Considerations on Connection Based Over-the-air Inter Base Station Communications: Logical Control Connection and its Application to Credit Token Based Coexistence Protocol

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Considerations on connection based over the air BS to BS communications

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Introduction

• Over the air BS to BS communication principle and mechanisms are under discussion in both IEEE 802.22 WG and 802.16h TG

• Purpose of this contribution is to:
  – Present principles of possible other approaches for over the air BS to BS communication as complementary approaches currently followed in IEEE 802.16h TG
  – Provide some more material on this topic to further progress in IEEE 802.16h TG

• Content of this contribution is two-fold:
  – Present Logical Control Connection (LCC) principles for inter BS communications over the air
  – Present joint usage of LCC and credit token based co-existence protocol (CRCP).
Connection Based Inter-BS Communications

- Connection identifier (CID) specified as a key component
- Define a mapping between transmission-reception processes for deterministic communication scheduling
- Enable communication prioritization and reliability guarantee
- Enable secure inter-BS communications (with security association between coexisting BSs via bridging CPEs)
- Complementary to the contention based inter-BS communications method
Logical Control Connections (LCC)

- Connection based inter-system communications
  - Reliable, efficient
- Enable the feasibility and overall efficiency of the collaborative coexistence mechanism (e.g. to support the credit token based co-existence protocol (CTCP))
- Very low communications overhead
  - Spectrum bandwidth, Messaging latency, Hardware/software complexities
Logical Control Connection: The Principle
Bridge CPE

- Located in the overlapping area of two cells
- Associated with one BS (service BS) through service connections;
- Associated with another BS (coexistence BS) through coexistence connections
  - Coexistence communications only
Co-existence Connections

• Regular connections
  – Carry co-existence communications only

• Established and maintained
  – Between a bridge CPE and the coexistence BS (C-BS) on request by the service BS (S-BS)
  – Between two BSs
    • if S-BS is within the arrange of C-BS
    • S-BS behaves as a CPE of C-BS in such case
  – On channels occupied by the coexistence BS
Co-existence Connections

• Establishment/maintenance performed along with service data transmission
  – Ranging, connection acquisition
  – Controlled by S-BS and shall be guaranteed that they are not co-scheduled with service communications
LCC Between Two Base Stations
Over-the-Air Co-existence Communications

• **S-BS communicates with C-BS for co-existence via B-CPE as a relay**
  – Communications via Service connection + coexistence connection
  – S-BS controls the coexistence operations between B-CPE and C-BS

• **Coexistence communications**
  – Messaging for spectrum contention/negotiation,
  – Sensing measurement sharing,
  – Operation parameter (transmission power, channel in-use, etc.) announcement
Coexistence Communications Control for LCC

- S-BS (Service BS) controls the coexistence communications between B-CPE and C-BS (Coexist BS)
Logical Control Connection: Coexistence Communications Scheduling
Basic Scenarios and Conditions

• Two basic scenarios
  – Two/Multiple WirelessMAN-CXs sharing a single channel, which can only be occupied by one WirelessMAN-CX
  – Two/Multiple WirelessMAN-CXs sharing two/multiple channels or sub-channels of the same channel simultaneously

• Basic conditions
  – WirelessMAN-CXs synchronize MAC frames by sharing a common clock.
    • UTC stamps WirelessMAN-CX synchronization
    • Or, GPS
  – Self Coexistence Window (SCW) ~ CMI/CSI
  – Offeror Slots (OS) available for dedicated radio resource announcement, discovery and negotiation.
MAC Frame Structure

- OS: Offeror Slot, dedicated to a Offering WirelessMAN-CX system for announcing, discovering and negotiations the available radio resource

- SCW: Self Coexistence Window, a contention window shared by all systems for transmitting/receiving coexistence messages
Communications between Two WirelessMAN-CXs on a Single Channel: Scenario I
Scenario I – Announcement and Discovery

- C-BS announces its existence through Self Coexistence Window (SCW) or offeror slots (OS).
- B-CPE captures C-BS’s announcements and reports to S-BS.
- S-BS instructs B-CPE to notify S-BS’s existence to C-BS through SCW.
- S-BS and C-BS use the OS to enable offeror and renter BSs to communicate for CTCP (discovery, negotiation)
Scenario I – Initial Coexistence Resolution

- C-BS sends coexistence messages in SCW.
- S-BS responds to C-BS’s requests via B-CPE in SCW.
- If C-BS acquires partial of the channel, follow the procedure for scenario II.
- Else if C-BS fails to acquire the channel, go back to step 1 to repeat the coexistence resolution process.
- Else if C-BS acquires the whole channel
  - S-BS instructs B-CPE to setup Coexistence Connections with C-BS after the channel is released.
  - S-BS instructs B-CPE to request “Reserved Time Slots” (RTS) for B-CPE to S-BS communications on the channel after the channel is release.
  - S-BS provides B-CPE parameters (e.g. credit tokens) and strategies for coexisting with C-BS.
  - S-BS releases the channel at the time both S-BS and C-BS agree upon.
Scenario I – Coexistence Connection Establishment and Maintenance

- B-CPE, as instructed by S-BS, sets up coexistence connections with C-BS.
- B-CPE requests for “Reserved Time Slots” (RTS) for B-CPE to S-BS communications in the channel.
  - RTS: interference free time slots for S-BS to B-CPE communications on the coexistence channel

C-BS has acquired Channel A from S-BS
Scenario I – Inter-BS Communications
(C-BS occupies the channel)
Scenario I – Inter-BS Communications
(C-BS occupies the channel)

- Periodic RTS monitoring (performed by S-BS)
- B-CPE to C-BS communications
- Coexistence bandwidth allocation (performed by C-BS)
  - RTS (Reserved Time Slots)
- Feedback of coexistence bandwidth allocation (by B-CPE)
- B-CPE to S-BS communications using the granted RTS
- B-CPE to C-BS communications
Scenario I - Coexistence Resolution

S-BS has acquired Channel A from C-BS
Scenario I – Inter-BS Communications
(S-BS occupies the channel)

B-CPE to C-BS Comm.
B-CPE to S-BS Comm.
Reserved Time Slots (S-BS)
Reserved Time Slots (C-BS)
Scenario I – Inter-BS Communications
(S-BS occupies the channel)

- Periodic RTS monitoring (performed by C-BS)
- B-CPE to S-BS communications
- Coexistence bandwidth allocation (performed by S-BS)
  - RTS (Reserved Time Slots)
- Feedback of coexistence bandwidth allocation (by B-CPE)
- B-CPE to C-BS communications using the granted RTS
- B-CPE to S-BS communications
Communications between Two WirelessMAN-CXs on Two Channel (Scenario II)
Scenario II – Announcement and Discovery

- S-BS and C-BS announce their existence in self coexistence window (SCW).
  - If SCW is used, announcements can be done by base stations themselves or via bridge CPEs.

- S-BS and C-BS use the offeror slots (OS) to enable offeror and renter BSs to communicate for CTRP (discovery, negotiation)

- S-BS and C-BS capture the existences and channel usages/sharing information of each other.
Scenario II - Coexistence Connection Establishment and Maintenance

- S-BS instructs B-CPE to establish and maintain coexistence connections with C-BS in channel B.

- Similarly, C-BS could instruct CPE1 to establish and maintain coexistence connections with S-BS in channel A.
Scenario II - Inter Base Station Communications
Scenario II - Inter Base Station Communications

- **Periodic Coexistence Polling Slots (CPS)**
  - After coexistence connections has been established with B-CPE, C-BS periodically schedules Coexistence Polling Slots for asynchronized B-CPE to C-BS communications.
  - S-BS also schedules periodic CPS to reestablish communications with B-CPE after coexistence communications between B-CPE and C-BS has completed.
  - CPS could be used for coexistence message transmissions
Scenario II - Inter Base Station Communications

- **B-CPE to C-BS Communications**
  - S-BS schedules B-CPE to communicate with C-BS through the coexistence connections for a Coexistence Operation Period (e.g. 2-frame duration)
    - B-CPE switches to channel B and decodes the MAP of C-BS;
    - B-CPE sends BW requests (could be w/ coexist messages) via the scheduled CPS;
    - C-BS grants BW to B-CPE for communicating with B-CPE.
    - C-BS and B-CPE communicate with each other using the allocated BW.
  - During B-CPE to C-BS communication period, S-BS does not schedule CPS for B-CPE.
  - C-BS resumes CPS scheduling for B-CPE after the communications with B-CPE is completed.
Scenario II - Inter Base Station Communications

- **B-CPE to S-BS Communications**
  - After the Coexistence Operation Period, S-BS periodically schedules Coexistence Polling Slots for asynchronized B-CPE to S-BS communications, until B-CPE to S-BS communications are reestablished.
  
  - After B-CPE to C-BS communications, B-CPE switches back to channel A, and decodes the MAP of S-BS, in search of CPS of the S-BS.
  
  - B-CPE sends BW requests (could be w/ coexist messages) to S-BS via the scheduled CPS.
  
  - S-BS grants BW to B-CPE for communicating with B-CPE.
  
  - C-BS and B-CPE communicate with each other using the allocated BW.
Joint LCC and Credit Token based Co-existence Protocol (CTCP) Usage

- CTCP between BSs enables a dynamic cooperative and fair radio resources sharing between offeror BS (O-BS) and renter BSs (R-BS).
- This protocol requires messages exchange between the O-BS and R-BS.
- Over the air messages between the offeror and renter BSs is needed to support the radio resources sharing opportunities advertisement discovery and negotiations between the WirelessMAN-CXs.
- The over the air discovery procedures consists in the discovery of O-BS’s radio resources sharing offers by the neighbouring R-BSs.
- The over the air negotiations consist of the different phases of the CTCP between O-BS and R-BSs.
- The messages between O-BS and R-BSs are conveyed by the CPEs that act as RF bridges between the O-BS and R-BSs.
- CTCP can use specific time intervals to convey these messages with the support of the LCC establishment and maintenance procedures.
In each RPT, N OS are available to any O-BS if needed. Different O-BSs can establish RF link with specific R-BS via LLC to enable CTCP. Each O-BS chooses an available OS.

CPS are used to establish the UL connections with B-CPEs to communicate with different R-BSs associated to a given O-BS operating on the corresponding OS.
Detection and identification of the O-BSs content by the renter CPEs (discovery).

Relaying of the O-BSs content to R-BS by the renter CPEs (discovery).

LCC procedures usage to support O-BS <-> R-BS communications enabling O-BS <-> R-BS negotiations with the CTCP

- B-CPE belongs to O-BS
- S-BS = O-BS
- C-BS = R-BS
Reliability Enhancement for Logical Control Connection
Reliable Inter-Bs Communication

• **Timeout and retransmission is used for**
  – handling message loss

• **Sequence number is used to make sure**
  – a response is for a appropriate request
  – duplicated messages are ignored by the receiver

• **To make sure that timeout mechanism works properly, a retransmission timeout (RTO) estimation algorithm is proposed**
Timeout and retransmission

Service Connections

Bridge CPE

Coexist Connections

Request Msg

Response Msg

Timer times out

Reset Timer

Service BS

Coexist BS
Sequence Number Maintenance

- 8 bits sequence number is used, the initial value is set to 0.
- The service BS maintains its sequence number
  - Each time a service BS sends a request message out, it increases sequence number.
- The coexist BS maintains one sequence number for each service BS which maintains a coexist relationship with it
  - if a request message with newer sequence number is received, the coexist BS shall send a response message out.
  - otherwise the received request message is deleted without response message being sent out.
Retransmission Timeout Estimation

srtt: smoothed RTT.
rttvar: smoothed mean deviation estimator.
RTO: retransmission timeout.
h, g: value which are smaller than 1.
Thank you!