

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

Submission Title: [Pre-proposal: PAC Operations and Frame Structure]

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Re: [.]

Abstract: [Presentation of PAC synchronous operations and frame structure]

Purpose: [Corresponding to Call for Proposal]

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PAC Operations and Frame Structure

May, 2013

Samsung

System Design Approach

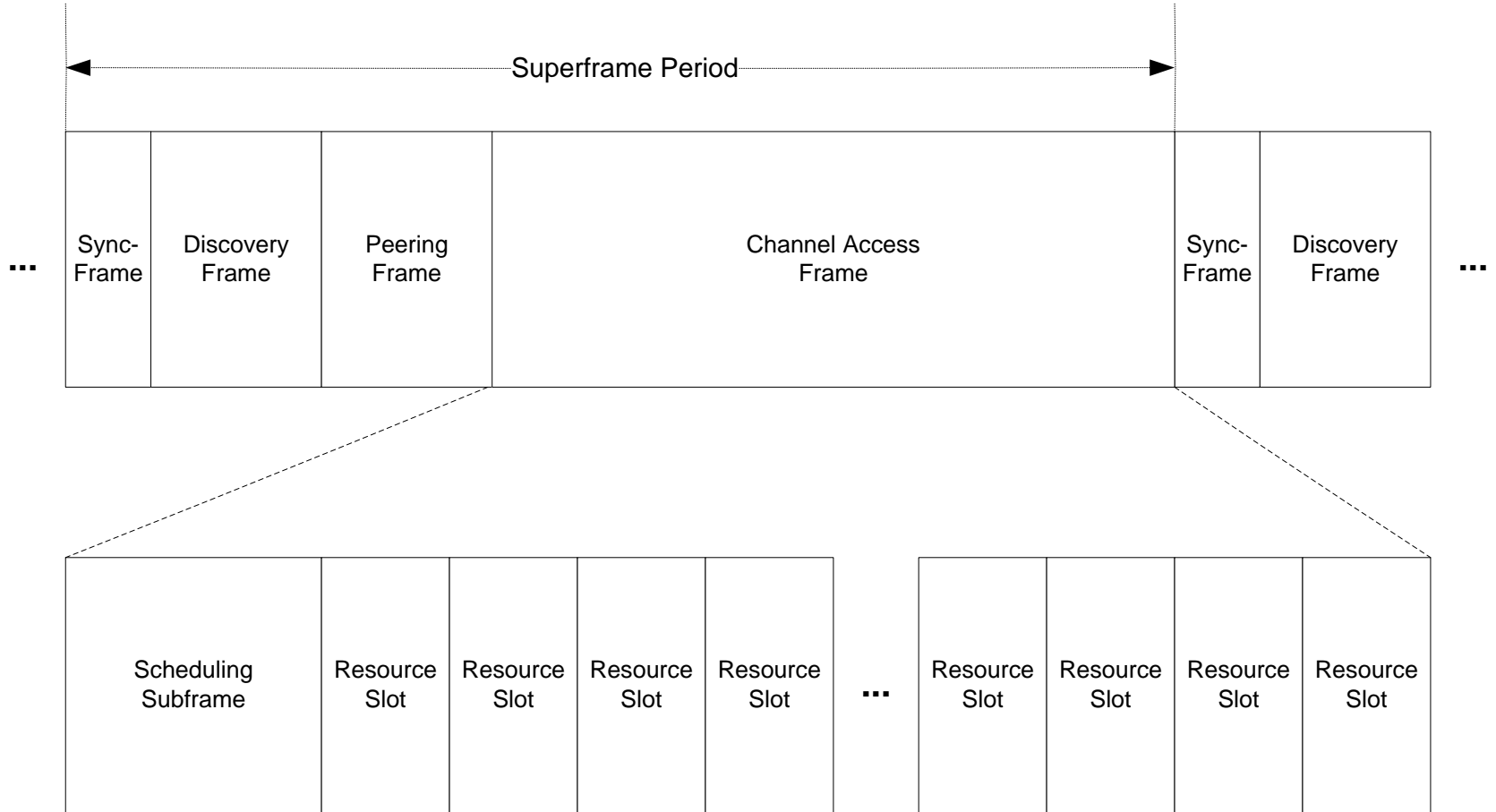
- Synchronous Operation
 - Low power consumption for peer discovery
 - Higher throughput

- Frame Structure
 - Peer discovery
 - Peering
 - Slotted channel access
 - Scheduling for efficient slot allocation

Fully Distributed Operations

- Synchronization
 - Based on Pulse-Coupled Oscillator (PCO) algorithm
- Peer Discovery
 - Prior to peering
 - Broadcast Peer Discovery Message via selected resource
- Peering
 - Link establishment
- Scheduling
 - Resource request and response

PAC Frame Structure

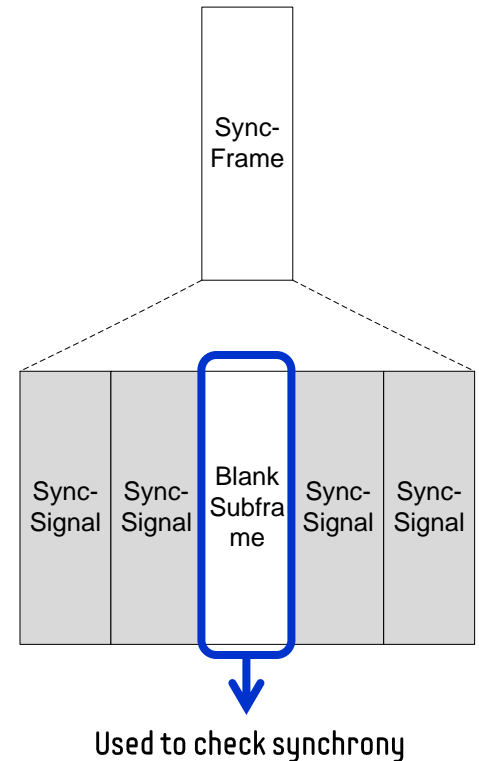


Synchronization

- Initial Synchronization
 - a. PD monitors sync-signals during superframe period
 - b. If sync-signal is detected, go to initial synchronization mode
 - c. Else, start PAC operations based on frame structure and go to maintaining synchronization mode

Synchronization

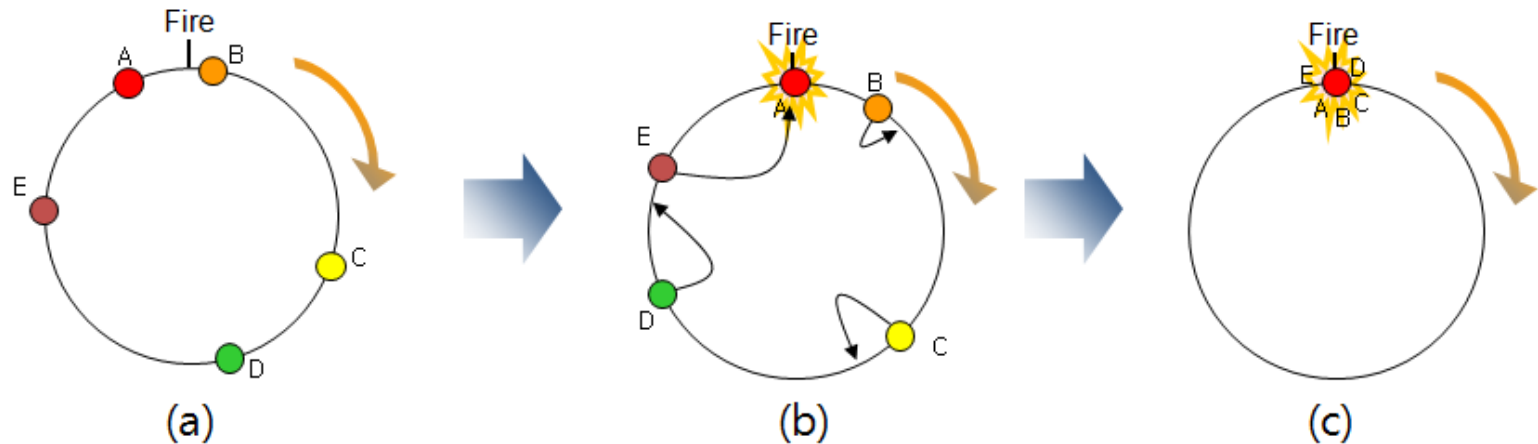
- Maintaining Synchronization
 - a. PD sends sync-signal periodically, but checks synchrony state sometime without sending sync-signal
 - b. If in-synchrony, PD adjusts oscillator for phase drift compensation
 - c. If out-of-synchrony, go to initial synchronization mode



Synchronization

■ PCO Synchronization [1]

- At initial synchronization mode
- Pulse-based approach
 - Oscillator coupled by pulse exchange via physical layer



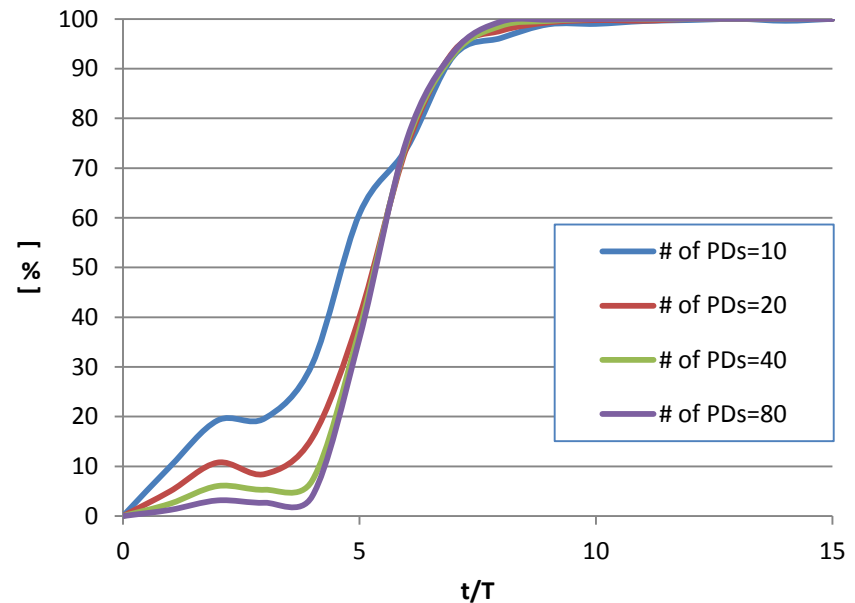
- (a) All nodes have oscillator with the same phase increment rate
- (b) One node fires, then other nodes adjust oscillator according to the predefined function without state other than its internal phase
- (c) Finally, all nodes converge to the same time base

Synchronization Performance

■ Simulation Condition

- Dimension
 - 500 x 500 m²
- Coupling factor
 - 0.05
- Dissipation factor
 - 10
- Sync-signal period
 - T = 100 msec

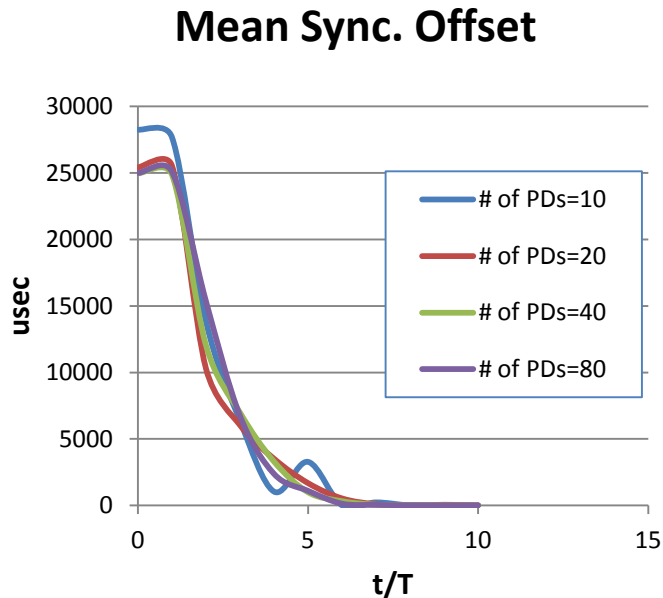
The Ratio of Synchronized PDs



* Simulation methodology refers from [2]

Synchronization Performance

■ Synchronization Accuracy



	$N_{PD}=10$	$N_{PD}=20$	$N_{PD}=40$	$N_{PD}=80$
0	28260.18	25418.36	24975.59	25000
1	27694.1	25552.14	24881.05	25101.9
2	13833.46	10297.46	12051.57	15352.84
3	6376.196	6033.111	6973.267	6729.542
4	1036.911	3505.74	3294.19	2374.513
5	3273.107	1669.398	985.3763	1094.029
6	0.248531	517.5309	312.7014	126.0405
7	223.569	78.55826	40.29059	36.55889
8	0.217967	0.239922	28.45693	14.23396
9	0.2067	39.74689	2.751351	0.258708
10	0.211183	0.253245	0.250434	0.257205

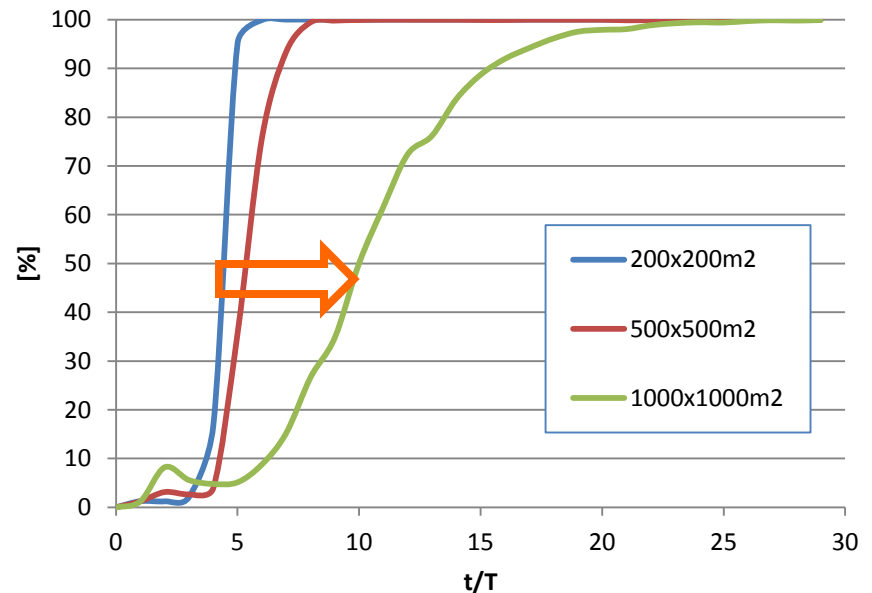
Achieves under 1 usec synchronization accuracy!

Synchronization Performance

■ Simulation Condition

- # of PDs
 - 80
- Coupling factor
 - 0.05
- Dissipation factor
 - 10
- Sync-signal period
 - $T = 100$ msec

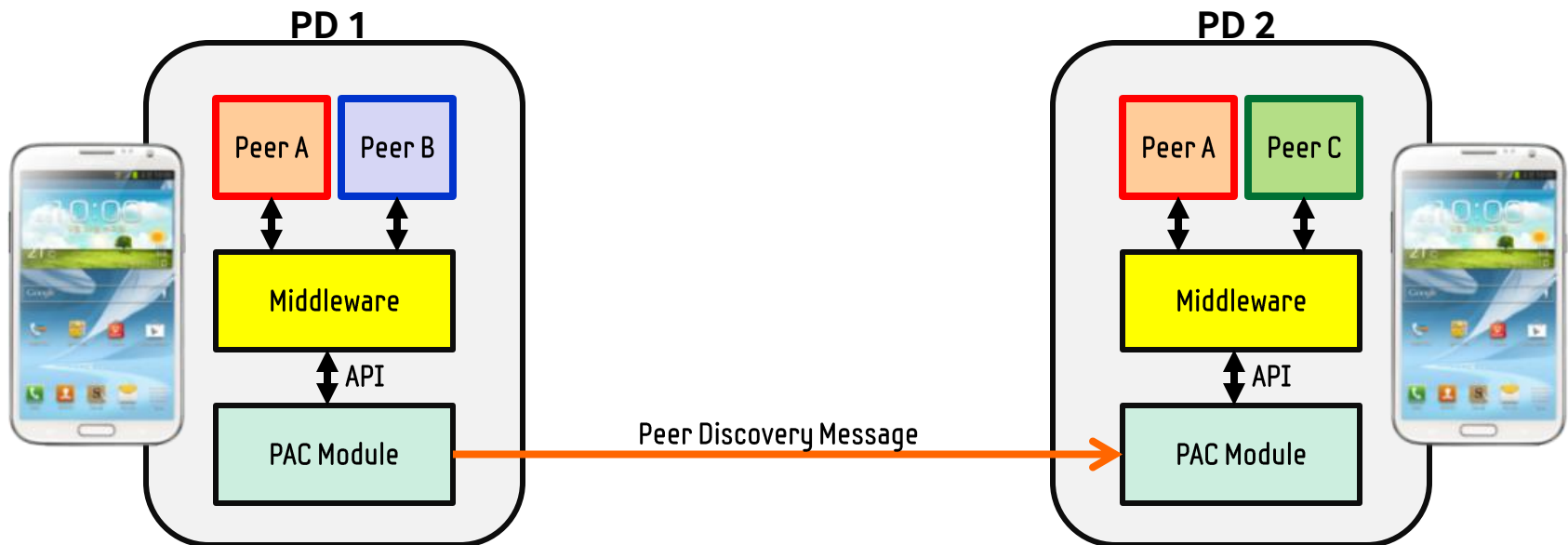
The Ratio of Synchronized PDs



Long latency as being in low density

Peer Discovery

- What is peer discovery?
 - A peer is an application, not a device
 - Application-centric discovery



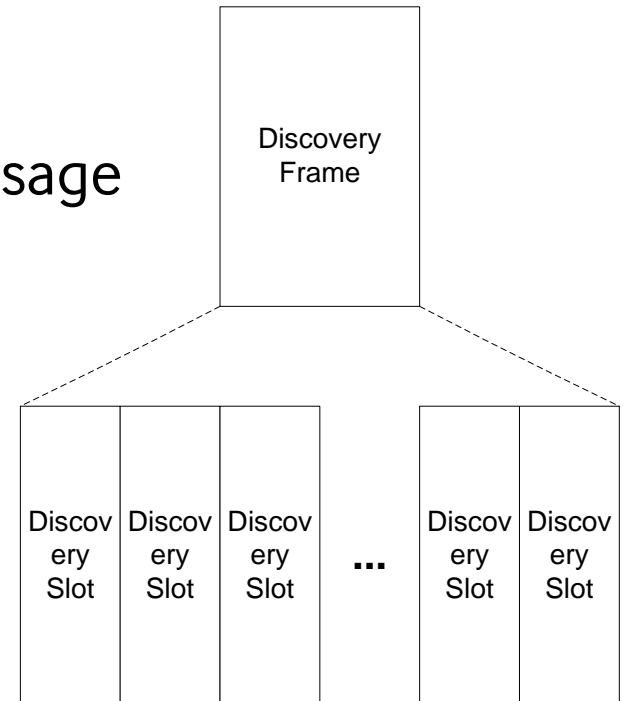
Peer Discovery

- Peer Discovery Message (PDM)
 - At middleware in PD1, it is generated based on
 - Application-specific ID or
 - Application-specific user ID or
 - Application-specific group ID
 - Middleware in PD1 indicates PDM to PAC module
 - At PAC module of PD1, it is broadcasted to PD2
 - At PAC module of PD2, it is delivered to middleware
 - Middleware in PD2 is aware of nearby peer
 - By matching result with pre-stored PDM

Peer Discovery

■ Discovery Frame

- It is comprised of multiple Discovery Slots
- PD selects one Discovery Slot
 - Based on monitoring result at past
- PD broadcasts Peer Discovery Message
 - At selected Discovery Slot



Peering

- The role of Peering
 - A procedure to connect to discovered peer
 - Link establishment
 - Between the discovering peer and the discovered peer
 - Exchange of information for setup
 - device capability, or etc
 - Determine link related parameters
 - Link ID, QoS class, link range, or etc
 - Messages
 - Peering Request
 - Peering Response

Channel Access

■ Design Approach

- Synchronized slotted channel access
- Distributed scheduling to avoid slot conflict
 - Scheduling Request and Scheduling Response
 - These signaling messages contain resource information
 - Related to resource slot assignment
 - Broadcasted to nearby PDs

Scheduling Request :

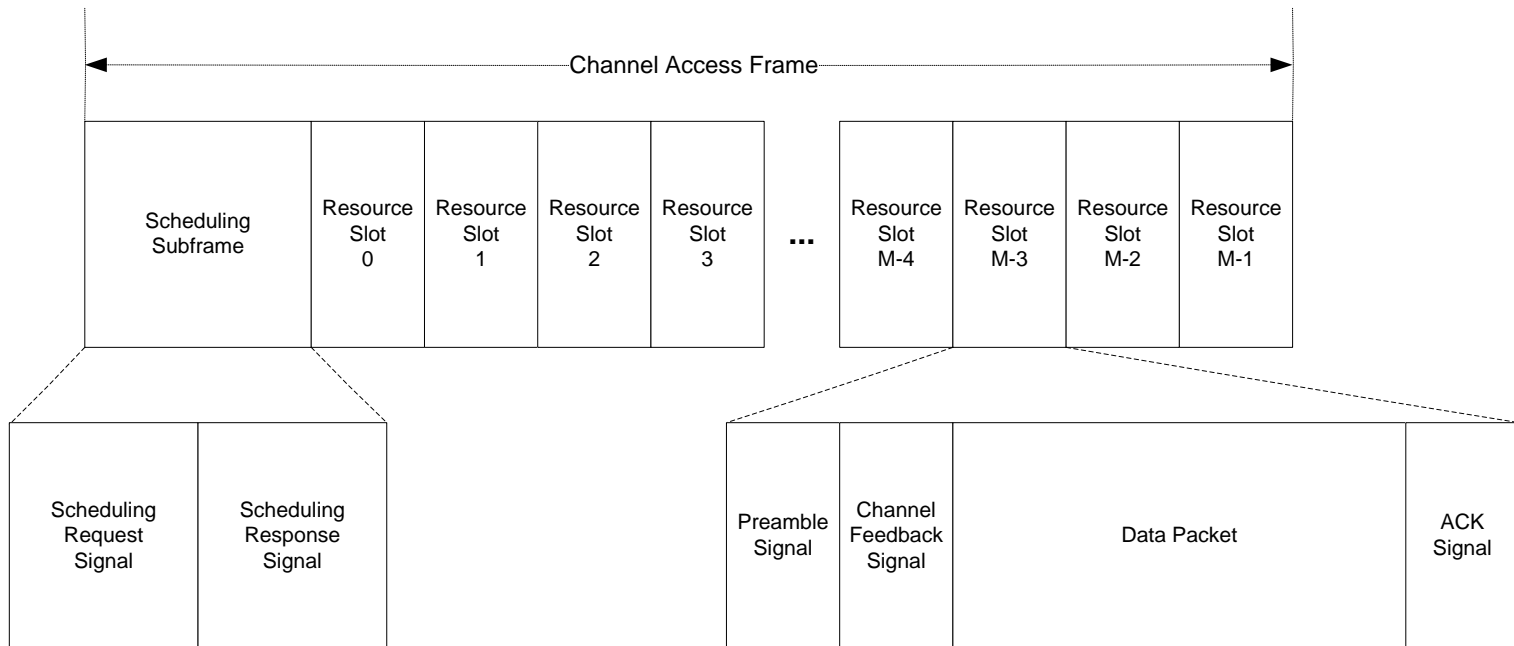
Link ID	Resource Slot Start Index	Resource Slot Length
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Scheduling Response :

Link ID	Resource Slot Adjusted Index	Resource Slot Length
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Channel Access

- Channel Access Frame
 - Scheduling Subframe
 - M Resource Slots



References

- [1] *Distributed synchronization in wireless networks*, Simeone, Osvaldo ; Spagnolini, Umberto ; Bar-Ness, Yesheskel ; Strogatz, Steven H., Signal Processing Magazine, IEEE Volume: 25 , Issue: 5, Digital Object Identifier: 10.1109/MSP.2008.926661, Publication Year: 2008 , Page(s): 81 – 97
- [2] *Emergent Slot Synchronization in Wireless Networks*, Tyrrell, A.; Auer, G.; Bettstetter, C., Mobile Computing, IEEE Transactions on, Volume: 9 , Issue: 5, Page(s): 719 – 732, Digital Object Identifier: 10.1109/TMC.2009.173, Publication Year: 2010 , Page(s): 719 – 732
- [3] *Selective Pulse Coupling Synchronicity for Sensor Network*, Yu Niu ; d'Auriol, B.J. ; Xiaoling Wu ; Jin Wang ; Jinsung Cho ; Sungyoung Lee, Sensor Technologies and Applications, 2008. SENSORCOMM '08. Second International Conference on, Digital Object Identifier: 10.1109/SENSORCOMM.2008.59 Publication Year: 2008 , Page(s): 123 - 128

Appendix

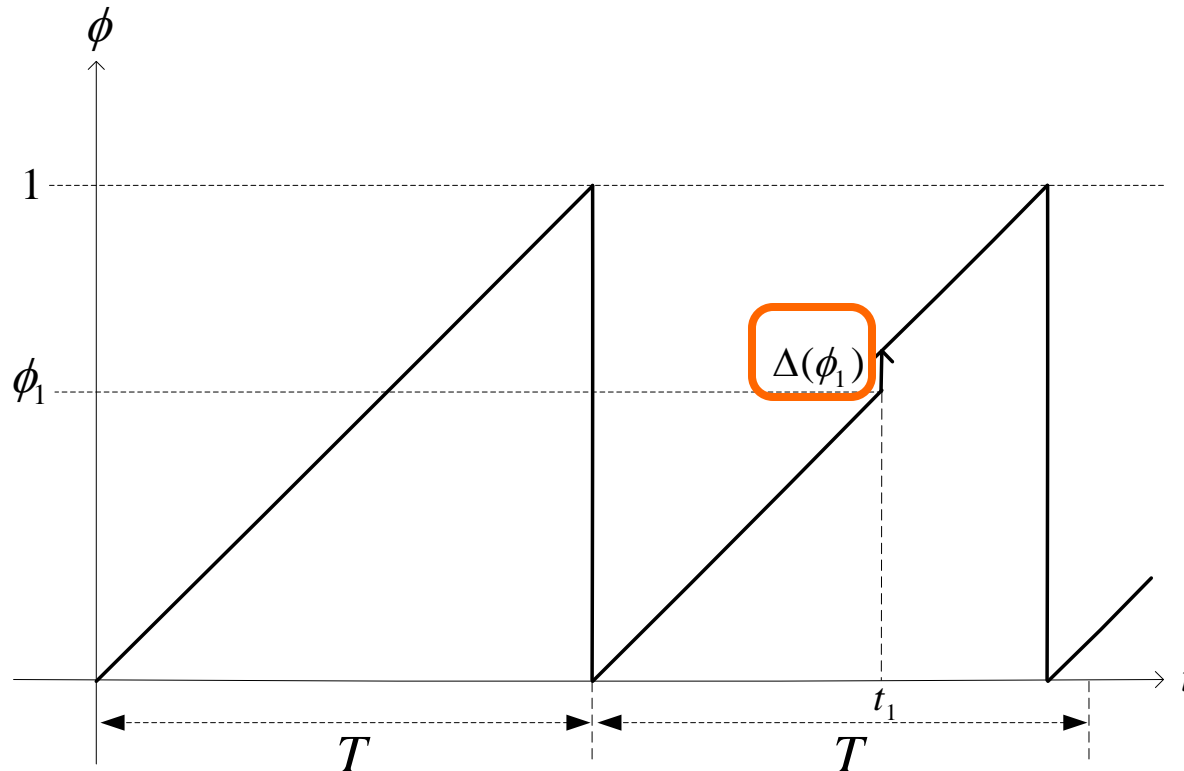
- PCO Synchronization
- Comparison of two ways for Peer Discovery

PCO Synchronization

- Pulse Coupled Oscillator (PCO) Synchronization
 - Fully distributed synchronization algorithm
 - Doesn't need other PDs timing information
 - Each PD has
 - an oscillator (or counter) with the identical increment rate
 - a same function to adjust phase of oscillator
 - Features
 - Simple
 - Scalable
 - no hierarchy (=flat)
 - Fast convergence time

PCO Synchronization

- Phase adjustment using only internal value



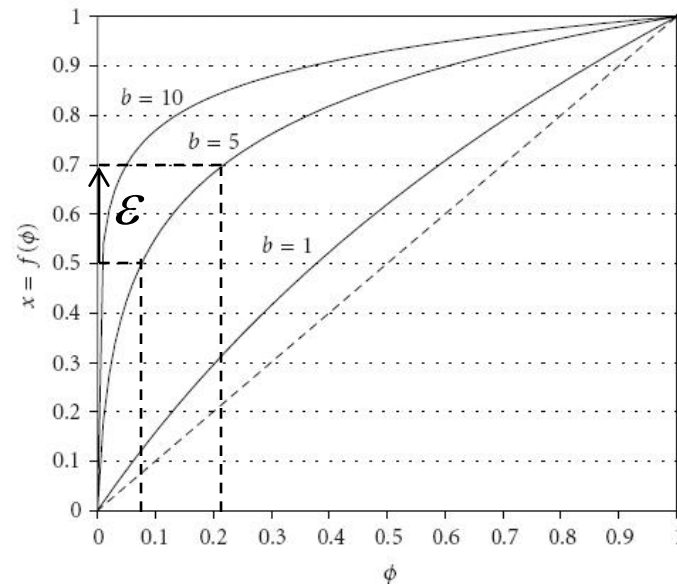
PCO Synchronization

■ Phase adjustment algorithm [2][3]

$$- \phi + \Delta(\phi) = f^{-1}(f(\phi) + \varepsilon)$$

$$- f(\phi) = \frac{1}{b} \cdot (1 + [e^b - 1] \cdot \phi)$$

- ε : coupling factor
- b : dissipation factor

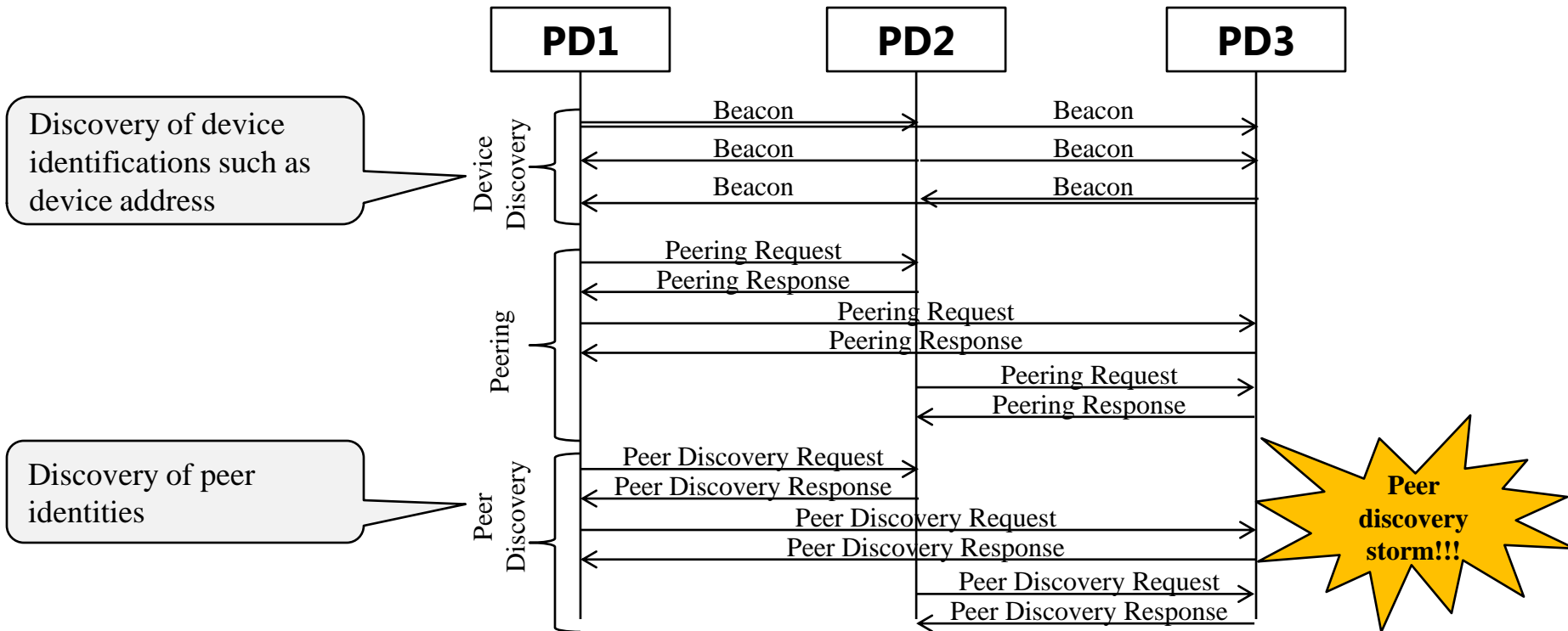


PCO Synchronization

- Phase adjustment algorithm [2][3]
 - selective update for fast convergence
 - If $(2 \times \phi + \Delta(\phi)) > 1$,
$$\hat{\phi} = \min(1, \phi + \Delta(\phi))$$
 - else no update
 - Refractory period to avoid ping-pong effect
 - No update when
$$\phi < \frac{2 \times T_{\text{max. propagation delay}}}{T}$$

Comparison of two ways for Peer Discovery

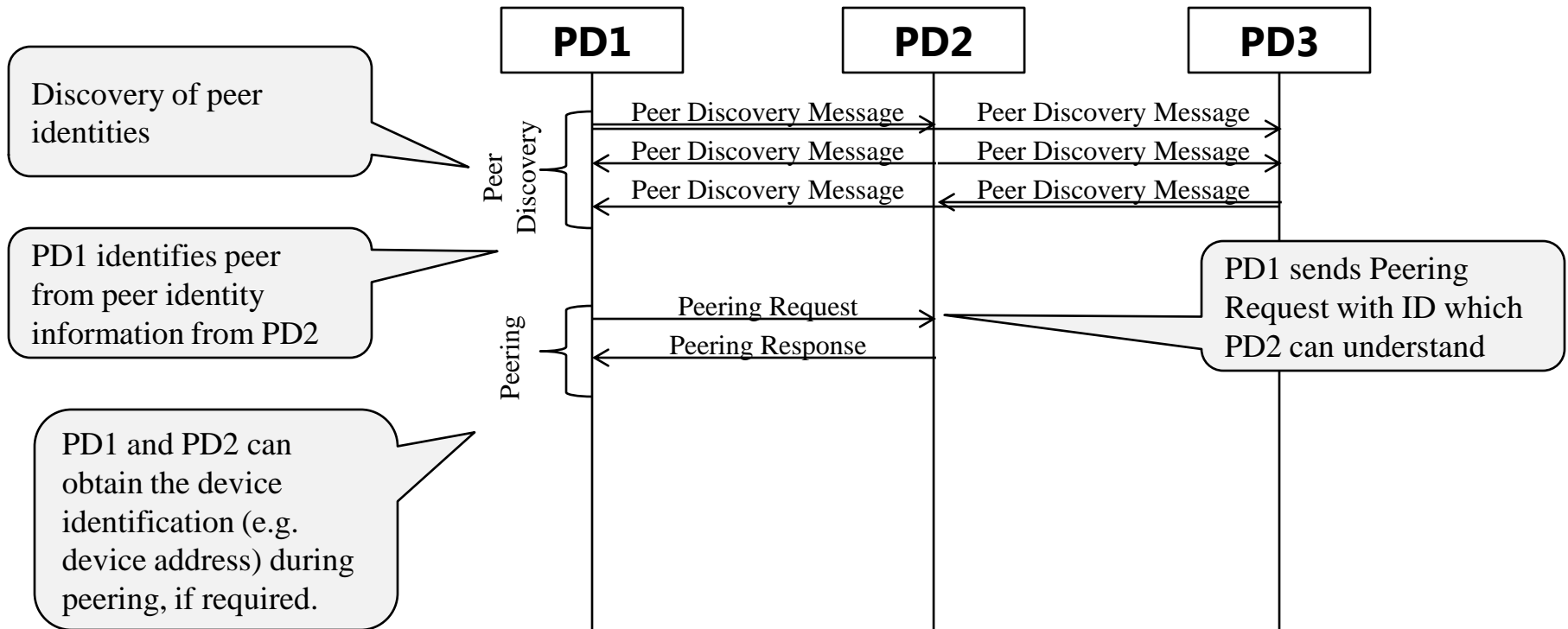
- Peer discovery after peering



* Terminologies are temporarily used for explanation

Comparison of two ways for Peer Discovery

- Peer discovery before peering



* Terminologies are temporally used for explanation