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

Submission Title: MAC proposal on interference avoidance in coexisting dependable BANs

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Re: In response to call for technical contributions

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 BAN. On the condition of use the superframe structure of 802.15.6-2012 and mandatory channel only, the beacon access phase and modified active superframe interleaving are proposed.

Purpose: Material for discussion in P802.15.6a TG

MAC Proposal on Interference Avoidance in Coexisting Dependable BANs

Seong-Soon Joo

ETRI

BAN creation in 802.15.6-2012

- hub shall choose an operating channel to start a BAN
  - based on policy regulations, channel conditions, application requirements, coexistence considerations
- UWB device implements
  - channel 1, channel 6 are mandatory
  - remaining channels are optional

Band group	Channel number	Central frequency (MHz)	Bandwidth (MHz)	Channel attribute
Low band	0	3494.4	499.2	Optional
	1	3993.6	499.2	Mandatory
	2	4492.8	499.2	Optional
High band	3	6489.6	499.2	Optional
	4	6988.8	499.2	Optional
	5	7488.0	499.2	Optional
	6	7987.2	499.2	Mandatory
	7	8486.4	499.2	Optional
	8	8985.6	499.2	Optional
	9	9484.8	499.2	Optional
	10	9984.0	499.2	Optional

Network synchronization

- node or a hub shall maintain a MAC clock
  - with a minimum resolution of mClockResolution
  - with a minimum accuracy of mHubClockPPMLimit to time
  - its frame transmission and reception

- node shall synchronize to the hub through
  - the beacons, T-Poll frames, acknowledgment frames
  - containing a timestamp

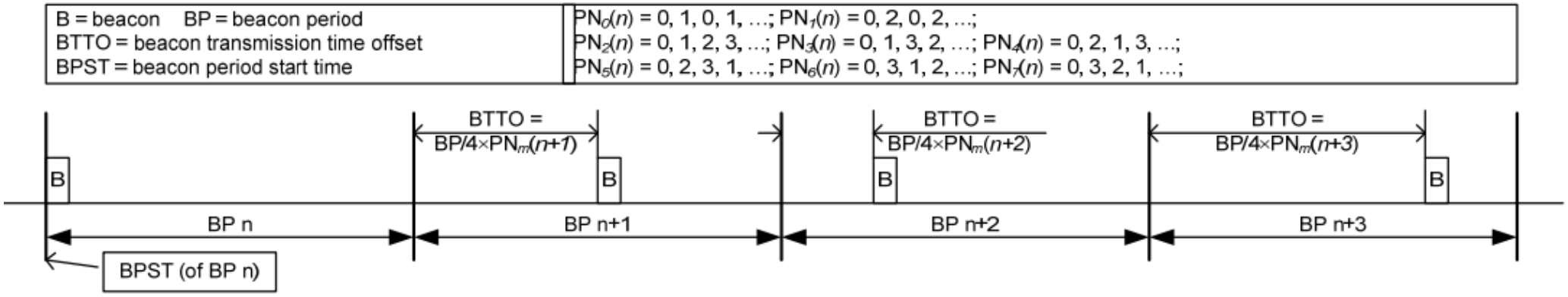
- node and hub shall include appropriate guard times in the scheduled allocation intervals
  - compute a nominal guard time GTn to compensate for their clock drifts
  - node and hub shall account for clock drifts and guard times in their frame transmission and reception
  - node shall synchronize with the hub at least once within its maximum synchronization interval

Interference mitigation in 802.15.6-2012

- frequency diversity
  - channel hopping enable
    - a narrow band (NB) PHY not operating in the MICS band
    - a frequency modulation ultra-wideband (FM-UWB) PHY
- beacon shifting
- active superframe interleaving

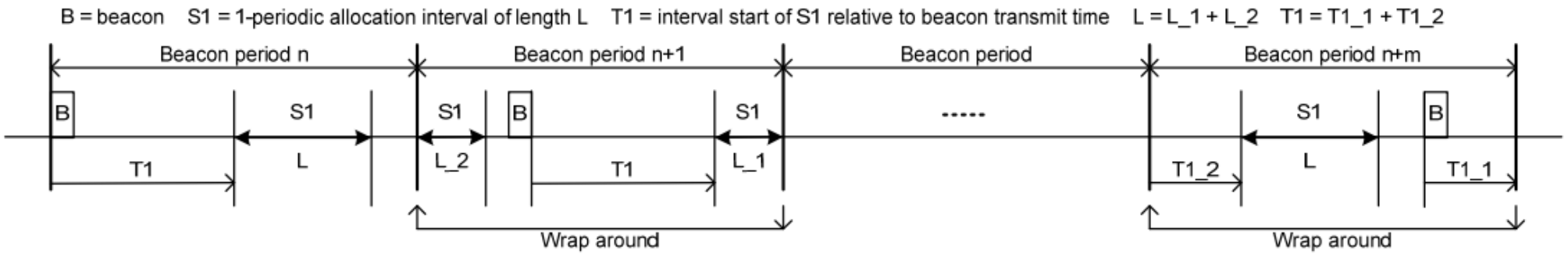
Beacon shifting

- to mitigate potential repeated beacon collisions and scheduled allocation conflicts
  - between overlapping or adjacent BANs operating in the same channel
- choose a beacon shifting sequence
  - is not being used by its neighbor hubs
- transmit its beacons at different time offsets
  - relative to the start of the beacon periods
  - beacon out of its PHY at a time t = PNm(n) × BP/4 relative to the start of beacon period n
    - m is the beacon shifting sequence index



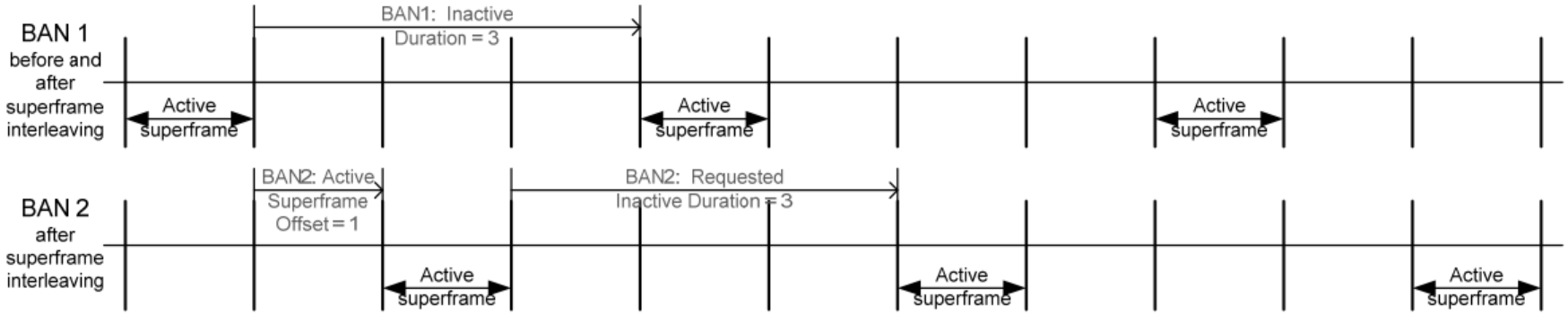
Allocation slots in a beacon period of beacon shifting

- access phases are shift around with the beacon transmit time
  - exclusive access phase 1 (EAP1), random access phase 1 (RAP 1), exclusive access phase 2 (EAP2), random access phase 2 (RAP2), and contention access phase (CAP)
  - beacon shift shall not result in a split of any of the aforementioned access phases into two parts
- scheduled allocation intervals are also shift around with the beacon transmit time
  - a scheduled allocation interval in a beacon period may be split into two portions
  - aggregate length remains the same



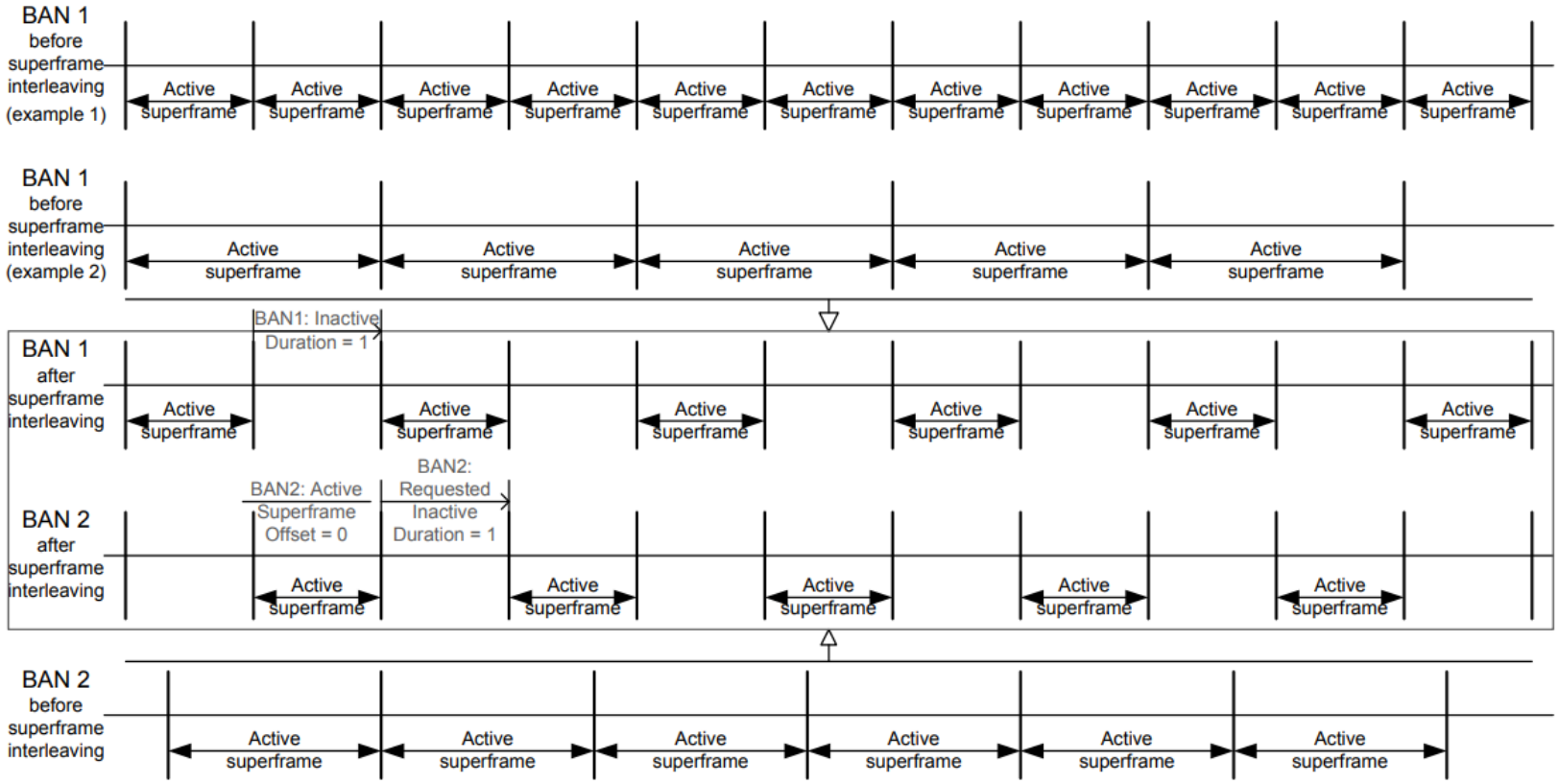
Active superframe interleaving

- share the same operating channel with one or more other BANs
  - hub 2 may send to hub 1 a Command–Active Superframe Interleaving Request frame
    - to request for active superframe interleaving between the two BANs
  - hub 1 should send to hub 2 a Command–Active Superframe Interleaving Response frame
    - to indicate whether it accepts or rejects the request
- active superframe interleaving without active superframe adjustment
  - continue with its current beacon period (superframe) length and inactive duration
  - to enable the offered active superframe interleaving



Active superframe interleaving - continued

- active superframe interleaving with active superframe adjustment
  - **adjust** its **beacon period (superframe) length** and **inactive duration**
  - to enable the offered active superframe interleaving before sending its response



Constraints on IEEE 802.15.6-2012

- configuration of superframe
  - the maximum number of allocation slot is 256
  - the shortest allocation slot length is 16us
  - the longest allocation slot length is 4,096us
  - the longest beacon period length is 1,048,576us
- number of node served in a BAN may be limited
  - depends on beacon period length and length of allocation interval for a node
- cyclic transmission of frame can not be guaranteed in coexisting BANs
  - beacon collisions and scheduled allocation conflicts

source: Seong-Soon Joo., “MAC proposal for supporting dependable BAN service classes”, 15-22-0354-00-006a

Requirements on Dependable BAN Operation

- support the dependable service classes
  - up and down transmission every 10 ms with 99.9% possibility
  - up and down transmission every 50 ms with 99% possibility

- coexist with multiple dependable BANs
  - a dependable BAN moves and encounters a dependable BAN in there
  - a hub creates a new dependable BAN on existing BAN area

- extend TSN to dependable BAN nodes
  - time synchronization
  - bounded latency

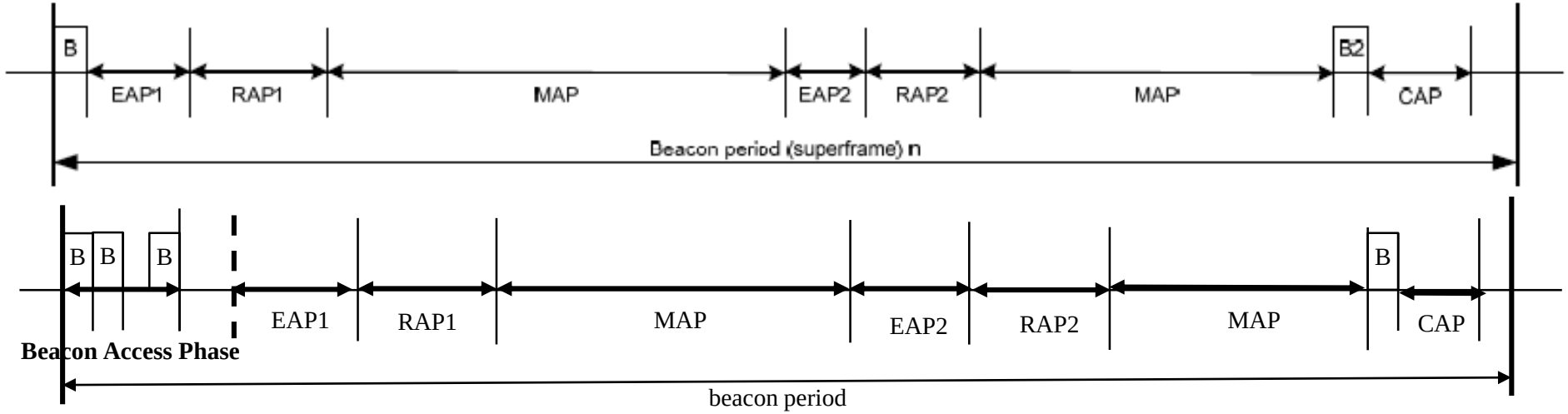
Design Consideration on MAC for 802.15.6ma

- use leverage of 802.15.6-2012 or not
  - **minor change based on the structure of 802.15.6-2012**
  - new mandatory feature with fully designed MAC
- use separated control channel or not
  - **802.15.6-2012 superframe structure on a mandatory channel**
  - separate control channel and data channel

- design dependable BAN features based on the structure of 802.15.6-2012
  - avoid beacon collision among coexisting dependable BANs
  - avoid scheduled allocation conflicts
  - synchronize network clock among coexisting dependable BANs
  - guarantee periodical transmission with bounded delay for supporting service class
  - satisfy service specific requirements such as the size of a BAN, …

Changes on Structure of Beacon Period

- beacon access phase
  - consist of beacon slots for coexisting multiple BANs
  - length of beacon access phase
    - beacon slot length
      - same to all BANs
      - common divisor of allocation slot length of coexisting BANs, fixed value
    - maximum number of coexisting BANs * beacon slot length
- start time of access phase
  - after beacon access phase, time to start EAP1



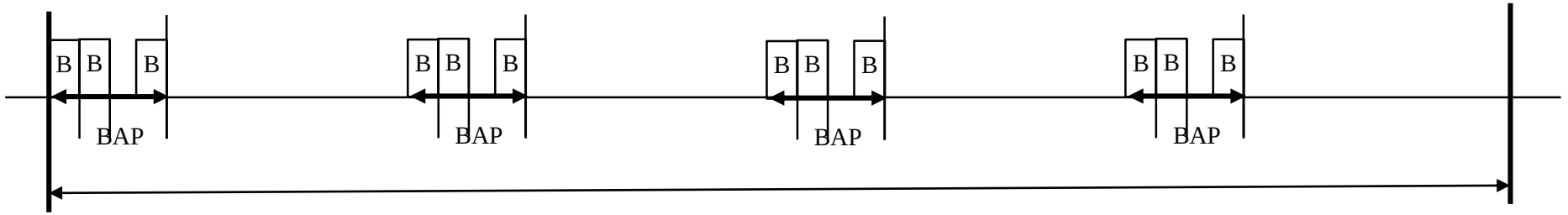
Changes on Structure of Beacon Period - continued

- beacon slot assign rules
  - BAN has a priority according to the service class
  - high priority BAN reserves the earliest beacon slot
  - low priority BAN reserves the latest beacon slot first
- beacon slot adjustment rules
  - if newly joined BAN's beacon collides to the existing BANs' beacon
  - newly joined BAN searches beacon access phase and relocates the beacon slot with beacon slot assign rules
- after beacon access phase, newly joined BAN selects an allocation slot to start access
  - to minimize the collision on EAP and scheduled allocation slots to the existing BANs

Changes on Structure of Beacon Period - continued

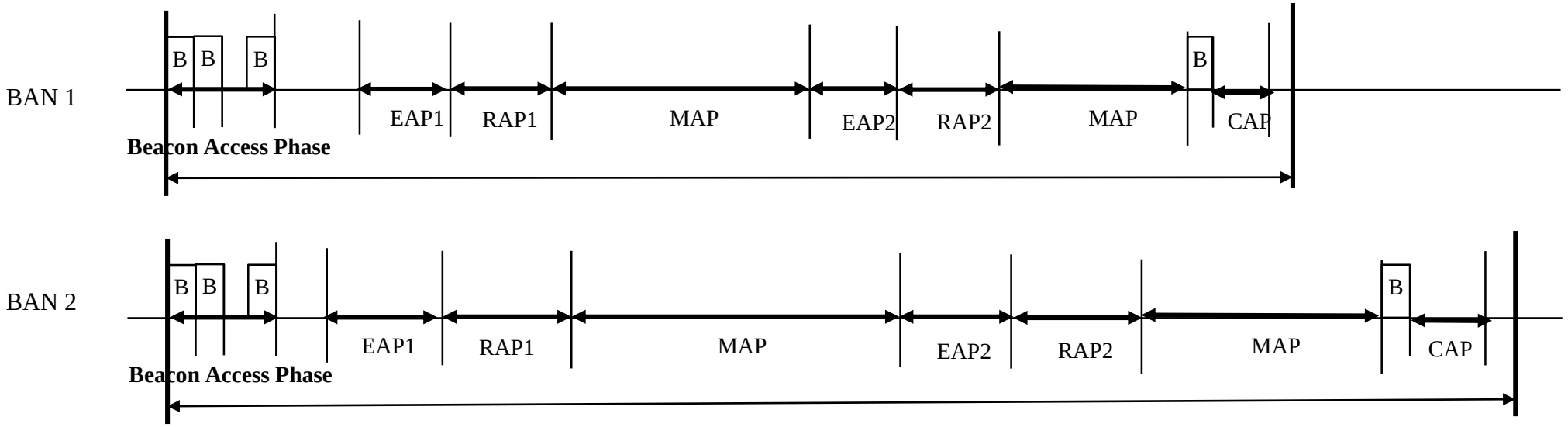
- increase the maximum number of allocation slot
  - from 256 to 4,096
- increase the scheduled allocation slot period
  - 1-periodic allocation → 1/10-periodic allocation

- share the structure of beacon period among coexisting BANs
  - a hub of newly joined BAN listens the beacon of existing BANs' beacon
  - after reserving the beacon slot, broadcast the structure of beacon period



Modified Active Superframe Interleaving with Adjustment

- negotiate active superframe interleaving among coexisting BANs
  - maintain the beacon period length of each BANs
  - adjust beacon slot for a BAN in beacon access phase
    - only when EAP and scheduled allocation of MAP of a BAN interfere the ones of existing BANs
    - adjust start time of EAP1



Modified Active Superframe Interleaving with Regulation

- regulate the transmission in joined BAN
  - regulate new link allocation when collision
    - BAN reject new link allocation depending on access mode priority
  - regulate transmission
    - BAN regulate transmission depending on access mode priority
  - access mode priority
    - BAP > EAP > Scheduled MAP > RAP > CAP

Summary

- frequency diversity is not available for UWB PHY
- beacon shifting and active superframe interleaving of 802.15.6-2012 are not appropriate for service class 1 and class 2

- on the condition of use the superframe structure of 802.15.6-2012 and mandatory channel only
- to avoid beacon collision and scheduled allocation conflicts among coexisting dependable BANs
- propose
  - beacon access phase
  - modified active superframe interleaving with adjustment and regulation