Title: **Main concepts of IEEE P802.16h / D1**

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Main Concepts of IEEE P802.16h / D1

Source: Mariana Goldhamer
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IEEE 802.16h Chair

Contents

- Basic mechanisms
- Interference detection
- Interference avoidance
- Cognitive Radio procedures for spectrum sharing
- Network and architecture
- Conclusions

Basic mechanisms

General classification of coexistence

Table h3—coexistence mechanism list for WirelessMAN-CX

Applicable	1: with wired IP communication available	Yes				No			
Condition	2: same PHY profile	Yes		No		Yes		No	
	3: in signaling/messaging range*	Y	N	Y	N	Y	N	Y	N
non-collaborative mechanism	*(CXCC:) dynamic frequency selection (DFS) *6.4.2.2*	✓	✓	✓	✓	✓	✓	✓	✓
	*(CXCC:) GPS timing recovery (GPS/UTC) *15.2.1*	✓	✓	✓	✓	✓	✓	✓	✓
	Extended quiet periods (EQP) *6.4.3.3*	✓	✓	✓	✓	✓	✓	✓	✓
	Adaptive EQP *6.4.3.4*	✓	✓	✓	✓	✓	✓	✓	✓
	Listen before talk *6.4.3.5*	✓	✓	✓	✓	✓	✓	✓	✓
	Uncoordinated Coexistence Protocol (UCP) *6.4.2.4*	✓	✓	✓	✓	✓	✓	✓	✓
collaborative mechanism	IP network message (CXP message) *15.5.2*	✓	✓	✓	✓				
	coexistence proxy (CXPRX) *15.1.6*	✓	✓	✓	✓				
	*(CXCC:) coexistence signaling (CSI/ radio signature) *15.3.1*	✓		✓		✓		✓	
	*(CXCC:) coexistence messaging (CMI/CCD) *15.3.2*	✓				✓			
	sub frame sharing (master sub frame) *15.4.2*	✓	✓	✓	✓	✓		✓	
	channel reallocation (ACS) *15.4.1*	✓	✓	✓	✓	✓		✓	
	Subframe Reallocation (ASFA) *15.4.2.2*	✓	✓	✓	✓	✓		✓	
	credit token *15.4.2.5*	✓	✓	✓	✓				

Basic Mechanisms - 1

- Defined inside of a “Community”
  - ***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 mutual interference and coexist

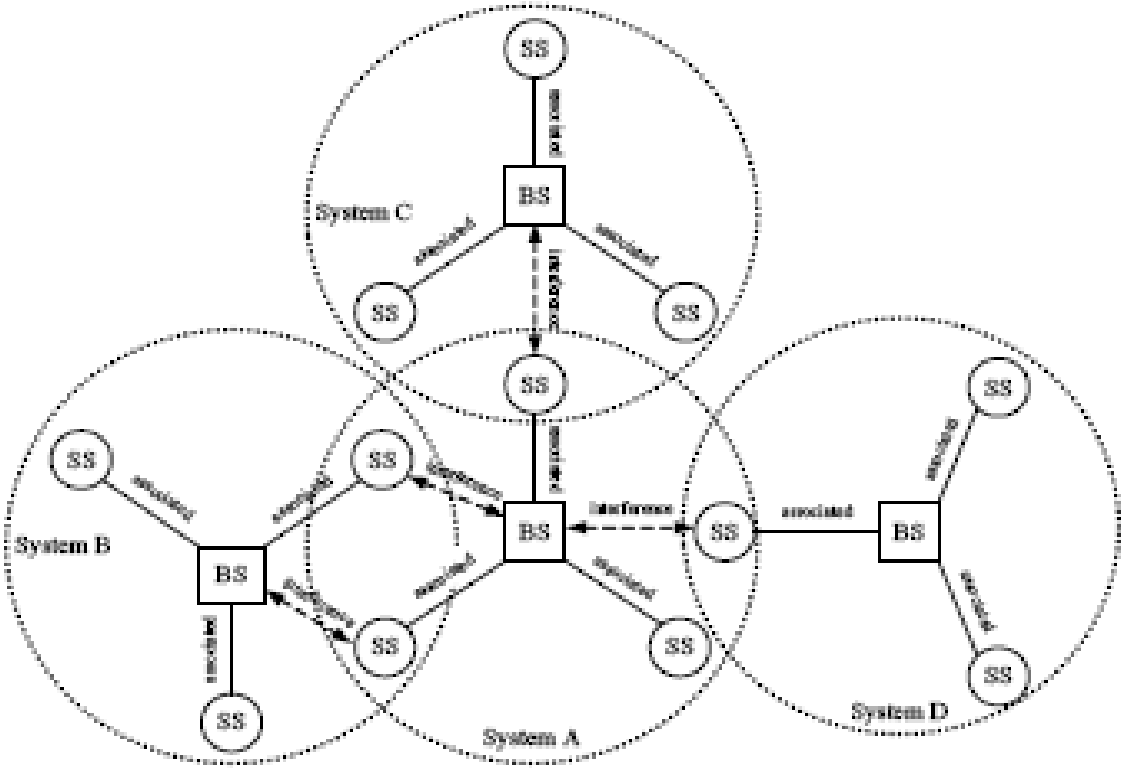


Figure h3—Neighbor relationship formed by bidirectional interference

Basic Mechanisms - 2

- MAC Frame synchronization using GPS clock
- Coexistence Control Channel (CXCC)
  - 1.9ms time-slots, repeated every 10sec., supports UL and DL as well as 5,10, 20ms MAC Frame durations
  - Forwards the GPS sync as signaling
  - Cumulated Radio Signatures
    - Separate slots for 802.16h systems and NON-802.16h systems
  - Every Master sub-frame has a dedicated CXCC slot, separately for DL and UL
  - Uses frequency signaling to send-out the IP Address of the CX Proxi Server
- Candidate Channel Determination
  - Interference evaluation by BS and SS
- Separation of remaining interference in time-domain
  - Master sub-frames for interference-free operation
    - Supports channel sharing between 3 systems
    - Basic operation – using CX Control Channel
    - Extended operation – using CX Protocol
      - Provides maximum spectral efficiency

Basic Mechanisms - 3

- Optimization of channel /sub-frame selection
  - Re-arrangement of occupied channels / Master sub-frames in a community – IP level protocol
- Co-existence with Ad-Hoc systems
  - Radio signaling protocol
- BSID and IP Proxi info transmission between systems
  - Using same PHY profile (CMI slots in CX_CC)
  - Using energy keying
    - In time domain (CSI slots)
    - In frequency domain (CX Control Channel slots)
  - The IP Proxy will get the BS IP address used in CX Protocol
- Token Protocol for dynamic coexistence trading
  - Makes available more interference-free system bandwidth

Basic Mechanisms - 4

- Enhancements for un-coordinated coexistence
  - Coexistence with Specific (Preferred) Spectrum Users
    - DFS
  - Dynamic Channel Selection (DCS)
  - Extended quiet periods
  - Listen before talk

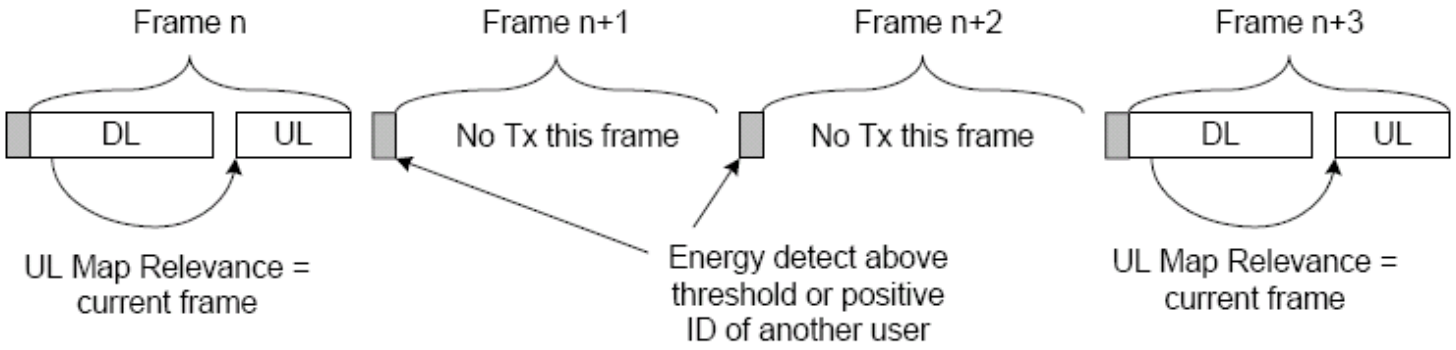


Figure h7—Listen-Before Talk

Inter-system communication

- Message-based for managed systems
  - High level IP based Coexistence Protocol (CXP)
  - MAC Messages using same PHY/co-channel communication:
    - BS to foreign SS
    - Foreign SS to BS
- Radio signaling for ad-hoc systems (LE specific)
  - Reservation of Rx interval
  - Announcement of Tx intervals
  - Based now on the FFT 256-sub-channelization preambles
    - Preambles for OFDMA should be added

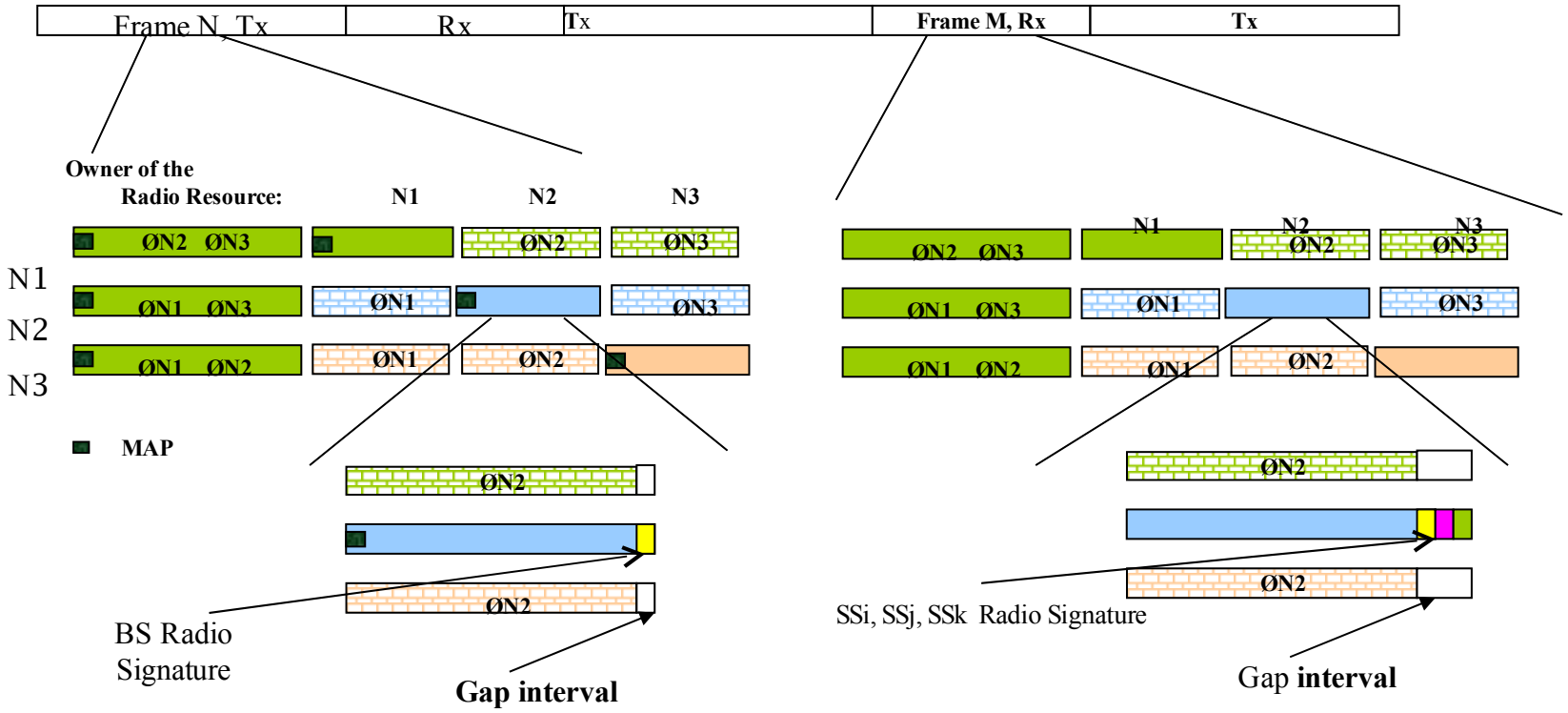
Interferer identification

Interferer identification with CXP

- The interferers will be identified by TIMMING of their radio signature
  - for example a short preamble for OFDM/OFDMA cases
- The radio signature consists 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, time-shift)* will be used for identification. The particular transmissions times are kept in the BS-data bases.

Sending the Radio Signature

- Scheduled intervals during Master sub-frames



Interference avoidance

Interference mitigation

- Separation in frequency domain – first
- Separation of the remaining interference in time-domain

Candidate Channel Determination using CMI slots in the CX Control Channel

- Candidate channel is selected based on:
  - Minimum interference in the corresponding CX Control Channel slots
  - REP REQ/RSP messages and the conveyed information

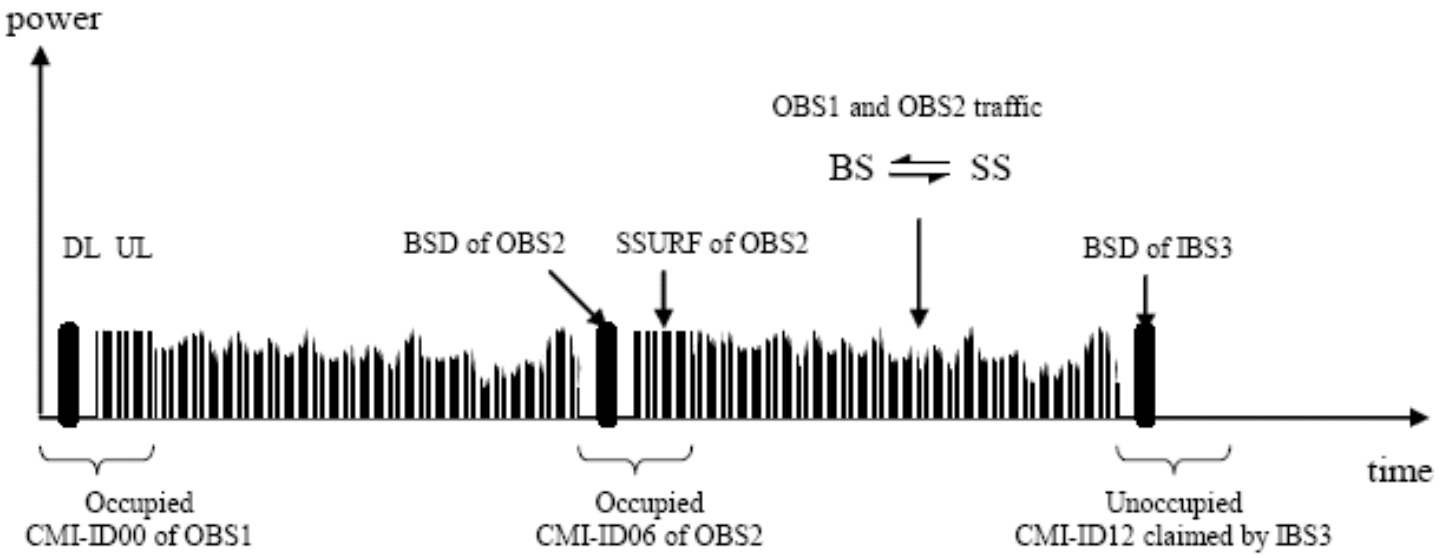
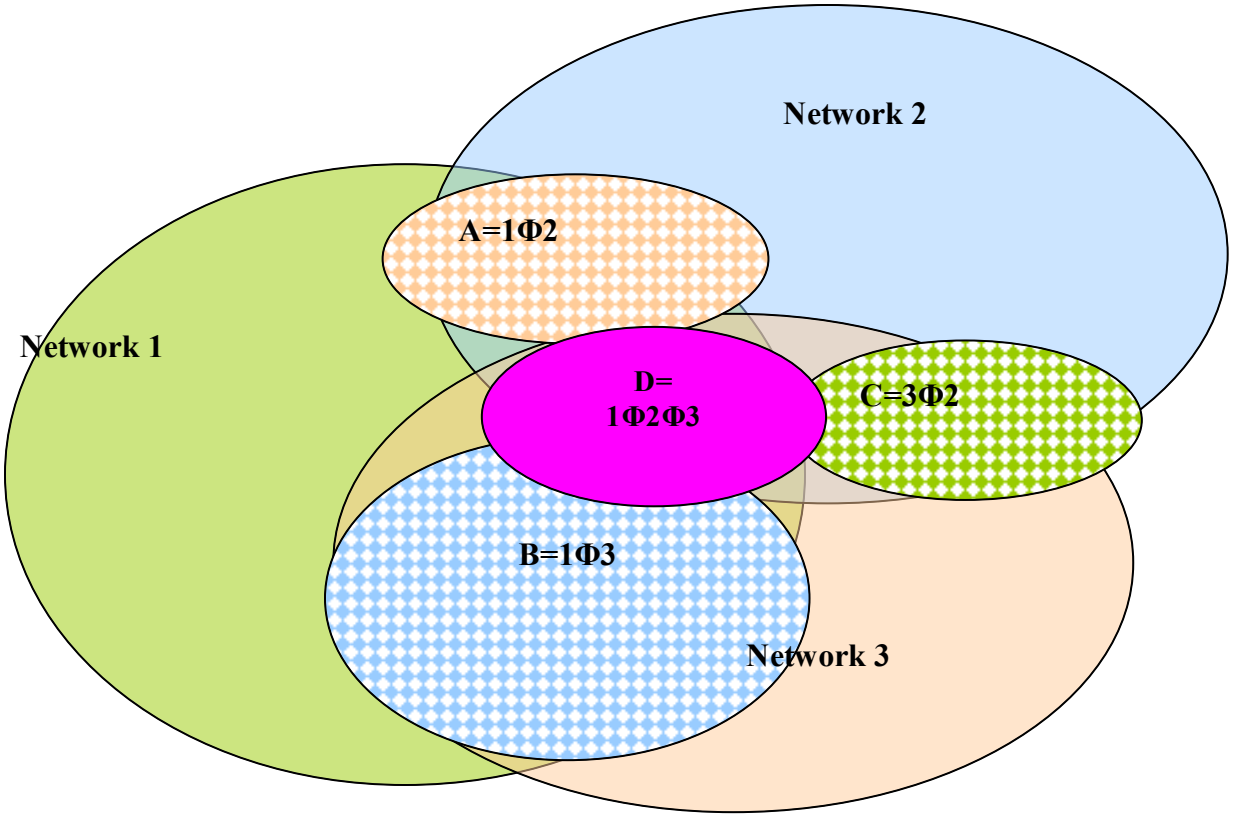


Figure h37—IBS3 Entry Signalling

Interference example



Legend:

Network i

Sub-network j, k not interfering with Network i

Interference avoidance in context of 802.16 MAC Frame

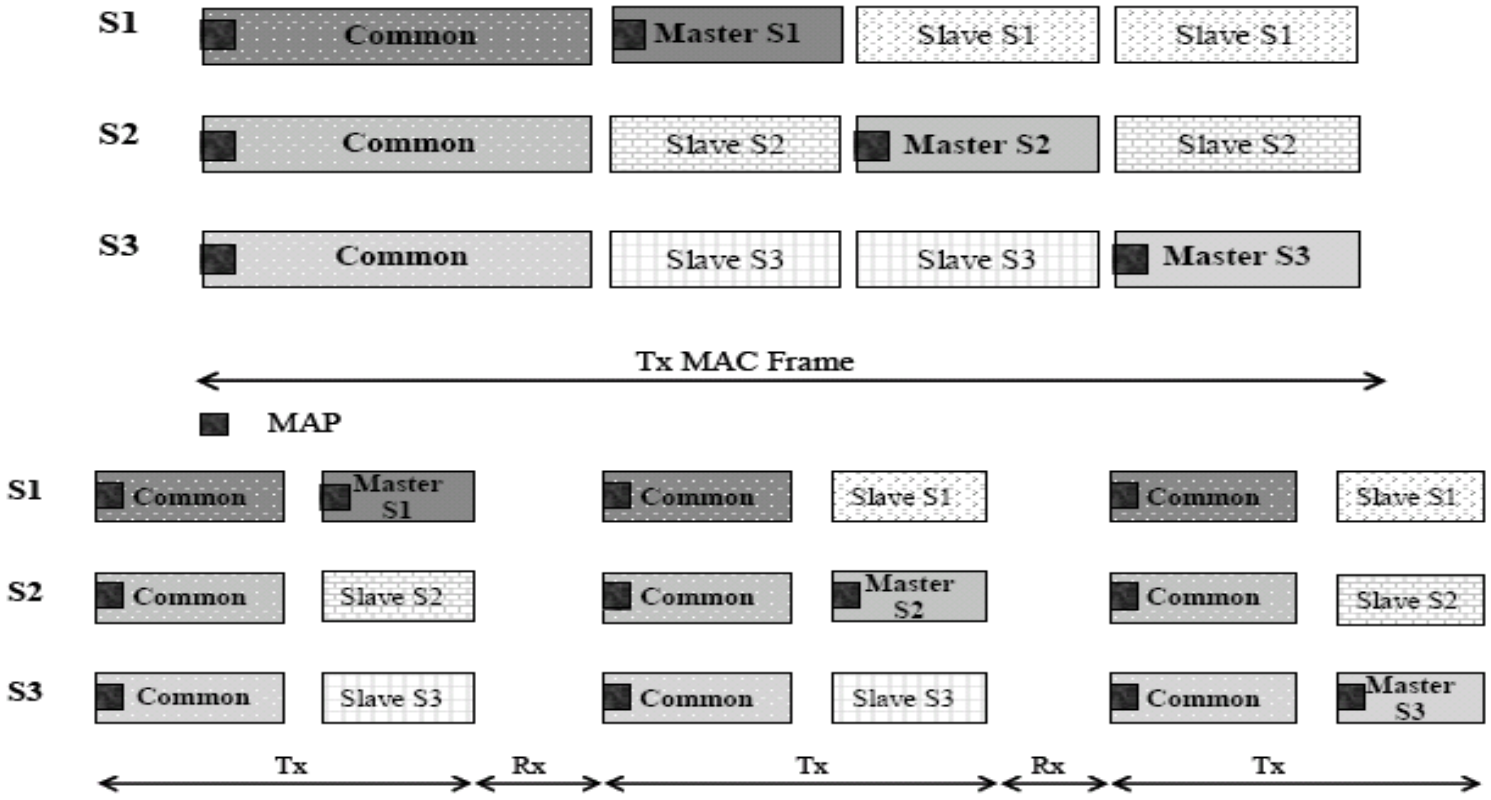
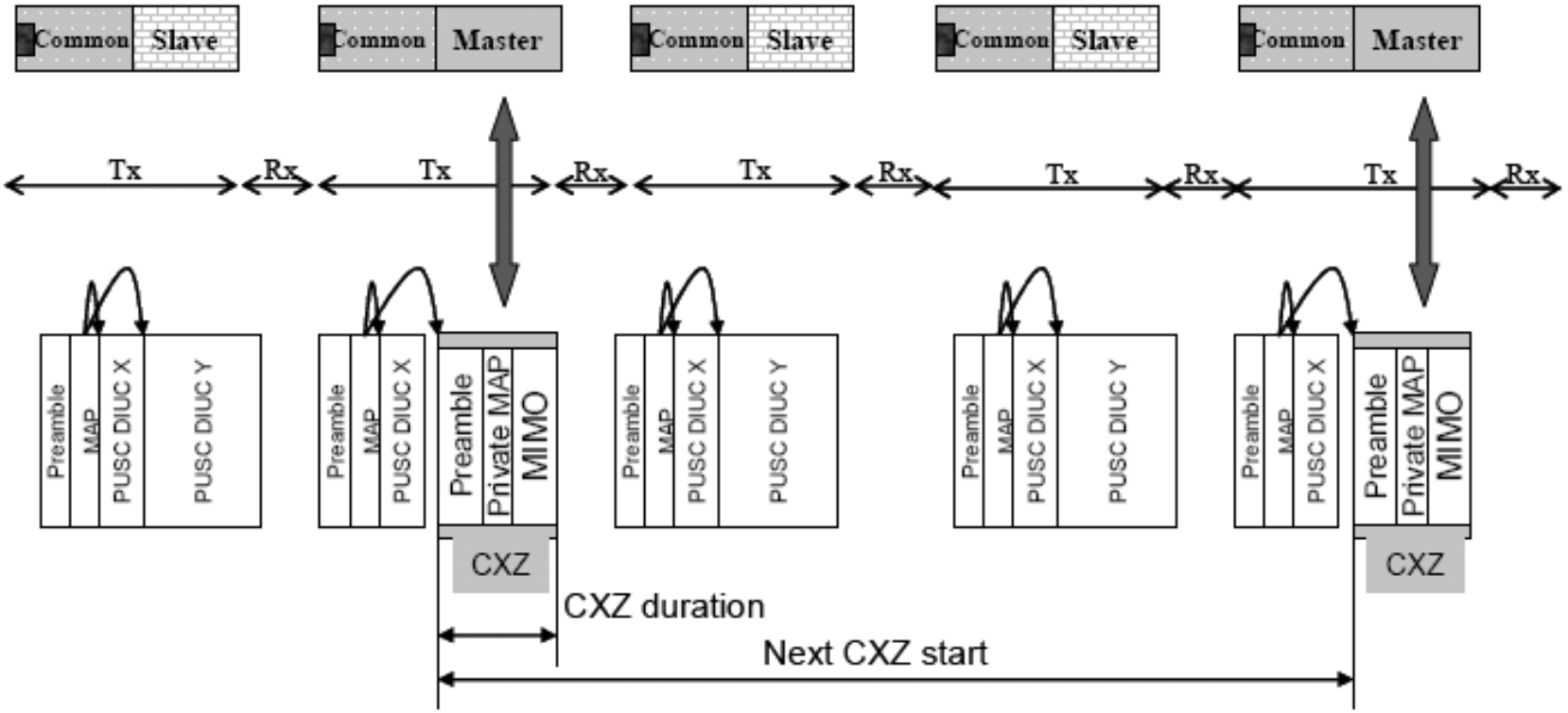


Figure h19—examples of WirelessMAN-CX Subframes

Candidate Master sub-frame determination using the CX Control Channel SMI Slots

- GPS synchronization of the time-slots
- Max. 3 systems supported
- For every DL and UL Master sub-frame
  - All the BSs, respective SSs, insert their radio signatures in the corresponding CX CC slot
    - Cumulated interference may be sensed
- A system will determine the less interfered Master sub-frame by
  - Listening to CC CX on all possible operating channels
  - Determine the less interfered one

Master sub-frame scheduling and CXZ



Controlling interference during Master sub-frames with CX Protocol

- A BS can request slave systems to reduce their power/ stop operating during its Master sub-frames
  - Systems not able to use the Coexistence Protocol are not allowed to operate as Slaves
  - 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:
  - Reduce_Power_Request
  - Stop_Operating_Request

Coexistence Protocol Messages - 1

Table h10—CXP messages

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

Table h12—CXP message codes

Code	CXP Message Name	CXP Message Type	Protocol type	Direction
0	Reserved	—	—	—
1	Identify Coexistence Request	CXP-REQ	TCP	BSIS->BSIS
2	Identify Coexistence Response	CXP-RSP	TCP	BSIS->BSIS
3	CoNBR Topology Request	CXP-REQ	TCP	BS-> BSIS
4	CoNBR Topology Reply	CXP-RSP	TCP	BSIS->BS
5	Registration Request	CXP-REQ	TCP	BS-> BSIS
6	Registration Reply	CXP-RSP	TCP	BSIS->BS
7	Registration Update Request	CXP-REQ	TCP	BS-> BSIS
8	Registration Update Reply	CXP-RSP	TCP	BSIS->BS
9	De-registration Request	CXP-REQ	TCP	BS-> BSIS
10	De-registration Reply	CXP-RSP	TCP	BSIS->BS
11	Add Coexistence Neighbor Request	CXP-REQ	TCP	BS->BS
12	Add Coexistence Neighbor Reply	CXP-RSP	TCP	BS->BS
13	Update Coexistence Neighbor Request	CXP-REQ	TCP	BS->BS
14	Update Coexistence Neighbor Reply	CXP-RSP	TCP	BS->BS
15	Delete Coexistence Neighbor Request	CXP-REQ	TCP	BS->BS
16	Delete Coexistence Neighbor Reply	CXP-RSP	TCP	BS->BS
17	Get_Param_For_Radio_Signature_Request	CXP-REQ	UDP	BS->BS
18	Get_Param_For_Radio_Signature_Reply	CXP-RSP	UDP	BS->BS
19	Evaluate_Interference_Request	CXP-REQ	UDP	BS->BS
20	Evaluate_Interference_Reply	CXP-RSP	UDP	BS->BS

Coexistence Protocol messages - 2

21	Work_In_Parallel_Request	CXP-REQ	UDP	BS->BS
22	Work_In_Parallel_Reply	CXP-RSP	UDP	BS->BS
23	Reduce_Power_or_Quit_Sub_Frame_Request	CXP-REQ	UDP	BS->BS
24	Reduce_Power_or_Quit_Sub_Frame_Reply	CXP-RSP	UDP	BS->BS
25	Create_New_Sub_Frame_Request	CXP-REQ	UDP	BS->BS(MC?)
26	Create_New_Sub_Frame_Reply	CXP-RSP	UDP	BS->BS
27	SS_CCID_IND	CXP-REQ	UDP	BS->BS
28	SS_CCID_RSP	CXP-RSP	UDP	BS->BS
29	PSD_REQ	CXP-REQ	UDP	BS->BS
30	PSD_RSP	CXP-RSP	UDP	BS->BS
31	Channel Switch Negotiation Request	CXP-REQ	TCP	BS->BS
32	Channel Switch Negotiation Reply	CXP-RSP	TCP	BS->BS
33	Channel Switch Request	CXP-REQ	TCP	BS->BS
34	Channel Switch Reply	CXP-RSP	TCP	BS->BS
35	Advertisement Request	CXP-REQ	TCP	BS->BS
36	Advertisement Reply	CXP-RSP	TCP	BS->BS
37	Negotiation Process Request	CXP-REQ	TCP	BS->BS
38	Negotiation Process Reply	CXP-RSP	TCP	BS->BS
39	Credit Token Proposal Request	CXP-REQ	TCP	BS->BS
40	Credit Token Proposal Reply	CXP-RSP	TCP	BS->BS

CXP Messages - 3

41	Negotiation Results Request	CXP-REQ	TCP	BS->BS
42	Negotiation Results Reply	CXP-RSP	TCP	BS->BS
43	Granting Request	CXP-REQ	TCP	BS->BS
44	Granting Reply	CXP-RSP	TCP	BS->BS
45	Co-existence Conflict Identification Request	CXP-REQ	TCP	BS->BS
46	Co-existence Conflict Identification Reply	CXP-RSP	TCP	BS->BS
47	Intra Operator Co-existence Coordination Request	CXP-REQ	TCP	BS->BS
48	Intra Operator Co-existence Coordination Reply	CXP-RSP	TCP	BS->BS
49	Inter Operator Co-existence Coordination Request	CXP-REQ	TCP	BS->BS
50	Inter Operator Co-existence Coordination Reply	CXP-RSP	TCP	BS->BS
51	Final Co-existence Decision Request	CXP-REQ	TCP	BS->BS
52	Final Co-existence Decision Reply	CXP-RSP	TCP	BS->BS
53	Regulatory Authority Request	CXP-REQ	TCP	RAIS ->BSIS
54	Regulatory Authority Response	CXP-RSP	TCP	BSIS->RAIS
55	FREQ_AVOIDANCE Request	CXP-REQ	TCP	BSIS-BS
56	FREQ_AVOIDANCE Response	CXP-RSP	TCP	BS-BSIS
57	Master Subframe Switch Request	CXP-REQ	TCP	BS->BS
58	Master Subframe Switch Reply	CXP-RSP	TCP	BS->BS
57-255	reserved			

Negotiation of interference-free intervals

- Credit Token based
- Allows to use the available interference-free zones
  - A Master may offer leasing for a given duration
    - advertise
  - A number of Slaves may bid
  - Every time-interval has a number of associated tokens
- Inter-BS communication:
  - Via IP Protocol
  - Over the air

Optimizations

- Channel selection optimization
  - Search process for an optimum frequency selection
  - Channel switch messages
    - Channel_Switch_Request
    - Channel_Switch_Replay
- Master sub-frame selection optimization
  - Similar

Regulatory domains and Cognitive Radio procedures for coexistence with other spectrum users

Regulatory Domains

- Initial text:

Table h61— Relevant regulatory domains and essential CX parameters

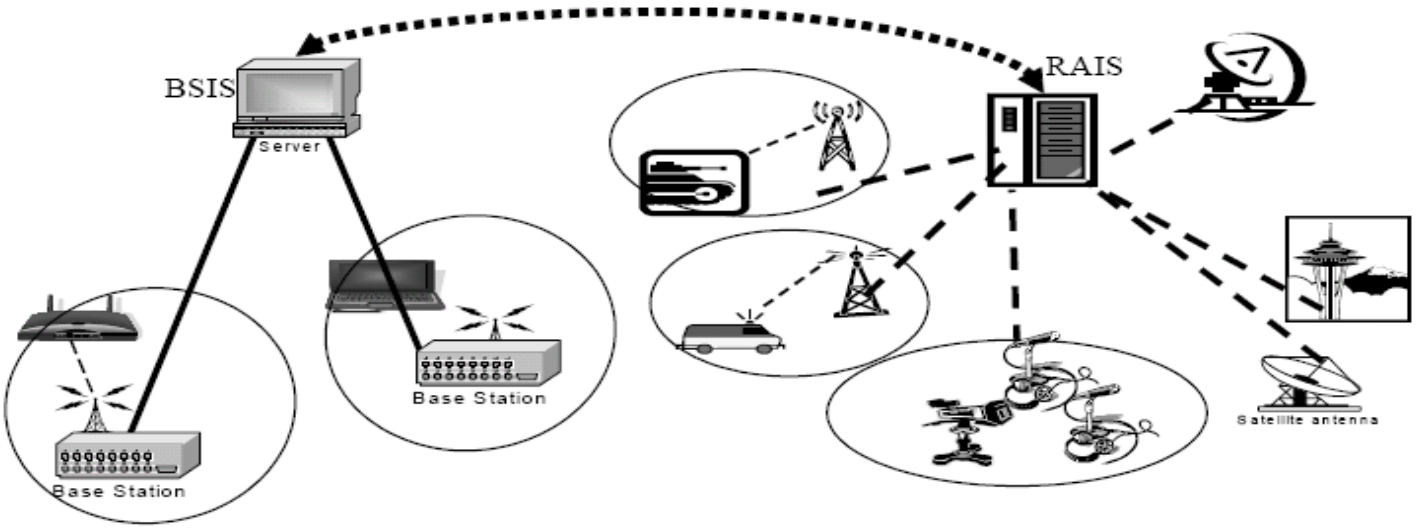
Regulatory Index	Frequency band	Regulatory authority	Channel Spacing (MHz)	Channel centers (MHz)	CXZ Parameters	Recommendations
1	5.25 – 5.875GHz	FCC, ECC	10, 20	See chap. 8.5	MAC Frame duration: 5ms, RI=20ms Sub-frame type: 2 DL Common sub-frame: 1ms	FFT sizes: up to 1k
2	3.65 – 3.7GHz	FCC	7	3654, 3661, 3.668 *3.675*,3682,3689, 3696	MAC Frame duration: 5ms, 10ms? RI=20ms, 30ms? Sub-frame type: 2? DL Common sub-frame: 1ms, 3ms?	FFT sizes: up to 512
2	3.65 – 3.7GHz (BWA)	FCC	20	3661, 3689	Idem	FFT sizes: up to 1k
3	< 850MHz (TV Bands)	FCC	6	Centers of the TV channels	MAC Frame duration: 10ms Sub-frame type: 2? DL Common sub-frame: 3ms?	FFT sizes: up to 1k
4	4.940-4990GHz (Public Safety)	FCC (03-99)	5	4942.5 +n*5MHz	MAC Frame duration: 5ms, RI=20ms Sub-frame type: 2 DL Common sub-frame: 1ms	FFT sizes: up to 512

Compliance with the FCC Coexistence requirements in 3.65GHz-3.7GHz

Requirements	16h – Coordinated CX
Multiple users to share the same spectrum	3 systems / channel
Defining the events that must occur when two or more transmitters attempt to simultaneously access the same channel	See P802.16h/D1 Clause 15
Rules by which a transmitter provides reasonable opportunities for other transmitters to operate.	Master / Slave / Common sub-frames
Interference and Subscriber Station Identification	With SSURF Messages in CX Control Channel With Radio signatures ID inside CPX

Coexistence with other spectrum users

- CX Control Channel
  - Spectrum users / applications can evaluate the interference created by 802.16 systems
- CX Protocol
  - Frequency channels may be made available upon REQUEST by 802.16 systems to Preferred spectrum Users or other Spectrum Applications



Network and Architecture

Network elements

- Network Architecture
  - Distributed
- Base Station Identification Server
  - BS GPS position
  - BS IP address
  - BS Operator information
  - BS Radio Signature scheduling info
  - BS RF emission characteristics: power, antennas, etc
- Security
  - Proxy Server for associating BSID with IP address for transmissions over the air during the CSI (Coex Signaling Interval)
    - Optionally used also for transmissions over the backbone

802.16h network architecture

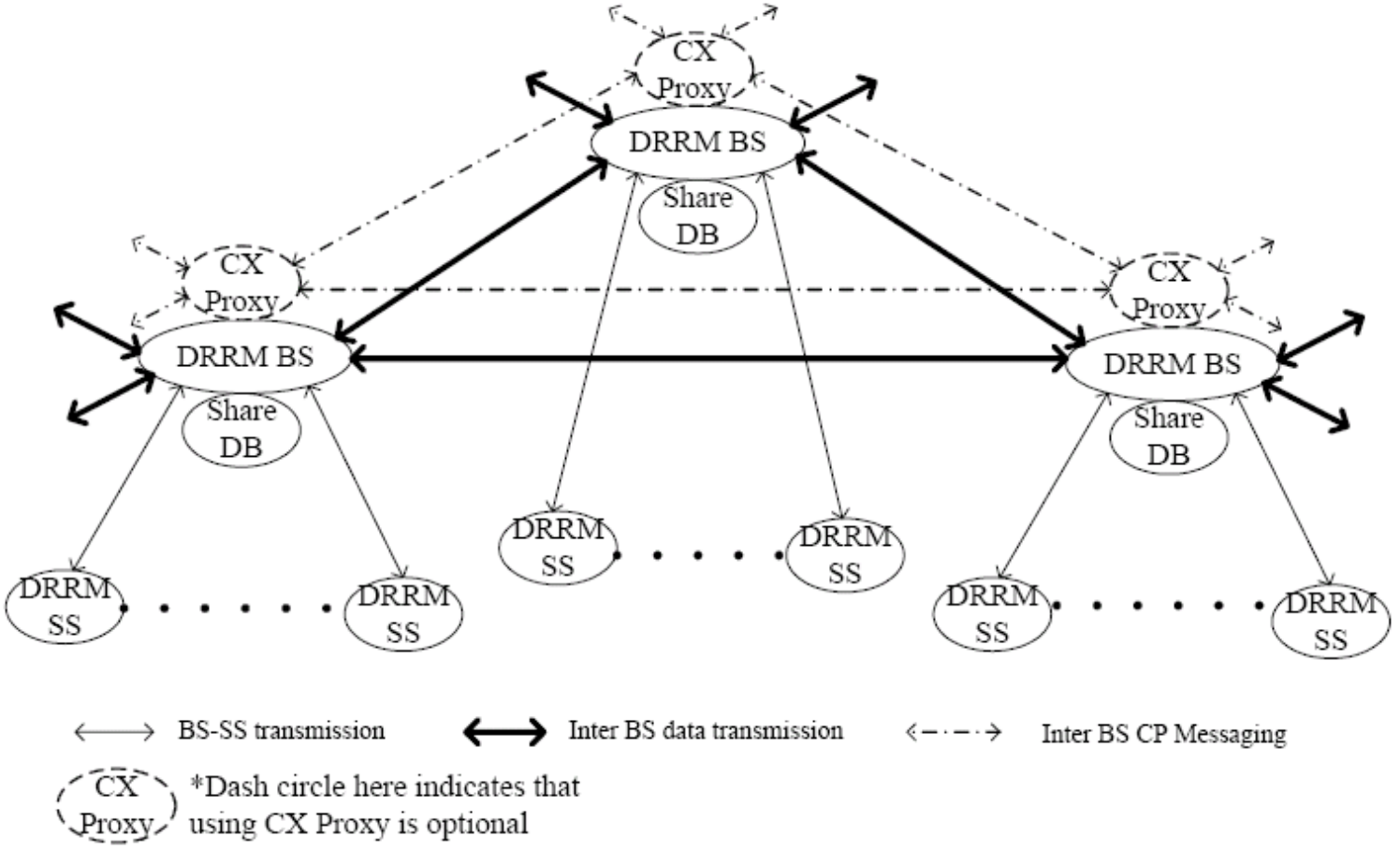
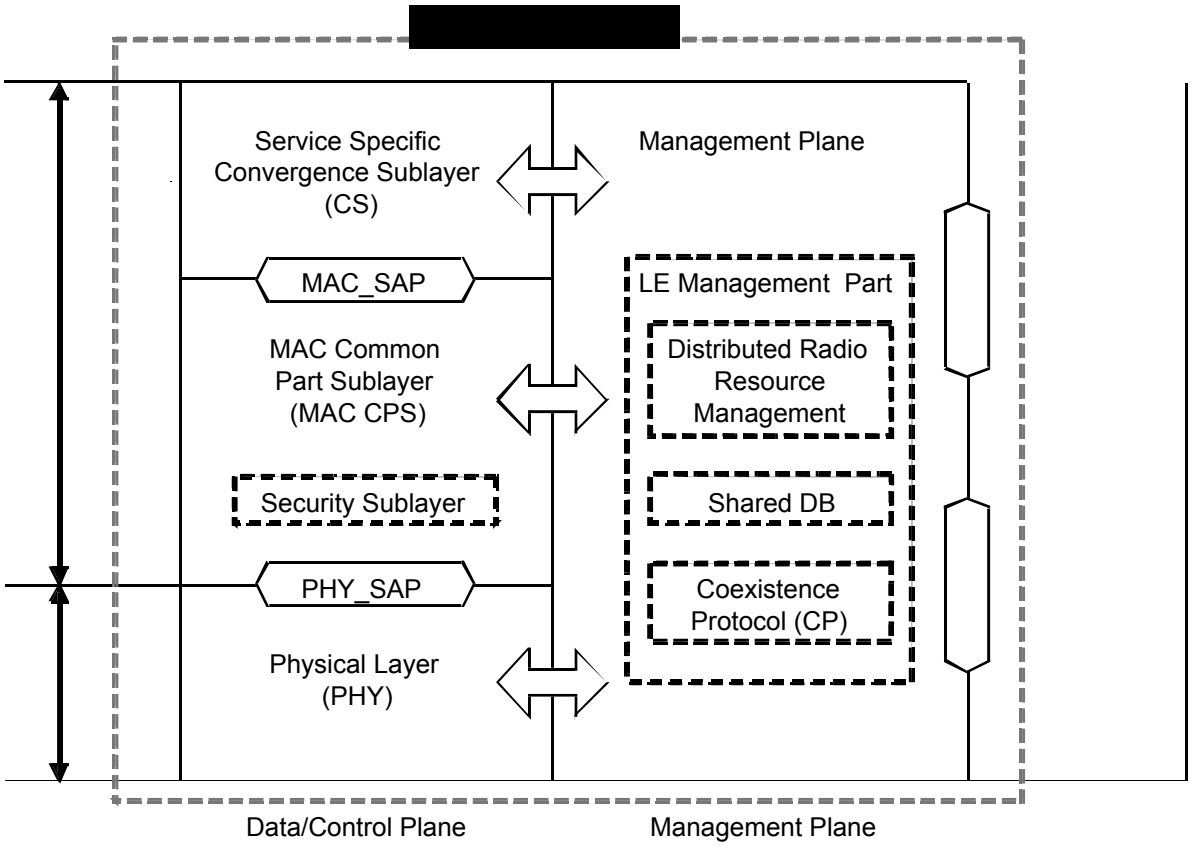


Figure h20—System Architecture

Base Station Protocol Architecture



Conclusion

- 802.16h – D1 adds
  - Cognitive Radio based coexistence
  - Separation of interference in both frequency and time domains
  - Elements for Coexistence with 802.11
  - Protocol-based coexistence
    - Allow higher cell sizes
    - Allow better spectral efficiency and capacity
    - Allow better QoS
    - Allow lower power consumption
    - Allow better spectrum sharing with other spectrum users/applications
- Coexistence with other 802 systems in the same bands
  - Highly desirable
  - Co-operation may be need!