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

Submission Title: MAC proposal for coexisting dependable BANs

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Re: In response to call for proposal

Abstract: To support possible uses cases of dependable BAN with IEEE 802.15.6-2012 features, it needs to avoid beacon collision and scheduled allocation conflicts among coexisting dependable BANs. On the superframe structure of 802.15.6-2012 and using mandatory channel only, three BAN service classes, the beacon access phase, coordinator hub and leaf hub, and adaptive superframe interleaving are proposed.

Purpose: Material for discussion in P802.15.6ma TG

MAC Proposal for Coexisting Dependable BANs

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Design Consideration on MAC for 802.15.6ma

- focus only on
  - **beacon mode with superframes over UWB PHY layer**
- use leverage of 802.15.6-2012
  - **minor change based on the 802.15.6-2012**
- use not separated control channel
  - **new features for 802.15.6-2012 superframe structure on a mandatory channel**

- design considerations for dependable BAN features based on the structure of 802.15.6-2012
  - support new time sensitive service
  - guarantee periodical transmission with bounded delay for providing three service classes
  - satisfy service specific requirements, the size of a BAN and coexisting multiple BANs
  - avoid beacon collision among coexisting dependable BANs
  - mitigate scheduled allocation conflicts
  - synchronize network clock among coexisting dependable BANs

Proposal 1 – Dependable BAN Service Classes (I)

- define new class of services provided by a BAN
  - class of services is determined by following specifications
    - deterministic (bounded) end-to-end latency
    - deterministic feedback update cycle time
    - reliable wireless transmission guaranteeing deterministic cycle time
  - specify three BAN service classes
    - class 1, class 2, class 3
  - coexisting BANs will coordinates based on the BAN class
    - allocate beacons and regulate access phases

Proposal 1 – Dependable BAN Service Classes (II)

- class 1 BAN supports the service required for
  - latency : few ms to 15 ms
  - cycle time : 10ms
  - delivery ratio : 99.9%
- class 2 BAN supports the service required for
  - latency : 100 ms
  - cycle time : 50ms
  - delivery ratio : 99%
- class 3 BAN supports the service required for
  - latency : 250 ms to 1s
  - cycle time : 1,000ms
  - delivery ratio : 95%

Proposal 1 – Dependable BAN Service Classes (III)

- proposal
  - insert new clause “4.7 Coexisting dependable BANs”
  - define the BAN service classes
  - specify the capability of the BAN according to the classes
  - describe overview of how coexisting multiple BANs coordinates for mitigating interference
    - define coordinator hub and leaf hub
    - coordinator hub maintains the beacon access phase
    - leaf hub shifts beacon access phase in a superframe and regulates the access phase to mitigate the mutual interference among coexisting dependable BANs

Proposal 2 – Beacon Period Extension (I)

- flexible configuration of the beacon period
  - support large number of nodes while guaranteeing short cycle time
    - nodes up to 64
    - class 1 cycle time 10ms, class 2 cycle time 50ms
  - guarantee that nodes can access the channel every cycle time
    - suitable beacon period for various slot length
    - provide slots in a superframe larger than 256
    - require more scalable length of the beacon period

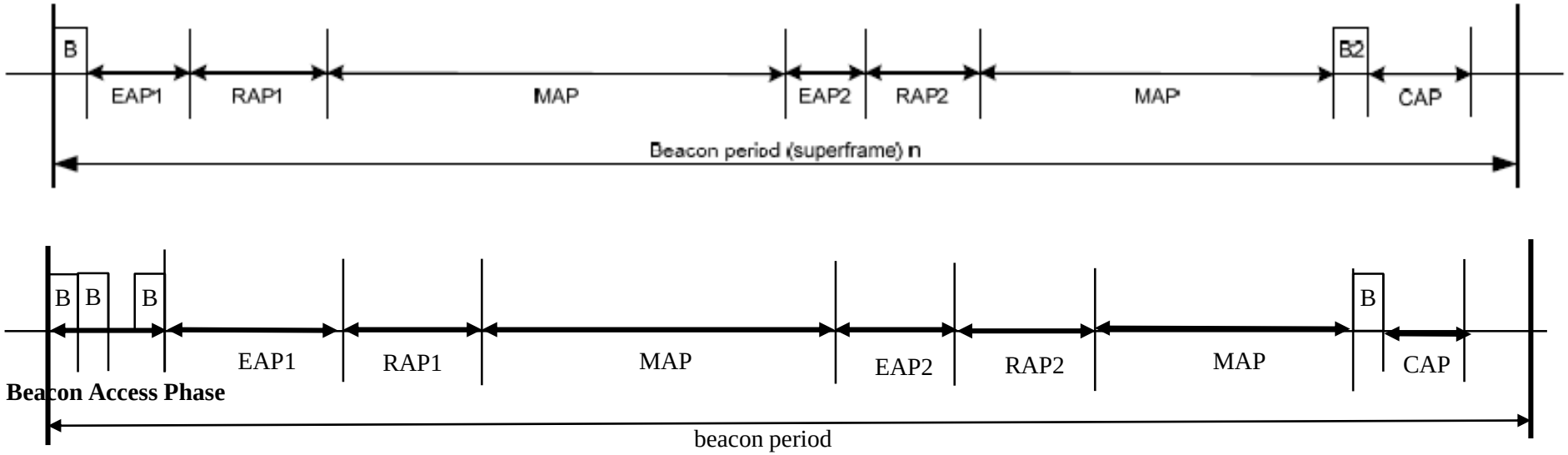
- increase the beacon period length
  - change maximum number of B to “1,024”

Proposal 2 – Beacon Period Extension (II)

- proposal
  - 4.4 Time base
    - change the value of *s* in “256” into “1,024”
  - 5.3.1.2 Beacon Period Length
    - change “a value of 256 allocation slots” into “a value of 1,024 allocation slots”
  - 5.7.7 Uplink Assignment IE
    - change the length of allocation assignment into 4 octets in Fig. 51
    - change the length of interval start and interval end into 10 bits in Fig. 52
  - 6.7 Scheduled access and scheduled-polling access
    - add case 0 < m < 1, multiple periodic access in a beacon period
    - periodic access with the smallest integer of 1/m
    - add 4 bits long periodic access field in Fig. 52 Allocation Assignment format

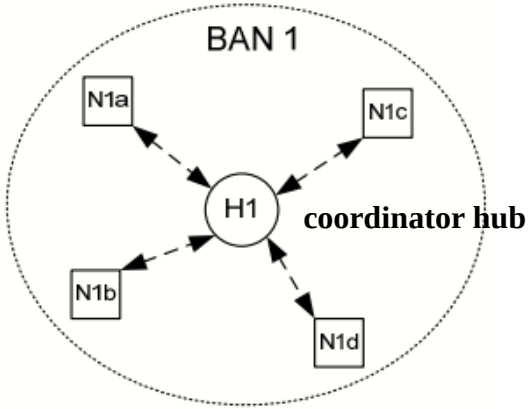
Proposal 3 – Coordinator Hub and Beacon Access Phase (I)

- define Beacon Access Phase (BAP) in the beacon period
  - beacon access phase is used for broadcasting beacons of coexisting dependable BANs
  - beacon slot length and beacon access phase length are fixed
    - beacon access phase length is calculated by allowable maximum number of coexisting BANs * beacon slot length
  - beacon access phase starts at the beacon period

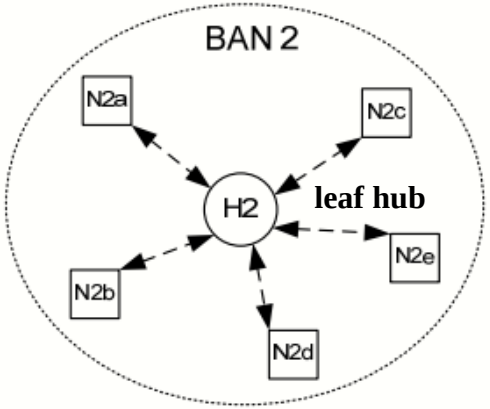


Proposal 3 – Coordinator Hub and Beacon Access Phase (II)

- specify coordinator hub and leaf hub
  - coordinator hub elected among coexisting multiple BANs coordinates to configure the superframe structure of leaf hubs, which join coexisting BAN group
  - coordinator hub assigns a beacon slot for a leaf hub in the beacon access phase of coordinator hub's superframe
  - leaf hubs broadcast their beacon on the assigned beacon slot of coordinator beacon access phase
  - leaf hubs and nodes listen the coordinator beacon access phase



- election of coordinator hub among coexisting dependable BANs
  - when creating a BAN or when a BAN moves into a region, hub of the BAN listens for allowable maximum length of beacon period
  - if finds a coordinator hub beacon in the region and the grade of found coordinator hub is higher, broadcast the request to join as a leaf hub
  - if finds a coordinator hub beacon in the region and the grade of found coordinator hub is lower, broadcast the challenge to join as a coordinator hub
  - if fail to find a coordinator hub beacon in the region, hub starts to perform as a coordinator hub



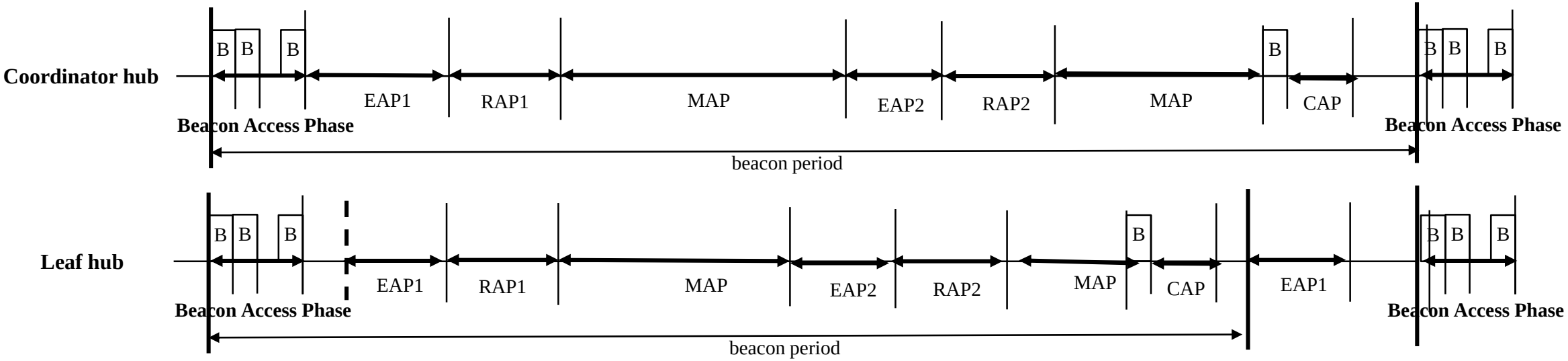
Proposal 3 – Coordinator Hub and Beacon Access Phase (III)

- beacon slot assign rules
  - the priority of BAN are determined according to the service class and mobility
  - class 1 service BAN and fixed BAN has the high priority
  - high priority BAN reserves a beacon slot from the first slot of beacon access phase
  - low priority BAN reserves a beacon slot from the last slot of beacon access phase

- beacon slot adjustment rules
  - newly joined BAN searches beacon access phase of the coordinator hub
  - if newly joined BAN's beacon collides to the existing BANs' beacon, relocates the beacon slot by following the beacon slot assign rules

Proposal 3 – Coordinator Hub and Beacon Access Phase (IV)

- share the structure of beacon period among coexisting BANs
  - a hub of newly joined BAN listens the beacon of existing BANs' beacon
  - after assigned the beacon slot by coordinator hub, leaf hub broadcasts the structure of beacon period
- after beacon access phase, newly joined BAN selects a slot to start access phases of the superframe
  - a hub of newly joined BAN interleaves beacon access phase of the coordinator hub in the superframe structure
  - a hub of newly joined BAN selects a start slot to minimize the collision on EAP and scheduled allocation slots of the existing BANs



Proposal 3 – Coordinator Hub and Beacon Access Phase (V)

- proposal
  - 5.3.1 Beacon
    - add beacon extension field
    - change beacon shifting sequence
  - insert 6.3.4 Beacon access phase mode with beacon periods (superframes)
    - describe Beacon Access Phase (BAP)
    - insert the modified Fig. 64, which contains Beacon Access Phase (BAP)
    - specify the role of coordinator hub and leaf hub
    - specify the ordering rules of assigning beacon for a BAN
    - describe shifting a beacon access phase in a leaf hub
  - 6.4.1 BAN creation/operation
    - specify the procedure of electing a coordinator hub

Proposal 4 – Scheduled Access Extension (I)

- configure flexible access phases
  - let a node have periodic access multiple times in a beacon period

- multiple periodic access in a beacon period
  - add case 0 < m < 1
  - multiple periodic access with the smallest integer of 1/m
    - m = 0.5 → 2 periodic access

Proposal 4 – Scheduled Access Extension (II)

- proposal
  - 5.7.7 Uplink Assignment IE
    - add 4 bits long periodic access field in Fig. 52 Allocation Assignment format
  - 6.7 Scheduled access and scheduled-polling access
    - add description about case 0 < m < 1
  - 6.7.1 Starting scheduled allocations
  - 6.7.2 Using scheduled allocations
    - specify the procedure of using multiple periodic access in a beacon period

Proposal 5 – Adaptative Superframe Interleaving with Adjustment and Regulation (I)

- mitigate mutual interference among coexisting multiple dependable BANs
  - avoid beacon collision among coexisting dependable BANs
  - mitigate scheduled access conflicts among coexisting dependable BANs
  - synchronize network clock among coexisting dependable BANs

- negotiate the structure of beacon period among coexisting dependable BANs
  - coordinator hub manages the schedule of beacons in beacon access phase
  - leaf hubs listen the beacon access phase of the coordinator hub's superframe and broadcast their beacon on scheduled beacon slot
  - while hubs of each BANs maintain their beacon period length, leaf hubs shift beacon access phase in a beacon period to synchronize to the beacon access phase of coordinator hub
  - a leaf hub may adjust the start time of EAP1 of its beacon period to mitigate interference existing BANs
  - a leaf hub may change the configuration of beacon period with advising of coordinator hub

Proposal 5 – Adaptative Superframe Interleaving with Adjustment and Regulation (II)

- regulate the transmission on a slot
  - regulate the transmission in access phase based upon the hub priority and access phase priority
  - access phase priority
    - BAP > EAP > Scheduled MAP > RAP > CAP
  - leaf hubs may block to access slots for a certain time not to interfere with the transmission of a specific BAN

- regulate the transmission in newly joined BAN
  - a leaf hub regulates new link allocation request when expecting to collide with already existing BAN's high priority transmission
    - a leaf hub rejects new link allocation request depending on the access phase priority

Proposal 5 – Adaptative Superframe Interleaving with Adjustment and Regulation (III)

- synchronize network clock among coexisting dependable BANs
  - Coordinator hub or leaf hubs shall maintain a MAC clock
    - with a minimum resolution of mClockResolution and
    - with a minimum accuracy of mHubClockPPMLimit to time its frame transmission and reception
  - a hub includes a timestamp in a beacon frame

Proposal 5 – Adaptative Superframe Interleaving with Adjustment and Regulation (IV)

- proposal
  - insert new clause “6.13.4 Adaptative superframe interleaving with adjustment and regulation”
    - 6.13.4.1 Beacon Access Phase shifting
      - specify the procedure how a leaf hub shifts beacon access phase in a beacon period to synchronize to the beacon access phase of coordinator hub
      - specify Information elements related to Beacon Access Phase shifting
    - 6.13.4.2 Access adjustment
      - specify the procedure how a leaf hub changes the configuration of beacon period with advising of coordinator hub
      - specify the procedure how a leaf hub adjusts the start time of EAP1 of its beacon period to mitigate interference existing BANs
    - 6.13.4.3 Access regulation
      - specify the procedure how a leaf hub regulates the transmission in access phase based upon the hub priority and access phase priority
      - specify the procedure how a leaf hub regulates new link allocation request when expecting to collide with already existing BAN’s high priority transmission

Proposal 5 – Adaptative Superframe Interleaving with Adjustment and Regulation (V)

- proposal
  - 6.11 Clock synchronization and guard time provisioning
    - describe the definition of network clock synchronization among coexisting dependable BANs
  - insert new clause “6.11.3 Network clock synchronization for coexisting dependable BANs”
    - specify Information elements related to network synchronization

Summary

- Proposal 1 – Dependable BAN Service Classes
- Proposal 2 – Beacon Period Extension
- Proposal 3 – Coordinator Hub and Beacon Access Phase
- Proposal 4 – Scheduled Access Extension
- Proposal 5 – Adaptative Superframe Interleaving with Adjustment and Regulation