Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Interference Scenario Case Studies for Synchronized WirelessMAN-CX Systems conforming to a Common PHY Profile**
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Re:	IEEE 802.16h-06/011 – working group review
Abstract	A case study for WirelessMAN-CX systems is provided. These systems are assumed to conform to the same PHY profile (Sec 15.2.2.2.1), they are synchronized to a universal time standard such as GPS and can support CMI timing and signaling as outlined in Sections 15.2.1.1.7 and 15.2.2.3.1.1. This case study summarizes all of the MAC and CP messages proposed for the same PHY profile systems.
Purpose	A case study for WirelessMAN-CX systems is provided in this document. This document is to be included as an annex to the IEEE 802.16h working document. It is for information only.
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Interference Scenario Case Studies for Synchronized WirelessMAN-CX Systems conforming to a Common PHY Profile.

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A case study for WirelessMAN-CX systems is provided. These systems are assumed to conform to the same PHY profile (Sec 15.2.2.2.1), they are synchronized to a universal time standard such as GPS and can support CMI timing and signaling as outlined in Sections 15.2.1.1.7 and 15.2.2.3.1.1.

In the Common PHY profile concept the following system features are given:

(1) Each System (consisting of a base station (BS) and its subscriber stations (SS)) claims a special interval in time called a CMI in which the BS sends a unique identifier called a BSD and the SS send unique identifiers called SSURF messages. Only one system in a Coexistence Neighborhood can transit during its CMI, all other systems remain quiet and monitor.

(2) All systems are universally synchronized to a common timing standard such as GPS; the beginning of a CMI is universally known. Additionally, the sub-frame sizes in the Time Division Duplexing (TDD) access scheme are all exactly the same across all networks (another common PHY characteristic).

(3) The BSD and SSURF messages can be demodulated and their RSSI values can be determined by systems with which they interfere, hence the rationale for the common PHY and the ability to quantify interference as it occurs on a per burst basis.

(4) Every Subscriber Station and Base Station contains an Interference Table in which is registered the RF emission characteristics, locations, and identities (as IP addresses, SS_ID, BS_ID, etc.) of all the interferers that the SS or BS have ever detected. The table also contains an indication as to whether the interference has been resolved by the Coexistence Protocol (CP) or not. These tables also contain the statistics pertaining to the interference detected, such as its frequency of occurrence, mean RSSI, etc.

(5) Every Subscriber Station and Base Station uses a special series of MAC and CP messages to resolve and indicate interference. The MAC messages are specifically for interference detected at the Subscriber Station and are called BS_CCID_IND and BS_CCID_RSP. These messages detail foreign BS interference detected by the SS. The Coexistence Protocol messages are specifically for interference detected at the Base Station and are called SS_CCID_IND and SS_CCID_RSP. These messages detail foreign SS interference detected by the BS.

There are 4 interference scenarios seen by WirelessMAN-CX systems when they are in an Interference Neighbourhood. It is assumed co-channel interference is at a nominal level where it is capable of being demodulated; it is *detected*. Interference below such levels, which is sporadic and changes with the variations in the propagation environment, is only *occasionally detectable*. It is assumed that the SSURF and BSD messages are received at S/N levels to make them at least occasionally detectable as interference. These scenarios assume the interference, when it occurs, is at least occasionally detectable and trigger the responses that are described (ie just one instance of sporadic interference will trigger a response). In more sophisticated control scenarios it will be possible to adjust the levels at which responses are triggered. For example, very occasional sporadic interference may not be worth considering and responses will be inhibited, as long as such unresolved interference is minimal.

Scenarios:

1. New interference is detected by a subscriber stations of one system with the interference generated by base stations of another system (the foreign system). Both systems are independent but form a Coexistence Community, (see Section 15.2.1.1 Definitions). The interference now generated, for example, can be of one in which a hidden SS which becomes exposed to the foreign BS because of some physical change in the coverage area; for example, the removal of a tree that once hid the affected SS or the erection of a metal clad building. This scenario can also happen when a new SS is installed. See Fig 1.
2. New interference is detected by a base station which is a member of a Coexistence Community. This interference is generated by a foreign subscriber station which is also a member of the same community. This scenario is equivalent to the one discussed in (1) above, but from the BS perspective. The physical changes discussed in (1) could give rise to the scenario described here.

3. New interference is detected at the SS and originates from foreign base stations which are not members of the Coexistence Community of the SS. The SS and foreign BS are initially not Coexistence Neighbors in this scenario. Figure 2 shows this scenario.
4. New interference is detected at the base station which originates from a foreign SS which in not a member of the Coexistence Community of the base station.. The foreign SS and its BS are initially not Coexistence Neighbors in this scenario. This is equivalent to scenario (3) but from the BS perspective.

Interference Resolution Process

Scenario 1 [Fig. 1]:

- Subscriber Stations have a SS Interference Table (Section 15.2.2.4 Table H4). Additionally, each system in the Coexistence Community has a unique CMI associated with it. During the CMI of the foreign system, the interfering (foreign) BS transmits a downlink BSD message (Sec 6.3.2.2.62) which is received as interference at the SS. Since it is new interference (caused by the removal of a tree, for example), the SS will demodulate the interfering BSD and extract its contents.
- Since the interference is new and the BSD from the foreign BS is not registered in the SS Interference Table, the SS will then create a new entry in the table for the foreign BS, labeling it as new unresolved interference. The SS then sends a BS_CCID_IND message to its home BS, indicating the identity of the interfering BS.
- Since the interfering BS is part of the Coexistence Community, the home BS will have negotiated non-interfering intervals between itself and the interfering BS (this being done previously via the Coexistence Protocol—See Sec. 15.2.1.1.2). If this were not the case, the two base stations would negotiate scheduling via the CP protocol. This undertaken successfully, the home BS will then schedule downlink transmissions directed to the reporting (interfered-with) SS to a time interval that is free of downlink interference from the interfering BS. This being done, the BS then sends a BS_CCID_RSP message to the SS, indicating that interference is resolved (this actually meaning that the BS transmissions to the SS will not be interfered because of scheduling).
- The SS, on receiving the BS_CCID_RSP from its BS, now assumes that downlink interference has been resolved. The SS then updates its SS Interference Table and will not send BS_CCID_IND messages whenever it detects the BSD of foreign BS. The SS will only listen for its downlink messages only during specifically scheduled intervals within the downlink sub-frame which are interference free and to which it has been assigned by its home BS.

Scenario 2.

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- All Base Stations have a BS Interference Table (Section 15.2.2.4 Table H2). Additionally, each WirelessMAN-CX system in the Coexistence Community has a unique CMI associated with it. During the CMI of the foreign system the interfering (foreign) SS transmits an uplink SSURF message (Sec. 6.3.2.3.63) which is received as interference at the BS. The SSURF contains information about the identity of the interfering SS and the BS which controls it.
- The interfered-with BS compares this information with the information it has in its BS Interference Table. The BS will determine that (a) the interference is from a new interfering SS and (b) that the interfering SS is registered to a system which is a known Coexistence Neighbor. Since both WirelessMAN-CX Systems are Coexistence Neighbors, they have interference free intervals scheduled amongst themselves. A SS_CCID_IND message is then sent by the interfered-with BS to the BS controlling the interfering SS, indicating a need to resolve the uplink interference. This message is sent via the backbone IP network; usually to the proxy IP address of the interfering BS (this address being registered in the Interference Tables).
- The BS of the interfering system, having received a SS_CCID_IND message realizes that one of its SS is causing unresolved interference. Since this interference is being caused to a Coexistence Neighbor system with which interfering-free scheduling exists; the interfering BS schedules that particular SS to only transmit during non-interfering intervals.
- A SS_CCID_RSP message is sent back via the IP backbone to the interfered-with BS, indicating a resolution of the uplink interference and that the SS causing the interference is scheduled only to transmit on the uplink during previously negotiated non-interfering intervals.

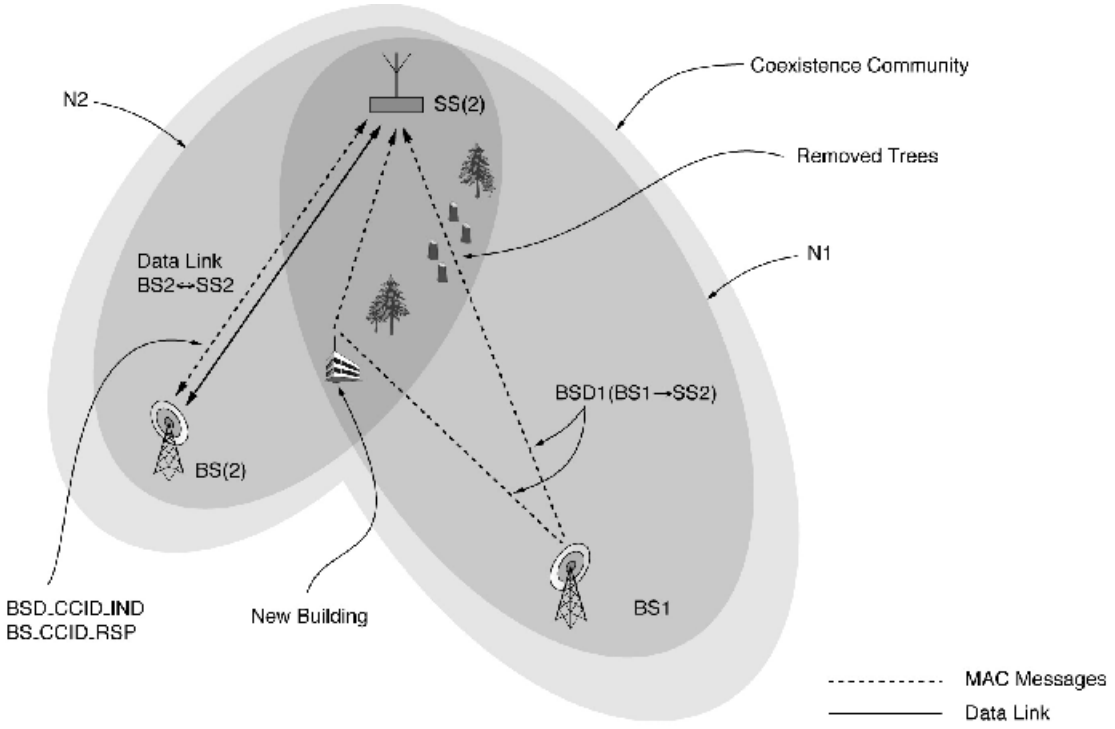
- The BS Interference Table at the previously interfered-with BS is updated to show the resolved status and the interference is deemed resolved. The interfered-with BS will now not send SS_CCID_RSP messages when it receives SSURF from the interfering SS.

Scenario 3 [Fig.2]:

- Interference from the foreign BS will be detected at the SS during the CMI of the foreign BS. Since the foreign BS (and its system) is not registered as a known interferer to the SS (by not being in the SS Interference Table), the SS will then create a new entry in the table for the foreign BS. By using the proxy IP address of the foreign BS extracted from the BSD of the foreign BS, the interfered-with SS sends a BS_CCID_IND message to its home BS thus indicating the identity of the interfering BS. At this point the interference is registered as detected and unresolved by the SS.
- The foreign BS is considered as an Interference Neighbour by the home BS. The home BS on receiving the BS_CCID_IND then contacts the interfering BS via the IP and initiates the Coexistence Protocol (CP) between the two BS. The negotiation necessitates the creation of a downlink slot which the interfering BS can use without interfering the SS. The home BS also needs to reschedule its downlinks also to accommodate this change. The process can result in changes to EIRP and scheduling and the creation of spatial isolation (if smart antennas are used), for example.
- On completing a successful CP negotiation the home BS will schedule its downlink messages to the SS during the interference free intervals. The interfering BS will accommodate this by appropriated modifying (or ceasing) its downlink transmissions during such intervals. A BS_CCID_RSP message is sent to the SS by the home BS, indicating a resolution of the interference.
- The SS, on receiving the BS_CCID_RSP from its BS, now assumes that downlink interference has been resolved. The SS then updates its SS Interference Table and will inhibit any further interference responses due to detection of the foreign BS's BSD messages. The SS now has specific downlink intervals in which it will look for traffic destined to itself. All other intervals are ignored.
- As a consequence of this process, the formerly interfering BS is now a member of a Coexistence Community that includes both BSs. Both BSs update their BS Interference Tables so that new interference can be more easily resolved now that the CP has established interference free intervals for the BSs.

Scenario 4:

- Interference from the foreign SSURF will be detected during the interfering system's CMI. Interference is detected at the BS. The SSURF message will be decoded by the BS which will determine that the interference originates from a system not registered in its BS Interference Table.
- The proxy IP address of the foreign BS controlling the interfering SS is derived from the SSURF. The interfered-with BS sends a SS_CCID_IND message to the foreign BS indicating that interference was received from its SS, thus there is a need to negotiate uplink coexistence.
- Both BS undertake the Coexistence Protocol and mutually determine interference free uplink slots which the foreign SS can use. The interfered-with BS will also modify (or altogether cease) its use of these slots for its uplink traffic
- On completion of the CP, both BSs update their Interference Tables to contain the characteristics of each other, such as location, IP address, emission characteristics, etc.
- The two base stations and their associated SS are now members of a Coexistence Community.
- The interfering BS sends a SS_CCID_RSP message via the IP backbone; indicating that it has completed its rescheduling, and that the interfering SS is now only transmitting uplink data during non-interfering slots.


N2
SS(2)
Coexistence Community
Removed Trees
N1
Data Link
BS2↔SS2
BSD1(BS1→SS2)
BS(2)
BSD_CCID_IND
BS_CCID_RSP
New Building
BS1
MAC Messages
Data Link

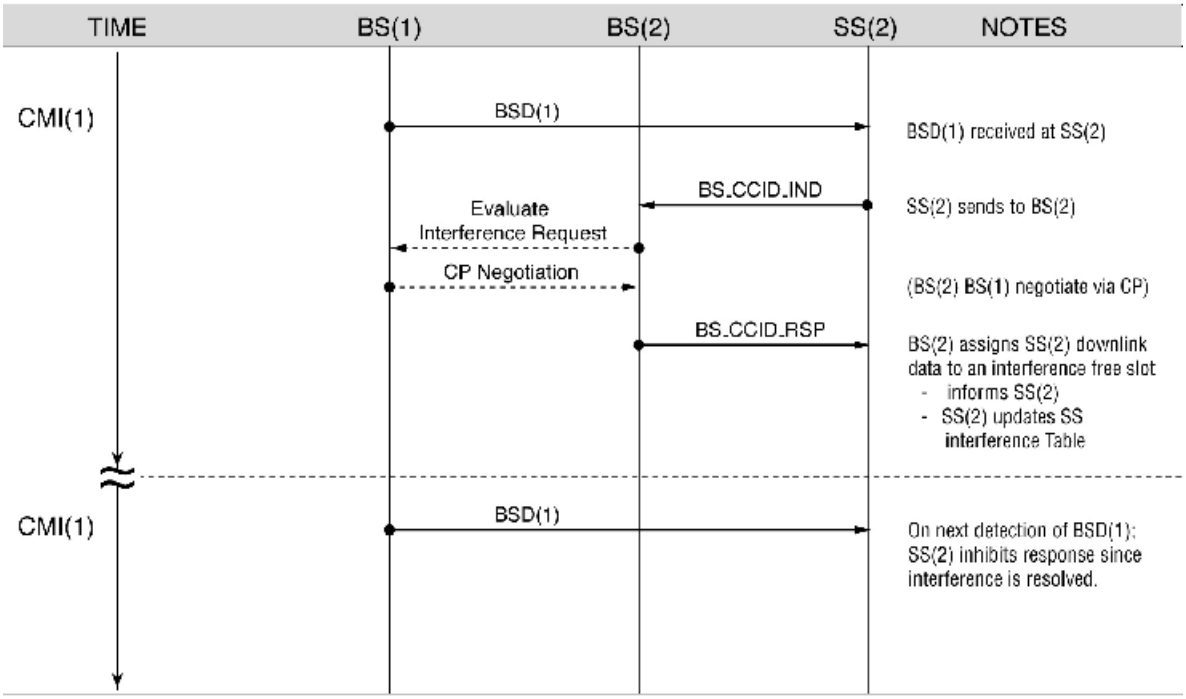
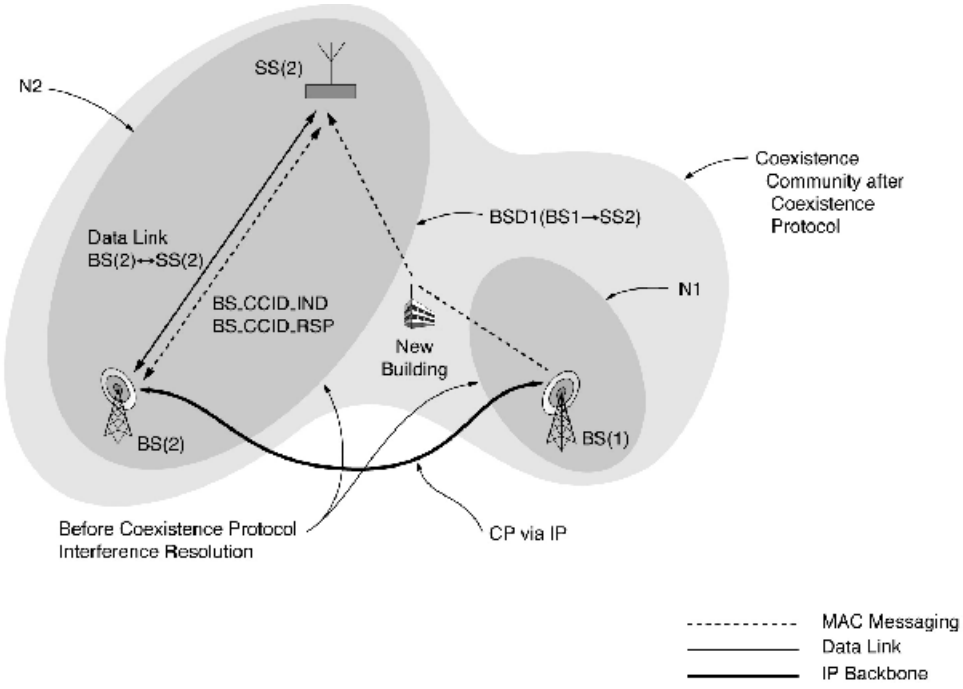

TIME
BS(1)
BS(2)
SS(2)
NOTES
CMI(1)
BSD(1)
BSD(1) received at SS(2)
BS_CCID_IND
SS(2) sends to BS(2)
Evaluate
Interference Request
CP Negotiation
(BS(2) BS(1) negotiate via CP)
BS_CCID_RSP
BS(2) assigns SS(2) downlink
data to an interference free slot
- informs SS(2)
- SS(2) updates SS
interference Table
CMI(1)
BSD(1)
On next detection of BSD(1):
SS(2) inhibits response since
interference is resolved.

Figure (1)


N2
SS(2)
Coexistence
Community after
Coexistence
Protocol
BSD1(BS1→SS2)
Data Link
BS(2)↔SS(2)
BS_CCID_IND
BS_CCID_RSP
N1
New
Building
BS(2)
BS(1)
Before Coexistence Protocol
Interference Resolution
CP via IP
MAC Messaging
Data Link
IP Backbone

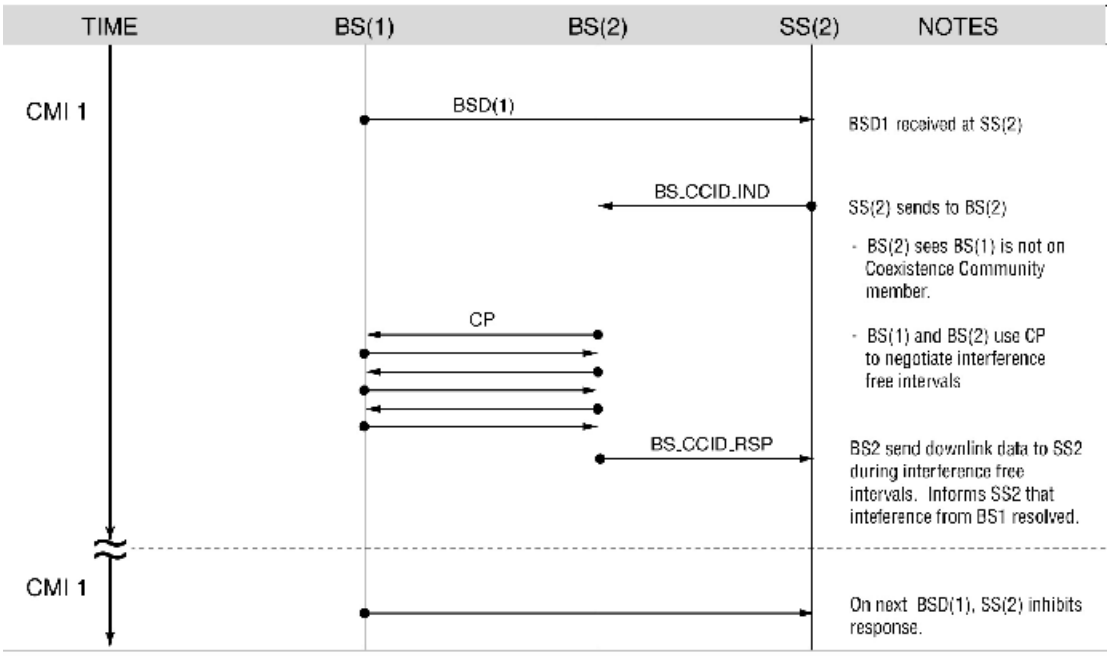

TIME
BS(1)
BS(2)
SS(2)
NOTES
CMI 1
BSD(1)
BSD1 received at SS(2)
BS_CCID_IND
SS(2) sends to BS(2)
- BS(2) sees BS(1) is not on Coexistence Community member.
CP
- BS(1) and BS(2) use CP to negotiate interference free intervals
BS_CCID_RSP
BS2 send downlink data to SS2 during interference free intervals. Informs SS2 that inteference from BS1 resolved.
CMI 1
On next BSD(1), SS(2) inhibits response.

Figure (2)