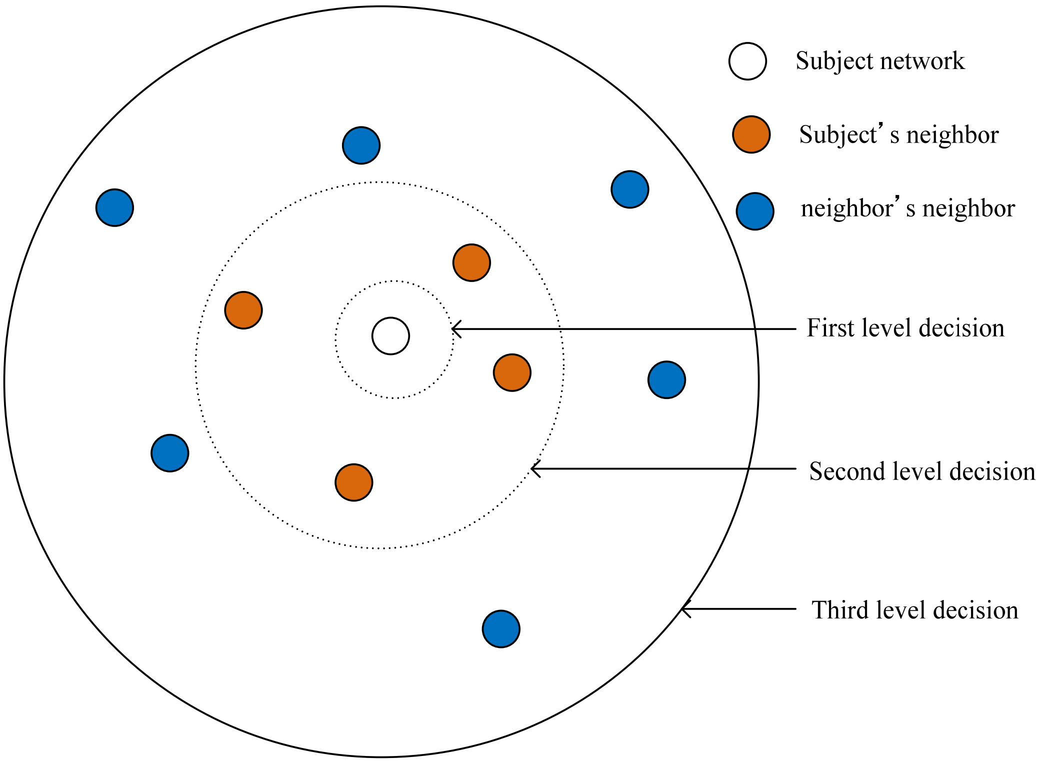

Figure 2: Decision making level

Input parameters for coexistence decision making algorithm

Below list includes decision parameters.

Obtain for subject network and neigbouring networks	
Network ID	
Network Technology	11af, 22
Repeat for each available frequency band of the network	
Start Frequency	
Stop Frequency	
ChannelFlag	Operating band or support band
Maximum transmit power over this frequency band	
Interference margin	defines as amount of interference that a device tolerates above the noise level from another device at a receiver input
Transmit power requirement	The minimum transmit power to achieve required transmission rate.
Status	Free, occupied known, occupied unknown, not measured
Occupancy	If currently operating in this band real occupancy at the moment, if not it is required occupancy to operate
Total Occupancy	Current total occupancy of the frequency band by neighbors
Total Interference level from neighbors	
Repeat for each of neighbor operating in this frequency band	
Network ID	
Network Technology	
Start frequency	
Stop frequency	
Coexistence status	Exclusive use, share with the network of the same type, share with transmit power reduction, share with interfere power reduction, using schedule,
Occupancy	
Possible Interference level to subject network	
Possible Interference level from subject network	
Total Interference level from other neighbors	
Interference margin	
Transmit power requirement	
Status	
Neighbor Networks Support frequency band	
Schedule support	

Detailed explanation of the algorithm steps

Step 1: If subject network is not specified, first step of the system analyzes the environment and selects the subject network among possible TVBD networks or devices to reconfigure. TVBD network or device with the minimum allocated resource percentage is chosen. The allocated resource percentage is defined as the resource that a TVBD network or device is allocated vs. the resource that a TVBD network or device expects.

Step 2: Parameters of coexistence decision making for the subject network and its neighbors are collected. Parameters include the list of subject network and the subject's neighbors.

Step 3: The third step of the algorithm is to find unoccupied frequency bands for subject network:

- According to available frequency bands, find frequency bands of subject network whose status are marked as "Free " $\mathrm{Ch} = \{\arg_i \mathrm{Status}_i = \text{"Free"} \mid i \in \mathrm{Int}, 1 \le i \le \#\text{of supported frequency bands}\}$
- Within all free frequency bands, find a frequency band with minimum "maximum power limitation" which are larger than the "transmit power requirement" of the subject network.

  $\mathrm{I} = \{\arg_i \min_i(\mathrm{PT}_i^{max} \ge \mathrm{PT}^{req}) \mid i \in \mathrm{Ch},\ 1 \le i \le \#\text{of supported freqency bands}\}$, where PT_i^{max} is the "maximum power limitation" for frequency band i.
- If no frequency band is available ($\mathrm{I} = \emptyset$,) go to step 4.
- If $\mathrm{I} \neq \emptyset$, assign the first available frequency band to subject network.

Step 4: System searches for a frequency band which is occupied by the network of the same type of the subject network

- Find among available frequency bands whose statuses are marked as "Occupied known" and check "Network Technology" and find the networks of the same type to the subject network. System should also check for power requirements.

  $$\mathrm{Ch} = \{\arg_i(\mathrm{Status}_i = \text{"Occupied known"}\ \&\text{NetTech} = \text{Type of subject network}\ \&(\mathrm{PT}_i^{max} \ge \mathrm{PT}^{req})) \mid i \in \mathrm{Int}, 1 \le i \le \#\text{of supported frequency bands}\}$$
- Check "Total occupancy" of those frequency bands, and find frequency bands with the remained frequency band occupancy is larger than the required load of subject network. . $\mathrm{I} = \{\arg_i \min_i((1 - \mathrm{O}_i^{Total} - \mathrm{O}_A^{Req})) \mid i \in \mathrm{Ch}\ \&\ (1 - \mathrm{O}_i^{Total} - \mathrm{O}_A^{Req}) > 0\}$, where O_i^{Total} is the total occupancy of frequency band, O_A^{Req} is the required frequency band load of network A.
- If no frequency band is available ($\mathrm{I} = \emptyset$,) go to step 5.

- If $I \neq \emptyset$, assign the first available frequency band to subject network.

Step 5: System searches for possible unoccupied frequency bands for neighbours of the subject network and checking if subject network can occupy current channel of the neighbor.

According to available frequency bands, find frequency bands of subject network whose status are marked as "Occupied known and there power limitations are supported " $I = \{\arg_i \text{Status}_i = \text{"Occupied known"} \ \& \ (PT_i^{max} \geq PT^{req}) \mid i \in Int, 1 \leq i \leq \#\text{of supported frequency bands}\}$, where PT_i^{max} is the "maximum power limitation" for frequency band i.

- Among those bands check if the neigbour networks has free available channels in which their power limitations are met, if they have, Assign those neighbors to new band and assign the subject network to their frequency band.
- If no frequency band can be cleared for subject network go to step 6.

Step 6: System check for frequency bands which are occupied by the neigbours of neigbour networks of the same types of neighbour network and checking if neighbor network can move that band

- According to available frequency bands , find frequency bands of subject network whose status are marked as "Occupied known and there power limitations are supported " $I = \{\arg_i \text{Status}_i = \text{"Occupied known"} \ \& \ (PT_i^{max} \geq PT^{req}) \mid i \in Int, 1 \leq i \leq \#\text{of supported frequency bands}\}$
- Among those bands check if the neigbour networks has available channels in which their power limitations are met, which is occupied by the same type of neigbours.
- Check "Total occupancy" of those frequency bands, and find frequency bands with the remained frequency band occupancy is larger than the required load of neigbour network.
- If no frequency band can be cleared for subject network go to step 5.
- If not, find the available frequency band in which mimimum number of neighbours is moved. Assign those neighbors to new band and assign the subject network to their frequency band.

Step 7: System checks whether subject network can support scheduling.

- If no go to step 8
- If yes, check whether all neighbours in an available band which enables subject network to use its full power supports scheduling with the subject network.
- Check "Total occupancy" of those frequency bands, and find frequency bands with the remained frequency band occupancy is larger than the required load of subject network.
- If yes, assign the subject network to the band with the highest occupancy.

- If no band can be found with enough remaining occupancy, check if occupancy loads can be reduced in the remaning bands.
- If yes assign the subject network to first available band.
- If not go to step 8.

Step 8: System checks if interference from interference source neighbors is tolerable for subject network.

- Within all free frequency bands, find a frequency band with minimum "maximum power limitation" which are larger than the "transmit power requirement" of the subject network. $I = \{\arg_i \min_i (PT_i^{max} \geq PT^{req}) \mid i \in \mathrm{Ch},\ 1 \leq i \leq \#\text{of available freqency bands}\}$, where PT_i^{max} is the"maximum power limitation" for frequency band i.
- Determine the received interference for each frequency band by summing up all interference from all networks in that frequency band

$$\{IR_i = \sum_{j=1}^{\max} IR_{ij} \mid 1 \in \mathrm{I}, 1 \leq \mathrm{j} \leq \#\ of\ networks\ \}$$

  Check whether the interference is tolerable for subject network, where IR^{Tol} is the maximum tolerable interference for network A. $\{IR_i \leq IR^{Tol} \mid i \in I\} \neq \emptyset$. If there is no frequency band with tolerable interference, terminate this algorithm and go to Step 9. Otherwise perform the following steps.
- Calculate possible maximum transmit power for each of links = Pathloss + Interference margin, that is, $PT_{ij} = PL_{ij} + IT_{ij}$ where PT_{ij} is the transmit power calculated based on the interference IT_{ij} to network j at frequency band i. PL_{ij} is the path loss between network j and subject network A in frequency band i. After calculation, we have a set $\{PT_{ij} \mid i \in I, 1 \leq i \leq \#\text{ of networks }\}$.
- Determine the transmit power for each frequency band by selecting the minimum one over j in order to avoid interference for other networks in the same frequency band.

$$\{PT_i = \min_j (PT_{ij}) \mid i \in I, 1 \leq j \leq \#\text{ of networks }\}$$

- Determine the frequency band number where the transmit power is larger than transmit power requirement PT^{Req}.
  $\tilde{I} = \{i = \arg_i (PT_i > PT^{Req}) \mid i \in I\}$. If $\tilde{I} = \emptyset$, terminate this algorithm and go to step 9. Otherwise perform the following steps
- Determine the frequency band and power by selecting frequency band with lowest inference
  $\{k = \arg_i \min_i \{IR_i\} \mid i \in \tilde{I}\ \}$, transmit power is PT_k

Step 9: System checks if interference from interference source neighbors can be reduced to a tolerable level for subject network.

- Within all free frequency bands, find a frequency band with minimum "maximum power limitation" which are larger than the "transmit power requirement" of the subject network. $I = \{\arg_i \min_i (PT_i^{max} \geq PT^{req}) \mid i \in Ch,\ 1 \leq i \leq \#\text{of available freqency bands}\}$, where PT_i^{max} is the "maximum power limitation" for frequency band i.

- Check whether added interference from subject network is tolerable for neigbour networks, if no, go to 10, if Yes perform the following operation
- Check whether any of the neighbors can reduce its power in those bands, recalculate the interference power to the subject network and the new interference margin of the neighbor networks. If it is tolerable for both subject network and neigbour networks, assign the band to the subject network and set the new power values for neighbours. If not go to step 10.

Step 10: CM checks if a frequency band can be allocated to subject network by finding another band for the neigbour networks in which the interference is tolerable.

- Within all free frequency bands, find a frequency band with minimum "maximum power limitation" which are larger than the "transmit power requirement" of the subject network. $I = \{\arg_i \min_i (PT_i^{max} \geq PT^{req}) \mid i \in Ch,\ 1 \leq i \leq \#\text{of available freqency bands}\}$, where PT_i^{max} is the"maximum power limitation" for frequency band i.
- Check if enough networks in a band can be moved to another band until the interference level is tolerable for the subject network.
- If interference from subject network is tolerable to remaining networks in the band, assign neighbor networks to new channels and subject network to the available channel. If not go to step 11.

Step 11: If all steps fail indicate that no channel is available.

Output of decision making algorithm

Coexistence status	
OperatingFrequency	StartFeq, StopFreq
Transmit PowerLimit	
Transmission schedule	
Synchronizing point (GPS time)	Negotiation between CMs if necessary
NumberOfScheduleRepetitions	
Schedule Repetition period	
Following parameters repeat for CMs	
ScheduleStartTime	
ScheduleDuration	
The following parameters repeat for networks	Controlled by one CM
TransmissionStartTime for a network	
TransmissionDuration for a network	

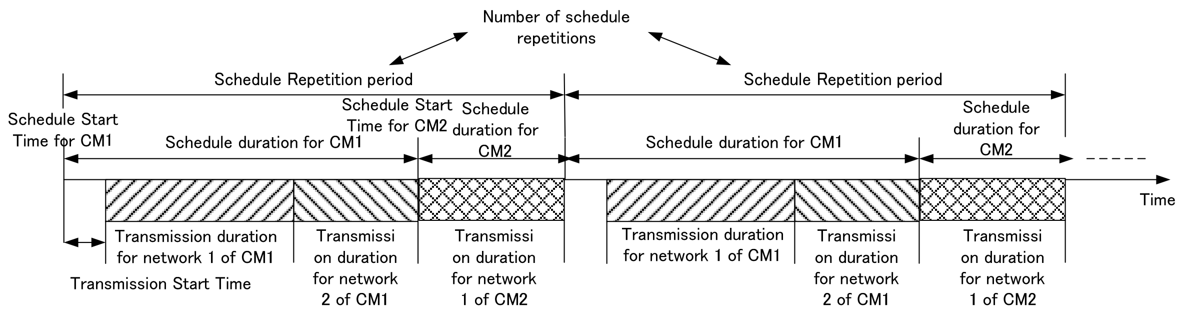

Figure 3 Scheduling

- Transmission start time and transmission duration is specified by a CM. One transmission duration is scheduled for one network.
- Schedule start time and schedule duration is decided by CM negotiation. One schedule duration is scheduled for one CM.
- Schedule repetition period is decided by CM negotiation. One schedule repetition period is shared by several CMs.