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

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

Date Submitted: [6 May 2013]

Source: [Seung-Hoon Park, Kyungkyu Kim, Sungjin Lee, Sangkyu Baek, Youngbin Chang, Chiwoo Lim, Hyunseok Ryu, Daegyun Kim and Won-il Roh]
Company [Samsung Electronics]
Address [416, Maetan-3Dong, Yeongtong-Gu, Suwon-Si, Gyeonggi-Do, 443-742, Korea]
Voice:[+82-10-9349-9845][1], FAX: [+82-31-279-0813][1], E-Mail:[shannon.park@samsung.com]

Re: [.]

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

Purpose: [Corresponding to Call for Proposal]

PAC Operations and Frame Structure

May, 2013

Samsung

System Design Approach

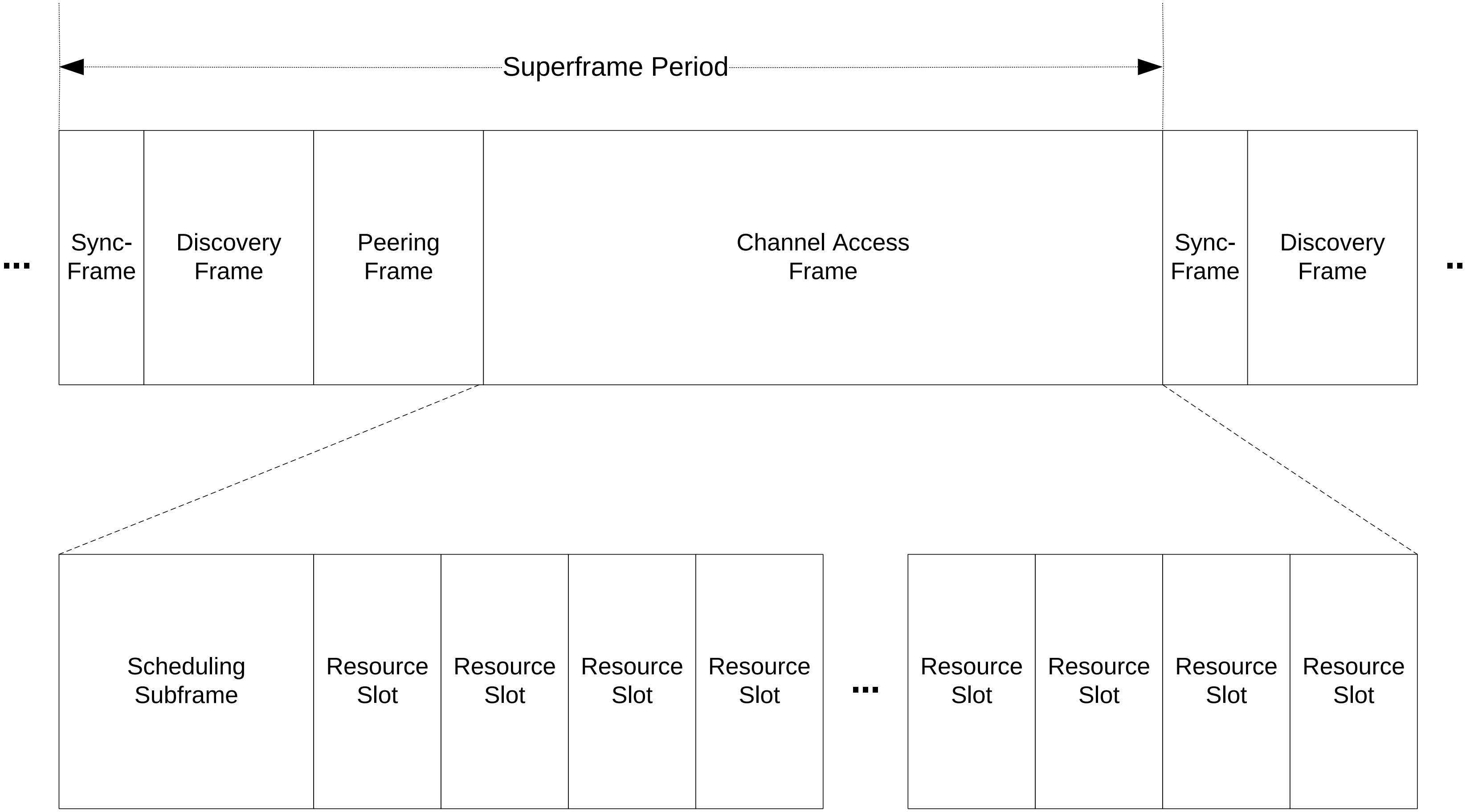
- Synchronous Operation
  - Low power consumption for peer discovery
  - Higher throughput

- Frame Structure
  - Synchronization
  - 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

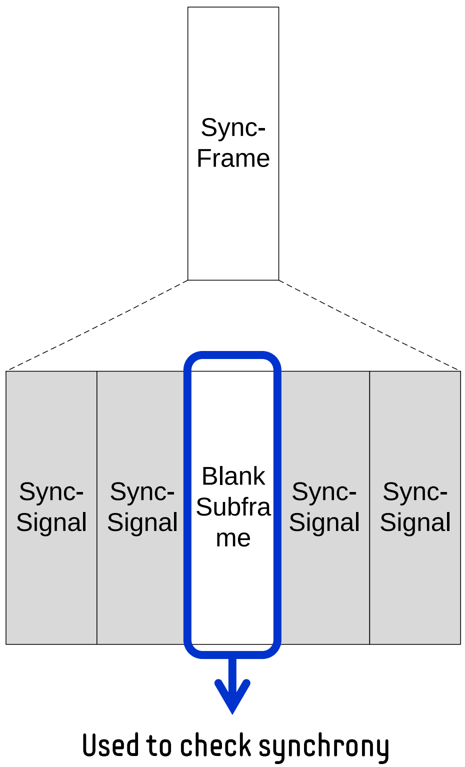
- Synchronization for Scalable Network
  - Distributed synchronization
    - Master-slave synchronization should be avoided
      - PDs between two different synchronized group happen
    - It is matched well to flat architecture (no hierarchy)
  - Synchronization should be done before peer discovery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

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

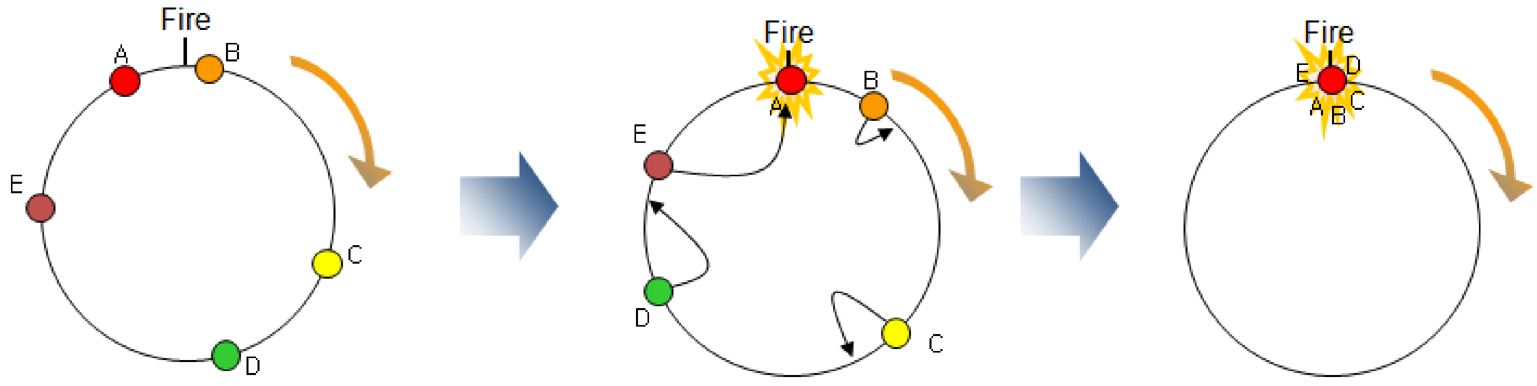
Synchronization

- Maintaining Synchronization
  a. PD sends sync-signal periodically, but checks synchrony state sometimes 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

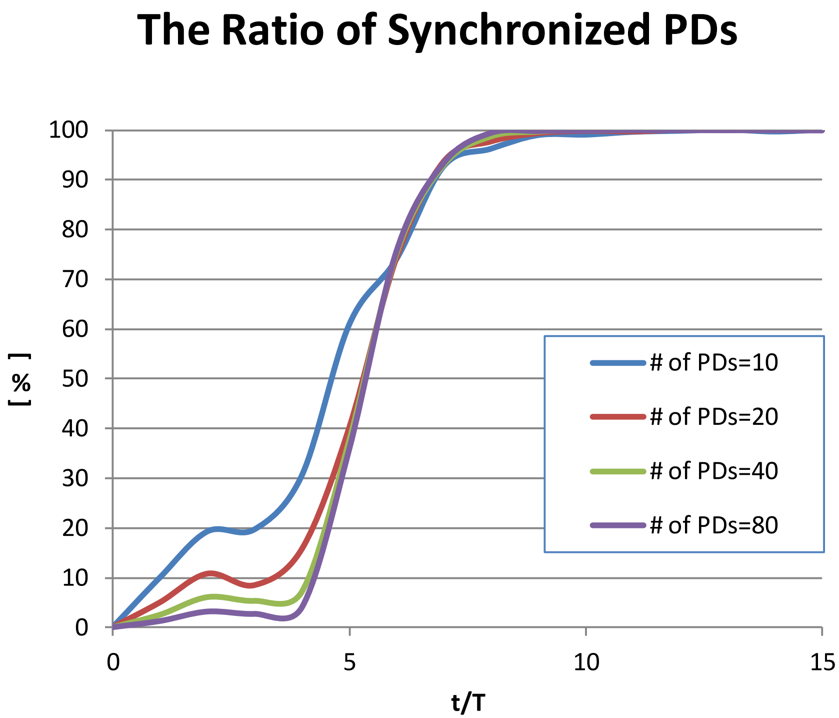
- PCO Synchronization [1]
  - At initial synchronization mode
  - Pulse-based approach
    - Oscillator coupled by pulse exchange via physical layer



(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 it's internal phase
(c) Finally, all nodes converges to the same time base

Synchronization Performance

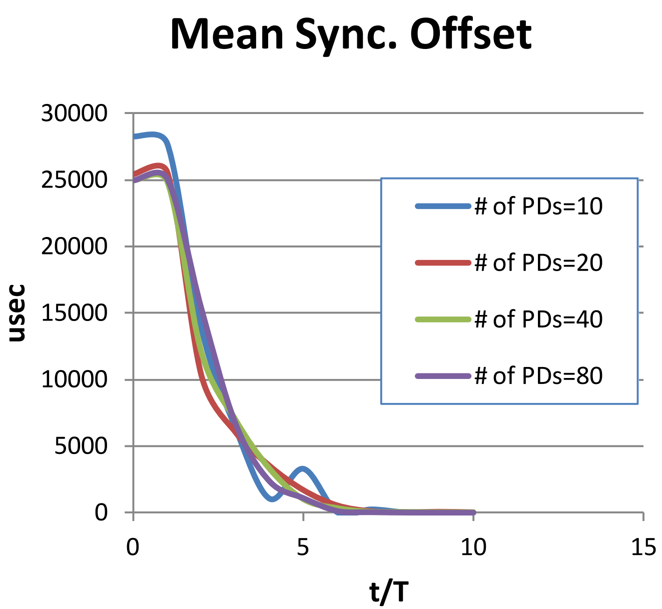
- Simulation Condition
  - Dimension
    - 500 x 500 m^2
  - Coupling factor
    - 0.05
  - Dissipation factor
    - 10
  - Sync-signal period
    - T = 100 msec



* Simulation methodology refers from [2]

Synchronization Performance

- Synchronization Accuracy

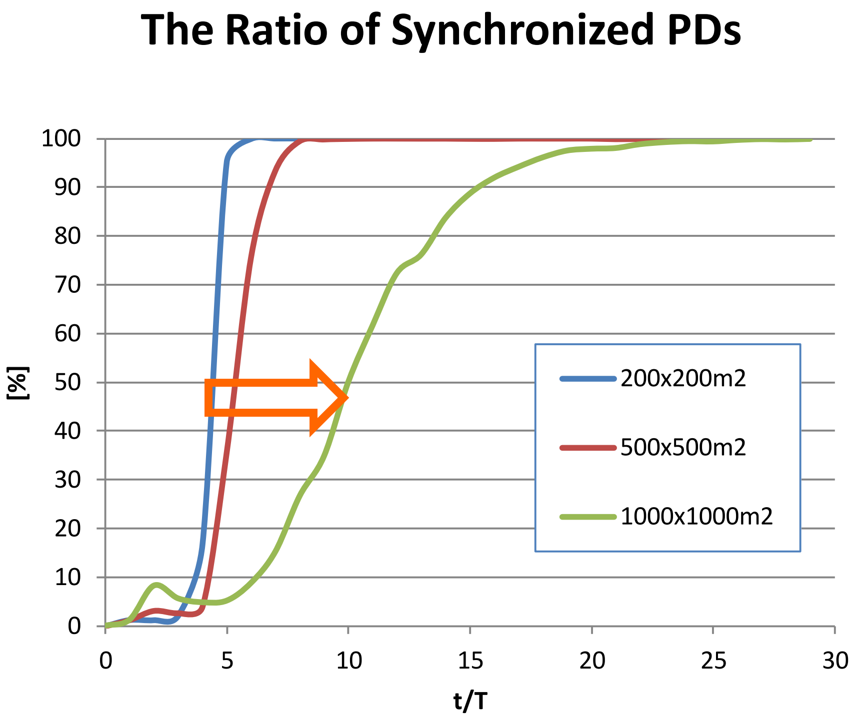


	N_{PD}=10	N_{PD}=20	N_{PD}=40	N_{PD}=80
0	28260.18	25418.36	24975.59	25000
1	27694.1	25552.14	24881.05	25101.9
2	13833.46	10297.46	12051.57	15352.84
3	6376.196	6033.111	6973.267	6729.542
4	1036.911	3505.74	3294.19	2374.513
5	3273.107	1669.398	985.3763	1094.029
6	0.248531	517.5309	312.7014	126.0405
7	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



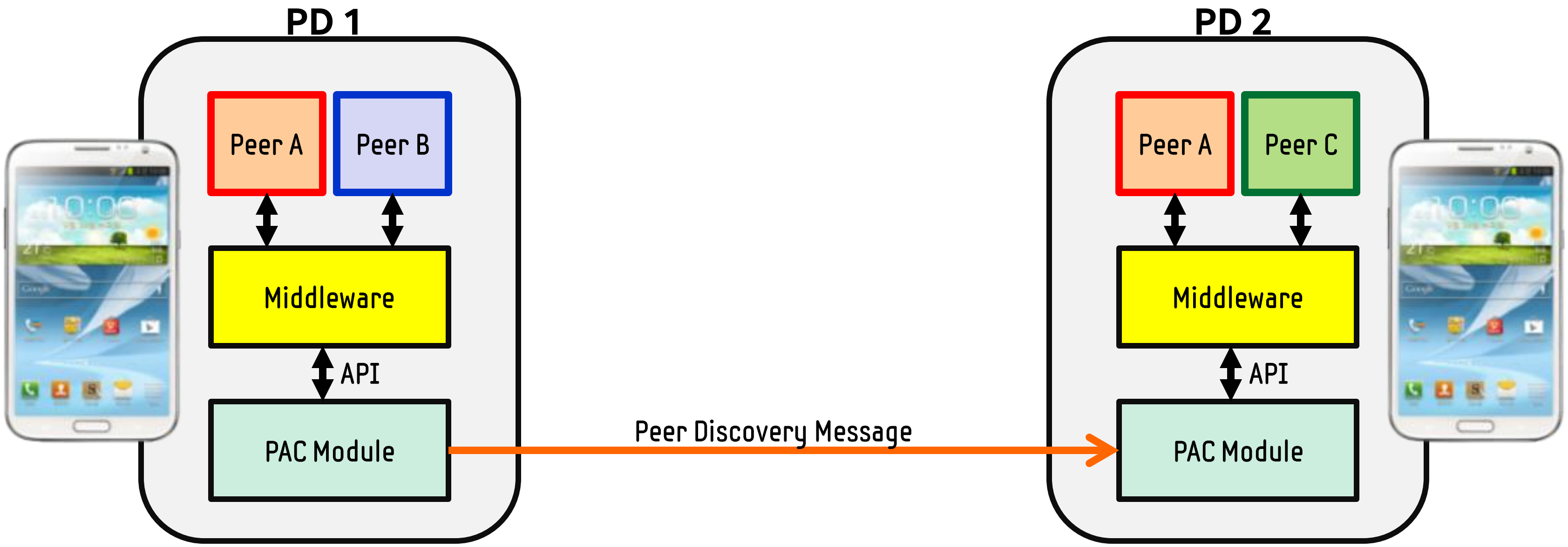
Long latency as being in low density

Peer Discovery

- Design Considerations
  - The meaning of Peer Discovery
    - It depends on what is discovered
      - Discovery of application → PACbook
      - Discovery of friend → bob@PACbook
      - Discovery of group → IEEE802@PACbook
  - Who gives peer discovery information (PDI)
    - Application or middleware
      - They may have access to internet or may not
    - Authentication
      - Only PDs with same PDI can be discovered each other
      - PDI may be pre-installed or given from network
  - Unified Peer Discovery mechanism required

Peer Discovery

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

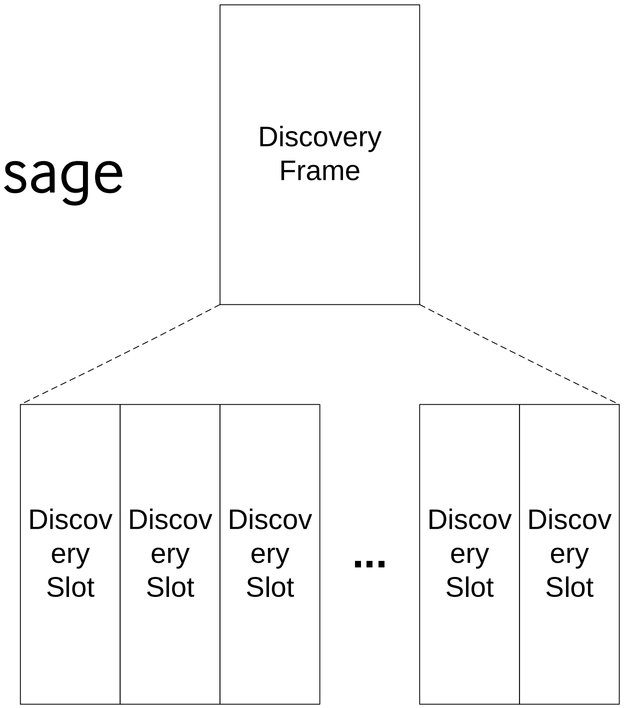


Peer Discovery

- Peer Discovery Message (PDM)
  - At middleware in PD1, it is generated based on
    - Application-specific ID,
    - Application-specific user ID,
    - Application-specific group ID,
    - Or any upper layer discovery information
  - 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
    - Triggered by application automatically or by user manually
  - 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

- Channel Access Frame
  - Only accessed by peered PDs
  - Signaling reduction using Link ID set up during peering
    - No necessity of keeping two IDs for both Tx PD and Rx PD

- Design Considerations
  - Connection is the result from peering
    - Unicast/multicast including single/multi-hop
    - Network protocol shall be operated only over connected links
      - E.g. routing, grouping, etc

Channel Access

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

Scheduling Request :

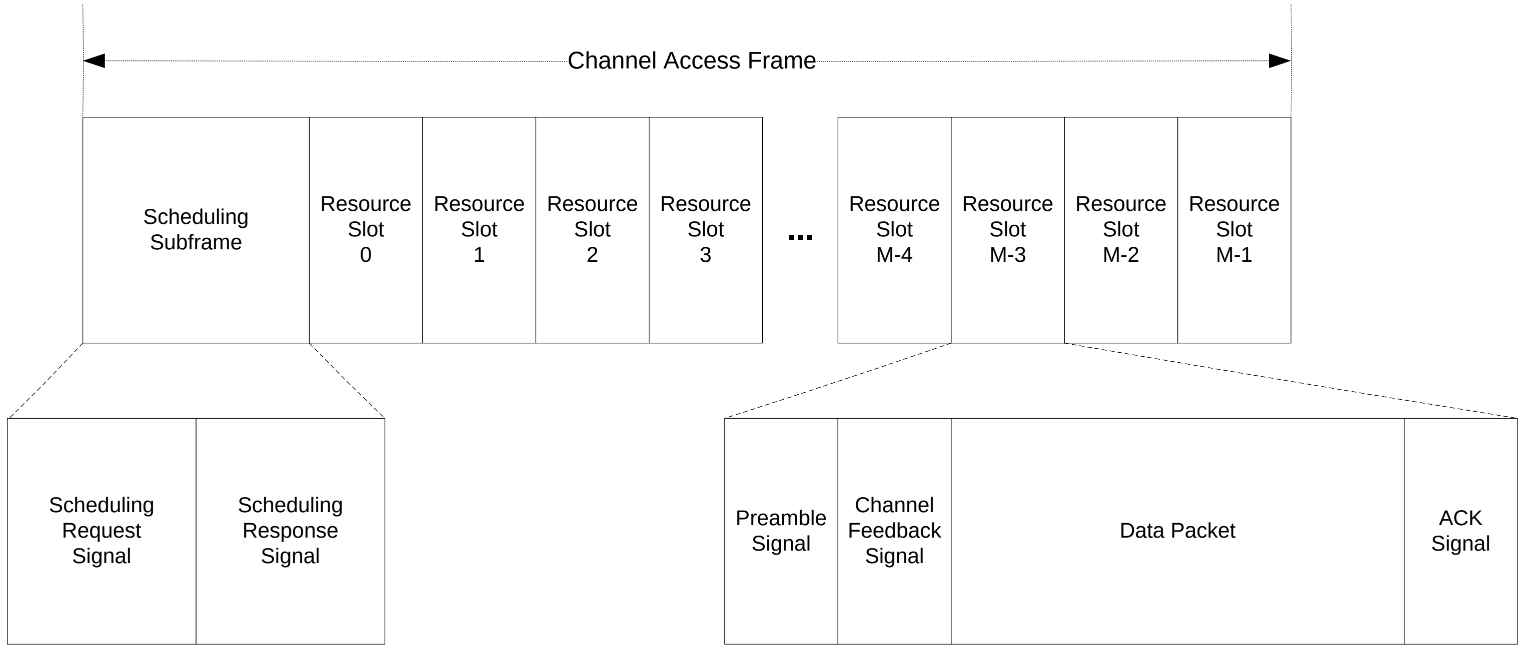
Link ID	Resource Slot Start Index	Resource Slot Length

Scheduling Response :

Link ID	Resource Slot Adjusted Index	Resource Slot Length

Channel Access

- Channel Access Frame
  - Scheduling Subframe
  - M Resource Slots



Summary

- Key Design Considerations
  - Synchronization prior to peer discovery
    - PCO synchronization
  - Peer discovery
    - Application-centric discovery
  - Peering
    - Triggered by application or users
  - Channel access
    - Slotted scheduling by request and response messages

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

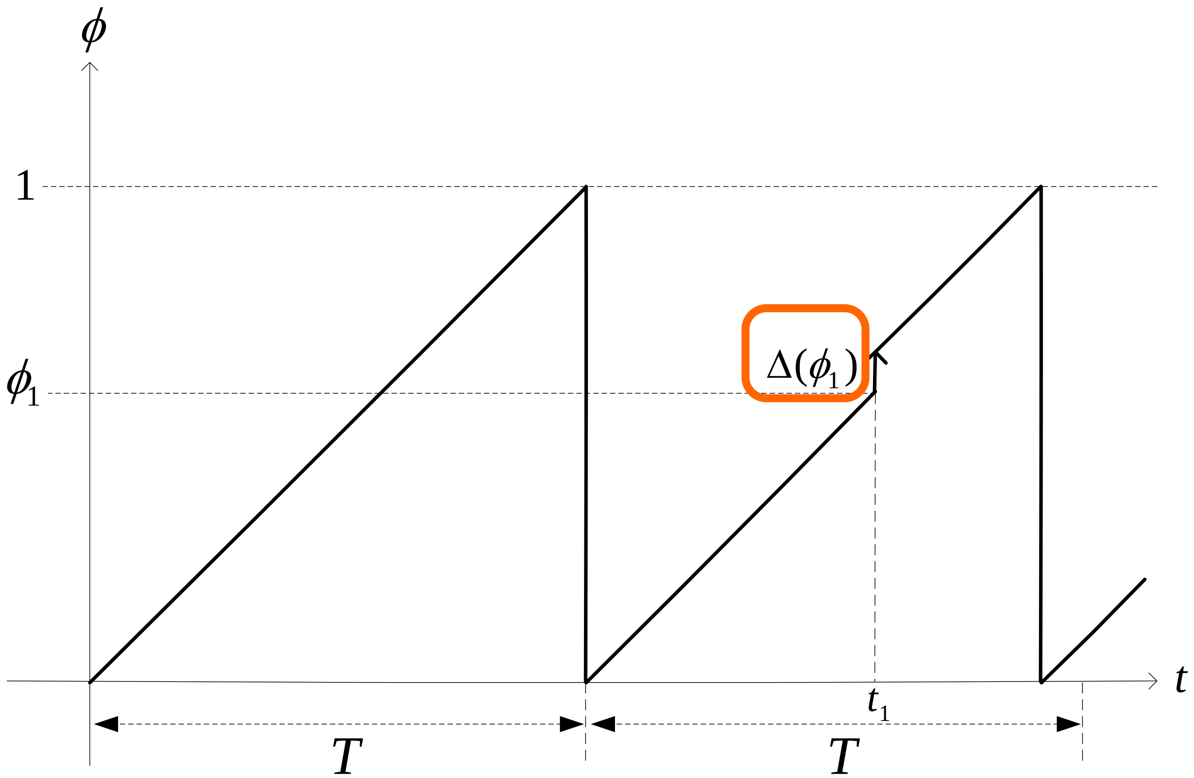
- PCO Synchronization
- Comparison of two ways for Peer Discovery

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

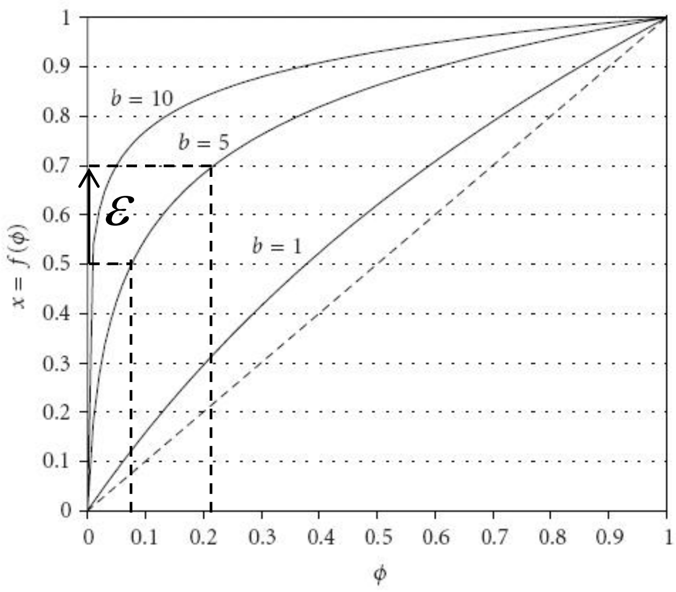
PCO Synchronization

- Phase adjustment using <u>only internal value</u>



PCO Synchronization

- Phase adjustment algorithm [2][3]
  - $\phi + \Delta(\phi) = f^{-1}\left(f(\phi) + \varepsilon\right)$
  - $f(\phi) = \frac{1}{b} \cdot \left(1 + \left[e^{b} - 1\right] \cdot \phi\right)$
    - ε : coupling factor
    - b : dissipation factor



PCO Synchronization

- Phase adjustment algorithm [2][3]
  - selective update for fast convergence
    - If $\left(2\times\phi+\Delta(\phi)\right)>1$,

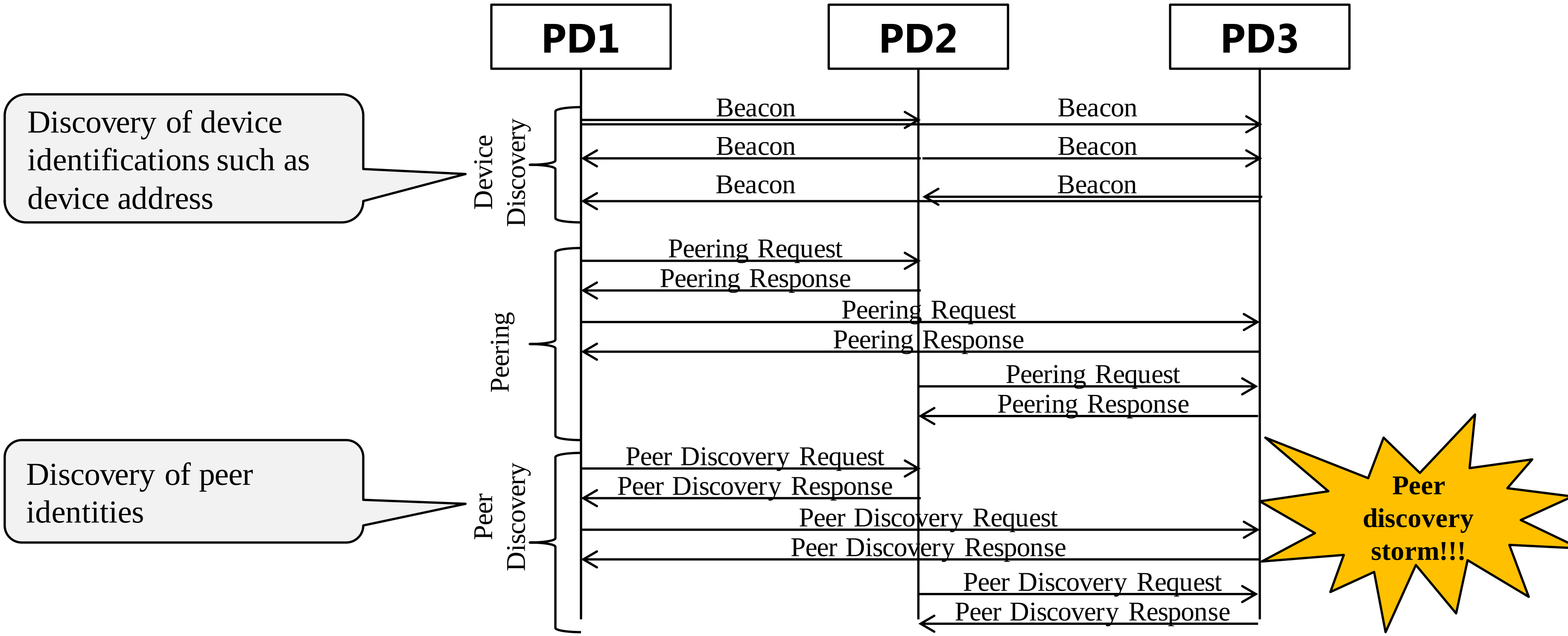
$$\hat{\phi}=\min(1,\phi+\Delta(\phi))$$

    - else no update
  - Refractory period to avoid ping-pong effect
    - No update when

$$\phi<\frac{2\times T_{\max.\, propagation\ delay}}{T}$$

Comparison of two ways for Peer Discovery

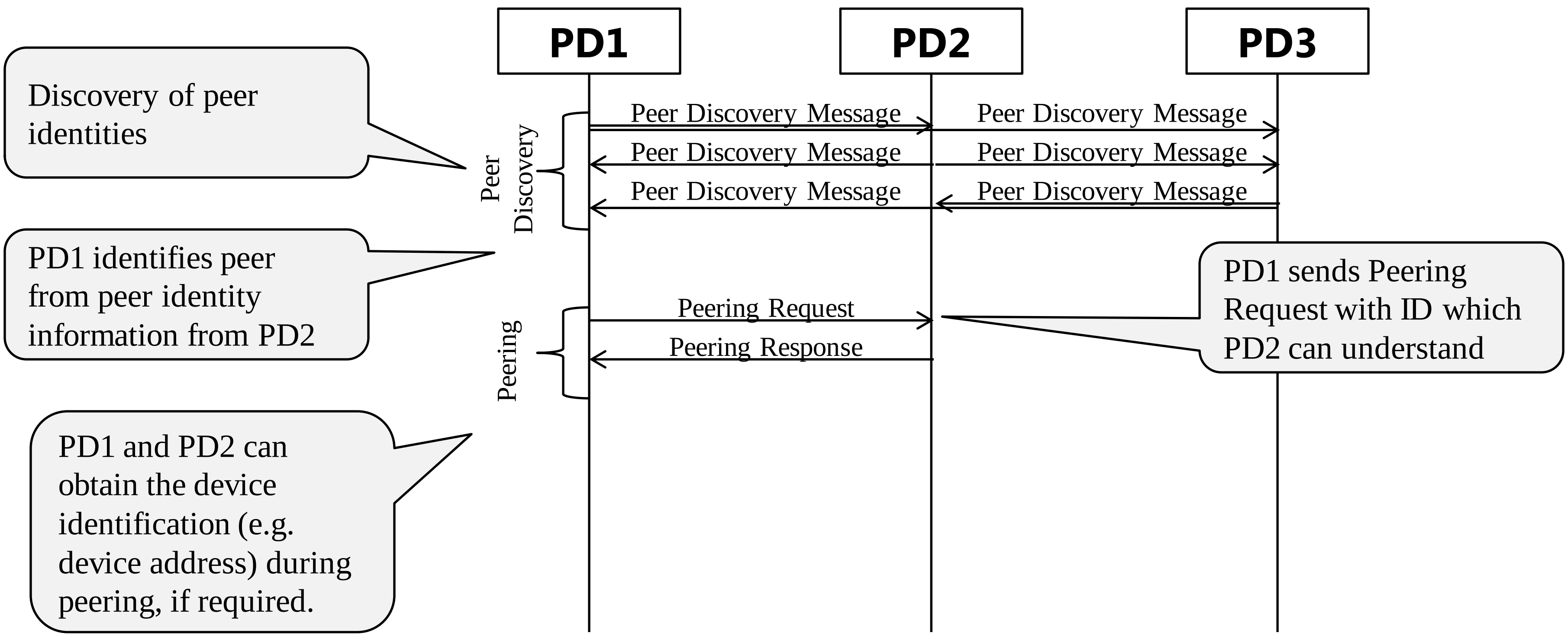
- Peer discovery after peering



* Terminologies are temporally used for explanation

Comparison of two ways for Peer Discovery

- Peer discovery before peering



* Terminologies are temporally used for explanation