~~Draft IEEE Standard~~ for
Local and metropolitan area networks

Part 16: Air Interface for Fixed Broadband Wireless Access Systems

Amendment for Improved Coexistence Mechanisms for License-Exempt Operation

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Introduction

This introduction is not part of IEEE P802.16h, ~~Draft Amendment to IEEE Standard for~~ Local and Metropolitan Area Networks Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems - Amendment for Improved Coexistence Mechanisms for License-Exempt Operation.

Participants

This document was developed by the IEEE 802.16 Working Group on Broadband Wireless Access, which-develops the WirelessMAN™ Standard for Wireless Metropolitan Area Networks.

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~~The following members of the IEEE 802.16 Working Group on Broadband Wireless Access participated in the Working Group Letter Ballot in which the draft of this standard was prepared and finalized for IEEE Ballot:~~

~~[to be determined]~~

~~The following participated as non-members in the Working Group Letter Ballot:~~

~~[to be determined]~~

~~The following members of the IEEE Balloting Committee voted on this standard, whether voting for approval or disapproval, or abstaining.~~

[to be determined]

~~The following persons, who were not members of the IEEE Balloting Committee, participated (without voting) in the IEEE Sponsor Ballot in which the draft of this standard was approved:~~

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~~When the IEEE-SA Standards Board approved this standard on [date], it had the following membership:~~

~~***[to be determined]***~~

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NOTE-The editing instructions contained in this amendment/corrigendum define how to merge the material contained herein into the existing base standard IEEE Std 802.16-2004.

The editing instructions are shown bold italic. Four editing instructions are used: change, delete, insert, and replace. Change is used to make small corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using strike through (to remove old material) and underscore (to add new material). Delete removes existing material. Insert adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. Replace is used to make large changes in existing text, subclauses, tables, or figures by removing existing material and replacing it with new material. Editorial notes will not be carried over into future editions because the changes will be incorporated into the base standard.

1. Overview

scope: *This amendment specifies improved mechanisms, as policies and medium access control enhancements, to enable coexistence among license-exempt systems based on IEEE Standard 802.16 and to facilitate the coexistence of such systems with primary users.*

applicability: *This amendment improves the coexistence of 802.16 systems in interference environments characteristic of license-exempt operation, including operation in lightly licensed situations where frequencies are not assigned exclusively. Some of the defined procedures could be applied in other cases, which require improved inter-system coexistence.*

[insert a new subclause 1.5]

1.5 Co-existence for license-exempt and uncoordinated systems

Section 1.3.3 acknowledges that the equipment conformant to this standard may be used in license-exempt and uncoordinated bands. The WirelessHUMAN PHY (section 8.5) addresses the additional needs of systems operating in license-exempt bands; and section 6.3.15 provides suggested procedures and MAC support for addressing the needs of 'specific spectrum users'; users who are deemed to be protected from interference by regulation. Further enhancements to facilitate co-existence for license-exempt and uncoordinated systems in utilizing improved co-existence mechanisms is embodied in policies, MAC enhancements, and recommended practice introduced in this section. This operation is designated WirelessMAN-CX. This designation, being PHY independent, provides specific features in additional to those supported for WirelessHUMAN and builds on new features and evolves those originally designed for licensed band operation.

License-exempt or uncoordinated bands may adopt RF profiling in terms of selecting a known set of RF parameters, such as a band plan. If such a convention is adopted the design, management and inter-working of uncoordinated systems is eased significantly. If no baseline assumptions about other systems sharing the band can be made then complexity is added to both system design and algorithms implemented. In adding license-exempt or uncoordinated operation to the WirelessMAN standard it is assumed that an amendment can draw heavily from the material embodied in the original air interface standard and provide a solution to a problem that is not significantly more complex than the base standard. To this end therefore assumptions about RF parameters, for example channel raster and channel bandwidths, are appropriate to the solution based on WirelessMAN. WirelessMAN-CX therefore provides enhancements to the MAC protocol to facilitate communication between infrastructure and subscriber devices for interference measurement, reporting and management; together with negotiation for spectrum sharing.

[Insert the following row into table-1:]

Designation	Applicability	PHY	Additional MAC requirements	Options	Duplexing alternative
WirelessMAN-CX	Below 11 GHz license-exemptor when needed for inter-system improved coexistence	Section 8	MAC enhancements for coexistence (6.4)	Those applicable to PHY implemented. Section 15.	TDD

2. References

3. Definitions

[Insert following sections after 3.85:]

3.86 WirelessMAN-CX: The designation used to describe the realization that adds co-existence procedures and recommended practice to systems implemented below 11GHz, in license-exempt bands or whenever improved inter-system coexistence is needed. This designation is PHY independent and adds additional MAC functionality, together with a recommended practice for achieving coexistence.

3.87 Interference Neighborhood: Interference neighborhood is relative to a system (BS and its subscribers). A system (BS and its SSs) will perceive as interference neighbors, all other systems (BSs and their SSs) which create/receive interference to/from it.

3.88 Community: is composed of those systems (BSs and their SSs) which coordinate to resolve their interference.

3.89 Coexistence Community: is composed of those systems (BSs and their SSs) which have resolved their interference and coexist.

3.90 Coexistence Proxy(CXPRX): Coexistence proxy isolates their BSs from the BSs and terminals in the internet. , Shall be used when the IP contact information is transmitted over the air and scan be optionally used to forward the CP message between coexistence BSs over the backbone. In the coexistence coordination process, all the BSs will not know other BSs' IP address, and contact BSs only via coexistence proxy and the BSID information. In order to prevent various attack from the internet, coexistence proxy could utilize various approach to protect the data service of BSs from being influenced.

3.91 Random Temporary Key (RTK): the temporary key generated and sent by the BS, contained in the air signaling, which is required to be contained in the request messages of coexistence protocol sent to this BS. RTK is used to obstruct the coexistence request from the unqualified internet terminals.

3.92 Alternative Channel (ALTCH): The alternative working channel decided by the base station, on which the base station haven't detected any user and also not currently chosen to be the working channel of this base station.

3.93 Coexistence Signaling Interval (CSI): a predefined time slot for the coexistence protocol signaling purpose, especially for the BS to contact its coexistence neighbor BS through one or more coexistence neighbor SSs in the common coverage area.

3.94 Initialization Coexistence Signaling Interval (ICSI): the periodically appointed CSI specially used by IBS to contact its neighbor OBS. When the IBS get the OCSI allocation and start the operating stage, it will ceased from using the ICSI.

3.95 Operation Coexistence Signaling Interval (OCSI): the rest CSI other than ICSI, periodically reallocated to OBSs.

3.96 Coexistence Signaling Interval Number (CSIN): the periodical number of CSI according to the time order. The range of CSIN is from 0 to the number of CSI in one OCSI cycle.

4. Abbreviations and acronyms

[Insert the following abbreviations at appropriate location:]

AH	Authentication Header
ALTCH	Alternative Channel
BSD	Base Station Descriptor
BSIS	Base Station Identification Server
CCD	Candidate Channel Determination
CMI	Coexistence Messaging Interval
CNTI	Cognitive Network Time Interval
CoNBR	Coexistence Neighbor
CR	Cognitive Radio
CR_NOC	Cognitive Radio Network Operations Centre.
CSI	Coexistence Signaling Interval
CSIN	Coexistence Signaling IntervalNumber
CTS	Coexistence Time Slot
CX	Co-eXistence

CXPRX	Coexistence Proxy
DRRM	Distributed Radio Resource Management
DSM	Distribution System Medium
ESP	IP Encapsulating Security Payload
IANA	Internet Assigned Numbers Authority
IBS	Initializing Base Station
ICSI	Initialization Coexistence Signaling Interval
IETF	Internet Engineering Task Force
IPBC	IP address Broadcast
IPsec	Internet Protocol Security
NOC	Network Operation Center
NURBC	Neighborhood Update Request BroadCast
OBS	Operating Base Station
OCSI	Operation Coexistence Signaling Interval
PKM	Private Key Management
PLE	Path Loss Exponent
PSD	Power Spectrum Density
RADIUS	Remote Authentication Dial-in User Service
RTK	Random Temporary Key
SAP	Service Access Point
SSURF	Subscriber Station Uplink Radio Frequency
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
UTC	Universal Coordinated Time
WirelessMAN-CX	Wireless Metropolitan Access Network Co-eXistence

Notes: the IP broadcasting in the airlink is to be reconsidered and call for contribution for modification.

5. Service-specific CS

6. MAC common part sublayer

6.3 Data/Control plane

6.3.2 MAC PDU Format

6.3.2.3 MAC management messages

[Insert the following rows into Table-14. MAC Management messages as indicate.]

Type	Message Name	Message Description	Connection
67	BSD	Base Station Descriptor	Broadcast
68	SSURF	SS Uplink RF Descriptor	Basic
69-255		reserved	

6.3.2.3.33 Channel measurement Report Request/Response (REP-REQ/RSP)

[change the text as indicate in section 6.3.2.3.33:]

If the BS, operating in bands below 11 GHz, requires RSSI and CINR channel measurement reports, or requires neighbor detection reports, it shall send the channel measurements Report Request message. The Report Request message shall additionally be used to request the results of the measurements the BS has previously scheduled. Table 62 shows the REP-REQ message.

The channel measurement Report Response message shall be used by the SS to respond to the channel measurements listed in the received Report Requests. Where regulation mandates detection of specific signals by the SS, the SS shall also send a REP-RSP in an unsolicited fashion upon detecting such signals on the channel it is operating in, if mandated by regulatory requirements. The SS may also send a REP-RSP containing channel measurement reports, in an unsolicited fashion, or when other interference is detected above a threshold value. In cases where specific signal detection by an SS is not mandated by regulation, the SS may indicate 'Unmeasured. Channel not measured.' (see 11.12) in the REP-RSP message when responding to the REP-REQ message from the BS. Especially for coexistence network, when SS have detected the IP broadcasting message from the coexistence neighbor BS, the SS need to use REP_RSP to report the information to its serving BS unsolicitedly. Table 63 shows the REP-RSP message.

[add a new section 6.3.2.3.62 as indicate:]

6.3.2.3.62 Base Station Descriptor (BSD) message

The base station descriptor (BSD) message specifies the base station identification information. This message is sent only in the CMI (see 15.2.1.1.7) claimed by the Base Station.

The length of BSD message is an integral number of bytes. The BSD messages are generated and broadcast within the downlink portion of a CMI every minute by a base station.

The BSD has two purposes. First, it contains pertinent information related to the base station, allowing foreign (interfered-with) Subscriber Stations to identify it as interference. Secondly, it allows the differentiation of a CMI from a non-CMI. When it is received, the SS associated with the BS will recognize the interval containing the BSD message as a CMI, and will transmit SSURF messages in response to it. Note that SSURF will use the uplink bandwidth granted only in the CMI, and is not transmitted in the data link.

A BSD message shall includes the following parameters:

IP_Proxy address information: The Coexistence Proxy IP address information and base station ID contained in the DL_MAP message are uniquely identifying a base station. The encoding of this field is given below in TLV format.

BS EIRP: The BS EIRP field is included this message to help determine the interference content. It is signed in units of 1 dBm.

RF Antenna Sector ID: The RF antenna sector ID is used to identify the RF antenna in a base station if multiple RF antennas are used for RF reuse purpose.

Table 108aa—BSD message format

Syntax	Size	Notes
BSD_Message_Format ( ) {		
Management Message Type =TBD	8 bits	
BS EIRP	16 bits	
BS RF antenna sector ID	8 bits	0-reserved for no RF reuse BS 1-255 for RF reuse BS
IP_Proxy_Address_IE( )	Variable	TLV specific
}		

[add a new section 6.3.2.3.63 as indicate:]

6.3.2.3.63 Subscriber Station Uplink Radio Frequency (SSURF) message

The Subscriber Station uplink radio frequency (SSURF) message is the complement to the BSD message except it is sent on the uplink during the CMI interval claimed by the Base Station to which the SS is registered.

This message if received by foreign (interfered-with) Base Stations, will identify the SS as being an interferer.

A SSURF message shall includes the following parameters to identify a subscriber station:

SS ID: Subscriber station identifier is a 48-bit long field identifying a subscriber station. This SS is the victim of co-channel interferences reported in this message.

Associated BS ID: Associated base station identifier is a 48-bit long field identifying the associated BS. Associated base station is a base station to which a subscriber station registered.

Associated BS Antenna Sector ID: The RF antenna sector ID is used to identify the RF antenna in a base station if multiple RF antenna are used for RF reuse purpose.

Associated BS IP_Proxy address information: The BS IP address information uniquely identifies a associated base station. The encoding of this field is given above in TLV format.

.

Table 108ab—SSURF message format

Syntax	Size	Notes
SSURF_Message_Format( ) {		
Management Message Type =TBD	8 bits	
SS ID	8 bits	
Associated BS ID	48 bits	Associated base station identifier
Associated BS Antenna sector ID	8 bits	
Associated BS IP Proxy_Address_IE( )	Variable	
}		

6.3.15 DFS for license-exempt operation

6.3.15.1 Introduction

[Add the following text at the end of section 6.3.15.1.]

Figure h 1 provides a flowchart representation of a generic scheme for operation in bands with specific spectrum users. WirelessMAN-CX provides enhanced reporting for specific spectrum users and addresses the need in situations where more than one type of specific spectrum user is operational in a given band.

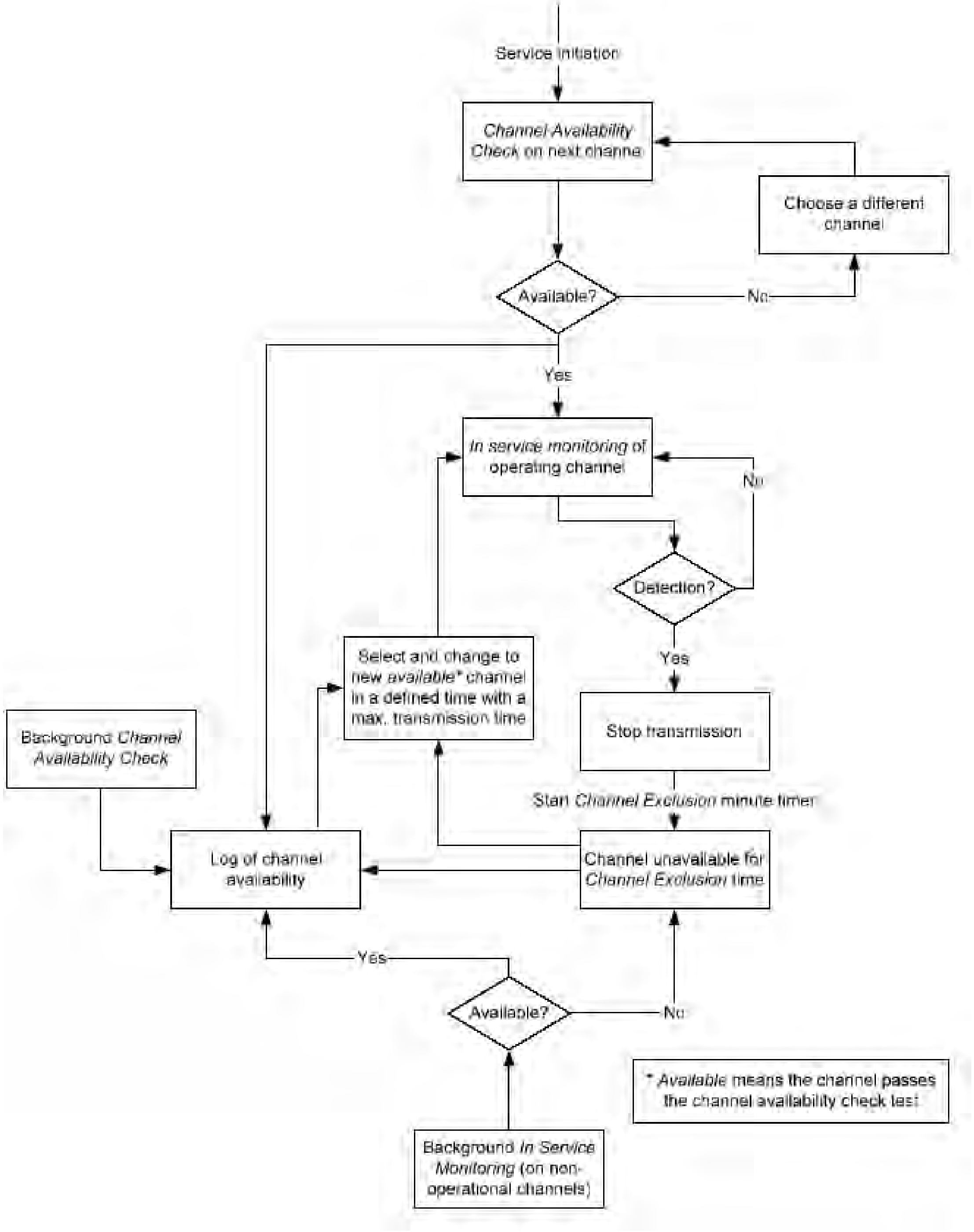

Service initiation
Channel Availability Check on next channel
Choose a different channel
Available?
No
Yes
In service monitoring of operating channel
No
Detection?
Yes
Select and change to new available* channel in a defined time with a max. transmission time
Stop transmission
Start Channel Exclusion minute timer
Background Channel Availability Check
Log of channel availability
Channel unavailable for Channel Exclusion time
Yes
Available?
No
* Available means the channel passes the channel availability check test
Background In Service Monitoring (on non-operational channels)

Figure h1—Flowchart showing generic operation in bands with specific spectrum users

[Insert a new section 6.4 :]

6.4 MAC enhancement for coexistence

This section describes MAC enhancements for WirelessMAN-CX in support of license-exempt and uncoordinated bands. Firstly concepts are described which are general to the MAC, after which PHY specific interactions are considered. PHY specific discussion is required since WirelessMAN-CX operation is dependant on the features supported for a given PHY.
[tbc for deriving the appropriate part from clause15 here]

6.4.1 General concepts

This section describes WirelessMAN-CX operation. These aspects are specific to the MAC and support of the PHY from the MAC..

6.4.1.1 Capability Negotiation

A mechanism is provided by which WirelessMAN-CX and non-WirelessMAN-CX devices are to interwork. This is an important mechanism for deployment scenarios where regulatory designation of WirelessMAN-CX operation is required. Some examples of how the capability negotiation can be used are given:

- A device with WirelessMAN-CX functionality will need to interact with infrastructure that knows nothing of WirelessMAN-CX.
- A non-WirelessMAN-CX device will need to interact with WirelessMAN-CX compliant infrastructure.
- A non-WirelessMAX-CX device shall have the ability to be barred from working in a WirelessMAX-CX network – this is deployment specific.
- A WirelessMAX-CX device shall work in a non- WirelessMAX-CX network as ‘normal’ non-WirelessMAX-CX device.

6.4.1.2 Extended channel numbering structure

License-exempt or uncoordinated bands may require or provide scope for the use of a defined channel raster or channel bandwidth. This section provides a means to achieve this, and therefore offer simplification to issues of interference managements. Extended channel numbering provide an enhancement to channelization and definition of channel number for WirelessHUMAN operation in section 8.5.1. This extension provides channelization references beyond the limits of 5-6GHz as defined. The channelization is defined accordingly.

- Extended Channel Number (ExChNr) – 1 byte specific channel number reference.
- Base Channel Reference (BaseChRef) – 1 byte base reference to frequency range or deployment band. This reference maps to an absolute frequency value
- Channel spacing (ChSp) - 2 byte channel spacing value (10kHz increments)

In summary the definition of the *Channel Centre Frequency* is:

*Channel Centre Frequency [MHz] = BaseFrequency(BaseChRef)[MHz] + (ExChNr*ChSp *0.01)[MHz]* *[xxx]*

This is shown in a graphical representation in Figure h 2.

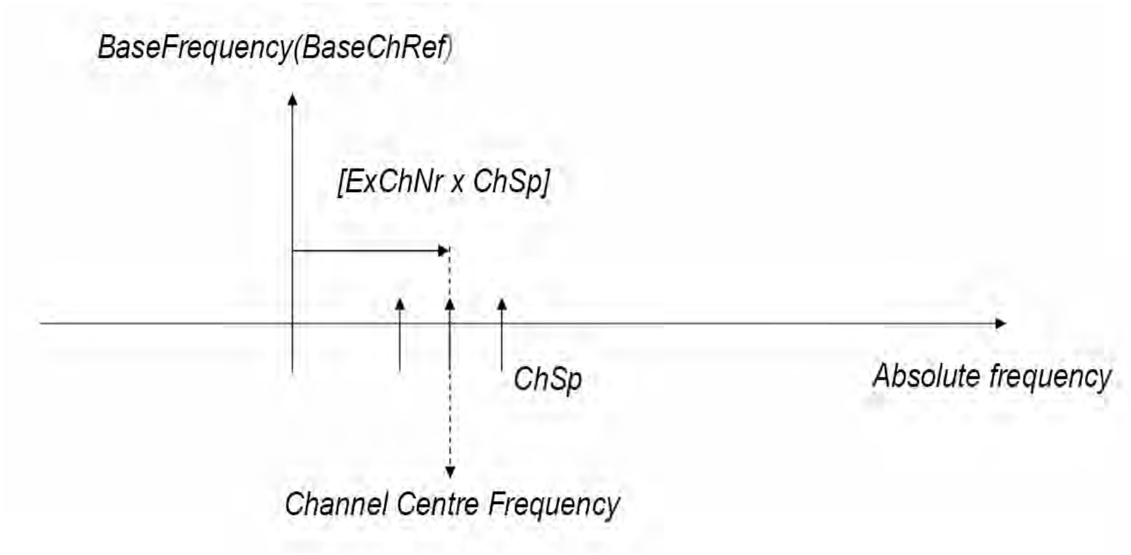


Figure h2—Representation of 'Channel Centre Frequency' calculation.

ExChNr is used in *REP-REQ/REP-RSP* messages while *BaseChRef*, and *ChSp* are communicated at a session setup or reconfiguration.

6.4.1.3 Measurement and Reporting

License-exempt or uncoordinated bands are likely to present an operating environment that has a significantly higher and more dynamic interference profile than licensed bands. Measurement and reporting of the prevailing environment is therefore an important consideration for system operation and stability. Measurement and reporting enhancements provide the ability to:

- Enhance details on environmental knowledge for license-exempt and uncoordinated band operation.
- Provide timely reports for fast link adaptation in an attempt to maintain BER performance.
- Provide bandwidth efficient reports maintain spectral efficiency but also to ensure interference reports are not out-of-date.
- Provide accurate measurements to retain WirelessMAN-CX integrity.
- Provide enhanced reporting for specific spectrum users.

6.4.2 WirelessMAN-CX support for OFDMA PHY

This section provides a description of WirelessMAN-CX support for the WirelessMAN-OFDMA PHY.

6.4.2.1 Co-existence zone (CXZ) for downlink and uplink

The addition of a CXZ provides the means to include all co-existence enhancements in a defined region within the WirelessMAN-OFDMA PHY. It is expected that all co-existence operation will occur within this zone.

6.4.2.2 Measurement and Reporting

In order to meet strict requirement on measurement and reporting in license-exempt and uncoordinated bands enhanced reporting for WirelessMAN-CX is supported through the REP-REQ/REP-RSP MAC messages (see sections 11.11 and 11.12 respectively). Also the use of the WirelessMAN-OFDMA fast feedback channel is used to enhance reporting capabilities. Section 6.3.18.2 discusses periodic CINR report with fast-feedback (CQICH) channel. It is recommended that interference measurements are undertaken on the effective (feedback type=0b01) or physical (feedback type=0b00) CINR measurement for a CXZ permutation zone (Zone permutation=0b110 and report type=1) from pilot subcarriers (measurement type=0). Section 8.4.5.4.12 gives specific details of the CQICH allocation IE.

7. Privacy sublayer

8. PHY

8.4 WirelessMAN-OFDMA PHY

8.4.4 Frame structure

8.4.4.2 PMP frame structure

[change the last paragraph of section 8.4.4.2 into the following text in 802.16 primary standard:]

The OFDMA frame may include multiple zones (such as PUSC, FUSC, PUSC with all subchannels, optional FUSC, and AMC, CXZ, TUSC1, and TUSC2), the transition between zones is indicated in the DL-Map by the STC_DL_Zone IE (see 8.4.5.3.4), CXZ_DL_IE (see 8.4.5.3.11), or AAS_DL_IE (see 8.4.5.3.3). No DL-MAP or UL-MAP allocations can span over multiple zones. Figure 219 depicts the OFDMA frame with multiple zones.

[change figure 219 as following:]

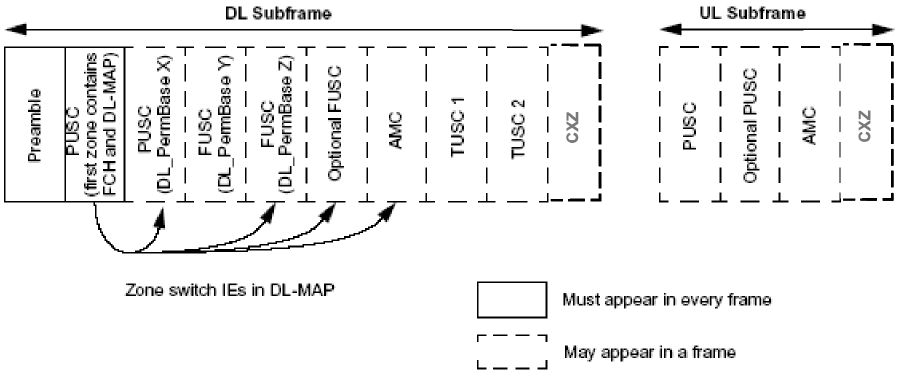


Figure 219—Illustration of OFDMA frame with multiple zones

[insert the following rows to table 277a, section 8.4.5.3.2.1.]

Extended DIUC (hexadecimal)	Usage
09	CXZ_DL_IE
~~09~~-0A	*reserved*

[Insert a new section 8.4.5.3.28:]

8.4.5.3.28 Co-existence zone (CXZ) downlink IE format

Within a frame, the switch to co-existence operation is marked by using the extended DIUC = 15 with the CXZ_DL_IE(). The CXZ_DL_IE defines a DL CX zone and spans continuous OFDMA symbols. Multiple CXZ zones can exist within the same frame. When used, the CID in the DL_MAP_IE() shall be set to the broadcast CID.

Table 286aa— CXZ downlink IE

Syntax	Size	Notes
CXZ_DL_IE() {		
Extended DIUC	4 bits	CXZ = 0x09
Length	4 bits	Length = 0x01
OFDMA symbol offset	8 bits	Denotes the start of the zone (counting from the frame preamble and starting from 0).
CXZ duration	10 bits	Denotes the duration of the zone
Next CXZ start	12 bits	The time interval, in symbols, until the start of the next downlink CXZ.
}		

[insert following row into table-289a as indicate(section 8.4.5.4.4.1):]

Extended UIUC (hexadecimal)	Usage
0B	CXZ_UL_IE
~~0B~~0C … 0F	*reserved*

[change the row in table 300 as indicate (section 8.4.5.4.12)]

Syntax	Size	Notes
Zone permutation	3 bits	The type of zone for which to report 0b000 - PUSC with 'use all SC = 0' 0b001 - PUSC with 'use all SC = 1' 0b010 - FUSC 0b011 - Optional FUSC 0b100 - Safety Channel region 0b101 - AMC zone (only applicable to AAS mode) 0b110 - CXZ 0b~~110-~~111 - Reserved

[Insert a new section 8.4.5.4.29]

8.4.5.4.29 Co-existence zone (CXZ) uplink IE format

Within a frame, the switch to co-existence operation is marked by using the extended UIUC = 15 with the CXZ_UL_IE(). The CXZ_UL_IE defines a DL CX zone spans continuous OFDMA symbols. Multiple CXZ zones can exist within the same frame. When used, the CID in the DL_MAP_IE() shall be set to the broadcast CID.

Table 302w—CXZ uplink IE

Syntax	Size	Notes
CXZ_UL_IE() {		
Extended DIUC	4 bits	CXZ = 0x09
Length	4 bits	Length = 0x01
CXZ zone length offset	8 bits	The length of the uplink CXZ zone.
CXZ duration	10 bits	Denotes the duration of the zone
Next CXZ start	12 bits	The time interval, in symbols, until the start of the next uplink CXZ.
}		

9. Configuration

10. Parameters and constants

[insert a new section 10.5 as indicate:]

10.5 Coexistence specific values

10.5.1 Radio signaling

The absolute time runs on a periodic base of 1800 sec. (30 minutes). For cases when one or more seconds are added/subtracted at the mid-night, the absolute time is supposed to follow those changes. All the values below are repeating based on the relation:

Time = (Absolute time) mod 1800.

The time is expressed as sec: ms, according to the decimal format xxxx:yyy.

Table 345a—parameter of absolute time reference

Absolute time reference	Chapter	Reference	Value
AT1	Radio signaling (15.5.1.2)	Start of the first MAC Frame (no. N) including cognitive radio signaling	0010:000
AT2	Radio signaling (15.5.1.2)	Start of the 2nd MAC Frame including cognitive radio signaling	0010:020

AT3	Radio signaling (15.5.1.2)	Start of the 3rd MAC Frame including cognitive radio signaling	0010:040
AT4	Radio signaling (15.5.1.2)	Start of the 4th MAC Frame including cognitive radio signaling	0010:060

Table 345b—parameter of radio signaling timer

Timer	Chapter	Reference	Value
T_cogn	Radio signaling (15.5.1.2)	Repetition period of the cognitive signaling	20s
Tcr_reg	Radio signaling (15.5.1.2)	Duration of the registration interval for ad-hoc transmitters	2s
Tcr_rep	Radio signaling (15.5.1.2)	Time interval between the start of consecutive time-slots for registration	100ms
Tcr_reg_ack	Radio signaling (15.5.1.2)	Time interval which starts immediately after a time-slot for registration and last as specified	20ms
Tad_reg	Radio signaling (15.5.1.2)	Maximum time-interval in which an ad-hoc unit has to repeat the registration	1800s
T_iptx	Radio signaling (15.5.1.2)	Time interval between the start of consecutive CSI slots for the transmission of the IP address using frequency-keyed energy pulses	20ms

11. TLV encodings

11.7 REG-REQ/RSP management message encodings

[Insert the following row into table 369a:]

Type	Parameter
45	WirelessMAX-CX capability
46	Base Channel Reference (BaseChRef)
47	Channel Spacing (ChSp)

11.7.8 SS capability encodings

[insert new subclause 11.7.8.14:]

11.7.8.14 WirelessMAX-CX capability

Name	Type (1 byte)	Length (1 byte)	Value	Scope
WirelessMAX-CX capability	45	1	Bit #0: No WirelessMAX-CX capability Bit #1: WirelessMAX-CX capability Bits #2 - #7: Reserved	REG-REQ
Base Channel Reference (BaseChRef)	46	1	Base Channel Reference in MHz providing base reference to frequency range or deployment band	REG-RSP
Channel Spacing (ChSp)	47	2	Channel Spacing in 10kHz increments.	REG-RSP

11.11 REP-REQ management message encodings

[insert the following entry in the second table of 11.11:]

Coexistence neighbor Interference Report	1.9	1	Bit #0: 1-include information received in BS_NURBC Bit #1: 1-include RSSI of CSI symbols(only valid when bit#0 is set to one) Bit #2: 1-include frame number that start to receive BS_NURBC Bit #3~7: reserved, shall be set to zero
ExChNr	1.10	2	Physical extended channel number (WirelessMAX-CX only)
Extended report type (WirelessMAN-CX only)	1.11	1	Bit #0 = 1: Include summary extended report Bit #1 = 1: Include full extended report Bit #2 = 1: Specific spectrum user extended report Bits #3 - #7: Reserved

11.12 REP-RSP management message encodings

[insert the following entry in the first table of 11.12:]

Coexistence neighbor Report	7	variable	Compound
Extended report type	8	variable	Compound

[insert the following table into 11.12 as indicates:]

Coexistence neighbor Interference Report type	Name	Type	Length	Value
all	CoNBR count / New NDS	7.1	1	Bit #0:1-New CoNBR Discovered by BS_NURBC received Bit #1-7:The number of CoNBR that interference to this SS

bit #0=1	Neighborhood update request report IPv4	7.2	12	Bits 15:0 - RTK Bits 63:16 - BSID Bits 95:64 - BS IP address(IPv4) 4bytes IPv4 address of CoNBR interference to this SS, 255. 255. 255. 255 indicate the fail of CRC check.
bit #0=1	Neighborhood update request report IPv6	7.3	24	Bits 15:0£¦RTK Bits 63:16£¦BSID Bits 191:64£¦BS IP address(IPv4) 16bytes IPv6 address of CoNBR interference to this SS, all ones indicate the fail of CRC check.
bit #1=1	BS_NURBC RSSI	7.4	2	1byte RSSI mean (see also 8.2.2, 8.3.9, 8.4.11) for details) 1byte standard deviation
Bit #2=1	Starting Frame Serial Number of BS_NURBC	7.5	3	Bit# 0-24: frame number of BS_NURBC starting frame

REP-REQ Extended report type	Name	Type	Length	Value
Bit #0 = 1 OR Bit #1 = 1 OR Bit #2 = 1	ExChNr	8.1	2	Extended physical channel number to be reported on.
Bit #0 = 1 OR Bit #1 = 1 OR Bit #2 = 1	Start frame	8.2	2	16 LSBs of Frame number in which measurement for this channel started
Bit #0 = 1 OR Bit #1 = 1 OR Bit #2 = 1	Duration	8.3	3	Cumulative measurement duration on the channel in multiples of Ts. For any value exceeding 0xFFFFFF, report 0xFFFFFF
Bit #0 = 1	WirelessMAX-CX interference indicator	8.4	1	Bit #0: Low interference indication Bit #1: Medium interference indication Bit #2: High interference indication Bit #3: Specific spectrum user detected on the channel Bit #4: Channel not measured.
Bit #1 = 1	Zone specific CINR report	8.5	2	1 byte: mean 1 byte: standard deviation
Bit #1 = 1	Zone specific RSSI report	8.6	2	1 byte: mean 1 byte: standard deviation
Bit #2 = 1	Specific spectrum user detection report	8.7	1	Bit #0: Specific spectrum user type #0 Bit #1: Specific spectrum type #1 Bit #2: Specific spectrum type #2 Bit #3: Specific spectrum type #3 Bit #4: Specific spectrum type #4 Bit #5: Specific spectrum type #5 Bit #6: Specific spectrum not known Bit #7: Channel not measured

[insert a new section 11.20 in clause 11 as indicate:]

11.20 BSD and SSURF Message and Encodings

IP_Proxy_Address_IE Encoding:

Name	Type (1 byte)	Length (1 byte)	Value	PHY Scope
ProxyIPv4 Address	1	4	Proxy IP address if IPv4 is supported.	all
ProxyIPv6 Address	2	16	Proxy IP address if IPv6 is supported.	all

There can be one and only one information element in an IP_Address_IE.

12. System profiles

13. 802.16 MIB structure for SNMP

14. Management Interfaces and Procedures

[insert new clause 15:]

15. Mechanism for improved coexistence

[Editor's notes: the figure number and table number is temporarily marked as Figure hxxx. And Table hxxx, these number should be corrected according to WG rules before the draft release]

15.1 General

This chapter introduces high-level protocols and policies to be used for coordinating the system operation, with the scope to reduce the inter-system interference.

The basic mechanisms for achieving better coexistence are different for managed networks and for ad-hoc networks. It is recognized that the managed networks, generally deployed by operators, should receive a higher priority than the ad-hoc networks.

Three basic mechanisms for achieving coexistence are envisioned as being:

- MAC Frame Synchronization, including Tx and Rx intervals;
- Adaptive channel selection, for finding a less interfered or less used frequency;
- Separation of the remaining interference in the time domain, by using coordinated scheduling and a fairness approach.

For inter-system communication, at infrastructure and radio level, are defined IP-level messages, MAClevel messages and Cognitive Radio Signaling.

The communication at IP level is the most general one, being PHY independent. It allows distributed BS-BS communication as well as communication with a central database. The messages defined for such communication constitute the Coexistence Protocol.

The MAC-level messages are intended for systems using the same PHY profile. These may convey special information between the BS and its subscribers, or may send messages between systems. In the last case, the communication takes place during the Coexistence Messaging Interval.

The radio signaling uses elements of the existing PHY modes and allows simple communication between different systems. The radio signaling may be used to communicate with ad-hoc systems, or to indirectly transmit contact information for the IP network during the Coexistence Signaling Interval.

[These simple signals are selected in such a way, to allow in the future the extension of these procedures for communication with other systems, not belonging to IEEE 802.16 family.]

The different system parameters, including their GPS coordinates and timing, may be shared between systems, through distributed communication between Base Stations grouped in a Coexistence Community.

The level of interference and the interference source may be assessed using the Radio Signatures and the interferer identification procedures.

Interference-free sub-frames are initially created based on the selection of one of three possible rules and controlling the system powers. The Coexistence Protocol includes procedures, which allow the interference-free radio resource re-allocation. Some of these procedures use credit tokens and negotiations, such that the interference-free resources may be dynamically apportioned to support the changing character of the traffic.

The protocols and policies described in this chapter enable the operation with reduced interference. The Coexistence Zone gives the support at the MAC level for scheduling the interference-free sub-frames.

15.2 Interference detection and prevention – general architecture

15.2.1 Operational Principles and Policies

15.2.1.1 General Principles

The approaches for interference resolution are based on separating the interference in the frequency and time domains.

The separation of interference in the frequency domain is undertaken first.

The separation of remaining interference is resolved by separation of interferers in time domain, by using procedures of the Coexistence Protocol. The Coexistence Protocol is defined at IP level and it is mainly intended for BS-BS communication.

In order to obtain the IP address of the Base Stations within the Coexistence Neighborhood, a number of procedures are defined, based on operator coordination, or on indirectly transmitting the contact information for the IP network.

The operators can exchange information tables containing the deployment information, such as GPS coordinates, IP address of the CX entity in the Base Station, etc.

Operators may also maintain a common database, including both deployment information and an IP identifier for allowing the operation of a technology-independent coexistence approach. In this case, it is assumed that:

1) *In some circumstances,*there is country/region data base, which includes, for every Base Station:
    - Operator ID
    - Base Station ID
    - Base Station GPS coordinates
    - IP identifier

    The local Radio Administration may use, for light licensing procedure, its own database, generally not including the Base Station ID and IP identifier information.

    There is a server that manage the write/reading of this Data Base, using the 802.16h standardized procedures; the server and the country/region data base can be hostedby one of the operators or a trusted entity, like the local Radio Administration.

    Otherwise, if the region/country database is not available, the base stations should try to find its neighbor and the community topology in a coordinatively distributed fashion.

2) Every Base Station includes a data base, open for other Base Station in the same community; the BS data-base contains information necessary for spectrum sharing, and includes the information related to the Base station itself and the associated SSs; a Base Station and the associated SSs form a system. Other Base Stations can send queries related to the information in the database to the DRRM entity, located in a Base Station (see Figure h 25).The base station shall represent its system in the cooperation with other systems when communicating over the backbone. It's possible to use the subscriber station to relay the control messages in some situations. The base station locations may be registered by GPS or other positioning systems, however there is no need to register the subscriber locations;

3) All the Base Stations forming a community will have synchronized MAC frames and frame number.

4) A community will be limited to a reasonable size; the size limitations and interactions between different coexistence neighborhoods: t.b.d.

5) All Base Stations and their networks will as a first step seek the avoidance of co-channel utilization of the same spectrum, and will be equipped with a spectrum detection and monitoring capability which will allow this.

6) All base stations are synchronized to a GPS clock. The start of all MAC frame and other transaction are referenced to the rising edge of this clock.

7) All base stations and their networks, operating in the LE bands, will provide the opportunity to other non-IEEE 802.16h systems to communicate their coexistence requests to the IEEE 802.16h networks.

8) The IEEE 802.16h systems will recognize the use of radar and other systems having higher priority to LE spectrum.

9) Every network will have a guaranteed minimum access time for the interference free use of the radio resource, being able to receive with minimum interference and to transmit at the needed powers for allowing communication between its Base Station and the remote subscribers

Interference Neighborhood: Interference neighborhood is relative to a system (BS and its subscribers). A system (BS and its SSs) will perceive as interference neighbors, all other systems (BSs and their SSs) which create/receive interference to/from it.

Community: is composed of those systems (BSs and their SSs) which coordinate to resolve their interference.

Coexistence Community: is composed of those systems (BSs and their SSs) which have resolved their interference and coexist.

The figures below explain possible ways of implementing the guaranteed radio resource principle, using a example of three overlapping radio networks.

The overlapping radio networks create different interference zones, based on spatial distance between transmitters and receivers. As example of BS to SS interference,, the radio receivers in Zone A, in the figure below, suffer from the interference (noted with) between Network 1 and Network 2. Interference Zone B includes also the Base Station of the Network B.

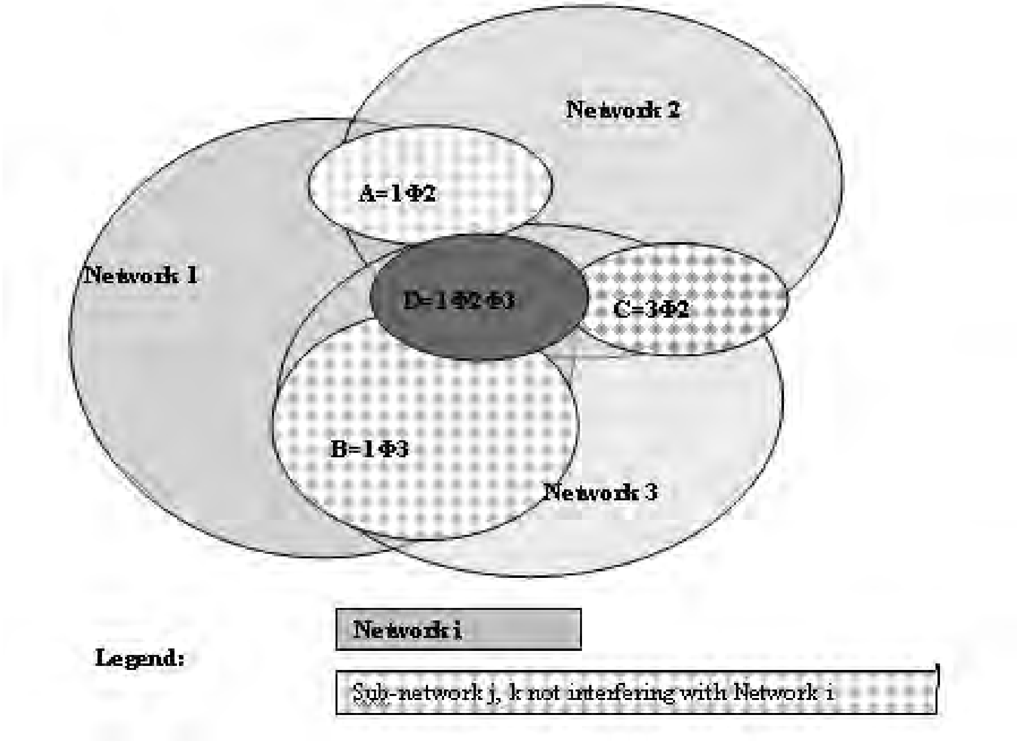


Figure h3—Interference due to overlapping networks

The operation of the 3 networks assume the following different situations:

Zones in which the networks 1,2,3 do not interfere;

- Zone A: Networks 1 and 2 interfere;
- Zone B: Networks 1 and 3 interfere;
- Zone C: Networks 3 and 2 interfere;

- Zone D: Networks 1 and 2 and 3 interfere.

Now lets suppose that we split a time frame in 3 sub-frames (being 3 different networks), and every network will receive an interference free interval for operation.

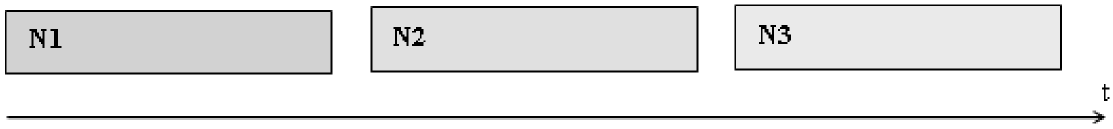


Figure h4—Equal splitting of radio resource between networks

Another possible approach will be to set an operating time for not interfering (noted Ø) situations, and split equally between the 3 networks the remaining resource, like shown below. It can be seen that non-interfering traffic may be scheduled in parallel, resulting a much better radio resource usage.

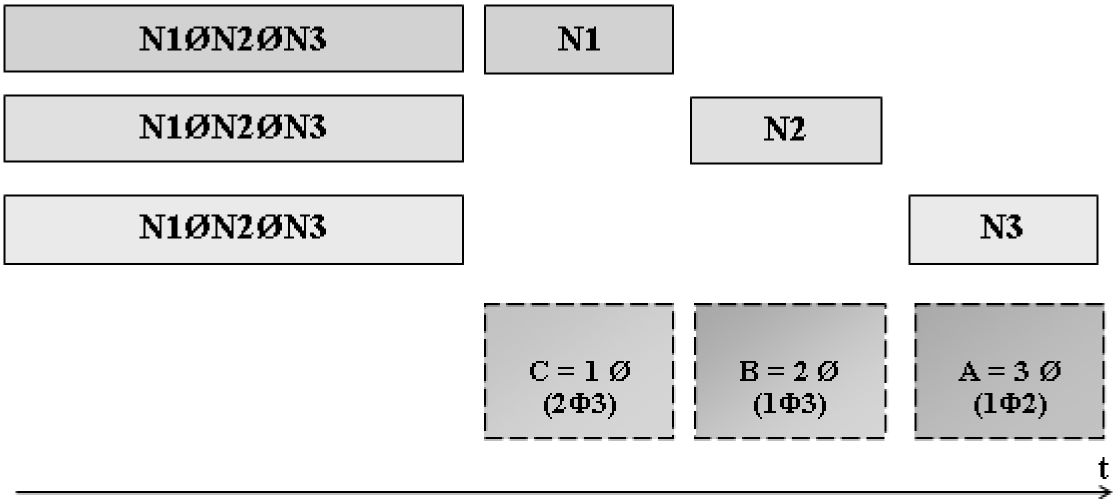


Figure h5—Usage of the spectrum by every system

Taking as example Network 1, it can be seen that this network operates in all the sub-frames, achieving in the same time interference-free operation and good spectral efficiency.

However, the networks working in the same time with the network having the control of the radio resource, shall use power control, sectorization or beam-forming in order to not create interference to that network.

15.2.1.1.1 Cooperation with other networks

A network may need more time resource for its BS communication with the SSs, than available for its operation in the assigned interference-free time interval. In this case, the specific network may request from one or more adjacent networks to reduce their interference free transmission intervals. The other networks will consider the request, and when possible will accept the request, by indicating the agreed new interference-free operating interval. The duration of each sub-frame may be negotiated through inter-network communication and using the common DRRM policy.

15.2.1.1.2 Scheduling of interference free intervals in the context of IEEE 802.16 MAC

A number of repetitive scheduling approaches are presented below, for Tx synchronized intervals. Same approach is valid for Rx intervals.

- *Type 1*: The MAC frame, for each Tx and Rx part, is split in N+1 sub-frames:
  - One for non-interfering traffic
  - Every other one to be used by a single BS or more non-interfering BSs which are assuming the Master role
- *Type 2*: The MAC frame, for each Tx and Rx part, is split in N sub-frames, every one to be used by a single BS or more non-interfering BSs which are assuming the Master role during a sub-frame
- *Type 3*: The MAC frame is split in two sub-frames: one for non-interfering traffic and one in which a single BS or more non-interfering BSs are assuming the Master role; each Base Station will assume the Master role after M frames

The duration of each sub-frame, in a given community, is calculated as follows:

for type 1:

- $T_{Tx\_sub\text{-}frame} = T_{TxMAC\ /\ (N+1)}$
- $T_{Tx\_sub\text{-}frame} = (T_{TxMAC} - T_{Txsh})\ /\ N$
- $T_{Rx\_sub\text{-}frame} = T_{RxMAC}\ /\ (N+1)$
- $T_{Rx\_sub\text{-}frame} = (T_{RxMAC} - T_{Rxsh})\ /\ N$

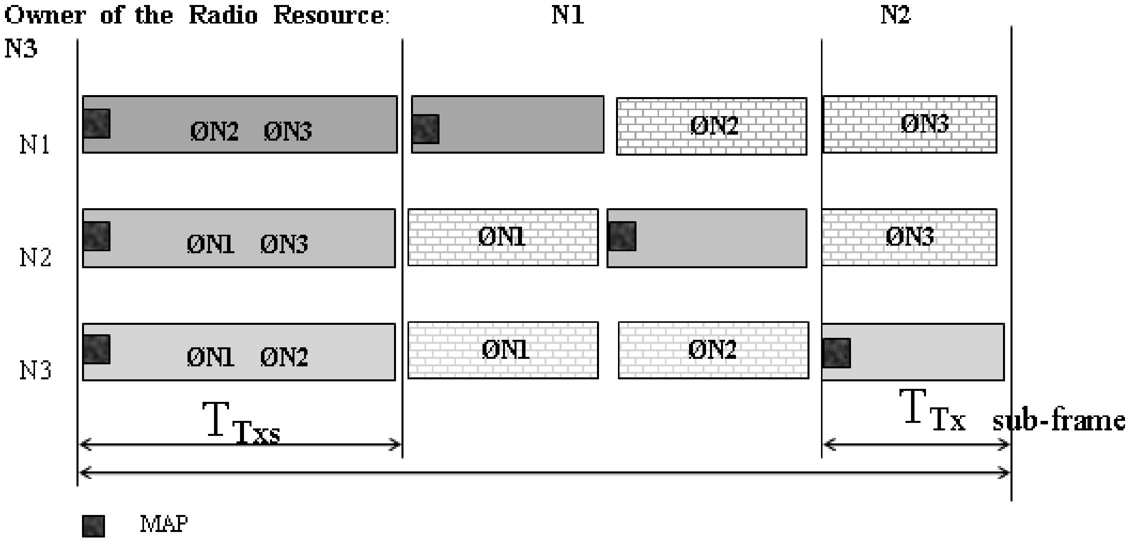


Figure h6—Sub-frame structure type1

for type 2:

- $T_{Tx\_sub\text{-}frame} = T_{TxMAC\ /\ N}$
- $T_{Rx\_sub\text{-}frame} = T_{RxMAC\ /\ N}$

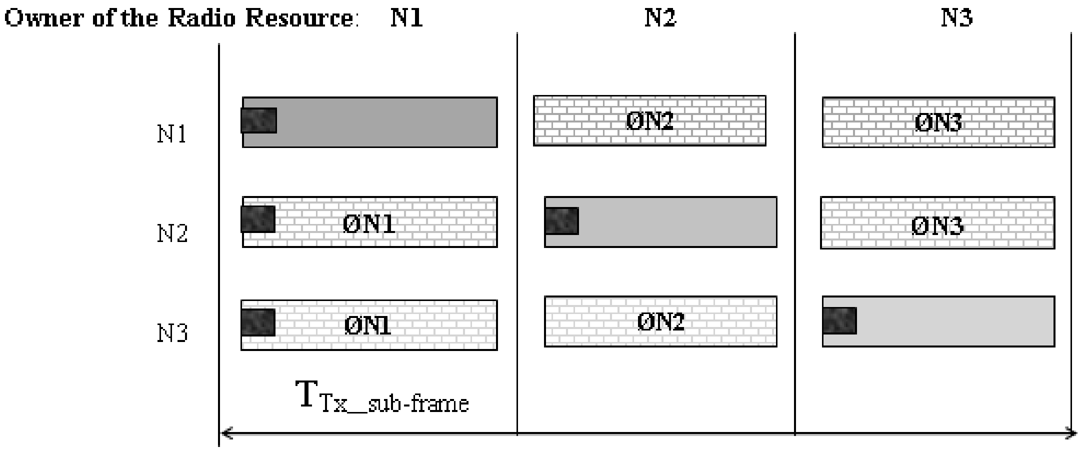


Figure h7—Sub-frame structure type 2

for type 3:

- $T_{Tx\_sub\text{-}frame} = T_{TxMAC} / 2$
- $T_{Tx\_sub\text{-}frame} = T_{TxMAC} - T_{Txsh}$
- $T_{Rx\_sub\text{-}frame} = T_{RxMAC} / 2$
- $T_{Rx\_sub\text{-}frame} = T_{RxMAC} - T_{Rxsh}$

repetition interval = $N*T_{MAC}$,

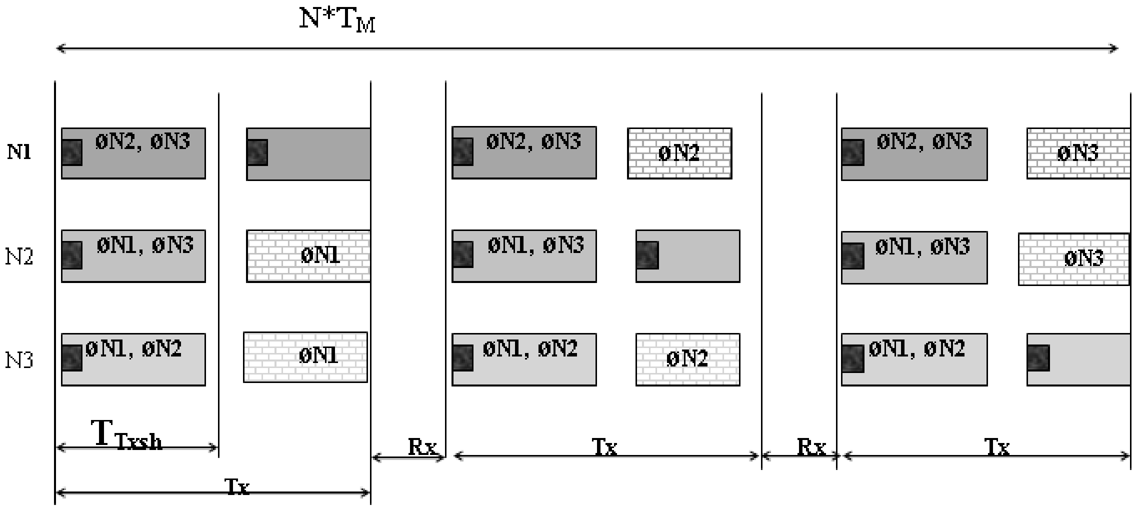


Figure h8—Sub-frame structure type 3

where T_{MAC}, T_{TxMAC}, T_{RxMAC}, T_{Txsh}, T_{Rxsh} are the durations of the respectively the MAC frame, Tx interval and Rx interval of the MAC frame or of the sub-frame used for shared used in the non-interfering sub-frame. In the above relations, the meaning of Tx or Rx is relative to the usage of the MAC Frame by a Base Station.

During the Master sub-frame the Base Stations assuming Master role may use their maximum power;

During every Master sub-frame, the Base Stations will create a slot, possibly not overlapping with another slot of a coexistence neighbor Base Station, during each every transmitter (BS or associated SS) will send a predefined signal; this signal, called "radio signature", will be used to measure the interference created by that transmitter.

- The "radio signature slot" for a Base Station will be created during its Tx Master sub-frame, every B MAC-frames;
- The "radio signature slot" for a Subscriber Station will be created during the Rx Master sub-frame;
- UL MAP and suitable UIUC for scheduling the "radio signature" are t.b.d.
- During "radio signature" intervals, all the other BSs and SSs shall use a GAP interval;
- The Base Station shall take care to provide enough transmit opportunities for the active SSs.

The figure below shows the possible allocation of the "radio signature" transmission opportunity for a given system, using for example the Type 1 repetitive pattern, with a focus on Network 2.

The Network 2 will transmit its Base Station radio signatures from time to time (every N MAC intervals); different radio signatures will be sent for every used power/sub-channelization/OFDMA sub-channel/ spatial direction combination. During these intervals the other Base Stations will schedule a GAP interval, in order to identify solely one Base Station. Base Stations using the same MAC sub-frame as Master sub-frames shall schedule the transmission of their "radio-signatures" in such a way that will not interfere one with the other.

The transmission of "radio-signatures" used by the active SSs will take place during the Master sub-frame, from time to time (a timer shall be defined). The repetition period and the duration of the signature transmission shall be a parameter in the BS Data Base. The active SSs will provide a signature for every used power/ OFDMA/sub-channelization/ direction partition.

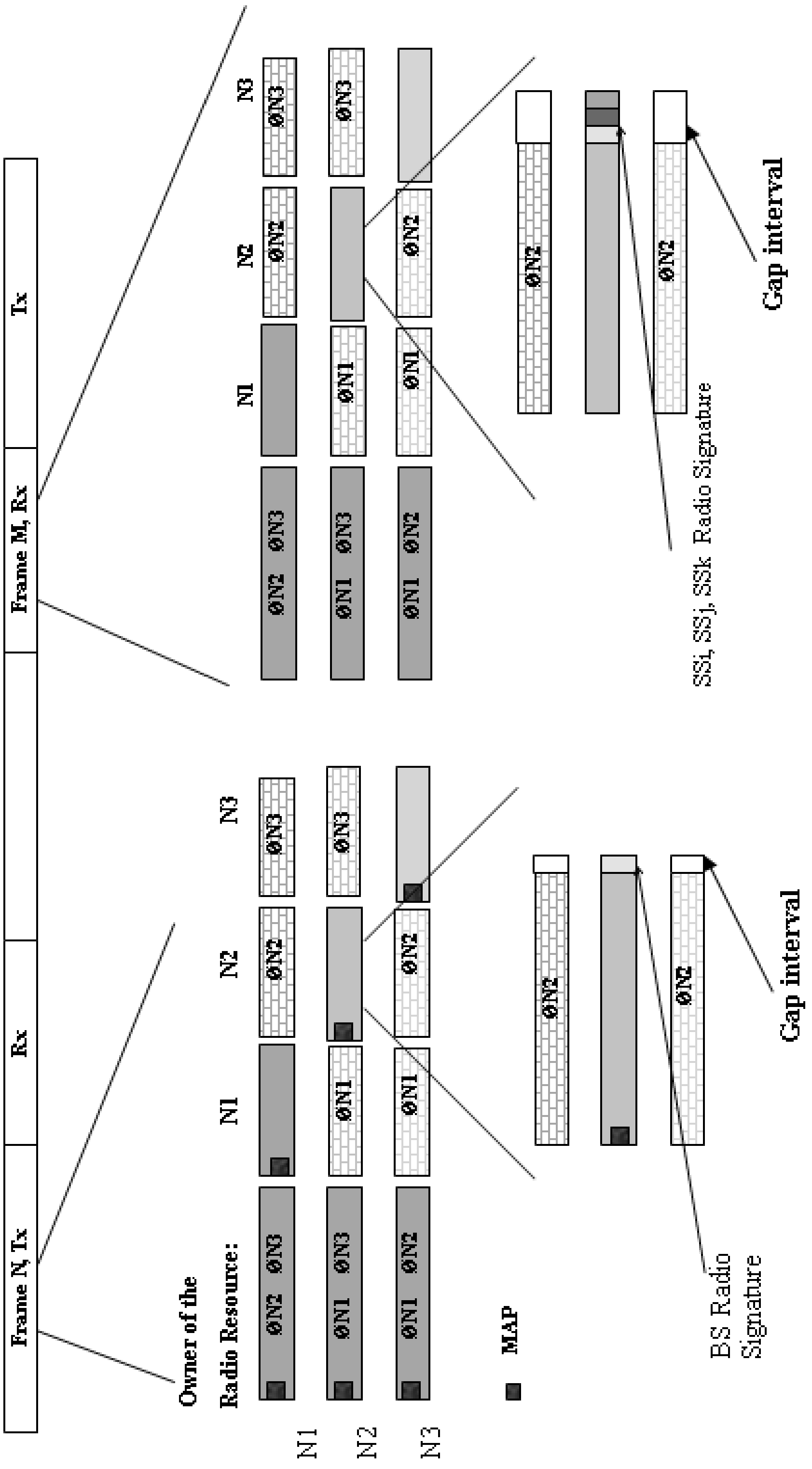


Figure h9—Allocation of slots for BS and SS radio signature

The BS data base will include:

- Operator ID
- Base Station ID
- MAC Frame duration (same for a community)
- Shared Tx and Rx sub-frame durations (same for a community)
- Type of sub-frame allocation (same for a community)
- MAC Frame number and sub-frame number chosen for the Master sub-frame (same for a community)
- Repetition period for Base Station radio-signature, measured in MAC-frames
- *Repetition interval between two Master sub-frames*, measured in MAC-frames
- *List of other used sub-frames*, in the interval between two Master sub-frames
- Time_shift from the Master sub-frame start, duration and the repetition information for the Base Station radio-signature transmission
- Time_shift from the Master sub-frame start, duration and the repetition information for the Subscriber Station radio-signature transmission
- *Time_shift from the Master sub-frame start and duration for network entry of a new Base Station*, which is evaluating the possibility of using the same Master slot.
- BS power relative to radio-signature, in the used sub-frames, in the interval between two Master subframes;
- For every active SS: SSID and its attenuation relative to radio-signature power, in the used subframes,in the interval between two Master sub-frames;
- For every coexistence neighbor BS: the BSID, the IP address of the coexistence neighbor and other profile information, and the SSs it interfered to, (and the SSs belong to it that interfered by the database owner BS.tbd.)
- For every BS in the same community: the contact IP address and the interference situation between this BS and other BS, including the interference situation with the DB owner.
- For every SS registered: the interference situation, the number of interference source, the IP address and RSSI of each source detected by the SS.

At the MAC level, the Master sub-frame is scheduled by using the Coexistence Zone.

The following figures show examples of the usage of the CXZ and the relation with the Master sub-frame types 1 and 3:

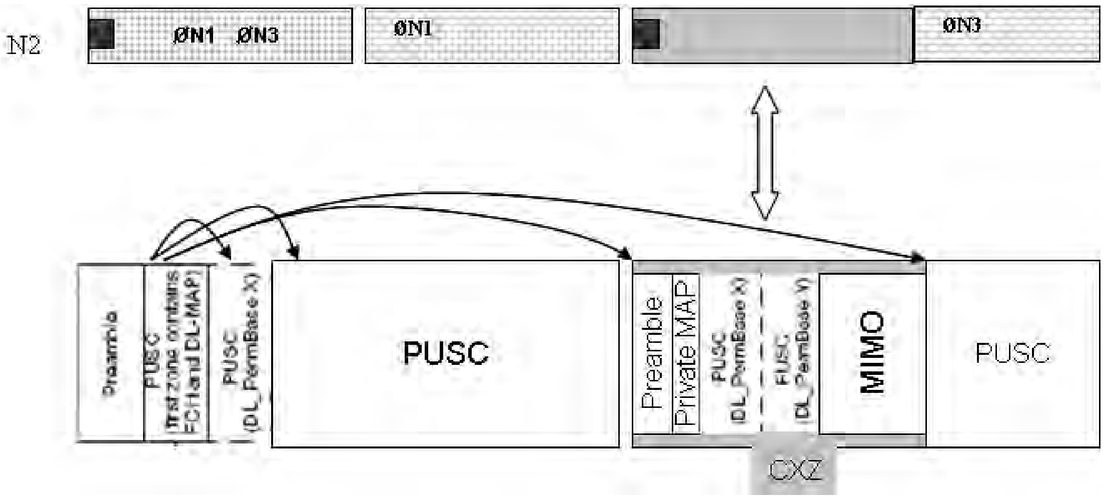


Figure h10—Relation between Master sub-frame type 1 and the CXZ

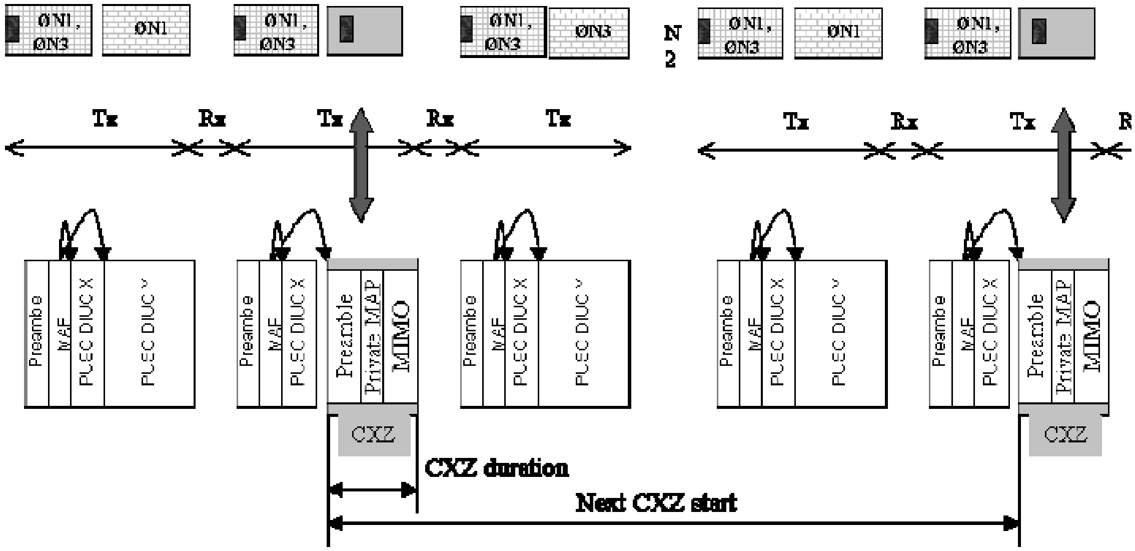


Figure h11—Relation between Master sub-frame type 3 and the CXZ

15.2.1.1.3 Coexistence Signaling Interval

CSI (Coexistence Signaling Interval) is predefined time slot for the coexistence protocol signaling purpose, especially for the BS to contact its coexistence neighbor BS through one or more coexistence neighbor SSs in the common coverage area. For the Initializing BS, periodical CSI called ICSI (Initialization Coexistence Signaling Interval) is appointed specially used by IBS to contact its neighbor OBS. Buy coordinate with other BS, the IBS will get its periodical OCSI (Operation Coexistence Signaling Interval) which is allocated only for this BS, and start the operating stage, hence ceased from using the ICSI.

Every CSI have its number, called CSIN (Coexistence Signaling Interval Number), that's a periodical number according to the time order.

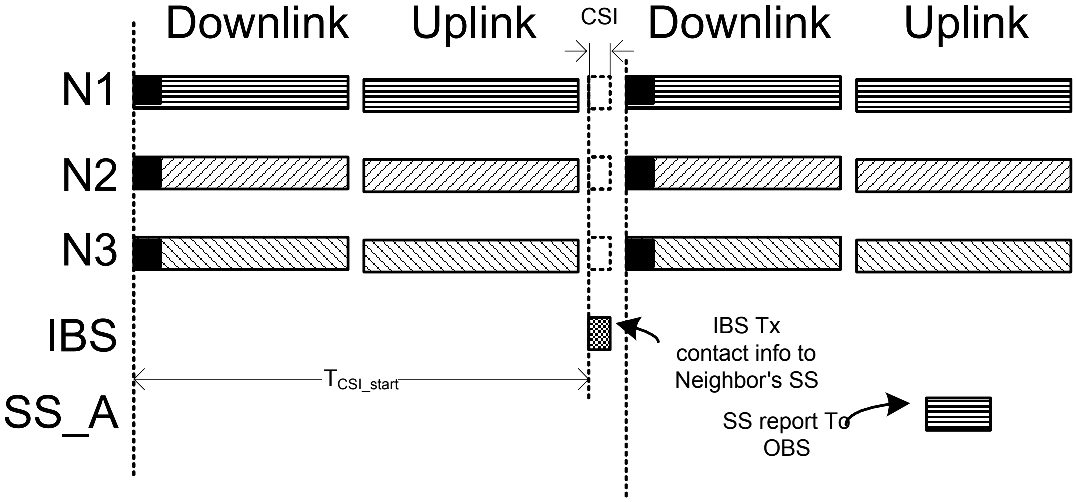


Figure h12—Timing of Coexistence Time Slot

Not to break the downlink PDU, and to diminish overhead of more preamble and gaps. CSI slots shall be located before RTG/TTG in TTD frame structure or before the preamble of downlink frame in FDD frame structure .To unify the location in these two kind of frame duplex, CSI slots in FDD frame shall be put into the downlink structure right before the preamble, and shall be located right before RTG in TDD frame.

The CSI/ICSI parameters need to be unified in a particular region, and to be well known by the BSs. So that each BS could know the exact time to transmit the broadcasting message in its initialization. The parameters include:

- $T_{CSIstart}$ *: CSI starting time from the beginning of the frame (ms)*
- $\boldsymbol{T_{CSIdurat}}$ **:** CSI duration time (ms)
- $\boldsymbol{N_{CSIstart}}$: CSI starting frame number frames
- $N_{CSIintv}$: number of frames in CSI interval

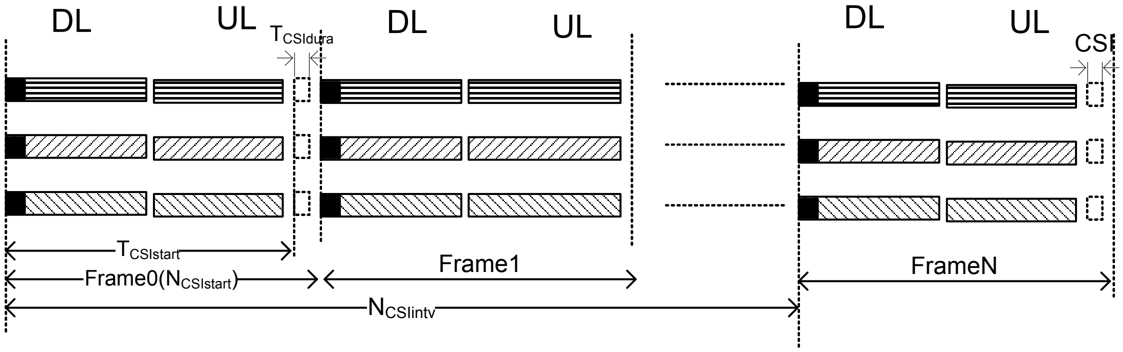


Figure h13—CSI parameters

- N_{ICSI_Cycle}: ICSI cycle counted in CSI cycles
- N_{OCSI_Cycle}: OCSI cycle counted in ICSI cycles

Assuming NCSIintv =4, NICSI_Cycle =4, NOCSI_Cycle =2, here is the example of the timing indication:

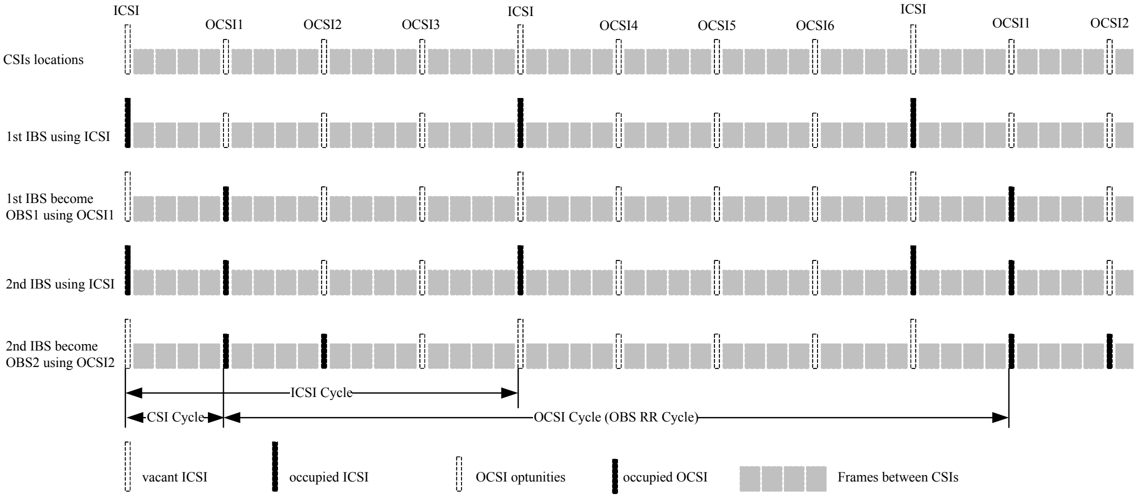


Figure h14—ICSI/OCSI occupation and timing example

[Notes: 15.2.1.1.4 & 15.2.1.1.5 is provisional, taken from C80216h-05_029 and call for comments and futher contribution]

15.2.1.1.4 Energy Symbols Used in the CSI

The symbols used in the CSI slots is used to broadcast by the BS and received by the SS in coexistence neighbor network. The modulation technology on both side should be one of the3 following: SCa, OFDM or OFDMA, and could be different on two side. The band of the two side shall have overlapped part, and the bandwidth of two side could be different.

The symbol is defined only in the power and time aspect, and could use any one of the modulation technology and any band that have been used in the equipment. The length of the energy symbol shall be 1/N of the CSI length, here N is a natural number and to be consolidated in region/country regulator.

There is 4 kinds of symbols:<SOF>,0/null,1,<EOF>, to be used to form any frame in CSI.

- <SOF>: Start Of Frame, indicating the data part will start at the following symbol.
- 0/null: Binary code 0 used to compose the data part, same with null symbol.
- 1: Binary code 1 used to compose the data part.
- <EOF>End Of Frame, indicating the data part ended at the last symbol

Each symbol is divided into two equal length parts. And for each part, there is 2 kinds of power keying level defined, H (high) and L (low). High power level part need the BS to use the maximum power to transmit and the SS will detect higher RSSI at that part, and the low power level part need BS to be silent and SS will detect lower RSSI at that time.

The format of each kind of symbols is shown in the table below:

Table h1—CSI symbol Format

format		signification
Part1	Part2	
L	H	<SOF>
H	L	<EOF>
L	L	0
H	H	1

The receiving SS shall follow up the CSI timing and detect each symbol continuously in every symbol space. The SSs shall verdict the symbol by this aspect of RSSI and time. One CSI consists of several symbols with the same length, the number of symbols in each CSI slot is standardized in region/country.

15.2.1.1.5 CSI Frame Structure

CSI frame is broadcasted from the base station to coexistence neighbor's subscriber station. They are loaded into serialized CSI slots. It consists of power keying energy symbols as basic element and carry the information from BS to the coexistence neighbor's SS. The CSI frame has the <SOF> symbols and <EOF> symbols as the boundary of slots, and two consecutive <SOF> and <EOF> indicate the message boundary, it shall be filled with symbol one in the rest part of last slots which have not enough payload and checking appendant.CSI frame should be continuously carried in the serialized CSI slots during the whole CSI frame structure. Each CSI frame shall have 8 bits cyclic redundancy check (Polynomial "X8+X2+X+1") appendant to check the validity of the information carried in the CSI frame. The basic structure is shown below:

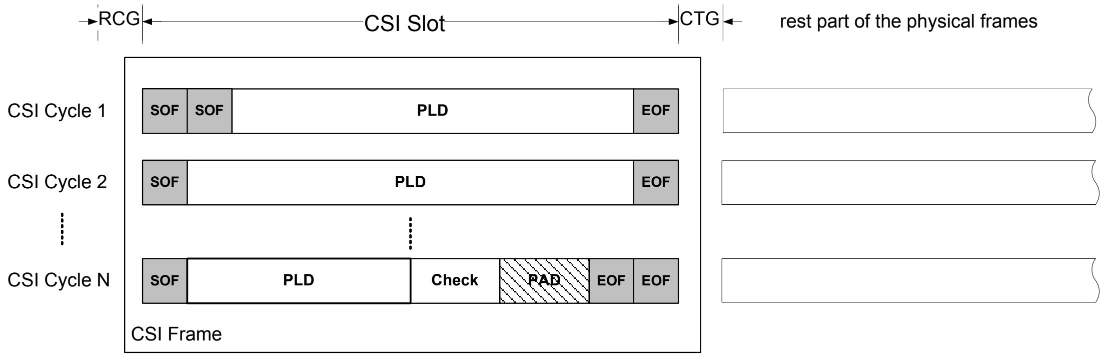


Figure h15—CSI frame construction

The PLD (payload) part of the CSI frame should be divided into TLV aspect. TYPE indicate the type of the payload, LENGTH correspond to the number of symbols/bits contained in the VALUE portion. (TYPE and LENGTH is 1 octet each.)

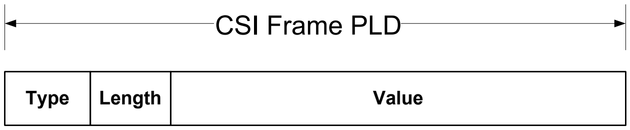


Figure h16—CSI frame PLD

15.2.1.1.6 Coexistence proxy

Every BS shall use its coexistence proxy to send/receive messages containing the IP contact information over the air so that BSs will not know the IP address of this BS. The coexistence proxy should have a stand alone physical port and an IP address to connect into the internet, it can connect the BS through internet, direct link or internal interface. The coexistence proxy could be a module of BS or a server stand alone.

Coexistence proxy can also optionally be used to forward the CP message between BSs, the proxy will isolate the BSs from BSs and terminals in the internet. In the coexistence coordination process, all the BSs will not know BSs' IP address, and contact them only via coexistence proxy and the BSID information. In order to prevent various attack from the internet, proxy could utilize various approach to protect BSs without influence the data service of BSs. *[Proxy could limit the forwarding bandwidth from one IP address or to one BSID. Proxy could qualify or block the message using various approach.]*

15.2.1.1.7 Coexistence Messaging Interval

[the following part of this section is taken from C802.16h-06_010r1, content below and above need to be harmonized.]

A Coexistence Messaging Interval (CMI) is a reserved physical frame used for the coexistence protocol signaling purposes. The CMI is used with systems having the same profile (15.2.2.3.1) and synchronized MAC frames. The position of the CMI and the subsequent IEEE 802.16 MAC frames are synchronized to a GPS timing signal (15.7.2.1.1). Furthermore, the CMI are identified by UTC time stamps (15.7.2.1.1.3). For example, the beginning of the first CMI is at HH:MM:00 UTC, the second CMI is at HH:MM:06 UTC, etc. The beginning of every CMI is specified by a UTC message (time stamp) (Figure h 17).

The CMI is used by WirelessMAN-CX systems (BSs and their SSs) to mediate their co-channel coexistence. The CMI will be an opportunity for systems (BSs and their SSs) to indicate to other systems (BSs and their SSs) the extent of the interference they can cause; newly arriving interfering base stations (IBS) will use the CMI to make themselves known to established communities of operating base stations (OBS). Newly entering SS will make their presence known when they are detected by base stations to which they are not associated (see Section ***TBD***). Sporadic interference from BS or SS will also be detected by the same process.

A Coexistence Community can consist of a maximum of 9 systems ***(TBD)***. Each system claims a unique CMI by a process outlined in Section 15.2.1.3.1. There are a total of 10 CMI which repeat every minute (***TBD***), but since CMI_ID 54 is reserved for noise measurement and foreign system identification purposes, there are only 9 CMI available to the Coexistence Community. A system must broadcast its BSD and SSURF messages once a minute on its CMI; when it does this all other members of the Coexistence Community remain silent and monitor to detect the extent of the interference that is caused by this.

[Notes: the term "CTS" in the following Figure h 17 should be updated as "CMI", need to be handled by the original contributor.]

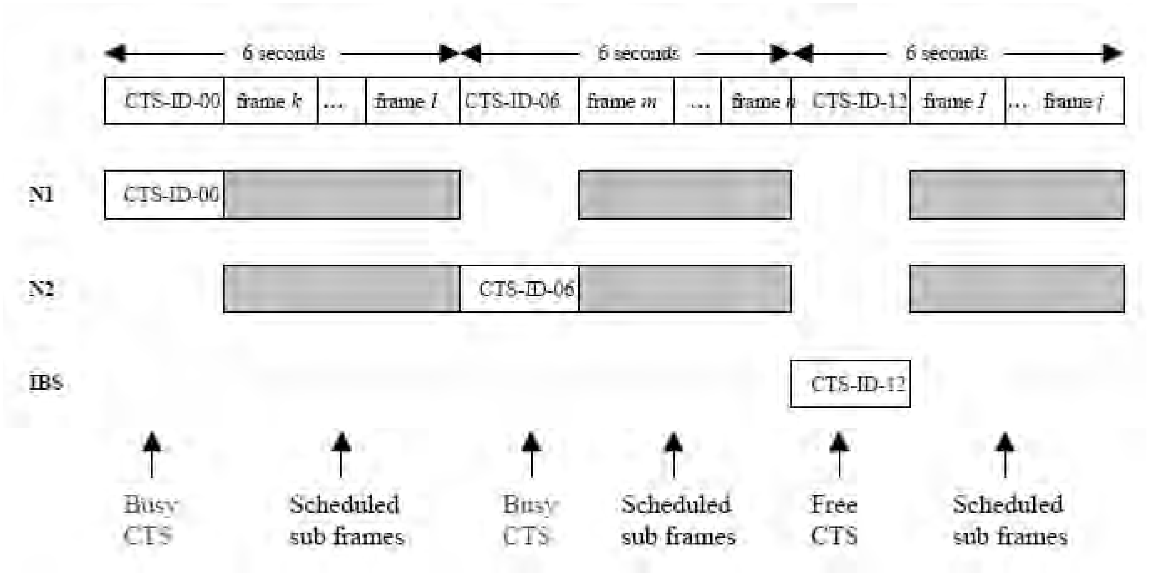


Figure h17—CMI Timing (CTS should be changed to CMI)

15.2.1.2 Interference Control

Interferer identification using the radio signature

- A receiver will listen to the media during the radio signature slot and will find out which are the strongest interferes; by scanning the BS data bases will be possible to identify, due to the knowledge of the frame number, sub-frame number and offset, to which BS is the interferer associated; based on time-shift information, the Base Station will be able to identify the Subscriber Station ID. During the allocated radio-signature transmit opportunity no other radio transmitters will operate.

Interference reduction

- A BS has the right to *request an interferer to reduce its power by P dB*, for transmissions during the time in which a Base Station is a Master; if the requested transmitter cannot execute the request, it has to cease the operation during the Master sub-frame of the requesting Base Station; this applies also for systems using the sub-frame as a Master

Sharing the Master time

- A Base Station will indicate in the data base *what portion of the sub-frame time, separately for Tx and Rx, is actually used*
- Other systems, which do not interfere one with each other, may use that time interval

Target acceptable interference levels during Master sub-frames:

For the Base Station and its SS, using the Master sub-frame: min. 14dB above the noise + interference level (16QAM 1/2 ***[note: we should define the interference criteria; the existing one may be too stringent and not necessary for short links]***

15.2.1.3 Community Entry of new BS

To enter the existing community of its neighbors, a new BS without any associated SS need to get contact with his neighbors and coordinate using the IP network. The new BS should synchronize to the timing of the CSI and ICSI in the air before using ICSI to broadcast the BS_NURBC (see 15.6.6.2.1) message to make its neighbor know its arrival and the contact information of this new coming one.

ICSI is used by IBS to establish communication with its neighbor BSs. Initializing BS (IBS) shall use ICSI slot to broadcast its coexistence proxy's IP address and the BSID of IBS, by sending a message and/or cognitive radio signaling. So that the coexistence neighbor operating BS could find the initializing coexistence neighbor in IP network via its coexistence proxy after receiving the SS report for this message. In order to obstruct coexistence request from unqualified internet terminal such as someone far away or some one without any capability of 16h air signaling which have known the static BSID and IP address information, the BS should put in a RTK (Random Temporary Key) in the broadcast massaging. To qualify the request of CP message, the RTK sender requires the request CP message sent back later via IP network to contain this random temporary key. Then the IBS and OBS begin further negotiation via their coexistence proxy for coexistence protocol. After coordination with the neighbors in the community, IBS will get periodical interference free OCSIs, and become OBS, after that, it will cease from using the ICSI.

The BS_NURBC (see 15.6.6.2.1) broadcasting procedure is unidirectional, only from the BS to the SSs in common coverage of the BS and its neighbors', and the SSs shall report all the useful information to their OBSs they associated to. The SSs that succeed in receiving the message should report the content of BS_NURBC and the frame number of the starting frame of BS_NURBC, the SSs which fail to received the broadcasting message but get BS_NURBC as interference in the CSI should report the error status and the starting frame number of receiving the interference in CSI. IBS use ICSI to broadcast BS_NURBC message, the content in the message will enable its neighbor systems to communicate with the IBS in the IP network to coordinate by coexistence protocol. By the IP address of IBS's coexistence proxy and the BSID reported from the SSs with RTK, the OBSs will then communicate with the IBS in the IP network via their coexistence proxy, and go further coordinate using IP network. And by checking the frame number in the report, OBS need to find out if the SSs that report the error status in BS_NURBC receiving have got the same interference source, then OBS will update the database and reply to the SSs which have send the error report.(see Figure h 18.)

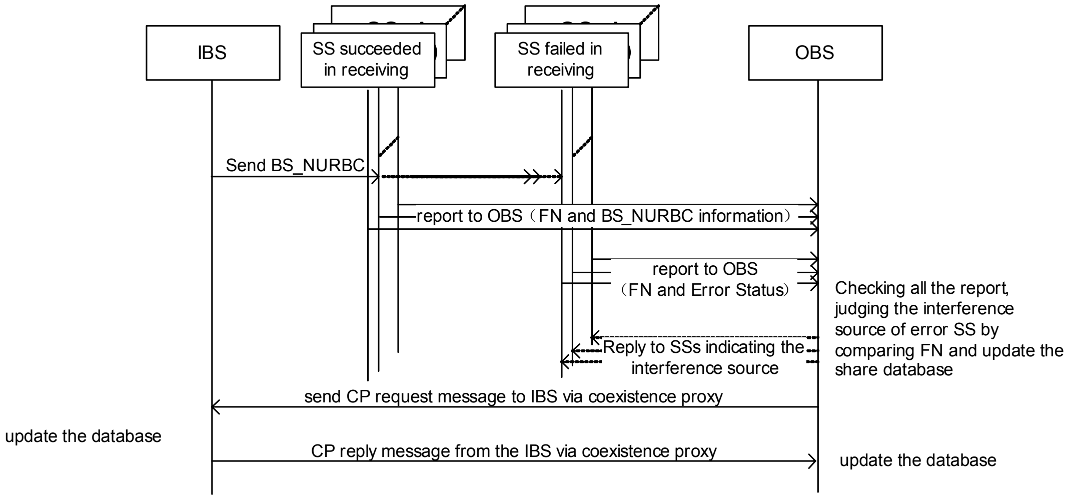
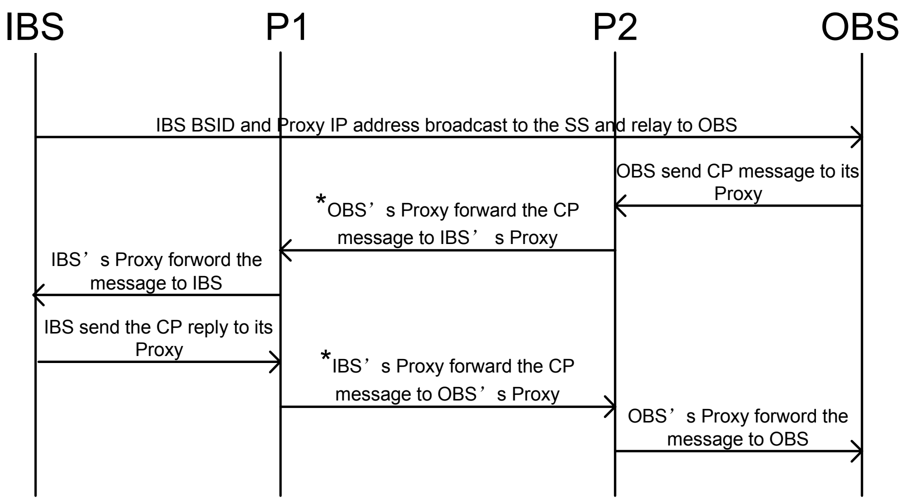

IBS
SS succeeded in receiving
SS failed in receiving
OBS
Send BS_NURBC
report to OBS（FN and BS_NURBC information）
report to OBS （FN and Error Status）
Checking all the report, judging the interference source of error SS by comparing FN and update the share database
Reply to SSs indicating the interference source
send CP request message to IBS via coexistence proxy
update the database
CP reply message from the IBS via coexistence proxy
update the database

Figure h18—IBS entering the community by neighborhood update request broadcasting

For a new entering BS, it need to know the IP address of its coexistence proxy. By broadcasting the IP address of its coexistence proxy and the BSID of itself, all the neighbor OBSs get the contact information should start to communicate with this IBS through internet via coexistence proxy. After receiving the CP request message from OBS, the OBS's coexistence proxy will then transform the source IP address into the IP address of the proxy, and forward the CP request message to the destination coexistence proxy which serves IBS. The IBS's coexistence proxy should get the destination BSID by parsing the CP request message, and map it into IBS's IP address. If the BSID is in the coexistence proxy service list and find the corresponding IP address, the coexistence proxy should forward the qualified CP request message to the IBS. Vice versa, IBS should send the CP reply message to the OBS via the coexistence proxy after receiving and processing the CP request message.


IBS
P1
P2
OBS
IBS BSID and Proxy IP address broadcast to the SS and relay to OBS
OBS send CP message to its Proxy
*OBS’s Proxy forward the CP message to IBS’s Proxy
IBS’s Proxy forword the message to IBS
IBS send the CP reply to its Proxy
*IBS’s Proxy forward the CP message to OBS’s Proxy
OBS’s Proxy forword the message to OBS

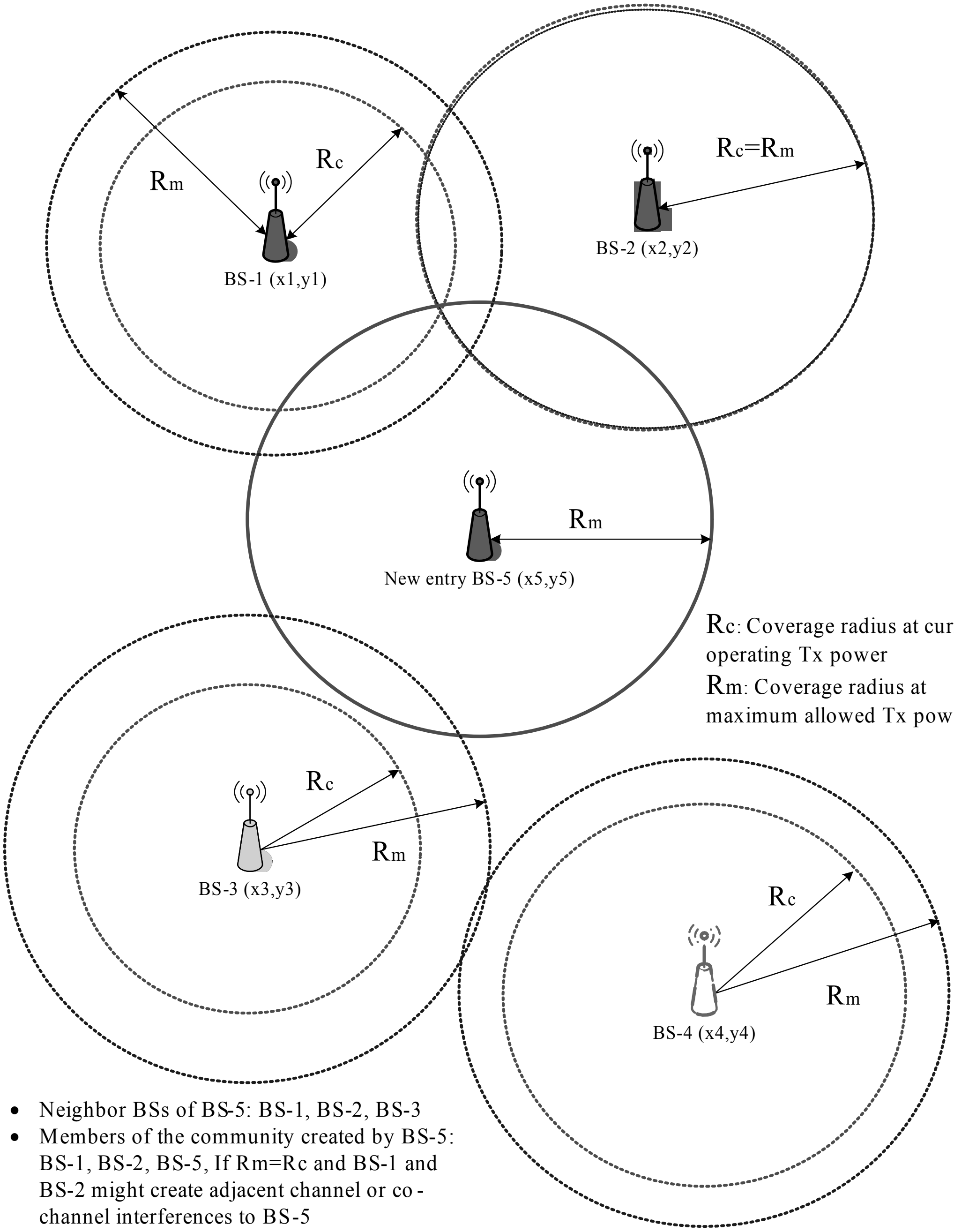
*only needed when P1 and P2 are not the same

Figure h19—IBS entering the community with proxy

Figure h 20 explains how one new entry BS discovers its coexistence neighbor BSs. The new entry BS-5 uses its GPS coordinates (x5, y5) and its maximum coverage radius in LOS, Rm, at allowed maximum transmission power. A BS is *potential* coexistence neighbor BS of another BS if:

- In co-channel operation the LOS maximum coverage area resulting for the allowed maximum transmission power overlaps one with each other. As depicted in Figure h 20,the regional LE DB will return BS-1, BS-2 and BS-3 as the *potential* coexistence neighbor BSs of the new entry BS.
- In first or alternate adjacent channels operation, the BS should consider the attenuation of the transmitted power, corresponding to the actual operation channels of different Base Stations

Once a LE BS has learnt its *potential* coexistence neighbor topology from the regional LE DB, it evaluates the coexisting LE BSs and identifies which BSs might create interferences. The Adaptive Channel selection will select the actual operating frequency, such that the probability of interference will be minimized. Each LE BS tries to form its own community. By including the coexistence neighbor BSs that create interferences to the associated SSs The members of community will change when the working frequency of any BSs changes or new interfering coexistence neighbor BS comes in.



Rc: Coverage radius at current operating Tx power
Rm: Coverage radius at maximum allowed Tx power

- Neighbor BSs of BS-5: BS-1, BS-2, BS-3
- Members of the community created by BS-5: BS-1, BS-2, BS-5, If Rm=Rc and BS-1 and BS-2 might create adjacent channel or co-channel interferences to BS-5

Figure h20—802.16 LE Coexistence neighbor BSs discovery and definition of coexistence neighbor and community

With the regional LE DB a LE BS can construct its coexistence neighbor topology and acquire the IP addresses of its coexistence neighbor securely.

In any case that the new coming BS could not find the region LE DB, it should start a ad-hoc method to find the neighbor topology. The new coming BS use the coexistence time slot to broadcast its IP address to the reachable SSs in the neighbor network. Once the SSs received this message, they will report to their serving BS one by one unsolicitedly, the information of the new BS and the interference status that they record during the receiving will be reported to there serving BS.

The serving BS will get all the information from the related SSs and saved the useful content to their database. After that, the serving BS will contact new BS using the IP address reported by the SS and transfer the parameter of its own to the new coming one with authorization and negotiation, thereafter the serving BS will also get the parameter and other corresponding information from the new coming BS.

In general, the coexistence detection, avoidance and resolution are performed in two stages, initialization stage and operating stage.

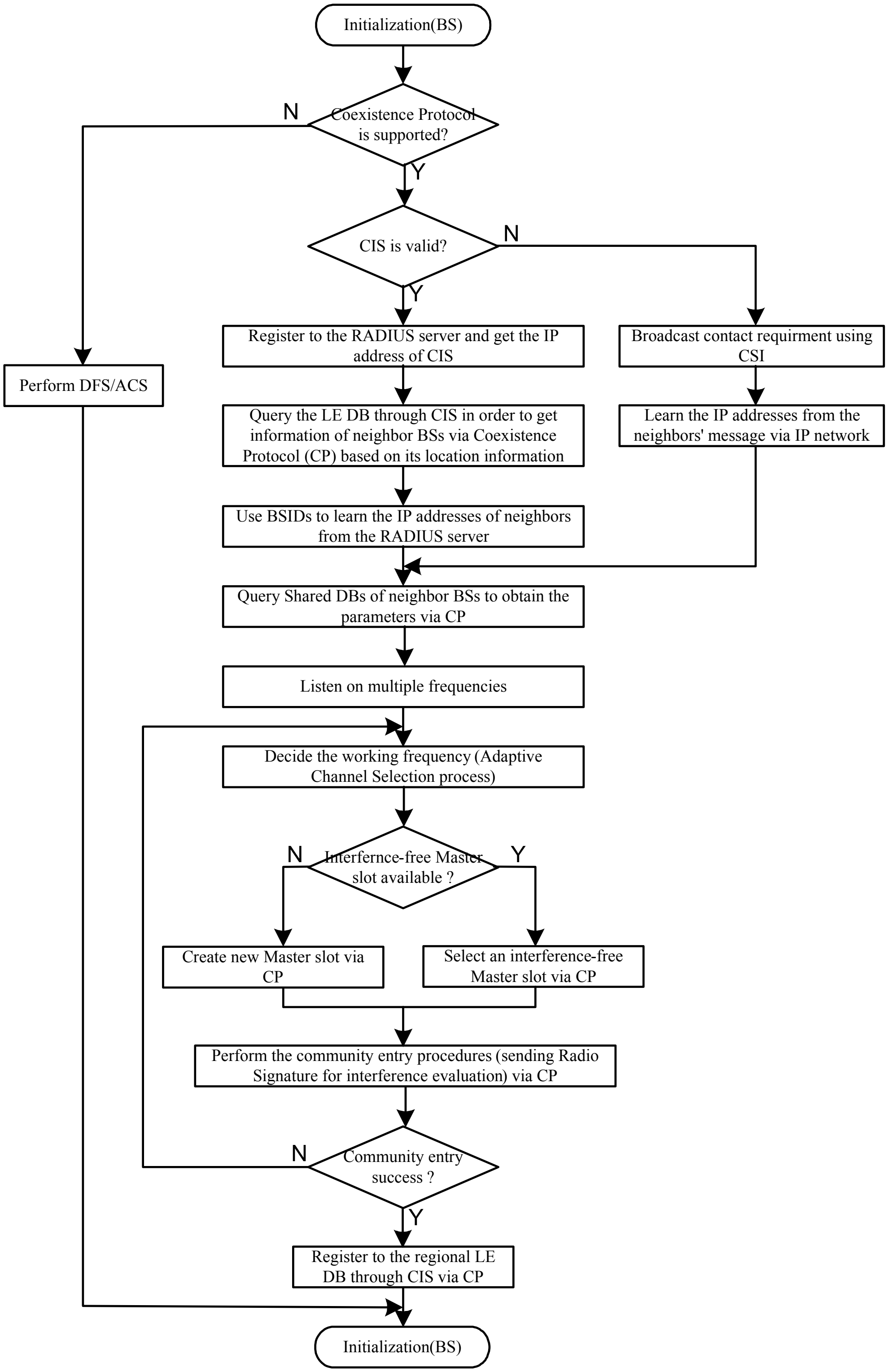
(1) *Initialization stage*

In initialization stage the LE BSs may avoid the co-channel or adjacent channel interference by scanning the available frequencies. But this method cannot avoid the *hidden* LE BS problem, i.e. the BS that cannot be heard directly but may have overlapping service coverage. Thus, with the knowledge of coexistence neighbor topology the LE BSs can detect the *hidden* LE BSs and can, therefore, avoid the possible interferences from coexisting coexistence neighbors. Alternatively, if the country/region database is not valid in this phase, the initializing BS will use the coexistence time slot to broadcast its IP address to its coverage using its maximum power. In this way, the SSs in the reachable zone of the new BS's interference will receive the message and forward the address to its serving BS. And after the neighbor BSs get the address via the SSs' reports, they will contact with their new coming neighbor via IP network and updating the database on both side. Thus, in ad-hoc fashion, it will avoid the hidden neighbor BS issue by the SSs in the neighbor network. If the LE BS finds that there is no “free” channel, the coexistence neighbor topology in the share database provides the information of with whom it should negotiate. LE BS may decide whether a “free” frequency can be allocated for itself by channel reallocation within community, If IBS can figure out optimized channel distribution in the community, which made every member in the community could occupy a exclusive channel, IBS should contact the BSs in the community which need to reallocate the channel in the new distribution and negotiate, after admitted by each BS, IBS should send a message to the candidate BS to indicate the switch time and the target channel, all the candidate BS should then follow the indication and switch to the target channel synchronously. Otherwise, if IBS can't get a “free” frequency whatever reallocation executed, that means IBS should have to share a frequency with one or some of its neighbors. The procedures are described in Figure h 21.

(2) *Operating stage*

In operating stage the LE BS has SS associated with it, however, even the operating system parameters has decided, the co-channel or adjacent channel interference from LE BSs of different network may still have a chance to happen due to the detection of interference from primary user, channel switching of coexistence neighbor BS or the entry of new coexistence neighbor BS makes the community so crowded that there is no enough channels. If the LE BS finds that there is no “free” channel at that moment, synchronous channel switching maybe executed, or the coexistence neighbor topology provides the guidelines of with whom it should negotiate to share the channel. ***[detailed procedures are to be defined]***

Figure h 21 shows the initialization procedures for the 802.16 LE BSs. Note that the procedures that BS tries to create a Master slot or channel switching are also applicable for operating stage. The detailed negotiation and update procedures are described in section 15.6.1and 15.7.1.4.



Initialization(BS)
Coexistence Protocol is supported?
N
Y
CIS is valid?
N
Y
Register to the RADIUS server and get the IP address of CIS
Broadcast contact requirment using CSI
Perform DFS/ACS
Query the LE DB through CIS in order to get information of neighbor BSs via Coexistence Protocol (CP) based on its location information
Learn the IP addresses from the neighbors' message via IP network
Use BSIDs to learn the IP addresses of neighbors from the RADIUS server
Query Shared DBs of neighbor BSs to obtain the parameters via CP
Listen on multiple frequencies
Decide the working frequency (Adaptive Channel Selection process)
Interfernce-free Master slot available ?
N
Y
Create new Master slot via CP
Select an interference-free Master slot via CP
Perform the community entry procedures (sending Radio Signature for interference evaluation) via CP
Community entry success ?
N
Y
Register to the regional LE DB through CIS via CP
Initialization(BS)

Figure h21—Initialization procedures — BS

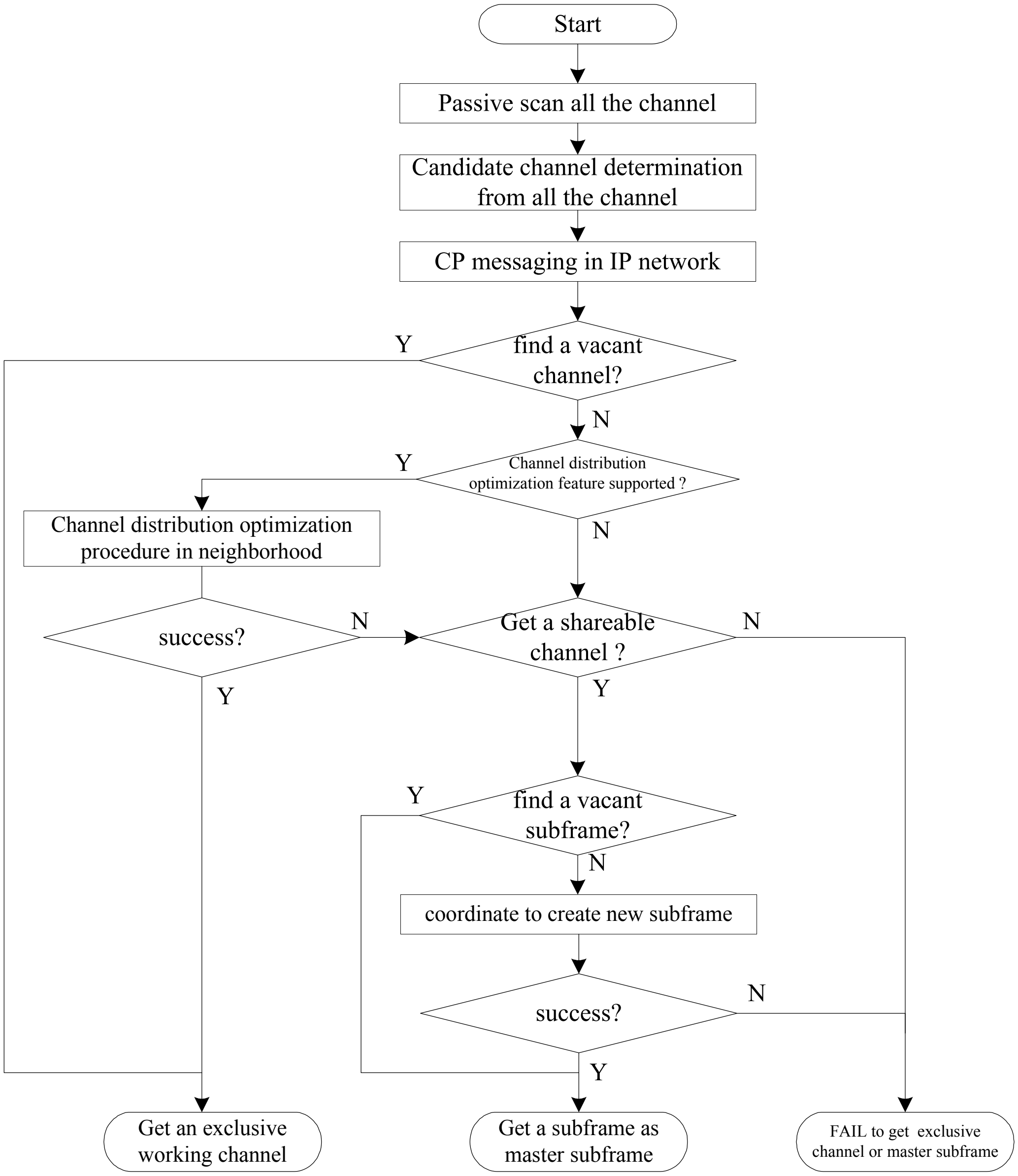

Start
Passive scan all the channel
Candidate channel determination from all the channel
CP messaging in IP network
find a vacant channel?
Y
N
Channel distribution optimization feature supported ?
Y
N
Channel distribution optimization procedure in neighborhood
success?
N
Y
Get a shareable channel ?
N
Y
find a vacant subframe?
Y
N
coordinate to create new subframe
success?
N
Y
Get an exclusive working channel
Get a subframe as master subframe
FAIL to get exclusive channel or master subframe

Figure h22—Initialization procedures - BS radio resource allocation

[Note: the following text needs further consideration]

— *The first phase of* the Community Entry is to judge the validity of country/region data base. If the country/region Root RADIUS serveris valid(t.b.c: what means valid?),, the processfurther queries Root RADIUS server::

- o Get the BSISs from the country/region Root RADIUS server;
- o *Read the data base maintained by BSIS via Coexistence Protocol;*
- o Identify which Base Stations might create interference, based on the location information;
- o The IBS learn the IP identifier for those Base Stations;

Otherwise:

- o New BS uses the interference free slot to broadcast the message containing the contact request and/or the cognitive radio signal transmitting the IP address
- o *The SS in the common coverage will forward the information to its operating base station. using REP_RSP message*
- o The operating BS update its database and send feedback informationto the IBS, using the IP network
- o *learn the IP identifier of the coexistence neighbor BS from the message sent by the coexistence neighbor BS via IP network*

- — Build the local image of the relevant information in the community BS's, *by copying the info in those BSs*
- — Listen on multiple frequencies
  - o Identify the level of interference on each frequency channel;
- — Decide the working frequency (ACS – Adaptive Channel Selection process);
  - o If no interference detected on some channels, select one randomly as working channel;
  - o If interference detected by IBS or OBS network on all channels, then IBS should decide whether an optimized channel distribution can allocate an exclusive channel for each BSs including IBS in community.
  - o If every BS in community can be allocated an exclusive channel without interfering with others, that means default interference-free Master slot is available for this initializing BS.
- — If available, select an interference-free Master sub-frame; if not, use the procedure for creating new Master sub-frames;
- — Search the Base Station data base for finding the BSs using the selected Master sub-frame;
- — *Request those Base Stations, by sending IP unicast messages, to listen during the BS_entry slot* in order to evaluate the interference from the new Base Station;
- — Use the allocated slots for transmitting the "radio signature" at maximum power, maximum power density and in all the used directions;
- — *Ask for permission of the Base Stations*, using the sub-frame as Masters, *to operate in parallel and use the same sub-frames;*
- — If all of them acknowledge, the Base Station acquires a "temporary community entry"status; the final status will be achieved after admission of the SSs;
- — If no free Master slot sub-frame is found, use the procedure for creating new Master slotssub-frames.

15.2.1.3.1 Entry of a new BS into a Interference Neighborhood and the Creation of a Coexistence Community Using GPS/UTC Time Synchronization and Common System Profile

In applications where the Coexistence Messaging Intervals (CMI see 15.2.1.1.7) are synchronized to a GPS (or similar precision timing reference) and are given UTC time stamps (Figure h 17), entry of a new Base Station (IBS) will be undertaken in 4 steps, with the IBS:

(a) Monitoring the CMI Intervals,
(b) Selecting an Empty CMI interval,
(c) Claiming an empty CMI interval,
(d) Membership in a Coexistence Community.

Prior to entry into a Community of Operating Base Stations (OBS) it is assumed that the IBS will have undertaken Candidate Channel Determination (Section 15.4.1.1.1) and has selected a candidate channel, is synchronized to a downlink GPS signal and can derive a UTC time stamp, and has no operational SS yet deployed. It is assumed that the IBS is deployed within an Interference Neighborhood: ie: active interference from existing Operating Base Stations is present. It is also assumed that the community which entered is WirelessMAN-CX compliant and uses a common (same) profile. The IBS entry process is shown in Figure h 23,Figure h 24 shows aspects of the entry procedure with signalling.

(a) Monitoring the CMI

Having tuned to the candidate channel, the IBS monitors and determines the level of activity on each CMI by demodulating the uplink SSURF (Sec 6.3.2.3.62) messages and storing their parameters in its Base Station Information Table(See Table h 2). All demodulated SSURF messages will be from SSs that will interfere with the BS on the uplink and eventually, coexistence will have to be arranged with each of the OBS controlling these SSs via the Coexistence Protocol (CP). Each CMI from CMI-ID-00 to CMI-ID-54 is monitored. Each CMI is monitored for 5 CMI cycles or minutes (***TBD***). If CMI-ID-54 has detectable power in it, the channel will be construed as occupied by a non-IEEE 802.16 system (See 15.3.1.1.3.1) which may also be synchronized to the GPS/UTC. The channel will be abandoned if CMI-ID-54 is occupied (See 15.3.1.1.3). The signalling seen by an IBS is shown in Figure h 24.

(b) Selection of an Empty CMI

The monitored CMI in which no (demodulated) SSURF messages are received becomes a candidate CMI, and is considered empty. Empty CMI indicate that it is still possible for the IBS to create a new Coexistence Community including the OBS (only a maximum of 9 (***TBD***) co-channel systems can be accommodated by a single channel. Full loading is indicated when all 9 (***TBD***) CMI are occupied by the systems forming a Coexistence Community).

During each candidate CMI a RSSI (see 8.4.11.2) will be undertaken by the IBS during the uplink duration. RSSI is undertaken to determine the presence or absence of low level (un-demodulated) uplink SSURF messages. Each candidate CMI is monitored in this manner over a duration of 10 CMI cycles or minutes (***TBD***). An interval will be considered as useable and chosen if the mean RSSI power measurement in it is no greater than {[N] +3 dB) (***TBD***); where [N] is the thermal noise floor of the IBS receiver as determined by the Candidate Channel Determination process (See 15.4.1.1.1).

The absence of uplink SSURFs means that the CMI is free of uplink (and possibly downlink occupancy). The particular CMI is now considered as being ready for claiming.

(c) Claiming Procedure.

The purpose of the claiming process is to make all adjacent OBS aware of the presence of the IBS. This process results in the delimitation of the Interference Neighborhood, that is, identification of all the adjacent systems that will see interference from the IBS. Claiming is undertaken by having the IBS broadcast its BSD during an empty CMI. Since all the OBS (both base stations and their SS) are silent and are monitoring the downlink on each CMI other than their own, the broadcast BSD message will likely be detected during what was previously an empty CMI (see discussion on undetected broadcasts below).

To begin the claiming procedure the IBS broadcasts at maximum EIRP a BSD (see 6.3.2.3.62) message. This message, when received by SS belonging to adjacent OBS systems that form the Interference Neighborhood, will result in those SS informing their associated base stations (OBS) of the presence of a new base station (the IBS). The SS inform their BS of this by using a MAC message called the BS_CCID_IND (***TBD***). This MAC message contains the Proxy IP address of the IBS, which was extracted by the SS from the interfering BSD message. Now having the proxy IP address, the OBS respond back to the IBS via a backhaul IP link, informing the IBS that it has been detected and is a de facto interferer on the co-channel

RF downlink. Having received this communication from the OBS, the IBS will now have discovered the systems in the Interference Neighborhood, and as part of this discovery process now has the identities of the adjacent OBS. The OBS identities are included in the IBS Information Table (see Table h 2). The IBS continues its BSD broadcast routine until no new OBS make themselves evident to the IBS. The IBS continues its BSD broadcasts every CMI cycle (every minute), and does so as long as it confirms to itself that it has formed a Coexistence Community with adjacent systems.

(d) Membership in the Coexistence Community

All of the adjacent systems with which the IBS creates or sustains interference to/from become listed in the BS Information Table (See Table h 2) of the IBS. This table contains the BS_IDs and related IP addresses derived either from uplink SSURF messages that the IBS demodulated during its monitoring phase (above (a)) or from the BS_CCID_IND and IP messages that it received via the IP backhaul from the OBS as part of the claiming procedure ((c) above).

Communication and negotiation with each OBS listed in the BS Information Table is undertaken via the ***[TBD]*** Coexistence Protocol (CP). Coexistence entails allocation of uplink and downlink transmission intervals in a manner that eliminates co-channel interference amongst users that would otherwise experience it and sustain degraded communications. This is done by parsing uplink and downlink intervals and establishing master subframes (see Sec 15.2.1.1.2). Each OBS that the IBS has listed in its BS Information Table as an interfering network must partake in such a resolution procedure. By undertaking this process the IBS thus creates a Coexistence Community for itself, and consequently becomes accommodated by the neighbouring networks of its interference neighbourhood. If the IBS for some reason cannot resolve all the interference it creates or sustains, then the entry process is repeated on a new channel taken from the rankings provided by the CCD procedures (see 15.4.1.1.1). In doing so the IBS would then abandon the CMI that it claimed in (c). If the CP process is successful, then the IBS (now OBS) continues its claim to the CMI, thereby now informing all other systems of its active presence in the Coexistence Community.

Undetected BSD Broadcasts/Undetected Uplink SSURF messages:

The BSD and SSURF messages are sent at the lowest, most robust modulation rate specified for IEEE 802.16 transmissions. However, because of the statistical variation in the propagation channel whose variance can exceed 10 dB, there is a finite probability that eventually such signals shall eventually exceed demodulation threshold levels and be detected. The time to achieve this is ***TBD***. Furthermore, below threshold signals can be detected by power detectors or detection techniques that will provide indication of signals below demodulation thresholds. These techniques can be instituted either as part of the RF system or in parallel with the demodulation process.

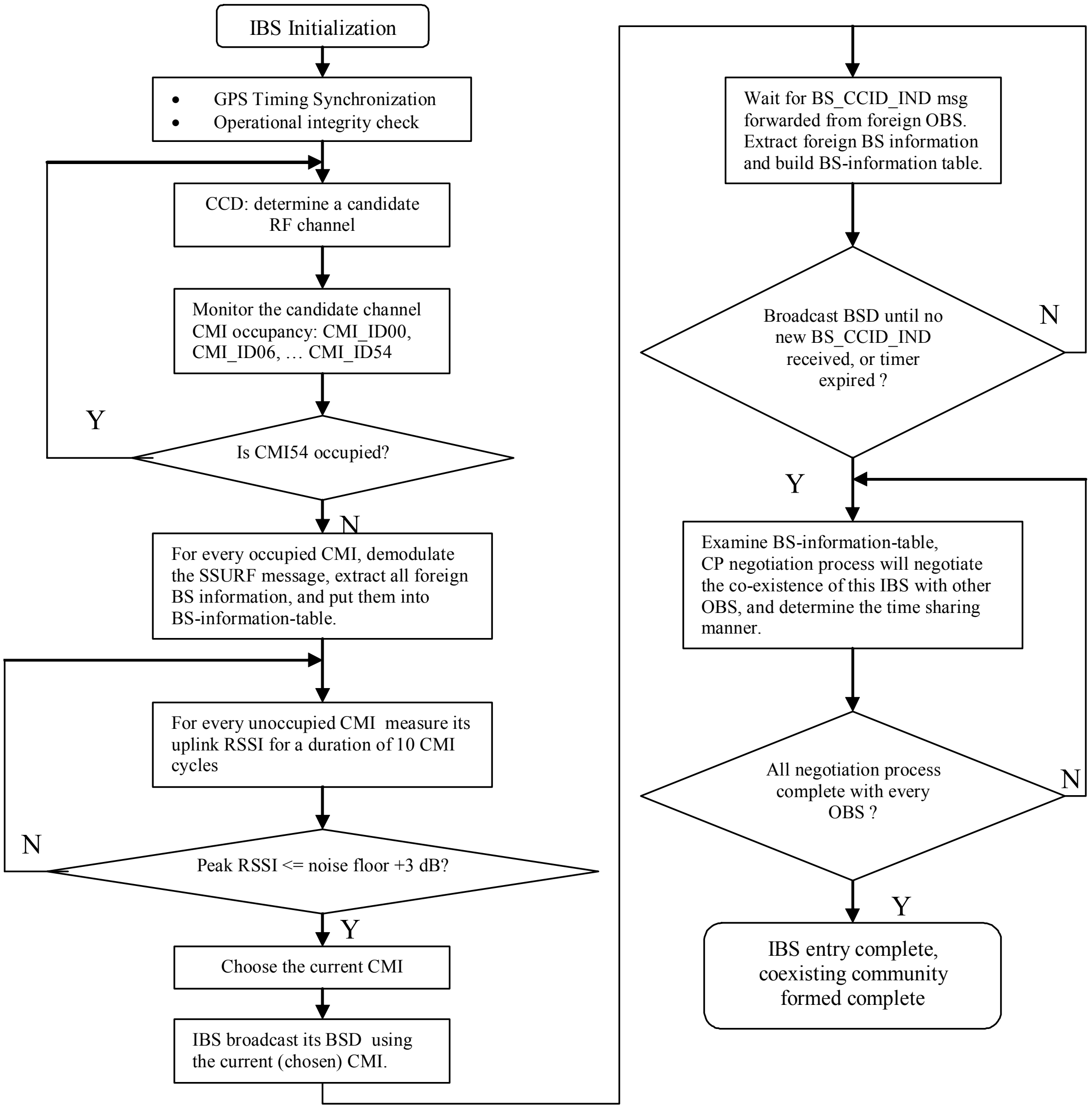

IBS Initialization
GPS Timing Synchronization
Operational integrity check
CCD: determine a candidate RF channel
Monitor the candidate channel CMI occupancy: CMI_ID00, CMI_ID06, … CMI_ID54
Y
Is CMI54 occupied?
N
For every occupied CMI, demodulate the SSURF message, extract all foreign BS information, and put them into BS-information-table.
For every unoccupied CMI measure its uplink RSSI for a duration of 10 CMI cycles
N
Peak RSSI <= noise floor +3 dB?
Y
Choose the current CMI
IBS broadcast its BSD using the current (chosen) CMI.
Wait for BS_CCID_IND msg forwarded from foreign OBS. Extract foreign BS information and build BS-information table.
Broadcast BSD until no new BS_CCID_IND received, or timer expired ?
N
Y
Examine BS-information-table, CP negotiation process will negotiate the co-existence of this IBS with other OBS, and determine the time sharing manner.
All negotiation process complete with every OBS ?
N
Y
IBS entry complete, coexisting community formed complete

Figure h23—IBS community entry process

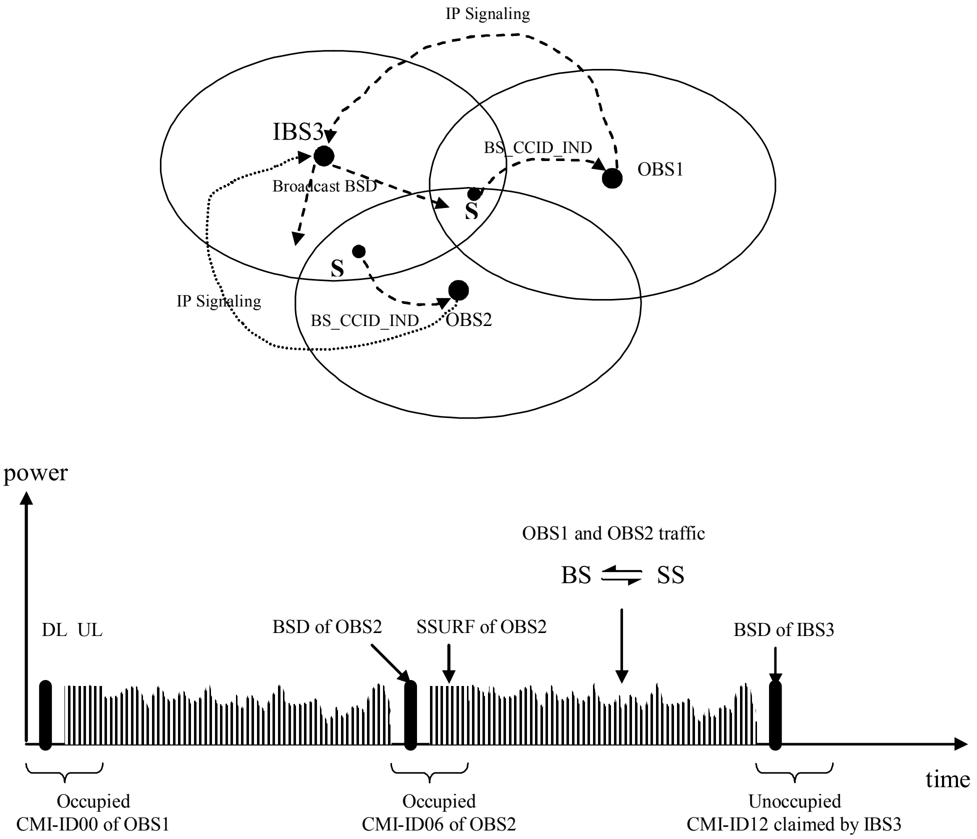


Figure h24—IBS3 Entry Signalling

15.2.1.4 Network and Community Entry for SS

- Start listening;
- Determine interference intervals;
- Assume that the interference is reciprocal;
- Build database for possible working slots and sub-frames;
- Wait for the Base Station community entry and start of operation;
- At BS request, s*end a list of the above identified time intervals;*
- If an old Base Station will perceive interference from the new SSs, it will *ask the new Base Station to find another sub-frame for that SS operation;*
- If the SS will sense interference, will request their Base Station to *find another sub-frame for operation as Master.*

15.2.1.5 BS regular operation

- Schedule SS traffic:The traffic of each served SS should be schedule into corresponding sub-frame/ resource based on the SSs' interference situation. Traffic of SSs in the interference free zone could be scheduled into any available sub-frame/resource of the serving BS, and traffic of SSs in the interference zone should take only corresponding master subframe/resource of the serving BS.

- Set Tx power levels, such to use minimum power levels for both BS and SSs;
- Maintain it own database when other BSs join the network.
- The BS need to keep updating the information of all the BS in the community including the coexistence neighbor BS, and the information of the served SSs in the own network. The information include the profile and the interference situation of the stations. The interference situation information include the interference status, the interference source and corresponding RSSI, the interference victims founded. Etc.

15.2.1.6 Operational dynamic changes

15.2.1.7 Creation of a new sub-frame

If none sub-frame can be used, a *new Base Station may request the addition of another sub-frame.* The effect of such a request will be the reduction of operating time for those Base Stations that interfere with the new Base Station. However, all the others, that do not interfere one with each other and with the new one, may work in parallel and use the same operating time.

A Base Station will request the creation of a new sub-frame by:

- Sending IP messages to all BS members of the community, and indicating:
    - The interfering operator ID and BS ID
    - The MAC frame-number in which the addition of a new sub-frame will take place.
- All the requested *BSs will acknowledge the request*, by
    - Sending back a message having as parameters:
    - Frame-number for the change (must be the same as the requested one
    - Master sub-frame number for the new BS (SF = Sfold+1).
    - If are missing acknowledges, those BS will be asked again, for another M attempts, after that will be considered that they are not working;
    - At the above specified MAC frame number, a new sub-frame partition will take place, by inserting in the sub-frame calculation relation N=N+1
    - The BSs will up-date the own SSs about the change
- Start to use the created Master sub-frame.

15.2.1.8 Controlling interference during master sub-frame

15.2.1.8.1 Interferer identification

The interferers will be identified by their radio signature, for example a short preamble for OFDM/OFDMA cases. The radio signature consist of:

- Peak power
- Relative spectral density

- Direction of arrival.

Every transmitter will send the radio signature during an interference-free slot. The *time position of this slot (frame_number, sub-frame, time-shift)* will be used for identification.

In IBS's coexistence neighbor discovery phase, the IBS's contact information and RTK shall be broadcast using the BS_NURBC frame with pulse energy keying. And this shall be detected by coexistence neighbor's SS in the IBS's coverage (see ANNEX C.1 case 3) and reported to its serving BS.

The BSID is used to identify the coexistence neighbor BS by the receiver SS. And also be the identifier of the BS for its coexistence neighbor BS.

15.2.1.8.2 Interference to BS

- Identify the interferers;
- Send messages to interfering BSs, *asking to drop the power of the specified transmitter by P dB;*
- Alternatively, send messages to related BSs, *asking to stop operating during the BS master slot*
- The requested Base Station has the alternative of looking for another Master slot.

15.2.1.8.3 Interference to SS

- *Report* to BS about experienced interference
- List of frame_number, sub-frame, offset, IP address of source BS (if detected)
- BS start process for interference reduction with *feedback from the SS.*

15.2.1.9 Controlling interference during not-interfering traffic sub-frames

The Base Station data base shall keep the following information regarding the usage of “ non-interfering sub-frame” or Master sub-frames belonging to other systems:

- BS power, relative to the radio signature ***power***, when using each of the sub-frames;
- List of SSs and their power, relative to the radio signature ***power***, when using each of the sub-frames.

The received power during other sub-frames can be obtained by using the radio signature measurement and suitable calculations, according to data-base information on used powers. Messages as Stop_Operating_Request and Reduce_Power_Request can be used for controlling the interference levels.

15.2.1.10 Power Control

Every network will strive to reduce its transmit powers to the minimum, such that the C/I+N will be sufficient to allow the operation at the minimum common rate, considered as QPSK1/2 for all the 802.16 systems; an exception from this rule is possible only when a network is operating during its interference-free period. The power control mandatory algorithm will be defined in chap. ***[t.b.c.]***

15.2.1.11 Coexistence with non-802.16 wireless access systems

The above principles are also applicable to non-802.16 systems, like 802.11. During every 802.16 MAC frame, a 802.11 system may find that a sub-frame may be used, due to the low created interference levels. In the case that no operation in parallel is possible, the new system will ask for the creation of a new Master sub-frame. The Coexistence Protocol, working at IP level, will allow the communication between systems using different PHY/MAC standards.

The scheduled use of the MAC frame is possible by using the 802.11 PCF mode.

15.2.2 Shared distributed system architecture

15.2.2.1 Architecture

The architecture for Radio Resource Management in the context of IEEE 802.16h it is a distributed one and allows communication and exchange of parameters between differentsystems. A system consists from a base station and its associated subscriber stations and its coexistence proxy.

Every base station includes a distributed radio resource management (DRRM) entity, to apply the 802.16h spectrum sharing policies, and a data base (DB) to store the shared information regarding the actual usage and the intended usage of the radio resource.

A subscriber station may include an instance of DRRM, adapted to SS functionality in 802.16h context. The following figure shows the functional diagram of the IEEE 802.16h network architecture:

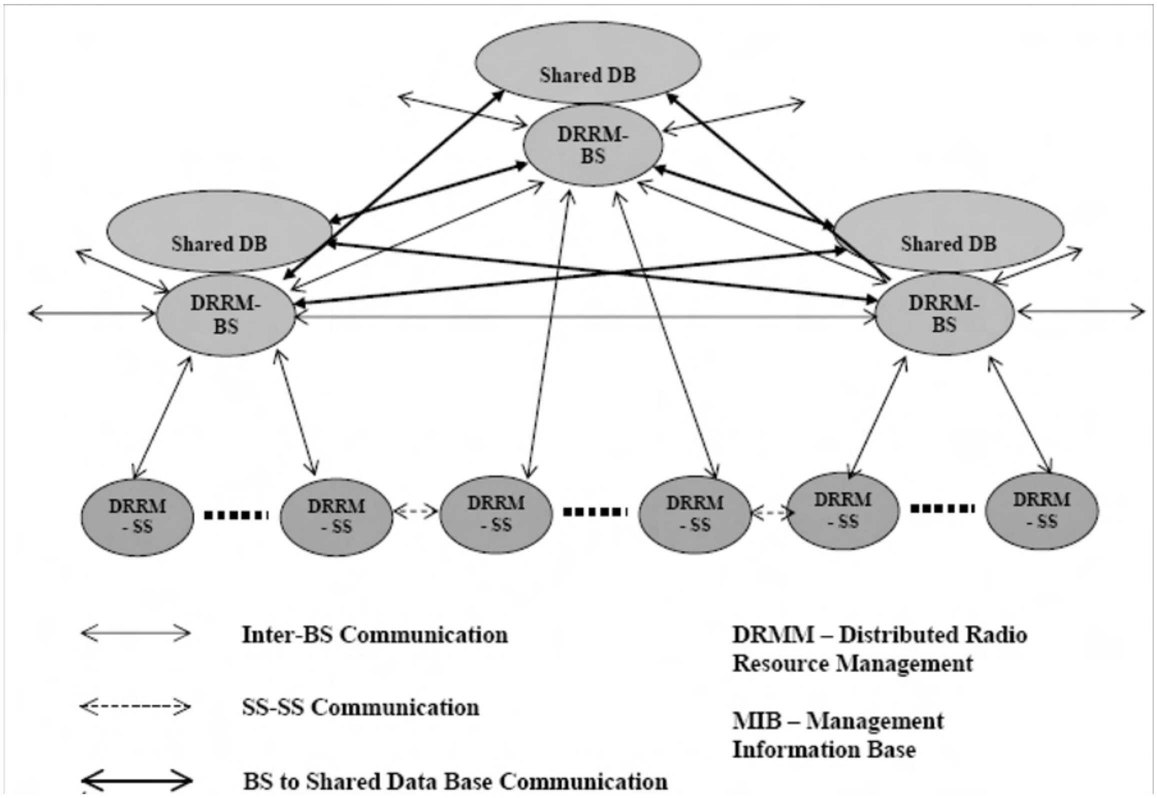


Figure h25—System Architecture type 1

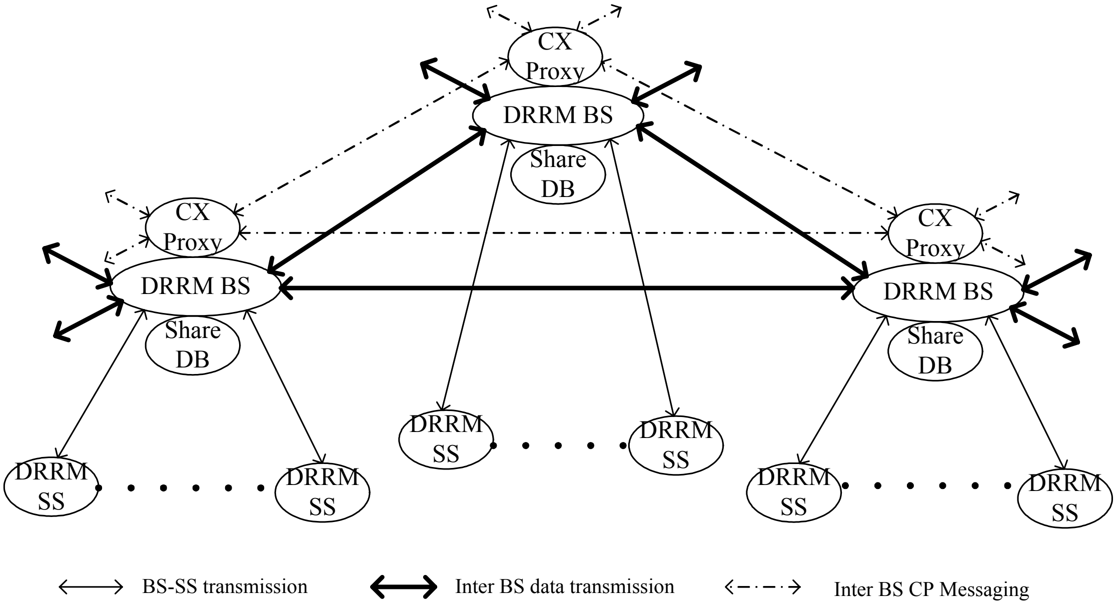


Figure h26—System Architecture type 2

Figure h 27 and Figure h 28_shows the IEEE 802.16 LE type1 and type2 inter-network communication architecture:

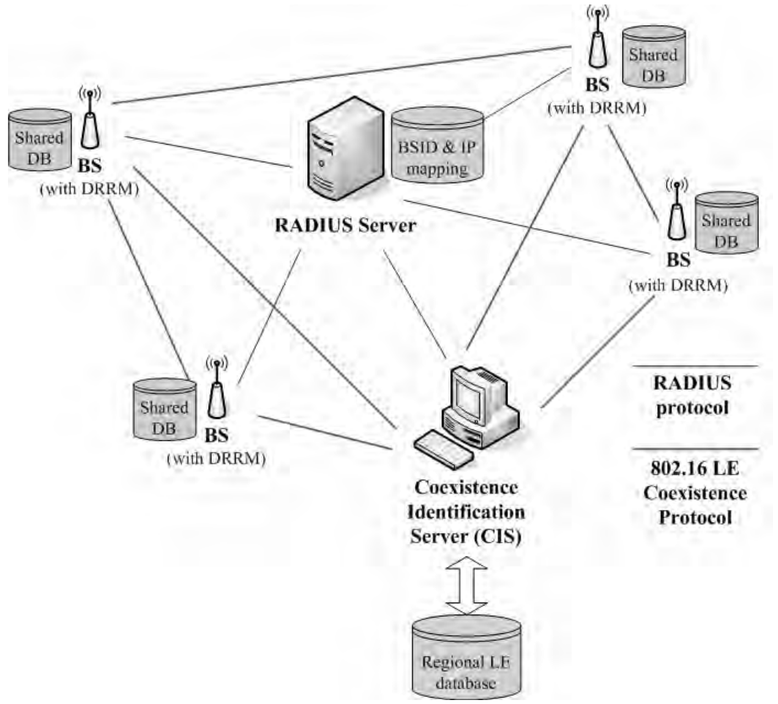


Figure h27—Network Architecture Type 1

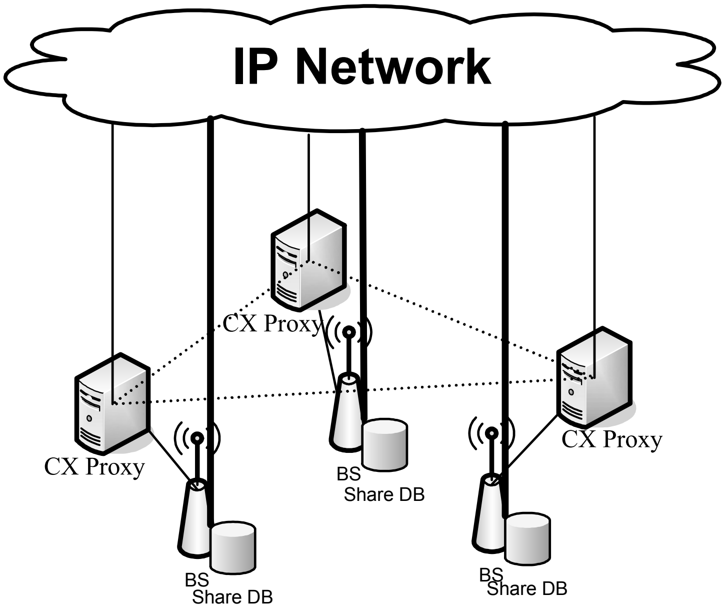


Figure h28—Network Architecture Type 2

General architecture includes the components operating over IP-based network:

For network architecture type 1:

- The RADIUS Server- The Base Station Identification Server (BSIS), described in detail in section xxx - The BSs cooperating with the Distributed Radio Resource Management (DRRM) procedure RADIUS server to maintain the address mapping of wireless medium addresses of BSs (their BSID) and medium addresses of BSIS to their IP addresses.

For the network architecture type 2:

- The coexistence proxy of every base station maintains the mapping of the IP address and the BSID of their serving BSs. All the CP messages between the different systems should be sent and received via their coexistence proxies instead of directly between the base stations. So the IP address will not be known outside the system. The coexistence proxy will forward the CP messages for the base station.

15.2.2.2 Inter-network communication

The inter-network communication consists in:

— Inter-netwo*rk messages*
  - o Base Station to/from Base Station
  - o Base Station to/from Subscriber Station to/from foreign Base Station; the subscriber Station is used as relay of signaling, if the two Base Stations are hidden one from the other

— Open access to DRRM Data Base (*optionally via coexistence proxy when between systems*):

- o To read the parameters of the hosting Base Station
- o *To request c*hange of the hosting Base Station operating parameters.

15.2.2.3 Coexistence Protocol

[Note: the security part is a temporary text adopted from contribution C802.16h-05/11r1 and is subject to further discussion.]

In order to get the coexistence neighbor topology, perform registration to the database and registration to peer, negotiation for Shared RRM etc. will be used a Coexistence Protocol (CP). Figure h 29 describes the 802.16h protocol architecture. The protocol architecture indicates that DRRM, Coexistence Protocol and Shared DB belong to LE Management Part located in management plane and the messages will be exchanged over IP network. Thus, DRRM in LE Management Part uses the Coexistence protocol to communicate with other BSs and with Regional LE DB and interact with MAC or PHY. Figure h 29 is LE BS architecture with Coexistence Protocol. The gray area indicates area where there is an absence of connection between blocks. DSM is Distribution System Medium which is another interface to the backbone network. Note that is architecture is only for reference. Similarly, Figure h 29 is the BSIS architecture with co-located regional LE database. Other architectures are not being illustrated. The Coexistence Protocol services are accessed by the LE Management Entity through CP SAP. The service primitives are described in t.b.d A BS uses the Coexistence Protocol, which is similar to PKM protocol, to perform the coexistence resolution and negotiation procedures. There are two types of messages to support Coexistence Protocol:

(1) CP-REQ: BS->BS or BS->BSIS

(2) CP-RSP: BS->BS or BSIS->BS

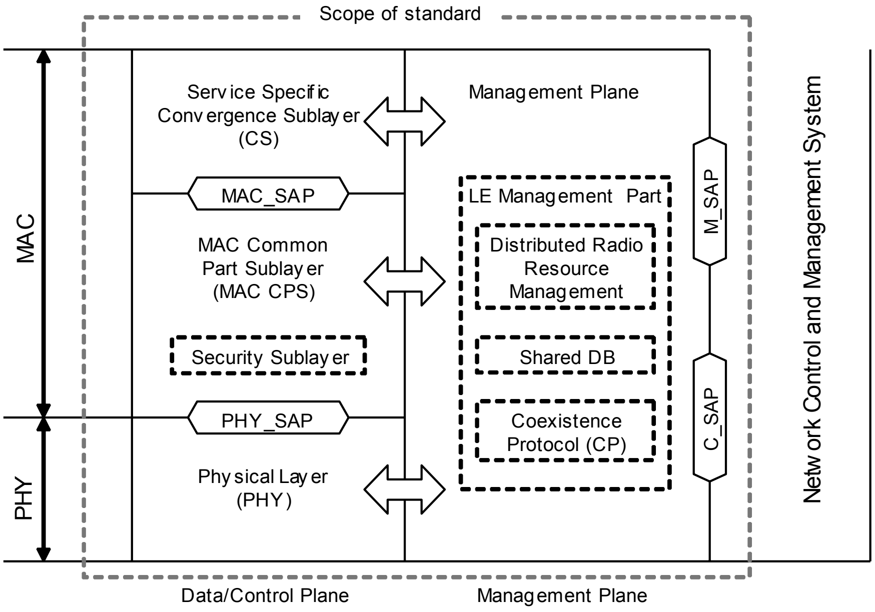

Scope of standard
Service Specific Convergence Sublayer (CS)
Management Plane
MAC_SAP
LE Management Part
Distributed Radio Resource Management
MAC Common Part Sublayer (MAC CPS)
Security Sublayer
Shared DB
PHY_SAP
Coexistence Protocol (CP)
Physical Layer (PHY)
M_SAP
C_SAP
MAC
PHY
Network Control and Management System
Data/Control Plane
Management Plane

Figure h29—802.16h BS Protocol architecture Model

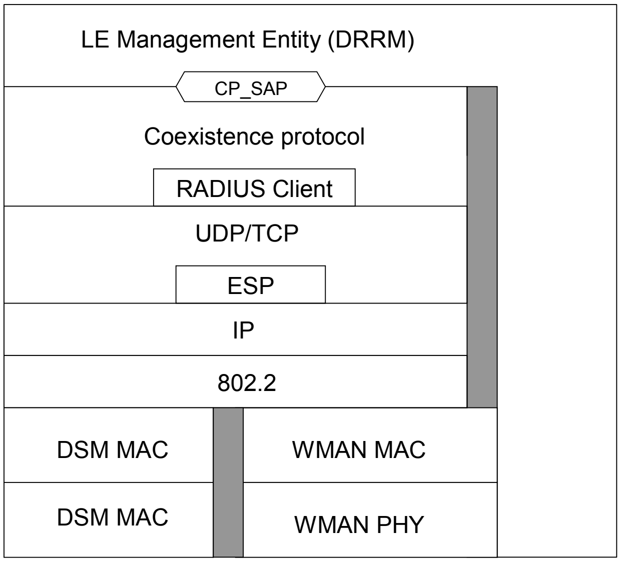


Figure h30—LE BS architecture with Coexistence Protocol

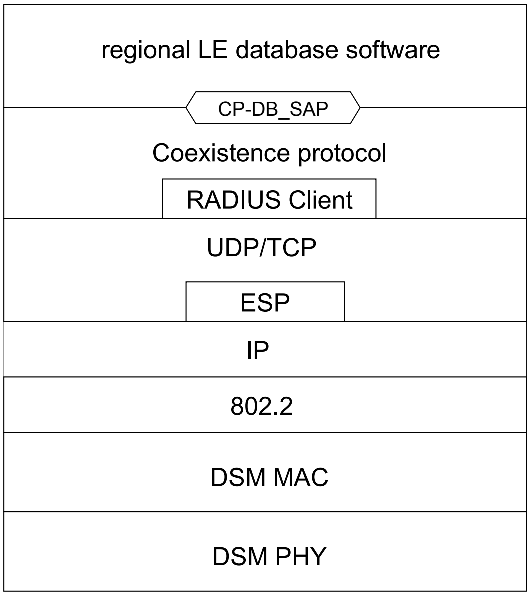


Figure h31—BSIS architecture with co-located regional LE database

15.2.2.3.1 Same PHY Profile

For networks using the same 802.16 PHY Profile, including elements as:

- Mandatory channel spacing for LE system in[tbd.] MHz will be[tbd.] MHz*;*
- PHY mode:
  - WirelessMAN-OFDM (256 FFT points)
    Mandatory profiles for operation in the LE 5725-5850 MHz band will be:
    - profM3_pmp,profP3_10,profC3_23,TDD,profR13
  - WirelessMAN OFDMA 2k (in future 128, 512, 1k) FFT points
  - *WirelessMAN* SCa,

the inter-network communication may be done using 802.16 messages over the air, including messages defined by 802.16h amendment. The procedures for sending these messages are described in ***t.b.d.***

15.2.2.3.1.1 CMI Use for Same Profile Systems

The CMI is the duration of a MAC frame (20 msec) and consists of an uplink and downlink intervals of equal size (10 msec) (TBD). Downlink messages carry information (BSD messages) unique to the identity of the base station controlling the system to which the particular CMI is associated. Uplink messages carry information (SSURF messages) unique to the subscriber stations within the system and base station associated with the same CMI. During a CMI all other systems, not associated with the particular CMI, remain silent and receive only.

Base station descriptor (BSD) messages (section 6.3.2.3.62) are broadcast within the downlink portion of the CMI every minute (***TBD***) by a base station. This is always done in the same CMI, claimed by the base station. In broadcasting in this manner the base station continually announces its (and its network's) existence. The BSD serves two purposes. First, it contains pertinent information related to the base station, allowing other base stations to identify it (via their SS). Secondly, it allows the differentiation of a CMI frame from a non- CMI frame. When it is received, SS associated with the BS will recognize the frame containing the BSD message as a CMI frame, and will transmit SSURF (uplink Radio Signature) messages (section 6.3.2.3.63) in response to it. Note that SSURF will use the uplink bandwidth granted only in the CMI frame, and is not transmitted in the data link.

Every BSD sent downlink has a BS_ID associated with it. This is thus a de facto tag to the downlink frame, and can be used as an interference identification tag as well. The message contains the UL-MAP, which addresses specific SS to send their SSURF messages. The duration of the BSD message is typically 1 msec (***TBD***).

There is only one downlink BSD PDU in the CMI and it is transmitted at random starting point within the downlink time interval of the CMI. The rationale for the random placement of the BSD within the downlink subframe is shown below:

There is the possibility that two or more potentially interfering base stations inadvertently choose the same CMI. Such base stations and the respective networks they control may coexist peacefully without causing interference to each other because of hidden SS or having no SS in the common coverage area. Essentially, such networks do not form an interference community because they do not interfere with each other. However, when the hidden SS or new SS enters into the common coverage area, co-channel interference will be detected at the new SS resulting in a situation that impacts the neighboring base stations having a common CMI.

BSD collision occurs in this situation. To resolve this situation the start times of downlink sub frame PDU and uplink SSURF messages in the CMI are randomized. This reduces the possibility that two networks, sharing the same CMI will overlap in their downlink and uplink BSD or SSURF transmissions. Realize that the downlink slot will be 10 msec wide and that the downlink sub frame BSD PDU itself is only < 1 msec. For the worst BSD collision case, there are n base stations in the common coverage area, the successful (non-overlapping) BSD transmission probability is

$$p = 1 - \frac{1}{m} \bullet \frac{1}{m} \bullet C_n^2 = 1 - \frac{1}{m} \bullet \frac{1}{m} \bullet \frac{n!}{(n-2)! \bullet 2!} \qquad \textit{(h1)}$$

Where $m = \frac{t}{td}$. Assume the CMI downlink duration time length is t which is the uplink portion of a physical frame (physical frame duration is varying from 2, 2.5, 4, 5, 8, 10, 12.5, to 20ms), the BSD downlink PDU time duration is d t , which is typically < 1 msec.

15.2.2.3.2 Mixed-PHY Profile communication

In the case of different PHY Profiles the communication will be done at IP Level. Every Base Station should know the IP address of the DRRM of the Base Stations around, by provisioning or/and by using a regional data base approach or/and by using cognitive radio signaling.

15.2.2.4 Information table in share database

Table h2—This BS information table

Syntax	Size	Notes
This BS information table(){		
BSID	48bits	
Operator ID	?bits	
IP version	1bits	0-IPv4 1-IPv6
(IP version = 0){		
IPv4 address	32bits	IPv4 address of this BS
CXPRX IPv4 address	32bits	CXPRX IPv4 address
}		
Else{		
IPv6 address	128bits	IPv6 address of this BS
CXPRX IPv6 address	128bits	CXPRX IPv6 address
}		
RTK	16bits	Random Temporary Key
Extended Channel Number (ExChNr)	8bits	1 byte base reference to frequency range or deployment band. This reference maps to an absolute frequency value.
Extended Channel Number (ExChNr)	8bits	1 byte specific channel number reference
Channel spacing (ChSp)	16bits	2 bytes channel spacing value (10kHz increments)
Master resource ID	8bits	Sub-frame number
OCSI ID	8bits	CSIN of OCSI allocation
Negotiation status	8bits	Bit0: get communication in the IP network Bit1: be registered in Bit2: registered to Bit3: done for resource sharing(if neighboring) Bit4-7: tbc.
CSI parameter(){		Regulated by region/country
Tcsi_start	16bits	In microseconds
Tcsi_duration	8bits	In microseconds
Period of frames	8bits	frames
Starting frames offset	16bits	frame serial number of the first frame that CSI presented
Length of Symbols	8bits	In microseconds, need to be 1/n of Tcsi_duration
ICSI cycle	8bits	ICSI cycle counted in CSI cycles
OCSI cycle	8bits	OCSI cycle counted in ICSI cycles
}		
Number of CoNBRs	8bits	m:The number of coexistence neighbors of this BS
for (i= 1; i <= m; i++) {		
BSID	48bits	
(Tbc.)	(Tbc.)	(Tbc.)
}		
Profile(){		
Band		
PHY mode(){		
Modulation		
Working Channel ID	8bits	Identifier of the working channel of this BS.
Number of alternative Channels	8bits	p: The number of alternative channels to which this BS can switch without interference.
For(i = 1; i <= p; i++){		

Alternative Channel ID	16bits	Identifier of the alternative channel.
}		
(Tbc.)		
}		
Maximum power	8 bits	dbm
Number of registered SS	12bits	n
for (i = 1; i <= n; i++) {		
SSID	48bits	
(tbc.)	(tbc.)	(tbc.)
}		
(tbc.)	(tbc.)	(tbc.)
}		
}		

Table h3—BS information table

Syntax	Size	Notes
BS information table(){		
Index	16bits	
BSID	48bits	
Operator ID	?bits	
RTK	16bits	Random Temporary Key
IP version	1bits	0-IPv4 1-IPv6
(IP version = 0){		
CXPRX IPv4 address	32bits	CXPRX IPv4 address
}		
Else{		
CXPRX IPv6 address	128bits	CXPRX IPv6 address
}		
Sector ID	8bits	
Extended Channel Number (ExChNr)	8bits	1 byte base reference to frequency range or deployment band. This reference maps to an absolute frequency value.
Extended Channel Number (ExChNr)	8bits	1 byte specific channel number reference
Channel spacing (ChSp)	16bits	2 bytes channel spacing value (10kHz increments)
Master resource ID	8bits	Sub-frame number
OCSI ID	8bits	CSIN of OCSI allocation
Negotiation status	8bits	Bit0: get communication in the IP network Bit1: be registered in Bit2: registered to Bit3: done for resource sharing(if coexistence neighboring) Bit4-7: tbc.
Coexistence neighboring	1bit	Coexistence neighbor with this BS? 1-yes 0-no
BS GPS coordinates	TBD	GPS coordinates of this Base Station
BS RF antenna sector ID	8bits	Identifier of antenna creating this sector
BS nominal EIRP	TBD	Nominal EIRP of this Base Station
BS PSD Vector	TBD	PSD as determined by this BS of all available channels using RSSI scanning process
BS antenna azimuth	TBD	Azimuth orientation of this Base Station's antenna

BS antenna beamwidth	TBD	Azimuth Beam width of this Base Station's antenna
If (Coexistence neighbor){		
Number of victim SSs	16bits	n:The number of victim SSs of this coexistence neighbor, in this network
for (i = i; i <= n; i++) {		
SSID	48bits	
RSSI	16bits	1byte RSSI mean (see also 8.2.2, 8.3.9, 8.4.11) for details) 1byte standard deviation
}		
(Tbc.)	(Tbc.)	(Tbc.)
}		
Number of Coexistence neighbors	8bits	m:The number of coexistence neighbors of this BS
for (i= 1; i <= m; i++) {		
BSID	48bits	
Working Channel ID	16bits	Identifier of the working channel of this neighbor.
Escape Channel Flag	1bit	Flag indicates this neighbor has one or more escape channels.
(Tbc.)	(Tbc.)	(Tbc.)
}		
Profile(){		
Band		
PHY mode(){		
Modulation		
Working Channel ID	16bit	Identifier of the working channel of this neighbor.
alternative Channel Flag	1bit	Flag indicates this neighbor has one or more alternative channels.
(Tbc.)		
}		
Maximum power	8 bits	dbm
Number of registered SS	12bits	
(tbc.)	(tbc.)	(tbc.)
}		
If (CMI Interval used) {		
Number of coexistence neighbors		
For (i=0; i<=n; i++) {	TBD	All Co-existing neighbor BS information. This is the list of foreign BS, which may be causing interference to this BS and its SS
Foreign BSID	TBD	BS_ID of this foreign BS
Foreign BS IP address	TBD	IP address of this foreign BS
Foreign BS CMI-ID	TBD	CMI_ID of this foreign BS
Number of foreign SSs causing Co-channel interfering	TBD	Number of SS associated with this foreign BS causing interference to this BS
For (j=0; j<=m; j++) {	TBD	All SSs associated with this foreign BS, which cause co-channel interference
Interfering SSID	TBD	SS_ID of this SS causing interference to this BS
CMI Interfering occurrence	TBD	Number of instances where interference recorded.
RSSI of interfering SS	TBD	RSSI of this interfering SS
SS interference resolved	1 bit	Has the interference caused by this SS been resolved by use of the CP between this BS and the foreign network?
}		
}		

}		
(tbc.)	(tbc.)	(tbc.)
}		

Table h4—SS information table

Syntax	Size	Notes
SS information table(){		
Index	16bits	
SSID	48bits	
SS location	TBD	Optional
SS GPS location	TBD	Optional
SS antenna beam width	TBD	Beam width of this SS antenna
SS nominal uplink EIRP	TBD	Nominal EIRP of this SS
SS PSD vector	TBD	Power Spectral Density determined by the SS by RSSI process scanning all available channels
Interference status	1bit	Interfered by coexistence neighbor? 1-yes 0-no
If (Interfered){		
Number of source BSs	8bits	n:The number of interference source of coexistence neighbor
for (i = 1; i<= n; i++) {		
BSID	48bits	
BS_NURBC detected	1bits	1-yes 0-no
If (BS_NURBC detected){		
IP version	1bits	0-IPv4 1-IPv6
(IP version = 0){		
CXPRX IPv4 address	32bits	the v4 IP address of the CXPRX reported by the SS
}		
Else{		
CXPRX IPv6 address	128bits	the v6 IP address of the CXPRX reported by the SS
}		
IBS BSID	48bits	The BSID reported by SS
RTK	16bits	RTK in the BS_NURBC reported by SS
Sector ID	?bits	Reported by SS
Frame number	24bits	Reported by SS
Error Status	?bits	0 -no error 1 - not capable to decode the energe pulse symbol.; 2 - not able to find the eligible <SOF>; 3 - not able to find the eligible <EOF>; 4 - not able to pass the CRC check for message;
(tbc.)	(tbc.)	(tbc.)
}		
RSSI	16bits	1byte RSSI mean (see also 8.2.2, 8.3.9, 8.4.11 for details) 1byte standard deviation
(tbc.)	(tbc.)	(tbc.)
}		
(tbc.)	(tbc.)	(tbc.)
}		
If (CMI frame used) {		
Associated BS ID	TBD	BS_ID to which this SS is associated

Associated BS RSSI	TBD	Mean RSSI of BS downlink to which this SS is associated
Associated BS RSSI Var	TBD	Variance of RSSI of downlink
Associated BS BER	TBD	BER of downlink
Number of foreign BSs	TBD	Number of foreign BS this SS has detected via BSD
For (I=0; I <=n; I++) {		
Foreign BS ID	TBD	BS_ID of this foreign BS as determined from its BSD
Foreign BS EIRP	TBD	EIRP of this foreign BS as determined from its BSD
Foreign BS antenna sector ID	TBD	Antenna sector ID of this foreign BS as per BSD
Foreign BS Proxy IP address	TBD	Proxy IP address of this foreign BS as per BSD
Foreign BSD occurrence ratio	TBD	Defined as the ratio of demodulated foreign BSD messages to CMI cycles. A metric indicating severity of interference caused by this foreign co-channel BS.
Interference resolution	1 bit	An indication that interference from this foreign BS has been resolved by the CP.
CMI-ID	TBD	CMI_ID of this foreign BS
}		
}		
(tbc.)	(tbc.)	(tbc.)
}		

15.3 Interference victims and sources

15.3.1 Identification of the interference situations

15.3.1.1 Interferer identification

The interferers will be identified by their radio signature, for example a short preamble for OFDM/OFDMA cases. The radio signature consist of:

- Peak power
- Relative spectral density
- Direction of arrival.

Every transmitter will send the radio signature during an interference-free slot. The *time position of this slot (frame_number, sub-frame, time-shift)* will be used for identification.

The transmitted power of non-interfering radio transmitters using a Master sub-frame will be known from the BS data base, indicating their power attenuation relative to the radio signature, for every used sub-frame.

15.3.1.1.1 Interference Identification & Resolution via CSI Detection

Downlink CSI is use by the BSs to broadcast signaling to the neighbor systems. These signals is used for Interference identification and resolution. In order not to collide with the neighbor, the coordinated community should prevent neighbor BSs to use the same CSI.

There was one ICSI for IBS in an ICSI cycle, and the rest CSI is leave to OBS as OCSI. Every OBS need to get its OCSI allocation in one OCSI cycle, which is formed by multiple ICSI cycle so that IBS can get more opportunity then OBS.

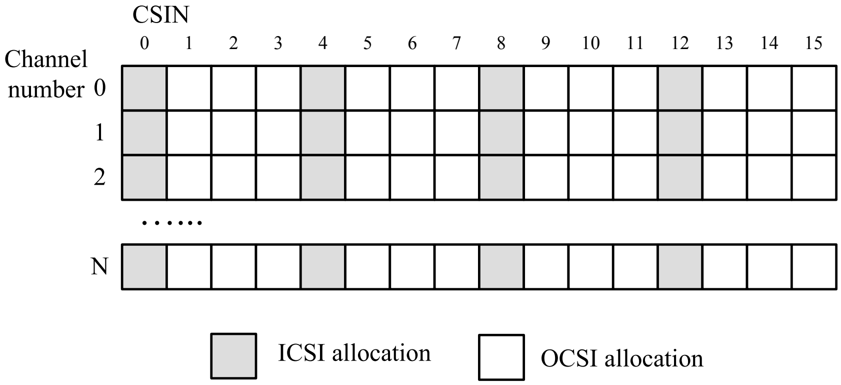


Figure h32—format of ICSI/OCSI allocation MAP

In the initialization phase of a BS, before having it's own OCSI allocation, BS should use ICSI to advertise its arrival in the air at every candidate channels one by one. The neighbor OBS will then send their current OCSI allocation and current subframe allocation to the IBS using CP message. After IBS choose the working channel for its radio link, it shall pick a vacant CSIN for OCSI in this channel and tell all the neighbor the occupation. After that, this BS will start using this OCSI allocation as its exclusive CSI allocation.

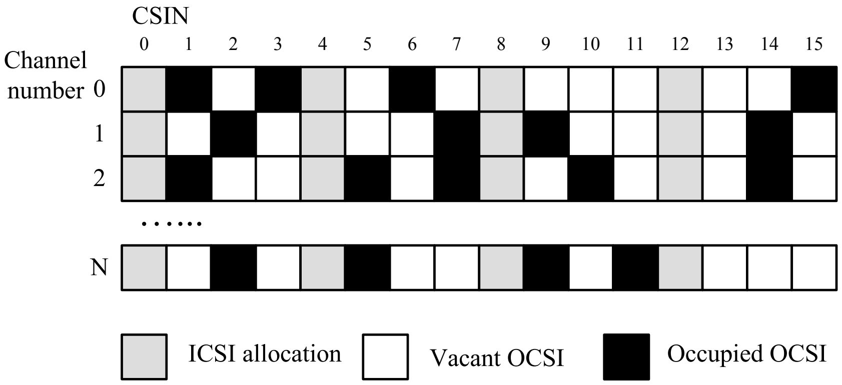


Figure h33—example of CSI allocation MAP in one BS's database

Here is an example of the CSI allocation MAP of one BS during his initialization phase by collecting the CP message information from his neighbors. Assume this BS have choose channel 0 as its working channel, it can pick any one of the CSIN 2,5,7,9,10,11,13,14 as its OCSI allocation number. Every BS have its own CSI allocation map indicating the current situation of CSI occupancy by the neighbors in the working channel and potential neighbors in the potential working channel. The CSI allocation MAP table of potential working channel will be used when BS move to another channel in cases. The CSI allocation MAP of the BS should be updated in time when any changes have been informed by its neighbors in the working channel and potential neighbors in the potential working channel.

In the OCSI mapping table, every neighbor in working channel or potential neighbor in potential channel is mapped to one OCSI allocation, every OCSI allocation will indicate its occupant or vacancy. By inquiring the mapping table of the OCSI allocations to the BSs, one BS can recognize the source of the interference or signaling in each OCSI allocation.

The initializing BS use the OCSI allocation table to find out its neighbors in the working channel. By the contact information it acquired from the CP message, the IBS will than use CP message to negotiate for interference resolution with its neighbors.

15.3.1.1.2 Interference from 802.16 networks

15.3.1.1.3 Interference from Non-IEEE 802.16 systems.

15.3.1.1.3.1 Non-IEEE 802.16 Systems (BSs and their SSs) capable of GPS/UTC Timing Recovery

Non-IEEE 802.16 LE systems (BSs and their SSs) that are capable of GPS/UTC timing recovery can monitor the CMI intervals to determine the existence of co -channel IEEE 802.16 users. Monitoring the intervals and undertaking CCI measurements over CMI cycles will allow a non -IEEE 802.16 system(BS and its SSs) to determine the occupancy on a channel and avoid settling on it.

Additionally, [CMI_ID54] [tbd.] will be left unoccupied by IEEE 802.16 systems (BSs and their SSs). Non -IEEE 802.16 systems(BSs and their SSs) occupying LE spectrum can insert downlink and uplink power bursts [tbd.] into this interval. Such energy can be detected by IEEE 802.16systems(BSs and their SSs) which will consequently avoid use of the given channel.

15.3.1.1.3.2 Non-IEEE 802.16 Systems(BSs and their SSs) not capable of GPS/UTC Timing Recovery

The majority of co-channel interferers will be systems (BSs and their SSs) and devices that cannot perform rudimentary of signaling required for IEEE 802.16 coexistence and channel detection. To deal with such interferers the IEEE 802.16 networks will have to opt for avoidance of such users. To facilitate this IEEE 802.16 BS and SS will have the ability to undertake [Power Spectral Density mappings] of selected bandwidth and disseminate such information as part of their [tbd.] inter-network messaging.

Sections 15.6.1.34. and 15.6.1.36 describe the instructions and formatting that will be used by the IEEE 802.16 systems(BSs and their SSs)to undertake [PSD] measurements of contented spectrum. These measurements should be undertaken by a BS prior to occupancy of spectrum space and they can be undertaken throughout the operational period of a network to determine encroachments and to identify other spectrum that may have to be used in the event of uncontrolled interference arising in the occupied spectrum. The [PSD] measurements will be undertaken by the SS as well and this sensor information will be sent to the BS. [PSD] measurement information forms part of the data base that is exchanged between networks as part of their mutual spectrum management tasks. SSURF messages [tbd.] could be used to transport spectrum information.

15.3.1.2 Grouping of interfering/not-interfering units

15.3.2 Identification of spectrum sharers

15.3.2.1 Regulations

15.3.2.2 Messages to disseminate the information

15.3.2.3 Avoid false-identification situations

15.3.2.4 Using centralized server

[Note: overlapping chapter]

15.3.2.4.1 Base Station Identification Server

[Note: The following part from 3.2.4.1 is a temporary text adopted from contribution C802.16h-05/11r1 and is subject to further discussion. A call for comment from security experts is open to comment on this text.]

The *Base Station Identification Server* (BSIS) acts as an interface between 802.16 LE BSs and the regional LE DB which stores the geographic and important operational information, e.g. latitude, longitude, BSID etc., of the LE BSs belonging to the same region. It converts the actions carried in PDUs received from the 802.16 LE BSs to the proper formats, e.g. SQL (Structured Query Language) string, and forwards the strings to the regional LE DB, which can be any available database software. BSIS converts the query results from the regional LE DB to the proper format, e.g. TLV encodings, and replies to the requested BSs. Figure h 27 shows the general architecture of inter-network communication across 802.16 LE systems. BSIS acts as a peer of 802.16 LE BSs in this architecture. The BSID of regional BSIS is well known among the 802.16 LE systems within certain domain. The messages exchanged between the LE BSs and the BSIS will be revealed in the next section.

[Note that the interface between BSIS and regional LE DB is out of scope.]

15.4 Interference prevention

15.4.1 Adaptive Channel Selection – ACS

First try to find a vacant channel:

- Passive scan
- Candidate channel determination (see 15.4.1.1)
- CP messaging using IP network with neighbors (see 15.6.1 & 15.2.1.3)

Next try to coordinate for an exclusive channel

- Optimization of channel distribution (see 15.7.1& 15.7.1.4)

Success of either step will enable the BS start working with an exclusive working channel;

Fail will begin a working channel sharing coordinate procedure.

15.4.1.1 Between 802.16 systems

15.4.1.1.1 Candidate Channel Determination (Using GPS/UTC Synchronized CMI and Common Profile)

Candidate Channel Determination (CCD) is the process used by WirelessMAN-CX systems (using a synchronized CMI and common profile) where a base station monitors a band to which it has access and selects, within that band, a channel having minimal use and occupancy by neighboring wireless systems. This process is used, for example, by an IBS prior to undertaking entry into a Coexistence Community. Since a base station can only receive uplink traffic, this process relies on the monitoring uplink transmission intervals and the measurement of interference signal power [I] and noise power [N]. Each candidate channel will be ranked in terms of its (I/N) ratio. Those channels with the lowest ratio or ideally a ratio of 1 will be selected for use by the base station and be candidates for entry by an IBS, since such channels will have the lowest amount of discernable activity on them, hence likely have lower interference.

[I] and [N] will be determined using the RSSI measurement capability of the base station receiver as detailed in Section 8.4.11.2. After synchronization to the GPS and initialization of the base station operating parameters, the base station will select a channel and undertake noise floor measurements on CMI_ID54, which is unoccupied by IEEE 802.16h networks but may be used by non-IEEE 802.16h networks (15.3.1.1.3.1).

CMI_ID54, in situations when it is unoccupied, will be free from all IEEE 802.16h transmissions and will provide an interval allowing the measurement of the receiver thermal noise floor [N]. The thermal noise floor is the noise power spectral density of the received channel (No) multiplied by the channel bandwidth. Measurements will be undertaken long enough to determine whether [N] has Gaussian characteristics. Characteristics not deemed as Gaussian and/or RSSI measurements that are 3 db (TBD) higher than a predetermined [N] value (which can be provided a priori as a Receiver Noise Figure estimate within RSSI measurement algorithm in the base station receiver) will be indicators that channel may be occupied by non-IEEE 802.16h users. In this instance the value of the mean RSSI will be taken as the [I] created by the occupying non-IEEE 802.16h network and the given channel will be discarded from further consideration. Otherwise, the measurement will provide a value for [N].

[I] measurements will be undertaken by calculating the mean signal strength and variance due to uplink SSURF messages summed over intervals CMI_ID00 to CMI_ID48. The number of CMI cycles to be measured will be a variable (***TBD***) set for the base station by the operator. Measurement of the RSSI will be done in accordance with Section 8.4.11.2, with care being taken to ensure that valid signals are being measured, even at close-to noise floor levels. The mean RSSI and variance calculated for the summed CMI intervals of the channel will be construed as interference values [I] and [Var I] for the channel.

The channels are then ranked, with the channel having the lowest I/N and smallest [Var I] measurements likely selected for IBS entry into a Coexistence Community. Figure h 34 shows the CCD process.

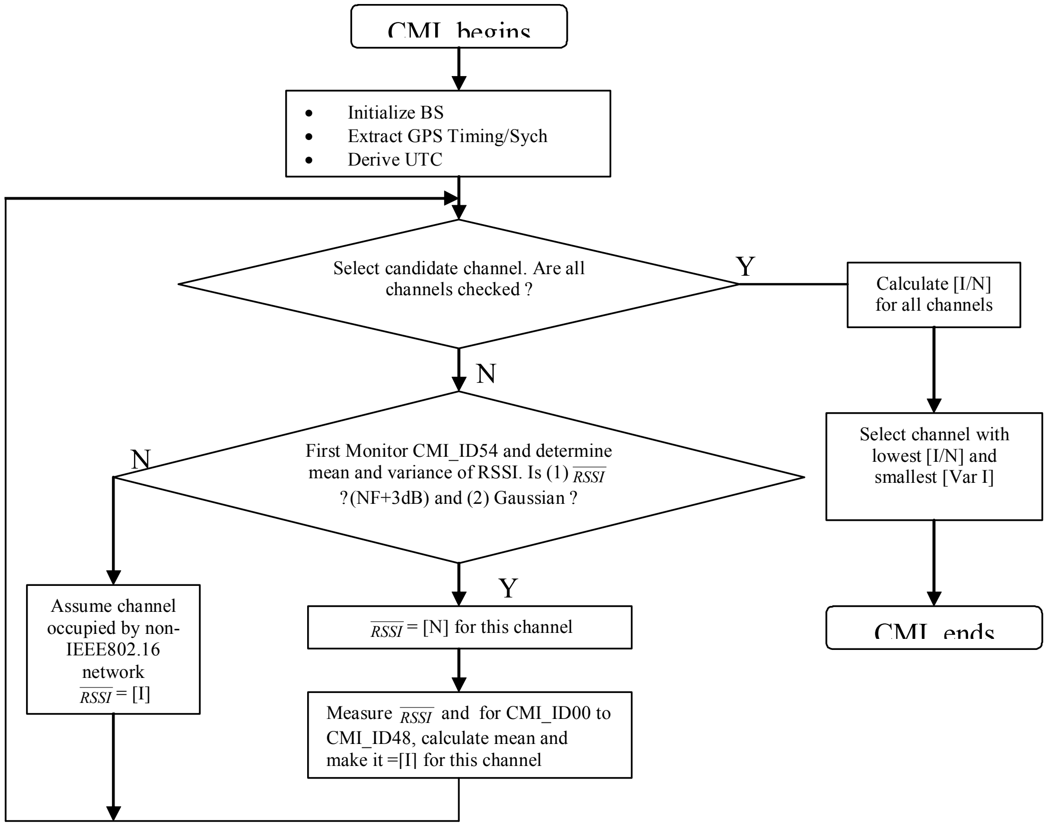

CMI begins
Initialize BS
Extract GPS Timing/Sych
Derive UTC
Select candidate channel. Are all channels checked ?
Y
Calculate [I/N] for all channels
N
First Monitor CMI_ID54 and determine mean and variance of RSSI. Is (1) $\overline{RSSI}$?(NF+3dB) and (2) Gaussian ?
N
Select channel with lowest [I/N] and smallest [Var I]
Y
Assume channel occupied by non-IEEE802.16 network $\overline{RSSI}$ = [I]
$\overline{RSSI}$ = [N] for this channel
CMI ends
Measure $\overline{RSSI}$ and for CMI_ID00 to CMI_ID48, calculate mean and make it =[I] for this channel

Figure h34—CCD Process

15.4.2 Dynamic Frequency Selection – DFS

15.4.2.1 Frequency selection for regulatory compliance

15.5 Pro-active cognitive approach

15.5.1 Signaling to other systems

15.5.1.1 Ad-hoc systems - operating principles using Radio signaling

In order to reduce the interference situations, in deployments in which may exist a combination of 802.16 systems using a Coexistence Protocol and 802.16 ad-hoc systems, the 802.16 ad-hoc systems will apply the Adaptive Channel Selection procedures and use radio signaling procedures to interact with systems using a Coexistence Protocol. The ad-hoc systems obtain a temporary Community registration status, that has to be renewed from time to time.

15.5.1.2 Registration

The 802.16h pro-active radio approach defines signals and procedures for the reservation of the activity intervals and registration of ad-hoc systems. The operational procedures are described below:

— 802.16h Community registered systems, using a Coexistence Protocol, will reserve the MAC frame Tx/Rx intervals by using, during the MAC Frame N, starting at the absolute time AT1, radio signals to indicate the MAC Tx_start, MAC Tx_end, MAC Rx_start, MAC Rx_end. These signals are transmitted by Base Stations and Repeaters. These procedures will repeat after T_cogn seconds; the values of these parameters are specified in section 10.5;

- During the MAC frame starting at the absolute time AT2, radio signals will indicate the beginning and the end of Master sub-frames, by transmitting signals indicating by their transmission start the Tx_start, Tx_end, Rx_start, Rx_end for the specific sub-frame; these signals are transmitted by Base Stations, Repeaters and those SSs which experiences interference, at intervals equal with N_{cog} MAC Frames;
- During the MAC frame starting at the absolute time AT2, will be indicated the position of the time-slots, in each Master sub-frame, to be used during the MAC Frame starting at the absolute time AT3 for registration using radio signaling. The start of the “Rx_slot” signal will indicate the start of the time-slot.
- The MAC frame starting at the absolute time AT4 is the beginning of a registration interval using the radio signaling; the registration interval has the duration of Tcr_reg seconds; The ad-hoc transmitters shall use during the MAC frame starting at the absolute time AT4, the marked slot for sending their radio signature. The radio signature will be used for the evaluation of the potential interference during the Master slot, to systems which use the sub-frame as Master systems. The next transmission opportunities for sending the radio signatures use time-slots having the duration as indicated previously and repeating every Tcr_rep sec during the Tcr_reg interval.
    - An ad-hoc radio unit (BS, Repeater or SS) will send this signal using a random access mode for Tcr_reg seconds, using the sub-frame intended for their regular transmission (BSs and SSs use different sub-frames for transmission).
    - The ad-hoc transmitters will have to use the registration procedures every Tad_reg seconds.
- Registration replay
    - The radio units using the Master sub-frame will send a NACK signal, to be sent in a random mode during the next Tcr_reg_ack seconds, if they appreciate that the ad-hoc transmitter will cause interference. Typically, to a registration signal sent during a DL sub-frame, the NAK will be sent by one or more SSs, while to a registration signal sent during UL sub-frame, the NACK signal will be sent by a Base Station. The radio units using the Master sub-frame will send their response in random mode.
    - The NACK signal indicates that the requesting ad-hoc device cannot use the specific sub-frame, while using the requesting radio signature
    - Same device may try again, if using a different radio signature (for example, lower power).
    - Lack of response, for Tcr_reg_ack seconds, indicates that the registration is accepted for transmission during the specific sub-frame.

15.5.1.3 Selection of suitable reception sub-frames

An ad-hoc unit will find his suitable reception sub-frames, by using the ACS and Registration process in a repetitive way, searching for a suitable operation frequency. The practical interference situations, with synchronized MAC Frames are BS-SS and SS-BS interference. Assuming similar transmit powers, the above mentioned process will have as result finding Master sub-frames in which the path attenuation between interfering units is maximal.

15.5.1.4 Signaling procedures using frequency-keyed energy pulses

The signaling and message exchange between an ad-hoc system and systems which are members of a Community use frequency-keyed pulses. The frequency-keyed energy pulses use for every single sub-channel the preambles defined for subchannelization in the chapter 8.3.3.5.3. Every energy bin is mapped to a OFDM sub-channel (see Table 211-OFDM symbols parameters), as shown in the Table h 5. The channels using sub-carriers at band edge or in the center are avoided.

The following figures show the desired spectral density for radio signaling. Independent of the actual channel width, the preambles are sent using the narrowest channel possible in the band. In the following example, in which channels of 5, 10 and 20MHz may be used, the narrowest channel is 5MHz and any other system will be able to detect the preambles, which are not attenuated by any radio filter.The narrowest channel will be centered in the frequency domain around the actually used channel center.

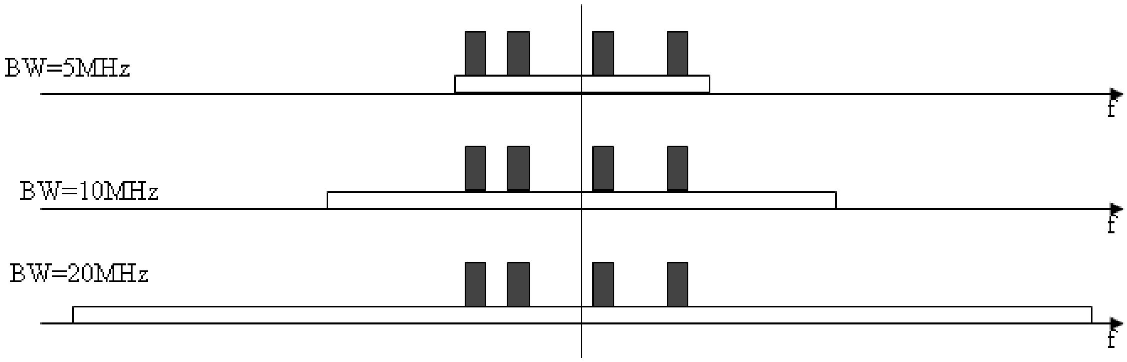


Figure h35—Desired spectral densities for different channel BWs

In Table h 5_were defined a number of radio signals, having low inter-correlation properties.

Table h5—Radio signal definition

Bin number /Signal number	**6**	**8**	**10**	**12**	**14**	**18**	**20**	**22**	**24**	**26**
Sub-channel number (1..31)	**7**	**9**	**11**	**13**	**15**	**17**	**25**	**27**	**29**	**31**
1 (Header)	H	L	L	H	H	L	L	L	H	L
2 (Tx_start)	L	H	L	L	H	H	L	L	L	H
3 (Rx_start or Rx_slot)	H	L	H	L	L	H	H	L	L	L
4 (Tx_end)	L	H	L	H	L	L	H	H	L	L
5 (Rx_end)	L	L	H	L	H	L	L	H	H	L
6 (NACK)	L	L	L	H	L	H	L	L	H	H
7 (CSI_Start)	H	L	L	L	H	L	H	L	L	H
8 (CSI_Continuation)	L	H	H	L	L	H	L	H	L	L
9	L	L	H	H	L	L	H	L	H	L

15.5.1.5 Using the coexistence slot for transmitting the BS IP identifier

The radio signaling described in the 15.5.1.4 may be also used for the transmission of the BS IP identifier, when there is no installed Base Station Identification Server.

The transmission is done in consecutive coexistence time slots, spaced by Tiptx seconds. The first CSI in the series starts with CSI start signal, the last CSI contains the Tx_end signal, the continuation in sequential CSI slots starts with the CSI_Continuation, as defined in Table h 5. Between these signals is transmitted the IP identifier of the BS and a 8bit CRC, the L.S.B (least significant bit) for each field being transmitted first. The transmission of the above information uses only the preambles for the sub-channels 6,8,10,12,14,18,20,22,24,26 (10bits / symbol), the L.S.B. corresponding to the lowest sub-channel number.

The transmission of a IPV4 address will request 1+ (32+8)/10 + 1 = 6 symbols and the transmission of a IPv6 address will request 1+ceil((128+8)/10) +1 = 16 symbols.

15.5.2 Recognition of other systems

15.6 Transmission of information

15.6.1 Coexistence Protocol (CP) messages (CP-REQ/ CP-RSP)

Coexistence Protocol employs two MAC message types: CP Request (CP-REQ) and CP Response (CP-RSP), as described in Table h 6.

Table h6—CP MAC messages

Type Value	Message name	Message description
0	CP-REQ	Coexistence Resolution and Negotiation Request
1	CP-RSP	Coexistence Resolution and Negotiation Response

These MAC management messages are exchanged between peers, e.g. BS and BSIS or BS and BS or BS and SS., and distinguish between CP requests (BS -> BS/BSIS/SS or SS-> BS) and CP responses (BS/BSIS/SS -> BS or SS->BS). Each message encapsulates one CP message in the Management Message Payload. Coexistence Protocol messages exchanged between the BS and BS or between BS and BSIS or between BS and SS shall use the form shown in Table h 7.

Table h7—CP message format

Syntax	Size	Notes
CP _Message_Format() {		
Version of protocol in use	*4* bits	1 for current version
Code	8 bits	See Table h 8
Management Message Type	16bits	0-CP-REQ 1-CP-RSP
Length of Payload	*16*bits	
Confirmation Code	8 bits	0-OK/success 1-Reject-other 2-Reject-unrecognized-configuration-setting 3-Reject-unknow-action 4-Reject-authentication-failure 5-255 Reserved
Alignment	4 bits	
AssociationID	*??*bits	
CP Message Seq_ID	8 bits	
TLV Encoded Attributes	variable	TLV specific

}		

The parameters shall be as follows:

Version of protocol in use

This specification of the protocol is version 1.

Code

The Code is one byte and identifies the type of CP packet. When a packet is received with an invalid Code, it shall be silently discarded. The code values are defined in Table x.

Length of payload

The length of payload descript the length of payload in bytes .

CP Message Sequence Identifier (CP Message Seq_ID)

The CP Message Sequence Identifier field is one byte. A BS/BSIS uses the identifier to match a BS/BSIS response to the BS's requests. The BS shall increment (modulo 256) the Identifier field whenever it issues a new CP message. The retransmission mechanism relies on TCP. The Identifier field in a BS/BSIS's CP-RSP message shall match the Identifier field of the CP-REQ message the BS/BSIS is responding to.

Association identifier(Association ID)

For uniquely identifying an CP connection between a initiator and responder

An Association ID is a parameter used to uniquely assign or relate a response to a request. The association identifier used on the responder and initiator MUST be a random number greater than zero to protect against blind attacks and delayed packets.

When the initiator sends subsequent messages, it uses the responder's association identifier in the Association ID field; when the responder sends a message it uses the initiator's association identifier in the Association ID field.

Confirmation Code

The appropriate CC for the entire corresponding CP-RSP.

Attributes

CP attributes carry the specific authentication, coexistence resolution, and coexistence negotiation data exchanged between peers. Each CP packet type has its own set of required and optional attributes. Unless explicitly stated, there are no requirements on the ordering of attributes within a CP message. The end of the list of attributes is indicated by the LEN field of the MAC PDU header.

Table h8—CP message codes

Code	CP Message Name	CP Message Type	Protocol type	Direction
0	Reserved	—	—	—
1	Identify Coexistence Request	CP-REQ	TCP	BSIS->BSIS
2	Identify Coexistence Response	CP-RSP	TCP	BSIS->BSIS
3	CoNBR Topology Request	CP-REQ	TCP	BS-> BSIS
4	CoNBR Topology Reply	CP-RSP	TCP	BSIS->BS
5	Registration Request	CP-REQ	TCP	BS-> BSIS
6	Registration Reply	CP-RSP	TCP	BSIS->BS
7	Registration Update Request	CP-REQ	TCP	BS-> BSIS
8	Registration Update Reply	CP-RSP	TCP	BSIS->BS
9	De-registration Request	CP-REQ	TCP	BS-> BSIS
10	De-registration Reply	CP-RSP	TCP	BSIS->BS
11	Add Coexistence Neighbor Request	CP-REQ	TCP	BS->BS
12	Add Coexistence Neighbor Reply	CP-RSP	TCP	BS->BS
13	Update Coexistence Neighbor Request	CP-REQ	TCP	BS->BS
14	Update Coexistence Neighbor Reply	CP-RSP	TCP	BS->BS
15	Delete Coexistence Neighbor Request	CP-REQ	TCP	BS->BS
16	Delete Coexistence Neighbor Reply	CP-RSP	TCP	BS->BS
17	Get_Param_Request	CP-REQ	UDP	BS->BS
18	Get_Param_Reply	CP-RSP	UDP	BS->BS
19	Evaluate_Interference_Request	CP-REQ	UDP	BS->BS
20	Evaluate_Interference_Reply	CP-RSP	UDP	BS->BS
21	Work_In_Parallel_Request	CP-REQ	UDP	BS->BS
22	Work_In_Parallel_Reply	CP-RSP	UDP	BS->BS
23	Quit_Sub_Frame_Request	CP-REQ	UDP	BS->BS
24	Quit_Sub_Frame_Reply	CP-RSP	UDP	BS->BS
25	Create_New_Sub_Frame_Request	CP-REQ	UDP	BS->BS(MC?)
26	Create_New_Sub_Frame_Reply	CP-RSP	UDP	BS->BS
27	Reduce_Power_Request	CP-REQ	UDP	BS->BS
28	Reduce_Power_Reply	CP-RSP	UDP	BS->BS
29	Stop_Operating_Request	CP-REQ	UDP	BS->BS
30	Stop_Operating_Reply	CP-RSP	UDP	BS->BS
31	BS_CCID_IND	CP-REQ	UDP	BS->BS
32	BS_CCID_RSP	CP-RSP	UDP	BS->BS
33	SS_CCID_IND	CP-REQ	UDP	BS->BS
34	SS_CCID_RSP	CP-RSP	UDP	BS->BS
35	PSD_REQ	CP-REQ	UDP	BS->BS
36	PSD_RSP	CP-RSP	UDP	BS->BS
37	Channel Switch Negotiation Request	CP-REQ	TCP	BS->BS
38	Channel Switch Negotiation Reply	CP-RSP	TCP	BS->BS
39	Channel Switch Request	CP-REQ	TCP	BS->BS

40	Channel Switch Reply	CP-RSP	TCP	BS->BS
41-255	reserved			

Formats for each of the CP messages are described in the following subclauses. The descriptions list the CP attributes contained within each CP message type. The attributes themselves are described in x.xx. Unknown attributes shall be ignored on receipt and skipped over while scanning for recognized attributes. The BS/ BSIS shall silently discard all requests that do not contain ALL required attributes. The BS shall silently discard all responses that do not contain ALL required attributes.

[Note: The following security part is a temporary text adopted from contribution C802.16h-05/11r1 and is subject to further discussion. A call for comment from security experts is open to comment on this text.]

The following Type-Length-Value (TLV) types may be present in the CP payload depending on the Message_Type:

Table h9—TLV types for CP payload

Type	Parameter Description
tbc	Operator ID
tbc	BS-ID
tbc	BS GPS coordinates
tbc	BS IP Address
tbc	MAC Frame duration
tbc	Type of sub-frame allocation
tbc	MAC Frame number chosen for the Master sub-frame
tbc	Sub-frame number chosen for the Master sub-frame
tbc	Repetition interval between two Master sub-frames, measured in MAC-frames
tbc	Time shift from the Master sub-frame start of the Base Station radio-signature transmission
tbc	Duration information for the Base Station radio-signature transmission
tbc	Repetition information for the Base Station radio-signature transmission
tbc	Time shift from the Master sub-frame start of the Subscriber Station radio-signature transmission
tbc	Duration information for the Subscriber Station radio-signature transmission
tbc	Repetition information for the Subscriber Station radio-signature transmission
tbc	List of other used sub-frames, in the interval between two Master sub-frames
tbc	Slot position
Tbc	Country Code
Tbc	Operator contact - phone
Tbc	Operator contact – E-mail
Tbc	PHY mode
Tbc	Maximum coverage at Max. power
Tbc	Current Tx power

15.6.1.1 Identify Coexistence Request message

The BSIS requests to the foreign BSIS with geographical information of the requesting LE BS.

Code: 1

Attributes are show in Table h 10

Table h10—Identify Coexistence Request message attribute

Attribute	Contents
Operator identifier	The operator ID of the BSIS.
Country code	The country code of the BSIS
Latitude	The latitude information of the BS.
Longitude	The longitude information of the BS.
Altitude	The altitude information of the BS.
Maximum coverage at Max. power	The maximum radius at maximum allowed/designed power that the BS intends to detect its coexistence neighbors.

15.6.1.2 Identify Coexistence Reply message

The BSIS responds to the foreign BSIS to Identify Coexistence Request with a Identify Coexistence Reply message.

Code: 2

The query results is in the format of Coexistence Neighbor Topology Parameter Set, each result will contain the attributes shown in Table h 11. Each BSID TLV indicates start of new result.

Table h11—Coexistence neighbor Topology Parameter Set

Attribute	Contents
BSID	The BSID of the requested BS.
Operator identifier	The operator ID.
Operator contact - phone	The phone number in ASCII string of the operator.
Operator contact – E-mail	The E-mail address in ASCII string of the operator.
Country code	The country code of the BS
PHY mode	The PHY modes of the requested BS.
Latitude	The latitude information of the BS.
Longitude	The longitude information of the BS.
Altitude	The altitude information of the BS.
Maximum coverage at Max. power	The maximum radius at maximum allowed/designed power that the BS intends to detect its coexistence neighbors.

15.6.1.3 Coexistence Neighbor Topology Request message

This message is sent by the BS to the BSIS to request its coexistence neighbor topology with its geometric information.

Code: 3

Attributes are shown in Table h 12.

Table h12—Coexistence Neighbor Topology Request message attribute

Attribute	Contents
Latitude	The latitude information of the BS.
Longitude	The longitude information of the BS.
Altitude	The altitude information of the BS.

Maximum Coverage at Max. power	The maximum radius at maximum power that the BS intends to detect its coexistence neighbors.

15.6.1.4 Coexistence neighbor Topology Reply message

The BSIS responds to the BS' to Coexistence neighbor Topology Request with a Coexistence neighbor Topology Reply message.

Code: 4

Specification of the query results of coexistence neighbor topology from BSIS specific parameters.

The query results is in the format of Coexistence Neighbor Topology Parameter Set, each result will contain the attributes shown in Table h 13. Each BSID TLV indicates start of new result.

Table h13—Coexistence neighbor Topology Parameter Set

Attribute	Contents
BSID	The BSID of the requested BS.
Operator identifier	The operator ID.
Operator contact - phone	The phone number in ASCII string of the operator.
Operator contact – E-mail	The E-mail address in ASCII string of the operator.
Country code	The country code of the BS
PHY mode	The PHY modes of the requested BS.
Latitude	The latitude information of the BS.
Longitude	The longitude information of the BS.
Altitude	The altitude information of the BS.
Maximum coverage at Max. power	The maximum radius at maximum allowed/designed power that the BS intends to detect its coexistence neighbors.

15.6.1.5 Registration Request message

This message is sent by the BS to the regional LE DB to perform the registration.

Code: 5

Attributes are shown in Table h 14.

Table h14—Registration Request message attributes

Attribute	Contents
BSID	The BSID of the requested BS.
BS IP	The IP address of BS.
Operator identifier	The operator ID.
Operator contact - phone	The phone number in ASCII string of the operator.
Operator contact – E-mail	The E-mail address in ASCII string of the operator.
Country code	The country code of the BS
PHY mode	The PHY modes of the requested BS.
Latitude	The latitude information of the BS.
Longitude	The longitude information of the BS.
Altitude	The altitude information of the BS.
Operational Range at Max. Power	The maximum operational radius of the BS at Max. power.

15.6.1.6 Registration Reply message

The BSIS responds to the BS' to Registration Request with a Registration Reply message.

Code: 6

No Attributes.

15.6.1.7 Registration Update Request message

This message is sent by the BS to the regional LE DB to update the registration.

Code:7

Attributes are shown in Table h 14.

15.6.1.8 Registration Update Reply message

The BSIS responds to the BS' to Registration update Request with a Registration update Reply message.

Code: 8

No Attributes.

15.6.1.9 De-registration Request message

This message is sent by the BS to the BSIS to perform de-registration.

Code: 9

Attributes are shown in Table h 15.

Table h15—De-registration Request message attributes

Attribute	Contents
BSID	The BSID of the request BS.

15.6.1.10 De-registration Reply message

The BSIS responds to the BS' to De-registration Request with a De-registration Reply message.

Code: 10

No Attributes.

15.6.1.11 Add Coexistence Neighbor Request message

This message is sent by the BS to the coexistence neighbor BS to request to add it to coexistence neighbor list.

Code: 11

Attributes are shown in Table h 16.

Table h16—Add Coexistence Neighbor Request message attributes

Attribute	Contents
BSID	The BSID of the requested BS.
BS IP	The IP address of requested BS.
Operator identifier	The operator ID.
Country code	The country code of the requested BS.
PHY mode	The PHY modes of the requested BS.
Latitude	The latitude information of the BS.
Longitude	The longitude information of the BS.
Altitude	The altitude information of the BS.
Current Tx power	Current Tx power of the BS.
Operational Range	The operational radius of the BS.
PHY specific parameters	The PHY specific encodings.

15.6.1.12 Add Coexistence Neighbor Reply message

The BSIS responds to the BS’ to Add Coexistence Neighbor Request with an Add Coexistence Neighbor Reply message.

Code: 12

No Attributes.

15.6.1.13 Update Coexistence Neighbor Request message

This message is sent by the BS to the coexistence neighbor BS to request to update its neighbor list.

Code: 13

Attributes are shown in Table h 17.

Table h17—Update Coexistence Neighbor Request message attributes

Attribute	Contents
BSID	The BSID of the requested BS.
PHY mode	The PHY modes of the requested BS.
Latitude	The latitude information of the BS.
Longitude	The longitude information of the BS.
Altitude	The altitude information of the BS.
Operational Range	The operational radius of the BS.
PHY specific parameters	The PHY specific parameters.

15.6.1.14 Update Coexistence Neighbor Reply message

The BSIS responds to the BS’ to Update Coexistence Neighbor Request with an Update Coexistence Coexistence neighbor Reply message.

Code: 14

No Attributes.

15.6.1.15 Delete Coexistence Neighbor Request message

This message is sent by the BS to the coexistence neighbor BS to request to delete form its coexistence neighbor list.

Code: 15

Attributes are shown in Table h 18.

Table h18—Delete Coexistence Neighbor Request message attrubutes

Attribute	Contents
BSID	The BSID of the requested BS.

15.6.1.16 Delete Coexistence Neighbor Reply message

The BSIS responds to the BS' to Delete Coexistence Neighbor Request with a Delete Coexistence Neighbor Reply message.

Code: 16

No Attributes.

15.6.1.17 Get_Param_Request message

Messages between BSs, used to request the list of parameters

Code:17

Parameters: list of the BS parameters

15.6.1.18 Get_Param_Reply message

Messages between BSs, reply to the Get_Param_Request

Code:18

Parameters: list of the BS parameters

15.6.1.19 Evaluate_Interference_Request message

A message sent by a new BS wishing to use an existing Master sub-frame, to the BSs already acting as Masters, requesting them to evaluate its interference

Code:19

Parameters: tbc.

15.6.1.20 Evaluate_Interference_Reply message

A message sent by the existing Master BSs, reply to the Evaluate_Interference_Request.

Code:20

Parameters: tbc.

15.6.1.21 Work_In_Parallel_Request message

A message sent by a new BS to request the use an existing Master sub-frame

Code: 21

Parameters: tbc.

15.6.1.22 Work_In_Parallel_Reply message

A message sent by a existing Master BS in response to the Work_In_Paraller_Request message.

Code: 22

Parameters: tbc.

15.6.1.23 Quit_Sub_Frame_Request message

A message sent by an old Base Station, in order to request the new Base Station to cease the operation as Master in the current sub-frame

Code:23

Parameters: tbc.

15.6.1.24 Quit_Sub_Frame_Reply message

A message sent by an new Base Station, in response to the old Base Station’s Quit_Sub_Frame_Request message.

Code:24

Parameters: tbc.

15.6.1.25 Create_New_Sub_Frame_Request message

A message sent by a BSs to all the community BSs, to request the creation of a new Master sub-frame; the message will include: interfering BSIDs and the frame-number in which the change will take place

Code:25

Parameters: tbc.

15.6.1.26 Create_New_Sub_Frame_Request message

A message sent in response to the Create_New_Sub_Frame_Request message.

Code:26

Parameters: tbc.

15.6.1.27 Reduce_Power_Request message

A message between a BS and an interfering BS requesting to reduce the power of the specified transmitter (identified by frame_number, sub-frame, time-shift) by P dB

Code: 27

Parameters: tbc.

15.6.1.28 Reduce_Power_Reply message

A message by an interfering BS in response to the Reduce_Power_Reply message.

Code: 28

Parameters: tbc.

15.6.1.29 Stop_Operating_Request message

A message sent by a Master BS to the BSs operating in its Master sub-frame, but not being Masters for this sub-frame, requesting to cease using this sub-frame in parallel

Code: 29

Parameters: tbc.

15.6.1.30 Stop_Operating_Reply message

A message sent by the BSs operating in its Master sub-frame,in response to the Stop_Operating_Request message.

Code: 30

Parameters: tbc.

15.6.1.31 BS_CCID_IND message

A message sent by BSs to indicate co-channel interference detected.

Code: 31

This is a message sent by a SS to CR_NMS when co-channel interference is detected at SS. This message shall contain the following minimum information to help determine the source and victim of co-channel interference:

- BS_NUM: total number of base stations from which CCI interference is detected.
- BS_ID: the base station IDs causing CCI
- Sector_ID: the sector IDs of the base stations causing CCI
- SS_ID: the SS that sent this message.

Essentially, this message will contain a table of co-channel interference sources for this SS.

Table h19—table of co-channel interference source for SS

Base station ID	Sector ID
123456	2
234534	4
…	…

15.6.1.32 BS_CCID_RSP message

A “set” message to BS.

Code: 32

This is a “set” message; it is to set the emission or reception qualities of the specified SS. Upon receiving co-channel interference notification, the algorithm in CR-NMS will determine an appropriate CCI mitigation decision and forward

This message to the victim SS.

SS_CCID_RSP can contain the following information for example:

SS_ID: the ID of subscriber station that causes/receives co-channel interference. It is the receiver of this message.

- EIRP for the specified SS. This is a reduced/increased EIRP value for this SS based on algorithm.
- Downlink/uplink frequency change.
- Reregistration request to a new BS
- Specification of allowable uplink timing slots.
- Adaptive antenna configuration parameters for reception/transmission.

15.6.1.33 SS_CCID_IND message

A message sent by SSs to indicate co-channel interference detected.

Code: 33

This is a message sent by a BS to CR_NMS when co-channel interference is detected at BS. This message shall contain the following information to help determine the source and victim of co-channel interference:

- SS_NUM: total number of subscriber stations that interference events were noted.
- SS_ID: the subscriber stations ID that causes the co-channel interference
- Sector_ID: the sector ID of the subscriber stations that cause interference
- Source basestation ID: the BS that sent this message.
- Source sector_ID: the antenna sector that detects the co-channel interference.

Essentially, this message will contain a table of co-channel interference sources for this BS.

15.6.1.34 SS_CCID_RSP message

A “set” message to SS.

Code: 34

This is a “set” message; it is to set the configuration of the BS. Upon receiving co-channel interference notification, the algorithm in CR-NMS will use this message to set the emission or reception qualities of the specified BS. It shall have the following information:

- BS_ID: Base station ID of Base Station receiving/causing interference. It is the receiver of this message.
- EIRP for the specified BS
- Downlink/Uplink frequency change.
- Adaptive antenna configuration parameters for reception/transmission.

15.6.1.35 PSD_REQ message

A”set” message to start PSD (power spectrum density) sampling

Code: 35

All co-channel interference that is created cannot necessarily be demodulated or decoded correctly, allowing the extraction of Tagged information from interference frames. Additionally, some users of license-exempt spectrum may not comply with any of the IEEE standards and be impossible to identify. In this event it is useful for a to be able to monitor the LE spectrum to determine available spectrum “white space” and determine sub-detection interference. “Snapshots” of spectrum space are useful to CR systems, especially when new base stations or terminals are installed and are searching for unoccupied spectrum.

This is a “set” message, it is requests a BS or SS to sample PSD (power spectrum density) data for next “get” message. Since sampling PSD data will take some time, depending on environment, nature of bursty users, the following “get” message shall wait long enough for BS/SS to complete the PSD data sampling.

There shall be only one scalar MIB object defined for this operation.

15.6.1.36 PSD_RSP message

A “get” message to get PSD (power spectrum density) data table.

Code: 36

This is a “get” response message, MIB objects shall be defined accordingly; it shall contain the following values for a complete PSD:

- Antenna Parameter List containing attributes of antenna undertaking PSD
- X-min, the lower bound of channel frequency (in kilohertz)
- X-max, the upper bound of channel frequency (in kilohertz)

- Resolution bandwidth
- Power spectrum density measurement

Resolution bandwidth is scalar, it is used together with X-max and X-min to determine how many PSD values are collected and contained in the STRUF_REP message (i.e.).

$$(X_{max} - X_{min}) / (resolutionBandwidth)+1 \qquad (h2)$$

Upon reception of this message, CR_NMS will stamp the message based on the arrival time and translate the information into internal format and store it into database.

Here is an example of PSD display:

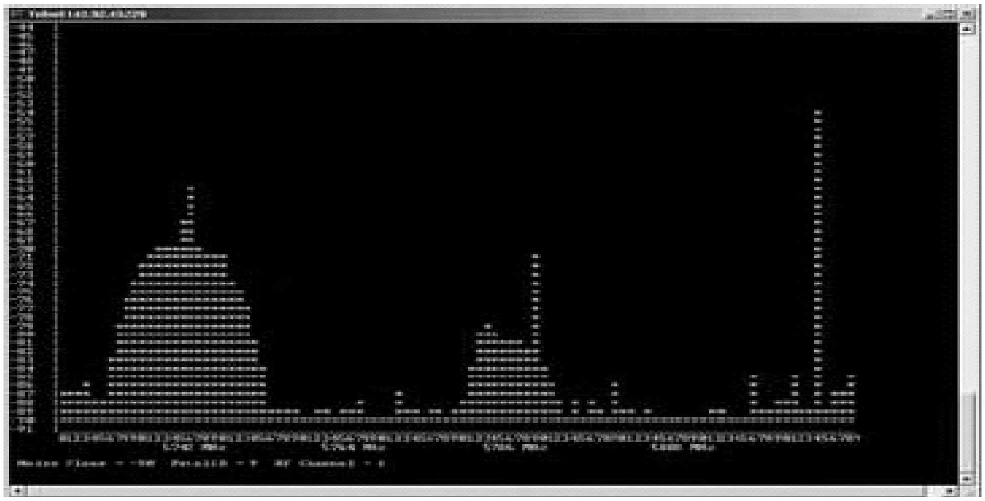


Figure h36—Example of PSD Display

15.6.1.37 Channel Switch Negotiation Request message

This message is send by BS to another coexistence BS in the community to negotiate to switch to a certain target channel.

Code: 37

Parameters: tbc.

15.6.1.38 Channel Switch Negotiation Reply message

A message sent by BS, reply to Channel Switch Negotiation Request message about whether it agree or refuse to switch.

Code: 38

Parameters: tbc.

15.6.1.39 Channel Switch Request message

This message is send by BS to another coexistence BS in the community to request to switch to an alternative channel.

Code: 39

Parameters:

Table h20—Channel Switch Request message attributes

Attribute	Contents
Operator ID	The Operator identifier of requesting BS.
BSID	The requesting BS identifier
Requested BSID	BS identifier of the requested BS
Working Channel ID	The current working channel ID of the requested BS
Rolling back indication	0: to switch to one of the alternative channels 1: to switch back to the channel before the last channel switching request
FSN	Frame sequence number to switch channel

15.6.1.40 Channel Switch reply message

A message sent by BS, reply to Channel Switch Request message indicating the result of the channel switching.

Code: 40

Parameters:

Table h21—Channel Switch Reply message attributes

Attribute	Contents
Operator ID	The Operator identifier of requesting BS.
BSID	The requesting BS identifier
Requested BSID	BS identifier of the requested BS
Acknowledge	0: rejection for fail in switching 1: succeeded in switching
Target working channel ID (new working channel)	The channel ID of the requested BS will switch to
FSN	Frame sequence number of the channel switching

[Note: the following part "RADIUS Protocol Messages" is from contribution C802.16-05/012r1, calling for comments, as all the security issues]

15.6.2 Sequencing and Retransmission

CP is a request-response protocol. In any particular message exchange, one party acts as the initiator (sends a request) and the other party acts as the responder (sends a response message).

The initiator sets the Message ID in the header to any value in the first message of the CP association, and increases the Message ID by one for each new request using serial number arithmetic. Retransmissions do not increment the Message ID. The responder sets the message ID in the response to the value of the message ID in the request.

The initiator is always responsible for retransmissions. The responder only retransmits a response on seeing a retransmitted request; it does not otherwise process the retransmitted request.

The retransmitted requests/responses are exact duplicates of previous requests/responses. The initiator must not send a new request until it receives a response to the previous one. Packets with out-of-sequence Message IDs are considered invalid packets and are discarded.

The initiator must retransmit after a configurable interval until either it gets a valid response, or decides after a configurable number of attempts that the CP association has failed. (Since the retransmission algorithm is implementation-dependent, it is not defined here.)

15.6.3 Message Validity Check

A message is only accepted if all the following holds true:

- Message version *field = 1.*
- Association ID must match a current association
- All messages received by peer have R bit in flag set to zero
- All responses received by authenticator have R bit in flag set to one.
- Message opCode is valid
- Message length equals size of payload
- Message ID must match the expected sequence number
- The payload contains only those TLVs expected given the value of the opCode
- *All TLVs within the payload are well-form*ed, TLVs marked as mandatory are recognized.

15.6.4 Fragmentation

CP does not provide support for fragmentation.

15.6.5 Transport Protocol

CP uses UDP as the transport protocol with port number[tbd.]. All messages are unicast.

15.6.6 Using dedicated messages

15.6.6.1 Common PHY

15.6.6.2 Between BS and SS

15.6.6.2.1 BS_NURBC

BS_NCRBC (*BS Neighborhood Update Request BroadCasting*) message is the message broadcasted by the initializing base station or the operating base station which need to update the neighbor list in the database. It is sent to the SS in the coexistence neighbor network. It use the CSI frame to carry the IP address information of its coexistence proxy and the BSID from the BS to the SS, and the IP & BSID information shall be reported by the SS to its serving coexistence neighbor BS. And the serving coexistence neighbor BS should communicate the initializing BS in the IP network via the coexistence proxy, and proceed the further coexistence negotiation.

RTK (*Random Temporary Key*) shall be random generated in the BS and broadcasted in BS_BURBC, neighbor BS which send CP request message need carry the RTK in the message. This will prevent the BS from being easily cheated by someone far away without any 16h airlink capability which have know the static contact information.

Table h22—BS_NURBC message TLV encoding

Name	Type(1byte)	Length	Value (Variable length)
NURBC_V4	0	12	Bits 15:0 - RTK Bits 63:16 - BSID Bits 95:64 - BS IP address(IPv4)
NURBC_V6	1	24	Bits 15:0 - RTK Bits 63:16 - BSID Bits 191:64 - BS IP address(IPv6)

15.6.6.3 BS to BS

15.6.6.4 Connection sponsorship

15.6.6.5 Using a common management system

15.6.6.6 Higher layers communication

15.6.6.7 Decentralized control

15.6.6.8 Information sharing

15.6.6.9 IP / MAC address dissemination

15.7 Common policies

15.7.1 How to select a “free” channel (for ACS and DFS)

BS should listen on multiple frequencies during the selection of working frequency. If the interference’s level is greater than the detection threshold, which is the required strength level of a received signal within the channel bandwidth, the channel is considered as a interfered channel. If IBS can’t find a “free” channel by scanning, it should figure out whether an indirect “free” channel can be found by optimized channel distribution, as described in 15.7.1.4.

Process of ACS is shown in Figure h 37. ACS results two kinds of resolution, a “free” channel found with or without channel switching, or no “free” channel found.

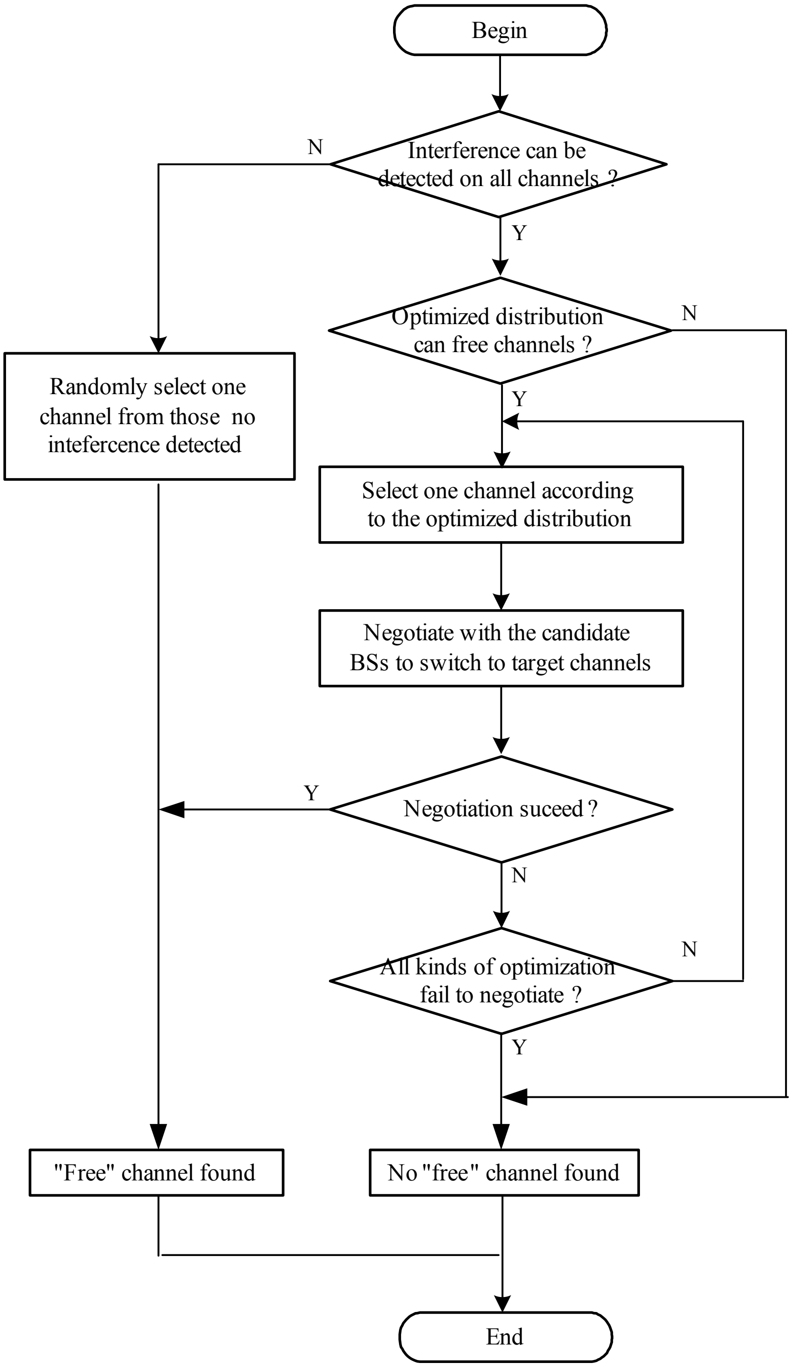

Begin
Interference can be detected on all channels ?
N
Y
Optimized distribution can free channels ?
N
Y
Randomly select one channel from those no intefercence detected
Select one channel according to the optimized distribution
Negotiate with the candidate BSs to switch to target channels
Negotiation suceed ?
Y
N
All kinds of optimization fail to negotiate ?
N
Y
"Free" channel found
No "free" channel found
End

Figure h37—Process of ACS

If a “free” channel found, means default interference-free Master slot is available, otherwise, IBS need to share the channel with coexistence neighbors, as described in 15.2.1.7.

15.7.1.1 Acceptable S/(N+I)

15.7.1.2 Acceptable time occupancy

15.7.1.3 Capability of sharing the spectrum

15.7.1.4 Optimization of Channel Distribution

In the initialization phase of an IBS, IBS's neighbors will send their current OCSI allocation or subframe allocation to IBS using CP message, as well as a flag of having alternative channels. IBS may maintain the channel information of all neighbors in BS information table.

When IBS cannot find any free channels for itself at the initialization, channel distribution may be optimized to vacate a free channel for IBS by switch some neighbors' working channels to others.

First, IBS picks up all the channels that every neighbor working on it has alternative channels, and sorts them according to the number of neighbor BSs working on it.

Afterwards, IBS selects one of the channel used by lest BS, and considers this channel as its potential working channel. The neighbors working on the selected channel are to be negotiated.

Then, to negotiate to every neighbor BS working on this channel, IBS should send channel switch request message. Neighbor OBS which have received this message should select one of its alternative channels as the its target working channel, and try to move its working channel to that channel as long as the request is qualified. After its working channel switch to its alternative channel, The neighbor OBS should acknowledge to IBS by sending back channel switch reply message with success indication, otherwise it should show rejection to IBS by sending back channel switch reply message with fail indication. If IBS received any rejection from the neighbors which IBS have sent the request, IBS should cancel the request by sending another message with the indication for the neighbors to back to the channel they used before the IBS's channel switching request.

When IBS receives all the acknowledged messages, it means the channel distribution optimization procedure has succeeded to vacate a channel for IBS. Otherwise, IBS should try the next channel.

In the case of success of the optimization procedure, list of alternative channels of relative BSs should be updated because its neighbors may change their working channels. For IBS, it should broadcast to all its neighbor that it will working on the selected channel, and all its neighbors should add IBS as its new neighbor in BS information table, and exclude IBS's target working channel in the list of alternative channel. For the neighbor OBSs working on this channel, they also should notify their change to all their neighbors for their switching from its current working channel to another, so their neighbors can update the database and their alternative channel according to that change.

If all the potential channels can not be vacated to become IBS's working channel, channel distribution optimization procedure is failed, and IBS shall try to share one channel with some of its neighbors.

The process of channel distribution optimization is shown in Figure h 38.

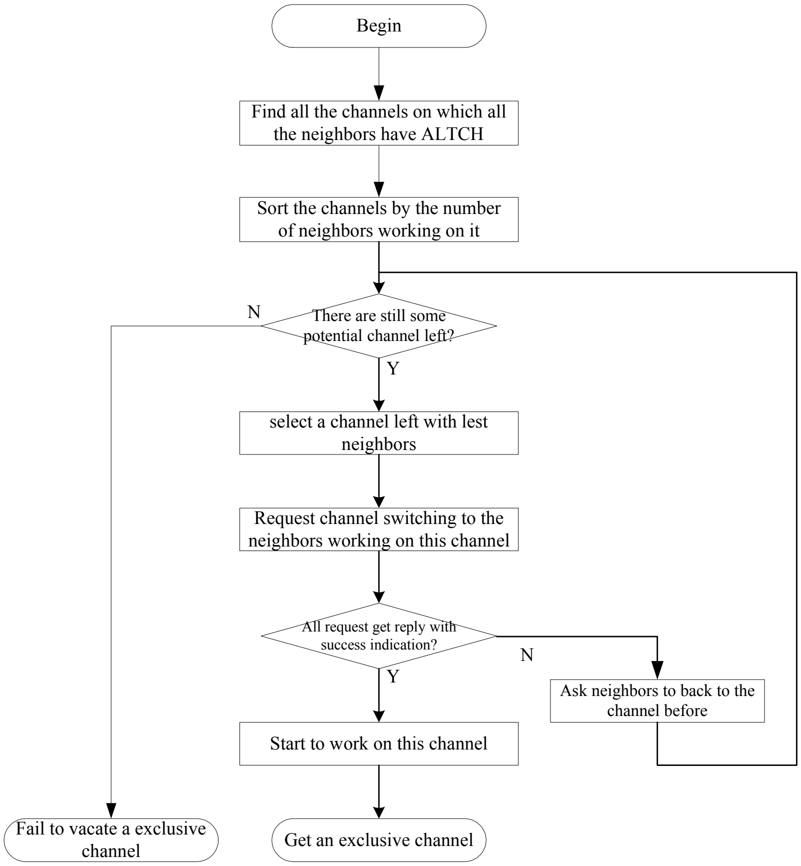

Begin
Find all the channels on which all the neighbors have ALTCH
Sort the channels by the number of neighbors working on it
There are still some potential channel left?
N
Y
select a channel left with lest neighbors
Request channel switching to the neighbors working on this channel
All request get reply with success indication?
N
Y
Ask neighbors to back to the channel before
Start to work on this channel
Fail to vacate a exclusive channel
Get an exclusive channel

Figure h38—Process of channel distribution optimization

15.7.2 Interference reduction policies

15.7.2.1 BS synchronization

15.7.2.1.1 Synchronization of the IEEE 802.16h Networks

All base stations forming a community of users sharing common radio spectrum will use a common clock to synchronize their MAC frames. The common clock will be available to all outdoor IEEE 802.16h networks. Such a clock can be provided by global navigational systems such as GPS (Annex 2) or can be distributed by other mean . Every BS upon activation, will as a first step ensure the derivation of the common system clock.

15.7.2.1.1.1 Network Time Interval

All synchronized IEEE 802.16h base stations will either synthesize or derive a 1 pps clock broadcast by a global navigational system or other means. The 1 sec duration is called the Network Time Interval (NTI). The rising edge of the 1 pps synchronization pulse will be considered as the start of the NTI. The 1pps pulse will have a stability of +/- 100 XX microseconds, as measured from rising edge to rising edge.

15.7.2.1.1.2 Granularity of the NTI

The NTI will be comprised of 1000 1 Millisecond slotsNTI_S unit that will be used by both TDD and FDD networks to negotiate times and durations of co-channel occupancy. Negotiation for access time to common spectrum will be specified in terms of the NTI_S unit 1 millisecond units. Occupancy times will be specified in terms of time from the beginning of the NTI and in terms of negotiated number of NTI_S unit1 millisecond intervals.

15.7.2.1.1.3 UTC Standard Time

The common clock specified in 15.7.2.1.1 will provide a Universal Coordinated Time (UTC) signal to all IEEE802.16h networks, making all networks synchronized to this referenced time stamp. IEEE 802.16h base stations will use the UTC time standard for coordinating and identifying specific NTI intervals.

15.7.2.1.2 Ad-hoc

15.7.2.2 Shared Radio Resource Management

15.7.2.2.1 Fairness criteria

15.7.2.2.1.1 Power control

15.7.2.2.1.2 Mutual tolerance

15.7.2.2.2 Distributed scheduling

15.7.2.2.2.1 Assignments

15.7.2.2.3 Distributed power control

15.7.2.2.4 Distributed bandwidth control

15.7.2.2.5 Beam-forming

15.7.2.2.6 Credit token based coexistence protocol

Spectrum sharing between several networks (NW) can be achieved through the sharing of a common MAC frame between the different NWs as exampled by Figure h 39. In such a MAC frame structure, dedicated portions (denoted as “master NW sub-frames”) of the frame are periodically and exclusively allocated to a NW (denoted as the “master NW”) respectively in the forward and reverse link. The terminology used hereafter defines a slave NW as a NW that may operate during the other master NWs sub-frames. With respect to this definition, the slave NW sub-frames are the time intervals operating in parallel of the master NWs sub-frames.

Additional flexibility can be provided by such a frame structure if The length of each master sub-frame(interference free sub-frame) can be dynamically adjusted as a function of the spatial and temporal traffic load variations of each NWas stated in section 15.2.1.1.1.

To achieve this, this section proposes the dynamic coordination of the frame structure sharing between BSs when several master NWs compete to share this common shared MAC frame.

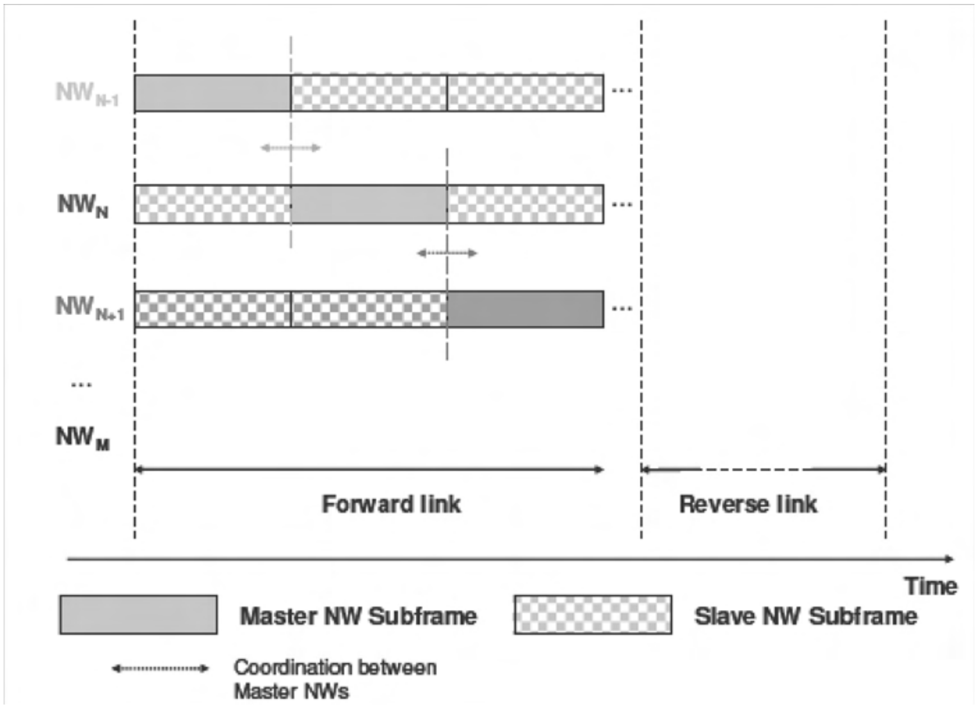


Figure h39—Example of TDD based MAC frame sharing structure between M NWs

15.7.2.2.6.1 General principle

In order to solve contention access channel and resources scheduling issues between NWs, the first step consists in defining credit tokens and designing appropriate reserve price auctioning and bidding mechanisms. Then, on the basis of the credit tokens based mechanisms usage, the second step consists in managing dynamically(temporally) the bandwidthrequests and grants mechanisms for the sharing of the master sub frames within the common MAC frame.

Based on the credit tokens transactions (selling, purchase and awarding), these two steps provide the mechanisms to enable spectrum efficiency and a fair spectrum usage in a real time fashion, while ensuring both the master and slave NWs QoS. These two steps enable to manage spectrum sharing between master NWs themselves. The result is the dynamic shaping of the MAC frame structure sharing as a function of the space time traffic intensity variations, and the dynamic credit tokens portfolio account of the master NWs. The transaction mechanisms are detailed in the following sections.

15.7.2.2.6.2 Credit tokens assignment and usage principles

- Each NW is initially allocated with a given credit tokens account.
- Negotiation for spectrum sharing between NWs is based on credit tokens transactions.
- Credit tokens transactions occur dynamically between a seller (master NW owner of the radio resources during the active master sub-frame) and one or several bidders (the other master NWs).
- The negotiation occurs dynamically between master NWs to agree the length of each master sub-frame as a function of the spatial and temporal traffic load variations need of each master NW.

15.7.2.2.6.3 Negotiation between master NWs

15.7.2.2.6.3.1 Definition and notation

- BSN denotes the BS belonging to the master NWN.
- BSk denotes the BS belonging to the slave NWk.
- Each BSk can dynamically make a bid BS_CT(n)k at the nth iteration. This bid corresponds to the amount of credit tokens per time unit corresponding to the BSk during the nth iteration of the auctioning/bidding phase.
- Resource scheduling is carried out by an auction like mechanism. The auction type used for the scheduling is dynamic in time. Starting from the reserved price auction RPA, the price of auction is successfully raised (at each iteration n) until the winning bidders remain.

15.7.2.2.6.3.2 Dynamic credit tokens based scheduling cycle

The contribution proposes a dynamic scheduling cycle between one BSN of master NWN and several BSk of different slave NWk. For the sake of simplicity, the cycle is illustrated (Figure h 40 and Figure h 41) for one BSN and one BSk of a given slave NWk. The cycle is composed of different phases, and each phase can be composed of several sequences as follows.

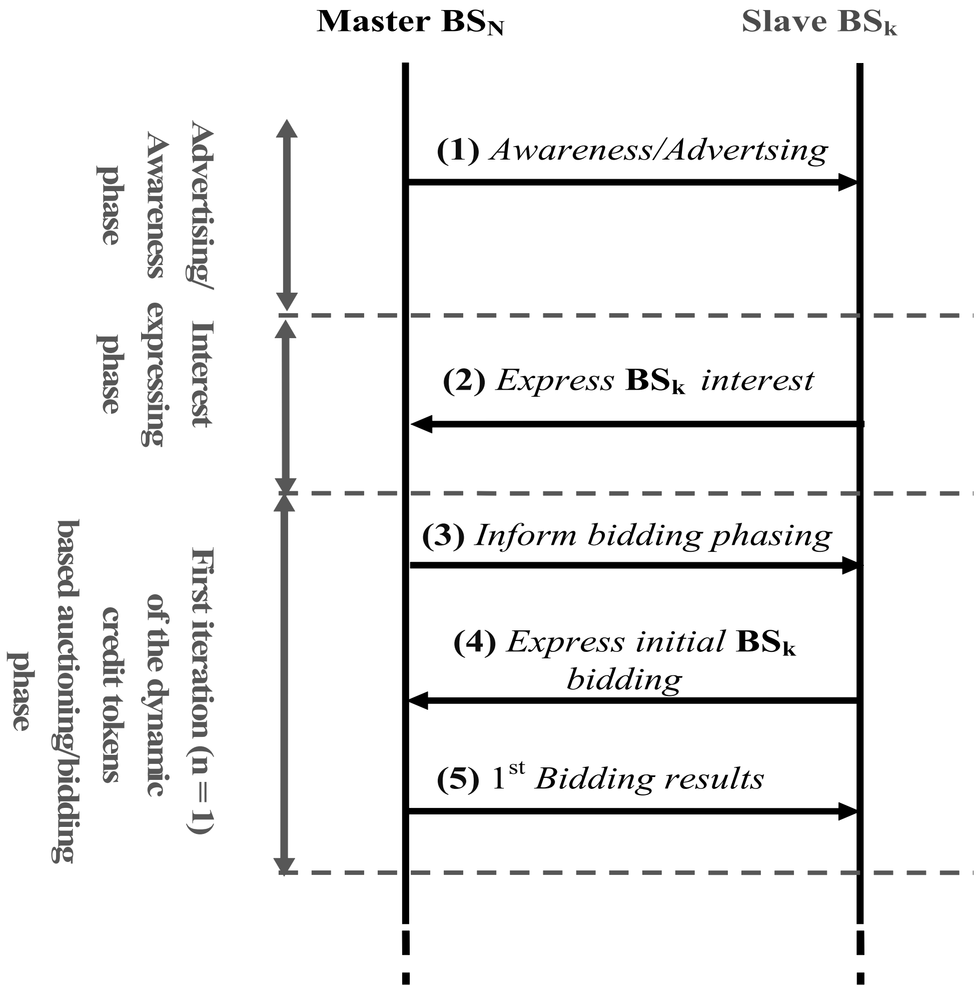

Master BS_N
Slave BS_k
Advertising/ Awareness phase
Interest expressing phase
First iteration (n = 1) of the dynamic credit tokens based auctioning/bidding phase
(1) Awareness/Advertsing
(2) Express BS_k interest
(3) Inform bidding phasing
(4) Express initial BS_k bidding
(5) 1st Bidding results

Figure h40—Dynamic (iterative) credit tokens based scheduling cycle – (sequences (1) to (5))

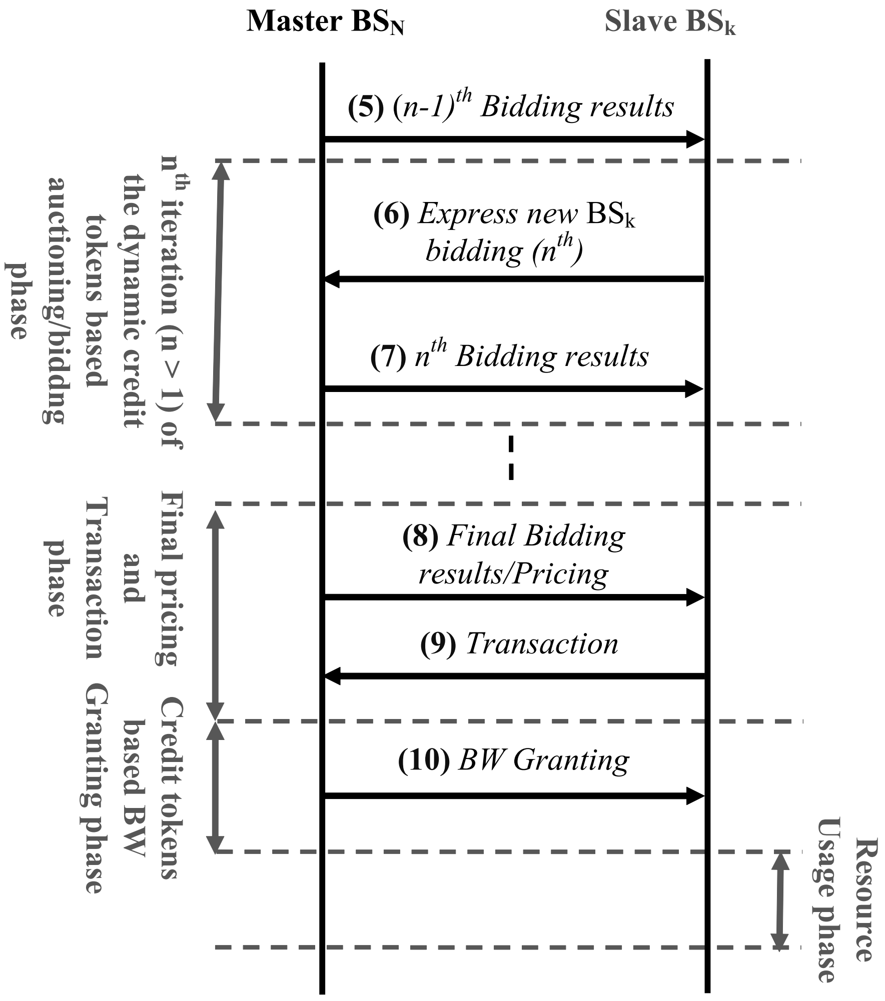

Master BS$_N$
Slave BS$_k$
(5) (n-1)th Bidding results
(6) Express new BS$_k$ bidding (nth)
(7) nth Bidding results
(8) Final Bidding results/Pricing
(9) Transaction
(10) BW Granting
nth iteration (n > 1) of the dynamic credit tokens based auctioning/biddng phase
Final pricing and Transaction phase
Credit tokens based BW Granting phase
Resource Usage phase

Figure h41—Dynamic (iterative) credit tokens based scheduling cycle – (sequences (5) to (10))

15.7.2.2.6.3.3 Negotiation mechanisms between master NWs

For each of the phase of the credit tokens based scheduling cycle presented in section 15.7.2.2.6.3.2, this section 15.7.2.2.6.3.3 describes the details of the enhanced mechanisms.

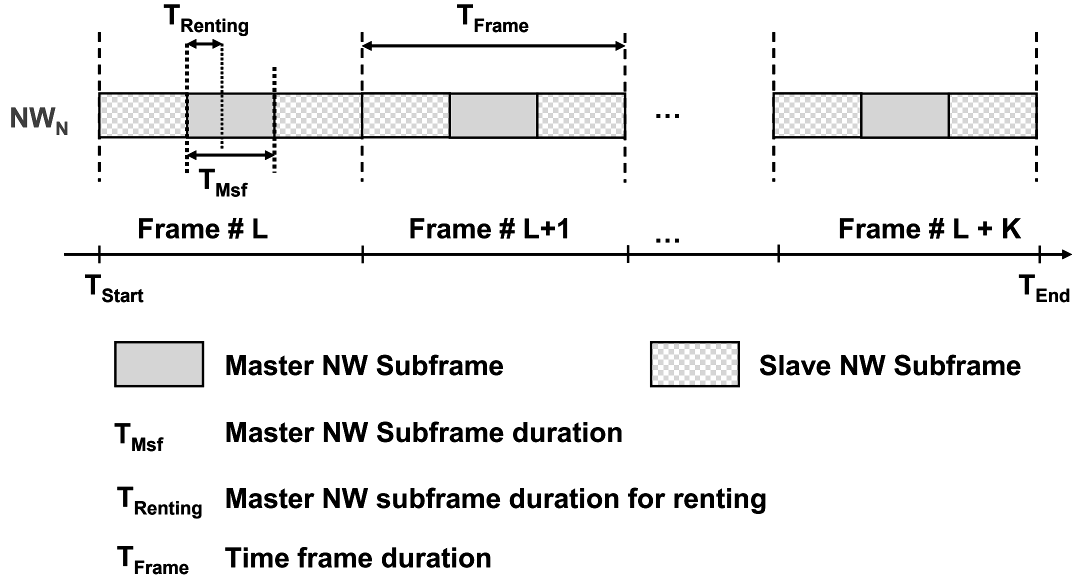


Figure h42—Simplified MAC frame structure illustrating master NW sub-frame renting principle and associated notations

Advertising/Awareness phase

This phase is composed of the single sequence (1) as follows:

- The master NW_N (seller) advertises that its periodic assigned master sub-frame is open for renting (Figure h 42) from starting time $\mathbf{T_{Start}}$ to ending time $\mathbf{T_{End}}$ for a fraction ($\mathbf{T_{Renting}}/\mathbf{T_{Msf}}$) of its master sub-frame duration $\mathbf{T_{Msf}}$. $\mathbf{T_{Renting}} = \mathbf{T_{End\ Renting}} - \mathbf{T_{Start\ Renting}}$.
- The master NW_N proposes a reserve price auction **RPA** for this renting. The **RPA** is expressed as a number of credit tokens per time unit.

Interest expressing phase

This phase is composed of the single sequence (2) as follows: each BSk informs the master BSN about its willingness (or not) to participate to the bidding. If the BSk is interested, it communicates its idk to the master BSN.

First iteration (n = 1) of the credit tokens based auctioning/bidding phase

This phase is divided into 3 sequences as follows:

- In sequence (3), the master BS_N provides the following information to the slave BS_ks that have expressed the interest to participate to the bidding:
    - $\mathbf{T_{Start\ Bidding}}$: time from which the bidding phase will start,
    - $\mathbf{T_{End\ Bidding}}$: time at which the bidding phase will end ($\mathbf{T_{End\ Bidding}} < \mathbf{T_{Start}}$),
    - Note: For this first iteration (n = 1), the initial $\{\mathbf{id_k}\}$ is noted $\{\mathbf{id^{(1)}_k}\}$.

- In sequence (4), each BS_k provides the following information to BS_N: $\mathbf{BID^{(1)}_k = \{BS\_CT^{(1)}_k, x_k, T_{Start\ k}, T_{End\ k}\}}$ where:
  - $\mathbf{BS\_CT^{(1)}_k}$ is the amount of bided credit tokens per time unit proposed by BS_k for the first iteration,
  - x_k is the fraction of $T_{Renting}$ for which bid $\mathbf{BS\_CT^{(1)}_k}$ applies for,
  - $[T_{Start\ k}, T_{End\ k}]$ is the time interval for which bid $\mathbf{BS\_CT^{(1)}_k}$ applies for. $[\mathbf{T_{Start\ k}}, \mathbf{T_{End\ k}}] \subset [\mathbf{T_{Start}}, \mathbf{T_{End}}]$.
- In sequence (5), BS_N performs the following action:
  - Given the set of intervals $\{[\mathbf{T_{Start\ k}}, \mathbf{T_{End\ k}}]\}$ received from different bidders $\{\mathbf{id^{(1)}_k}\}$, BS_N partitions $\{[\mathbf{T_{Start}}, \mathbf{T_{End}}]\}$ into contiguous time segments $\{\mathbf{TS_m}\}$. Each $\mathbf{TS_m}$ corresponds to a time window (integer number of $\mathbf{T_{Frame}}$) in which a subset of intervals of $\{[\mathbf{T_{Start\ k}}, \mathbf{T_{End\ k}}]\}$ overlap.
  - The different bidders $\{\mathbf{id^{(1)}_k}\}$ assigned to a given $\mathbf{TS_m}$ are identified by $\{\mathbf{id^{(1)}_{k,m}}\}$. $\{\mathbf{id^{(1)}_{k,m}}\}$ compete for each $\mathbf{TS_m}$. Each involved bidder $\mathbf{id^{(1)}_{k,m}}$ competes with his respective $\mathbf{BID^{(1)}_k}$.
  - Then, for each $\mathbf{TS_m}$, the master BS_N calculates the payoff $\mathbf{P^{(1)}_k} = \mathbf{BS\_CT^{(1)}_k} * \mathbf{x_k} * \mathbf{T_{Renting}} * \mathbf{N_{Frame\ m}}$ for each bidder k, and searches the subset ($\{\mathbf{id^{(1)}_{k,m}}\}_{selected}$) of $\{\mathbf{id^{(1)}_{k,m}}\}$ such as $sum(\mathbf{x_k}) = \mathbf{1}$ and $sum(\mathbf{P^{(1)}_k})$ is maximal. $\mathbf{N_{Frame\ m}}$ is the number of frames within $\mathbf{TS_m}$ ($\mathbf{N_{Frame\ m} = TS_m/T_{Frame}}$).
  - For each $\mathbf{TS_m}$, BS_N informs all $\{\mathbf{id^{(1)}_{k,m}}\}$ about $\mathbf{P^{min,(1)}_m}$ and $\mathbf{P^{max,(1)}_m}$ where $\mathbf{P^{min,(1)}_m}$ is the minimal payoff from $\{\mathbf{id^{(1)}_{k,m}}\}_{selected}$ and $\mathbf{P^{max,(1)}_m}$ is the maximal payoff from $\{\mathbf{id^{(1)}_{k,m}}\}_{selected}$ during the first iteration. With this approach, each BS_k is directly informed whether it has been selected or not, and has some information on how far it is from $\mathbf{P^{min,(1)}_m}$ while still having some information on $\mathbf{P^{max,(1)}_m}$. This approach enables to keep the privacy of competing $\{\mathbf{id^{(1)}_{k,m}}\}$ on $\mathbf{TS_m}$.

$\mathbf{n^{th}}$ iteration of the credit tokens based auctioning/bidding phase

This phase is composed of 2 sequences as follows:

- In sequence (6):
  - If $\mathbf{P^{(1)}_k} < \mathbf{P^{min,(1)}_m}$, this means that BS_k has not been selected for being granted the resources he has bided for during the first iteration $n = 1$. More generally speaking, for $n>1$, if $\mathbf{P^{(n-1)}_k} < \mathbf{P^{min,(n-1)}_m}$, this means that BS_k has not been selected for being granted the resources he has bided for during the $(n-1)^{th}$ iteration.
  - If $\mathbf{P^{(n-1)}_k} < \mathbf{P^{min,(n-1)}_m}$ and if BS_k is still interest to be allocated with the additional resources he initially requested for, it can propose a new $\mathbf{BS\_CT^{(n)}_k}$ for the n^{th} iteration. Then, BS_k computes the new $\mathbf{P^{(n)}_k} = \mathbf{BS\_CT^{(n)}_k} * \mathbf{x_k} * \mathbf{T_{Renting}} * \mathbf{N_{Frame\ m}}$ where $\mathbf{x_k}, \mathbf{T_{Renting}}$ and $\mathbf{N_{Frame\ m}}$ are fixed for all n on $\mathbf{TS_m}$.
  - If $\mathbf{P^{(n)}_k} > \mathbf{P^{(n-1)}_k}$ and $\mathbf{P^{(n)}_k} > \mathbf{P^{min,(n-1)}_m}$, BS_k expresses its interest to keep on participating in the bidding with the new bid $\mathbf{P^{(n)}_k}$. In that case, it informs BS_N with its new (update) value of $\mathbf{BS\_CT^{(n)}_k}$. In case $\mathbf{P^{(n)}_k} = \mathbf{P^{(n-1)}_k}$ or $\mathbf{P^{(n)}_k} < \mathbf{P^{min,(n-1)}_m}$, BS_k leaves the bidding phase and will not be granted with the additional resources he asked for.
- In sequence (7), BS_N updates $\{\mathbf{id^{(n-1)}_{k,m}}\}$ into $\{\mathbf{id^{(n)}_{k,m}}\}$. Based on the new received biddings $\{\mathbf{BS\_CT^{(n)}_k}\}$ for each $\mathbf{TS_m}$, the master BS_N calculates the new payoff $\mathbf{P^{(n)}_k} = \mathbf{BS\_CT^{(n)}_k} * \mathbf{x_k} * \mathbf{T_{Renting}} * \mathbf{N_{Frame\ m}}$ for each bidder k who still participates to the bidding. Then, for each $\mathbf{TS_m}$,

BS_N searches the subset ($\{\mathbf{id^{(n)}_{k,m}}\}_{selected}$) of $\{\mathbf{id^{(n)}_{k,m}}\}$ such as sum($\mathbf{x_k}$) = **1** and sum($\mathbf{P^{(n)}_k}$) is maximal. Next, BS_N performs the same actions as in sequence (5): for each $\mathbf{TS_m}$, BS_N informs all $\{\mathbf{id^{(n)}_{k,m}}\}$ about $\mathbf{P^{min,\,(n)}_{\ m}}$ and $\mathbf{P^{max,\,(n)}_{\ m}}$ where $\mathbf{P^{min,\,(n)}_{\ m}}$ is the minimal payoff from $\{\mathbf{id^{(n)}_{k,m}}\}_{selected}$ and $\mathbf{P^{max,\,(n)}_{\ m}}$ is the maximal payoff from $\{\mathbf{id^{(n)}_{k,m}}\}_{selected}$ during the n^{th} iteration.

Final pricing and credit tokens transaction phase

This phase is composed of two sequences as follows:

- In sequence (8):
  - As long as $\mathbf{T_{End\ Bidding}}$ - $\mathbf{T_{Start\ Bidding}}$ > 0 (i.e. the bidding phase duration has not yet elapsed), n is increased and the credit tokens based bidding phase mechanisms of the previous paragraph "***n***" are applied.
  - When $\mathbf{T_{End\ Bidding}}$ - $\mathbf{T_{Start\ Bidding}}$ = 0, bidding phase is over. None BS_k can propose a new bid. $\{\mathbf{id^{(n\ final)}_{k,m}}\}_{selected}$ is derived. At this point, BS_N derives the clearing price auction $\mathbf{BS\_CPA_k}$ (expressed as a number of credit tokens per time unit) for each $\mathbf{TS_m}$ and each k from $\{\mathbf{id^{(n\ final)}_{k,m}}\}$. For each k and m, $\mathbf{BS\_CPA_k}$ can correspond to the $\mathbf{BS\_CT^{(final)}_k}$, or for example can follow another price auction method.
- In sequence (9), each BS_k is requested to pay $\mathbf{Pr_k} = \mathbf{BS\_CPA_k} * \mathbf{x_k} * \mathbf{T_{Renting}} * \mathbf{N_{Frame\ m}}$ to be allowed to use the resources it won on its corresponding $\mathbf{TS_m}$. Provided that $\mathbf{Pr_k}$ does not exceed the credit tokens account of BS_k, the token transaction between BS_N and each BS_k is performed.

Credit tokens based bandwidth granting phase

This phase is composed of the single sequence (10). During this phase, BS_N grants the resource to each BS_k who has successfully performed the credit transaction operation in sequence (9).

Resource usage phase

After BS_k has been granted with the resources, BS_k can use them during during $x_k * T_{Renting}$ time unit of NW_N and for $\mathbf{N_{Frame\ m}}$ frames from the beginning on its corresponding $\mathbf{TS_m}$.

15.7.2.2.6.4 Inter BSs communication

The credit tokens mechanisms (section 15.7.2.2.6.3) require inter BSs communication between different NWs. This inter BS communications is necessary to exchange the parameters related to the credit tokens based scheduling cycle.

The primitive parameters include: T_{Start}, T_{end}, $T_{End\_Renting}$, $T_{Start\_Renting}$, $T_{Msf,}$ RPA, id_k, $BS\_CT^{(n)}_k$, x_k,, T_{Start_k}, T_{End_k}.

The derived parameters include: TS_m, $\{id^{(n)}_{\ k,m}\}_{selected}$, $P^{min,\,(n)}_{\ m}$, $P^{max,\,(n)}_{\ m}$.

These parameters are stored into the regional LE DB and into the local database of each LE BS of the shared distributed system architecture (section 15.2.2).

The information exchange about these parameters between these databases and the RADIUS/BSIS servers can be either supported by IP based wired or by secured over the air signallingcommunication between the BSs.

For the implementation of the credit tokens based co-existence protocol, these two methods for BS-BS communication are proposed.

IP based wired BS-BS communication method:

With this method; the IP based wired communications between BSs can be supported by the inter network messages defined in the shared distributed system architecture (section 15.2.2).

Over the air based BS-BS communication method:

The credit tokens based scheduling cycle requires signaling in both the downlink and uplink. Here:

- BS-BS downlink (DL BS-BS) stands for the communication from the master BS towards one or several slave BS(s).
- BS-BS uplink (UL BS-BS) stands for the communication from the slave BS towards one master BS.

With respect to this terminology, the UL BS-BS signaling is dedicated to the following sequences of the credit tokens based scheduling cycle:

- Awareness/Advertising (sequence 1),
- Inform bidding phase (sequence 3),
- n^{th} ($n \geq 1$) bidding results (sequence 5 & 7),
- Final bidding results/pricing (sequence 8),
- BW granting (sequence 10).

With respect to this terminology, the DL BS-BS signaling is dedicated to the following sequences of the credit tokens based scheduling cycle:

- Express BSk interest (sequence 2),
- Express initial BSk bidding (sequence 4),
- Express new nth (n >1) BSk bidding (sequence 6),
- Transaction (sequence 9).

15.7.2.2.7 Legitimate Request for Bandwidth and Transmission Time

An IEEE 802.16h network that is a member of a community of networks granted access to shared spectrum resources only if it forms an actual network comprised of at least one base station and one subscriber station and supports a bi-directional link.

15.7.2.2.8 Coverage Area

15.7.2.2.9 Direction of Coverage Area

15.7.2.2.10 Bandwidth Utilization

Annexes

Annex A

(informative)

Mechanism of security in coexistence –reference

A.1 General Principal

The access to Data Bases is secured by authentication and possibly encryption

[Note: the security part is a temporary text adopted from contribution C802.16h-05/11r1 and 802.16h is calling for comments]

Figure h A1 shows the IEEE 802.16 LE inter-network communication architecture:

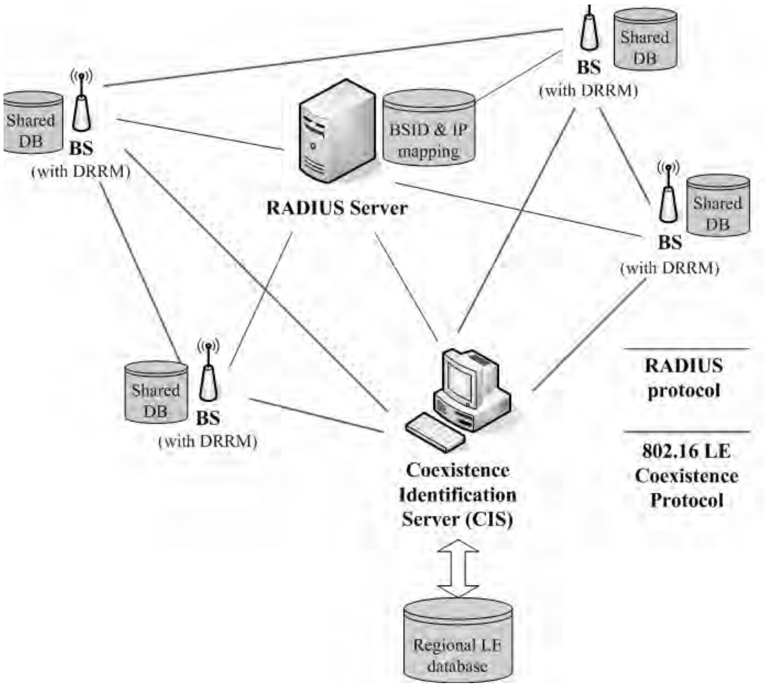


Figure h-A1—Network Architecture

General architecture includes the components operating over IP-based network:

- The RADIUS Server- The Base Station Identification Server (BSIS), described in detail in section xxx - The BSs cooperating with the Distributed Radio Resource Management (DRRM) procedureRADIUS server performs two primary functions. The first one is to authenticate 802.16 LE BSs and BSIS. Keyed-Hashing for Message Authentication (HMAC) with Message Digest 5 (MD5) (RFC2869:2000) is adopted for authentication. The second one is to maintain the address mapping of wireless medium addresses of BSs (their BSID) and medium addresses of BSIS to their IP addresses. This mapping is to distribute the keys for ESP used by BSs belonging to different networks.

BSIS maintains the geographic and operational information such as latitude, longitude and the BSID of LE BSs within certain management domain. BSs operating under LE system shall first query the foreign BSISs which are geographically close to the local BSIS and find the coexistence neighbor BSs while starting up, following the Coexistenceprotocol (detailed description in section 15.2.2.3). After the successful query procedure, the BS can obtain the BSIDs of the coexistence neighbor BSs. Intercommunication between BSs belonging to different networks is permitted after the BS acquires coexisting neighbor's Pairwise Masterkey. and PMK-index for ESP.

Considering the IP network firewalls and different filtering rules, we should find a common security solution to make BSs/BSISs data connection transparent under almost common network management cases. IPSec is used to IPv4 and also included in IPv6 for the IP-Layer security solution. And all BSs/BSISs don't just reside in the same network environment. The data connections should go through some routers/firewalls and need to follow a common security rules.

Figure h A2 shows the BSs/BSISs connections encrypted in IPSec. Based on IPSec, all data connections between BSs/BSISs could pass through firewalls and routers unless some firewalls block IPSec connections.

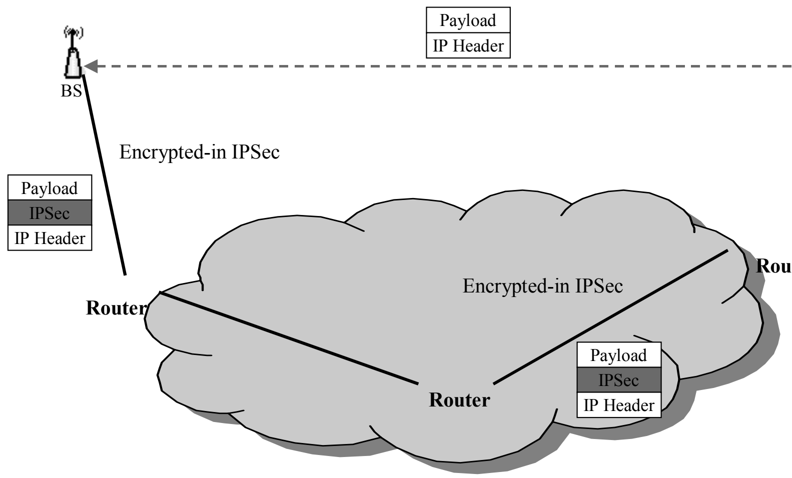


Figure h-A2—BSs/BSISs connection encrypted in IPSec

Figure h A2 demonstrates the IEEE 802.16 LE inter-network communication architecture under multi-Operators with multi-RADIUS Servers.

If BS-1 wants to communicate with BS-2, it must get BS-2's Country's Code, Operator ID and BSID from local BSIS first. And then work as the following steps

(1) BS-1 send RADIUS-Access-Request frame with BS-2's Country's Code, Operator ID and BSID to local RADIUS-Server

(2) Local RADIUS-Server will act as RADIUS-Proxy and transfer this RADIUS-Access-Request to the target RADIUS-Server

(3) Target RADIUS-Server will response RADIUS-Access-Accept with Pairwise-Master-Key and PMK-index for BS-1 and Security-Block for BS-2

(4) Local RADIUS-Server will generate Security-Block including Pairwise-Master-Key and PMK-index from target Raidus-Server

(5) BS-1 will receive RADIUS-Access-Accept from its local RADIUS-Server and get the Pairwise-Master-Key PMK-index and ESP Authentication/Transform IDs in Security-Block for BS-1

(6) BS-1 will act as a PKM-initiator to send Session-Key-Start to BS-2 with Security-Block for BS-2

(7) BS-2 will calculate the ESP-Key-Stuffs with Pairwise-Master-Key, choose the ESP Authentication/ Transform IDs supported by BS-2 and response Session-Key-Request to BS-1

(8) BS-1 will also calculate the ESP-Key-Stuffs with Pairwise-Master-Key to verify Key-Signature, compare ESP Authentication/Transform IDs support by BS-2 with current settings supported by BS-1 and response Session-Key-Response to BS-2

(9) BS-2 will verify Key-Signature and response Session-Key-Accept to BS-1

(10) After the above procedures, BS-1 and BS-2 could communicate in IPSec with the ESP-Key-Stuffs generated dynamically

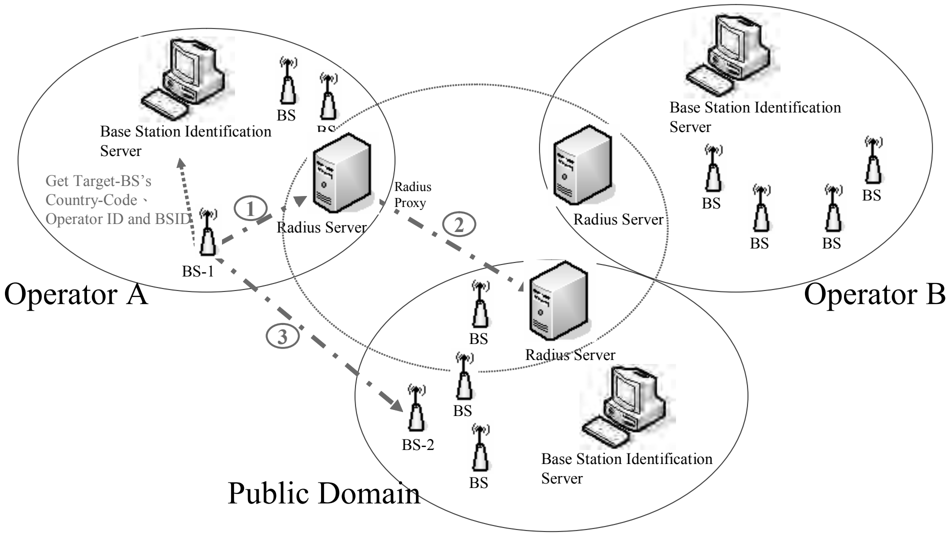

Base Station Identification Server
BS
BS
Get Target-BS's Country-Code、Operator ID and BSID
①
Radius Server
Radius Proxy
②
BS-1
Operator A
③
Base Station Identification Server
Radius Server
BS
BS
BS
BS
Operator B
BS
Radius Server
BS
BS-2
Base Station Identification Server
BS
Public Domain

Figure h-A3—Network Architecture under multi-Operators with multi-RADIUS Servers

The following figure shows the each connection of BSs/BSISs will be encrypted in individual Session-Key in IPsec

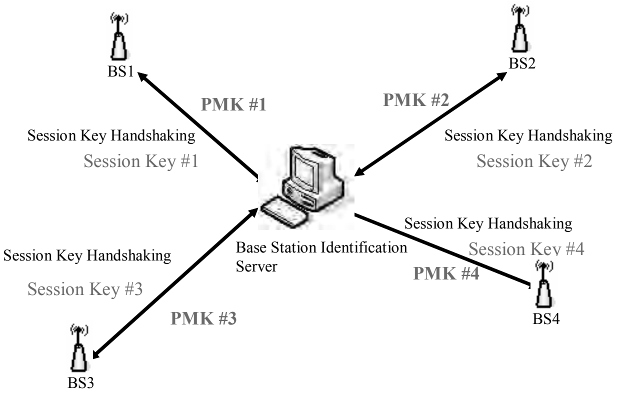


Figure h-A4—Individual Session-Key

For the BSs/BSISs, each connection with different BSs/BSISs will use individual Session-Key in IPsec. Those Session Keys would be generated from PKM-Handshaking with Pairwise-Master-Keys between each pair BSs/BSISs. The re-key procedures also don't need RADIUS-Servers and just use Pairwise-Master-Keys.

A.2 Coexistence Protocol

[Note: the security part is a temporary text adopted from contribution C802.16h-05/11r1 and is subject to further discussion.]

In order to get the coexistence neighbor topology, perform registration to the database and registration to peer, negotiation for Shared RRM etc. will be used a Coexistence Protocol (CP). Figure h A5 describes the 802.16h protocol architecture. The protocol architecture indicates that DRRM, Coexistence Protocol and Shared DB belong to LE Management Part located in management plane and the messages will be exchanged over IP network. Thus, DRRM in LE Management Part uses the Coexistence protocol to communicate with other BSs and with Regional LE DB and interact with MAC or PHY. Figure h A5 is LE BS architecture with Coexistence Protocol. The gray area indicates area where there is an absence of connection between blocks. DSM is Distribution System Medium which is another interface to the backbone network. Note that is architecture is only for reference. Similarly, Figure h A5 is the BSIS architecture with co-located regional LE database. Other architectures are not being illustrated. The Coexistence Protocol services are accessed by the LE Management Entity through CP SAP. The service primitives are described in t.b.d A BS uses the Coexistence Protocol, which is similar to PKM protocol, to perform the coexistence resolution and negotiation procedures. There are two types of messages to support Coexistence Protocol:

(1) CP-REQ: BS->BS or BS->BSIS

(2) CP-RSP: BS->BS or BSIS->BS

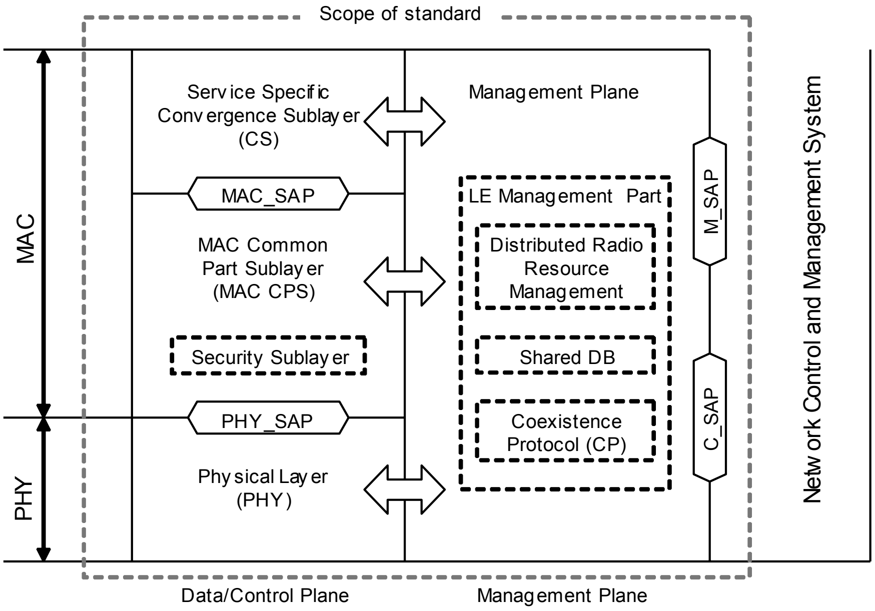

Scope of standard
Service Specific Convergence Sublayer (CS)
Management Plane
MAC_SAP
LE Management Part
MAC Common Part Sublayer (MAC CPS)
Distributed Radio Resource Management
Security Sublayer
Shared DB
PHY_SAP
Coexistence Protocol (CP)
Physical Layer (PHY)
MAC
PHY
M_SAP
C_SAP
Network Control and Management System
Data/Control Plane
Management Plane

Figure h-A5—802.16h BS Protocol architecture Model

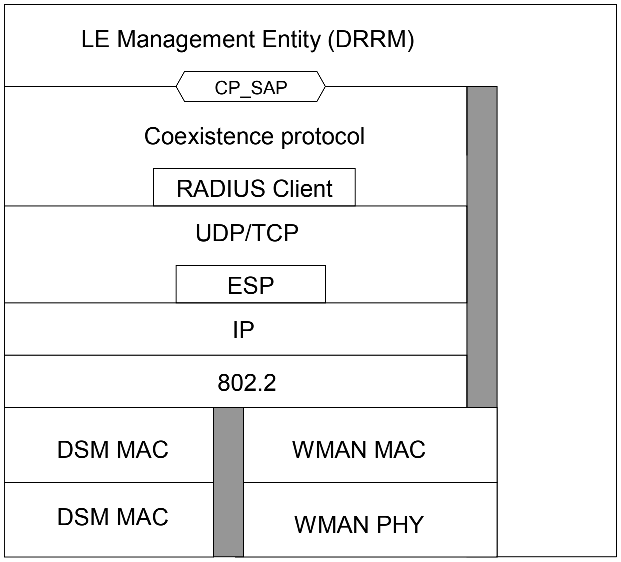


Figure h-A6—LE BS architecture with Coexistence Protocol

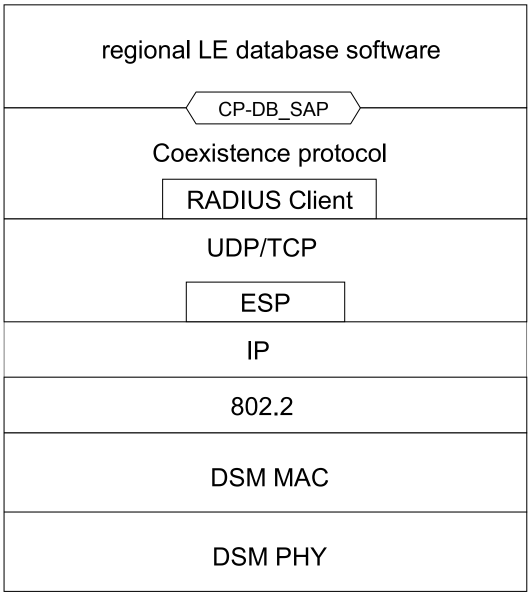


Figure h-A7—BSIS architecture with co-located regional LE database

To use the Coexistence Protocol, which is similar to PKM protocol, to perform the coexistence resolution and negotiation procedures a BS sends a CP-REQ to another BS or BSIS and waits for the CP-RSP.

Before any data can be exchanged between BS and BS/BSIS, security association must be setup first. IEEE 802.16 LE security associations between peers are established through RADIUS server. Any BS wants to communicate with another BS or BSIS shall first send a *RADIUS Access-Request* to request the establishment of the security association between originated BS and terminated BS/BSIS. RADIUS server replies a *RADIUS Access-Accept*, which includes security information for ESP operation, to the BS. At this point, only *virtual* security association is established between the peers. The BS sends the Security Block for the peer, which it received from the RADIUS Server, as a CP-REQ packet with message type *Send-Security-Block*. This is the first message in the Coexistence Protocol TCP exchange between the BS and BS or BS and BSIS. The peer returns CP-RSP packet with message type *Send-Security-Block*. At this point both sides have the information to encrypt all further packets for this exchange between the BS and BS or BS and BSIS.

The UDP port number assigned by IANA to be opened for the CP for transmission and reception of CP packets is *xxxx*.

The TCP port number assigned by IANA to be opened for the CP for transmission and reception of CP packets is xxxx.

A.3 Base Station Identification Server

[Note: The following part from 3.2.4.1 is a temporary text adopted from contribution C802.16h-05/11r1 and is subject to further discussion. A call for comment from security experts is open to comment on this text.]

The *Base Station Identification Server* (BSIS) acts as an interface between 802.16 LE BSs and the regional LE DB which stores the geographic and important operational information, e.g. latitude, longitude, BSID etc., of the LE BSs belonging to the same region. It converts the actions carried in PDUs received from the 802.16 LE BSs to the proper formats, e.g. SQL (Structured Query Language) string, and forwards the strings to the regional LE DB, which can be any available database software. BSIS converts the query results from the regional LE DB to the proper format, e.g. TLV encodings, and replies to the requested BSs. Figure h A7 shows the general architecture of inter-network communication across 802.16 LE systems. In this architecture, the 802.16 LE systems (BSs and BSIS) from different networks set up security association (including BS and BS, BSIS and BSIS) with each other by utilizing the services provided by the RADIUS server. BSIS acts as a peer of 802.16 LE BSs in this architecture. The BSID of regional BSIS is well known among the 802.16 LE systems within certain domain.In summary, ESP with RADIUS can discover a Rogue BS or BSIS. The messages exchanged between the LE BSs and the BSIS will be revealed in the next section. Note that the interface between BSIS and regional LE DB is out of scope.

A.4 RADIUS Protocol Usage

For future interoperability consideration, similar mechanisms are maintained. Secure exchange of 802.16 LE signaling information can be achieved after successful procedures of the RADIUS protocol. To include RADIUS support, the RADIUS server and the BS/BSIS RADIUS client must be configured with the shared secret key and with each other’s IP address. Each BS/BSIS acts as a RADIUS client and has its own shared secret key with the RADIUS server. The shared secret key may be different from that of any other BS/BSIS.

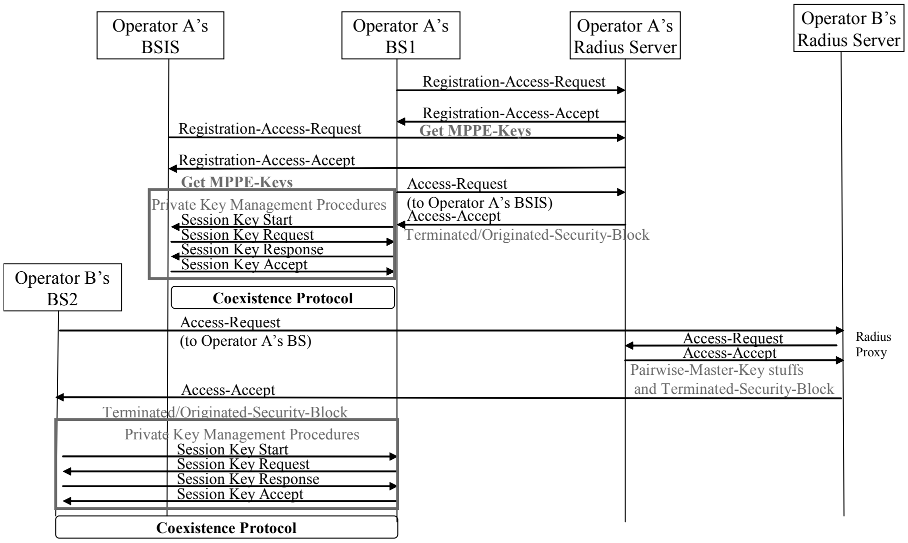


Figure h-A8—RADIUS protocol example

Figure h A8 shows the RADIUS protocol message exchange sequence. At starting up, each BS or BSIS must send a RADIUS-BS/BSIS-Registration-Access-Request (shown in Table h A1) to the RADIUS server for authentication purpose and leave the address mapping (BSID to IP) information in the server. At this time, the RADIUS server will retain the following information of registered BS or BSIS:

a) Wireless medium address of BS (BSID) or medium address of BSIS,

b) MPPE-Keys in RADIUS-BS/BSIS-Registration-Access-Request/Accept Procedures

c) IP address or DNS name,

d) Cipher suites supported by the BS or BSIS for the protection of Coexistence Protocol communications,

e) and Pairwise-Master-Key for BS or BSIS to establish Session-Key-Handshaking procedures

Same as [2], Microsoft Point-to-Point Encryption (MPPE) (RFC 2548:1999) key is introduced. The MS-MPPE-Send-Key, which could be got in the RADIUS-BS/BSIS-Registration-Access-Accept message (shown in Table h A1) and RADIUS-BS/BSIS-Access-Accept message (shown in Table h A1), is used for encrypting the security blocks in the RADIUS-BS/BSIS-Access-accept message for PKM-target and PKM-initiator. A registration access reject message may be issued due to a BS not supporting the ESP Transform or ESP Authentication algorithm selected for use in securing the following intercommunication, or for other RADIUS configuration reasons not discussed here.

Once a BS wants to get the knowledge of coexistence neighbor topology, it must first send RADIUS-BS/BSIS-Access-Request message (shown in Table h A1) to the RADIUS server in order to acquire the regional BSIS's IP address. The wireless medium addresses of regional BSIS, similar to BSID, well known by all BSs supporting LE operation, is sent in the RADIUS-BS/BSIS-Access-Request message to the RADIUS server for looking up IP address of the BSIS. Upon receiving the request message, the RADIUS server will respond with a RADIUS-BS/BSIS-Access-Accept message (shown in Table h A1) if the BS is a valid member which is allowed to perform inter-communication. The RADIUS-BS/BSIS-Access-Accept message would contain Originated-BS-Security-Block(for BS encrypted in MPPE-Send-Key from current RADIUS-BS/BSIS-Access-Request/Accept message) and Terminated-BS/BSIS-Security-Block(for BSIS encrypted in MPPE-Send-Key from BSIS's RADIUS-BS/BSIS-Registration-Access-Request/Accept message). Security-Block (shown in Table h A1) contains Pairwise Master Key IndexPairwise-Master-KEYKey Lifetime-the list of ESP Authentication/Transform IDs for initiator-send/receive for establishing a secure connection with the BSIS .

After querying process between the BS and the regional BSIS in Coexistence Protocol, the BSIS will respond to the BS with possible coexistence neighbor BSs candidates and their BSIDs. The BS, then, tries to establish secure connections with the coexistence neighbor BSs after evaluating the coexistence relationships with these candidates. The BS sends RADIUS-BS/BSIS-Access-Request message to local RADIUS server for Originated/Terminated-BS/BSIS-Security-Blocks. After getting Security-Blocks from RADIUS-BS/BSIS-Access-Accept messages, the BS establishes secure connections with each evaluated coexistence neighbor BS.

An access reject message may be issued due to a BS or the regional BSIS not supporting the ESP Transform or ESP Authentication algorithm selected for the following intercommunication, or for other RADIUS configuration reasons not discussed here.

Table h-A1—Security Block Format

Element ID	Length	Information
1	1	Pairwise Master Key Index for BS/BSIS (0-255)
2	32	Pairwise-Master-KEY
3	4 * number	The list of ESP Authentication IDs corresponding to the ESP Authentication algorithms for initiator-send

4	4 * number	The list of ESP Transform IDs corresponding to the ESP transforms for initiator-send
5	4 * number	The list of ESP Authentication IDs corresponding to the ESP Authentication algorithms for initiator-receive
6	4 * number	The list of ESP Transform IDs corresponding to the ESP transforms for initiator-receive
7	4	Pairwise-Master-KEY Lifetime

The Security-Block would be encrypted in 32-bytes MPPE-Send-Key with the following manner ('+' indicates concatenation):

b(1) = MD5(MPPE-Send-Key+BSID) c(1) = p(1) xor b(1) C = c(1)

b(2) = MD5(MPPE-Send-Key+BSID + c(1)) c(2) = p(2) xor b(2) C = C + c(2)

. .

. .

. .

b(i) = MD5(MPPE-Send-Key+BSID + c(i-1)) c(i) = p(i) xor b(i) C = C + c(i)

Break plain text into 16 octet chunks p(1), p(2)...p(i), where i = len(P)/16. Call the ciphertext blocks c(1), c(2)...c(i) and the final ciphertext C. Intermediate values b(1), b(2)...c(i) are required. The resulting encrypted String field will contain c(1)+c(2)+...+c(i).

For Originated Security Block, the encrypted MPPE-Send-Key is from “RADIUS-Access-Request/Accept”.For Terminated Security Block, the encrypted MPPE-Send-Key is from “RADIUS-Registration-Access-Request/Accept”.

A.5 Privacy Key Management protocol usage

The PKM protocol would provide a flexible and easy-to-maintain key exchange mechanism. The PKM is based on the Pairwise-Master-Key to provide a symmetric key for the PKM-Initiator and PKM-Target side.

The following figure shows the PKM Session-Key-Handshaking procedures

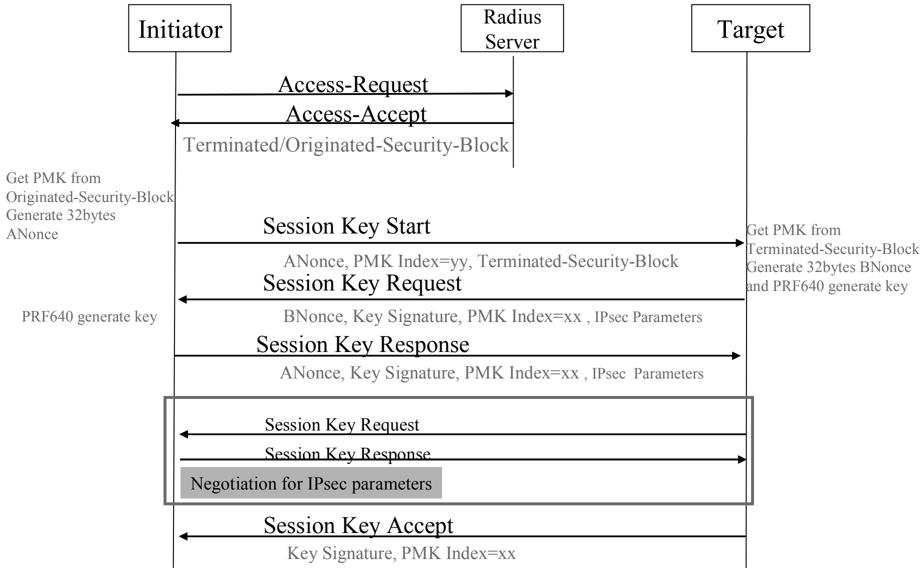

Initiator
Radius Server
Target
Access-Request
Access-Accept
Terminated/Originated-Security-Block
Get PMK from Originated-Security-Block Generate 32bytes ANonce
Session Key Start
ANonce, PMK Index=yy, Terminated-Security-Block
Get PMK from Terminated-Security-Block Generate 32bytes BNonce and PRF640 generate key
Session Key Request
PRF640 generate key
BNonce, Key Signature, PMK Index=xx , IPsec Parameters
Session Key Response
ANonce, Key Signature, PMK Index=xx , IPsec Parameters
Session Key Request
Session Key Response
Negotiation for IPsec parameters
Session Key Accept
Key Signature, PMK Index=xx

Figure h-A9—Figure 5 PKM Session-Key-Handshaking procedures

The PKM-Initiator will need to get the Pairwise-Master Key in Originated-BS-Security-Block from RADIUS-Server. And then perform the following steps

1) PKM-Initiator would get Pairwise-Master-Key-IndexPairwise -Master-KeyESP Authentication/Transform IDs and Key-Lifetime in originated Security-Block in RADIUS-BS/BSIS-Access-Accept message and then generate a random 32-bytes ANonce.
2) PKM-Initiator would will send Session-Key-Start message to PKM-Target with “ANonce””Pairwise-Master-Key-Index” and “Terminated Security-Block”.
3) After receiving Session-Key-Start message, PKM-Target would generate a random 32-bytes BNonce. And perform the PRF640 algorithm to generate the 640-bits Key. Keep the first 512-bits ESP-Transform/Authentication Keys and use the last 128-bits M-Key as the HMAC-MD5 key to generate 16-bytes Key-Signature.
4) PKM-Target would will send Session-Key-Request message to PKM-Initiator with “BNonce””Pairwise-Master-Key-Index” and ” ESP Authentication/Transform IDs”(PKM-Target chosen).
5) After receiving Session-Key-Request message, PKM-Initiator would perform the PRF640 algorithm to generate the 640-bits Key. Keep the first 512-bits ESP-Transform/Authentication Keys and use the last 128-bits M-Key as the HMAC-MD5 key to generate 16-bytes Key-Signature to verify the Key-Signature field on the Session-Key-Request message. If it is wrong, PKM-Initiator would perform silent-drop and doesn’t response any message. If it is correct, PKM-Initiator would prepare the Session-Key-Response message and use HMAC-MD5 generate Key-Signature filed.
6) PKM-Initiator would will send Session-Key-Response message to PKM-Target with “ANonce””Pairwise-Master-Key-Index” and ” ESP Authentication/Transform IDs”(PKM-Initiator chosen) .
7) After receiving Session-Key- Response message, PKM-Target would check the ANonce value if equal to the previous ANonce value in Session-Key-Start message and use HMAC-MD5

generate Key-Signature filed to verify the Key-Signature field. Compare the values of ”ESP Authentication/Transform IDs” to make sure the security parameters.

8) After the above, PKM-Target will send Session-Key-Accept with Key-Signature filed to PKM-Initiator to verify.

9) The following IPsec connection will use the first 512-bits ESP-Transform/Authentication Keys from PRF640 as keys and perform the ESP-Transform/Authentication algorithms from chosen ESP Authentication/Transform IDs.

The following figure shows the PKM Session-Key Re-Key procedures

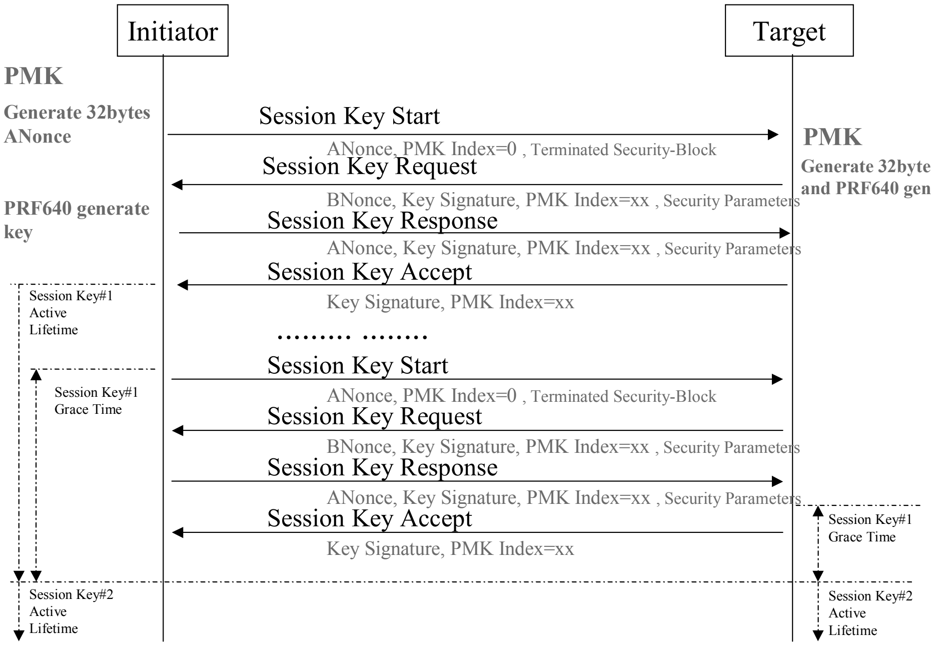

Initiator
Target
PMK
Generate 32bytes ANonce
Session Key Start
ANonce, PMK Index=0 , Terminated Security-Block
PMK
Generate 32bytes BNonce and PRF640 generate key
Session Key Request
BNonce, Key Signature, PMK Index=xx , Security Parameters
PRF640 generate key
Session Key Response
ANonce, Key Signature, PMK Index=xx , Security Parameters
Session Key Accept
Key Signature, PMK Index=xx
Session Key#1 Active Lifetime
……… ……..
Session Key Start
ANonce, PMK Index=0 , Terminated Security-Block
Session Key#1 Grace Time
Session Key Request
BNonce, Key Signature, PMK Index=xx , Security Parameters
Session Key Response
ANonce, Key Signature, PMK Index=xx , Security Parameters
Session Key Accept
Key Signature, PMK Index=xx
Session Key#1 Grace Time
Session Key#2 Active Lifetime
Session Key#2 Active Lifetime

Figure h-A10—Figure 6 PKM Session-Key Re-Key procedures

Each Session-Key would set a Key-Lifetime, and PKM-Initiator could set a Session-Key grace time to perform Session-Key-Handshaking for the next new Session-Key#2 to be generated until the end of the key lifetime. The Session-Key#1 could use up its lifetime and then activate the Session-Key#2. If each side use the Session-Key#2 first in IPsec connection, it could also activate the Session-Key#2. If the lifetime of Session-Key#1 use up, the PKM-Initiator doesn’t perform the Session-Key Re-Key procedures. PKM-Target would disconnect the IP connection until the Session-Key#2 generated.

The following figure shows the PKM Session-Key Re-Key procedures with the PMK update

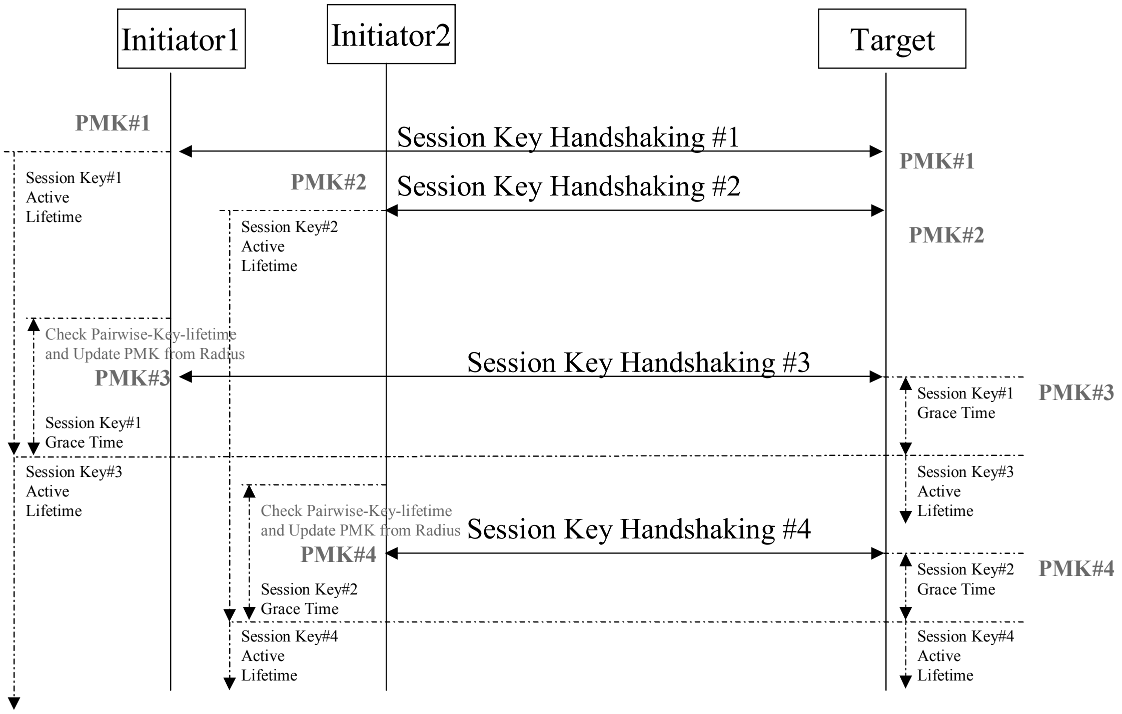


Figure h-A11—PKM Session-Key Re-Key procedures with the MK update of PKM-Target

The PKM-Initiator will check the current Pairwise-Key-Lifetime if still valid. If the PKM-Initiator detects the Pairwise-Key-Lifetime used up, it would perform RADIUS-BS/BSIS- Access-Request/Accept procedures to get the latest Pairwise-Master-Key in Security-Blocks from RADIUS-Server.

Each Pairwise-Master-Key would set a Pairwise-Master-Key-Lifetime, and BSs/BSISs could set a Pairwise-Master-Key grace time to perform Access-Request/Accept procedures for the new Pairwise-Master-Key until the end of the Pairwise-Master-Key lifetime. If the lifetime of Pairwise-Master-Key use up, the originated BSs/BSISs don’t perform the Access-Request/Accept procedures, the terminated BSs/BSISs should discard the connections.

The following figure shows the 640-bits Key generated by PRF640

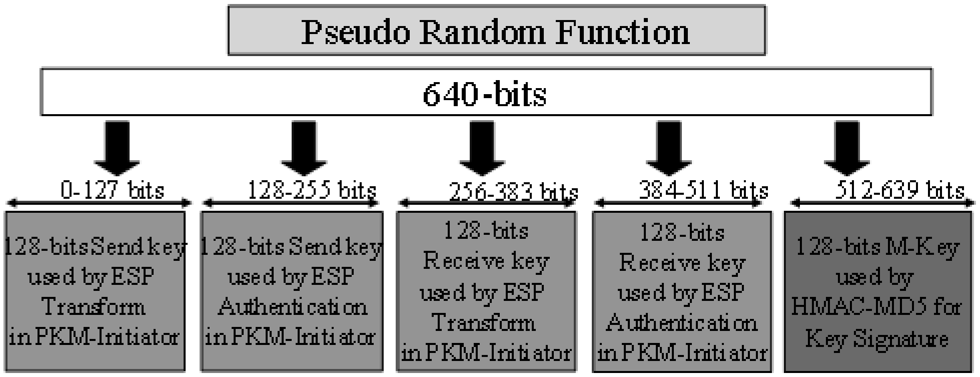

Pseudo Random Function
640-bits
0-127 bits
128-255 bits
256-383 bits
384-511 bits
512-639 bits
128-bits Send key used by ESP Transform in PKM-Initiator
128-bits Send key used by ESP Authentication in PKM-Initiator
128-bits Receive key used by ESP Transform in PKM-Initiator
128-bits Receive key used by ESP Authentication in PKM-Initiator
128-bits M-Key used by HMAC-MD5 for Key Signature

Figure h-A12—the 640-bits Key generated by PRF640

The BSs/BSISs get Pairwise-Master-Key from RADIUS-Servers and generate 32-bytes Nonce value to derive 640-bits key as follows

PRF-640(PMK, "BS-BSIS key expansion", Min(BS1ID,BS2ID) || Max (BS1ID,BS2ID)||
Min(ANonce,BNonce) || Max(ANonce,BNonce))

Where

```
PRF-640 (K,A,B) =
        for i=0 to 4 do
                R=R|HMAC-SHA-1(K, A|0|B|I)

        return LeastSignificant-640-bits( R )
and "|" denotes bitstring concatenation
```

A.6 Security consideration

In this model, data traffic is protected by using IPsec.

The IP Security Protocol provides cryptographically based security for IPv4. The protection offered by IPsec is achieved by using one or both of the data protection protocols (AH and ESP). Data protection requirements are defined in the Security Policy Database (SPD). IPsec assumes use of version 2 of the Internet Key Exchange protocol , but a key and security association (SA) management system with comparable features can be used instead.

A.7 RADIUS Protocol Messages

The following messages are listed to support RADIUS protocol:

Note that[tbd.] means To Be Defined.

- *RADIUS-*BS*/BSIS-Registration-Request (BS/BSIS* RADIUS *server): A startup BS/BSIS sends this message for authentication purpose.*

Table h-A2—RADIUS-BS/BSIS-Registration-Access-Request

Attribute number	**Attribute name**	**Value**
1	User-Name	BSID. The BSID should be represented in ASCII format, with octet values separated by a “-“. Example: “00-10-A4-23-19-C0”.
4	NAS-IP-Address	BS’s IP Address
6	Service-Type	Coexistence-Protocol-Register (value =[tbd.], ex. IAPP-Register, value = 15)
26	Vendor-Specific-Attribute (VSA)	
26-TBD	Supported-ESP-Authentication-Algorithms	The list of ESP Authentication IDs corresponding to the ESP Authentication algorithms supported by this BS (See Table h A7)
26-TBD	Supported-ESP-Transforms	The list of ESP Transform IDs corresponding to the ESP transforms supported by this BS (See Table h A6
32	NAS-Identifier	BS’s NAS Identifier
80	Message-Authenticator	The RADIUS message’s authenticator

According to RFC 2865:2000, other RADIUS attributes may be included in the RADIUS-BS/BSIS-Registration-Access-Request packet in addition to the ones listed in Table h A3.

- RADIUS-*BS/BSIS-Registration-Accept (RADIUS server BS/BSIS): After RADIUS server verifies the valid membership, it will respond with this accept message.*

Table h-A3—RADIUS-BS/BSIS-Registration-Access-Accept

Attribute number	**Attribute name**	**Value**
1	User-Name	BSID.
6	Service-Type	Coexistence-Protocol -Register (value =[tbd.], ex. IAPP-Register, value = 15)
26	Vendor-Specific-Attribute (VSA)	
26-TBD	Supported-ESP-Authentication-Algorithms	The list of ESP Authentication IDs corresponding to the ESP Authentication algorithms approved by Radius Server
26-TBD	Supported-ESP-Transforms	The list of ESP Transform IDs corresponding to the ESP transforms approved by Radius Server
27	Session-Timeout	Number of seconds until the BS should re-issue the registration Access-Request to the RADIUS server to obtain new key information.
80	Message-Authenticator	The RADIUS message’s authenticator

According to RFC 2865:2000, other RADIUS attributes may be included in the RADIUS-BS/BSIS-Registration-Access-Accept packet in addition to the ones listed in Table h A4.

- RADIUS-BS/BSIS-Access-Request (BS/BSIS RADIUS server): The BS sends this message to request for inter-communication with another coexistence neighbor BS or a regional BSIS.

Table h-A4—RADIUS-BS/BSIS- Access-Request

Attribute number	Attribute name	Value
1	User-Name	User-Name must include Country-CodeOperator ID and Regional BSIS's WM address or coexistence neighbor BS's BSID
4	NAS-IP-Address	Original BS's IP Address (the BS sending this request message)
6	Service-Type	CS/CIS-Check (value =[tbd.], ex. IAPP-AP-Check, value = 16)
61	NAS-Port-Type	Wireless – Other (value = 18)
80	Message-Authenticator	The RADIUS message's authenticator

According to RFC 2865:2000, other RADIUS attributes may be included in the RADIUS-BS/BSIS-Access-Request packet in addition to the ones listed in Table h A5.

RADIUS-BS/BSIS-Access-Accept (RADIUS server BS/BSIS): After verifying that the coexistence neighbor BS is valid member, RADIUS server will respond with the security blocks necessary for establishing a secure connection between the coexistence neighbor BS and requesting BS or between BSIS and requesting BS.

Table h-A5—RADIUS-BS/BSIS- Access-Accept

Attribute number	Attribute name	Value
1	User-Name	User-Name must include Country-CodeOperator ID and Regional BSIS's WM address or coexistence neighbor BS's BSID
8	Framed-IP-Address	IP Address of Regional BSIS or coexistence neighbor BS.
26 26-TBD 26-TBD	Vendor-Specific-Attribute (VSA) Originated-BS-Security-Block Terminated-BS/BSIS-Security-Block	Security Block encrypted using originated BS's MPPE-SEND-KEY, to be decrypted and used by the original BS Security Block encrypted using coexistence neighbor BS's MPPE-SEND-KEY (or BSIS's), to be decrypted and used by the coexistence neighbor BS (or BSIS)
80	Message-Authenticator	The RADIUS message's authenticator

According to RFC 2865:2000, other RADIUS attributes may be included in the RADIUS-BS/BSIS-Access-Accept packet in addition to the ones listed in Table h A6.

Table h-A6—ESP Transform identifiers

Transform identifier	Value	Reference
RESERVED	0	[RFC2407]
ESP_DES_IV64	1	[RFC2407]
ESP_DES	2	[RFC2407]
ESP_3DES	3	[RFC2407]
ESP_RC5	4	[RFC2407]
ESP_IDEA	5	[RFC2407]
ESP_CAST	6	[RFC2407]
ESP_BLOWFISH	7	[RFC2407]
ESP_3IDEA	8	[RFC2407]
ESP_DES_IV32	9	[RFC2407]

ESP_RC4	10	[RFC2407]
ESP_NULL	11	[RFC2407]
ESP_AES-CBC	12	[RFC3602]
Reserved for privacy use	249-255	[RFC2407]

Table h-A7—ESP Authentication algorithm identifiers

Transform identifier	Value	Reference
RESERVED	0	[RFC2407]
HMAC-MD5	1	[RFC2407]
HMAC-SHA	2	[RFC2407]
DES-MAC	3	[RFC2407]
KPDK	4	[RFC2407]
HMAC-SHA2-256	5	[Leech]
HMAC-SHA2-384	6	[Leech]
HMAC-SHA2-512	7	[Leech]
HMAC-RIPEMD	8	[RFC2857]
RESERVED	9-61439	
Reserved for privacy use	61440-65535	

A.8 Privacy Key Management protocol messages

The PKM protocol procedures contain 4 message actions, and each-side could check the code value of the begin of PKM message to recognize which *action need to perform this moment. The meaning of codes for PKM message as follows*

- *0* = Session Key Start
- 1 = Session Key Request
- 2 = Session Key Response
- 3 = Session Key Acc*ept*

The PKM message uses TLV format *to add the following attributes*

Table h-A8—Session Key frame TLV

Type	Length	Value Information
1	32	Nonce
2	8	Replay Counter
3	8	Key lifetime in seconds
4	16	Key Signature
5	4	Security Parameter Index
6	4 * number	The list of ESP Authentication IDs corresponding to the ESP Authentication algorithms for initiator-send supported by this BS
7	4 * number	The list of ESP Transform IDs corresponding to the ESP transforms for initiator-send supported by this BS
8	4 * number	The list of ESP Authentication IDs corresponding to the ESP Authentication algorithms for initiator-receive supported by this BS
9	4 * number	The list of ESP Transform IDs corresponding to the ESP transforms for initiator-receive supported by this BS

10	33 + 4*n	Security Block

The Length field contains a 16-bits value to record the whole frames size starting from Code field, with the ESP-Transforms-and-Authentication-Algorithms-Codes field filled in if present.

The PMK-Index field contains a 8-bits value to record the current Pairwise-Master-Key-Index each PKM-side used. If the PKM-Target detects the PMK-Index different of PKM-Initiator, it must update the latest Pairwise-Master-Key.

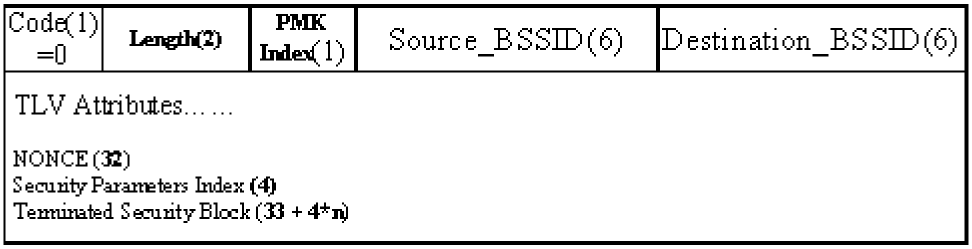
The Replay-Counter field contains a 64-bits random number (such as 64-bit NTP timestamp) and does not repeat within the life of the Master-Key material.

The Key-Lifetime field contains a 64-bits value to record the Session-Key lifetime in seconds.

The Key-Signature field contains an HMAC-MD5 message integrity check computed over the Session-Key-Frame starting from Code field, with the ESP-Transforms-and-Authentication-Algorithms-Codes field filled in if present, but with the Key Signature field set to zero. The M-Key is used as the HMAC-MD5 key.

The Security-Parameters-Index field contains a 32-bits value to assign to the IPsec Security Association (including the encryption and authentication keys, the authentication algorithm for AH and ESP, the encryption algorithm for ESP, the lifetime of encryption keys…etc in this session). PKM-Initiator/Target could check the SPI value in ESP-Header to detect to use which SA for this IPsec connection.

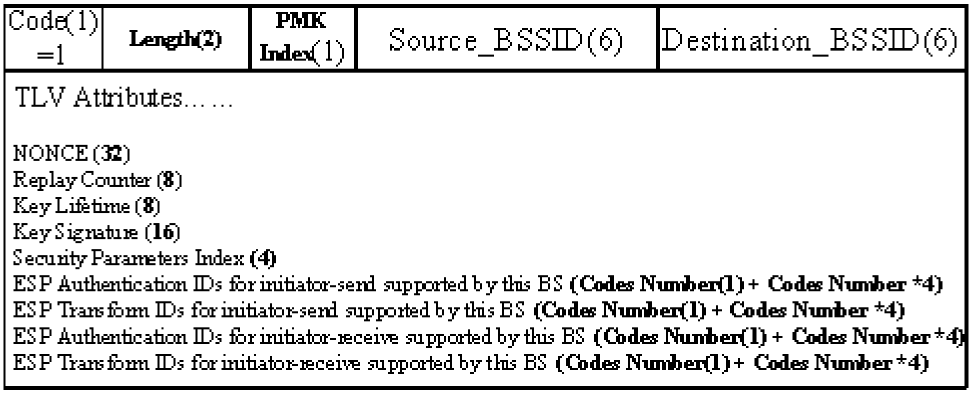
The following figure shows the Session-Key-Start message format



Code(1) =0	**Length(2)**	**PMK Index**(1)	Source_BSSID(6)	Destination_BSSID(6)
TLV Attributes…… NONCE (**32**) Security Parameters Index **(4)** Terminated Security Block (**33 + 4*n**)				

Figure h-A13—Session-Key-Start message format

The following figure shows the Session-Key-Request message format



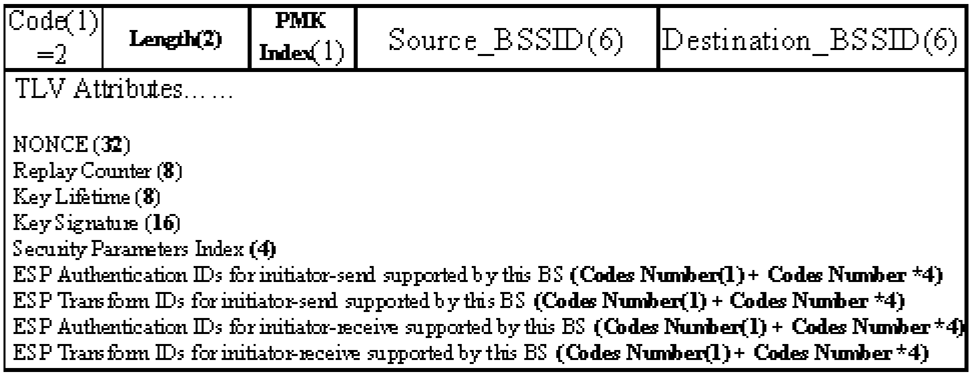
Code(1) =1	Length(2)	PMK Index(1)	Source_BSSID(6)	Destination_BSSID(6)

TLV Attributes……

NONCE (32)
Replay Counter (8)
Key Lifetime (8)
Key Signature (16)
Security Parameters Index (4)
ESP Authentication IDs for initiator-send supported by this BS (Codes Number(1) + Codes Number *4)
ESP Transform IDs for initiator-send supported by this BS (Codes Number(1) + Codes Number *4)
ESP Authentication IDs for initiator-receive supported by this BS (Codes Number(1) + Codes Number *4)
ESP Transform IDs for initiator-receive supported by this BS (Codes Number(1) + Codes Number *4)

Figure h-A14—Session-Key-Request message format

The following figure shows the Session-Key-Response message format



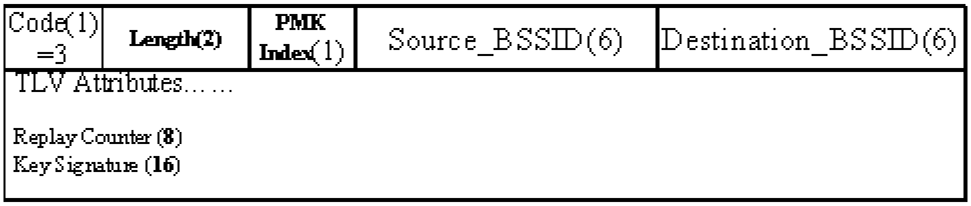
Code(1) =2	Length(2)	PMK Index(1)	Source_BSSID(6)	Destination_BSSID(6)

TLV Attributes……

NONCE (32)
Replay Counter (8)
Key Lifetime (8)
Key Signature (16)
Security Parameters Index (4)
ESP Authentication IDs for initiator-send supported by this BS (Codes Number(1) + Codes Number *4)
ESP Transform IDs for initiator-send supported by this BS (Codes Number(1) + Codes Number *4)
ESP Authentication IDs for initiator-receive supported by this BS (Codes Number(1) + Codes Number *4)
ESP Transform IDs for initiator-receive supported by this BS (Codes Number(1) + Codes Number *4)

Figure h-A15—Session-Key-Response message format

The following figure shows the Session-Key-Accept message format



Code(1) =3	Length(2)	PMK Index(1)	Source_BSSID(6)	Destination_BSSID(6)

TLV Attributes……

Replay Counter (8)
Key Signature (16)

Figure h-A16—Session-Key-Accept message format

Annex B

(informative)

GPS Timing and Base Station Synchronization

Every IEEE 802.16h network will be synchronized to a globally distributed reference timing system that is capable of allowing the network Base Stations to synthesize a 1 pps NTI and a UTC time stamp. The Global Positioning System (GPS) is capable of providing such a temporal references to the Base Stations providing they are equipped with GPS receivers.

Every base station equipped with a GPS receiver would be capable of receiving a UTC synchronized 1 pps timing signal. The accuracy of the clock pulses derived from using GPS are accurate to +/- 100 usec and the pulses that are derived typically have rise times within +/- 2.5 nsec. Fig 1 shows a typical GPS 1 sec pulse and its duration (Trimble Inc. Palisade output).

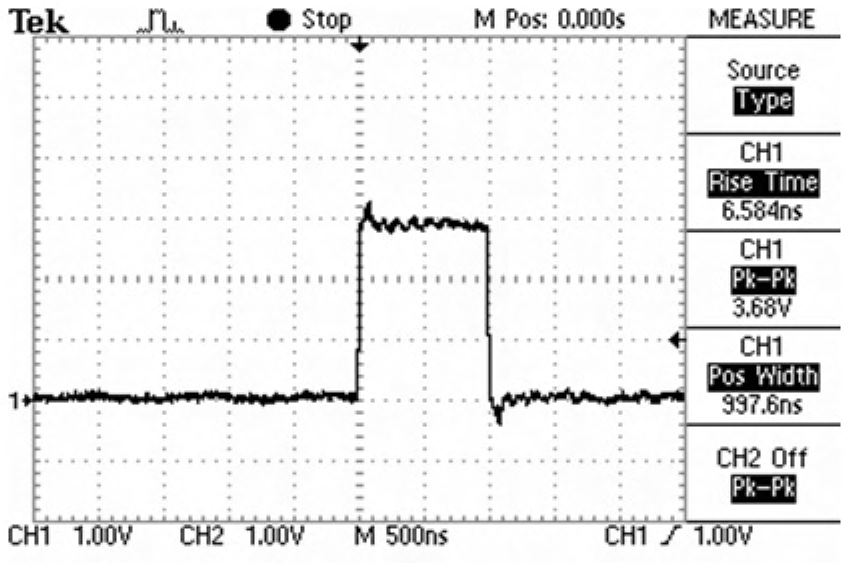


Figure h-B1—GPS 1pps Pulse

The availability of a globally distributed clock will result in a common temporal unit that can be used in negotiating access times to spectrum shared by a community of ad-hoc users. Non-IEEE 802.16h networks having different architectures and messaging signals could also use a common 1 sec interval for synchronization of their networks. This would conceivably allow communication between them and IEEE 802.16h networks in a synchronized manner, to facilitating the exchange of information related to coexistence and spectrum sharing.

The one second unit is considered ideal because it is distributed by the GPS as such and the length of the unit is seemingly appropriate. IEEE 802.16h networks typically have frames in the order of several to tens of milliseconds, which is of a granularity that could allow several to several tens of networks to negotiate coexistence subintervals within the 1 second span. Additionally, for IP networks, the 1 second interval is of a length sufficient to accommodate inter-router TCP/IP latency, especially over networks that are likely to be close to each other, such as ad-hoc LE networks.

Annex C

(informative)

interference scenario case study

C.1 Base Station initialization scenario case study

See to the figure below:

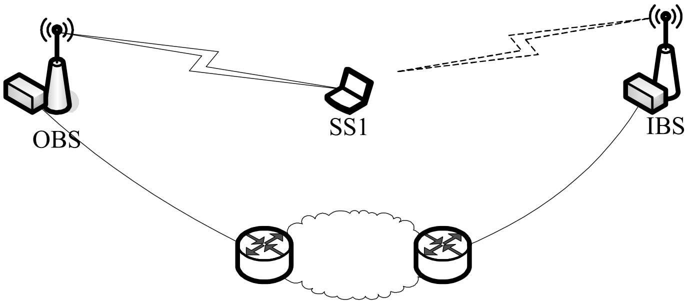


Figure h-C1—Enviorment of initializing basestation

Suppose OBS and SS1 is part of a operation network, SS1 have a stable air link with it's BS before IBS start, OBS have a wired link Now the IBS comes into this area with wire link to the core network, IBS could contact OBS if he knows the address, unfortunately it does not know the IP address and probably there may be no regulatory server to ask for help. Notice here, the IBS will not have any SS attached before IBS itself has finished initialization. Based on list of assumptions referred to the working document, we can study on cases IBS is in and what kind of problems it may meet.

There is three kind of situation may exist in both SS2BS and BS2SS interference/signaling,

- not able to be detected
- interference detected but signaling not able to be decoded
- interference detected and the signaling is decodable

We will use three kind of line with arrow to indicate these situation in the following figure during discussion.

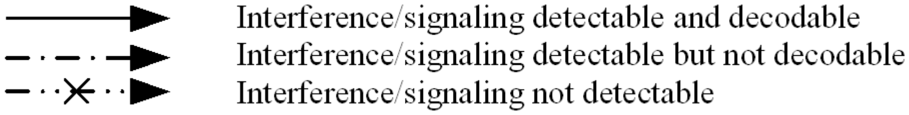

Interference/signaling detectable and decodable
Interference/signaling detectable but not decodable
Interference/signaling not detectable

Figure h-C2—Legend of arrow indicating interference direction

[note: based on the synchronization assumption, the BS/BS and SS/SS interference could be ignored.]

We can easily list out the possible cases by logical thinking as below:

- Case1x: IBS interference/signaling can not detected by SS1
    - Case1a: the IBS can not detect the signal from the operating network
    - Case1b: the IBS can detect the signal from the operating network, but not decodable
    - Case1c: the IBS can detect and decode the signaling from the operating network
- Case2x: IBS interference/signaling can detected by SS1 but not decodable
    - Case2a: the IBS can not detect the signal from the operating network
    - Case2b: he IBS can detect the signal from the operating network, but not decodable
    - Case2c: the IBS can detect and decode the signaling from the operating network
- Case3x: IBS interference/signaling can detected and decoded by SS1
    - Case3a: the IBS can not detect the signal from the operating network
    - Case3b: the IBS can detect the signal from the operating network, but not decodable
    - Case3c: the IBS can detect and decode the signaling from the operating network

We can discuss these cases one by one in the following:

Note:

1)The red tick here means one of the BS may know the IP address of another BS by receiving the signaling from the air; The red cross here stands for that the BS can not know the IP address of another BS by the signaling from the air.

2)The red dot line in one side means that from this side, the station can decode the signaling from the transmitter; The red dash line means from this side, the station can detect but can not decode; and the read solid line means the station can not sense the existence of the transmitter.

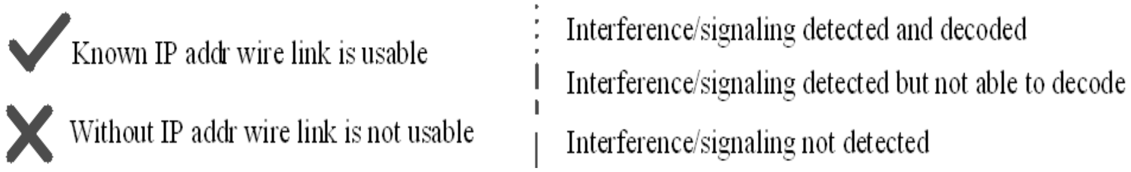

Known IP addr wire link is usable
Without IP addr wire link is not usable
Interference/signaling detected and decoded
Interference/signaling detected but not able to decode
Interference/signaling not detected

Figure h-C3—Legend of line indicating interference situation and symbols indicating wire-link usability

Case 1x:

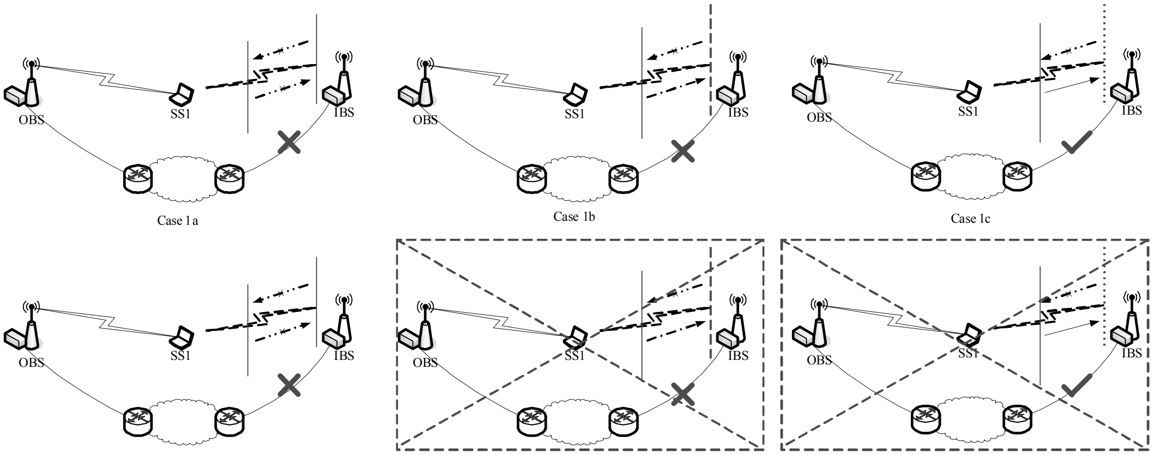


Figure h-C4—case 1x study

[Note: although logically case 1b and 1c could happen, these cases are not normally exist, because the channel propagation are symmetric in both direction, but the BSs' transmition power are normally higher than the SSs'. So when the IBS couldn't been detected by SS1, the IBS will not detect SS1's signal also.]

In these cases IBS doesn't interference with SS1, which means the OBS's network is not necessary to contact IBS. So case 1x(1a/1b/1c) are not the target initialization scenarios in 16h.

Case 2x:

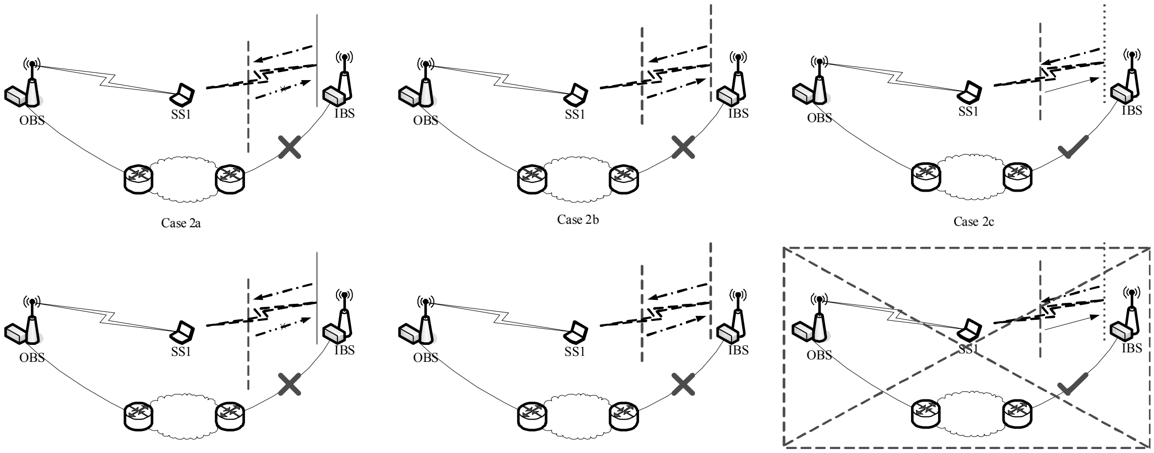


Figure h-C5—case 2x study

[Note: case 2c normally doesn't happen for the same reason with case 1b & 1c.]

In these cases, IBS's signaling could be detected by SS1, but SS1 could not decode the signaling. The problem here is, IBS may interfere to SS1, but SS1 can't know who is the interferer, so it can not tell the OBS who is the interferer, so the OBS could not contact IBS for cooperation. These cases is the worst cases that 16h should deal with.

The reason for this problem is the difference of condition between decodable signaling and troubling interference. The condition could be measured in SNR requirement, the lower SNR required for the signaling, the lower probability to have this problem; another approach may help was introduced to the working document 15.2.1.1.3 in the meetings before is shown in IEEE C802.16h-05/041,and we could easily understand it in the following figure.

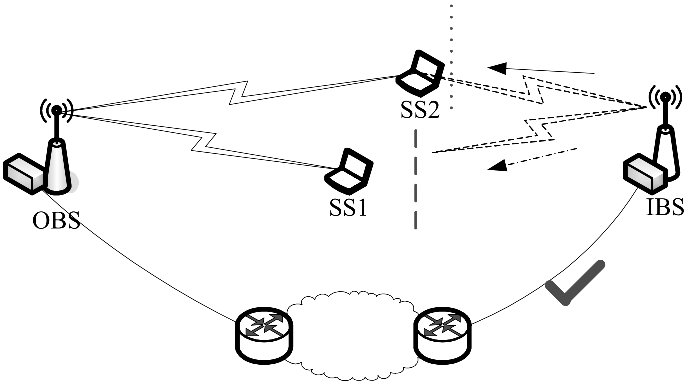
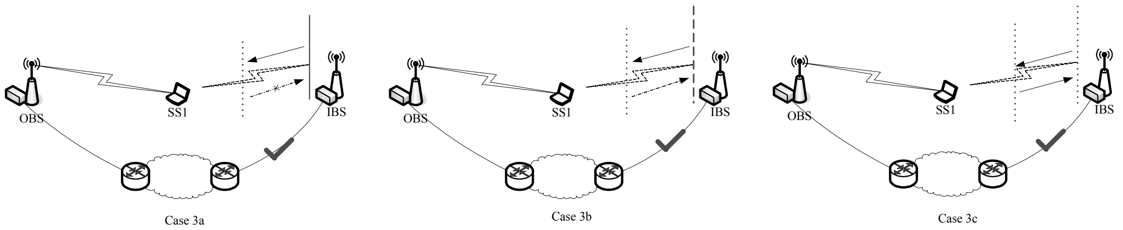


Figure h-C6—Enhanced mechanism dealing with case 2x

No matter how hard we try, we could not absolutely get rid of the difference, so we can not totally get rid of this problems, all we could do is to make the probability as low as possible. Once in operating network all the interfered SSs could not decode the signaling, we have no chance to tell who is coming to interfere the network, and this operating network may need to switch/escape to another channel.

Case 3x:



Case 3a Case 3b Case 3c

Figure h-C7—case 3x study

These cases are most interesting cases that 16h need to make out the solution. We can see each one of the 3 cases here is a normal case, and we need to deal with them all. In order to find the common solution, we need to take the advantage of the common condition. That is, SS can decode the IBS signaling. It's understood that if we don't depends on the IBS signaling transmition, in case 3a and 3b, operation network will not be able to find IBS in the core network. And the only way we may enable the operating network to do this is using the SS to relay the signaling which is managed to contain the IP address information.

The security issue may be mitigated by checking the instant random key and frame numbering in the contact requirement message sent by the OBS. That may prevent the IBS being cheated by someone faraway or by someone which is not able to control or access the 16h air link. We may need to think about this approach if we have no other choice to meet the cooperation contact requirement in case 3a and 3b.

For the sake of Case 2a and 3a, it's not logical to randomly choose the periodically silent CSI to occupy by the IBS, otherwise in the CSI which the IBS choose will cause collusion and make the initializing procedure not effective. Instead, it's needed to have a predefined periodical ICSI among all the CSI, and every IBS know the timing of ICSI as well. And the rest CSI will be used as OCSI and reallocated periodically to carry the signaling such as radio signature by the OBSs.