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

Submission Title: [Samsung-ETRI Merged MAC Proposal to TG8 CFC]
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Re: [.]

Abstract: [Presentation of PAC procedures to meet functional requirements including identified features from PFD]

Purpose: [Corresponding to Call for Contribution]

Samsung-ETRI
Merged MAC Proposal to CFC

May, 2014

1. Overall

- High Competition for Next Big Trend
  - **Proximity-based Service**

Title	Company/ Organization	Note
iBeacon	Apple	Launched in December 2013
LTE Direct	3GPP	Specified until September 2014
NAN†	WiFi Alliance	Spec. 1.0

†NAN(Neighbor Awareness Networking)

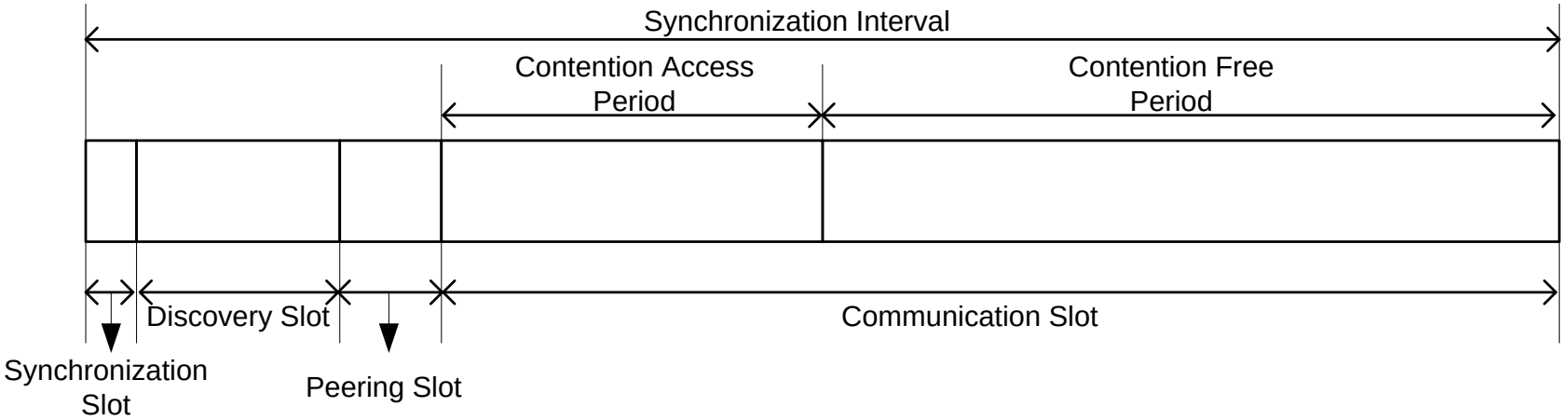
- PAC Competitive Features
  - Low power consumption for peer discovery
  - Large number of detected discovery information
  - Higher throughput for communication

1.1. PAC Procedures

- Synchronization
  - Based on distributed synchronization mechanism
- Peer Discovery
  - Broadcast Discovery Information via selected resource
- Peering
  - Link establishment for unicast and multicast links
- Data Traffic
  - Contention-based Access Period (CAP)
  - Contention-free period (CFP)
    - Request/Response-based resource assignment

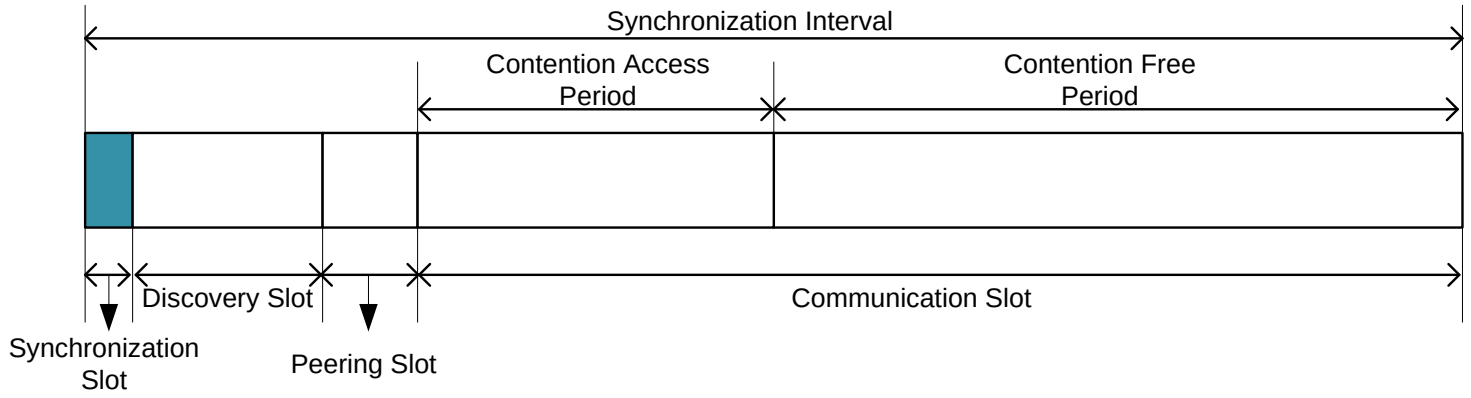
1.2 Frame Structure

- Synchronization Slot
- Discovery Slot
- Peering Slot
- Communication Slot
  - CAP (Contention Access Period)
  - CFP (Contention Free Period)



2. Synchronization

- Synchronization for Scalable Network
  - Distributed synchronization
    - Master-slave synchronization should be avoided
      - PDs between two different synchronized group happen
    - It is matched well to flat architecture (no hierarchy)
  - Synchronization should be done before peer discovery
    - Peer discovery prior to link connection (peering)
    - Broadcast-based synchronization mechanism is required



2. Synchronization

- Synchronization Reference Signal (SRS)
  - Transmitted during the synchronization slot
  - Contains timing offset (backoff time) information
- How to transmit
  - Energy sensing prior to transmit
    - Robust in the presence of interference from other beacons or other networks (e.g., WLAN)
  - Transmitted with random back-off

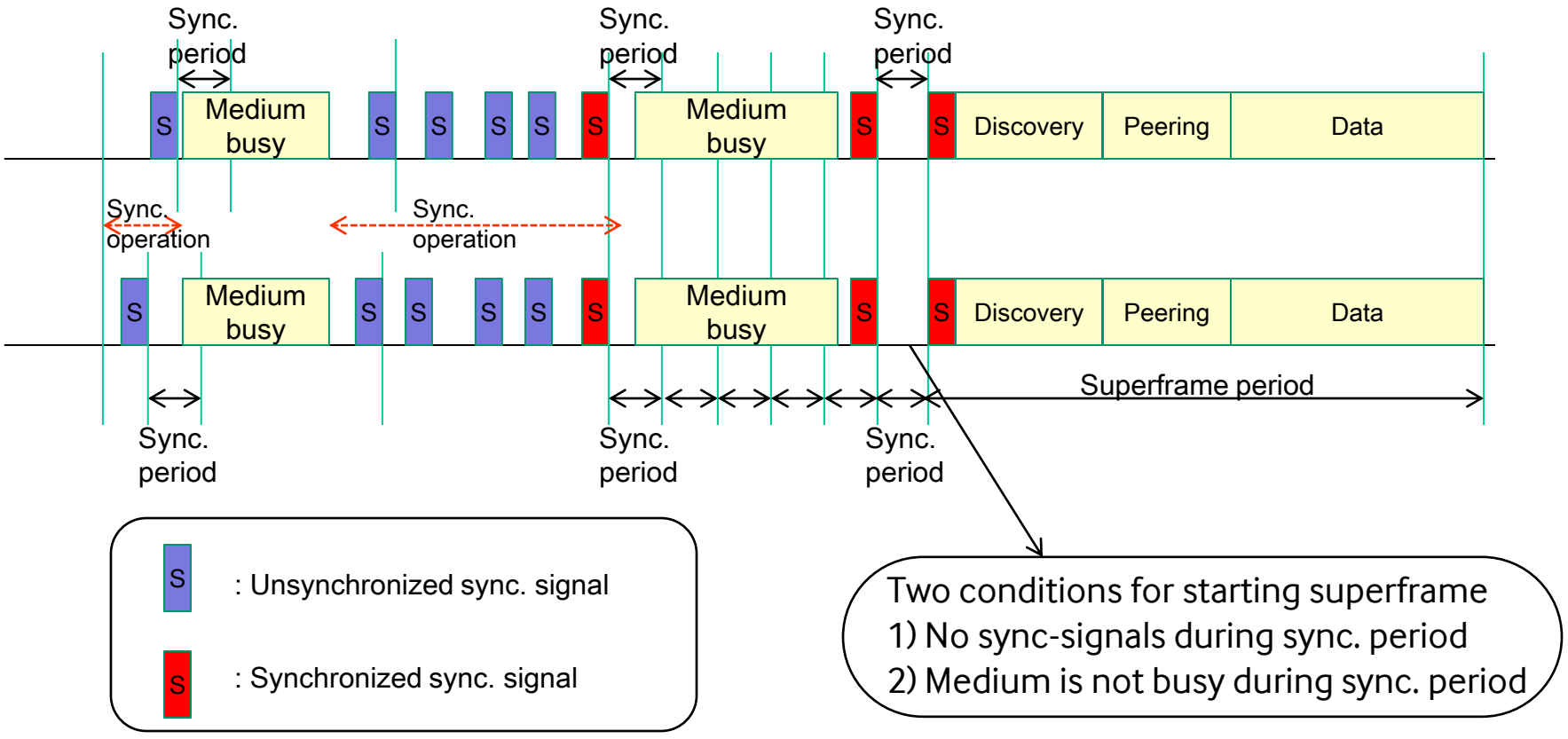
2. Synchronization

- Two Type of Synchronization Phase
  - Type-1: for initial synchronization
    - PD performs just synchronization without frame structure
    - Short SRS interval: e.g. 10 ms
    - Sensing and TX restriction
  - Type-2: for maintaining synchronization
    - PD follows operations defined in frame structure
    - Long SRS interval: e.g. 100ms
    - Sensing and backoff during synchronization slot
  - System-level synchronization algorithm
    - Pulse-coupled oscillator (refer to 15-13-0376-02-0008)

* SRS (Synchronization Reference Signal)

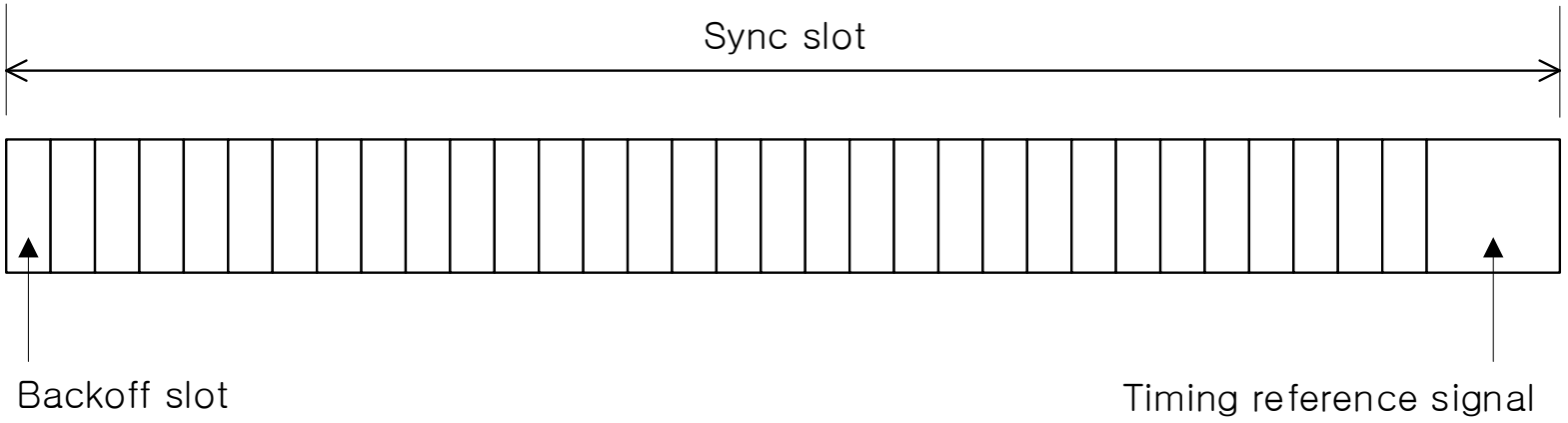
2. Synchronization

- For type-1 synchronization (w/o superframe)



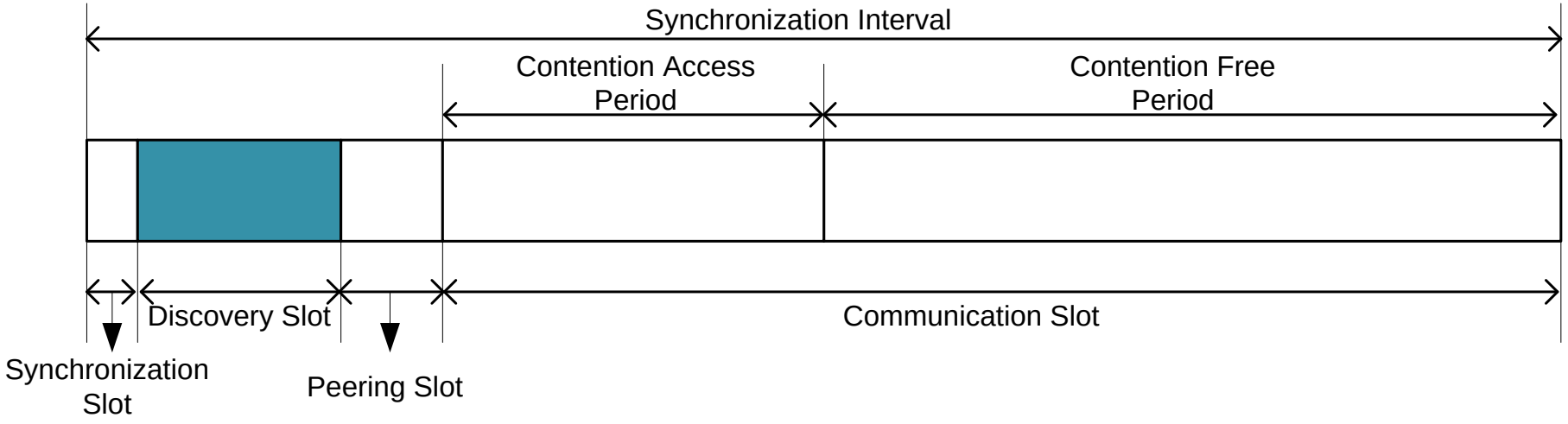
2. Synchronization

- For type-2 synchronization (w/ superframe)
  - Sync slot = 416 usec
    = (N backoff slot) + (1 timing reference signal)
  - N = 32
  - Backoff slot = 12 usec
  - Timing reference signal = 32 usec
  - Details in 15-14-0249



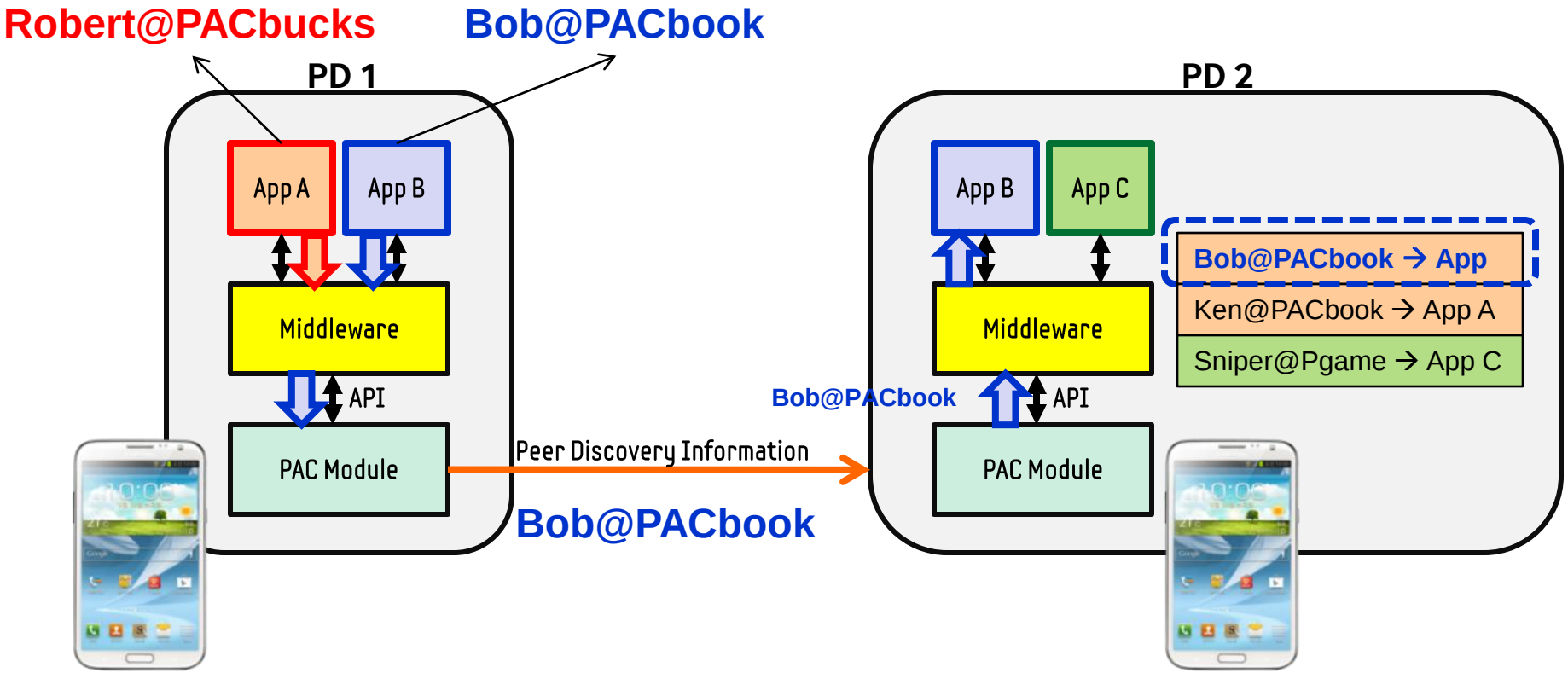
3. Peer Discovery

- Design Considerations
  - Discovery Information (DI)
    - Came from application or middleware
      - Plain ID: Application ID (PACbook), or User ID (Bob@PACbook), or etc
      - Coded DI: generated by middleware or retrieved from server
    - Discovery matching
      - PD A is matched by other PDs storing DI representing PD A



3. Peer Discovery

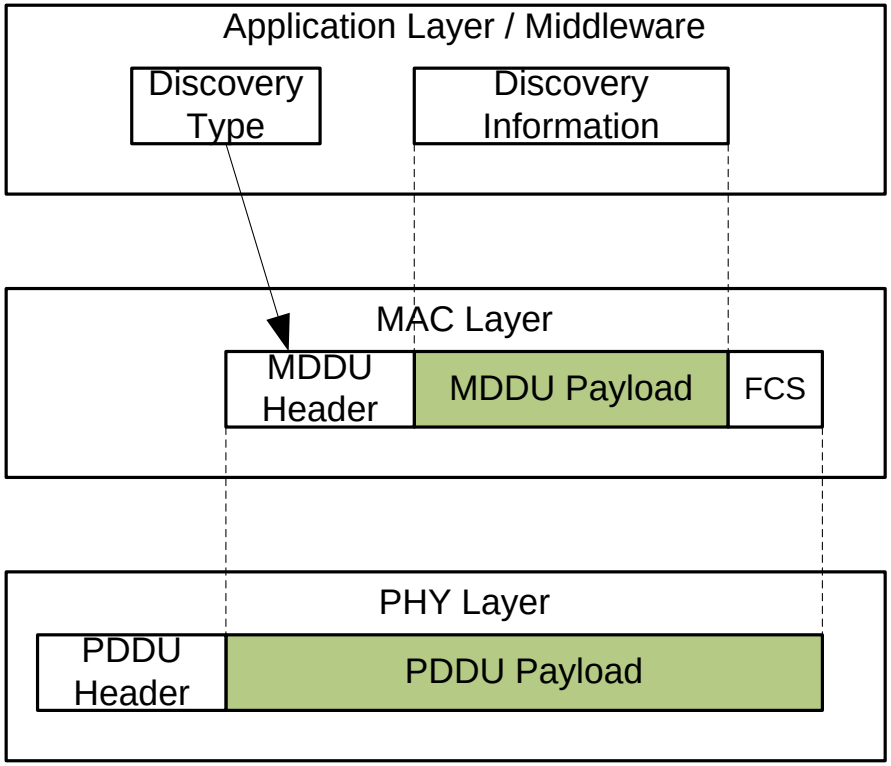
- What is Peer Discovery?
  - A peer represents an application-specific entity, not a device



3. Peer Discovery

- Protocol Stack for Peer Discovery
  - MAC/PHY Discovery Data Unit (MDDU/PPDU)

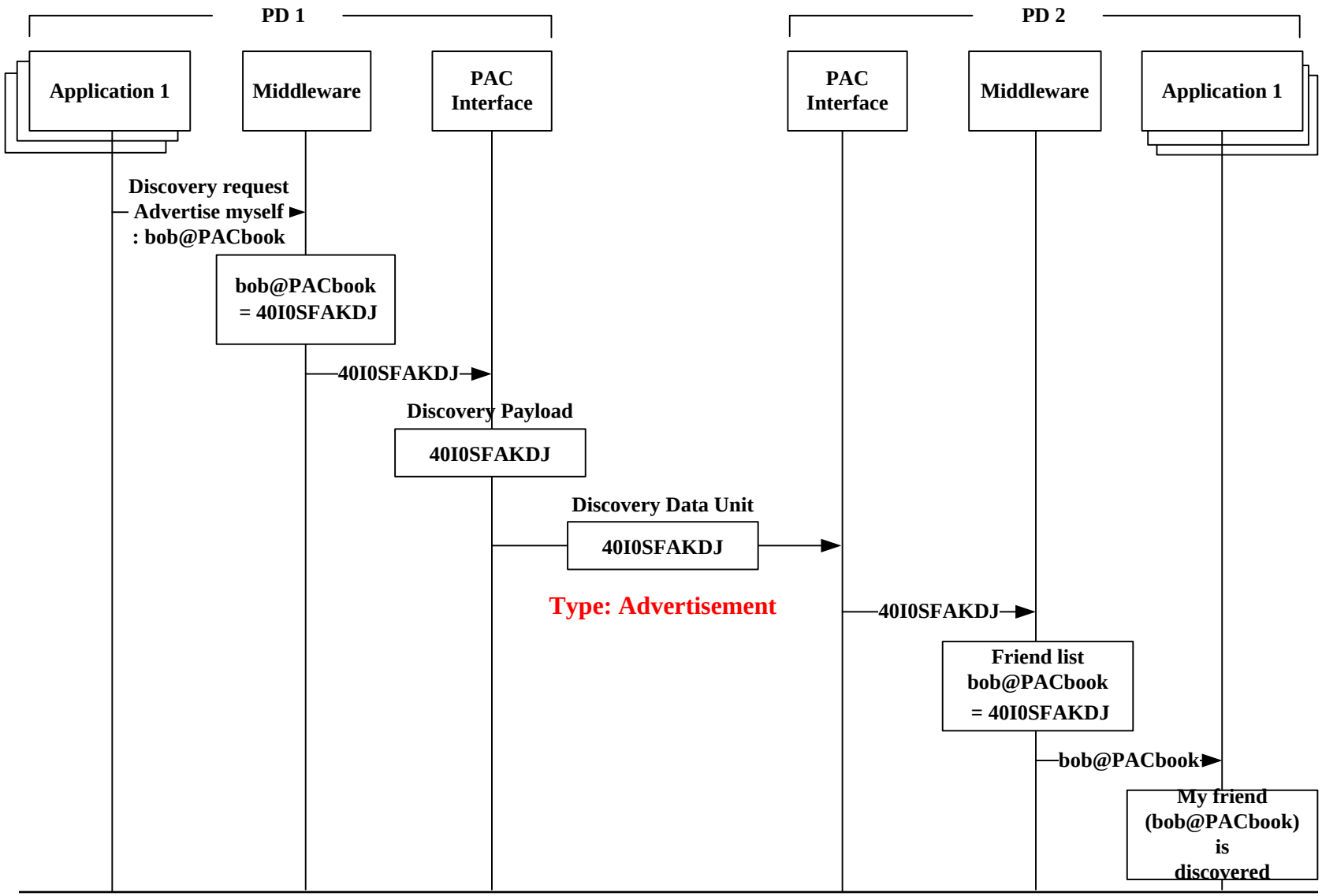
Discovery Type
- Advertisement
- Publish/Subscribe
- Query/Reply



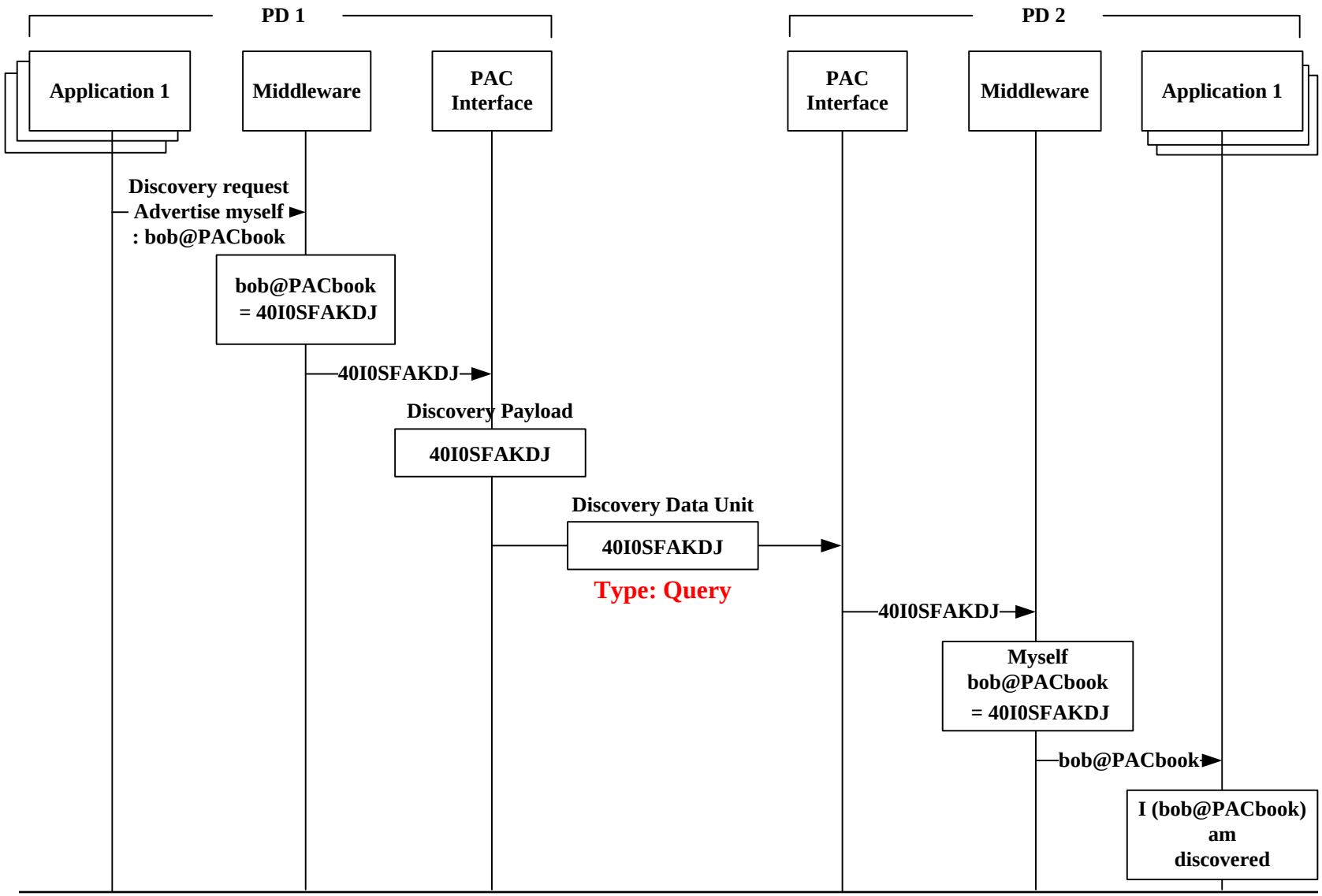
Discovery Message

- Supported discovery types
  - Advertisement
  - Publish/subscribe
  - Query/reply
  - SSF (Self Spatial Filtering) aka LnL (Look-and-Link)
  - Emergency messages
- Discovery message content
  - Driven from higher layer
  - Middleware standards: e.g. UUID (16 bytes)
  - Plain texts: e.g. Human readable ID

Advertisement/Publish Scenario

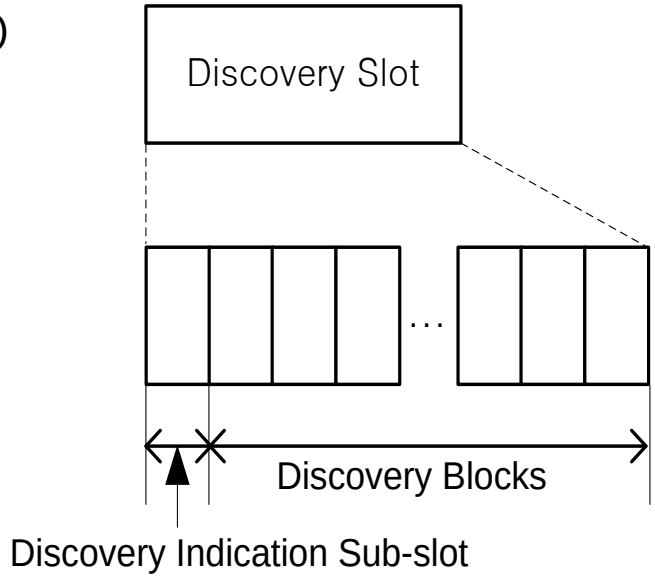


Query Scenario



3. Peer Discovery

- Discovery Slot
  - It is comprised of multiple Discovery Blocks (DBs)
  - Basic procedure
    - PD selects one DB in a Discovery Slot
    - PD broadcasts DDU (Discovery Data Unit)
      - At selected DB
- Proposal
  - Congestion-aware DB selection
  - Hashing-based DB selection



3. Peer Discovery

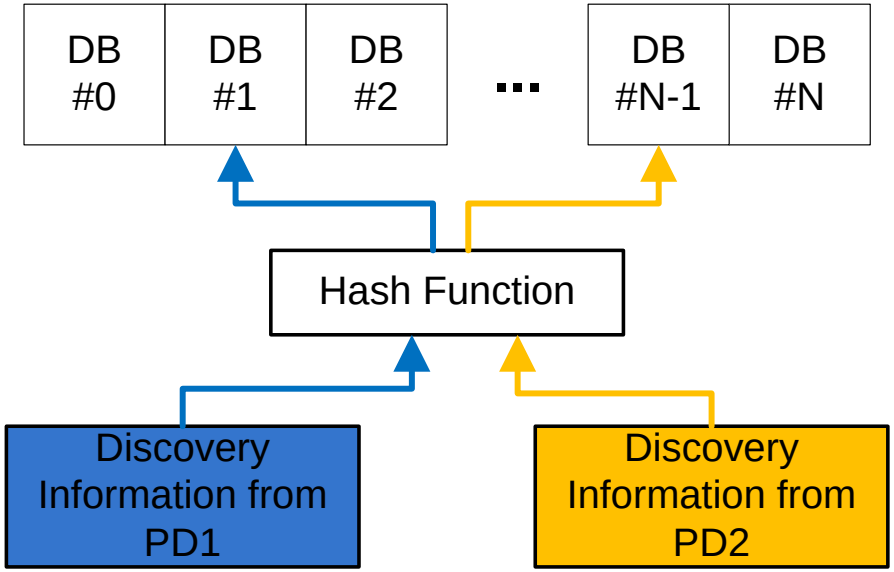
- Sleep mode support
  - A PD with a discovery message to transmit
    - Transmit discovery indication signal in the discovery indication sub-slot
    - Transmit the discovery message in the discovery sub-slot
  - A PD without a discovery message to transmit
    - Listens to the discovery indication sub-slot. If carrier is sensed, listens to discovery sub-slot for discovery messages
    - Listens to the discovery indication sub-slot. If no carrier is sensed, does not listen to the discovery sub-slot to reduce power consumption

3. Peer Discovery

- Congestion-aware DB selection
  - Based on the received power
    - Compare received power between current DB and candidate DB
    - Details referred from 15-13-0376-01
  - Based on congestion condition
    - Discovery Transmission Interval (DTI) control
    - Depending on the number of detected DDU
      - e.g.) DTI is increased when the number of detected DDU is high

3. Peer Discovery

- Hashing-based DB Selection
  - DI index is determined based on the hashed DI
    - A receiving PD monitors only DB with hashed index based on monitoring DI
    - Benefit for receiver PD in power consumption perspective



3. Peer Discovery

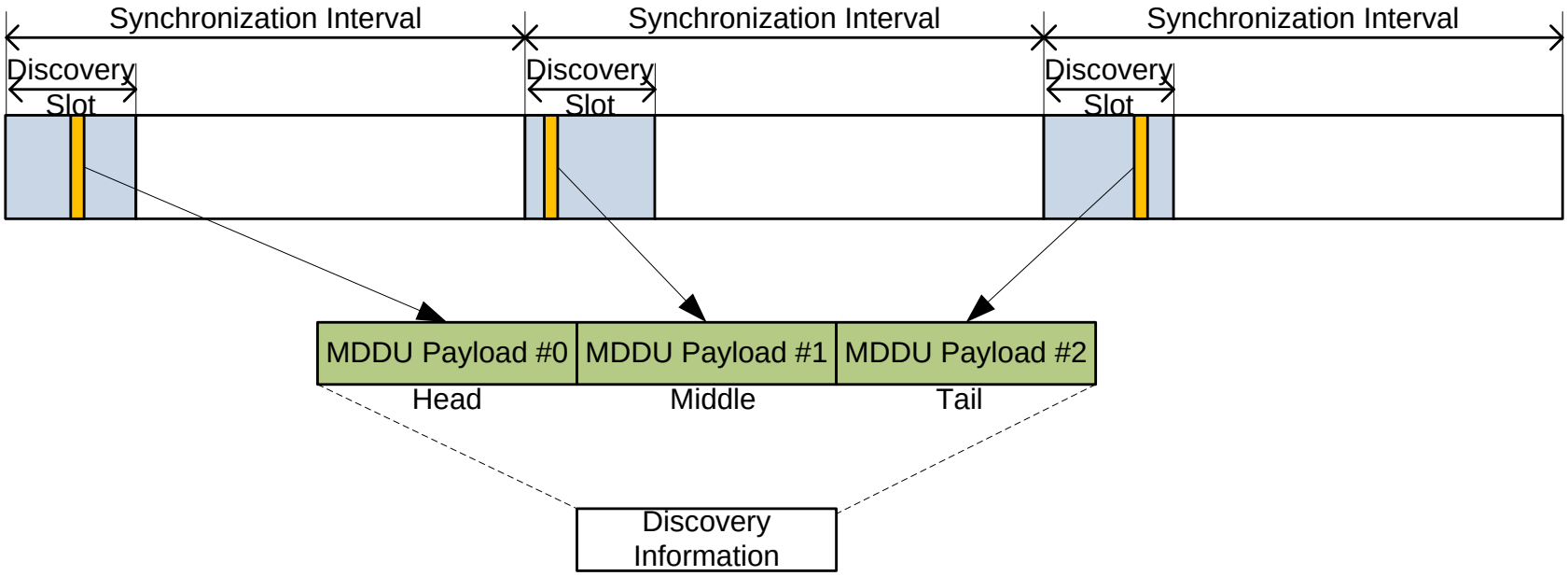
- Technical Issues
  - Support of various length of discovery information
  - Subject to provide low power discovery

- Background
  - Current distributed middleware platform in the industry

Platform	Feature	Required size of discovery information
XMPP[5]	Decentralized protocol for instant messaging and presence	Up to 3071 bytes
UUID[6]	Distributed systems to uniquely identify information without significant central co ordination	16 bytes

3. Peer Discovery

- Proposal
  - Discovery information fragmentation
    - to support long discovery information
    - Discovery Information is divided into multiple MDDU payloads



3. Peer Discovery

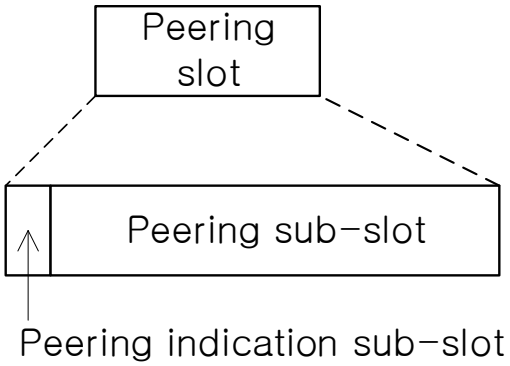
- Possible Solution to Link MDDU Payloads
  - Low overheads required
  - Option 1
    - Discovery Session ID (DSID)
      → to distinguish different DIs from different PDs as well as same PD
    - Potential problem
      - Who coordinates and assign DSID?
      - How to guarantee collision avoidance when using small length of DSID?
  - Option 2
    - Location Indicator
      - Each MDDU indicates the location of next MDDU
      - Receiving PD can aggregate based on the known location

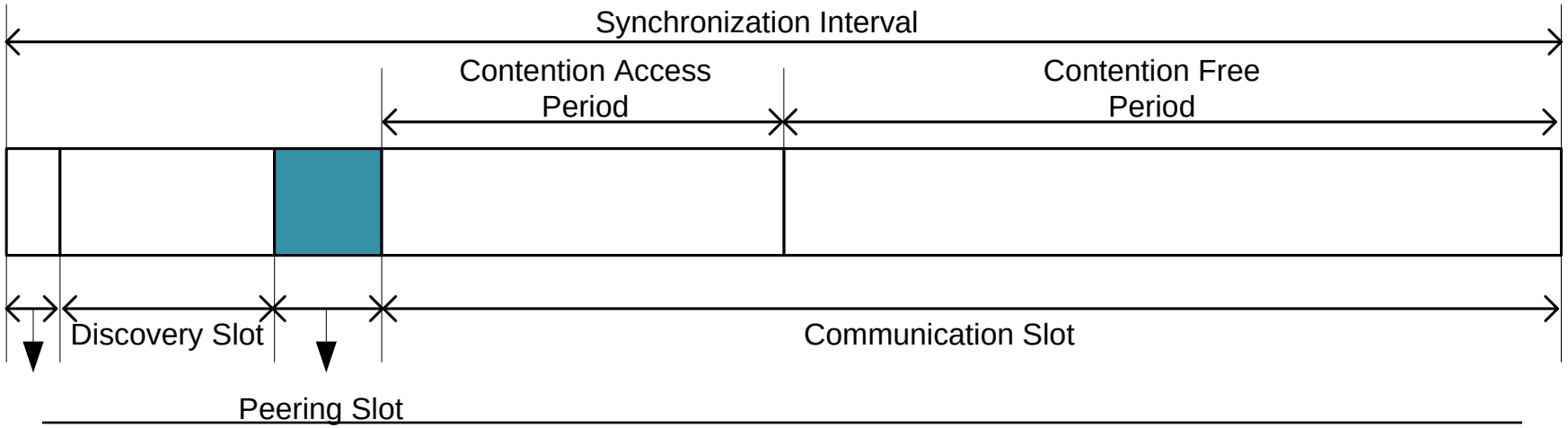
4. Peering

- The role of Peering
  - A procedure to connect to discovered peer
    - Triggered by application automatically or by user manually
    - **No MAC-level triggering**
  - Link establishment for unicast/multicast link
    - Between a TX PD and RX PD(s)
    - Exchange of information for setup
      - TX/RX ID (MAC address), capability, or etc
    - Determine link related parameters
      - Link ID, QoS class, link range, or etc
  - Messages
    - Peering, re-peering, de-peering messages

4. Peering

- Design Consideration for Peering Slot
  - Small radio resource comparing to Discovery Slot
    - Peering happens sparsely
  - Handling of multiple peering response to peering requests
  - Channel access scheme
    - Contention-based access (same as CAP access)



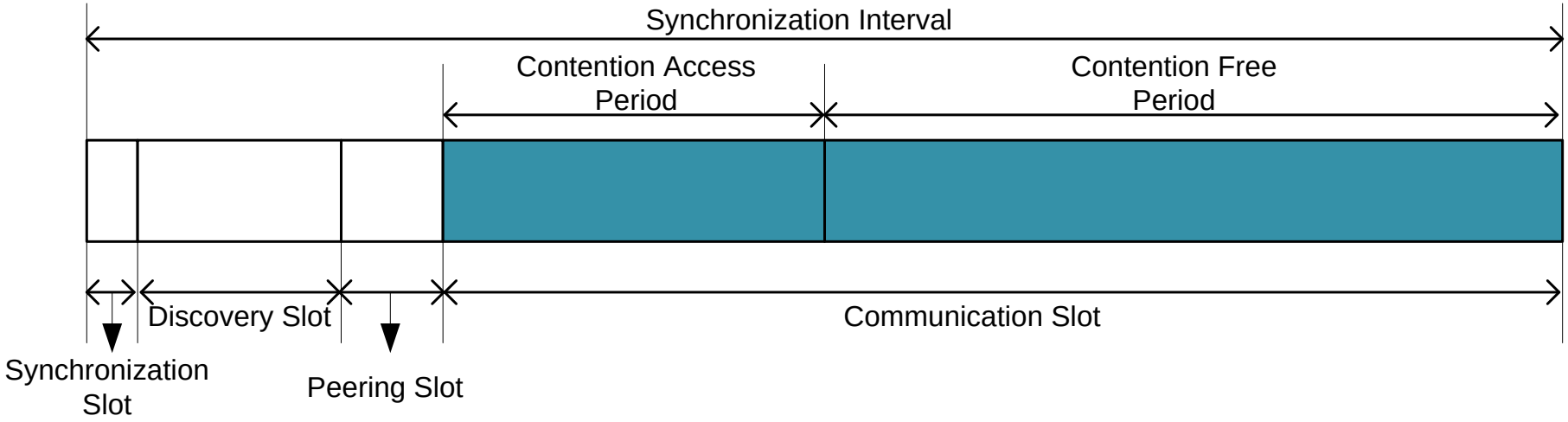


4. Peering

- A PD with a peering message to transmit
  - Transmit peering indication signal in the peering indication sub-slot
  - Transmit the peering message in the peering sub-slot
- A PD in sleep mode without a peering message to transmit
  - Listens to the peering indication sub-slot. If carrier is sensed, listens to peering sub-slot for peering messages
  - Listens to the peering indication sub-slot. If no carrier is sensed, do not listen to the peering sub-slot to reduce power consumption
- A PD not in sleep mode without a peering message to transmit
  - Listens to the peering indication sub-slot. If carrier is sensed, listens peering sub-slot for peering messages
  - Listens to the peering indication sub-slot. If no carrier is sensed, use peering sub-slot as a CAP (contention access period)

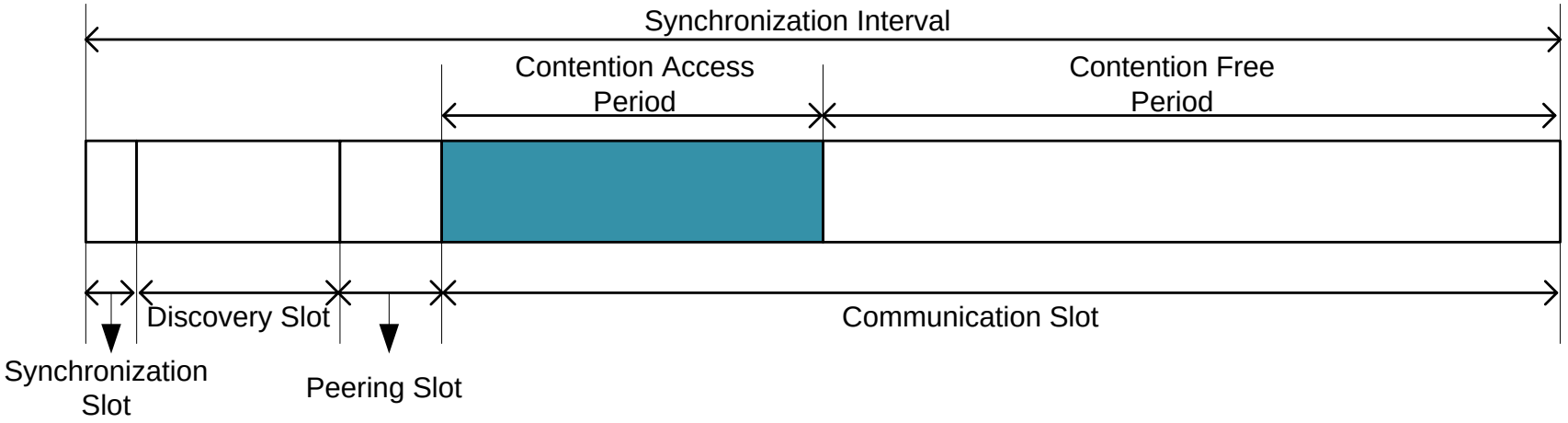
5. Communication

- Communication Slot
  - Comprising CAP and CFP
    - CAP (Contention Access Period)
    - CFP (Contention Free Period)
  - CAP for both peered and un-peered data communication
  - CFP for only peered data communication



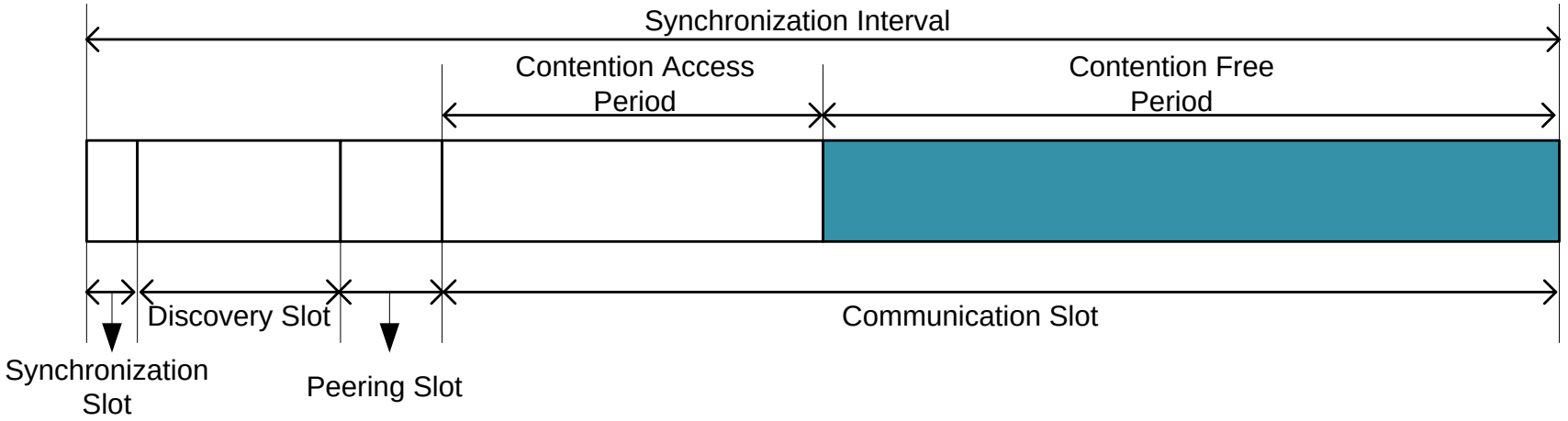
5-1. CAP

- Features of CAP
  - For both peered and un-peered data communication
  - Support of broadcast data transmission within un-peered PDs
  - CSMA/CA based on EIED algorithm [4]
  - Details in 15-14-0249



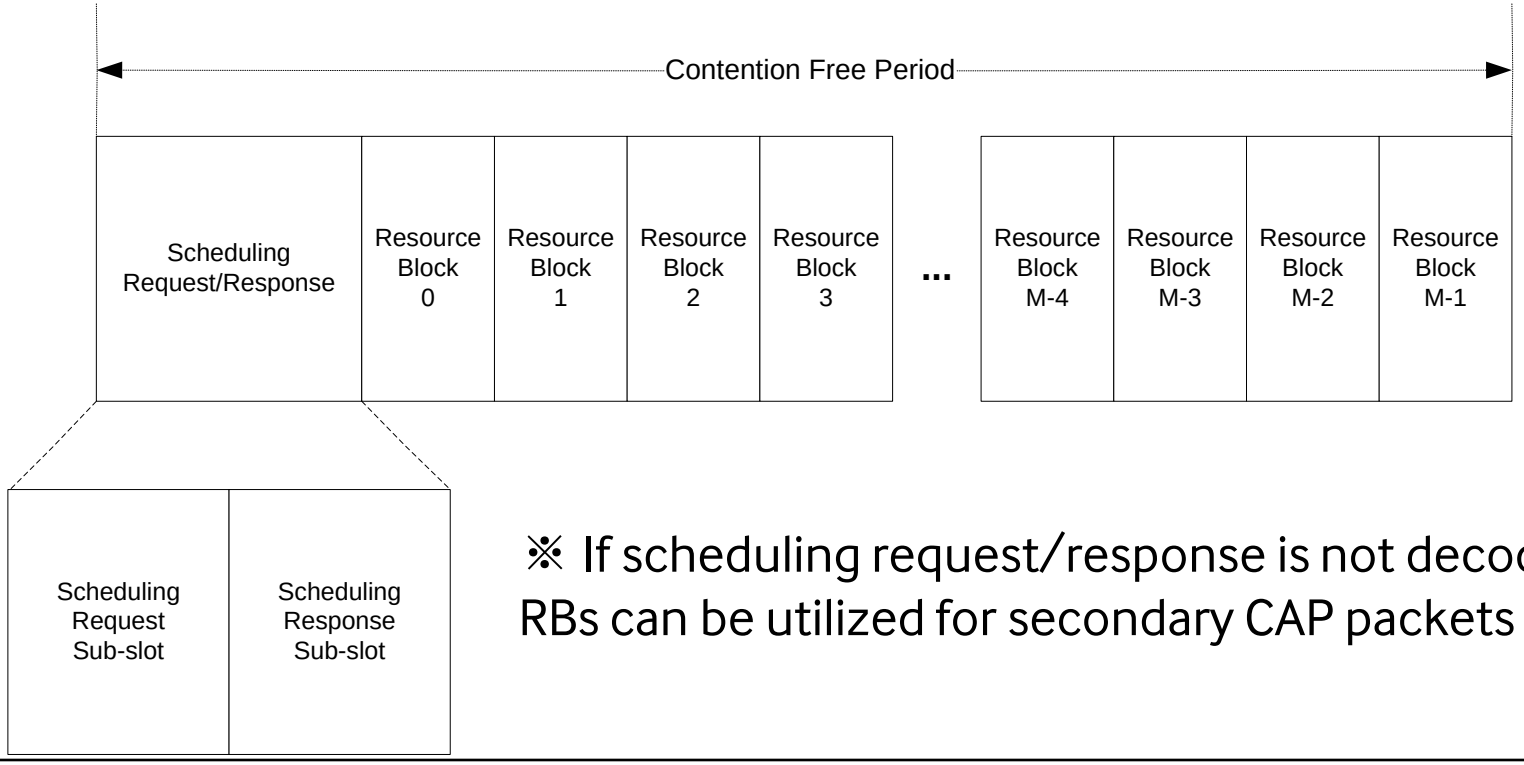
5-2. CFP

- Features of CFP
  - Only accessed by peered PDs
  - Signaling reduction using Link ID
    - No necessity of sending multiple MAC addresses of both TX PD and RX PD(s)



5-2. CFP

- CFP comprises
  - Scheduling Request/Response Sub-slots
  - Resource Blocks (RBs) (using CSMA/CA in a RB)



※ If scheduling request/response is not decoded, RBs can be utilized for secondary CAP packets

5-2. CFP

- Design Approach
  - Contention-free channel access
    - Low signaling overhead & high spatial reuse
  - Distributed scheduling
    - Scheduling Request and Scheduling Response
    - These signaling messages contain resource information
      - Related to RB assignment
      - Broadcasted to nearby PDs

Scheduling Request :

Link ID	Resource Block Start Index	Resource Block Demand

Scheduling Response :

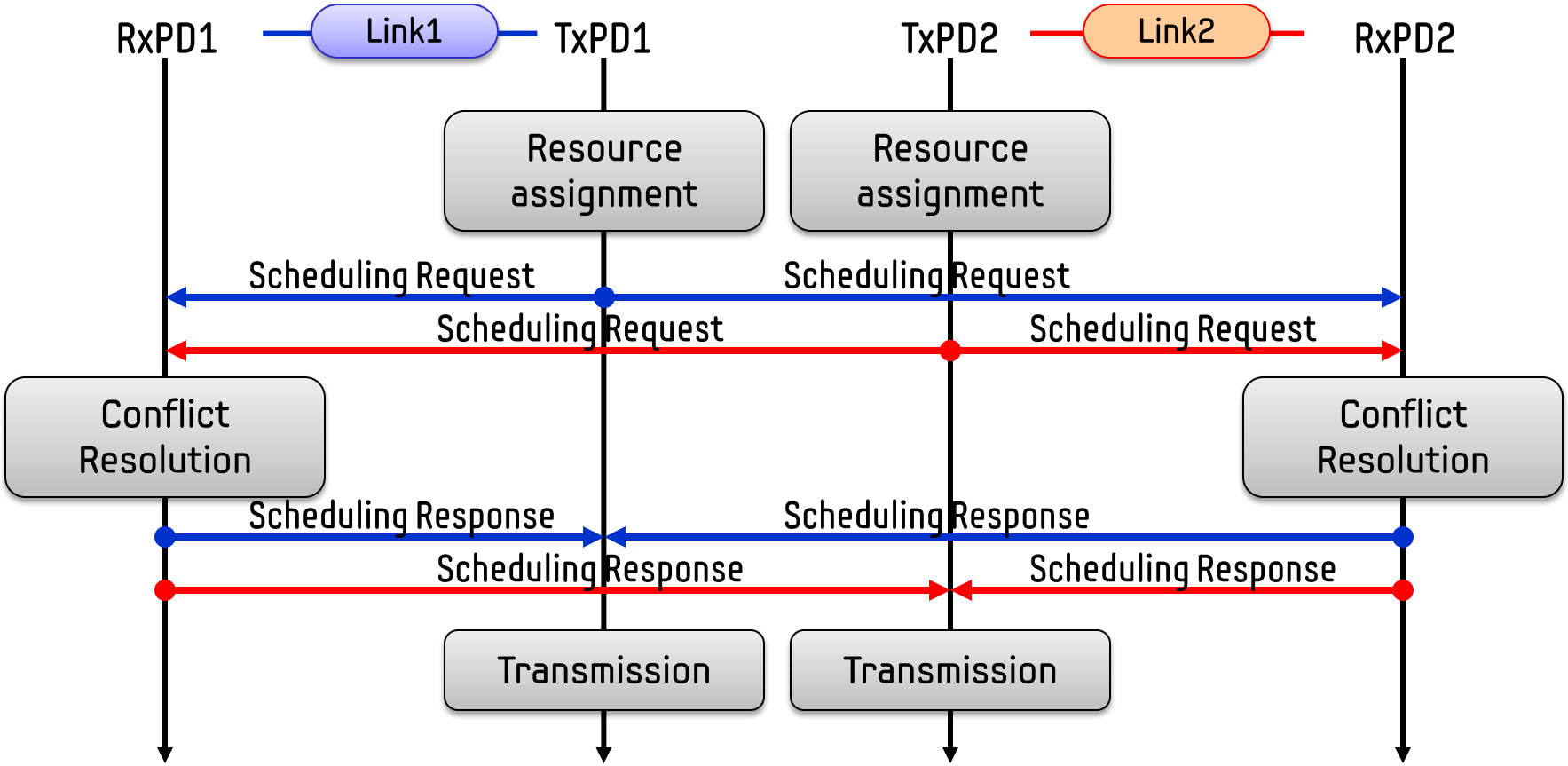
Link ID	Resource Block Adjusted Index	Resource Block Adjusted Demand

5-2. CFP

- Required Features of Distributed Scheduling
  - Resource conflict avoidance [referred from 15-13-0376-01]
    - Throughput can be increased by high spatial reuse
    - Link assignment based on the SIR of receiving PD's
  - Congestion-aware resource assignment
    - Resource is assigned according to results of congestion monitoring

5-2. CFP

- Operation Flowchart



7. Summary

- Key Design Considerations
  - Frame structure
  - Distributed synchronization
  - Peer discovery
    - Protocol stack
    - Discovery Block selection
  - Peering
    - Contention-based access to establish links
  - Communication (CAP)
    - Enhanced contention-based access within peered and un-peered PDs
  - Communication (CFP)
    - Contention-free access within peered PDs
    - Distributed scheduling by request and response

8. References

- [1] Jung-Hyun Kim, Jihyung Kim, Kwangjae Lim, Dong Seung Kwon, "Distributed Frequency Synchronization for Global Synchronization in Wireless Mesh Networks," World Academy of Science and Technology, vol. 70, 2012, pp. 1080-1084.
- [2] Nah-Oak Song, Byung-Jae Kwak, Jabin Song, L. E. Miller, "Enhancement of IEEE 802.11 Distributed Coordination Function with Exponential Increase Exponential Decrease Backoff Algorithm," Proceedings of IEEE 57th Vehicular Technology Conference (VTC 2003-Spring), vol. 4, pp. 2775–2778, Jeju, Korea, April 22–25, 2003.
- [3] IEEE 802.15-14-0132-00-0008, "Collision Detection based PHY Proposal for PAC," March 2014.
- [4] IEEE 802.15-13-0650-00-0008, "Collision Detection Based Random Access Scheme for IEEE 802.15 TG8 PAC," Nov. 2013.
- [5] XMPP (Extensible Messaging and Presence Protocol) http://xmpp.org/
- [6] UUID (Universally Unique Identifier) http://en.wikipedia.org/wiki/Universally_unique_identifier

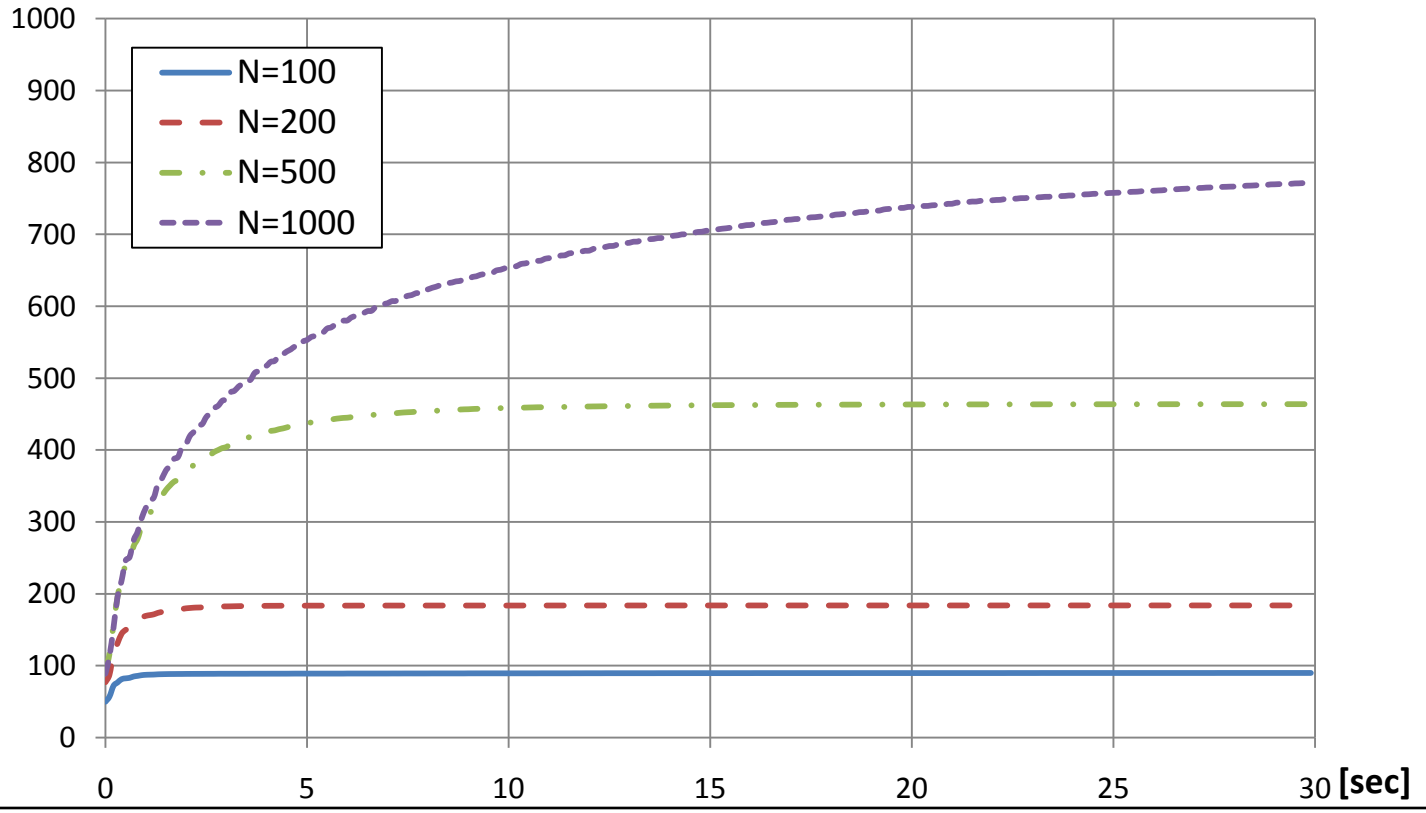
Annex A. Peer Discovery

- Simulation Parameters
  - General parameters (refer to DCN: 15-12-0568-05)
  - Specific parameters (Scenario 1-mandatory)

Parameter	Value
System bandwidth	20 MHz
Multiplexing	OFDM
OFDM symbol duration	**64** usec
Discovery Slot duration	256 usec (**4** OFDM symbols)
The number of Discovery Slots	100
Superframe period	100 msec
Discovery frame duration	25.6 msec

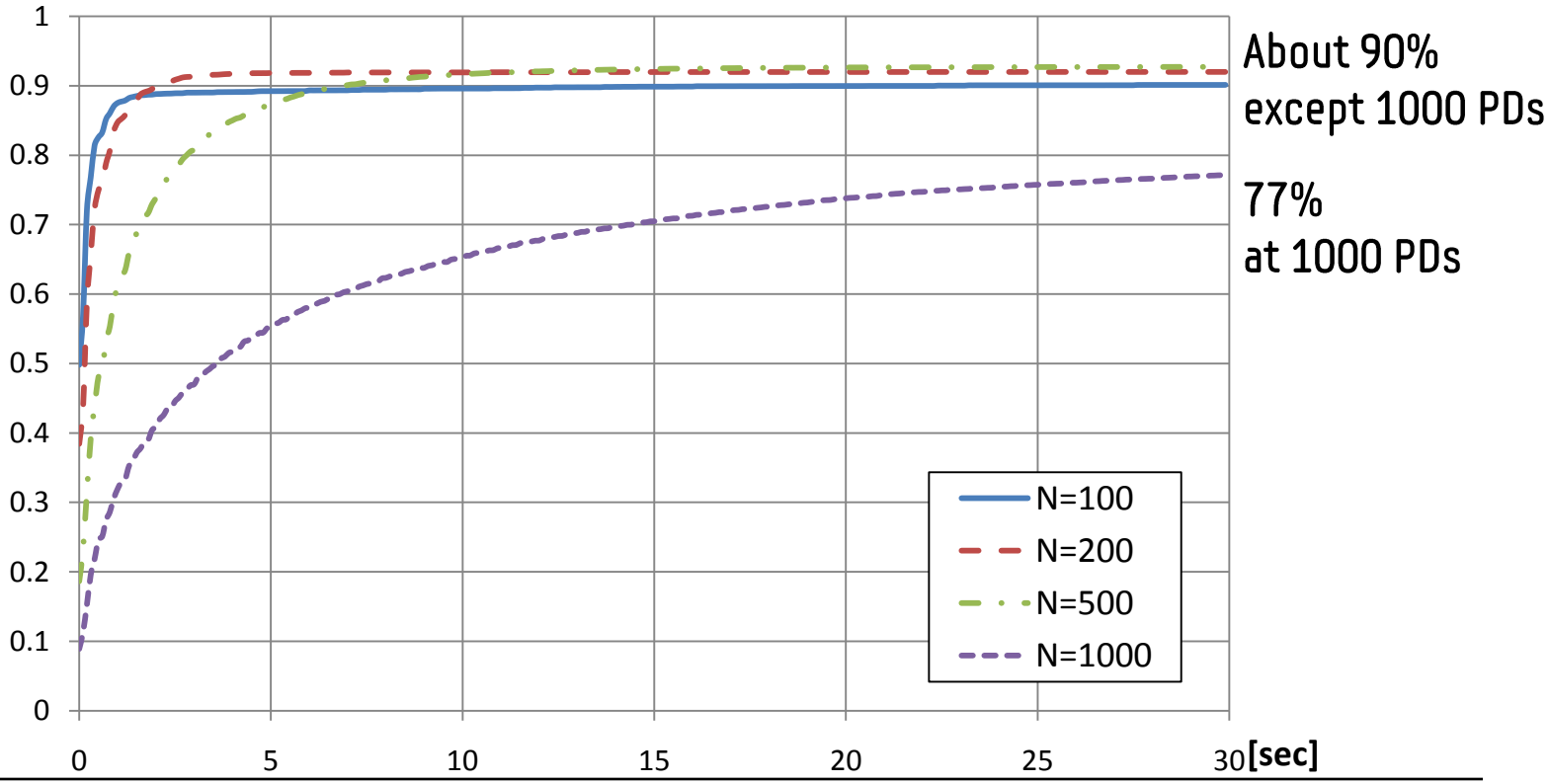
Annex A. Peer Discovery

- Performance Results : Scenario 1
  - The number of discovered PDs



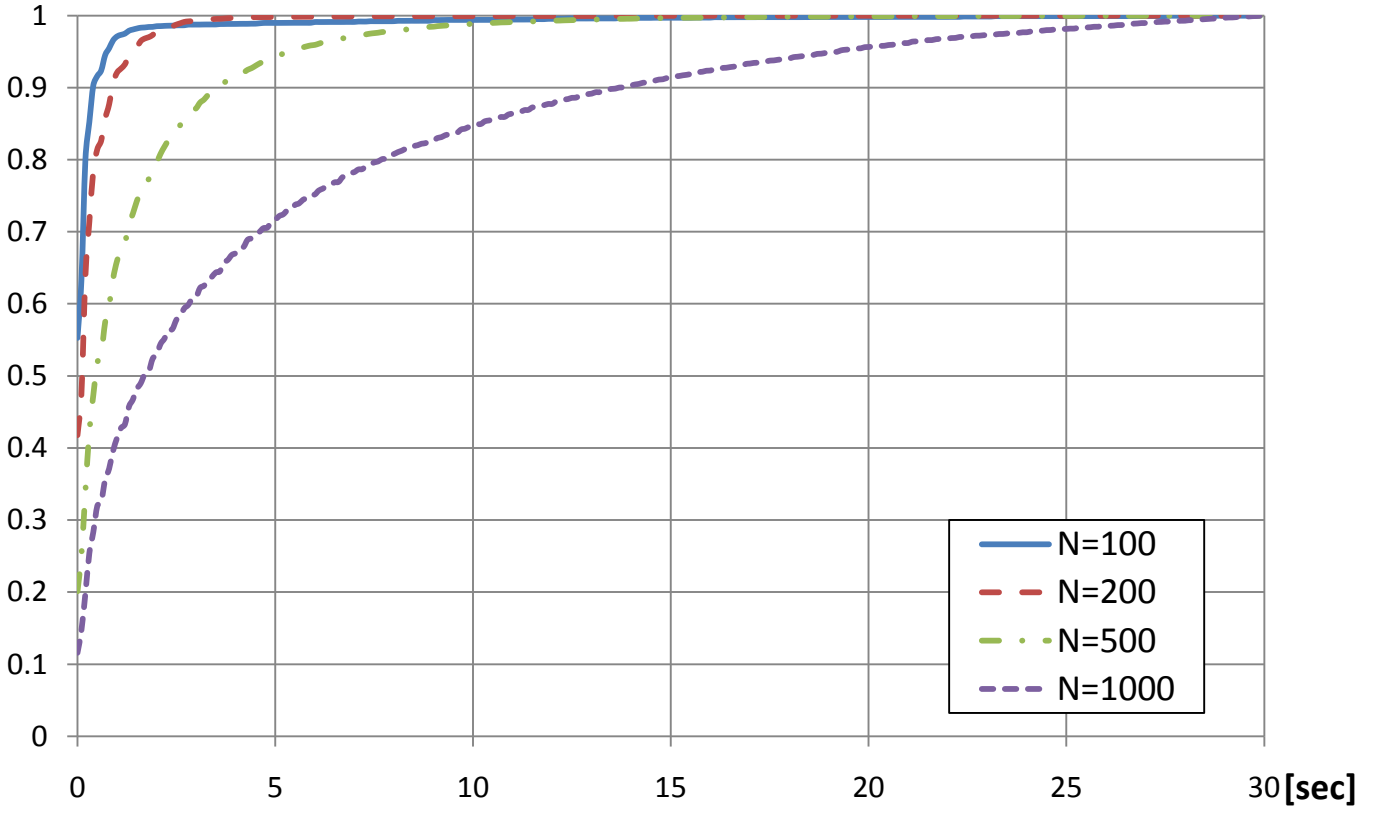
Annex A. Peer Discovery

- Performance Results : Scenario 1
  - The ratio of discovered PDs (normalized by total PDs)



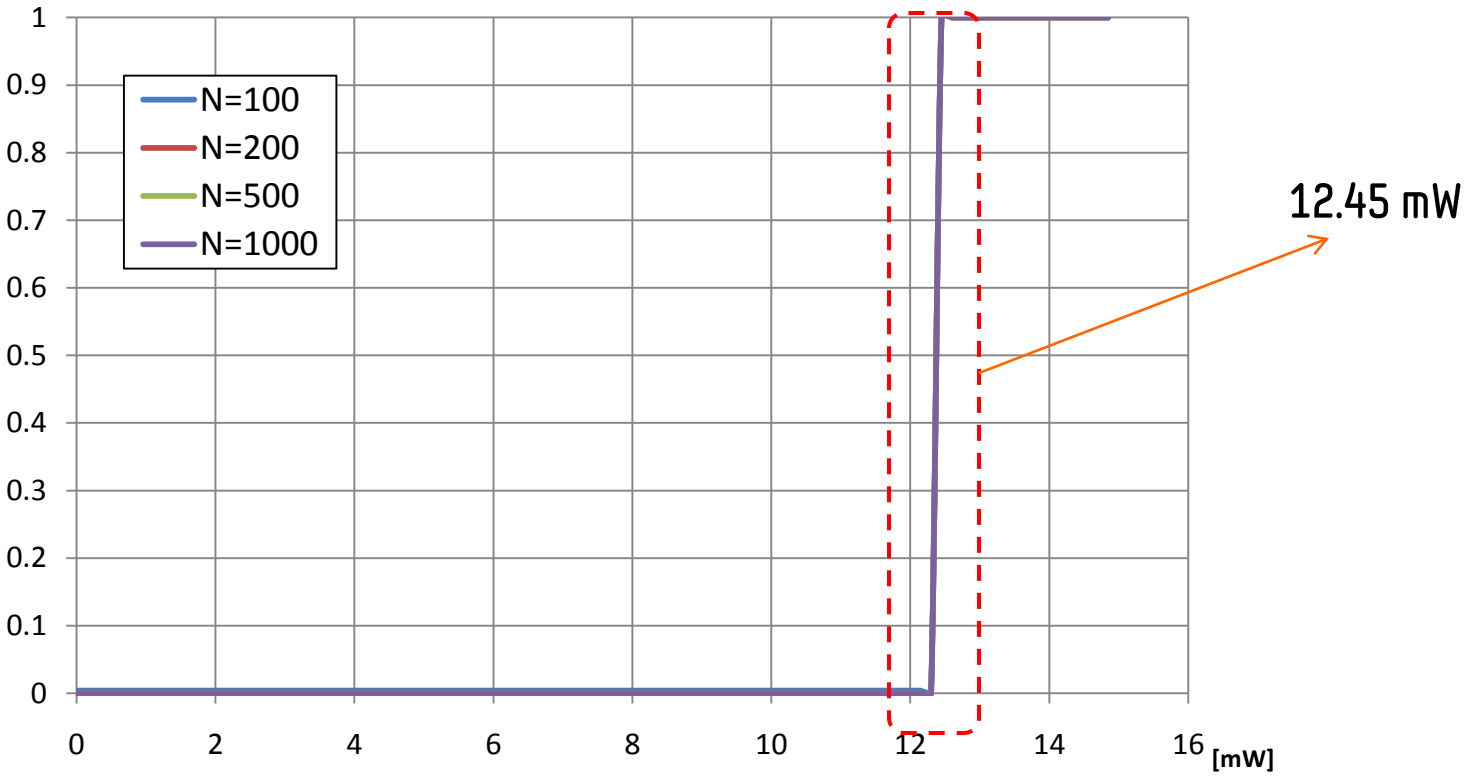
Annex A. Peer Discovery

- Performance Results : Scenario 1
  - CDF of the discovery latency



Annex A. Peer Discovery

- Performance Results : Scenario 1
  - CDF of power consumption



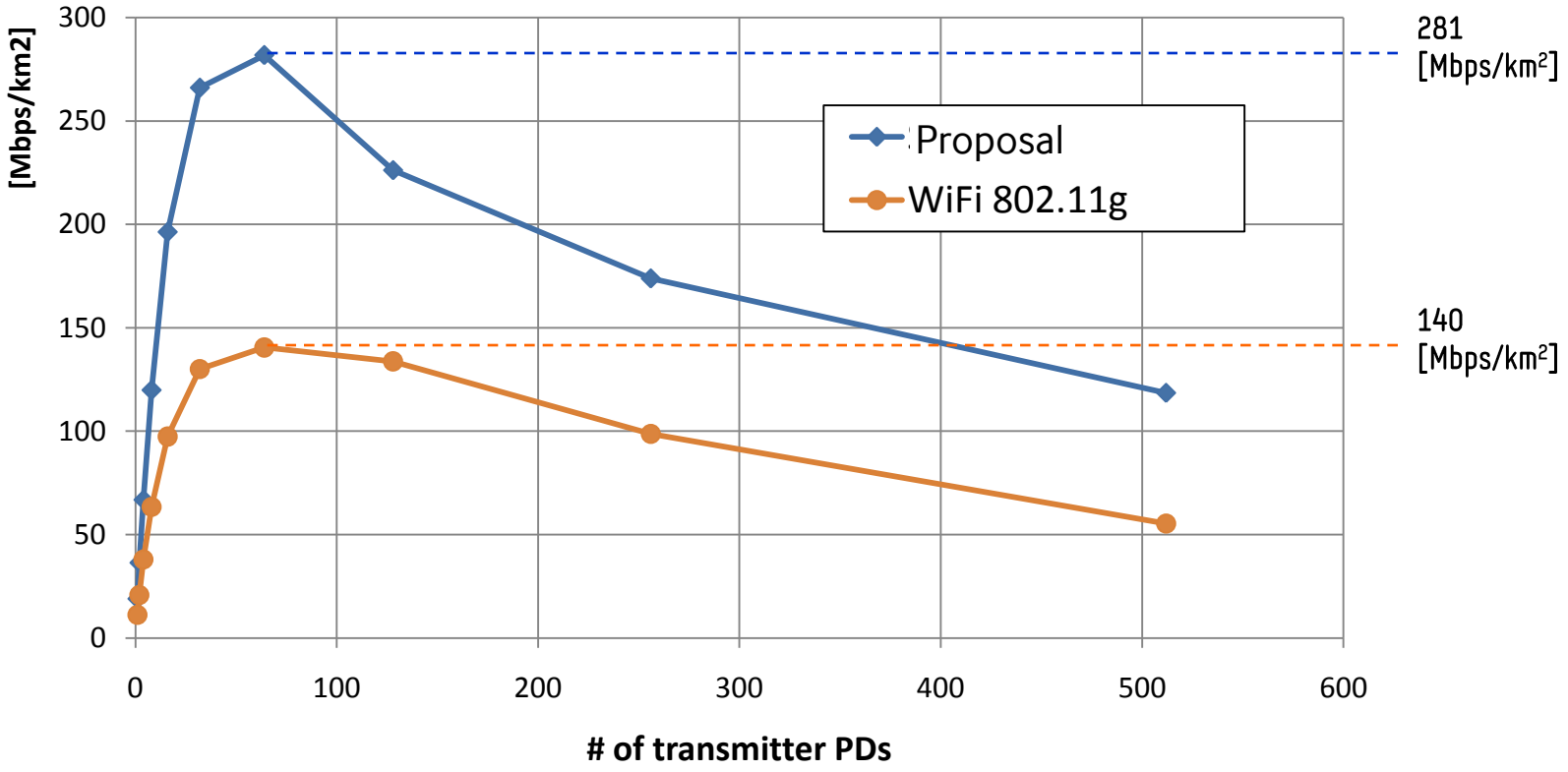
Annex B. Distributed Scheduling

- Simulation Parameters
  - General parameters (refer to DCN: 15-12-0568-05)
  - Specific parameters (Scenario 1)

Parameter	Value
System bandwidth	20 MHz
Multiplexing	OFDM
OFDM symbol duration	64 usec
The number of symbols per Resource Slot	16
The number of Resource Slots per Data Frame	32

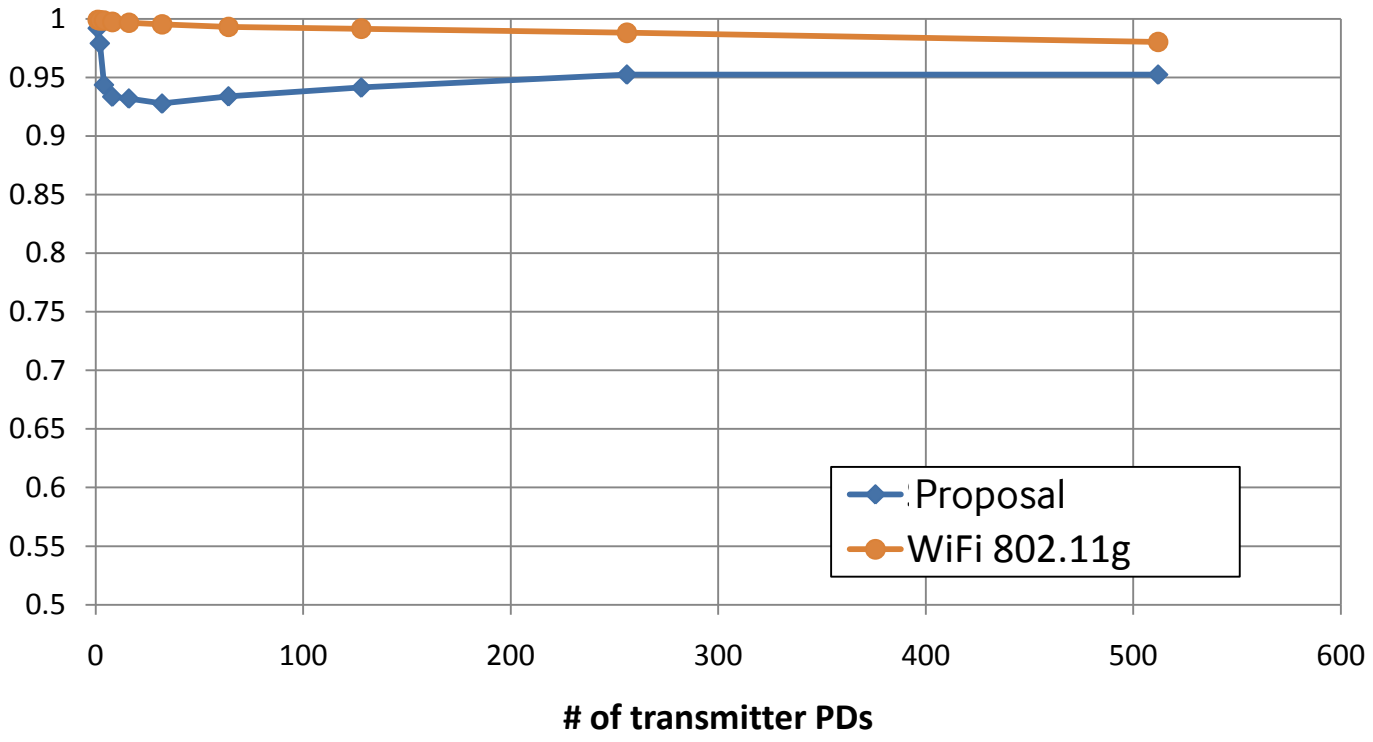
Annex B. Distributed Scheduling

- Performance Results (full buffer)
  - Areal sum goodput [Mbps/km^2]



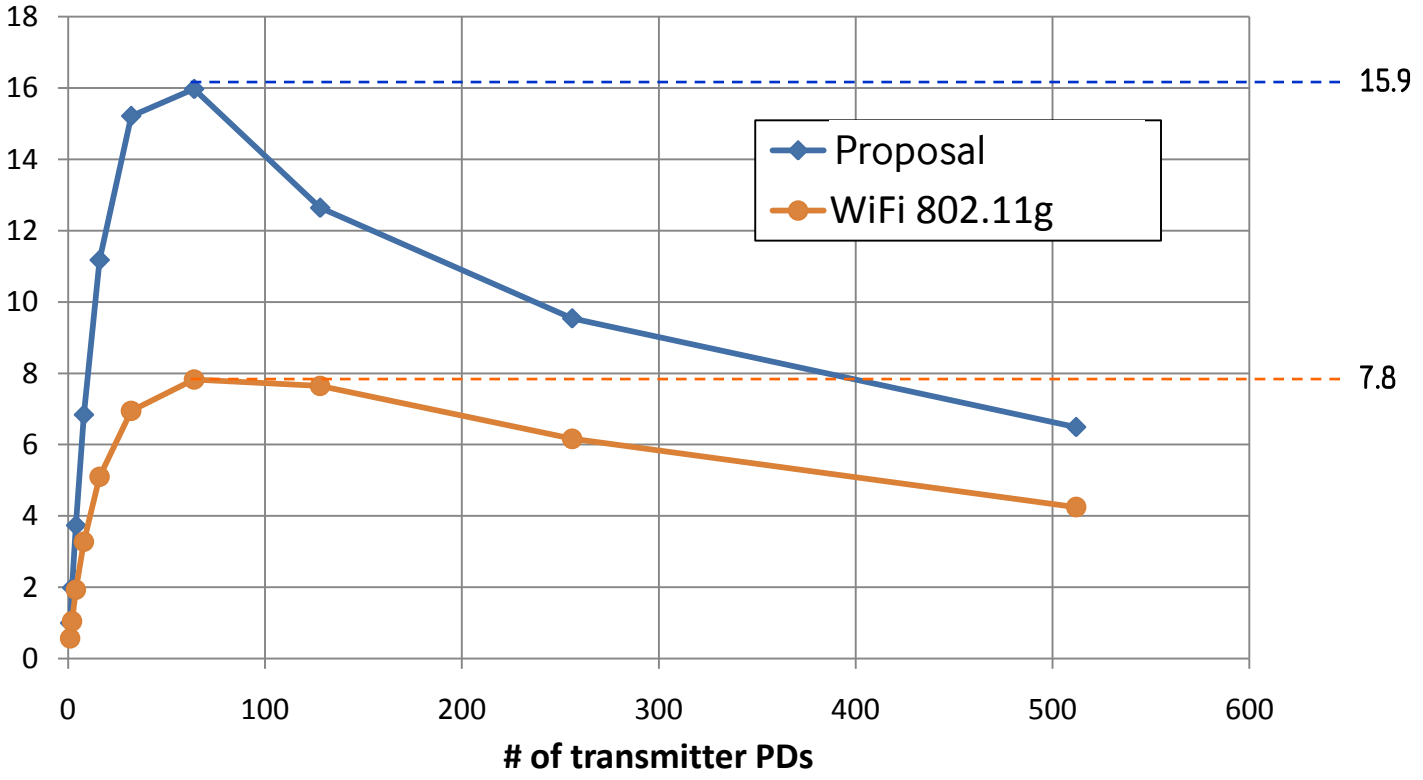
Annex B. Distributed Scheduling

- Performance Results (full buffer)
  - Data packet reception efficiency [ratio]



5. Data Transmission

- Performance Results (full buffer)
  - The number of concurrent transmission links



Annex B. Distributed Scheduling

- Performance Results (full buffer)
  - Jain's fairness index (modified)

$$J(x_1, x_2, \ldots, x_n) = \frac{\left(\sum_{i=1}^{n} x_i\right)^2}{\sqrt{n} \cdot \sum_{i=1}^{n} x_i^{\,2}}$$