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Wireless Specialty Networks

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| IEEE 802.15.13 Text proposal for MAC management and control frame format |
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Abstract

# This document contains a text proposal for MAC general frame structure.

1. **Overview**
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4. **General description**
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	1. **MAC functional description**
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		1. **Association Request Frame**

The association request allows a device to request association with an OWPAN through the coordinator. This command shall only be sent by an unassociated device that wishes to associate with an OWPAN. A device shall only associate with an OWPAN through the coordinator as determined through the scan procedure.

All devices shall be capable of transmitting this frame, although a device is not required to be capable of

receiving it.

The association request frame shall be formatted as illustrated in Table 1.

Table 1 Association request frame format

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Octets: 2 | 2 | 2 | 6 | variable | 0/variable | 4 |
| MHR | Capability information | Listen Interval | OWPAN ID | Supported Rates | Extended Supported Rates | MFR |

* + - 1. **Capability Information**

The 16-bit Capability Information field is used to advertise the network’s capabilities. Capability Information is also used in Probe Request and Probe Response frames. In this field, each bit is used as a flag to advertise a particular function of the network. Devices use the capability advertisement to determine whether they can support all the features in the OWPAN. Devices that do not implement all the features in the capability advertisement are not allowed to join.

* + - 1. **Listen interval**

To reduce power consumption, devices may shut off the antenna units. While devices are sleeping, coordinators must buffer frames for them. Dozing devices periodically wake up to listen to traffic announcements to determine whether the coordinator has any buffered frames. When devices associate with a coordinator, part of the saved data is the Listen Interval, which is the number of Beacon intervals that devices wait between listening for Beacon frames. The Listen Interval allows devices to indicate how long the coordinator must retain buffered frames. Higher listen intervals require more coordinator memory for frame buffering. Coordinators may use this feature to estimate the resources that will be required and may refuse resource-intensive associations.

* + - 1. **OWPAN ID**

OWPAN ID field gives the ID for the requested OWPAN, hence the corresponding coordinator processes the association request.

* + - 1. **Supported rates**

Several data rates have been standardized for each PHY in IEEE 802.15.13. When mobile devices attempt to join the network, they check the data rates used in the network. Some rates are mandatory and must be supported by the mobile device, while others are optional.

* + - 1. **Extended supported rates**

Extended Supported Rates element was standardized to handle more than eight data rates.

* + 1. **Association Response Frame**

The association response allows the coordinator or a coordinator to communicate the results of an association attempt back to the device requesting association. If the coordinator accepts the device, the frame includes information regarding the association, such as association ID (AID) and supported rates.

This response shall only be sent by the coordinator or a coordinator to a device that is currently trying to associate.

All devices shall be capable of receiving this frame, although a device is not required to be capable of transmitting it.

The association response frame shall be formatted as illustrated in Table 2.

Table 2 Association response frame format

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Octets: 2 | 2 | 2 | 0/2 | 0/variable | 0/variable | 4 |
| MHR | Capability information | Status Code | AID | Supported Rates | Extended Supported Rates | MFR |

* + - 1. **Capability Information**

The 16-bit Capability Information field is used to advertise the network’s capabilities. Capability Information is also used in Probe Request and Probe Response frames. In this field, each bit is used as a flag to advertise a particular function of the network. Devices use the capability advertisement to determine whether they can support all the features in the OWPAN. Devices that do not implement all the features in the capability advertisement are not allowed to join.

* + - 1. **Status code**

Status codes indicate the success or failure of an operation. The Status Code field is 0 when an operation succeeds and nonzero on failure.

* + - 1. **Association ID**

The Association ID is a 16-bit field. When devices associate with a coordinator, they are assigned an Association ID to assist with control and management functions. Even though 14 bits are available for use in creating Association IDs, they range only from 1-2,007. The two most significant bits are reserved.

* + - 1. **Supported rates**

Several data rates have been standardized for each PHY in IEEE 802.15.13. When mobile devices attempt to join the network, they check the data rates used in the network. Some rates are mandatory and must be supported by the mobile device, while others are optional.

* + - 1. **Extended supported rates**

Extended Supported Rates element was standardized to handle more than eight data rates.

* + 1. **Reassociation Request Frame**

The re-association request allows a device to request re-association with a target OWPAN through the coordinator. This request shall only be sent by a device that is already associate with an original coordinator

and that wishes to associate with another OWPAN. A device shall only re-associate with an OWPAN

through the coordinator as determined through neighboring OWPAN measurements.

All devices shall be capable of transmitting this command, although a device is not required to be capable of receiving it.

The re-association request frame shall be formatted as illustrated in Table 3.

Table 3 Reassociation request frame format

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Octets: 2 | 2 | 2 | 6 | 6 | variable | 0/variable | 4 |
| MHR | Capability information | Listen Interval | Current coordinator address | OWPAN ID | Supported Rates | Extended Supported Rates | MFR |

* + - 1. **Capability Information**

The 16-bit Capability Information field is used to advertise the network’s capabilities. Capability Information is also used in Probe Request and Probe Response frames. In this field, each bit is used as a flag to advertise a particular function of the network. Devices use the capability advertisement to determine whether they can support all the features in the OWPAN. Devices that do not implement all the features in the capability advertisement are not allowed to join.

* + - 1. **Listen interval**

To reduce power consumption, devices may shut off the antenna units. While devices are sleeping, coordinators must buffer frames for them. Dozing devices periodically wake up to listen to traffic announcements to determine whether the coordinator has any buffered frames. When devices associate with a coordinator, part of the saved data is the Listen Interval, which is the number of Beacon intervals that devices wait between listening for Beacon frames. The Listen Interval allows devices to indicate how long the coordinator must retain buffered frames. Higher listen intervals require more coordinator memory for frame buffering. Coordinators may use this feature to estimate the resources that will be required and may refuse resource-intensive associations.

* + - 1. **Current Coordinator Address**

Mobile devices use the Current coordinator address field to indicate the MAC address of the coordinator with which they are associated. This field is used to ease associations and reassociations. Devices transmit the address of the coordinator that handled the last association with the network. When an association is established with a different coordinator, this field can be used to transfer the association and retrieve any buffered frames.

* + - 1. **OWPAN ID**

OWPAN ID field gives the ID for the requested OWPAN, hence the corresponding coordinator processes the reassociation request.

* + - 1. **Supported rates**

Several data rates have been standardized for each PHY in IEEE 802.15.13. When mobile devices attempt to join the network, they check the data rates used in the network. Some rates are mandatory and must be supported by the mobile device, while others are optional.

* + - 1. **Extended supported rates**

Extended Supported Rates element was standardized to handle more than eight data rates.

* + 1. **Reassociation Response Frame**

The reassociation response allows the coordinator to communicate the results of a reassociation attempt back to the device requesting reassociation.

This response shall only be sent by the coordinator or a coordinator to a device that is currently trying to associate. If the coordinator accepts the device, the frame includes information regarding the reassociation, such as AID and supported rates.

All devices shall be capable of receiving this frame, although a device is not required to be capable of transmitting it.

The reassociation response frame shall be formatted as illustrated in Table 4.

Table 4 Reassociation response frame format

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Octets: 2 | 2 | 2 | 0/2 | 0/variable | 0/variable | 4 |
| MHR | Capability information | Status code | AID | Supported Rates | Extended Supported Rates | MFR |

* + - 1. **Capability Information**

The 16-bit Capability Information field is used to advertise the network’s capabilities. Capability Information is also used in Probe Request and Probe Response frames. In this field, each bit is used as a flag to advertise a particular function of the network. Devices use the capability advertisement to determine whether they can support all the features in the OWPAN. Devices that do not implement all the features in the capability advertisement are not allowed to join.

* + - 1. **Status code**

Status codes indicate the success or failure of an operation. The Status Code field is 0 when an operation succeeds and nonzero on failure.

* + - 1. **Association ID**

The Association ID is a 16-bit field. When devices associate with a coordinator, they are assigned an Association ID to assist with control and management functions. Even though 14 bits are available for use in creating Association IDs, they range only from 1-2,007. The two most significant bits are reserved.

* + - 1. **Supported rates**

Several data rates have been standardized for each PHY in IEEE 802.15.13. When mobile devices attempt to join the network, they check the data rates used in the network. Some rates are mandatory and must be supported by the mobile device, while others are optional.

* + - 1. **Extended supported rates**

Extended Supported Rates element was standardized to handle more than eight data rates.

* + 1. **Probe Request Frame Format**

The probe request allows a device to send a request with information to a target coordinator in order to scan an area for existing IEEE 802.15.13 networks. A Probe Request frame contains two fields: the OWPAN ID and the rates supported by the mobile device. Coordinators that receive Probe Requests use the information to determine whether the mobile device can join the network. To make a happy union, the mobile device must support all the data rates required by the network and must want to join the network identified by the OWPAN ID. This may be set to the OWPAN ID of a specific network or set to join any compatible network. Drivers that allow cards to join any network use the broadcast OWPAN ID in Probe Requests.

All devices shall be capable of transmitting this command, although a device is not required to be capable of receiving it.

The probe request frame shall be formatted as illustrated in Table 5.

Table 5 Probe request frame format

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Octets: 2 | 6 | variable | 0/variable | 4 |
| MHR | OWPAN ID | Supported Rates | Extended Supported Rates | MFR |

* + - 1. **OWPAN ID**

OWPAN ID field gives the ID for the requested OWPAN, hence the corresponding coordinator processes the request.

* + - 1. **Supported rates**

Several data rates have been standardized for each PHY in IEEE 802.15.13. When mobile devices attempt to join the network, they check the data rates used in the network. Some rates are mandatory and must be supported by the mobile device, while others are optional.

* + - 1. **Extended supported rates**

Extended Supported Rates element was standardized to handle more than eight data rates.

* + 1. **Probe Response Frame Format**

If a Probe Request encounters a network with compatible parameters, the network sends a Probe Response frame. The coordinator that sent the last Beacon is responsible for responding to incoming probes. After a coordinator transmits a Beacon, it assumes responsibility for sending Probe Response frames for the next Beacon interval.

This response shall only be sent by the coordinator or a coordinator to a device that is currently trying to associate.

All devices shall be capable of receiving this frame, although a device is not required to be capable of transmitting it.

The probe response frame shall be formatted as illustrated in Table 6.

Table 6 Probe response frame format

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Octets: 2 | 8 | 2 | 2 | 6 | 0/variable | 0/variable | 4 |
| MHR | Timestamp | Beacon Interval | Capability information | OWPAN ID | Supported Rates | Extended Supported Rates | MFR |

* + - 1. **Timestamp**

The Timestamp field allows synchronization between the devices in an OWPAN. The master timekeeper for an OWPAN periodically transmits the number of microseconds it has been active. When the counter reaches its maximum value, it wraps around.

* + - 1. **Beacon interval**

Each OWPAN can transmit Beacon frames at its own specific interval.

* + - 1. **Capability Information**

The 16-bit Capability Information field is used to advertise the network’s capabilities. In this field, each bit is used as a flag to advertise a particular function of the network. Devices use the capability advertisement to determine whether they can support all the features in the OWPAN. Devices that do not implement all the features in the capability advertisement are not allowed to join.

* + - 1. **OWPAN ID**

OWPAN ID field gives the ID for the OWPAN.

* + - 1. **Supported rates**

Several data rates have been standardized for each PHY in IEEE 802.15.13. When mobile devices attempt to join the network, they check the data rates used in the network. Some rates are mandatory and must be supported by the mobile device, while others are optional.

* + - 1. **Extended supported rates**

Extended Supported Rates element was standardized to handle more than eight data rates.

* + 1. **Authentication Frame**

Authentication operates at the link level between devices. Authentication frames are sent back and forth between the device requesting authentication and the device to which it is attempting to assert its authentic identity. With open system authentication, the device sends only one authentication frame, and the coordinator responds with an authentication frame as a response indicating acceptance or rejection.

The authentication frame shall be formatted as illustrated in Table 7.

Table 7 Authentication frame format

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Octets: 2 | 2 | 2 | 2 | 0/128 | 4 |
| MHR | Authentication Algorithm Number | Authentication Transaction Sequence Number | Status code | Challenge text | MFR |

* + - 1. **Authentication algorithm number**

Two bytes are used for the Authentication Algorithm Number field. This field identifies the type of authentication used in the initial authentication process before association occurs. 802.1X authentication occurs after association and is not assigned an algorithm number. The values permitted for this field are shown in Table 4-3. Only two values are currently defined. Other values are reserved for future standardization work.

0 indicates: Open System authentication (typically used with 802.1X authentication);

1 indicates: Shared Key authentication;

2-65535 are reserved.

* + - 1. **Authentication transaction sequence number**

Authentication is a multistep process that consists of a challenge from the coordinator and a response from the device attempting to associate. The Authentication Transaction Sequence Number is a two-byte field used to track progress through the authentication exchange. It takes values from 1 to 65,535; it is never set to 0.

* + - 1. **Status code**

Status codes indicate the success or failure of an operation. The Status Code field is 0 when an operation succeeds and nonzero on failure.

* + - 1. **Challenge text**

When the Status code is successful, the frame also includes a fourth information element, the Challenge Text. The Challenge Text is composed of 128 bytes generated using the WEP keystream generator with a random key and initialization vector. This field is optional depending on the authentication algorithm. For instance, this field is not needed in Open-system authentication but required in shared-key authentication.

* + 1. **De-authentication Frame**

The de-authentication service is invoked when an existing authentication is to be terminated. This frame is an announcement stating that the device is no longer authenticated. It is a one-way communication from the authenticating device and must be accepted. It takes effect immediately.

The de-authentication frame shall be formatted as illustrated in Table 8.

Table 8 De-authentication frame format

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Octets: 2 | 2 | 6 | 6 | 4 |
| MHR | Reason code | OWPAN ID | Device ID to de-authenticate | MFR |

* + - 1. **Reason code**

In response to traffic when the sender has not properly joined the network, reason code is given by the coordinator. The 16-bit Reason Code field indicates what the sender has done incorrectly. Table 9 lists the reason codes.

Table Reason codes

|  |  |
| --- | --- |
| **Reason code** | **Explanation** |
| 0-1 | Reserved |
| 2 | Prior authentication is not valid |
| 3 | Device has left the OWPAN and is de-authenticated  |
| 4 | Inactivity timer expired, and device was disassociated |
| 5 | Disassociated due to insufficient resources at the coordinator |
| 6 | Incorrect frame type or subtype received from unauthenticated device |
| 7 | Incorrect frame type or subtype received from disassociated device |
| 8 | Device has left the OWPAN and is disassociated |
| 9 | Association or reassociation requested before authentication is complete |
| 10-65535 | Reserved  |

* + - 1. **OWPAN ID**

OWPAN ID field gives the ID for the OWPAN.

* + - 1. **Device ID to de-authenticate**

This field gives the ID of the device to be de-authenticated. Thus, devices other than the sender and receiver may also update their own list of recipients.

* + 1. **Beacon Frame**

Beacon frames announce the existence of a network. They are transmitted at regular intervals (i.e., each beacon interval) by coordinators to allow devices to find and identify a network and possibly join it. Beacon frames are supposed to be transmitted exactly as the beacon interval ends, at the so-called target Beacon transmission time (TBTT). In an infrastructure network, the coordinator is responsible for transmitting Beacon frames with information such as timestamp, OWPAN ID, and other parameters regarding the coordinator to devices that are within range.

All devices shall be capable of receiving this frame.

The beacon frame shall be formatted as illustrated in Table 10.

Table 10 Beacon frame format

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Octets: 2 | 8 | 2 | 2 | 6 | 0/variable | variable | 0/variable | 4 |
| MHR | Timestamp | Beacon Interval | Capability information | OWPAN ID | Supported Rates | Country | Extended Supported Rates | MFR |

* + - 1. **Timestamp**

The Timestamp field allows synchronization between the devices in an OWPAN. When coordinators prepare to transmit a Beacon frame, the coordinator timer is copied into the Beacon’s timestamp field. Devices associated with a coordinator accept the timing value in any received Beacons, but they may add a small offset to the received timing value to account for local processing by the antenna and transceiver.

* + - 1. **Beacon interval**

Each OWPAN can transmit Beacon frames at its own specific interval.

* + - 1. **Capability Information**

The 16-bit Capability Information field is used to advertise the network’s capabilities. In this field, each bit is used as a flag to advertise a particular function of the network. Devices use the capability advertisement to determine whether they can support all the features in the OWPAN. Devices that do not implement all the features in the capability advertisement are not allowed to join.

* + - 1. **OWPAN ID**

OWPAN ID field gives the ID for the OWPAN.

* + - 1. **Supported rates**

Several data rates have been standardized for each PHY in IEEE 802.15.13. When mobile devices attempt to join the network, they check the data rates used in the network. Some rates are mandatory and must be supported by the mobile device, while others are optional.

* + - 1. **Country**

The initial specifications were designed around the existing regulatory constraints in place in the major industrialized countries. Rather than continue to revise the specification each time a new country was added, a new specification was added that provides a way for networks to describe regulatory constraints to new stations. Maximum transmission power is specified using the country element in beacon frames. The information is available to any station wishing to associate to a network. The Country element specifies the regulatory maximum power, and the Power Constraint element can be used to specify a lower maximum transmission power specific to the network.

* + - 1. **Extended supported rates**

Extended Supported Rates element was standardized to handle more than eight data rates.

* + 1. **Disassociation Frame Format**

The disassociation service is invoked when an existing association is to be terminated.

The disassociation service can be invoked by either party in an association (device or coordinator). Disassociation is a notification, not a request.

A coordinator can disassociate device to enable the coordinator to be removed from a network for service or for other reasons. Devices attempt to disassociate when they leave a network. However, the MAC protocol does not depend on devices invoking the disassociation service. The de-authentication service is invoked when an existing authentication is to be terminated. This frame is an announcement stating that the device is no longer authenticated. It is a one-way communication from the authenticating device and must be accepted. It takes effect immediately.

The disassociation frame shall be formatted as illustrated in Table 11.

Table 11 Disassociation frame format

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Octets: 2 | 2 | 6 | 6 | 4 |
| MHR | Reason code | OWPAN ID | Device ID to de-authenticate | MFR |

* + - 1. **Reason code**

In response to traffic when the sender has not properly joined the network, reason code is given by the coordinator. The 16-bit Reason Code field indicates what the sender has done incorrectly. Table 12 lists the reason codes.

Table Reason codes

|  |  |
| --- | --- |
| **Reason code** | **Explanation** |
| 0-1 | Reserved |
| 2 | Prior authentication is not valid |
| 3 | Device has left the OWPAN and is disassociated  |
| 4 | Inactivity timer expired, and device was disassociated |
| 5 | Disassociated due to insufficient resources at the coordinator |
| 6 | Incorrect frame type or subtype received from unauthenticated device |
| 7 | Incorrect frame type or subtype received from disassociated device |
| 8 | Device has left the OWPAN and is disassociated |
| 9 | Association or reassociation requested before authentication is complete |
| 10-65535 | Reserved  |

* + - 1. **OWPAN ID**

OWPAN ID field gives the ID for the OWPAN.

* + - 1. **Device ID to de-authenticate**

This field gives the ID of the device to be de-authenticated. Thus, devices other than the sender and receiver may also update their own list of recipients.

* 1. **MAC control frame**
		1. **Waveform Control Frame**

The waveform control frame relates to the adaptive OFDM technique. Multiple waveforms such as eU-OFDM and RPO-OFDM may exist in the network. The control frame could be used when adaptive adjustment of the waveform is required.

The waveform control frame shall be formatted as illustrated in Table 13.

Table 13 Waveform control frame format

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Octets: 2 | 8 | 6 | 8 | 1 | 4 |
| MHR | Timestamp | OWPAN ID | Time to switch | Waveform to switch to | MFR |

* + - 1. **Timestamp**

The Timestamp field allows synchronization between the devices in an OWPAN. The master timekeeper for an OWPAN periodically transmits the number of microseconds it has been active. When the counter reaches its maximum value, it wraps around.

* + - 1. **OWPAN ID**

OWPAN ID field gives the ID for the OWPAN.

* + - 1. **Waveform to switch to**

The 8 bits are to indicate the waveform to switch to among the supported waveforms by IEEE 802.15.13.

* + 1. **Advanced Modulation Control Frame**

Advanced modulation control frame indicates the advanced modulation capabilities of a communication node.

The CSI control frame shall be formatted as in Table 14.

Table 14 Advanced modulation control frame format

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Bits: 16 | 1 | 4 | 1 | 4 | 1 | 4 | 32 |
| MHR | Adaptive loading | eU | RPO | Relaying | MIMO | Number of MIMO Channels | MFR |

* + - 1. **Adaptive Loading**

A single bit indicates whether the communication node transmitting the advanced modulation control

frame supports adaptive bit and energy loading:

“1” indicates: Adaptive bit and energy loading is supported.

“0” indicates: Adaptive bit and energy loading is not supported.

* + - 1. **eU**

The 4 bits indicate if the node supports eU-OFDM. The bit value at a given position out of the four positions

indicates whether eU-OFDM implementation with the same number of streams as the bit position is supported. Positions are counted from left to right. For example:

“1000” indicates eU-OFDM with one stream only is supported.

“1100” indicates eU-OFDM with one and two streams only is supported.

“1010” indicates eU-OFDM with one and three streams only is supported.

“1111” indicates eU-OFDM with all possible streams is supported.

“0000” indicates eU-OFDM is not supported.

* + - 1. **RPO**

A single bit indicates whether the communication node transmitting the advanced modulation control frame supports RPO-OFDM:

“1” indicates: RPO-OFDM is supported.

“0” indicates: RPO-OFDM is not supported.

* + - 1. **Relaying**

The 4 bits indicate the types of relaying operations the communication node transmitting the advanced modulation

control frame supports.

The first bit indicates whether relaying in FD is supported:

“1” indicates: Relaying in FD is supported.

“0” indicates: Relaying in FD is not supported.

The second bit indicates whether relaying in HD is supported:

“1” indicates: Relaying in HD is supported.

“0” indicates: Relaying in HD is not supported.

The third bit indicates whether AF relaying is supported:

“1” indicates: AF relaying is supported.

“0” indicates: AF relaying is not supported.

The fourth bit indicates whether DF relaying is supported:

“1” indicates: DF relaying is supported.

“0” indicates: DF relaying is not supported.

* + - 1. **MIMO**

A single bit indicates whether the communication node transmitting the advanced modulation control frame supports MIMO communication:

“1” indicates: MIMO is supported.

“0” indicates: MIMO is not supported.

* + - 1. **Number of MIMO Channels**

The 4 bits indicate the maximum number of MIMO communication channels which the communication node transmitting the advanced modulation control frame supports.

A value of '0000' corresponds to 1 channel, and a value of '1111' corresponds to 16 channels.