**IEEE P802.15**

**Wireless Specialty Networks**

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| Re: | Contribution to IEEE 802.15.6ma | |
| Abstract | This document provides a proposed text draft for resolving LB212 comment, CID 154, 155, 156 on BAN operation and maintenance. | |
| Purpose | Support development of technical content for the draft | |
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Draft Standard for Wireless Body Area Network

1. **Overview** 
   1. MAC Services
      1. Communication in a dependable BAN
      2. Communication in a dependable group BAN
      3. Starting and maintaining a dependable BAN
         1. Starting a dependable BAN

A node may be set prior as coordinator disabled or coordinator enabled, or group coordinator enabled. A node set to coordinator enabled or group coordinator enabled may start a dependable BAN. The node shall perform a passive scan across a specified set of channels and separate IEEE Std 802.15.4 HRP UWB, IEEE Std 802.15.6-2012, IEEE Std 802.15.4z/ab, and IEEE Std 802.15.6ma networks operating within interfering range.

If the node is set to coordinator enabled, the node becomes a coordinator and starts a BAN by selecting one of the following procedures:

When any of the above UWB networks is not searched and the node doesnot find a coexisting BAN or a group BAN, the node specifies a superframe structure, which can support BAN’s grades of services and max number of nodes in a BAN as described in the MIB, and starts a BAN in coexistence class 0 by transmitting a beacon frame.

When the node finds a coexisting BAN or a group BAN, the node selects a group BAN to join and sends a group association frame during the group coordination period, as described in 6.5.5.1. After receiving a group allocation map frame, the node specifies superframe structure, which considers the coexistence class 1 and supports BAN’s grades of services and max number of nodes in a BAN as described in the MIB, and starts a BAN in coexistence class 1 by transmitting a beacon frame.

When one more of the above UWB networks is searched and the node cannot find a coexisting BAN or a group BAN, the node selects an interference mitigation mode according to the coexistence class, which will be class 2 with a coexisting IEEE Std 802.15.6-2012 network and class 4 with coexisting 15.4 network. The node specifies superframe structure, which considers the coexistence class, interference mitigation mode, grades of services, and max number of nodes in a BAN as described in the MIB, and starts a BAN in coexistence class 2 or 4 by transmitting a beacon frame.

If the node is set to group coordinator enabled, the node becomes a coordinator or coordinator/group coordinator and starts a BAN by selecting one of the following procedures:

When any of above UWB networks is not searched and the node cannot find a coexisting BAN or a group BAN, the node specifies a superframe structure, which can support BAN’s grades of services and max number of nodes in a BAN as described in the MIB, and specifies a group superframe structure, which can support max number of BANs in a group BAN as described in the MIB. The node starts a group BAN, as described in 6.5.4.1. The node also starts a BAN in coexistence class 0 by transmitting a beacon frame on a superframe.

When the node finds a coexisting BAN or a group BAN, the node checks the superiority to the group coordinator of a coexisting group BAN as described in 6.5.6.1. If the node is lower-level, the node becomes a coordinator, selects a group BAN to join, and sends a group association frame during the group coordination period, as described in 6.5.5.1. After receiving a group allocation map frame, the node specifies superframe structure, which considers the coexistence class 1, BAN’s grades of services, and max number of nodes in a BAN as described in the MIB, and starts a BAN in coexistence class 1 by transmitting a beacon frame from the next group beacon interval. If the node is higher-level, the node follows the group coordinator migration procedure as described in 6.5.6.1.

When one more of the above UWB networks is searched and the node cannot find a coexisting BAN or a group BAN, the node selects an interference mitigation mode according to the coexistence class, which will be class 2 with a coexisting IEEE Std 802.15.6-2012 network and class 4 with coexisting 15.4 network. The node specifies superframe structure, which considers the coexistence class, supports BAN’s grades of services, and max number of nodes in a BAN as described in the MIB, and specifies a group superframe structure, which can support max number of BANs in a group BAN as described in the MIB. The node starts a group BAN, as described in 6.5.4.1. The node starts a BAN in coexistence class 2 or 4 by transmitting a beacon frame.

* + - 1. Maintaining a dependable BAN

A coordinator of a BAN provides communication services to nodes in a BAN by maintaining a superframe structure. The superframe structure is changed when the number of nodes in a BAN is changed or when the group superframe structure of a group BAN is changed. The coordinator manages the superframe structure and let nodes in a BAN synchronize to the superframe structure.

A coordinator broadcasts a beacon frame periodically, as described in 5.5.2. The beacon frame provides timestamp for clock synchronization, superframe structure specification, which contains the length of beacon interval, length of active superframe duration, length of CFP, and CFP description that has number of CFP allocated nodes and CFP allocation map.

A coordinator joining a group BAN wakes up on the start of a group superframe and receives a group beacon and group allocation map frame. If the coordinator finds a change on the length of group beacon interval or a change on the assigned slot for the start of active superframe duration of the coordinator BAN, the coordinator notifies the reallocation of active superframe duration and the change on the inactive superframe duration to the nodes in a BAN by broadcasting a beacon with beacon change notification IE, as described in 5.5.16.2, and realigns the start of the superframe from the next beacon interval.

The coordinator listens to a specified set of channels periodically to find out the changes in coexisting devices that will affect the superframe structure. If a BAN is on coexistence class 0 and finds a coexisting group BAN, a coordinator follows the group BAN join procedure as described in 6.5.5.1. If a BAN is on coexistence class 1, when a coordinator can’t reach the group coordinator, a coordinator follows the group BAN leave procedure as described in 6.5.5.2.

* + 1. Association and disassociation of a dependable BAN
       1. Association of a dependable BAN

A node set to coordinator disabled may join a dependable BAN. The node shall perform a passive scan across a specified set of channels and searches a dependable BAN. The node selects a BAN to join based on policy regulations, channel conditions, application requirements, coexistence considerations, etc.

A node requests a connection between a node and a coordinator by sending an association request frame, as described in 5.5.4, during the CAP of the selected BAN. A node may request to assign CFP slots by describing CFP slots configuration on CFP Descriptor field in an association request frame as Table 44. A node may configure CFP slots by three types:

Aperiodic GTS: Single slot part specified with the length of slots over reserving duration..

Periodic Uniform GTS: Equally distributed slot parts are specified with the number of parts, the interval of slot parts, and the length of consecutive slots of a slot part.

Periodic Configured GTS: Unequally distributed slot parts are specified with the number of parts, the starting slot number of each slot part, and the length of consecutive slots of each slot part.

When receiving an association response frame, as described in 5.5.5, the node synchronizes to the superframe from the next beacon interval and starts to access the CFP slots as allocated in the CFP descriptor field of the Association Response frame.

A node wakes up on the start of a superframe and receives a beacon frame. If the node finds a change on the superframe structure, the node realigns the start of the superframe from the next beacon interval.

* + - 1. Disassociation of a dependable BAN

When a node decides to leave a BAN, a node requests disassociation of a BAN by sending a disassociation frame, as described in 5.5.1. When receiving the disassociation frame, the BAN coordinator reconfigures the CFP slots allocation and transmits a beacon frame in which the CFP Descriptor Count field and CFP Descriptor List field are modified.

A node will listen to a beacon frame. If the node finds that CFP slots are still allocated for the node, the node retransmits a disassociation frame and leaves a BAN.

* + 1. Starting and maintaining a dependable group BAN
       1. Starting a dependable group BAN

A node set to group coordinator enabled may start a dependable group BAN. The node shall perform a passive scan across a specified set of channels and separate IEEE Std 802.15.4 HRP UWB, IEEE Std 802.15.6-2012, IEEE Std 802.15.4z/ab, and IEEE Std 802.15.6ma networks operating within interfering range.

If the node cannot find a coexisting BAN, the node becomes a group coordinator. The group coordinator configures a group superframe to support the coexisting BANs’ services and starts a group BAN by broadcasting a group beacon, as described in 5.5.6, and a group allocation map frame, as described in 5.5.7, periodically and by maintaining the group superframe structure.

* + - 1. Maintaining a dependable group BAN

A group coordinator of a group BAN provides management services to coordinators in a group BAN. A group coordinator supervises allocation of communication resources to the BANs in a group BAN for mitigating the interference occurred among coexisting BANs. The group coordinator manages the group superframe structure and lets coordinators in a group BAN synchronize to the group superframe structure.

A group coordinator broadcasts a group beacon frame periodically, as described in 5.5.6. The group beacon frame provides a timestamp for clock synchronization, group identification, supported rates, supported FEC, FEC configuration, supported channels, group beacon interval, and group joined BANs’ information, such as BAN identification, BAN coordinator address, and BAN’s superframe duration.

A group coordinator receives a group association frame or group disassociation frame during GCP and reconfigures group superframe structure to add newly joined BANs’ active superframe duration to GAP or to remove newly leaving BAN’s active superframe duration from the GAP. A group coordinator checks the configuration of the GAP for every group beacon interval, reallocates the active superframe durations of BANs joined in the group, and broadcasts a group allocation map frame, as described in 5.5.7. The group allocation map frame contains timestamp, group identification, group beacon interval, and GAP allocation map consisting of the number of BANs and each BANs’ allocation description, which has BAN identification, BAN coordinator address, BAN superframe duration, and slot number of starting active superframe in the GAP.

The group coordinator listens specified set of channels periodically to find out the changes in coexisting devices which will affect the group superframe structure or interference mitigation mode.

If a group BAN finds a coexisting network, a group coordinator maintains a group BAN by selecting one of the following procedures:

When a group coordinator finds a BAN and a new coexisting coordinator challenges to become a group coordinator, the group coordinator starts the group coordinator migration procedure, as described in 6.5.6.1.

When a group coordinator finds a group BAN, and a new coexisting group coordinator challenges to merge a group BAN, the group coordinator starts the group merging procedure, as described in 6.5.6.2.

If a group BAN decides to resign the group coordinator role or to leave the group BAN, the group coordinator starts the group coordinator migration procedure, as described in 6.5.6.1.

If a group BAN decides to resign the group coordinator role and not to hand over the group coordinator role, the group coordinator starts the group disband procedure, as described in 6.5.6.3.

* + 1. Association and disassociation in a dependable group BAN
       1. Association a dependable group BAN

A coordinator of a BAN may join a group BAN. A coordinator sends a group association frame, as described in 5.5.8, which contains BAN identification, coordinator address, beacon interval, superframe duration, supported rates, supported FEC, and QoS capability.

When receiving a group association frame, a group coordinator assigns a location of active superframe duration of a newly joined BAN and reconfigures group superframe and group allocation map. A group coordinator broadcasts group allocation map frame on the group notification slot. In the next group beacon interval, a group coordinator broadcasts newly modified group beacon.

The coordinator requesting an association the group BAN is notified the slot number of starting active superframe duration of the BAN from the received group allocation map frame or by receiving the group association response frame. The coordinator will synchronize to the group BAN from the next group beacon interval. The coordinator broadcasts a beacon frame that contains a Beacon Change Notification IE. The nodes in the coordinator’s BAN will calculate the start slot of the next beacon by using the Beacon Offset field of Beacon Change Notification IE and following the beacon from the next beacon interval, which is specified in Beacon Change Notification IE.

* + - 1. Disassociation a dependable group BAN

A coordinator of a BAN may leave a group BAN. A coordinator sends a group disassociation frame with a reason code, as described in 5.5.9.

When receiving a group disassociation frame, a group coordinator removes active superframe duration of a leaving BAN and reconfigures group allocation map. A group coordinator broadcasts group allocation map frame on the group notification slot. In the next group beacon interval, a group coordinator broadcasts newly modified group beacon.

The BAN coordinator will listen to channels for group beacon intervals to check disassociation. If BAN’s active superframe duration is still allocated in the group allocation map, the BAN coordinator retransmits the group disassociation frame and leaves a group BAN.

* + 1. Migrating and disbanding a dependable group BAN
       1. Migration a dependable group BAN coordinator

A group coordinator of a group BAN may be migrated to another coordinator of the group BAN, when a group coordinator wants to leave from the group BAN or when a new coexisting coordinator, which is set to enabled group coordinator, challenges to become the group coordinator.

Before leaving a group BAN, a group coordinator designates a new group coordinator among the coordinators of the group BAN by following procedure:

A group coordinator broadcasts a group coordinator resign frame, which contains the group BAN ID as described in 5.5.10, on the group notification slot of the GCP.

A group coordinator will listen group coordination slots of the GCP for two group beacon intervals to receive group coordinator challenge frames, which contain group BAN ID, BAN ID, beacon interval, superframe duration, and CFP descriptor count as described in 5.5.11, from the coordinators in the group BAN.

A group coordinator selects a coordinator, which has the largest superframe duration and/or the largest number of nodes in a BAN, as the group coordinator. If no coordinator responds to a group coordinator resignation frame, a group coordinator designates a coordinator, which has the largest superframe duration and/or the largest number of nodes in a BAN among coordinators of the group BAN, as the group coordinator. A group coordinator broadcasts a group coordinator migration frame, which contains the group BAN ID, designated group coordinator address, group beacon interval, and group allocation descriptor as described in 5.5.12, on the group notification slot of the GCP.

When receiving a group coordinator challenge frame, a group coordinator designates new group coordinator by following procedure:

A group coordinator checks the superframe duration and the number of nodes in the BAN by the superframe duration field and the CFP descriptor count filed of the group coordinator challenge frame.

If the number of nodes in the BAN who challenge to become a group coordinator is larger than the number of nodes in the BAN maintained by the group coordinator, the group coordinator broadcasts the group coordinator migration frame, as described in 5.5.12, on the group notification slot of the GCP.

When receiving a group coordinator migration frame, a designated group coordinator becomes a group coordinator from the next group beacon interval. A designated group coordinator reconfigures the group superframe by reallocating the active superframe durations of BANs in a group BAN. A designated group coordinator broadcasts the current group beacon with group change notification IE, which has the reconfigured group superframe information as defined in 5.5.16.3, at the next group beacon interval. After two group beacon intervals, a group BAN will operate on the new group superframe structure.

When receiving a group coordinator migration frame, a coordinator of BANs in a group BAN will cease transmission in a BAN for two group beacon intervals and listen to the GCP. After receiving a group beacon from the new group coordinator, a coordinator of a group BAN notifies the reallocation of active superframe duration and the change on the inactive superframe to the nodes in a BAN by broadcasting a beacon with beacon change notification IE, as described in 5.5.16.2, and realigns the start of the superframe from the next group beacon interval.

* + - 1. Merging a dependable group BAN

A group coordinator may try to merge group BANs when it detects a coexisting group BAN.

A group coordinator starts merging group BANs by following the procedure:

A group coordinator broadcasts the group merging challenge frame as defined in 5.5.13 on group coordination slots of the GCP for consecutive group beacon intervals

When receiving a group merging frame from a coexisting group BAN’s group coordinator, a group coordinator checks the Group BAN ID field.

If it is same as the Group BAN ID of the group coordinator, the group coordinator becomes the group coordinator of the merged group BAN. The group coordinator reconfigures the group superframe of the merged group BAN.

When receiving a group merging challenge frame from a group coordinator of the coexisting group BAN, a group coordinator responds by following the procedure:

If the group coordinator determines to merge, the group coordinator checks the length of the group beacon interval and the number of BANs of the coexisting group BAN from the group merging challenge frame.

If the group coordinator’s group BAN has the longer length of group beacon interval and/or the larger number of BANs in the group BAN than the coexisting group BANs, the group coordinator becomes the group coordinator of the merged group BAN.

The group coordinator responds to the group coordinator of the coexisting group by transmitting a group merge frame as defined in 5.5.14. If the group coordinator becomes the group coordinator of the merged group BAN, the group coordinator sets the Group BAN ID field as the group coordinator’s group BAN ID. The group coordinator reconfigures the group superframe of the merged group BAN and sets the Group Beacon Interval and Group Allocation Descriptor fields.

Newly selected group coordinator broadcasts group beacon frame which contains new group superframe structure and group allocation map. The coordinators of a group BAN will cease transmission to realign group superframe for two GBI.

* + - 1. Disbanding a dependable group BAN

A group coordinator may disband a group BAN, when a group coordinator BAN decides to resign the group coordinator and not to hand over a group coordinator role.

A group coordinator broadcasts a group disband frame, as described in 5.5.15. When receiving a group disband frame, the coordinators of a group BAN cease the transmission for two group beacon intervals, reconfigure the superframe structure, and notify the changes on the superframe by broadcasting a beacon frame containing Beacon change notification IE, as described in 5.5.16.2. When receiving a beacon frame, nodes in a BAN cease a transmission and synchronize to the new superframe structure from after time offset instructed in the beacon change notification IE.

* + 1. Interference mitigation in a dependable group BAN
       1. Interleaved active superframe

A group coordinator allocates the active superframe of each BAN in a group on the Group Allocation Period to mitigate interference among coexisting BANs. The allocation of active superframe is notified by broadcasting the group allocation map frame, as described in 6.3.

When a BAN joins a group BAN or a BAN leaves a group BAN, allocation of active superframe is renewed and group superframe structure is also reconfigured. A group allocation map frame is broadcasted every GBI, even though allocation of active superframe is not changed.

For coexistence class 1, whenever a BAN joins or leaves, a group coordinator reallocates active superframe on a group allocation period with keeping sequential order of joining a group BAN. A group coordinator may allocate multiple active superframes for a BAN to adjust the beacon interval of the BAN.

A group coordinator may choose a mode whether set the length of group allocation period fixed or varied. In fixed mode, the length of group inactive superframe will be the rest of GAP after allocating active superframe of each BANs in a group. In varied mode, GAP contains active superframe only and the length of group inactive superframe is always zero.

When GAP is not affordable to accept for newly joined BAN, a group coordinator sends group association response frame with reason of GAP not available.

* + - 1. Access regulation

According to the coexistence class, a group coordinator may reconfigure a group superframe structure not to collide a group beacon slot and group notification slot with coexisting IEEE Std 802.15.6-2012 beacon or IEEE Std 802.15.4 beacon.

For coexistence class 2, a group coordinator reconfigures a group superframe by moving the start of group superframe not to collide a group beacon slot or group notification slot with coexisting IEEE Std 802.15.6-2012 beacon frame. For coexistence class 4, a group coordinator reconfigures a group superframe by moving the start of group superframe not to collide a group beacon slot or group notification slot with coexisting 15.4 beacon frame.

A group coordinator may regulate the access from nodes by assigning blocked period on group allocation period.

For coexistence class 2, a group coordinator assigns blocking period to guarantee the transmission of IEEE Std 802.15.6-2012 beacon frame. For coexistence class 4, a group coordinator assigns blocking period to guarantee the transmission of IEEE Std 802.15.4 beacon frame. The blocking period is notified in a group allocation map frame. A coordinator of a group BAN notifies block periods to nodes in a BAN by containing access regulation IE in a beacon frame.

* + - 1. FEC selection

According to the coexistence class, a coordinator of a group BAN may select the FEC configuration which depends on the QoS traffic type (see Table 77) and coexistence environment of operation.

* + - 1. **Coordinator-to-Coordinator (C2C) Ranging and Communication for Monitoring Coexistence Status in Multiple BANs**

This specification is for ranging among coordinators of coexisting multiple BANs. To identify status of overlaid radio coverage range of multiple 15.6ma BANs, ranging capability of BAN coordinators is applied in option because two-way ranging (TWR) technology of UWB PHY can perform more accurate ranging among coordinators of approaching or leaving one another than RSSI technology using received power of narrowband PHY as shown Figure 2 in 4.2.

C2C ranging can enhance dependability of BANs by authentication of desired and undesired coordinators in environment of coexistence among multiple BANs.

C2C ranging is an optional service, but its feasible implementation may be performed by the manner of IEEE Std 802.15.4z and its amendment IEEE Std 802.15.4ab using UWB PHY [B20][B21]. In IEEE Std 802.15.6ma MAC, Group BAN coordinator periodically broadcasts beacons for seeking neighboring BAN coordinators for C2C ranging. Once group BAN coordinator to other BAN coordinators link has been established, TWR based on UWB packets proceeds C2C ranging to identify coordinators of approaching or leaving one another.

C2C communication or negotiation performs management of access controlling packets between a coordinator to nodes within each BAN and among coexisting multiple BANs.