IEEE P802.19
Wireless Coexistence Working Group

Project	IEEE 802.19 Wireless Coexistence Working Group (WG)
Title	Coexistence Mechanisms and Algorithms
Date Submitted	July 15, 2011
Source	Hyunduk Kang, Donghun Lee, Byung-Jang Jeong, Heonjin Hong, Jaeick Choi ETRI, 138 Gajeong-Ro, Yuseong-Gu, Daejeon, 305-700, South Korea, +82-42-860-1074, +82-42-860-0865, +82-42-860-6765, +82-42-860-4860, +82-42-860-6160 henry@etri.re.kr, mmdang@etri.re.kr, bjjeong@etri.re.kr, hjhong@etri.re.kr, jichoi@etri.re.kr Jari Junell, Mika Kasslin Nokia, Itämerenkatu 11-13, 00180 Helsinki, Finland jari.junell@nokia.com, mika.kasslin@nokia.com Päivi Ruuska Nokia, Visiokatu 1, 33720 Tampere, Finland paivi.m.ruuska@nokia.com Stanislav Filin, Junyi Wang, M. A. Rahman, Chen Sun, Chen Song, Yohannes Alemseged, Ha Nguyen Tran, Gabriel Villardi, Hiroshi Harada NICT, 3-4 Hikarino-oka, Yokosuka, Kanagawa, Japan, 239-0847 sfilin@nict.go.jp, junyi.wang@nict.go.jp, aziz@nict.go.jp, songe@nict.go.jp, sun@nict.go.jp, yohannes@nict.go.jp, haguen@nict.go.jp, gpvillardi@nict.go.jp, harada@nict.go.jp Junho Jo, Bonghoe Kim, Jihyun Lee, Suhwook Kim LG Electronics, Inc., LG R&D Complex 533, Hogye-1dong, Dongan-Gu, Anyang-Shi, Kyungki-Do, 431-749, Korea +82-31-450-1911, +82-31-450-4131, +82-31-450-1860, +82-31-450-1936 Junho.jo@lge.com, Bonghoe.kim@lge.com, Jihyun1220.lee@lge.com, Suhwook.kim@lge.com Ryo Sawai, Naotaka Sato, Ryota Kimura Sony corporation, 5-1-12, Kitashinagawa, Shinagawa-ku, Tokyo 141-0001 Japan +81-3-5448-4018, +81-3-5448-4005, +81-3-5448-4018 Ryo.Sawai@jp.sony.com, Naotaka.sato@ieee.org, Ryota.Kimura@jp.sony.com Guo Xin Sony China, Room 701, Raycom Infotech Park Tower C, No.2 Kexueyuan South Road, Zhongguancun, HaiDian District, Beijing 100080, P.R.C. +86-10-8286-1668 Xin.Guo@sony.com.cn
Re:	
Abstract	Proposal for Chapter 4
Purpose	
Notice	This document has been prepared to assist the IEEE P802.19. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.
Release	The contributor acknowledges and accepts that this contribution becomes the property of IEEE and may be made publicly available by P802.19.

Contents

4. System Description

This clause presents the concepts used within this standard. The key architectural components and their interrelations are introduced. System architecture is used to describe functional components of the coexistence system. The architectural descriptions are not intended to represent any specific physical implementation of the coexistence system.

4.1 System architecture

The coexistence system has three logical entities and five logical interfaces. Each logical entity is defined by its functional roles and interfaces with other logical entities.

Figure 1 shows system architecture of the coexistence system.

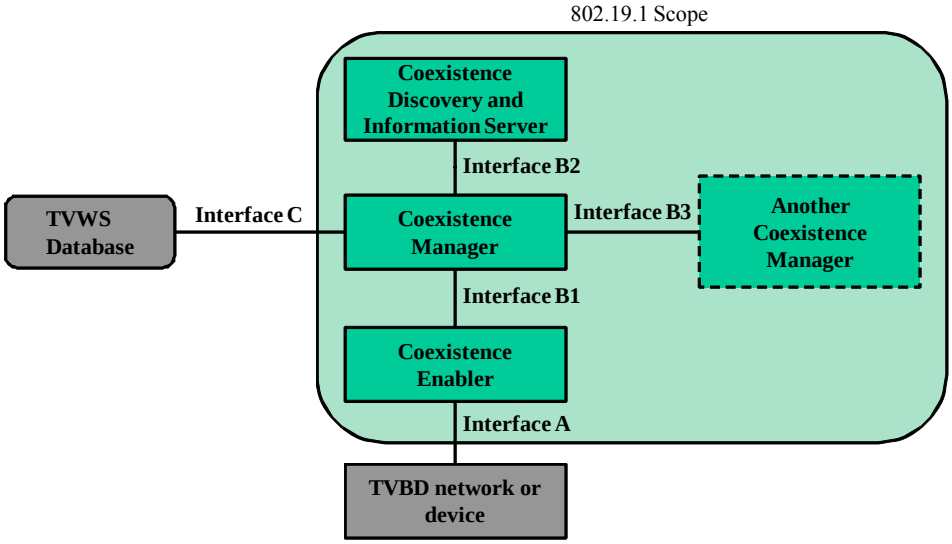

Figure 1—System architecture

Three logical entities of the coexistence system are:

— Coexistence Enabler (CE)

— Coexistence Manager (CM)

— Coexistence Discovery and Information Server (CDIS).

The CE enables all communication between a TVBD network or device and a coexistence manager that serves this TVBD network or device.

The CM is responsible for coexistence decision making related to reconfiguration of TVBD networks or devices to solve coexistence problems between them. The CM obtains all necessary information for this decision making. CM decisions are informed to TVBD networks or devices. Different CMs may communicate with each other.

The CDIS is responsible for calculating neighbor TVBD networks or devices for CMs. Also, the CDIS supports discovery of CMs by each other in order to open interfaces between them.

Five logical interfaces of the coexistence system are:

- Interface A between a CE and a TVBD network or device
- Interface B1 between a CE and a CM
- Interface B2 between a CM and a CDIS
- Interface B3 between different CMs
- Interface C between a CM and a TV bands database.

4.2 Logical entities / Entities

4.2.1 Coexistence enabler

The CE enables all communication between a TVBD network or device and a coexistence manager.

The key functions of the CE are the following:

- Perform authentication/deauthentication and registration of the TVBD network or device in the coexistence system
- Perform subscription and subscription update of the TVBD network or device to the coexistence services
- Request and obtain information required for coexistence from the TVBD network or device
- Translate reconfiguration requests received from the CM into TVBD-specific reconfiguration requests and send them to the TVBD network or device
- Translate measurement results or coexistence information from the TVBD network or device into coexistence messages and send them to the CM.

4.2.2 Coexistence manager

The CM is responsible for coexistence decision making related to reconfiguration of TVBD networks or devices to solve coexistence problems between them. The CM obtains all necessary information for this decision making. CM decisions are informed to the TVBD networks or devices. Different CMs may communicate with each other.

The CM has the following main functions:

- Perform registration/deregistration of the TVBD networks and devices in the CDIS
- Exchange information required for coexistence with CEs, CDIS, and other CMs
- Request TVBD networks or devices to perform measurements required for coexistence
- Perform channel classification and selection
- Generate coexistence white space map
- Calculate intra-CM neighbor TVBD networks or devices
- Make coexistence decisions related to TVBD network or device reconfiguration
- Request reconfiguration of the TVBD network or device according to the decisions
- Obtain available channel information from a TVWS database directly or via the TVBD network or device

- Select master CM
- Maintain information required for coexistence decision making and provide this information to TVBD network or device as needed
- Perform TVBD network or device output power level management
- Perform balancing of processing load during coexistence decision making.

4.2.3 Coexistence discovery and information server

The CDIS is responsible for calculating neighbor TVBD networks or devices for CMs. Also, the CDIS supports discovery of CMs by each other in order to open interfaces between them.

The CDIS has the following main functions:

- Store registration information of TVBD networks and device
- Calculate neighbor TVBD networks or devices
  - Inter-CM
  - Intra-CM
- Select master CM
  - To support balancing of processing load during coexistence decision making
- Provide neighbor TVBD network or device and CM information
- Perform network geometry classification.

4.3 Interfaces

4.3.1 Interface A

Interface A between a CE and a TVBD network or device may be used to transmit the following:

- From a TVBD network or device to a CE:
  - TVBD network or device registration information
  - Available channel information obtained from a TVWS database
  - Information required for coexistence
  - Measurement results
  - Reconfiguration results
  - Neighbor report requests
  - Channel classification informaiton requests
  - Event indications
- From a CE to a TVBD network or device:
  - Neighbor and radio environment information
  - Information requests
  - Measurement requests
  - Reconfiguration requests

- Channel classification information.

4.3.2 Interface B1

Interface B1 between a CE and a CM may be used to transmit the following:

- From a CE to a CM:
  - TVBD network or device registration information
  - Available channel information obtained from a TVWS database
  - Information required for coexistence
  - Measurement results
  - Reconfiguration results
  - Neighbor report requests
  - Channel classification information requests
  - Event indications
- From a CM to a CE:
  - Neighbor and radio environment information
  - Information requests
  - Measurement requests
  - Reconfiguration requests
  - Channel classification information.

4.3.3 Interface B2

Interface B2 between a CM and a CDIS may be used to transmit the following:

- From a CM to a CDIS:
  - CM registration information
  - Neighbor informaiton requests
  - Information requried for balancing of processing load during coexistence decision making
- From a CDIS to a CM:
  - Neighbor information
  - Master CM announcement.

4.3.4 Interface B3

Interface B3 between CMs may be used to transmit the following:

- Information required for coexistence
- Channel classification information requests
- Channel classification information
- Reconfiguration requests
- CM negotiation messages
- Messages for master CM selection.

4.3.5 Interface C

Interface C between a CM and a TVWS database may be used to transmit the following:

— From a CM to a TVWS database:
  — Available channel list request
  — Request for the information required for output power level management
— From a TVWS database to a CM:
  — Available channel list
  — Information required for output power level management.

4.4 Coexistence services

4.4.1 Introduction

Coexistence services are services provided by the coexistence system to dissimilar or independently operated TVBD network or device, as well as, services provided by entities of the coexistence system to other entities of the coexistence system. Correspondingly, there are two categories of the coexistence services:

— Services provided to TVBD devices or networks
— Service provided to CMs.

The coexistence services are summarized in Figure 2.

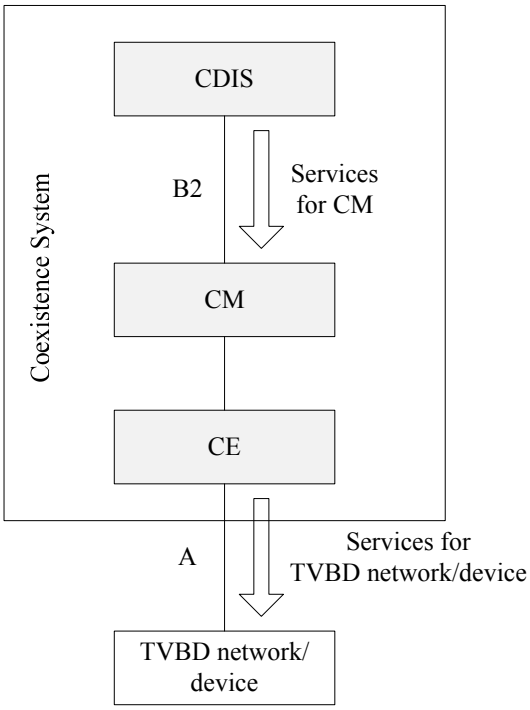

Figure 2—Summary of coexistence services

4.4.2 Services for TVBD network or device

The coexistence system provides coexistence services to a TVBD network or device via interface A. To obtain services from the coexistence system, a TVBD network or device needs to authenticate and register to the system and subscribe to its services.

After the registration, the TVBD network or device can get one of the following coexistence services from the coexistence system:

— Information service

— Management service.

A TVBD device or network can be subscribed to only one service at a time.

Within the information service, the TVBD network or device gets neighbor and radio environment information.

Within the management service, the TVBD network or device gets reconfiguration requests generated by the coexistence system. The TVBD network or device needs to provide information to the coexistence system while using this service. Also, the TVBD network or device needs to perform measurements according to requests from the coexistence system. These information and measurement results are used by the coexistence system to make coexistence decisions.

4.4.3 Service for CM

A CDIS provides coexistence services to CMs via interface B2. A CM can get the following coexistence service from a CDIS:

— Neighbor discovery service.

Within the neighbor discovery service, the CM gets the neighbor lists for TVBD networks or devices served by this CM.

Two types of neighbour discovery service are provided by the CDIS to the CM. Within the first type, the CM gets neighbour list information for inter-CM neighbors only. Within the second type, the CM gets all neighbour list information, that is, for both inter-CM and intra-CM neighbors.

4.5 Coexistence algorithms

4.5.1 Introduction

Coexistence algorithms are algorithms executed inside the coexistence system in order to provide the coexistence services.

Two classes of algorithms are defined:

— Coexistence decision making algorithms

— Neighbor discovery algorithms.

Coexistence decision making algorithms are algorithms used by CM to make coexistence decisions related to TVBD network or device reconfiguration.

Neighbor discovery algorithms are algorithms used by CDIS and CM to discover neighbor TVBD networks or devices.

The standard defines several algorithms for each class. Implementation is not intended to be limited by one particular algorithm.

4.5.2 Coexistence decision making algorithms

4.5.2.1 Algorithm based on neighbor report and radio environment information

This coexistence decision making algorithm is as follows. First, CM selects one TVBD network or device. It selects the TVBD network or device with the maximum unsatisfied demand for resources. Then, CM tries to allocate necessary spectrum resources to the selected TVBD network or device.

The algorithm considers at most neighbors of neighbors of the selected TBD network or device to keep the complexity low. The following input parameters are taken into account: operational frequency bands, interference margins, total interference level from neighbors, transmit powers, and support for scheduling.

The key principle of the algorithm is to enable acceptable performance for all TVBD networks or devices while minimizing the number of required reconfigurations. Following this principle, the CM checks first the possibility to reconfigure the selected TVBD network or device only. If this is impossible, the CM tries solutions that require reconfiguration of neighbors.

Priority is given to the solutions that do not require to reduce capacity of already operating TVBD networks or devices. Also, power control is left to the last stages of the algorithm because providing largest range for their devices is desirable.

The result of the algorithm consists of the indication of the operating frequencies, transmission power limits, channel sharing, and sharing schedule to the selected TVBD network or device and to other affected TVBD networks or devices.

4.5.2.2 Algorithm based on channel classification and channel set transition

This coexistence decision making algorithm is based on TV channel classification and channel set transition to maintain channel availability information by the CM. All TV channels are classified in the following eight sets:

- Disallowed channels
- Allowed channels
- Available channels
- Protected channels
- Restricted channels
- Unclassified channels
- Operating channels
- Coexistent channels.

The disallowed set is a set of channels disallowed for any TVBD networks or devices by regulation, or by the request of incumbents. It should be provided by TV bands database and will be updated if necessary. For example, in the U.S. TV channel 3, 4, and 37 are disallowed by regulation. Also a TV channel

registered at TV bands database by a licensed wireless microphone is disallowed for any TVBD networks or devices.

The allowed set is a set of channels allowed for TVBD networks or devices. It should be provided by TV bands database and will be updated if necessary. All TVBD networks or devices should first obtain a list of the allowed channels before their operating over TV channels.

The available set is a set of free channels available for TVBD networks or devices.

The restricted set is a set of channels restricted to use with limitations due to regulation. It can be used by TVBD networks or devices under limited conditions predefined by regulation. For example, in the U.S. a portable/personal TVBD can use "the first adjacent channel of the incumbent activating channel" with limited transmit power (≤ 40mW EIRP) by FCC regulation.

The protected set is a set of channels to be protected due to incumbent activity. It cannot be used by any TVBD networks or devices.

The unclassified set is a set of channels has not been classified as one of listed above three sets.

The operating set is a set of operating channels being used by each TVBD network or device. If each TVBD network or device has different operating channel, spectrum etiquette, i.e., FDM (frequency division multiplexing), among TVBD networks or devices is achievable.

The coexistent set is a set of channels being shared by two or more TVBD networks or devices as an operating channel. TVBD networks or devices might need a coexistence mechanism to resolve co-channel interference among them.

Figure 3 shows Venn diagram of TV channels.

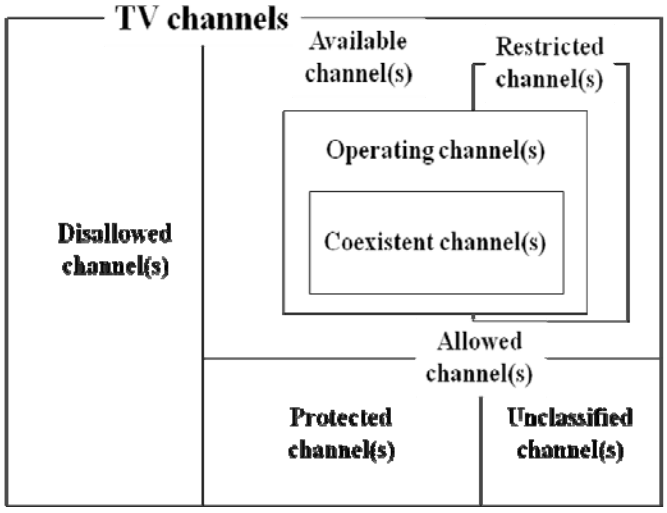

Figure 3 · Venn diagram of TV channels

4.5.2.3 Algorithm based on operating channel selection mechanism

This coexistence decision making algorithm is based on operating channel selection mechanism that allocates a proper operating channel to TVBD networks or devices. The following three channel allocation methods for operating channel selection are considered:

- Individual TV channel allocation
- Shared TV channel allocation by TVBD networks of the same type
- Shared TV channel allocation by TVBD networks of the dissimilar type

In the individual TV channel allocation, TV channels are dynamically assigned to each TVBD network which use different TV channels. So it is possible that non-overlapped TV channels are allocated to TVBD networks. This guarantee co-channel-interference-free TV channel use and coexistence problem can be eliminated through a proper TV channel allocation.

In shared TV channel allocation, two or more TVBD networks share the same TV channel. There could be a number of TV channels that are being shared. If a TV channel is shared by the TVBD networks of the same type, self-coexistence mechanisms shall be applied to mitigate co-channel interference. If a TV channel is shared by TVBD networks of the dissimilar type, inter-system coexistence mechanisms shall be applied to mitigate co-channel interference.

4.5.2.4 Algorithm based on negotiation among neighbor CMs

This coexistence decision making algorithm enables the coexistence system to share the frequency bands of the coexistence managers effectively in a case where two or more TVBDs are inter-CM neighbor relation. The inter-CM neighbors are registered to the different CM and interfered with each other over the same operating channel due to their geo-location, transmission range, interference range, and etc. The key processing components, which are conducted in CM, are decision making of operating channel list, round-robin mode parameters and competition mode parameters.

Based on the decision making of operating channel list, when all neighbor CMs allow the independent use, the inter-CM neighbor network uses independent operating channels, i.e., non-overlapped operating channels with neighbor networks or devices, called etiquette mode. On the other hand, when some neighbor CMs disallow the independent use, the inter-CM neighbor network shares operating channels with neighbor networks or devices, called contention mode. Time-division multiplexing (TDM) is the promising technique for sharing operating channels. Based on this technique, time slot is assigned sequentially to all inter-CM neighbor networks, called round-robin mode, or assigned to particular inter-CM neighbor networks through competition among inter-CM neighbor networks, called competition mode.

4.5.2.5 Algorithm based on processing load balancing

This coexistence decision making algorithm enables the coexistence system to utilize the distributed processing power of the coexistence managers effectively, and to maximize the number of the registered TVBD(s) in accordance with the conditions of the coexistence system operation. The key component is to adapt different channel selection policies, which are composed of centric coordination by master CM, cooperative coordination between CM and TVBD itself and autonomous/distributed coordination by different CMs, to the conditions of the coexistence system operation.

The centric coordination means that a master CM makes final decisions on channel selections for its TVBD networks or devices and for all TVBD networks or devices of its slave CMs. The cooperative coordination means that CM has capability to ask TVBD networks or devices to make final decisions required for coexistence. The autonomous/distributed coordination means that each CM individually makes final decisions on channel selections for its TVBD networks or devices.

4.5.2.6 Algorithm based on co-channel sharing via TVBD network geometry classification

This coexistence decision making algorithm enables the coexistence system to optimize the efficiency of the frequency utilization as much as possible in managing TVWS operation, in a case where the system

cannot assign different channel among neighbor TVBD networks. The key processing parts, which are conducted in CDIS or CM, are composed of four processing parts which are the neighbor TVBD discovery process based on network geometry classification, the network coexistence protocol check process, the interference power level check process and the backhaul connection check process.

4.5.2.7 Algorithm based on output power level control

This coexistence decision making algorithm enables the coexistence system to address the aggregated interference problem in the target protection service contour due to the multiple simultaneous transmission of neighbor TVBDs. The calculation basis may be applicable in conducting an information service on a potential aggregated interference power level, or a management service on power control of TVBDs.

4.5.3 Neighbor discovery algorithms

Neighbor discovery algorithms are part of neighbor discovery system with which a CDIS finds out TVBD networks or devices that potentially interfere with other TVBD networks or devices that are registered to it. In the neighbor discovery algorithms the CDIS estimates interference level caused by a TVBD and if the interference level is high enough in the location of another TVBD the two TVBDs are deemed neighbors.

Interference level estimates are done based on propagation models that take into account characteristics of the frequency band and the operating environment. In the estimations the CDIS takes into account also the TVBDs transmitter and receiver capabilities and characteristics like maximum transmit power and antenna configurations.