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

Submission Title: [A proposal for PAC framework document]
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Re: [In response to call for proposals to TG8]

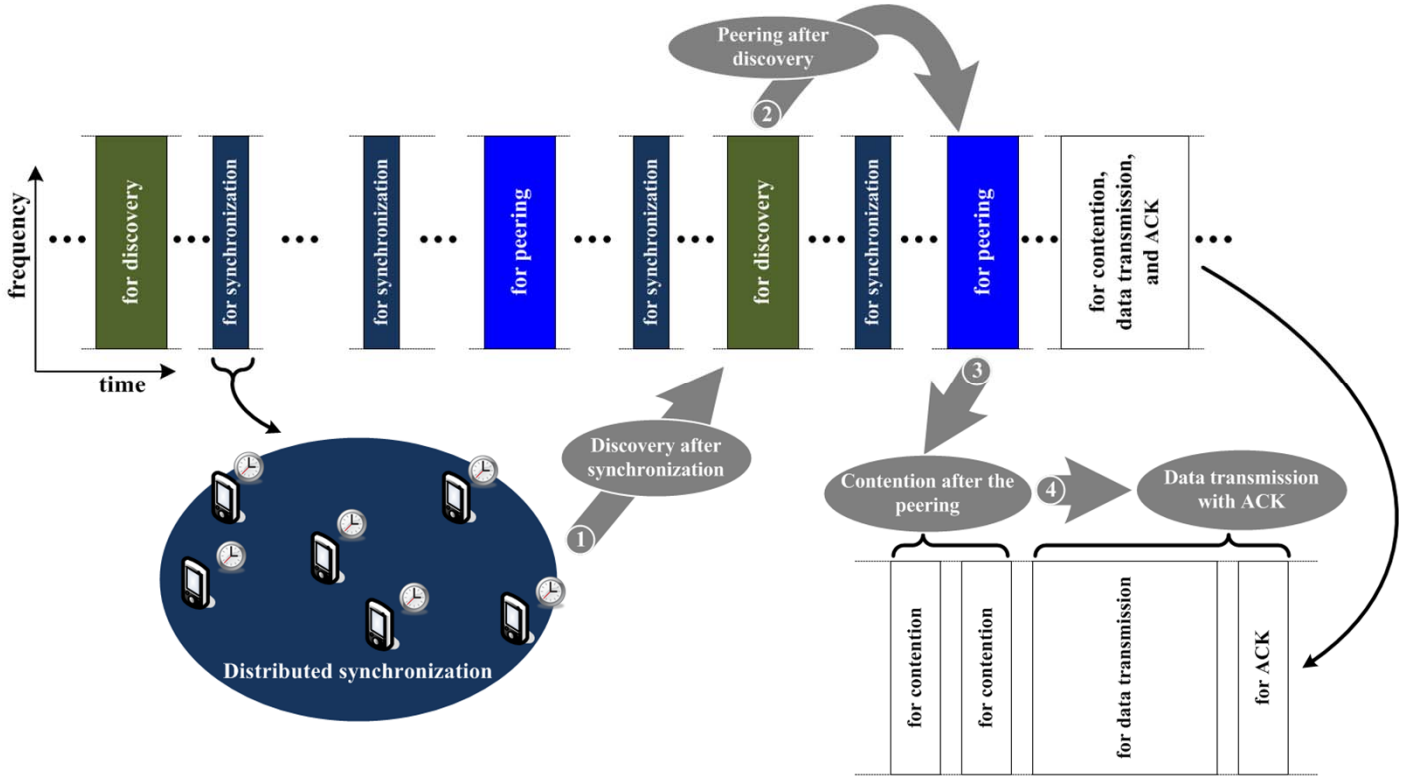
Abstract: [This document contains the proposal for PAC framework document]

Purpose: [Materials for Proposal in 802.15.8 TG]

Contents

Overview

- Radio resource is divided in time by its usage
  - Preliminary example in licensed bands



Sectionized frame format with synchronization

- PAC device operating in licensed bands:
  - Tight time synchronization among PAC devices is maintainable.
  - If synchronization among PAC devices is maintained, a fixed frame structure has advantages such as achieving high network throughput and power saving schemes.
  - Thus, major functionalities of PAC features can be executed in number of a few sections for their objectives in the frame format to minimize resources.
    - The sectionized frame format may allocate discovery, peering, distributed data transmission scheduling (TDMA), and etc. in separate sections.

Issues in the unlicensed bands

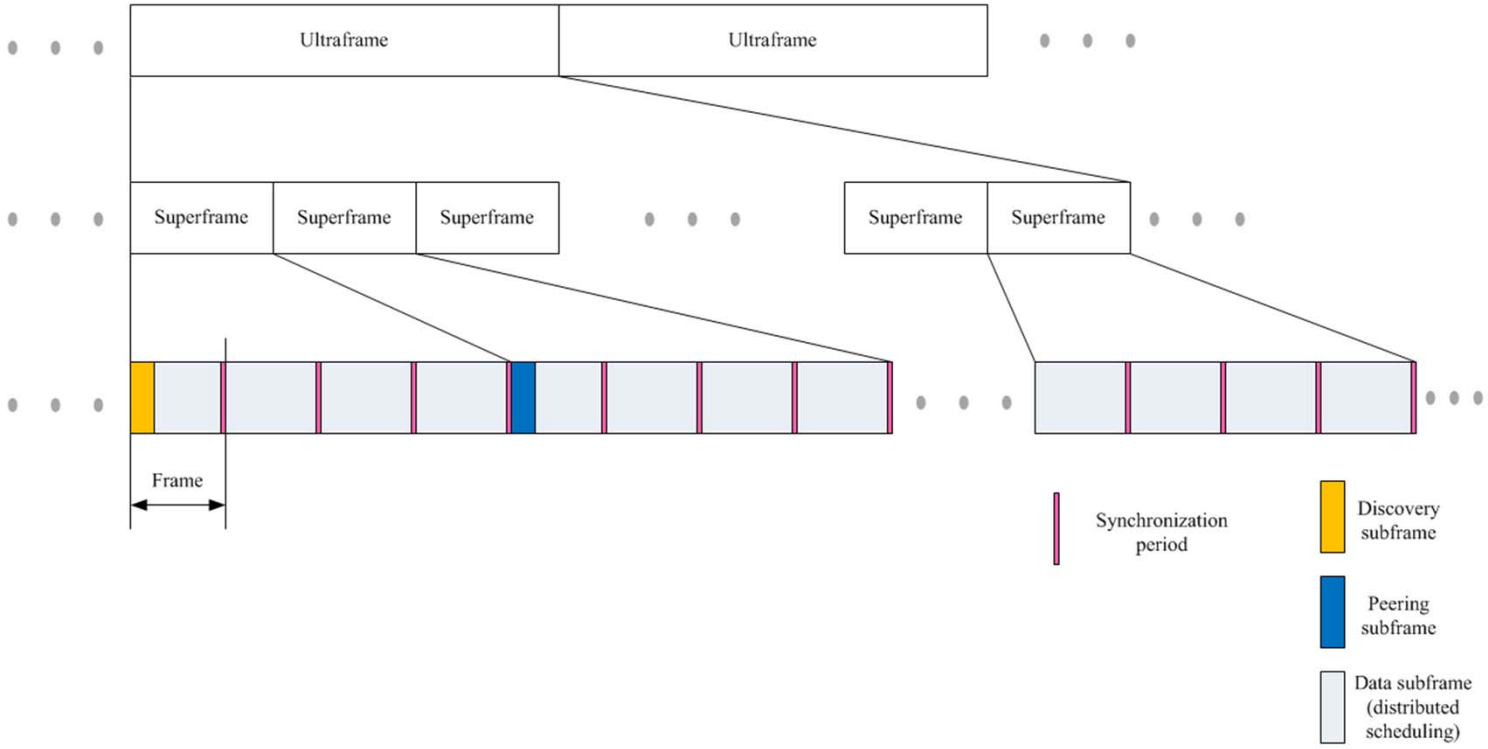
- PAC device operating in unlicensed bands:
  - Tight time synchronization among PAC devices is difficult to maintain.
  - Multiple access scheme with packet collision avoidance mechanism such as the CSMA/CA should be employed for the unlicensed bands: the only way to meet coexistence requirement with other devices sharing the spectrum.
  - There has been not enough discussions on coexistence issues with heterogeneous devices (e.g., IEEE 802.15.4 Zigbee, IEEE 802.11b/g/n/ac WLAN).
  - A different frame format from licensed band's might be required for network throughput efficiency.

PAC Subframes

- Synchronization period:
  - This short period is utilized to maintain synchronization (physical transmission symbol, frame and MAC level) and corresponding sectionized frame format.
- Discovery subframe:
  - Assuming synchronization is maintained, all PAC devices sends/receives discovery signals in a designated time slot.
- Peering subframe:
  - Unknown which pair is going to do peering (and when it occurs), thus, a designated region for random trial of peering is allocated.
- Data subframe (Distributed scheduling + data transmission + ACK):
  - Scheduling without a centralized scheduler in the licensed band
  - Various transmitter/receiver pairs mutually recognize how to resolve distributed data transmission scheduling issue by:
    - Orthogonal scheduling

Proposed frame structure for licensed bands

- Example of general synchronized frame structure
  - Ultraframe, Superframe, and subframes/period



Some preliminary results on distributed synchronization

- Simulation environment
  - Pulse-based, multi-point to multi-point synchronization
    - Refer : IEEE 802.15-13-0121-00-0008
  - TDD
  - Tx/Rx sync signals per 20 msec

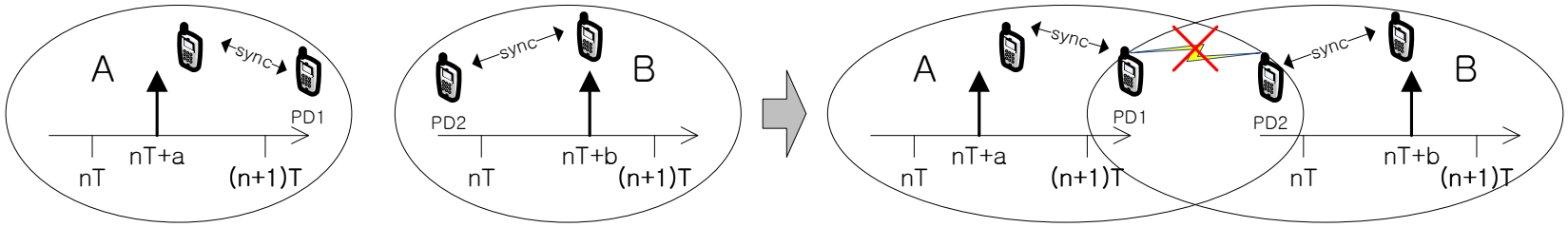
- Simulation result

[usec]

	40 PDs 100x100 m^2	100 PDs 100x100 m^2	100 PDs 500x500 m^2	1000 PDs 500x500 m^2
Variance	0.020	0.013	0.045	0.021
Mean of maximum time offset	0.57	0.56	0.93	0.86
Variance of maximum time offset	0.031	0.011	0.028	0.014

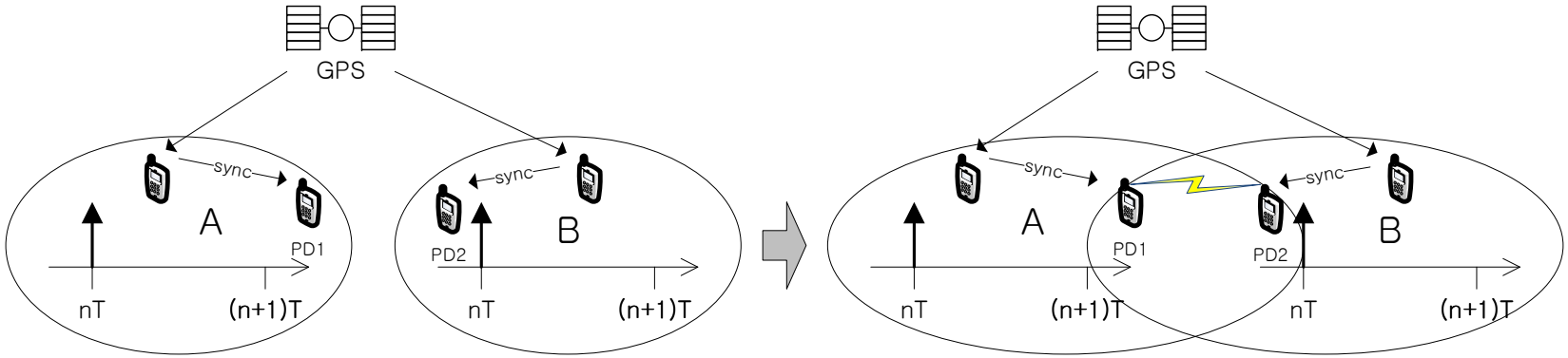
Considerations on synchronization

- Inter-group synchronization
  - Re-synchronization among groups are required if groups physically merge together to form a new/integrated group



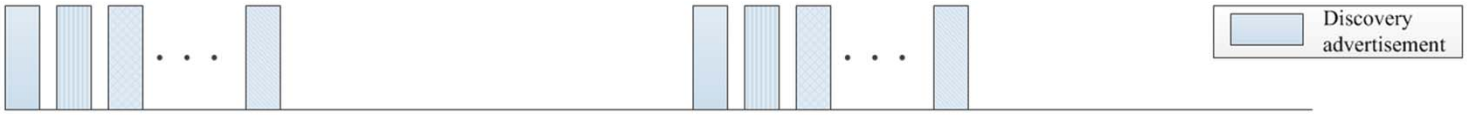
Considerations on synchronization (Cont'd)

- Availability on global reference time
  - If all devices and groups are synchronized to each other (global synchronization), inter-group synchronization procedure is not needed.
  - Global synchronization should be considered when some of the devices have the global reference time



Discovery

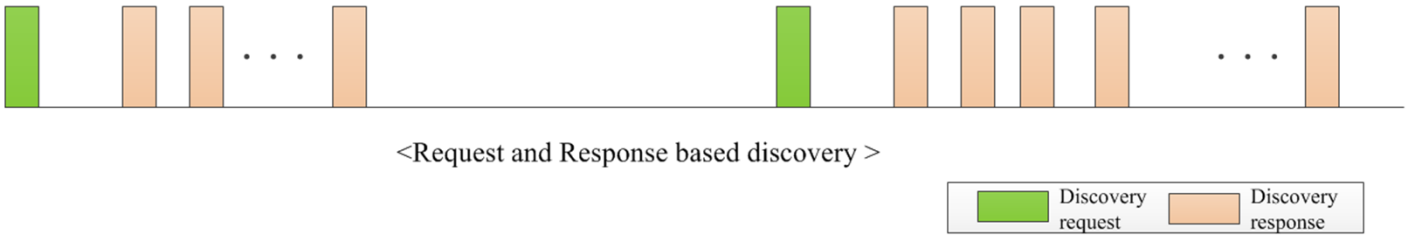
- Types of discovery
  - Broadcasting based discovery
    - Unidirectional discovery no response from neighbor PDs
      - Discoveree broadcast own information on a common channel
      - Discoverer monitor on common channels
    - Power saving scheme can be implemented with a synchronous fixed frame structure
    - Resources can be divided into multiple channels for parallel discovery
      - Channel resource selection in a distributed manner after listening
      - Reservation of channel resource can be possible after initial selection
      - Resource contention and collision among the discoverees
    - Suitable for finding neighbor PDs autonomously and continuously
      - Target peer discovery is supportable but there can be long latency



<Broadcasting based discovery>

Discovery

- Request and response based (query-based) discovery
  - Bi-directional(/mutual) discovery
    - Discoverer transmits discovery request to neighbor PDs
    - Discoveree responds to discovery request with own information
    - Discoverer receives discovery response from neighbor PDs
  - Power saving scheme can be implemented with a synchronous fixed frame structure
  - Resources can be assigned separately
    - Other resources can be assigned for query-based discovery
    - Resource contention and collision among the discoverers or discoverees
  - Suitable for finding target peer
    - User/application triggered discovery with short latency



<Request and Response based discovery >

Peering

- Recognition of Peering through PIDs
  - With(or without) mutual discovery
  - Triggered by one of the PDs that want to link establishment
    - A designated region for random trial of peering can be allocated with a fixed frame structure
  - Sharing a Peering ID(PID) after peering
    - The shared PID is a basic material for resource contention

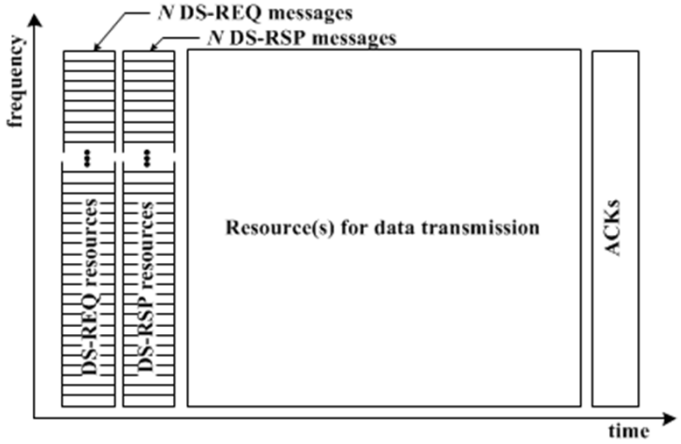
A need for a distributed and scalable contention protocol

- 802.11 CSMA/CA may be inefficient for PAC mandating the distributed multiple access with a large number of PDs
  - Performance of 802.11 CSMA/CA deteriorates dramatically as the number of contending STA(station)s exceeds a certain threshold
    - Most of papers on the performance analysis of wireless LAN analyzed the performance (access delay, throughput, …) with no more than 20~50 STAs
  - Only the winner of contention takes all at the expense of the high overhead of RTS/CTS exchange

- PAC should discuss much more to support the large number of PDs
  - PAC considers “at least a hundred of PDs”
  - Low overhead multiple access scheme is required for PAC

OFDMA structure for contention

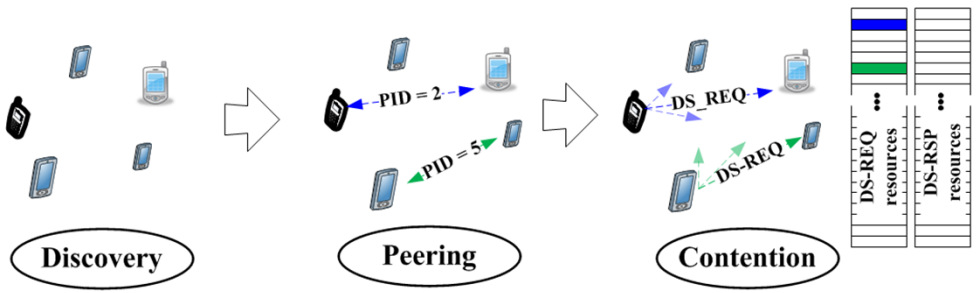
- Packing the resource request/response messages into a dedicated resource in an OFDMA fashion
  - Logical structure



  - DS-REQ (Distributed Scheduling – REQuest) message
    - Transmitted by a contending PD which are trying to access the resource for data transmission
  - DS-RSP (Distributed Scheduling – ReSPonse) message
    - Transmitted by the recipient PD in a response to the received DS-REQ

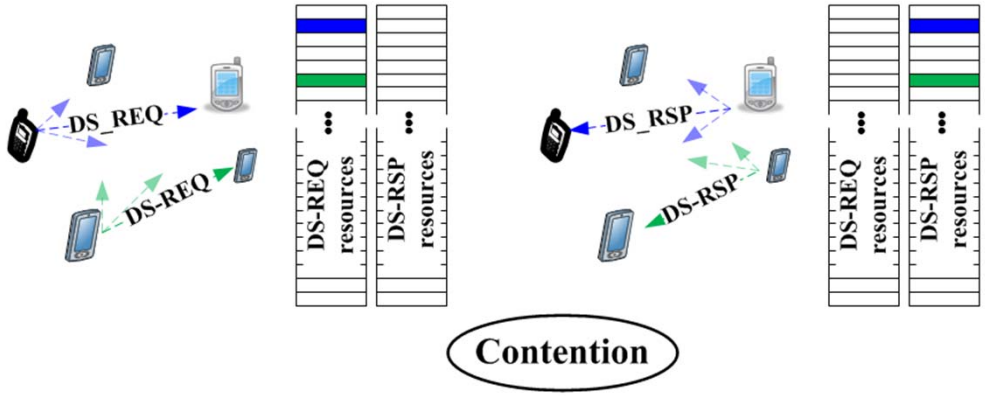
OFDMA structure for contention (Cont'd)

- Signaling procedure
  - After peering, *peered* PDs share a common PID
    - Shared PID is locally orthogonal
  - DS-REQ location in DS-REQ resources are determined *based on PID*
    - Only PDs that has competed peering can access the DS-REQ resource
  - A PD (Tx PD) trying to transmit data sends DS-REQ message using the determined DS-REQ resource
    - Collision will not occur in this stage except when the other peered PD tries to Tx at the same time



OFDMA structure for contention (Cont'd)

- Signaling procedure (Cont'd)
  - The peered PD replies with DS-RSP in a response to the DS-REQ with the paired DS-RSP resource
    - Collision will not occur in this stage except when the other peered PD tries to Tx at the same time
  - After the successful exchange of DS-REQ & DS-RSP between the peered PDs, the Tx PD can figure out its relative access priority among the contending PDs

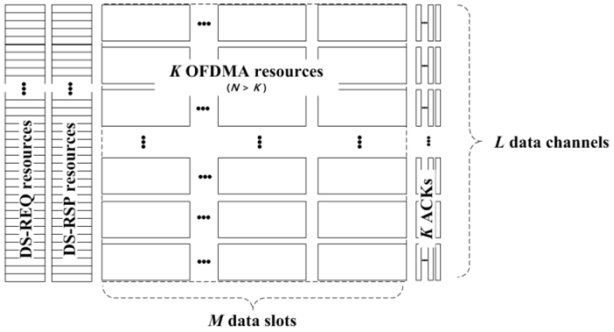


Required resource granularity

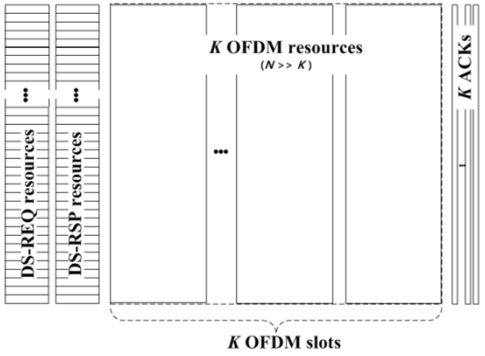
- PAC are supposed to support not only coarse-grained but also fine-grained granularity
  - Two-way voice communication in the application matrix is an example for fine granularity
  - Large network machine type communication is another example of application with a small payload
    - The exemplary application, smart grid, may have a couple of bytes of payload to be transmitted
- PAC should provide a fine-grained resource allocation which has low overhead in resource allocation
  - Moreover, the overhead should be minimized even when there are “at least a hundred of PDs”

OFDMA and TDMA/OFDM structure for data transmission

- OFDMA structure
  - Comprised of *K* (*N* > *K*) OFDMA resources
    - *L* "*data channels*" along the frequency direction
    - *M* "*data slots*" along the time direction
    - There are *K* (= *L* x *M*) "*OFDMA slots*"

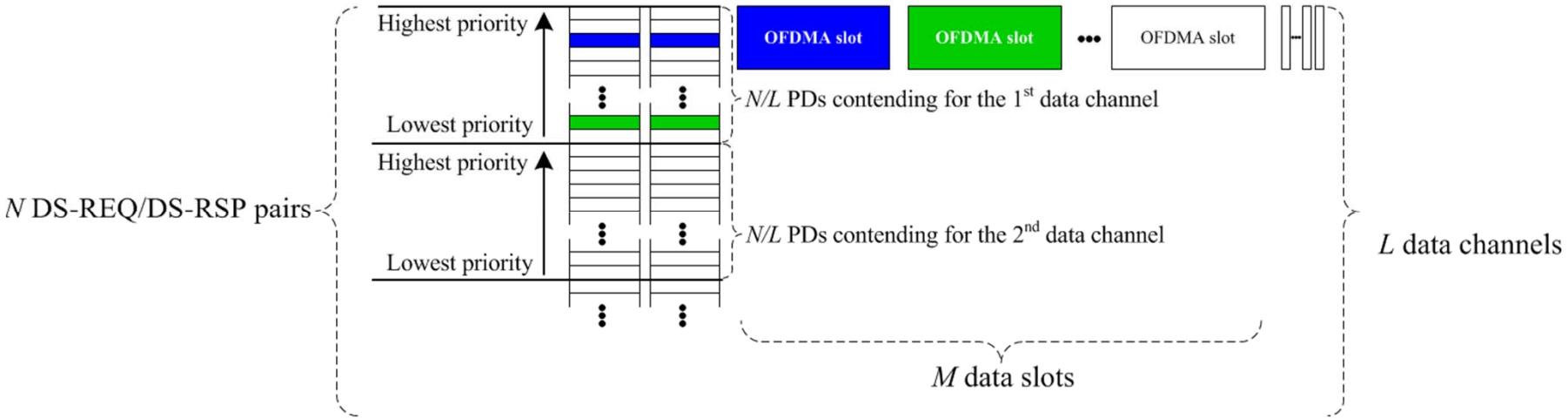


- TDMA/OFDM structure
  - Comprised of *K* (*N* >> *K*) OFDM resources
    - *K "OFDM slots" along the time direction*



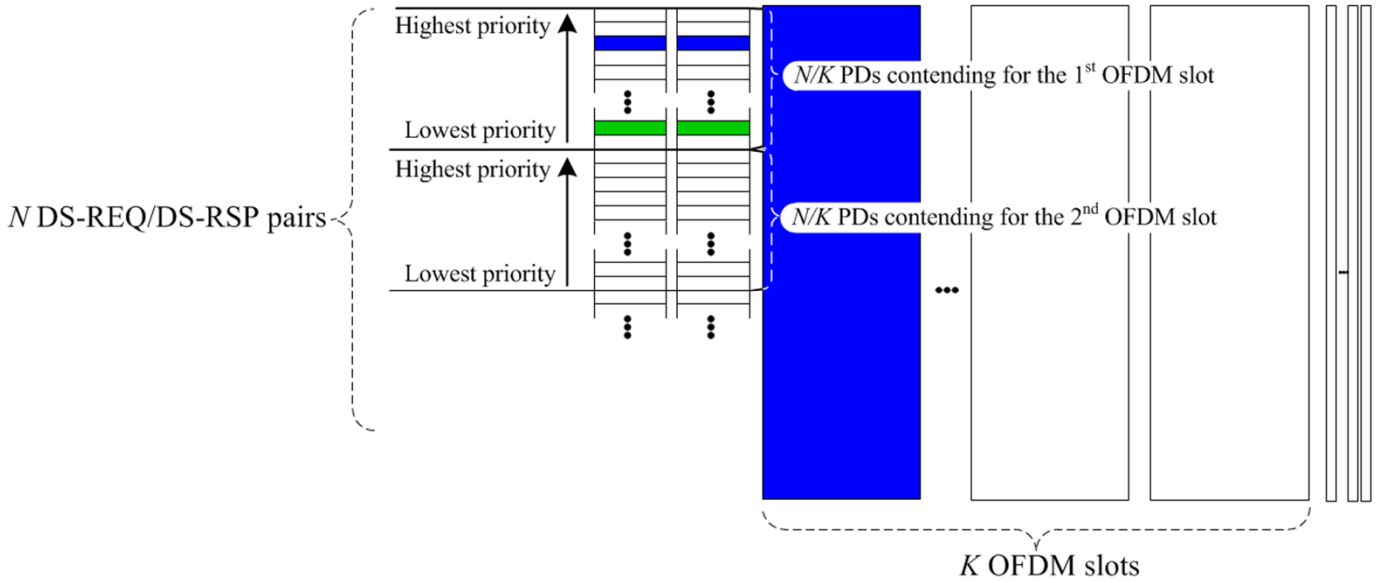
Contention resolution

- In OFDMA structure
  - Contention occurs among (*N*/*L*) PDs in a data channel
    - Each DS-REQ/DS-RSP pair in a data channel has a priority according to the position in the frequency direction
    - The PD with the highest priority takes the first OFDMA slot in the data channel
      - In a data channel, maximum *M* PDs can take one OFDMA slot at the same time



Contention resolution (Cont'd)

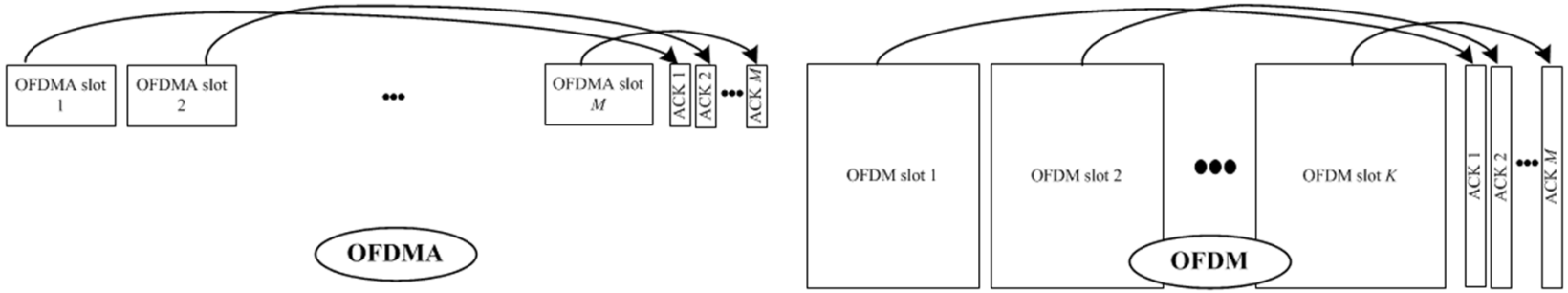
- In OFDM structure
  - Contention occurs among (*N*/*K*) PDs for a OFDM slot
    - Each DS-REQ/DS-RSP pair in a data channel has a priority according to the position in the frequency direction
    - The PD with the highest priority takes the OFDM slot



ACK

- Dedicated resource for Acknowledgement
  - No need for additional resource contention simply to send Acknowledgement, which would be of great help to avoid excessive contention overhead

- ACK relevance



Conclusion

- A simple yet functional PAC frame format for licensed bands operation was proposed.
- According to the preliminary results, tight time synchronization among PAC devices is maintainable in the license bands.
- A brief overview of two different discovery types was presented (Broadcasting based discovery / Request and response based discovery).

Conclusion (Cont'd)

- PID was introduced as a signature for resource contention/allocation in a distributed way.
- OFDMA structure has been proposed for resolving contention of multiple requests in distributed data transmission scheduling.
- Both OFDMA and TDMA/OFDM have been proposed for data transmission resource structure.
- A detailed proposal for unlicensed bands will be submitted in the next meeting.