IEEE 802.19 Wireless Coexistence Working Group

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<td>Date Submitted</td>
<td>January 17, 2011</td>
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Re:

Abstract
Proposal for Coexistence Mechanisms and Algorithms clause

Purpose
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7 Coexistence mechanisms and algorithms

7.1 General description

Coexistence mechanisms and algorithms shall enable coexistence among dissimilar or independently operated TVBD networks and dissimilar TVBDs. There are two coexistence problems to be solved related to TV channel use. One is how to allocate a proper operating channel to each TVBD or TVBD network regarding its neighbor TVBD or TVBD network. The other is how to share the same channel if two or more TVBDs or TVBD networks have the same operating channel. Regarding this, two mechanisms and algorithms are considered as the following:

- Operating channel allocation mechanism and algorithm
- Co-channel sharing mechanism and algorithm

7.2 Operating channel allocation mechanism and algorithm

After the interface setup as defined in section 6.1 has been done between two entities, each entity starts its operating stage. Each entity at operating stage is described by a number of designated procedures and events that triggers them. During its operating stage, CM, CE, and CDIS shall interactively operate to allocate an operating channel to each TVBD or TVBD network.

7.2.1 CM Operation

Figure 1 describes coexistence manager operating procedures that define a specific event and designated procedure triggered by it. At first the CM shall conduct channel classification to prepare channel allocation to its registered CEs. After that, the CM shall perform channel allocation based on channel classification and other aspects such as TVWS DB update, registered CE discovery update, neighbor CM discovery update, and registered CE’s channel move request and so on. Main operating procedures of the CM consist of two parts: Channel classification and channel allocation. Including these, operating procedures of coexistence manager are as follows:

- CM_Channel_Classification
- CM_Channel_Allocation
- CM_TVWS_Channel_Update
- CM_Registered_CE_Discovery
- CM_Registered_CE_Discovery_Update
- CM_Neighbor_CM_Discovery
- CM_Neighbor_CM_Discovery_Update
- CM_Initiate_Registered_CE_Channel_Move
- CM_Initiate_Channel_Reallocation
- CM_Channel_Identification
- CM_Inform_Event

The procedure CM_Channel_Classification is triggered if flag ‘Initiate_Channel_Classification’ is set to be 1. This flag is set to be 1 if the CM has been initialized after power on or TVWS channels from TVWS DB have been updated. As depicted in figure 2, the CM firstly executes the procedure CM_Registered_CE_Discovery in order to find out context information of registered CEs belong to the CM. After getting context information from registered CEs, the CM accesses TVWS DB to get the list of allowed channels such as the available channel and the restricted channel that can be used by TVBD networks or devices. To do that, the CM might send FCC identifier of each TVBD as required by FCC.
regulation. In case, TVWS DB is not available within a certain time limit, the CM requests each registered CE to send disconnection request to the CM.

After getting available or restricted channel lists from TVWS DB, the CM executes the procedure CM_Neighbor_CM_Discovery to get context information of neighbor CMs from the CDIS.

Once neighbor CM discovery is accomplished, the CM executes the procedure CM_Channel_Identification as depicted in figure 3. Through this procedure, the CM shall identify the available channel, the restricted channel, the operating channel already taken by the registered CE of the neighbor CM among allowed channels from TVWS DB.

The CM finally sets flag ‘Initiate_Channel_Allocation’ to be 1, in order to trigger the procedure CM_Channel_Allocation.

The procedure CM_Channel_Allocation is triggered if flag ‘Initiate_Channel_Allocation’ is set to be 1. This flag is set to be 1 if the following occurs:
- If the CM has done the procedure CM_Channel_Classification
- If the neighbor CM discovery has been updated
- If the registered CE discovery has been updated
- If the registered CE requests channel move and there are no available channels or restricted channels to allocate

As shown in figure 4, the CM firstly checks if Timer $T_{\text{Refresh TVWS DB}}$ is expired. If it is expired, the CM executes the procedure CM_TVWS_Channel_Update. If not, the CM enters the channel allocation process and checks current channel classification.

Based on current channel classification, the CM shall decide if individual channel assignment is possible for all registered CEs considering its neighbor CM. If possible, i.e., in individual channel assignment mode, the CM allocates an exclusive operating channel to each registered CE and sends reconfiguration request to registered CEs. If a registered CE does not accept the CM’s reconfiguration request, the CM discards that registered CEs. The CM updates channel classification again to reflect channel allocation, and sets flag ‘Initiate_Registered_CM_Channel_Classification_Discovery’ to be 1. Finally the CM sends context Information to CDIS.

If individual channel assignment mode is not possible, the CM enters co-channel sharing mode and shall apply a proper operating channel selection algorithm and a co-channel sharing mechanism to each registered CE. Negotiation might be needed if a negotiation with its neighbor CM is needed. An operating channel selection algorithm for the CM is shown in figure 5.

The procedure CM_TVWS_Channel_Update is periodically executed during the CM operation. If TVWS DB is updated, the CM executes the procedure CM_Initiate_Channel_Reallocation notifying channel shutdown to all registered CEs, and goes back to the procedure CM_Channel_Classification. In case, TVWS DB is not available within a certain time limit, the CM notifies shutdown of all operating channels to all registered CEs, and requests each registered CE to send disconnection request to the CM.

The procedure CM_Registered_CE_Discovery_Update is triggered if registered CE list of the CM has been changed. Through this procedure the CM executes the procedure CM_Regisetered_CE_Discovery and the procedure CM_Channel_Allocation one by one.

The procedure CM_Neighbor_CM_Discovery_Update is triggered if neighbor CM list has been changed. The CM executes the procedure CM_Neighbor_CM_Discovery and the procedure CM_Channel_Allocation by turns.

The procedure CM_Initiate_Registered_CE_Channel_Move is triggered if a registered CE of the CM requests channel move due to failure of required quality of service (QoS) with allocated operating channel
from the CM. As depicted in figure 6 the CM shall allocate a new operating channel to the CE requesting channel move if there are available channels or restricted channels. After that the CM shall update channel classification, and send context information to the CDIS. If there are no available channels or restricted channels to allocate, the CM shall set flag ‘Initiate_Channel_Allocation’ to be 1 and execute the procedure CM_Channel_Allocation.

The procedure CM_Inform_Event is triggered if the CM detected an event that should inform to the CDIS or its neighbor CMs. The specific procedure and message with contents are presented in Section 6.2.9 for procedure and Section 6.3.8.5, Section 6.3.8.6, Section 6.3.8.7, and 6.3.8.8 for message, respectively.

![CM operating procedures](image)
Figure 2 Procedure CM_Channel_Classification
Figure 3  Procedure CM_Channel_Identification
Start

Is Timer \( T_{\text{Refresh TVWS}} \) expired?

Yes

Execute Procedure CM_TVWS_Channel_Update

Return

No

Reset Flag "Initiate Channel Allocation" to 0

Check current channel classification

Individual Channel Assignment Mode?

Yes

Allocate an exclusive operating channel to each registered CE

Send Reconfiguration Request to registered CEs

Is reconfiguration successful for each registered CE?

Yes

Discard registered CEs that fail to accept reconfiguration command

No

Update channel classification

Set Flag "Initiate Registered CM_Channel_Classification_Discovery" to 1 and Send Context Information to CDIS

Return

No

Is a negotiation with neighbor CM needed?

Yes

Execute Negotiation Policy and Update channel classification

Execute Channel Selection and Determine Channel Sharing Mechanism for registered CEs

Figure 4  Procedure CM_Channel_Allocation
Figure 5  Operating channel selection algorithm
7.2.2 CE operation

Figure 7 describes coexistence enabler operating procedures that define a specific event and designated procedure triggered by it. Operating procedures of coexistence manager are as follows:

- CE_Inform_Context_Information
- CE_Request_Channel_Move
- CE_Inform_Event
- CE_TVBD_Reconfiguration

The procedure CE_Inform_Context_Information is triggered if the CE receives context information request from the CM. The main purpose of this procedure is to provide the fundamental information of the corresponding TVBD to the CM. When this procedure is triggered, the CE sends the fundamental information to the CM. The considered fundamental information of the TVBD is TVBD type, TVBD network type and TVBD geolocation, etc. The specific procedure and message with contents are presented in Section 6.2.3 for procedure and Section 6.3.2.3 and 6.3.2.4 for message, respectively.

The procedure CE_Request_Channel_Move is triggered if the CE detects failure of required quality of service (QoS) with allocated operating channel from the CM. The main purpose of this procedure is to request a new operating channel of the CE to the CM. This procedure is implemented by notifying the TVBD QoS change event of the corresponding CE to the CM where the TVBD QoS change event is triggered when QoS of the corresponding TVBD is degraded under the required reliability. Through this procedure, the CE shall request a new operating channel to the CM. The specific procedure and message
The procedure CE_Inform_Event is triggered if the CE event is occurred. This procedure is used to notify the detected event of the corresponding CE to CM, which gives effect on the neighbor discovery. Then, when this procedure is triggered, the CE informs the detected events to the CM. As a reported CE, we consider TVBD QoS change, TVBD geolocation change and TVBD coverage change events. As mentioned above, through the TVBD QoS change event, the CE requests a new operating channel to the CM. Further, because of having effects on the neighbor discovery, TVBD geolocation and overage change events are considered as a reported CE event. The specific procedure and message with contents are presented in Section 6.2.9 for procedure and Section 6.3.8.1 and 6.3.8.2 for message, respectively.

The procedure CE_TVBD_Reconfiguration is triggered if the CE receives reconfiguration request from the CM. Through this procedure the CE shall reconfigure TVBD as the CM requested where the considered reconfiguration parameters are coexistence mode, channel classification list and service duration, etc. The CE shall check the validity of allocated operating channel from the CM by asking TVWS DB. After then, the CE gives the reconfiguration response which provides the status information whether the corresponding reconfiguration parameter from the CM is accepted or not. The specific procedure and message with contents are presented in Section 6.2.7 for procedure and Section 6.3.6.1 and 6.3.6.2 for message, respectively.

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**Figure 7** CE operating procedures
7.2.3 CDIS operation

Figure 8 describes coexistence enabler operating procedures that define a specific event and designated procedure triggered by it. Operating procedures of coexistence manager are as follows:

- CDIS_TVWS_Channel_Update
- CDIS_Neighbor_CM_Discovery
- CDIS_Registered_CM_Channel_Classification_Discovery
- CDIS_Inform_Event

The procedure CDIS_TVWS_Channel_Update is periodically executed during the CDIS operation whenever the refresh timer TRefresh_TVWS_DB is expired. The main purpose of this procedure is to update TVWS channel information of the CDIS from TVWS DB. Then, when this procedure is triggered, the CDIS accesses the TVWS DB and updates the TVWS channel information. The considered TVWS channel information is allowed TVWS channel list and channel use constraint. The specific procedure and message with contents are presented in Section 6.2.5 for procedure and Section 6.3.4.1 and 6.3.4.2 for message, respectively.

The procedure CDIS_Neighbor_CM_Discovery is triggered if flag ‘Initiate_Neighbor_CM_Discovery’ is set to be 1. This flag is set to be 1 if the registered CM list or context information of the registered CM has been updated. The main purpose of this procedure is to find inter-CM TVBD neighbor that might cause harmful co-channel interference between them. Then, this procedure is triggered, the CDIS updates the context information from all registered CMs. Using context information from all registered CMs, CDIS regards two or more TVBD as an inter-CM TVBD neighbor if they interfere each other with the same operating channel due to their geo-location, transmission range, interference range, etc. Based on this procedure, CDIS discovers the inter-CM TVBD neighbor and provides neighbor discovery information to the CMs where the considered neighbor discovery parameters are neighbor CM ID list, neighbor CE ID list, and neighbor CE channel number list. The specific procedure and message with contents are presented in Section 6.2.4 for procedure and Section 6.3.3.1 and 6.3.3.2 for message, respectively.

The procedure CDIS_Registered_CM_Channel_Classification_Discovery is triggered if flag ‘Initiate_CDIS_Registered_CM_Channel_Classification_Discovery’ is set to be 1. This flag is set to be 1 if channel classification of the registered CM has been updated. The main purpose of this procedure is to update the channel classification information of each registered CM. Then, when this procedure is triggered, the CDIS shall gather information on channel classification of each registered CM. The specific procedure and message with contents are presented in Section 6.2.5 for procedure and Section 6.3.4.5 and 6.3.4.6 for message, respectively.

The procedure CDIS_Inform_Event is triggered if the CDIS event is occurred. This procedure is used to notify the detected event of the corresponding CDIS to the CM, which gives effect on the resource allocation of the CM. Then, when this procedure is triggered, the CDIS informs the detected events to the CM. As a reported CDIS event, we consider TVWS channel information change, neighbor CMs information change and neighbor CEs information change events. Through the TVWS channel information change event, the CDIS informs the TVWS channel information update to the CM. Further, to check the neighbor discovery update, neighbor CMs and CEs information change events are considered. The specific procedure and message with contents are presented in Section 6.2.9 for procedure and Section 6.3.8.3 and 6.3.8.4 for message, respectively.
7.3 Co-channel sharing mechanism and algorithm

7.3.1 CE operation

CE operation is described below using SDL flowcharts.
Figure 9  CE operation
Send GetAuthInfo.request to TVBD network or device

Receive GetAuthInfo.response from TVBD network or device

Perform CE authentication procedure

Is CM authentication successful and Status = Success in Authentication_Response from CM?

Y

Send GetRegInfo.request to TVBD network or device

Receive GetRegInfo.response from TVBD network or device

Perform CE registration procedure

Check subscrCxServType in GetCxServSubscr.response

N

Send GetAuthInfo.confirm to TVBD network or device with authStatus = false

Figure 10  CE operation
Perform CE neighbour discovery procedure

Send NewNeighbourList.indication to TVBD network or device

New message received? Y N

Message type?

NewRegInfo.indication from TVBD network or device 2b
Event.indication from TVBD network or device 2c
Other message from TVBD network or device 2a
CE_NeighbourList_Announcement from CM 2e
Deregistration_Announcement from CM 2f
SessionActive_Request from CM 2g
Event_Indication from CM 2h
Other message from CM 2j

Figure 11  CE operation
Perform CE registration update procedure

Perform send event from CE to CM procedure

Figure 12  CE operation
Send NewNeighbourList.indication to TVBD network or device

Send CMIsNotReady.indication to TVBD network or device

Send SessionActive_Confirm to CM

Send Event.indication to TVBD network or device

Send Event.confirm to CM

Send MessageUnsupported_Indication to CM

Figure 13  CE operation
Figure 14  CE operation
Perform CE registration update procedure

Send Measurement_Report to CM

Send GetAvailableChannels_Response to CM

Send Measurement_Report to CM

Send GetAvailableChannels_Response to CM

Send InfoAcquiring_Response to CM

Send Reconfiguration_Response to CM

Send Event_Indication to CM

Figure 15 CE operation
Figure 16  CE operation
Send GetInfo.request to TVBD network or device

Receive GetInfo.response from TVBD network or device

Send InfoAcquiring_Response to CM

Send Event.indication to TVBD network or device

Send Event.confirm to CM

Send PerformReconfiguration.request to TVBD network or device

Receive PerformReconfiguration.response from TVBD network or device

Send Reconfiguration_Response to CM

Send MessageUnsupported_Indication to CM

Send MessageUnsupported_Indication to CM

Figure 17  CE operation
Perform CE deregistration procedure

Perform CE deauthentication procedure

Power-off

Any time when there is an indication that TVBD network or device is going to power-off

Figure 18 CE operation

7.3.2 CM operation

CM operation is described below using SDL flowcharts.
Start

Check coexistence status

Send Connection_Request to CDIS

Is Connection_response received?

End of CDIS candidate list

Send CM Authentication_Request

Is CM authentication successful and Authentication_Response received with Status = Success?

Any Message/event received or timer expires?

Set timer 1 and Stop Timer 2 and Counter n=0 for CE Session Activity Check of subject CE

Figure 19 CM operation
Figure 20  CM operation
Figure 21 CM operation

Figure 22 CM operation
Figure 23  CM operation

Figure 24  CM operation
Figure 25  CM operation

Figure 26  CM operation
Figure 27 CM operation

1. Perform CM Registration update procedure

2. Send De-registration confirm to CE

Figure 28 CM operation

1. Send De-Authentication Response to CE

Figure 29 CM operation

1. Send InfoAquiring request to CM

Figure 30 CM operation
Update local record of neighbor list

Check subscribed coexistence services of subject TVBD

Send CE_NeighbourList Announcement to CE

Update local record of available channel list

Figure 31 CM operation

Figure 32 CM operation
7.3.3 CDIS operation

CDIS operation is described below using SDL flowcharts.
Figure 35  CDIS operation
Figure 36  CDIS operation
Figure 37  CDIS operation

Figure 38  CDIS operation
Send MessageUnsupported_Indication to corresponding CM

Send SessionActivity_Request to subject CM

Reset timer 2 and Counter n++

Figure 39  CDIS operation

Figure 40  CDIS operation
Figure 41  CDIS operation