IEEE 802.19.1a
Wireless Coexistence

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| Text proposal on the low latency resource reassignment for coexistence management  |
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Abstract

This contribution provides text proposals for low latency resource reassignment for coexistence management based on 802.19.1 standard and approved text.

7Coexistence mechanisms and algorithms

* 1. Coexistence algorithms
		1. Coexistence decision algorithms

***Insert the following text***

7.2.2.x Algorithm for low latency resource reassignment for coexistence management

7.2.2.x.1 Introduction

The available spectrum for a new entrant GCO is determined taking into account the spectrum usage pattern of existing GCO under the constraint of protection to higher priority GCO. That is, the existing GCOs jointly provide strong constraints to the investigated GCOs in obtaining spectrum resources. With the wireless network operating, the released spectrum resource of some GCO maybe cannot be used by any other GCOs, due to current spectrum usage limit. Consequently, the system bears dramatically increasing consumption if reassignment and reconfiguration of spectrum resources for all GCOs occurs. This raises the need to design efficient resource reassignment scheme.

This algorithm presents a practical solution for reshuffling the spectrum resource among as less GCOs as possible to increase the spectrum utilization efficiency while reducing the system reconfiguration complexity. We start by constructing an elegant mathematical modeling, termed spectrum transition graph, to integrate all the spectrum usage information of GCOs and thus generate the correlation among them. With this starting point, we establish the connection between spectrum rearrangement problem and graph theory. Therefore, we can utilize graph theory to solve the spectrum reassignment according to different system optimization targets flexibly, especially when we explore hyper-dense GCOs network. As an example, the following subclause gives the procedure of CM operation of reassigning spectrum among the GCO by searching directed path within the relative spectrum transition graph.

7.2.2.x.2 Resource Reassignment based on Spectrum Transition Graph

The spectrum rearrangement algorithm could be launched by CDIS in any of the following conditions. Case 1 the spectrum released by some GCO cannot be allocated to the GCO which requires resource without bringing harmful interference to higher priority GCOs or other GCOs. Case 2 there exits GCO, which cannot be allocated any spectrum in long time duration without harmful interference to existing spectrum usage state of other systems.

Triggered by CDIS, CM firstly obtains the parameter of GCO, termed ***spectrumTransitionCapability***, which indicates spectrum transmission is supported by the GCO or not. The type of ***spectrumTransitionCapability*** is BOOLEAN. If GCO supports the operation of spectrum transition, the value is set to be TRUE, and vice versa. The parameter is introduced under the following consideration: the system accommodates the widest range of GCOs with a variety of architecture and QoS requirements. For example, GCO could be categorised from a single communication device to a network of devices. Therefore, different GCOs have different sensitive level to the earlier than expected reconfiguration brought by spectrum transition. The expected reconfiguration could be caused when the availability time period on current occupied spectrum expires. For a single communication device, the consumption brought by reconfiguration is not so much. But a large network would suffer from dramatic performance degradation caused by signalling and operation for reconfiguration. The parameter of ***spectrumTransitionCapability*** guarantees that each GCO is able to choose joining spectrum transition according to its own characteristics or requirement.

Secondly, CM constructs spectrum transition graph only within the GCOs, which support spectrum transition. One example spectrum transition graph G is shown in Figure xx. Where, each vertex represents a GCO; any two GCOs vi and vj are associated by a directed arc, depicted by $v\_{i}\rightarrow v\_{j}$, if and only if the protection to higher priority GCO can still be guaranteed when the tail vertex (vi) vacates its operating spectrum $CH\_{vi}$ to be used by the head vertex (vj); the corresponding spectrum used by tail vertex (vi), represented as $CH\_{vi}$, is the weight for the arc. The source vertex vs represents the GCO which releases spectrum, and the destination vertex vd represents the GCO which requires resource but cannot use the released spectrum directly.



Figure xx Example of Spectrum Transition Graph

To determine the arc between GCOs, CM needs to obtain two more information from each considered GCO: available spectrum list and used spectrum list. The available spectrum list includes all available spectrums for any GCO and is determined according to the GCO's location by the Spectrum Management Database. The used spectrum list includes all spectrums which are currently occupied by the corresponding GCO.

Figure yy shows an example of determination of arc between a pair of GCO vi and vj. Where P1 represents any higher priority GCO operating on the same spectrum $CH\_{vi}$ as GCO vi. The left part of this figure shows the status before spectrum transition, where $I\_{S\rightarrow P1}$represents the aggregated interference to P1, S denotes the set of all GCOs having $CH\_{vi}$ in their available spectrum list. $I\_{P1,th}$ describes the maximized tolerable interference for GCO P1. Then, the expression of $I\_{S\rightarrow P1}\leq I\_{P1,th}$ indicates the protection constraint to P1. The right part of this figure shows the supposed status after spectrum transition. If GCO vi vacates its $CH\_{vi}$ to be used by GCO vj, then the newly aggregated interference is rewritten as $I\_{S⋃\{vj\}\\{vi\}\rightarrow P1}$, where the operation of $S\\{vi\}⋃\{vj\}$ represents that set $S$ includes element vj and excludes element vi. In that case, the inequality of $I\_{S⋃\{vj\}\\{vi\}\rightarrow P1}\leq I\_{P1,th}$ holds or not determines the arc $v\_{i}\rightarrow v\_{j}$ exists or not.

Based on the relation between GCO vi’s operating spectrum $CH\_{vi}$ and GCO vj, CM further classifies the GCO pairs into two cases, as follows:

Case 1 if the spectrum $CH\_{vi}$ belongs to the available spectrum list of GCO vj but has not been involved in the used spectrum list of vj, then the utilization of $CH\_{vi}$ on GCO vj won’t break protection to higher priority GCOs. Therefore, an arc can be directly associated between GCO vi and GCO vj.

This can be proved briefly as follows: according to the definition of set S, the spectrum $CH\_{vi}$ belongs to the available spectrum list of GCO vj means $vj\in S$. That is to say $S⋃\{vj\}\\{vi\}=S\\{vi\}$. Then, we can get $I\_{S⋃\{vj\}\\{vi\}\rightarrow P1}=I\_{S\\{vi\}\rightarrow P1}\leq I\_{S\rightarrow P1}$. Recall that we have $I\_{S\rightarrow P1}\leq I\_{P1,th}$. Thus, $I\_{S⋃\{vj\}\\{vi\}\rightarrow P1}\leq I\_{P1,th}$ holds.

Case 2 if the spectrum $CH\_{vi}$ does not belong to available spectrum list of the GCO vj, then the influence of the newly aggregated interference to higher priority GCOs cannot be determined directly. In that case, the relation between $I\_{S⋃\{vj\}\\{vi\}\rightarrow P1}$ and $I\_{P1,th}$ cannot be got directly. Hence, we have to send reconfiguration request including parameter ***specRequestModification*** to corresponding GCOs, which request recalculation of aggregated interference to Spectrum Management Database and sends the results back to CM. With the recalculation results, CM can determine the arcs for case 2.



Figure yy Example of Determination of Arc between GCOs

Thirdly, CM determines reassignment strategy by searching a directed path from source GCO vs to destination GCO vd within the pre-generated spectrum transition graph. The directed path is constrained by the target performance requirements. For example, if the number of reconfigured GCOs is minimized, then the directed path with shortest length starting from vs and ending at vd should be selected. The length of a directed path is defined as the number of arcs along the path. We can search a directed path in a spectrum transition graph through Depth First Search or Breadth First Search. In Figure xx, we can get the shortest directed path from vs to vd with length of 3 as: $v\_{s}\rightarrow v\_{i}\rightarrow v\_{j}\rightarrow v\_{d}$.

CM makes reconfiguration request based on the spectrum transition results and sends to corresponding GCO, which operates the reconfiguration accordingly.

7.2.2.x.3 Algorithm description

The flowchar is shown in Figure zz. The processes are as follows.

* P#1
When the trigger-events described in previous subclause happen, this spectrum reassignment procedure is launched by CDIS where the CDIS obtains the receiver information of the GCO through the GCO registration procedure as specified in 5.2.3.1 WSO registration procedure.
* P#2
In this stage the CM obtains the parameter *spectrumTransitionCapability* of each GCO and selects the GCOs whose *spectrumTransitionCapability* value is TRUE. The information can be obtained through the WSO Registration Procedure in 5.2.2.1. When there are multiple CMs, the information can be obtained through the Obtaining Operating Frequency Information procedure in 5.2.18 and Obtaining Operating Frequency Information procedure over Coordination Enabler in 5.2.19.
* P#3
In this process, the CM uses the obtained information to generate spectrum transition graph and determine spectrum transition operations among the GCOs by searching a directed path in the graph. During the procedure of graph generation, if the recalculation of aggregated interference is needed, the CM can use the 5.2.10.1 WSO Reconfigure procedure to send the parameter *spectrumCheck* to corresponding GCO, which will request the spectrum management database to do the recalculation and then send the recalculation results back to CM.
* P#4
In P#4 CM uses the 5.2.10.1 WSO Reconfigure procedure to send the spectrum transition operation to corresponding GCOs.
* P#5
In P#5 GCO operates reconfiguration according to the spectrum transition results.



Figure zz Flowchart of the low latency resource reassignment for coexistence management