**IEEE P802.15**

**Wireless Specialty Networks**

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| Title | **Proposed resolution draft for SA Ballot – dependable BAN**  |
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| Re: | Contribution to IEEE 802.15.6ma  |
| Abstract | This document provides a proposed text draft for resolving SA Ballot comment, I-28 and 29, on forming a dependable BAN and group BAN. |
| Purpose | Provide technical content for the SA ballot draft |
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Draft Standard for Wireless Body Area Network

1. Overview
	* 1. Initiating a BAN
			1. ED channel scan
	1. Dependable BAN features
		1. General

The standard supports enhanced dependability of data transmission and ranging of BAN networks operating in an unlicensed frequency spectrum shared with other wireless networks. A dependable BAN operates in beacon mode with superframes over IR-UWB PHY and establishes low latency, low jitter, and high update cycle access channel for the time critical medical services of human BAN (HBAN) and/or for the feedback loop control services of vehicle BAN (VBAN). The combination of technologies for the revised UWB PHY and MAC depends on the coexistence scenario with other BANs and wireless networks operating in the same spectrum.

For coexistence and interference mitigation between adjacent or overlapping BANs, dependable BANs, which are located within interfering range, form a dependable group BAN for coordinating each other to coexist. To identify if communication ranges of multiple BANs are overlapped or not, each coordinator keeps broadcasting beacons periodically every superframe to range distance with neighboring BANs, C2C ranging. C2C communication is applied to decide a group BAN coordinator, which is a master coordinator of coexisting multiple BANs, and to synchronize and control packet access among multiple BANs MAC. A control channel for C2C communication may be assigned on dedicated channel or on shared media with data channel.

* + 1. **Single dependable BAN**

The dependable BAN shall operate in beacon mode with superframes over impulse radio ultra-wide band (IR-UWB) PHY. A coordinator of a BAN forms a multi-superframe that consists of one active superframe, which contains a beacon period, CFP, and CAP, and inactive superframe, which contains multiple idle superframes of 1 BTU long, as shown in Figure 21. The active superframe duration (ASD) is a multiple of BTU and the beacon interval (BI) is a multiple of BTU. The maximum BI is 224 BTU.

A coordinator broadcasts a beacon frame on the beacon period. A coordinator and nodes of a BAN communicate on CAP with contention access mode for transmitting frames. A coordinator may assign GTS of CFP for reserving up or down preemptive communication with requesting from a node. The GTS may be one of aperiodic, periodic uniform, and periodic configured type. Aperiodic GTS reserves preemptive time slots for a duration, which is within one active superframe or over multiple active superframes. Periodic uniform GTS reserves consecutive time slots for fixed inter-arrival time. Periodic configured GTS reserves a sequence of GTS that is specified with the start time and number of consecutive slots for a GTS. A node in a BAN requests GTS allocation by using sending an Association Request management frame.



1. — Multi-superframe structure for a dependable BAN

Coexistence class 1: multi-BANs operationBAN coordination refers to multiple BANs coordinated with each other to jointly perform data transmission to mitigate interference in dense scenarios (environment classes 1, 3, and 4). BAN coordination enables a coordinator-to-coordinator exchange of information to better schedule resources in time and frequency in their respective BAN network. Hence, BAN coordination enables multiple BANs to transmit data in a period denominated as Group Allocation Period.

The coordination may be centralized or distributed, each with advantages and disadvantages. This clause describes centralized coordination as it allows better control for coexistence.

This technology requires a group coordinator to handle the scheduling of transmission resources and group members following the group coordinator's scheduling commands. The coordination with each other enables a group of BANs to improve the overall network performance.

The BAN coordination protocol is as follows:

1. At the start of a group transmission, meaning two or more BANs detect their presence via beacons, each BAN coordinator competes for the mandatory channel with LBT. Once a BAN coordinator wins access to the mandatory channel, it becomes the group coordinator (also a preconfigured coordinator may be labeled as a group coordinator), and the rest of the coordinators become group members (see 8.4).
2. Upon becoming group coordinator, it will send a Trigger Frame (TF) during the CAP to inform other BAN coordinators they became group members. Moreover, the TF frame is a way to inquire if group members have data to transmit or receive in a GAP. The beacon of the group coordinator will indicate that it is a group coordinator. Hence, a new BAN in the surroundings will detect it. Moreover, the group coordinator and group members shall synchronize their respective MAC superframes.
3. The group members that want to be scheduled in a GAP, send a Request to Send (R2S) frame to the group coordinator, indicating they have data to transmit or receive, which includes: a requested MAC frame duration, the number of MAC frames (including a Block ACK frame (B.AckK) if requested[[1]](#footnote-2)). If the group coordinator has data to transmit or receive, the group coordinator is scheduled first, followed by the group members’ scheduling in the order their R2S frame was received and priority order, if any. The transmission of data and ACK frames is allocated in the GAP (Figure 19); however, it is up to the corresponding BAN coordinator to divide the allocated duration into CAP and CFP.
4. The group coordinator schedules resources in time slots (labeled Data & ACK in Figure 19) and frequency bands according to the requested transmission duration and priority by each group member and available resources. The scheduler is a sophisticated state-machine and implementation dependent.
5. The group coordinator sends a Trigger Frame Allocation (TFA) frame with the scheduling information, including the allocated transmission period [and frequency band] for every group member. During the Group Allocation Period, BANs listening to the TFA frame shall refrain from using the medium unless allocated.
6. Upon receiving the TFA frame from the group coordinator, the group members obtain the time segment information of the scheduled transmission time duration [and frequency band] assigned by the group coordinator. Using the group coordinator beacon and TF frame, each group member shall be able to synchronize the start of their MAC superframe, respectively.
7. When the assigned time segment arrives, the corresponding group member sends or receives MAC superframes during the assigned period and frequency band. Every group member shall finish transmissions before the next time segment is scheduled to another group member. The process is shown in Figure 19.



1. —General BAN coordination protocol during group formation

Figure 19 shows the BAN coordination process using one frequency band. The BAN coordination allows multiple BANs to coexist without interfering with each other by coordinating transmissions. However, there is a limit in the number of coexisting multiple BANs and Group Allocation Period maximum duration. Hence, the protocol allows the use of multiple frequency bands, as illustrated in Figure 20.



1. — General BAN coordination protocol with frequency bands
	* 1. Dedicating a channel for control frames

Implementations of the standard may use a control channel, different from the data channel, for the transmission of control and management MAC frames.

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		1. Dependable group BAN

A dependable BAN may coexist with other dependable BANs within interfering range. For coexisting multiple dependable BANs, a dependable BAN coordinates other dependable BANs to avoid interference or to mitigate interference by forming a dependable group BAN.

A node of a dependable BAN may become a coordinator that maintains a dependable BAN. A coordinator of a dependable BAN may become a group coordinator who maintains a dependable group BAN. The capability of a node may be set as coordinator disabled, coordinator enabled, or group coordinator enabled prior to start a node.

When an out-of-band channel for a group BAN control is not available, a group coordinator of a dependable group BAN forms a group superframe structure, which contains group coordination period (GCP) and GAP, as shown in Figure 22. GCP contains a group beacon slot, group coordination slots, and a group notification slot. GAP contains active superframe duration of BANs in a group BAN that contains beacon period, CFP, and CAP of each BANs. In Figure 22 GB is Group Beacon, GC is Group Coordination, and GN is Group Notification.

GCP is a control channel for coordinators of a dependable group BAN. A group coordinator broadcasts a group beacon frame on the group bacon slot and a group allocation map frame on the group notification slot of GCP for maintaining a dependable group BAN. A group coordinator and coordinators of a dependable group BAN may use group coordination slots with contention access mode for transmitting management frames such as group association request, group response frame, group disassociation frame, group migration frame, group disband frame, and group merged frame which come to and from a group coordinator and coordinators of a group BAN.

The length of a group superframe is specified with the number of BTU. A BTU is a fixed length of time, 1,024 us long. A group superframe duration, group beacon interval (GBI), is varied according to the number of BANs in a group BAN. The group coordination period consists of one time slot for a group beacon, one time slot for a group notification, and multiple time slots for group coordination, which are the two times the number of BANs in a BAN group. The length of the group allocation period is varied according to the length of active superframe duration of each BAN in a group BAN. For a BAN joined in a group BAN, the length of the beacon interval and the inactive superframe duration are varied whenever the group superframe of a group BAN is changed. A group BAN coordinator may assign multiple active superframe of a BAN in a group beacon interval.

 

1. —Group superframe structure for a dependable group BAN
1. A single block acknowledgment frame (B.ACK) is used to acknowledge the reception of multiple MAC frames, instead of individually acknowledging each MAC frame with a separate acknowledgement (ACK) frame. This reduces the number of ACK frames and corresponding interframe spaces, resulting in increased throughput. [↑](#footnote-ref-2)