Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Pre-proposals for IEEE802.15.8]
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Abstract: [This document presents pre-proposals on the PHY and MAC system design for 802.15.8 (PAC)]

Purpose: [To discuss technical feasibility of proposed system design for 802.15.8 (PAC)]

Content

1. Overview
2. System Architecture
3. Frame Structure
4. Peer Information (PI) and Context-aware ID (CAID)
5. General Scan Procedures
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7. Context-aware Association Procedures
8. Context-aware Synchronization Procedures
9. Channel Management Procedures
10. Reliable Multicast Transmission Procedures
11. Context-aware Power Control Procedures
12. Measuring & Reporting Procedures
13. Cross Layer Function
14. Conclusion
15. Contributors

Overview

Peer Aware Communication

- Infrastructure-less communication among peers within proximity
- Peer-to-Peer communication or Peer-to-Peer Network (P2PNW) is formed for a desired service/application within proximity
- Many P2PNWs can coexist in proximity
- One peer can participate in multiple services or applications, i.e. multiple P2PNWs

Context
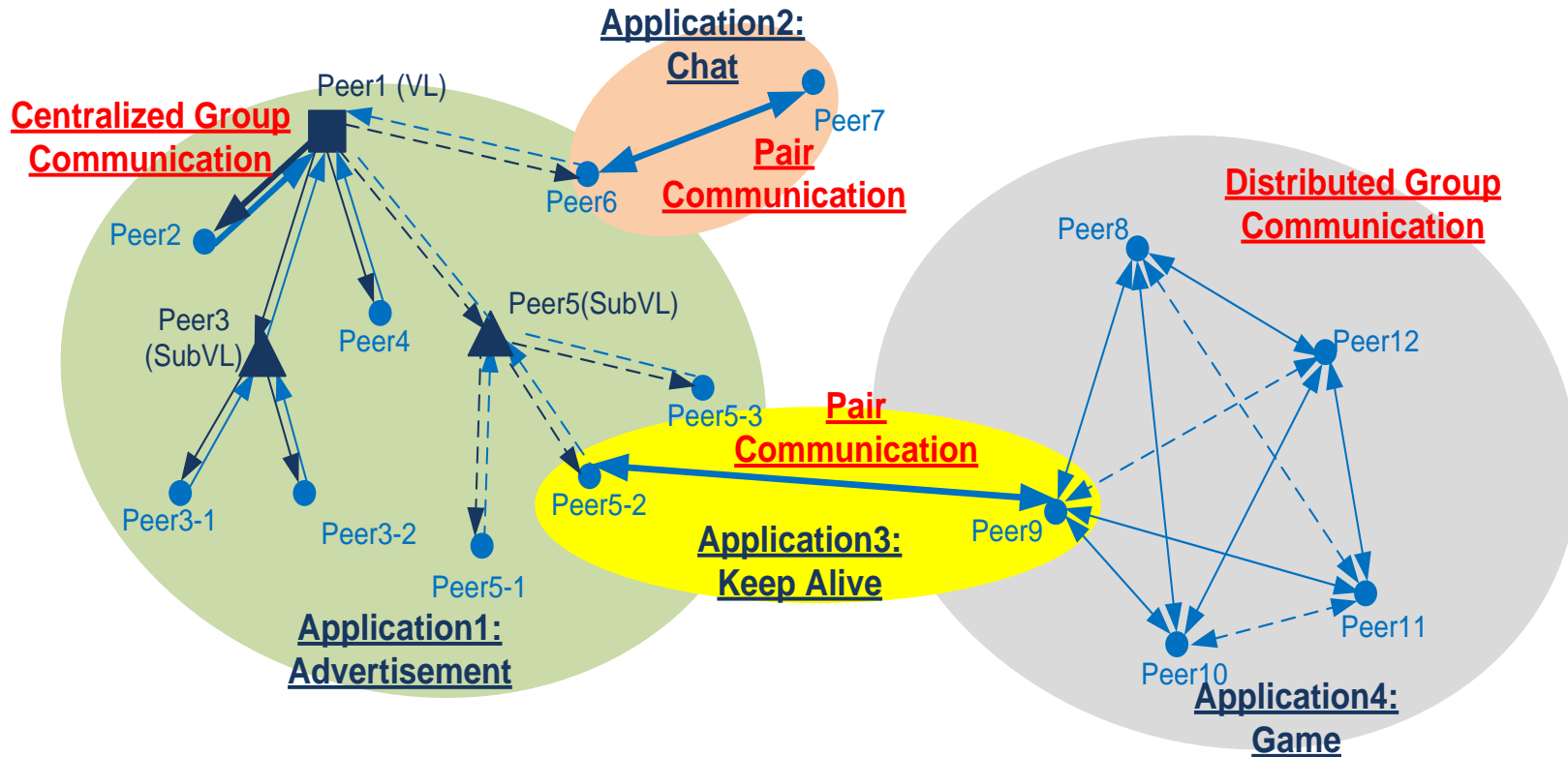
- Services, applications, users, devices, proximity, security, etc.

Context-aware

- All the peer-to-peer communications are formed for the **desired services /applications /users /devices** etc. in the proximity, i.e. **Context-aware Peer-to-Peer Communications** or **Context-aware P2PNWs**.

Overview (cont.)

PAC Networks in Proximity
→ Context-Aware Peer-to-Peer Communications

Overview (cont.)

PAC Challenges

- Infrastructure-less: no central controller or coordinator.

- Service driven: the P2P networks are formed and ceased very dynamically based on the desired services.

- Vast range of use cases: low data rate & low duty cycle, such as the keep alive for social networking; high data rate & long duty cycle, such as gaming.

- Most end-to-end devices are battery constrained: both end devices may need battery saving mode, i.e. the device won't be there checking or listening all the time.

➔ There is no one-fit-all solution. Need multiple control or management approaches to cover all the use cases.

Peers in P2P Communications

Virtual Leader (VL):

- A peer defined to represent, manage, and coordinate the P2P communications among a group of peers sharing the same context-based service/application, or intra-P2PNW communications.
- A VL may be dynamically determined and/or changed within the P2PNW.
- One VL for one application; one application can have only one VL.
- The peer initiates a P2P communication or P2PNW is the default VL until a new VL is selected within the P2PNW.

Super Virtual Leader (SuperVL):

- A peer defined to coordinate with all VLs, or inter-P2PNW communications in proximity.
- A super virtual leader may be dynamically determined and/or changed among the virtual leaders.
- The super virtual leader is the top leader of the VLs' hierarchical structure. Only one SuperVL in the proximity.
- The peer initiated the first P2P communication or P2PNW is the default SuperVL until a new SuperVL is selected in the proximity.

Sub-Virtual Leader (SubVL):

- A peer defined to extend coverage through multi-hop. A SubVL is a VL for the subgroup peers under; a peer under the VL or a SubVL.
- The SubVL may have a subset of VL's function.

Virtually Centralized Control Scheme
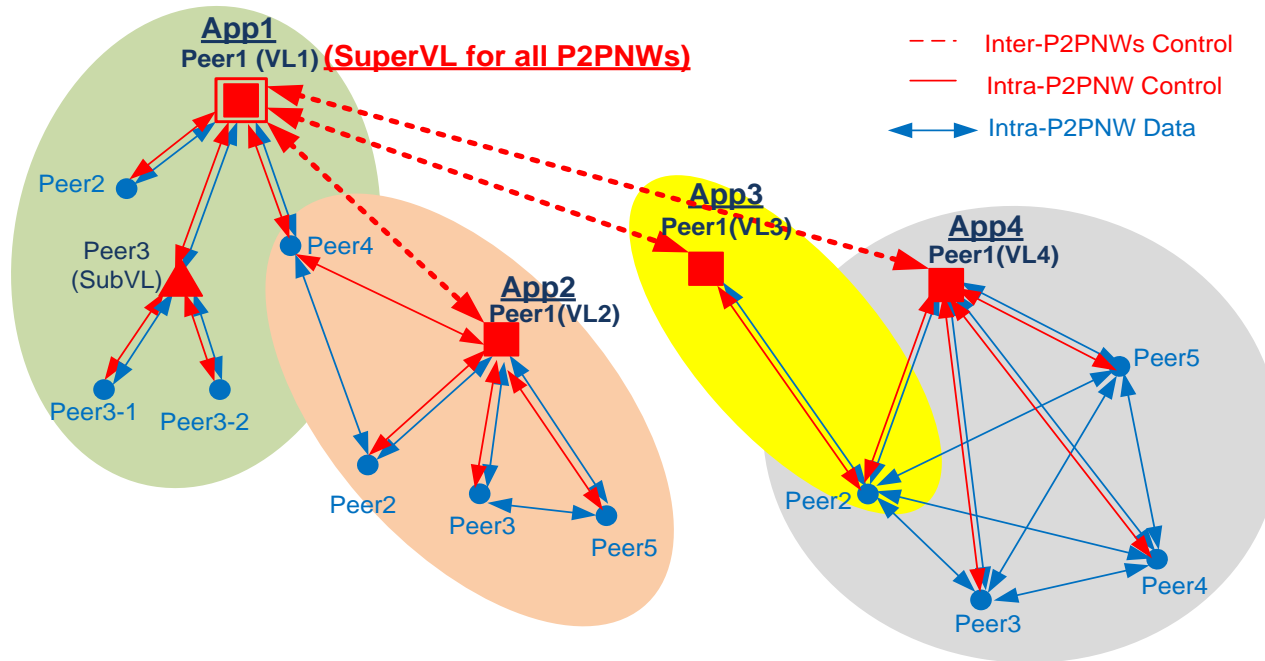
- **Inter-P2PNWs**: virtually centralized control by SuperVL among P2PNWs
- **Intra-P2PNW**: virtually centralized control by VL within a P2PNW

- **Typical Scenario**: high density of peers with variety of P2P services, e.g. shopping mall, amusement park, sport arena, etc. For example, a department store's advertisement "Peer" at a shopping mall can be a superVL virtually coordinating and managing all the P2P communications in the proximity.

Fully Distributed Control Scheme
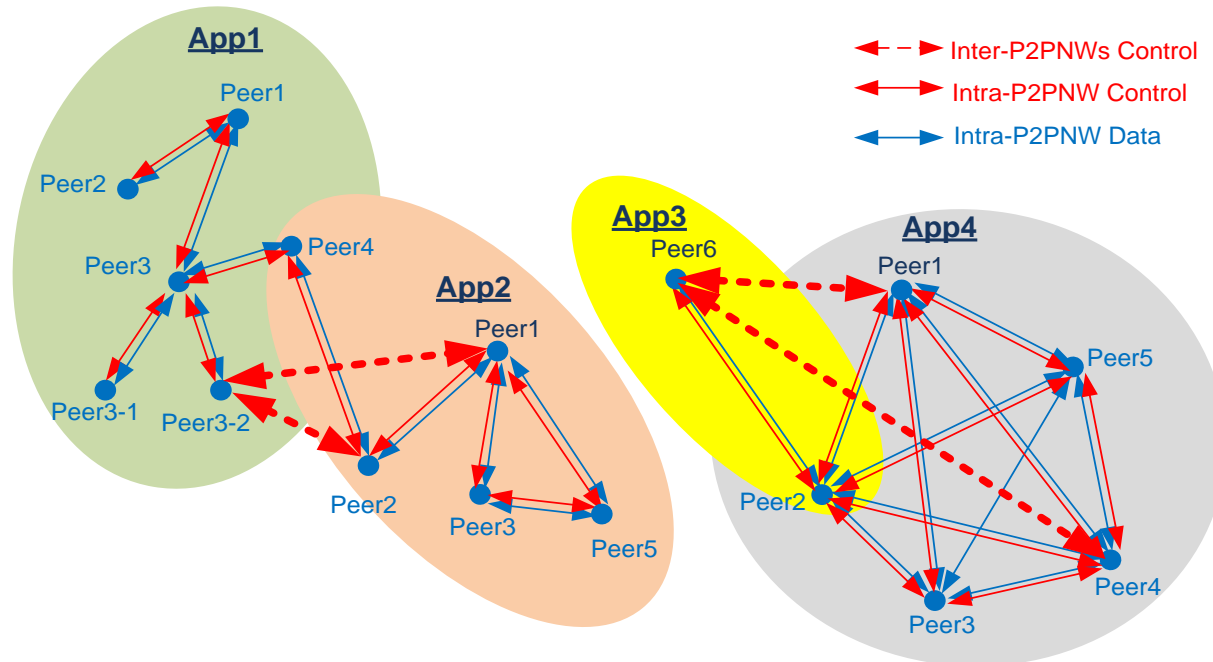
- **Inter-P2PNWs**: distributed control among peers in proximity
- **Intra-P2PNW**: distributed control among peers within a P2PNW
- **Typical Scenario**: low density of peers with a few P2P services in proximity, e.g. rural area. For example, P2P communications among the searching or exploring teammates.

Hybrid Control Scheme
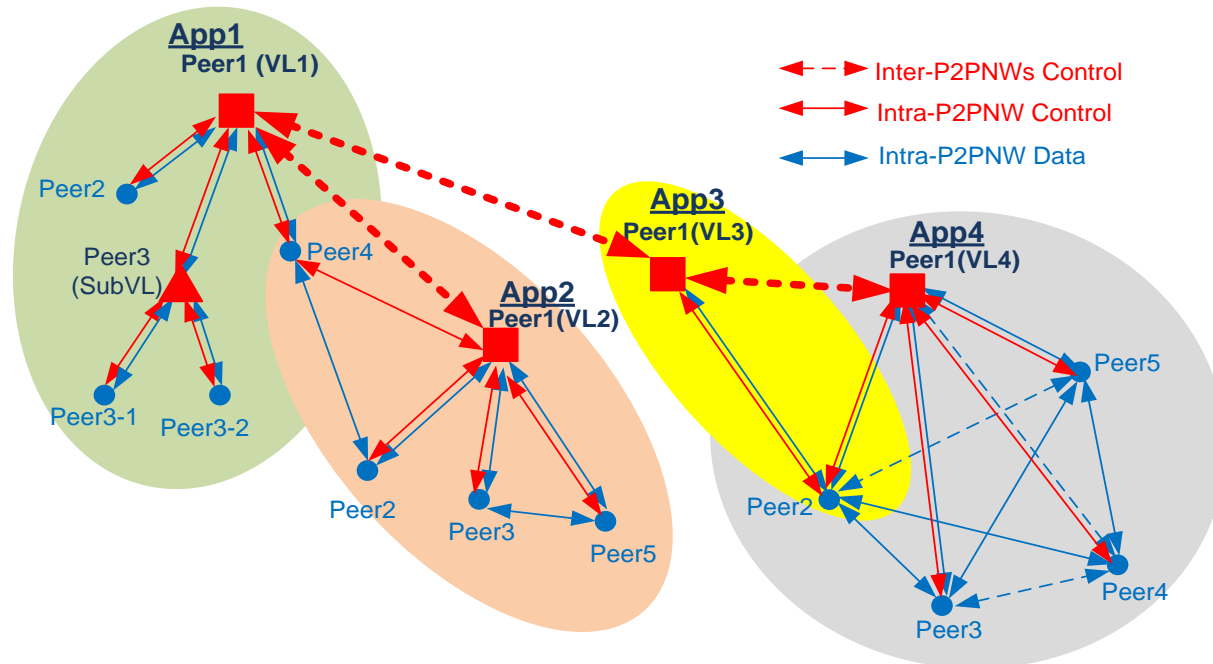
- **Inter-P2PNWs**: distributed control among VLs in proximity
- **Intra-P2PNW**: virtually centralized control by VL within a P2PNW
- **Typical Scenario**: medium density of peers with some P2P services in proximity, e.g. smart office or smart home. For example, P2P conference and P2P brainstorming sessions in the office area.

System Architecture

- Block diagram of system architecture
- Call flow of system procedures
- Flowchart of system operations
- Interfaces of system logic functions

Frame Structure

- Super frame structure

- PHY & MAC frame structure

- Multiplex schemes:
  - TDMA/OFDM
  - OFDM
  - CDMA/DSS

Common and Dedicated Channels

CCDCH (Common Control and Data Channel) is defined for inter-P2PNWs communications and shared by SuperVL, VLs, SubVL(s) or Peers of all services or applications or P2PNWs in proximity.

- Common control messages for inter-P2PNWs in proximity
- Paging or broadcast messages for inter-P2PNWs in proximity
- Short high priority data transmissions to all P2PNWs in proximity

DCDCH (Dedicated Control and Data Channel) is defined for intra-P2PNW communications and shared by the VL, SubVLs and peers within a P2PNW.

- Common control messages for intra-P2PNW
- Paging or broadcast messages for intra-P2PNW
- Short high priority data transmissions within a P2PNW

Super Frame Structure (TDMA/OFDM)

Super Frame Structure (OFDM)

DCDCH3
(k₃ subcarriers)

App3
DCDCH3
(1ˢᵗ i₃ slots)

App3
DCDCH3
(1ˢᵗ i₃ slots)

CCDCH
(k subcarriers)

DCDCH1
(k₁ subcarriers)

CCDCH
(1ˢᵗ i slots)

App1
DCDCH1
(1ˢᵗ i₁ slots
after CCDCH)

CCDCH
(1ˢᵗ i slots)

App1
DCDCH1
(1ˢᵗ i₁ slots
after CCDCH)

DCDCH2
(k₂ subcarriers)

DCDCH4
(k₄ subcarriers)

App2
DCDCH2
(1ˢᵗ i₂ slots)

App4
DCDCH4
(1ˢᵗ i₄ slots)

Frame 1

Frame 2

QL, CW, ZD, HL, PR, InterDigital
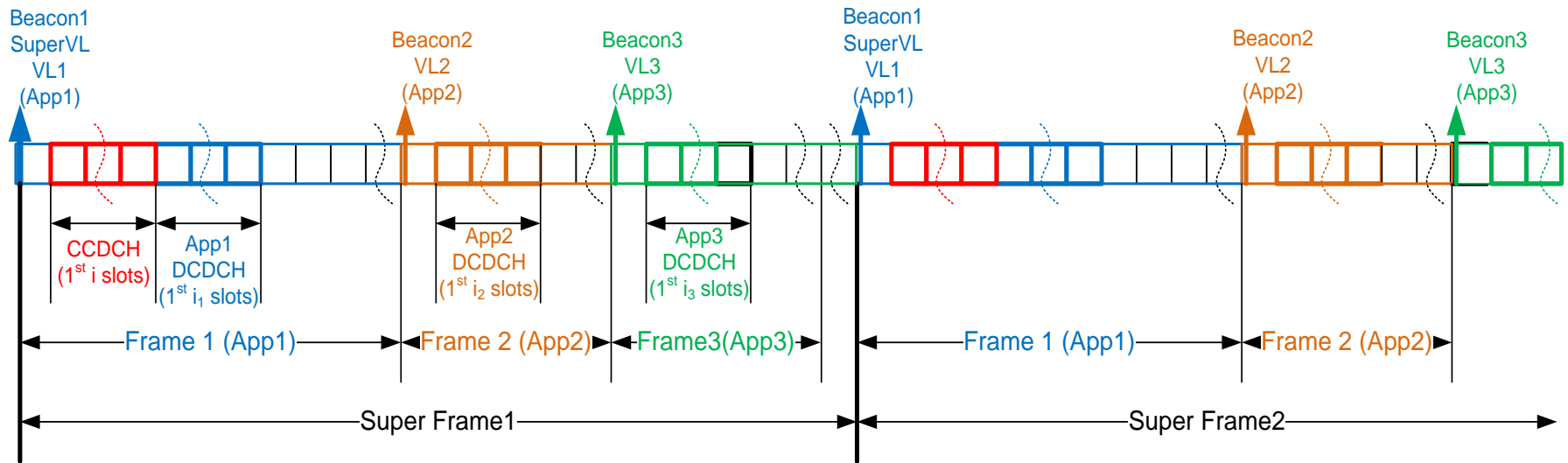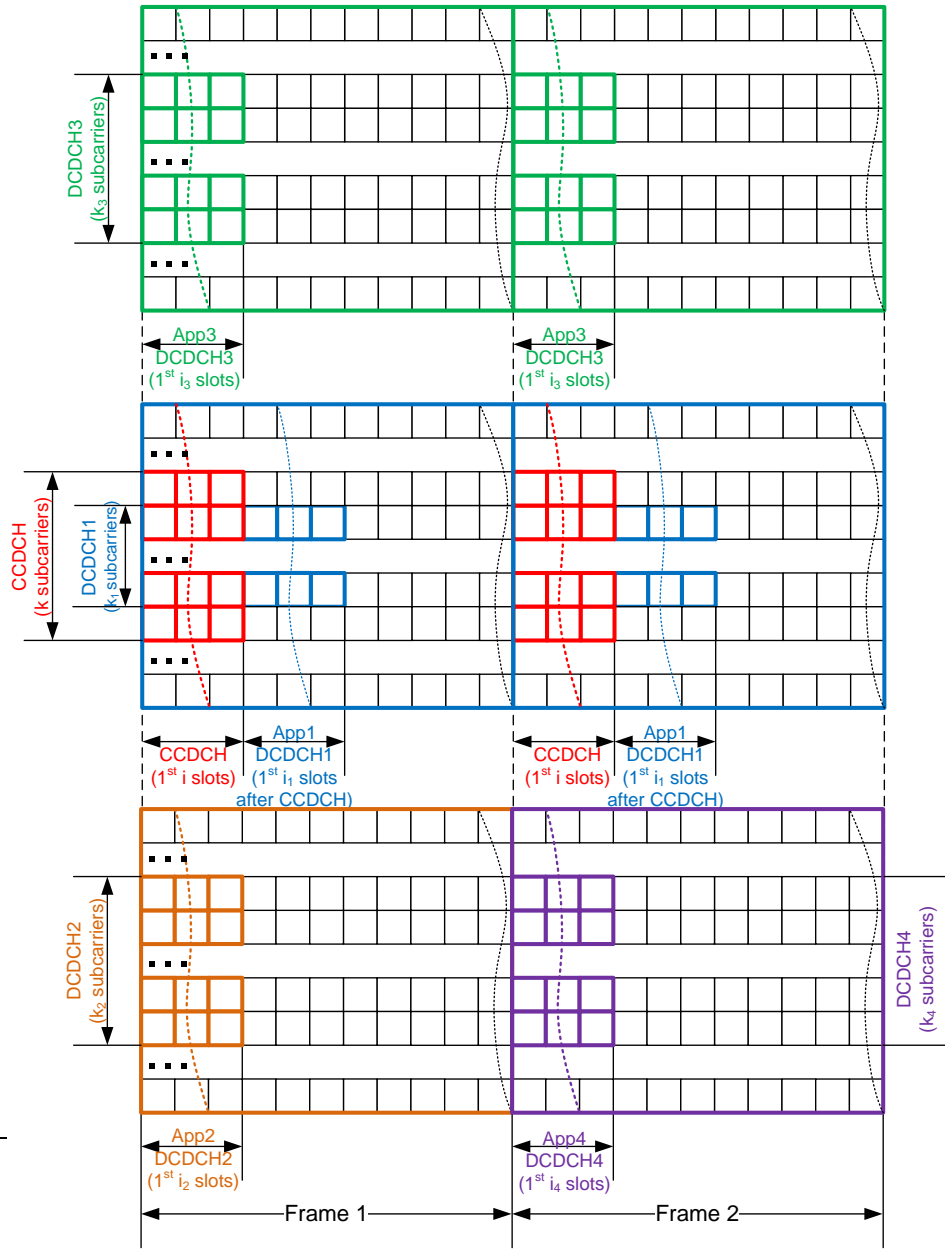
Super Frame Structure (CDMA/DSS)
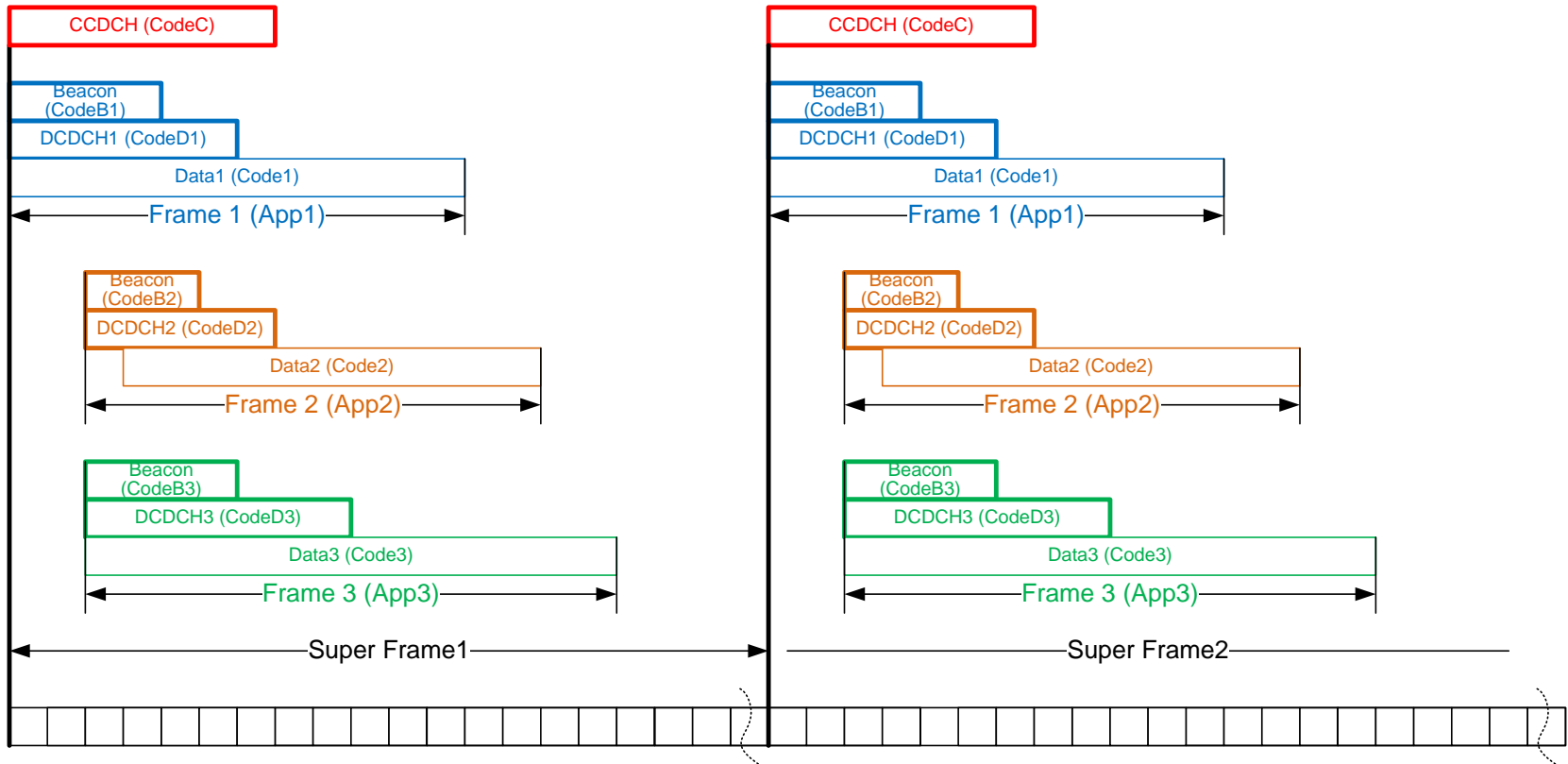
Peer Information (PI) and Context-aware ID (CAID)

PI and CAID

Hierarchical Structure of PI

Context item(s)	User ID/Device ID	Context item(s)	Payload Data	...

Context-aware Identifier (CAID)

PI
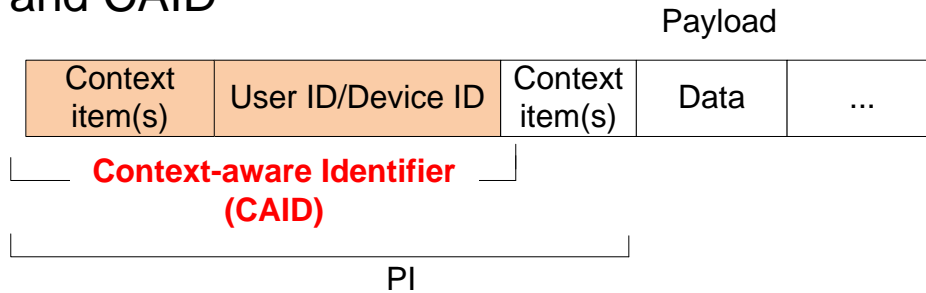
CAID based PAC
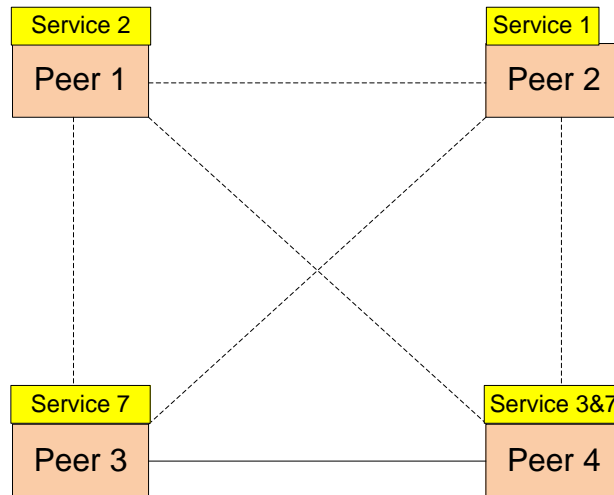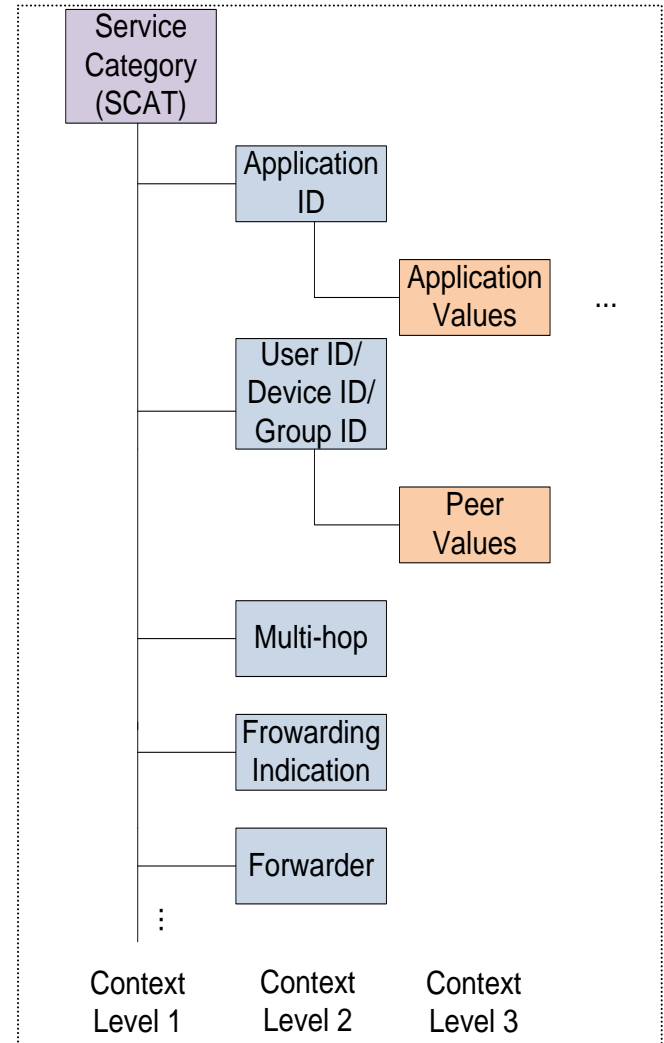
General Scan Procedures

- General Procedures

- Schemes
  - Virtually Centralized control
  - Hybrid control
  - Distributed control

Context-aware Fast Discovery Procedures

- General context-aware discovery procedure

- Fast peer discovery scan procedure

- 1-to-N discovery procedure

- Multi-hop discovery procedure

General Context-aware Discovery Procedure

Fast Peer Discovery Scan Using Context-aware ID

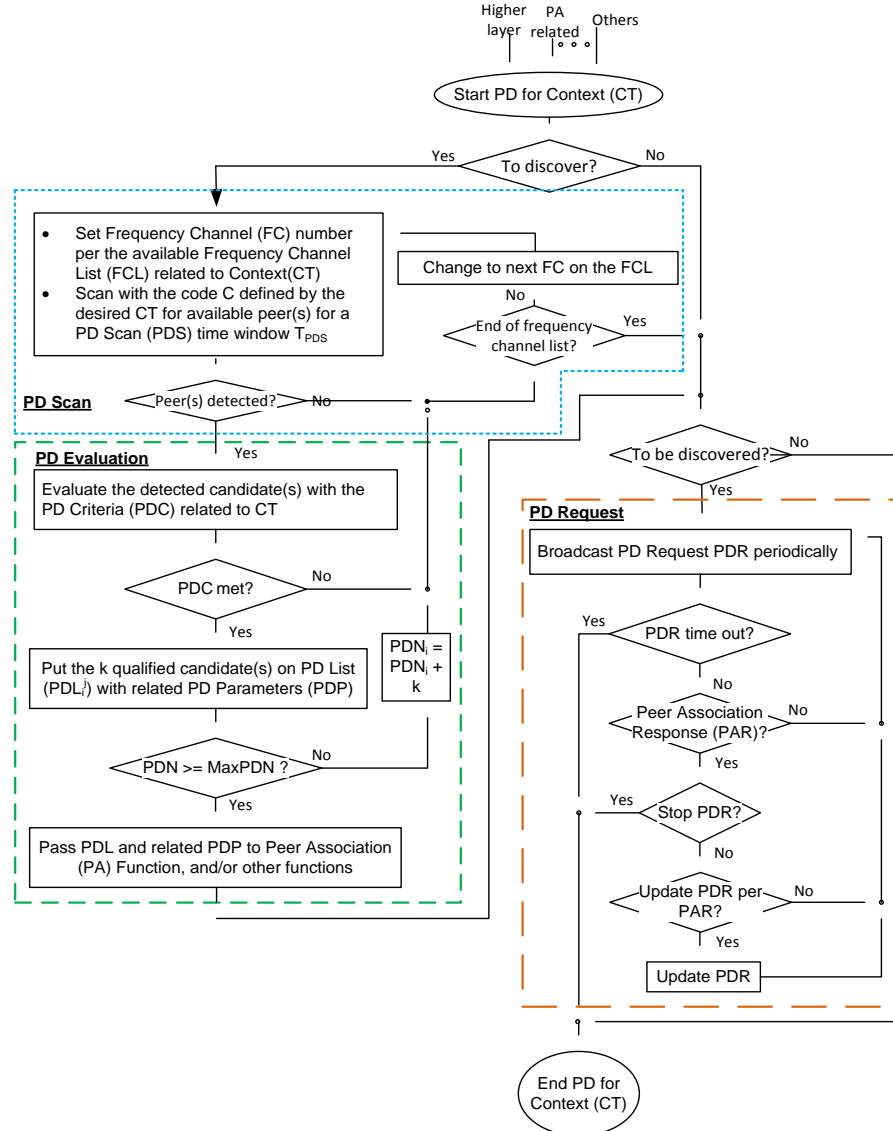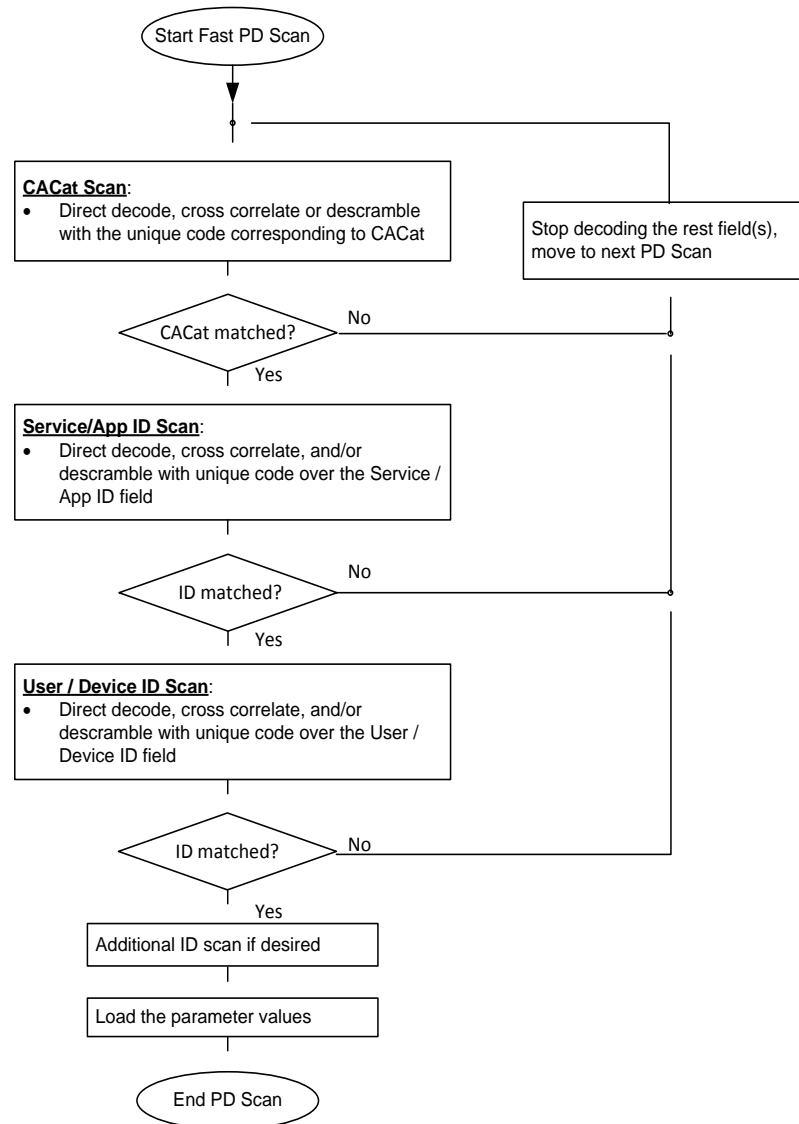| Service Based				
Context-aware Category (CACat)	*Service ID (SID)*	*User ID (UID)*	*AP Parameters (APParam)*	*Others*
Emergency	War Fire Medical …	Homeland Security Police Patient …	Region, broadcast/multi-cast… Location, severity, help center… Hospital, doctor, privacy level… …	
High Priority	Flood watch …	Weather forecast center …	Region, time, severity, help center…	
Connection	Facebook …	Facebook User ID	Chat, status update…	
Advertisement	Service x Product y …	Agent or store Manufacture or store …	Price, discount, forward credit… Price, club coupon, expiring date… …	
User Centric Activities	Content exchange	User ID	Content name, size, privacy…	
Smart Environment	Device Sync	User ID	Device list, items to synchronize…	
Smart Transportation	Traffic	Traffic controller	Location, time, status…	
Network of Network	Network name	Network ID	Context, load, parent network…	
User Based				
Context-aware Category (CACat)	*User ID (UID)*		*User Parameters (UParam)*	*Others*
Gamer	User ID or virtual User ID		Games, game skill level…	
Multi-hopper	User ID		Level of hops, number of peers behind…	
Device Based				
Context-aware Category (CACat)	*Device ID (DID)*		*Device Parameters (DParam)*	*Others*
Tablet	Device ID		Manufacturer, operating system…	
Monitoring System	Device ID		Manufacturer, model…	

Fast Peer Discovery Scan Procedure

Start Fast PD Scan

CACat Scan:
- Direct decode, cross correlate or descramble with the unique code corresponding to CACat

Stop decoding the rest field(s), move to next PD Scan

CACat matched? — No / Yes

Service/App ID Scan:
- Direct decode, cross correlate, and/or descramble with unique code over the Service / App ID field

ID matched? — No / Yes

User / Device ID Scan:
- Direct decode, cross correlate, and/or descramble with unique code over the User / Device ID field

ID matched? — No / Yes

Additional ID scan if desired

Load the parameter values

End PD Scan

Association Identifier and
Association Context Information

- Association Identifier (AID)
  - DAID: Device-based Association Identifier
  - SAID: Service-based Association Identifier
  - UAID: User-based Association Identifier
- Association Context Information (ACI)
  - An ACI contains properties and related information of an established association
    - AID, Association Type, Creation Time, Association Duration, Association Priority, Current Status, etc
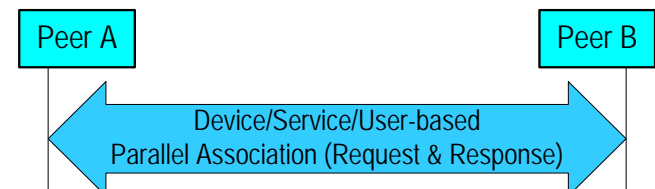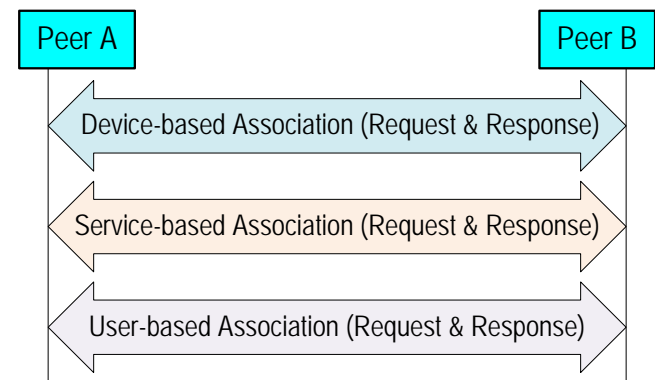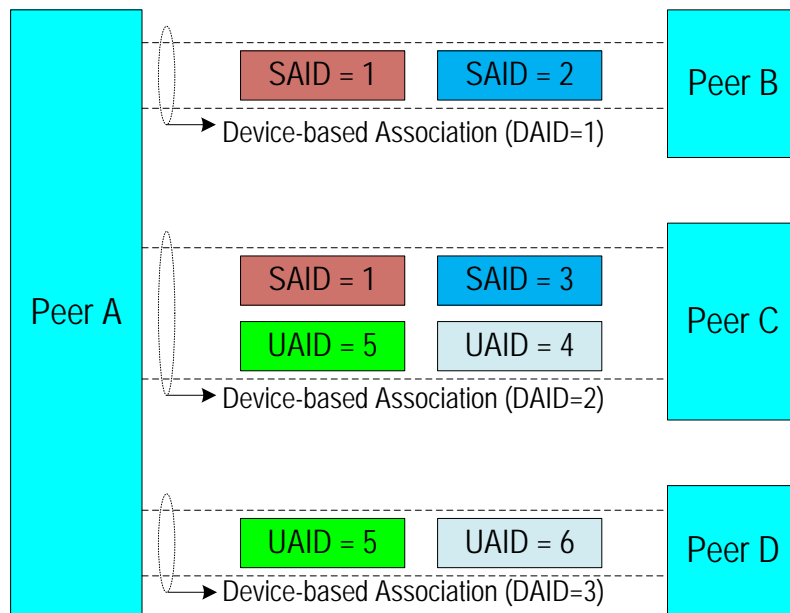
Context-Aware Peer Association

- Association Request: Requesting association (Approach 1 & 2)
  - Association Request Info: device profile, service profile, user profile, association requirement, etc
- Association Notification: Requesting mutual association (Approach 2)
  - Association Notification Info: device profile, service profile, user profile, communication configuration, etc
- Association Response: Responding association requests (Approach 1 &2)
  - Association Response Info: device profile, service profile, user profile, communication configuration, etc

Approach 1

Peer A		Peer B
	Association Request (Association Request Info) →	
	Acknowledgement	
	← Association Response (Association Response Info)	
	Acknowledgement	

Approach 2

Peer A		Peer B
	Association Request (Association Request Info) →	
	Acknowledgement	
	← Association Notification (Association Notification Info)	
	← Association Response (Association Response Info)	
	Acknowledgement	
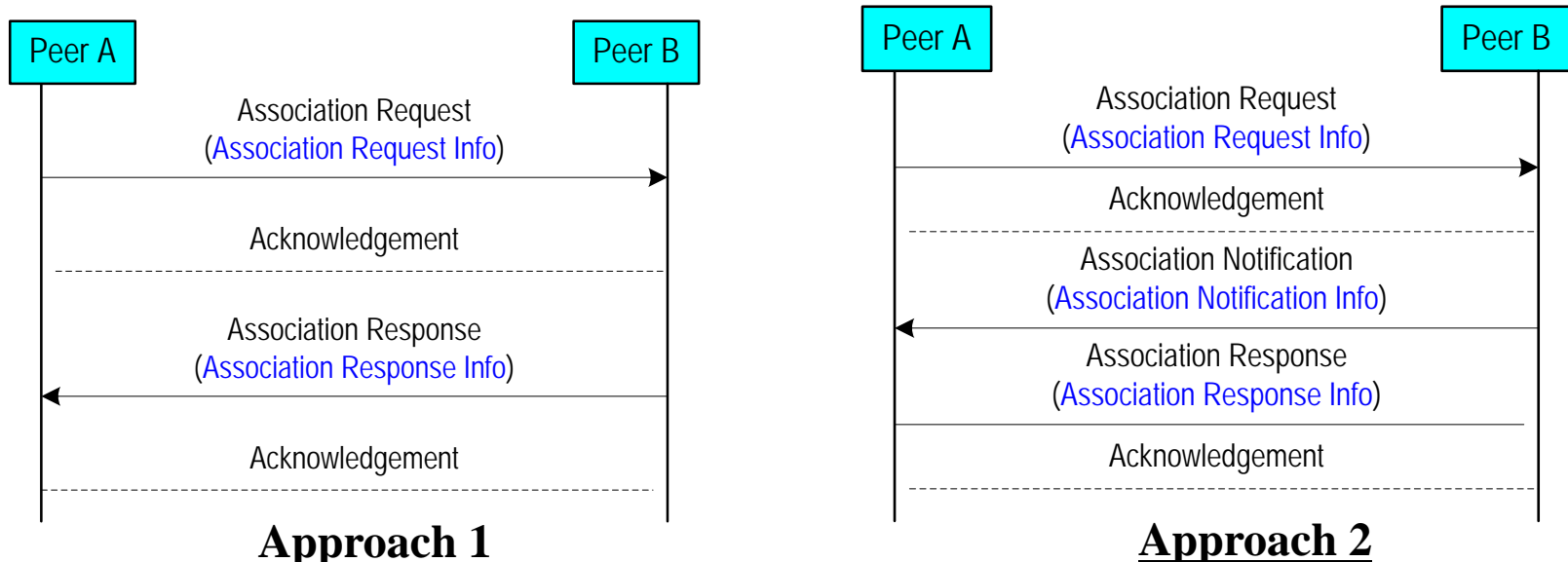
Overall Association-related Procedure

- Context-aware association, association update, dis-association, and re-association

Peer A	Peer B

Context-Aware Peer Discovery

Context-Aware Peer Selection

Context-Aware Association: generate an Association ID (AID)

Actions   Actions

Context-aware Association Update (an existing AID): optionally a new AID

Actions   Actions

Context-aware Disassociation (an existing AID)

Actions   Actions

Context-aware Re-association (an optimally existing AID): generate a new AID

Actions   Actions

Context Aware Synchronization

- Synchronization with a P2PNW (Intra-P2PNW Sync)
  - Initial synchronization by leveraging context information
  - Synchronization under different control schemes
    - Virtually Centralized control
    - Hybrid Control
    - Fully distributed Control

- Synchronization between P2PNWs (Inter-P2PNW Sync)
  - A peer may support multiple applications (involved in multiple P2PNWs)
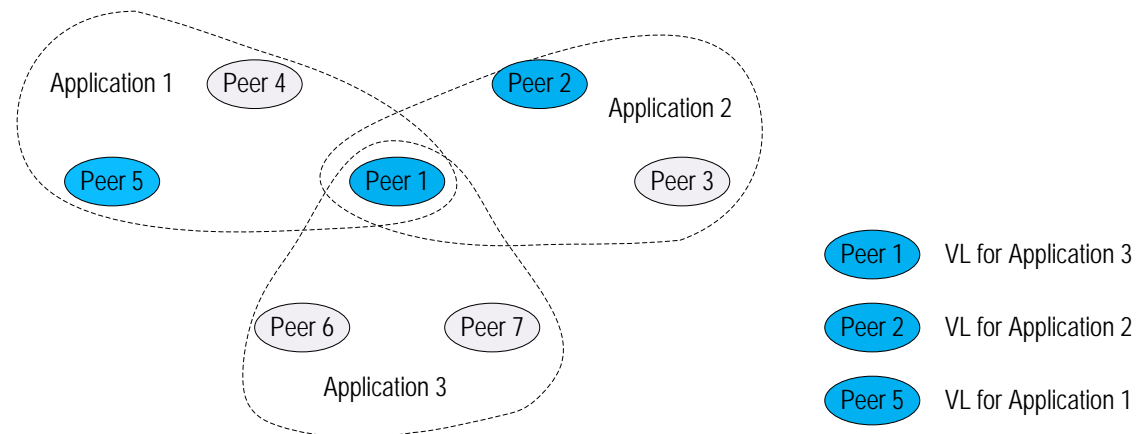
Intra-P2PNW Sync

- Take virtually centralized control as an example
- Super beacon sent by the Sup-VL contains context information
- Peer do not need to synchronize with the peers who are not of interest
- Different PHY sync schemes can be adopted into the framework
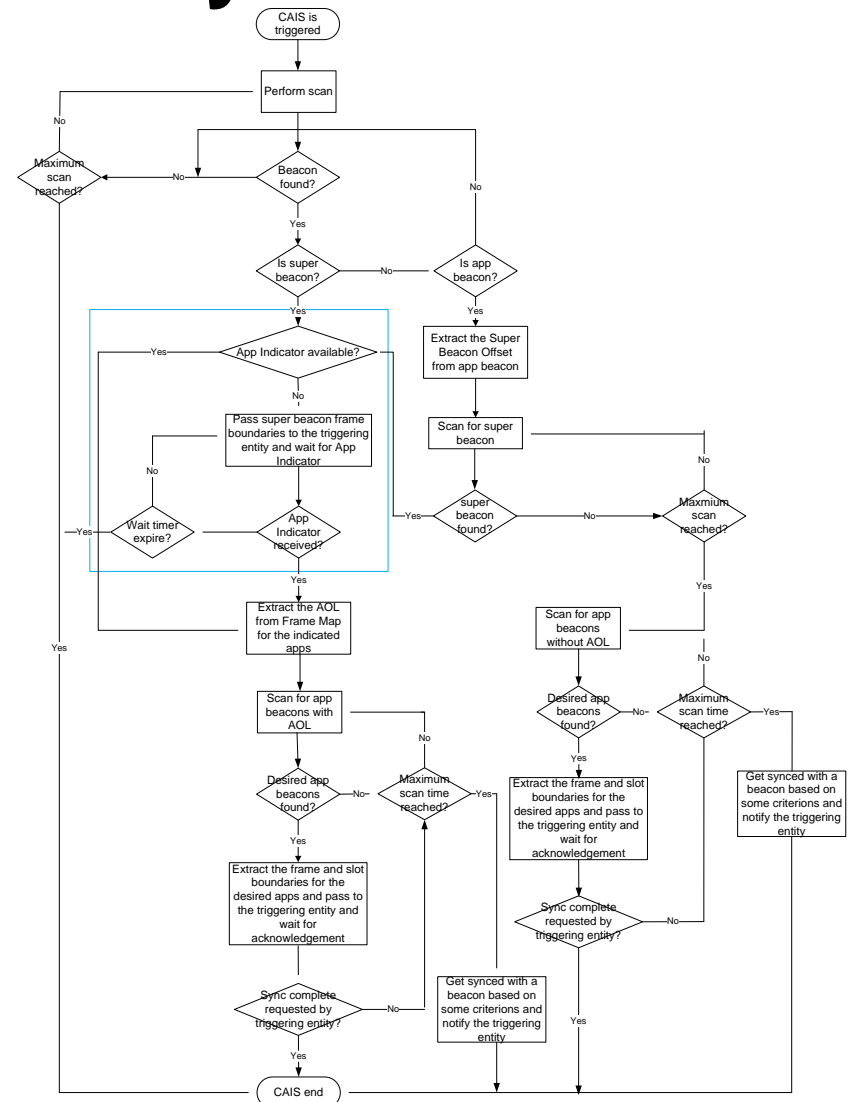
Inter-P2PNW Sync

- A peer may support multiple applications

- A new VL needs to sync to the existing P2PNWs

- The VL needs to periodically sync with the Sup-VL

- Different PHY sync schemes can be adopted into the framework
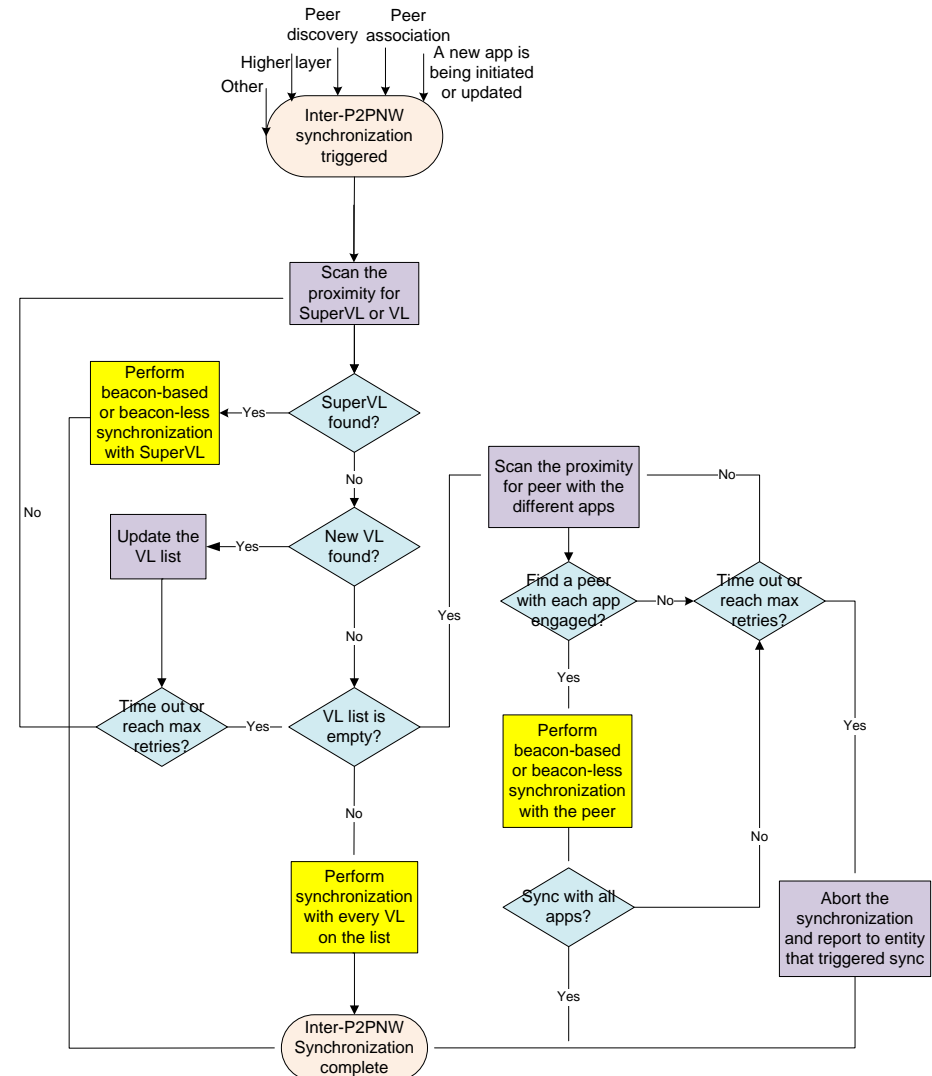
Channel Management Procedures

- Fast Inter-P2PNW Channel Accessing Procedure
- Fast Intra-P2PNW Channel Accessing Procedure
- Inter-P2PNWs Channel Allocation with P2PNW detection
  - for virtually centralized control
  - for distributed control
  - for hybrid control
- Inter-P2PNWs Channel Allocation with P2PNW cooperation.
  - for virtually centralized control
  - for distributed control
  - for hybrid control
- Intra-P2PNW Channel Allocation/Accessing with peer detection
  - for virtually centralized control
  - for distributed control
- Intra-P2PNW Channel Allocation/Accessing with peer cooperation
  - for virtually centralized control
  - for distributed control
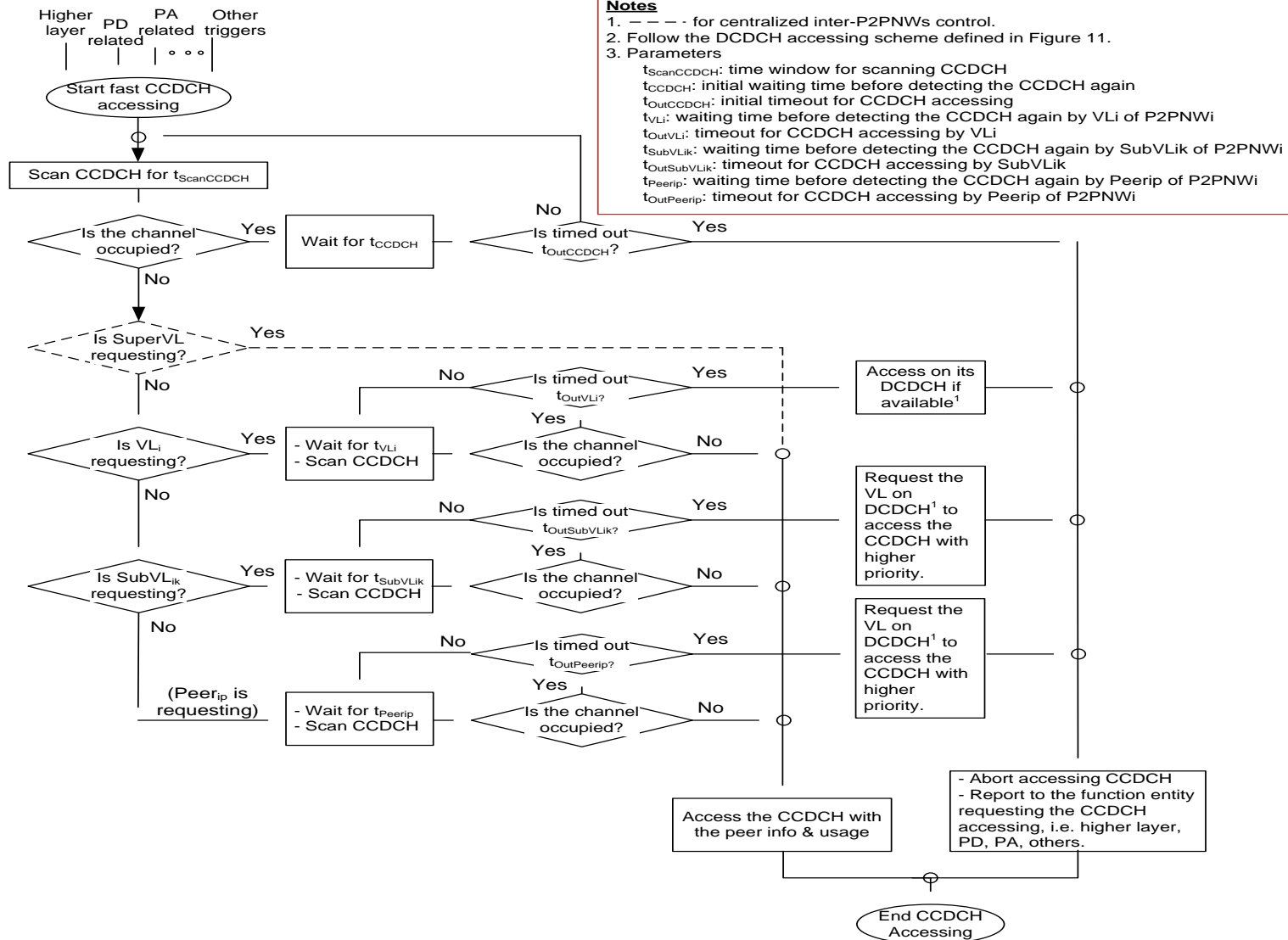
Fast Inter-P2PNW Channel Accessing Procedure

Notes
1. $---$ - for centralized inter-P2PNWs control.
2. Follow the DCDCH accessing scheme defined in Figure 11.
3. Parameters
   $t_{ScanCCDCH}$: time window for scanning CCDCH
   t_{CCDCH}: initial waiting time before detecting the CCDCH again
   $t_{OutCCDCH}$: initial timeout for CCDCH accessing
   t_{VLi}: waiting time before detecting the CCDCH again by VLi of P2PNWi
   t_{OutVLi}: timeout for CCDCH accessing by VLi
   $t_{SubVLik}$: waiting time before detecting the CCDCH again by SubVLik of P2PNWi
   $t_{OutSubVLik}$: timeout for CCDCH accessing by SubVLik
   t_{Peerip}: waiting time before detecting the CCDCH again by Peerip of P2PNWi
   $t_{OutPeerip}$: timeout for CCDCH accessing by Peerip of P2PNWi

Fast Intra-P2PNW Channel Accessing Procedure

Inter-P2PNW Channel Allocation (CA)

P2PNWs are **formed** and **ceased** very **dynamically** based on the needs for desired services or applications in proximity. Therefore any predefined channel allocation for P2PNWs in proximity is either limiting or inefficient.

➔Inter-P2PNWs CA with P2PNW Detection
- ✓ for Virtually Centralized Control
- ✓ for Distributed Control
- ✓ for Hybrid Control

➔Inter-P2PNWs CA with P2PNW Cooperation
- ✓ for Virtually Centralized Control
- ✓ for Distributed Control
- ✓ for Hybrid Control

Inter-P2PNWs CA with P2PNW Detection for Virtually Centralized Control

Higher | PD PA° ° ° | Others
layer | |

Start CA

P2PNW VL Detection

VLreq scans beacon/paging/
broadcast for VL

Timed out?   No
                    Yes

VL   Yes   - VLreq extracts superframe/frame
detected?   & slot/code/subcarriers info
                   - VLreq updates its VL list.
No

VL list   Yes *(No P2PNW detected)*
empty?

No *(No new P2PNW detected)*

CA for a   New VL

VLreq decides its superframe/frame & slot/code/
subcarriers based on the application, current VL list and
related superframe/frame & slot/code/subcarriers usage.

- VLreq broadcasts its request
with superframe/frame & slot/
code/subcarriers on CCDCH.
- VLreq waits for peers responses
on CCDCH.

Timed out?   No
                    Yes

Cooperation

Response?   No
Yes

Rejected?   No   All responses   No
Yes   on VL list?
                                    Yes

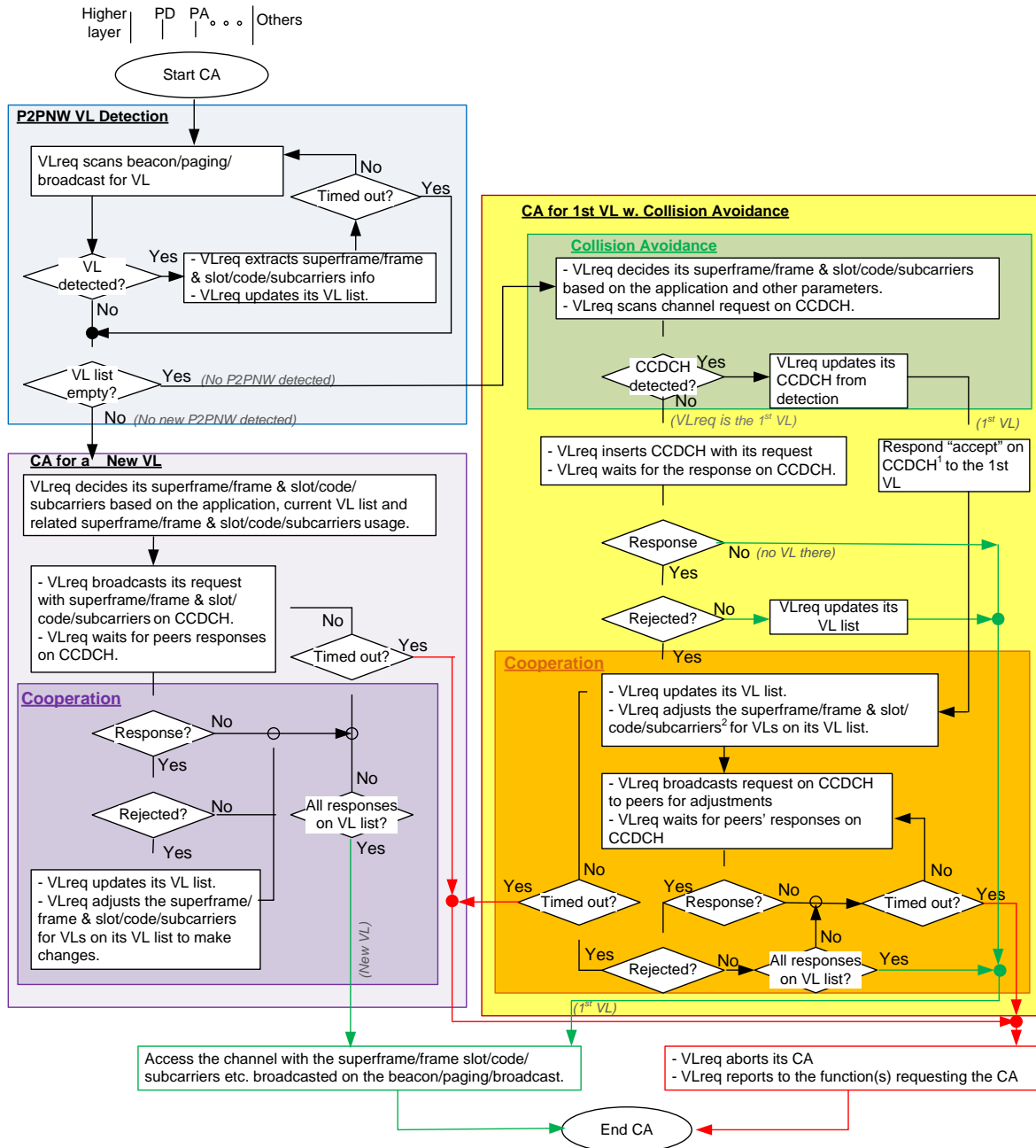- VLreq updates its VL list.
- VLreq adjusts the superframe/
frame & slot/code/subcarriers
for VLs on its VL list to make
changes.

(New VL)

CA for 1st VL w. Collision Avoidance

Collision Avoidance

- VLreq decides its superframe/frame & slot/code/subcarriers
based on the application and other parameters.
- VLreq scans channel request on CCDCH.

CCDCH   Yes   VLreq updates its
detected?   CCDCH from
                  detection
No

(VLreq is the 1st VL)   *(1st VL)*

- VLreq inserts CCDCH with its request   Respond "accept" on
- VLreq waits for the response on CCDCH.   CCDCH[1] to the 1st
                                            VL

Response   No *(no VL there)*
Yes

Rejected?   No   VLreq updates its
                 VL list
Yes

Cooperation

- VLreq updates its VL list.
- VLreq adjusts the superframe/frame & slot/
code/subcarriers[2] for VLs on its VL list.

- VLreq broadcasts request on CCDCH
to peers for adjustments
- VLreq waits for peers' responses on
CCDCH

Yes   No   Yes   No   No
Timed out?   Response?   Timed out?   Yes
                                   No

Yes   No   All responses   Yes
Rejected?   on VL list?

(1st VL)

Access the channel with the superframe/frame slot/code/
subcarriers etc. broadcasted on the beacon/paging/broadcast.

- VLreq aborts its CA
- VLreq reports to the function(s) requesting the CA

End CA

**Inter-P2PNWs CA
with P2PNW
Cooperation for
Hybrid Control**

Intra-P2PNW Channel Allocation/Channel Accessing

Intra-P2PNW Channel Allocation (CA)

- The intra-P2PNW Channel Allocation can be very dynamic,
  - a peer joins or leaves the P2PNW for gaming
  - a peer becomes a subVL for hopping or vice visa
  - personalized commercial advertisement in a store
- The intra-P2PNW CA needs to be adjusted accordingly whenever the inter-P2PNW CA with P2PNW cooperation is conducted

  → Intra-P2PNW Channel Allocation
  - ✓ For Virtually Centralized Control
  - ✓ For Distributed Control

## Intra-P2PNW Dynamic Channel Accessing (CAc)

- For a fully distributed group based P2PNW, the channel resources can be too limited to provide a dedicated channel for each peer. This can be very severe in a large fully distributed group based P2PNW at a very crowded area, i.e. many P2PNWs in proximity.
  - Share the limited channels with other peers each time for sending/receiving
  - Clear Channel Assessment (CCA) is required for accessing shared channels to avoid collision.
  - Fast DCDCH accessing, a very efficient approach for CCA.

  → Intra-P2PNW Channel Accessing (CAc).
 - ✓ For Virtually Centralized Control
  - ✓ For Distributed Control
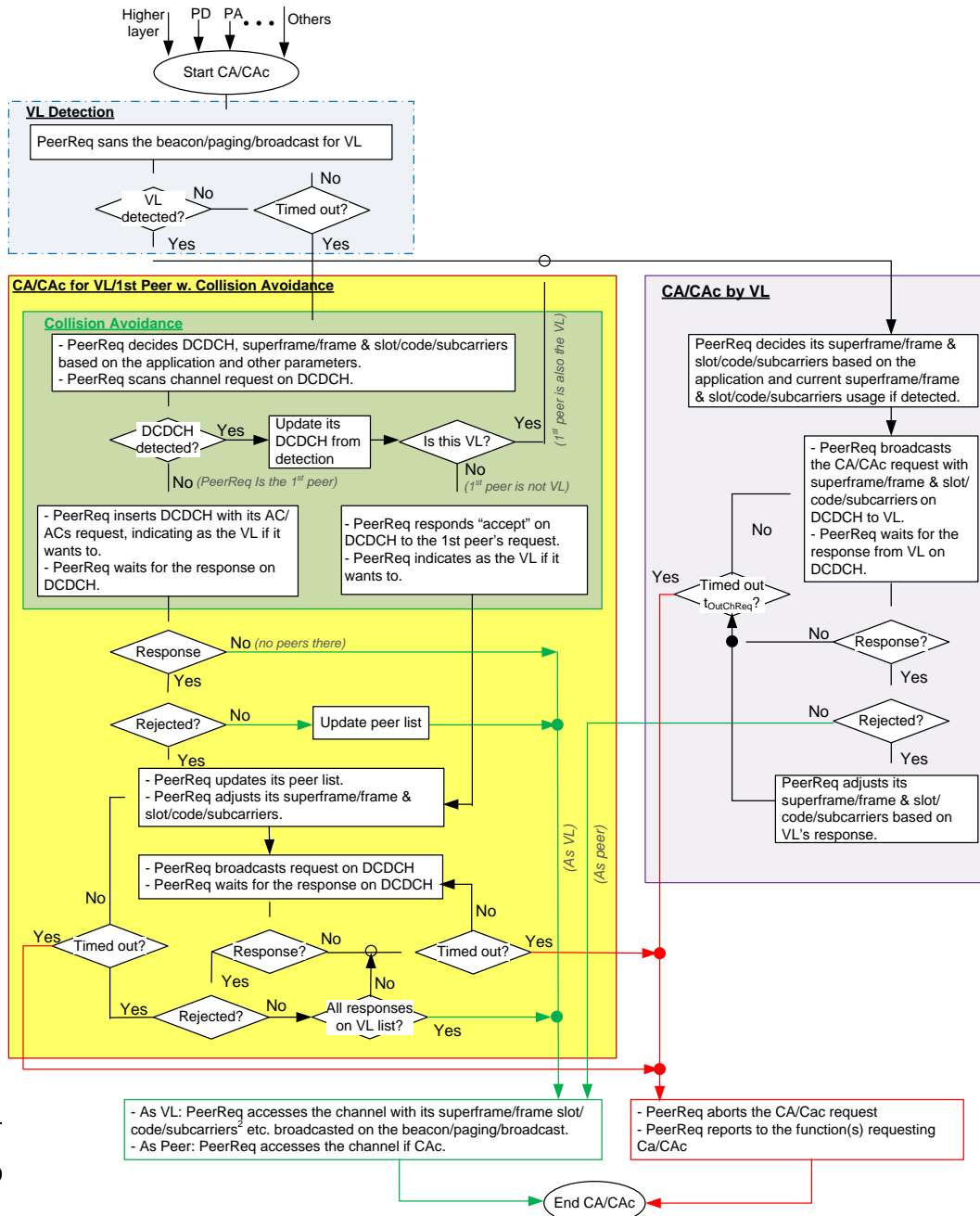
**Intra-P2PNW CA/CAc with Peer Detection for Virtually Centralized Control**
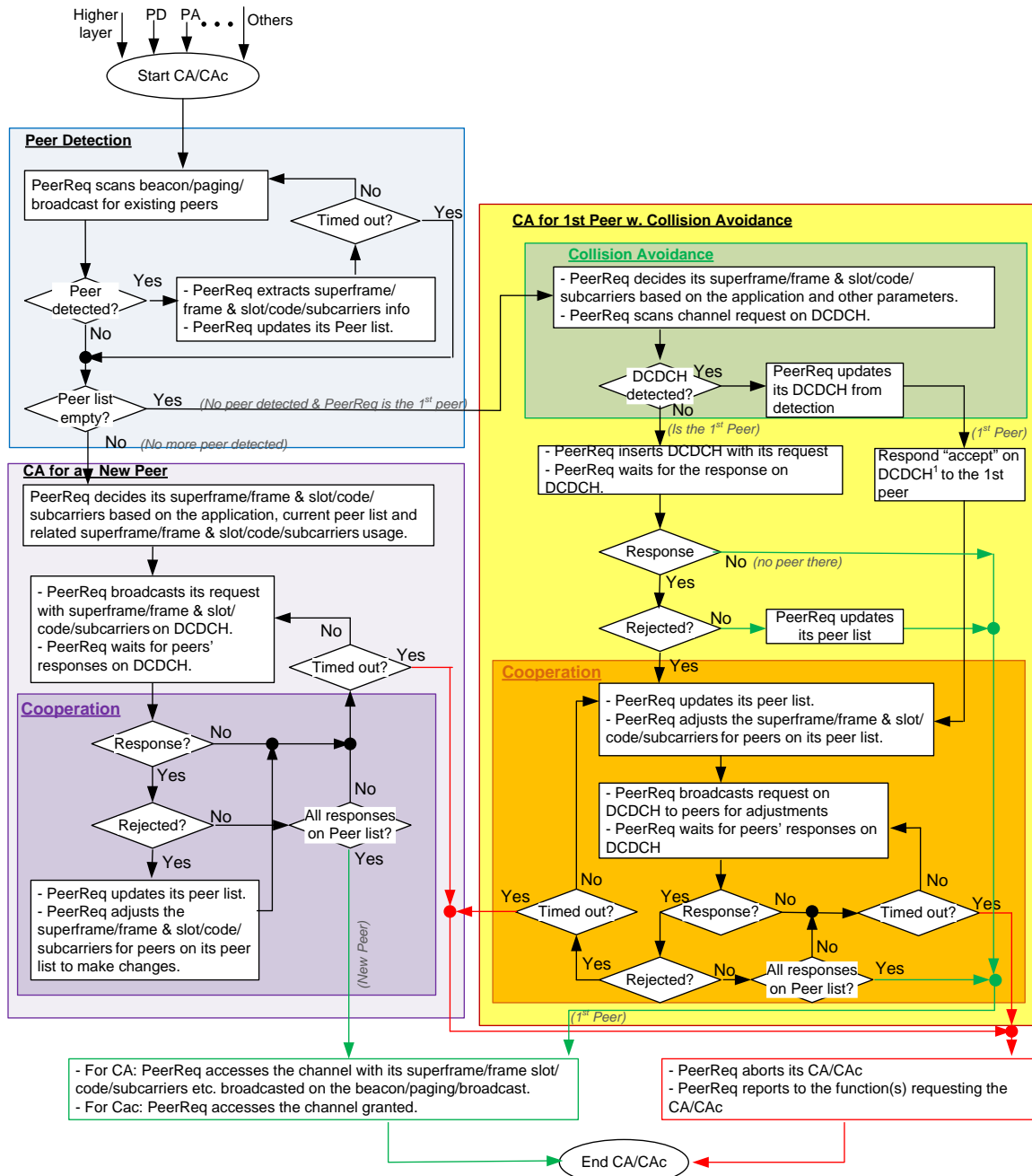
Intra-P2PNW CA/CAc with Peer Cooperation for Distributed Control

QL, CW, ZD, HL, PR, InterDigital

Reliable MAC Multicast Transmissions

- MAC Multicast Scenarios: One-Hop & Multi-Hop
- Context-Aware Reliable MAC Multicast
  - Flexible Reliability
    - ACK Type (Contained in MAC Data Frame): Full ACK, Partial ACK, Any ACK, Location-based ACK, Context-based ACK, Information-based ACK
  - ACK Collision Avoidance
    - ACK Broadcast, ACK Alignment, ACK Aggregation
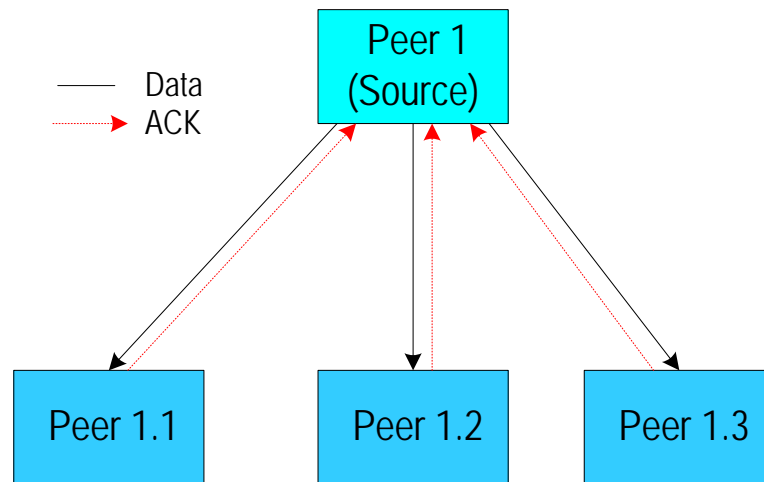
One-Hop
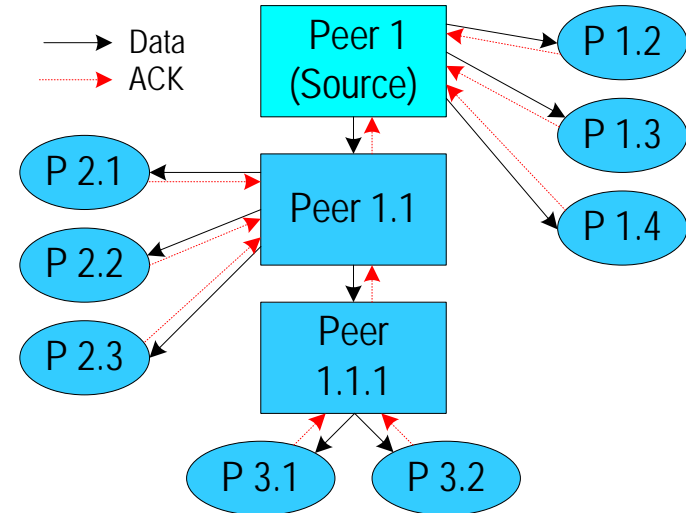
Multi-Hop

Context-aware Power Control Procedures

- Inter-P2PNWs power control
- Intra-P2PNW power control

Conclusion

A system design is proposed for infrastructure-less Peer-to-Peer communications.

- Context-aware
  - Context-aware Fast Discovery
  - Context-aware Fast Association/Disassociation/Re-association
  - Context-aware Synchronization

- Infrastructure-less
  - Channel Management / Accessing based on Peer Detection
  - Channel Management / Accessing based on Peer Cooperation

- Group Communication
  - Reliable multicast transmission

Contributors

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  - Zongrui Ding
  - Hongkun Li
  - Qing Li
  - Paul Russell, Jr.
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Thank You!

Any Questions?
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