IEEE P802.15
Wireless Specialty Networks

Project	IEEE P802.15 Working Group for Wireless Specialty Networks (WSNs) – 802.15.6ma
Title	**Proposed text for 6ma – MAC Service Features**
Date Submitted	July 4, 2024
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Re:	Contribution to IEEE 802.15.6ma
Abstract	This document provides a text draft of 6ma MAC for specifying MAC service features to support coexisting dependable BANs in clause 6.
Purpose	Support development of technical content for the draft
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Insert the sub-clause 6.5 as follows:

6.

6.5 MAC Services

6.5.1 General

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

6.5.2 Communication in a dependable BAN and in a dependable group BAN

The dependable BAN shall operate in beacon mode with superframes over IR-UWB PHY. A coordinator of a BAN forms a superframe structure which contains beacon period, contention access period (CAP), contention free period (CFP), and inactive period. A coordinator broadcasts a beacon frame on beacon period. A coordinator and nodes of a BAN communicate on CAP with contention access mode for transmitting frames. A coordinator may assign timeslots of CFP for reserving up or down preemptive communication with requesting from a node.

A group coordinator of a dependable group BAN forms a group superframe structure which contains group coordination period (GCP) and group allocation period (GAP), as shown in Fig.1. 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, CAP, and CFP of each BANs.

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/response frame, group disassociation frame, group migration frame, group disband frame, 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 time slot. A time slot is fixed length of a time that is enough for a pair of devices to exchange a frame and an acknowledgment. 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 timeslots for group coordination which are the two times number of BANs in a BAN group. The length of group allocation period is varied according to the length of CAP and CFP of each BAN in a group BAN. For a BAN joined in a group BAN, the length of beacon interval and inactive period of the superframe are varied, whenever group superframe of a group BAN is changed.

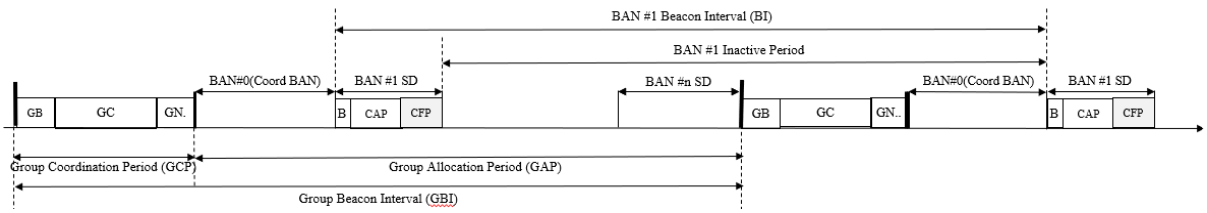

Figure 1—Group superframe structure for a dependable group BAN

6.5.3 Starting and maintaining a dependable BAN

6.5.3.1 Starting a dependable BAN

A node may 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 passive scan across a specified set of channels and separate out 15.4 HRP UWB, 15.6-2012, 15.4z/ab, and 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 following procedures:

- When any of above UWB networks is not searched and the node can't 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 found a coexisting BAN or a group BAN, the node selects a group BAN to join and sends a group association frame during group coordination period, as described in 6.5.6.1. 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 above UWB networks is searched and the node can't 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 coexisting 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 following procedures:

- When any of above UWB networks is not searched and the node can't 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 6.5.5.1. The node also starts a BAN in coexistence class 0 by transmitting a beacon frame on a group superframe.
- When the node found a coexisting BAN or a group BAN, the node checks the superiority to the group coordinator of a coexisting group BAN as described in 6.5.7.1. If the node is lower-level, the node becomes a coordinator, selects a group BAN to join, and sends a group association frame during group coordination period, as described in 6.5.6.1. 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 6.5.7.1.
- When one more of above UWB networks is searched and the node can't 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 coexisting 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 6.5.5.1. The node starts a BAN in coexistence class 2 or 4 by transmitting a beacon frame.

6.5.3.2 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 5.6.2. 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 period to the nodes in a BAN by broadcasting a beacon with beacon change notification IE, as described in 5.6.16.1, and realigns the start of the superframe from the next beacon interval.

The coordinator listens specified set of channels periodically to find out the changes in coexisting devices which 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 6.5.6.1. 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 6.5.6.2.

6.5.4 Association and disassociation a dependable BAN

6.5.4.1 Association a dependable BAN

A node set to coordinator disabled may join a dependable BAN. The node shall perform 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 5.6.4, during the CAP of the selected BAN. A node may request to assign CFP slots with describing CFP slots configuration on CFP Descriptor field in an association request frame as Table x29. A node may configure CFP slots by three types:

- single consecutive slot part specified with the length of consecutive slots
- equally distributed slot parts specified with the number of parts, interval of slot parts, and length of consecutive slots of a slot part
- unequally distributed slot parts specified with the number of parts, starting slot number of each slot parts, and length of consecutive slots of each slot parts

When receiving an association response frame, as described in 5.6.5, the node synchronizes to the superframe from the next beacon interval and starts to access the CFP slots as allocated in 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.

6.5.4.2 Disassociation a dependable BAN

When a node decides to leave a BAN, a node requests disassociation a BAN by sending a disassociation frame, as described in 5.6.3. When receiving the disassociation frame, the BAN coordinator reconfigures the CFP slots allocation and transmits a beacon frame that CFP Descriptor Count field and CFP Descriptor List field are modified.

A node will listen 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.

6.5.5 Starting and maintaining a dependable group BAN

6.5.5.1 Starting a dependable group BAN

A node set to group coordinator enabled may start a dependable group BAN. The node shall perform passive scan across a specified set of channels and separate out 15.4 HRP UWB, 15.6-2012, 15.4z/ab, and 15.6ma networks operating within interfering range.

If the node can't 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 5.6.6, and a group allocation map frame, as described in 5.6.7, periodically and by maintaining the group superframe structure.

6.5.5.2 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 5.6.6. The group beacon frame provides 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 order.

A group coordinator receives a group association frame or group disassociation frame during GCP and reconfigures group superframe structure to add newly joined BAN's 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 5.6.7. 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 order, and slot number of starting active superframe duration 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 networks, a group coordinator maintains a group BAN by selecting one of following procedures:

- When a group coordinator finds a BAN and new coexisting coordinator challenges to become a group coordinator, the group coordinator starts group coordinator migration procedure, as described in 6.5.7.1.
- When a group coordinator finds a group BAN and new coexisting group coordinator challenges to merge a group BAN, the group coordinator starts group merging procedure, as described in 6.5.7.2.

If a group BAN decides to resign the group coordinator role or to leave the group BAN, the group coordinator starts group coordinator migration procedure, as described in 6.5.7.1.

If a group BAN decides to resign the group coordinator role and not to hand over the group coordinator role, the group coordinator starts group disband procedure, as described in 6.5.7.3.

6.5.6 Association and disassociation a dependable group BAN

6.5.6.1 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 5.6.8, which contains BAN identification, coordinator address, beacon interval, superframe order, 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. The coordinator will synchronize to the group BAN from the next group beacon interval. The coordinator broadcasts a beacon frame that contains Beacon Change Notification IE. The nodes in the coordinator's BAN will calculate the start slot of next beacon by using the Beacon Offset field of Beacon Change Notification IE and follow the beacon from the next beacon interval which is specified in Beacon Change Notification IE.

6.5.6.2 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 5.6.9.

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

6.5.7 Migrating and disbanding a dependable group BAN

6.5.7.1 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 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 new group coordinator among coordinators of the group BAN by following procedure:

- A group coordinator broadcasts group coordinator resign frame, which contains group BAN ID as described in 5.6.10, on 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 order, and CFP descriptor count as described in 5.6.11, from the coordinators in the group BAN.

- A group coordinator selects a coordinator, which has the largest superframe order and/or the largest number of nodes in a BAN, as the group coordinator. If no coordinator responds to a group coordinator resign frame, a group coordinator designates a coordinator, which has the largest superframe order and/or the largest number of nodes in a BAN among coordinators of the group BAN, as the group coordinator. A group coordinator broadcasts group coordinator migration frame, which contains group BAN ID, designated group coordinator address, group beacon interval, and group allocation descriptor as described in 5.6.12, on group notification slot of the GCP.

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

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

- If the number of nodes in the BAN who challenges to become a group coordinator is larger than the number of nodes in the BAN maintaining by the group coordinator, the group coordinator broadcasts group coordinator migration frame, as described in 5.6.12, on 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 current group beacon with group change notification IE, which has the reconfigured group superframe information as defined in 5.6.16.2, 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 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 period to the nodes in a BAN by broadcasting a beacon with beacon change notification IE, as described in 5.6.16.1, and realigns the start of the superframe from the next group beacon interval.

6.5.7.2 Merging a dependable group BAN

A group coordinator may try to merge group BANs, when finds a coexisting group BAN.

A group coordinator starts merging group BANs by following procedure:

- A group coordinator broadcasts group merging challenge frame as defined in 5.6.13 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 procedure:

- If the group coordinator determines to merge, the group coordinator checks the length of 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 BAN's, the group coordinator becomes the group coordinator of the merged group BAN.

- The group coordinator responds the group coordinator of the coexisting group by transmitting a group merge frame as defined in 5.6.14. 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 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.

6.5.7.3 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 group disband frame, as described in 5.6.15. When receiving group disband frame, the coordinators of a group BAN cease the transmission for two group beacon interval, reconfigure the superframe structure, and notify the changes on superframe by broadcasting beacon frame containing Beacon change notificaiton IE, as described in 5.6.16.1. 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.

6.5.8 Interference mitigation in a dependable group BAN

6.5.8.1 Interleaved active superframe duration

A group coordinator allocates active superframe duration of each BANs in a group on the Group Allocation Period to mitigate interference among coexisting BANs. The allocation of active superframe durations is notified by broadcasting group allocation map frame, as described in 5.xx.

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

For coexistence class 1, whenever a BAN joins or leaves, a group coordinator reallocates active superframe durations on a group allocation period with keeping sequential order of joining a group 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 period will be the rest of GAP after allocating active superframe durations of each BANs in a group. In varied mode, GAP contains active superframe duration only and the length of group inactive period 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.

6.5.8.2 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 15.6-2012 beacon or 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 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 15.6-2012 beacon frame. For coexistence class 4, a group coordinator assigns blocking period to guarantee the transmission of 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.

6.5.8.3 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 18) and coexistence environment of operation.