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Recommendation

ITU-T J.198.3 (01/2024)

SERIES J: Cable networks and transmission of television, sound programme and other multimedia signals

Cable modems and home networking

MAC layer specification for third-generation HiNoC

ITU-T J-SERIES RECOMMENDATIONS

Cable networks and transmission of television, sound programme and other multimedia signals

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Recommendation ITU-T J.198.3

MAC layer specification for third-generation HiNoC

Summary

Recommendation ITU-T J.198.3 defines the medium access control (MAC) layer specification of third generation high performance network over coax (HiNoC 3.0), which provides 10 Gbit/s data transmission over coaxial networks in the cable industry. HiNoC consists of HiNoC bridge (HB) and HiNoC modem (HM) in terms of architectural functional entities, and is layered into medium access control (MAC) layer and physical (PHY) layer.

HiNoC 3.0 MAC layer selects the time division duplexing (TDD) mode to adjust the bandwidth for upstream and downstream feasibly. HiNoC 3.0 MAC layer adopts time division multiple access (TDMA) and optional orthogonal frequency division multiple access (OFDMA). HiNoC 3.0 MAC layer supports the channel bonding mechanism. The HiNoC 3.0 MAC layer is composed of the convergence sublayer (CS), the common part sublayer (CPS) and the optional security sublayer (SS).

This Recommendation contains descriptions for HiNoC 3.0 MAC frame types, functions and mechanisms of CS and CPS.

History *

Edition	Recommendation	Approval	Study Group	Unique ID
1.0	ITU-T J.198.3	2024-01-13	9	11.1002/1000/15801

Keywords

MAC layer, third generation HiNoC.

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Recommendation ITU-T J.198.3

MAC layer specification for third-generation HiNoC

1 Scope

This Recommendation defines the medium access control (MAC) layer protocol and is part of a series of third generation HiNoC Recommendations for high-speed data transmission over coaxial cable.

The functional requirements of third-generation HiNoC is defined in [ITU-T J.198.1], and the physical layer specification for third-generation HiNoC is defined in [ITU-T J.198.2].

This Recommendation applies to bidirectional high-performance broadband access digital systems that use coaxial cable connected between fibre-to-the-building (FTTB) and customer premises equipment (CPE).

Frequency planning, safety and electromagnetic compatibility (EMC) requirements are a national matter and are not covered by this Recommendation. Compliance remains the operators' responsibility.

Information on the main differences between the third-generation HiNoC (HiNoC 3.0) and the second-generation HiNoC (HiNoC 2.0) is available in [b-ITU-T J Sup 12].

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T J.196.1] Recommendation ITU-T J.196.1 (2016), *Functional requirements for second generation HiNoC.*

[ITU-T J.196.2] Recommendation ITU-T J.196.2 (2016), *Physical layer specification of second generation HiNoC.*

[ITU-T J.196.3] Recommendation ITU-T J.196.3 (2024), *MAC layer specification for second generation HiNoC.*

[ITU-T J.198.1] Recommendation ITU-T J.198.1 (2022), *Functional requirements for third-generation HiNoC.*

[ITU-T J.198.2] Recommendation ITU-T J.198.2 (2024), *Physical layer specification for third-generation HiNoC.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 control frame [b-ITU-T J.195.2]: Frame of the MAC layer used for access control and channel allocation.

3.1.2 data frame [b-ITU-T J.195.2]: Frame of the MAC layer used to carry data of the upper layer.

3.1.3 downlink [b-ITU-T J.195.2]: Link from HiNoC bridge (HB) to HiNoC modem (HM).

3.1.4 HiNoC 2.0+ channel [ITU-T J.198.2]: A channel that supports the access of HiNoC 3.0 and 2.0 modems, and has a bandwidth of 128 MHz.

3.1.5 HiNoC 3.0 channel [ITU-T J.198.2]: A channel that only supports the access of HiNoC 3.0 modems, and has a bandwidth of 128 MHz.

3.1.6 MAP cycle [b-ITU-T J.195.3]: A period of time planned by a MAP frame.

3.1.7 packing [b-ITU-T J.195.1]: A procedure of combining multiple Ethernet medium access control (MAC) frames with the same destination and priority to form a high performance network over coax (HiNoC) MAC frame.

3.1.8 Pd cycle [b-ITU-T J.195.2]: A time interval between two adjacent downlink probe frames.

3.1.9 segmentation [b-ITU-T X.233]: The act of generating two or more derived PDUs from an initial or derived PDU. The derived PDUs together carry the entire user data of the initial or derived PDU from which they were generated.

3.1.10 signalling frame [b-ITU-T J.195.2]: Frame of the MAC layer used for node admission, node quitting/deletion and link maintenance.

3.1.11 uplink [b-ITU-T J.195.2]: Link from HiNoC modem (HM) to HiNoC bridge (HB).

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 channel bonding: A mechanism used by a HiNoC bridge (HB) and HiNoC modems (HMs) to transmit upper-layer service flows over multiple channels to increase the overall transmission rate of the HiNoC system.

3.2.2 HiNoC 2.0: The short form for the second generation HiNoC defined by [ITU-T J.196.1], [ITU-T J.196.2] and [ITU-T J.196.3].

3.2.3 HiNoC 3.0: The short form for the third generation HiNoC defined by [ITU-T J.198.1], [ITU-T J.198.2] and this Recommendation.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AU	Allocation Unit
BCH	Bose-Chaudhuri-Hocquenghem (code)
Cd	downlink Control
CH	Channel
CPE	Customer Premises Equipment
CPS	Common Part Sublayer
CRC	Cyclic Redundancy Check
CS	Convergence Sublayer
Dd	downlink Data
Du	uplink Data
EISF	Extended Information Subframe
EMAC	Ethernet MAC
EMC	Electromagnetic Compatibility

FEC	Forward Error Correction
FTTB	Fibre To The Building
HB	HiNoC Bridge
HiMAC3.0	HiNoC 3.0 MAC
HiNoC	High performance Network over Coax
HM	HiNoC Modem
ID	Identifier
IFG	Inter-frame Gap
LDPC	Low Density Parity Check Code
MAC	Medium Access Control
MAP	Media Access Plan
NHM	New HiNoC Modem
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
Pd	downlink Probe
PDU	Protocol Data Unit
PG	Profile Group
PGID	Profile Group Identifier
PHY	Physical
Pu	Physical
QoS	Quality of Service
R	Report
Ru	uplink Report
SS	Security Sublayer
SSC	Symbol Sub-Cell
TDD	Time Division Duplexing
TDMA	Time Division Multiple Access
TLV	Type-Length-Value

5 Conventions

In this Recommendation:

The keywords "**is required to**" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this Recommendation is to be claimed.

The keywords "**is recommended**" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

The keywords "**is prohibited from**" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this Recommendation is to be claimed.

The keywords "**can optionally**" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

In this Recommendation, the words shall, shall not, should and may sometimes appear, in which case they are to be interpreted, respectively, as is required to, is prohibited from, is recommended, and can optionally. The appearance of such phrases or keywords in an appendix or in material explicitly marked as informative are to be interpreted as having no normative intent.

6 MAC layer structure

The HiNoC 3.0 MAC (HiMAC3.0) layer is required to consist of the convergence sublayer (CS) and common part sublayer (CPS), and can optionally include the security sublayer (SS). The CS provides adaptation functions between the CPS and higher layer, including address learning, packet forwarding table generation, priority mapping and framing/deframing functions. The CPS provides media access control, channel allocation, node admission, node quitting/deleting and link maintenance functions. The security sublayer (SS) provides identity authentication, data encryption/decryption and secret key management functions. The structure of the HiMAC3.0 is shown in Figure 1.

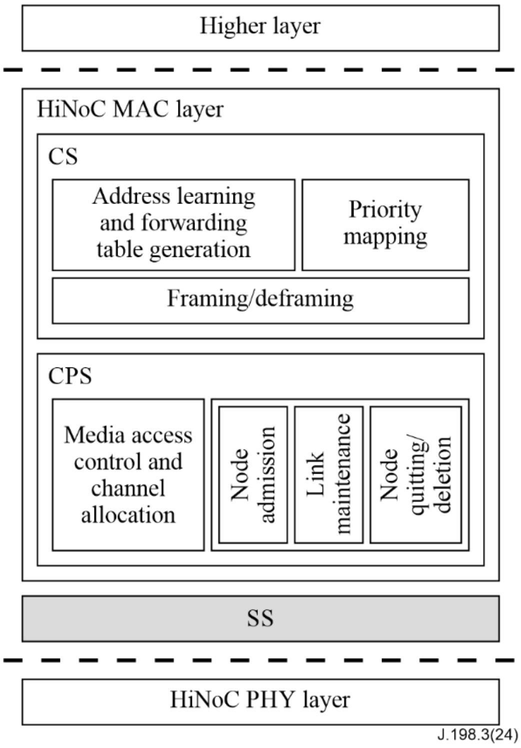

Figure 1 – HiMAC3.0 structure

When receiving protocol data units (PDUs) from the higher layer, the CS is required to perform forwarding table querying, priority mapping and framing, and then send HiMAC3.0 data frames to the corresponding queues. The CPS is required to forward the HiMAC3.0 data frames and utilize report-authorization-based medium access control and channel allocation mechanism to transfer data between the HiNoC bridge (HB) and HiNoC modem (HM).

7 MAC layer frame types

7.1 Overview

Three types of HiMAC3.0 frames are defined: signalling frame, control frame and data frame.

7.2 Signalling frame

Signalling frames are required to provide the function of signalling exchange between HB and HMs during node admission, node quitting and link maintenance.

The generic signalling frame structure is shown in Figure 2. The frame consists of four distinct regions: the frame header, the payload, the optional padding and the tail. The detailed definition of the signalling frame format is provided in clause A.1.

Both the frame header and the payload include a fixed part followed by an optional extended part. The optional extended part has the same format in the frame header and the payload for all frame types and it is used for function expansion. It consists of a TLV_NUM field and one or more type-length-value (TLV) coding blocks. The value of TLV_NUM field indicates the number of TLV coding blocks. The length of the extended part is variable. The detailed definitions of the extended part and the TLV coding format are provided in clause A.1.1.

The optional padding region is required to be filled with Bit '0' and its length is variable (≥ 0). It is added to the signalling frame or the last signalling frame fragment as specified in clause 7.5.1 of [ITU-T J.196.3] to guarantee that the length of the signalling frame/the last signalling frame fragment equals to the fixed value N_{SF} defined in Table B.1.

The tail is required to be the 32-bit cyclic redundancy check (CRC) sequence generated over all the regions before the tail. The generator polynomial is defined in equation (1).

$$g_1(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1 \quad (1)$$

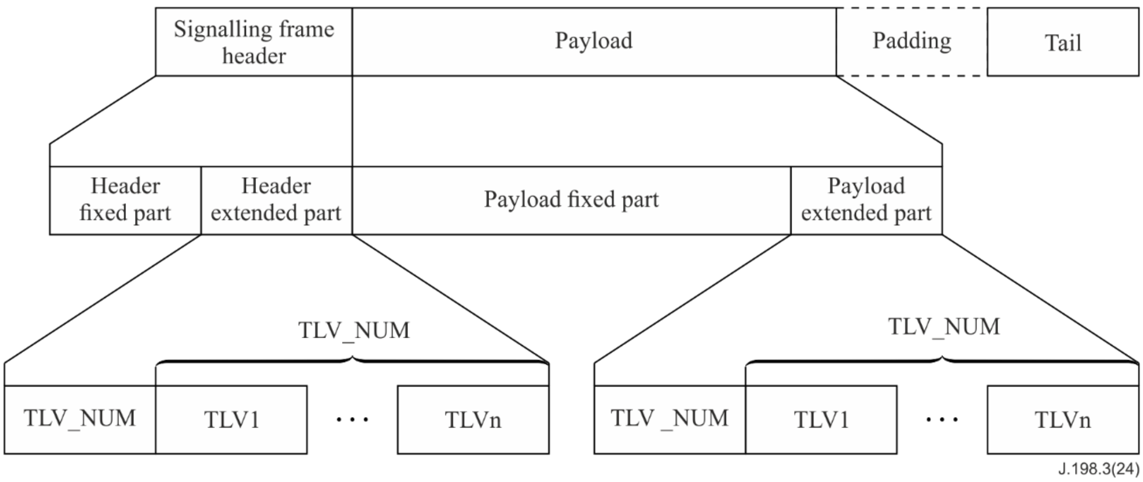

Figure 2 – Generic signalling frame format

Signalling frames are divided into downlink signalling frames and uplink signalling frames.

a) Downlink signalling frame

HiNoC 3.0 defines the nine types of downlink signalling frames listed in Table 1.

Table 1 – Downlink signalling frames

Frame type	Function
EMPTY	Used in downlink training and ranging
ADM_RES	Responses to an admission request
REJ	Indicates that the HB refuses the admission request from the corresponding HM or will delete the corresponding HM from the current channel or the network
ULINK_REPORT	Informs about the uplink parameters
ACK	Acknowledgement to DLINK_REPORT
CMP_REPORT	Advertises the downlink broadcast parameters/profile group parameters of the network
LINK_UPDATE	Informs HMs to update their link parameters
QUIT_ACK	Acknowledgement to QUIT
POWER_CTRL	Informs an HM to adjust its transmission power gain

For downlink signalling frames, the frame header in Figure 2 is required to be the downlink signalling frame header. The format of the downlink signalling frame header fixed part is the same for all downlink signalling frame types. The format of the payload fixed part is different for different downlink signalling frame types. The detailed definitions of the fixed part in the downlink signalling frame header and the payload and the tail are provided in clause A.1.1.

b) Uplink signalling frame

HiNoC 3.0 defines the seven types of uplink signalling frames listed in Table 2.

Table 2 – Uplink signalling frames

Frame type	Function
EMPTY	Used in uplink training and ranging
ADM_REQ	Admission request from a new HM
ADM_ACK	Acknowledgement to ADM_RES
REJ_ACK	Acknowledgement to REJ
DLINK_REPORT	Informs about the downlink parameters
ACK	Acknowledgement to ULINK_REPORT
QUIT	Indicates quitting the current channel or the network

For uplink signalling frames, the frame header in Figure 2 is required to be the uplink signalling frame header. The format of the uplink signalling frame header fixed part is the same for all uplink signalling frame types. The format of the payload fixed part is different for different uplink signalling frame types. The detailed definitions of the fixed part in the uplink signalling frame header and the payload and the tail are provided in clause A.1.2.

7.3 Control frame

Control frames are required to provide the functions of channel allocation and queue information report. Two types of control frames are defined: media access plan (MAP) frame and report (R) frame. The transmission modes of these two types of frames are different.

a) MAP frame

MAP frames are generated by HB and are transmitted independently on each channel. For one channel, each MAP frame is used to broadcast the channel allocation information of each MAP cycle to all the HMs admitted in the current channel. MAP frame is encapsulated into downlink control (Cd) frame in the physical (PHY) layer.

The MAP frame format is shown in Figure 3 and the detailed definition is given in clause A.2. A MAP frame consists of eight fields: MAP cycle identifier (MAP_ID), the number of channel allocation units (AU_NUM), the length of the MAP frame (MAP_LENGTH), symbol sub-cell pattern (SSC_MAP), Padding (optional), HM node online state (HM_STATE), reserved field (RSVD) and CRC. The SSC_MAP field contains one or more channel allocation units (AUs), and each AU consists of an AU type (AU_TYPE) subfield and the corresponding AU function (FUNCTION) subfield. The value of the CRC field is generated over all the fields before the CRC field. The generator polynomial is required to comply with equation (1) defined in clause 7.2.

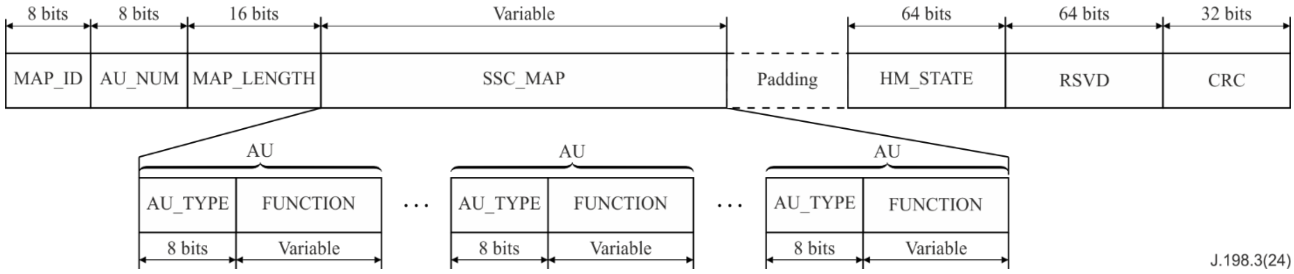

Figure 3 – MAP frame format for HiNoC 3.0

b) R frame

R frames are generated by HMs and are used for each HM to report its current queue information to HB for channel allocation. R frame is encapsulated into uplink report (Ru) frame in the PHY layer.

The R frame format is shown in Figure 4, and the detailed definition is given in clause A.2. An R frame consists of eight queue information indication (Q_FLAG) fields, quitting indication (QUIT_IND) field, link maintenance request indication (LM_REQ) field, indication for quitting the current channel (QUIT_FLAG) field, reserved field (RSVD) and CRC field. The value of the CRC field is generated over all the fields before the CRC field. The generator polynomial is defined in equation (2).

$$g_2(x) = x^4 + x + 1 \qquad (2)$$

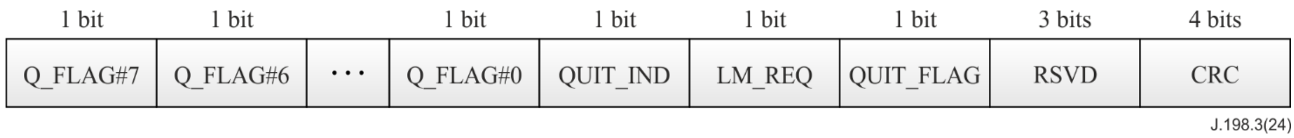

Figure 4 – R frame format for HiNoC 3.0

7.4 Data frame

Data frames (HiMAC3.0 data frames) are used to carry higher layer services. The HiNoC 3.0 data frame format is shown in Figure 5 and the detailed definition is given in clause A.3. A data frame consists of four regions: header, payload, padding and tail.

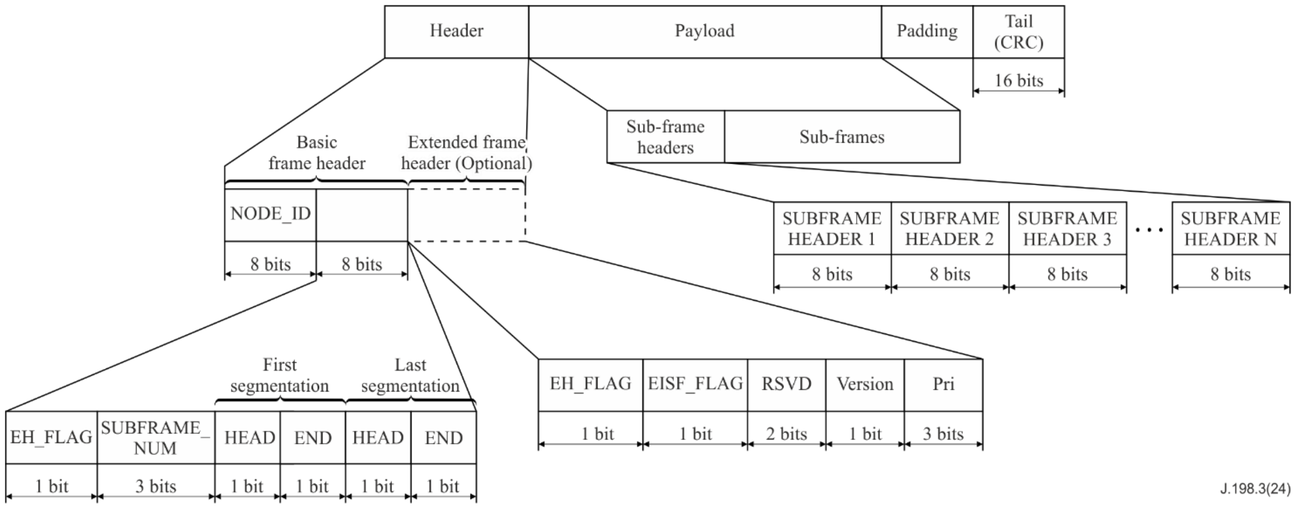

Figure 5 – HiNoC 3.0 data frame format

The data frame header consists of the basic frame header and the extended frame header. The length of the basic frame header is two bytes and it consists of the NODE_ID field, the extended header flag (EH_FLAG) field, the SUBFRAME_NUM field and two Ethernet MAC (EMAC) segment indication field groups. The NODE_ID field indicates the HM node/nodes that will send or receive this frame in the current channel. The value of the SUBFRAME_NUM field is the number of subframes contained in the payload region. The last two EMAC segment indication field groups are used to identify the first and the last EMAC segments contained in the payload region. The EH_FLAG field indicates whether the frame header contains the extended frame header or not.

In HiNoC 3.0, the 1-bit EH_FLAG field in the basic frame header is required to be set to 1, which means that the extended frame header is required to be present in the frame header. The length of the extended frame header can be one byte or more than one byte. The format of the first byte in the extended frame header is explicit and it consists of extended header flag (EH_FLAG) field, extended information subframe flag (EISF_FLAG) field, reserved field, data frame version (Version) field, and priority (Pri) field. The following bytes are optional for function expansion and each byte conforms to the definition that the first bit is still defined as EH_FLAG field while the other bits are reserved. If the EH_FLAG field is set to 1, then the following byte is still a part of the extended frame header. If the EH_FLAG field is set to 0, then the current byte is the last byte of the extended frame header which means it is also the last byte of the frame header.

If EISF_FLAG field in the first byte of the extended frame header is set to 1, then the first subframe in the payload region is required to be an extended information subframe (EISF). EISF is used to convey extended information such as detailed queue information report, frame sequence number, multicast receiving member list and so on. An EISF consists of one or more TLV coding fields and a CRC field. The TLV coding format is required to comply with the detailed definition provided in clause A.1.1. The value of the CRC field is generated over all the fields before it in the EISF. The generator polynomial is required to comply with equation (1) defined in clause 7.2. EISF is prohibited from being segmented and is required to be entirely encapsulated into one data frame payload. The EISF format is shown in Figure 6, and the detailed definition is provided in clause A.3.

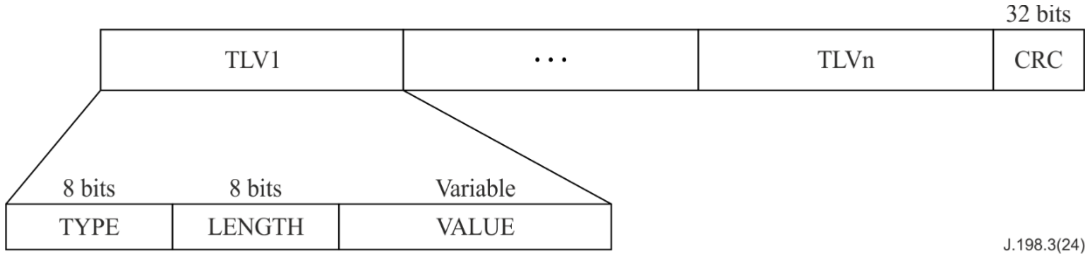

Figure 6 – EISF format

The payload region of a data frame is required to sequentially consist of N (N ≥ 0) subframe headers and the corresponding N subframes as shown in Figure 5. The value of the subframe header is the length of the corresponding subframe, in the unit of byte. If the EISF is contained in the payload region, the EMAC frames are required to be placed following the EISF.

The padding region is required to be filled with Bit '0' and its length is variable (≥ 0). It is used to guarantee that the length of the data frame equals to the fixed value L_{HIMAC}, so only when the sum of the length of header, payload, and tail region is less than L_{HIMAC}, the padding region is required in data frames.

The tail is CRC which is generated over all the regions before the tail. The generator polynomial is defined in equation (3).

$$g_3(x) = x^{16} + x^{12} + x^5 + 1 \quad (3)$$

7.5 Encapsulation of HiMAC3.0 frames into PHY layer frames

The encapsulation of HiMAC3.0 frames into PHY layer frames is required to conform to clause 7.5 of [ITU-T J.196.3].

7.6 Bit and octet transmission order

The bit and octet transmission order is required to conform to clause 7.6 of [ITU-T J.196.3].

8 Convergence sublayer

8.1 Function of the CS

The CS is responsible for receiving PDUs from the higher layer, mapping them to the CPS and executing the reverse operations. The PDUs from the higher layer mainly refer to EMAC frames. Other types of services can also be supported which are not defined in this Recommendation.

The functions of CS are required to include address learning/forwarding table generation, priority mapping, and framing/deframing.

8.2 Address learning/forwarding table generation

The address learning/forwarding table generation function is to establish a mapping relationship between the higher layer PDU addresses and HiNoC network nodes, so that HiNoC nodes can perform framing accordingly and forward the higher layer PDUs correctly. A HiNoC network node refers to the HB or an HM in the HiNoC system. Both the HB and the HM are identified by the system-unique Device ID, which is specified in clause 9.1.4.

HiNoC 3.0 specifies three data transmission methods: unicast, multicast and broadcast. Multicast and broadcast transmission are only applicable to the downlink. When the higher layer PDU is an EMAC frame, the behaviour of the address learning and forwarding table generation function depends on the data transmission method: For unicast transmission, this function establishes the mapping relationship between the Ethernet MAC address and the corresponding HiNoC node. For multicast transmission, this function establishes the mapping relationship between the Ethernet multicast MAC address and several corresponding HM nodes. For broadcast transmission, this function establishes the mapping relationship between the Ethernet MAC address and all HM nodes in the system.

The implementation method of the address learning/forwarding table generation function is not covered in this recommendation.

8.3 Priority mapping

The priority mapping function is required to conform to clause 8.4 of [ITU-T J.196.3].

8.4 Data frame framing/deframing

The data frame framing/deframing function is to realize encapsulation of EMAC frames as the higher layer PDUs to HiMAC3.0 data frames and decapsulation of HiMAC3.0 data frames to EMAC frames according to the mapping relationship established by the address learning/forwarding table generation function and the priority mapping function. The EMAC frame to be encapsulated is required to include all the fields from the Destination Address field to the tail Frame Check Sequence (FCS) field. The data frame framing function includes data frame packing and data frame segmentation. The data frame defaming function includes data frame unpacking and data frame reassembly.

The data frame packing function is to combine one or more EMAC frames/EMAC frame segments as well as the EISF (optional), and to encapsulate them into a HiMAC3.0 data frame for transmission. EMAC frames, EMAC frame segments, and the EISF constitute subframes in a HiMAC3.0 data frame. The structure of a packed HiMAC3.0 data frame is shown in Figure 7. Each HiMAC3.0 SDU in the figure corresponds to an EMAC frame/EMAC frame segment. If the data frame contains an EISF, the EISF is required to be placed in the first subframe position.

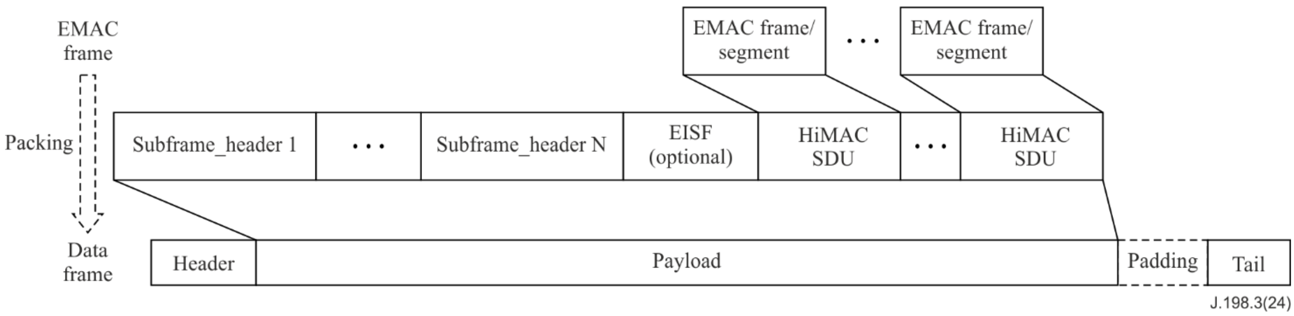

Figure 7 – Packing of EMAC frames in HiNoC3.0 system

The data frame segmentation function is to divide an EMAC frame into two or more parts, each of which is called an EMAC frame segment, and to encapsulate each EMAC frame segment into a different HiMAC3.0 data frame for transmission. Segmentation is performed only when a HiMAC3.0 data frame cannot carry a complete EMAC frame. In order to realize the segmentation function, two 2-bit fields are defined in the HiMAC3.0 data frame header as Segmentation flags to provide segmentation information of the first and the last subframe that carries EMAC frame/EMAC frame segment respectively. The definition of Segmentation flag is shown in Table 3.

If the HiMAC3.0 frame contains the EISF, the first subframe that carries EMAC frame/EMAC frame segment refers to the first subframe that follows the EISF.

Table 3 – Segmentation flag definition of the first/last subframe

Value	Function
0b00	This subframe is neither the first segment nor the last segment of an EMAC frame
0b01	This subframe is the last segment of an EMAC frame
0b10	This subframe is the first segment of an EMAC frame
0b11	This subframe is a complete EMAC frame

Data frame packing and segmentation functions can be used in combination, an example of which is shown in Figure 8.

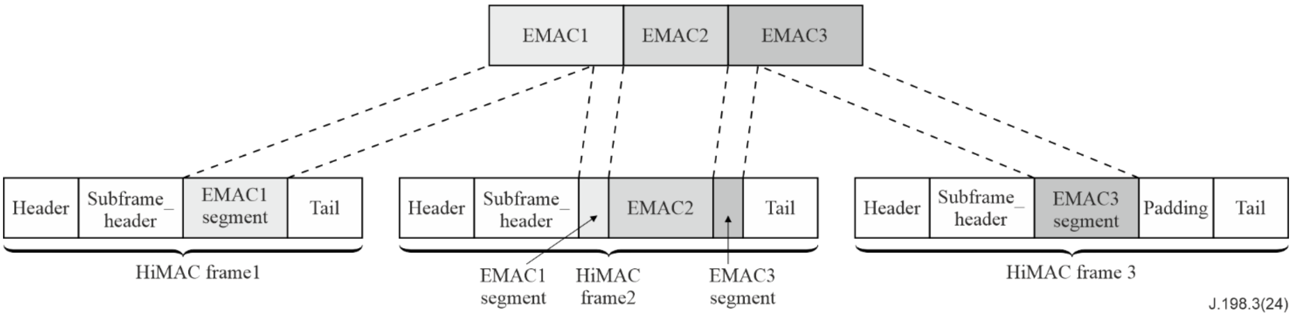

Figure 8 – An example of combination of packing and segmentation functions

The HiMAC3.0 data frame payload after framing includes N (N $\geq$ 0) combined subframe headers (SUBFRAME_HEADER) and N corresponding subframes from front to back in time. Each subframe header corresponds to a subsequent subframe respectively. All the subframe headers are combined and accommodated at the beginning of the payload field.

For unicast, multicast and broadcast transmission modes, all the HiMAC3.0 unicast, multicast and broadcast data frames adopt the same data frame structure specified in clause 7.4 and clause A.3, but the specific framing/deframing functions for each transmission mode are as follows.

a) Framing/deframing function for Unicast transmission mode

The data frame framing function for unicast transmission mode is to encapsulate one or more EMAC frames/EMAC frame segments and an EISF which are transmitted to the same HiNoC node with the same priority into a HiMAC3.0 data frame which is a unicast frame.

For one HiMAC3.0 unicast data frame, the NODE_ID field in the unicast frame header indicates the HM node that will receive or send this frame, and is required to be filled with the value of HM's Node ID that is the identifier of the HM node on the current channel to which this unicast frame is to be transmitted. For the HB node, the value of this field is the Node ID of the HM node that will receive the frame on the current channel. For the HM node, the value of this field is the Node ID of the HM node that will send the frame on the current channel.

The priority (Pri) field of the first extended frame header in the unicast frame header indicates the priority of the unicast frame.

The HiMAC3.0 unicast data frame is required to contain an EISF, so the value of the EISF_FLAG field in the unicast frame header is required to be 1. For the channel bonding mechanism specified in clause 9.1.4, the EISF is required to contain HiMAC3.0 unicast data frame sequence number information in the TLV/TLVs, so that the receiving node can reorder the unicast data frames from multiple channels to restore the EMAC frames in sequence. For the unicast data frames going to the same HiNoC node with the same priority, the sequence numbers of every two adjacent frames are required to be continuous (to wrap around to 0 when the frame sequence number reaches the maximum value). For the unicast data frames going to different HiNoC nodes or with different priorities, the frame sequence numbers are required to be generated independently. If there are any other information to be reported by the EISF, it can also be filled into the EISF in the form of TLV to be transmitted together with the frame sequence number information.

An example of a HiMAC3.0 unicast data frame is shown in Figure 9. In this example, the EISF includes a TLV indicating the frame sequence number and a TLV indicating the length of the eight priority queues in one HiNoC node.

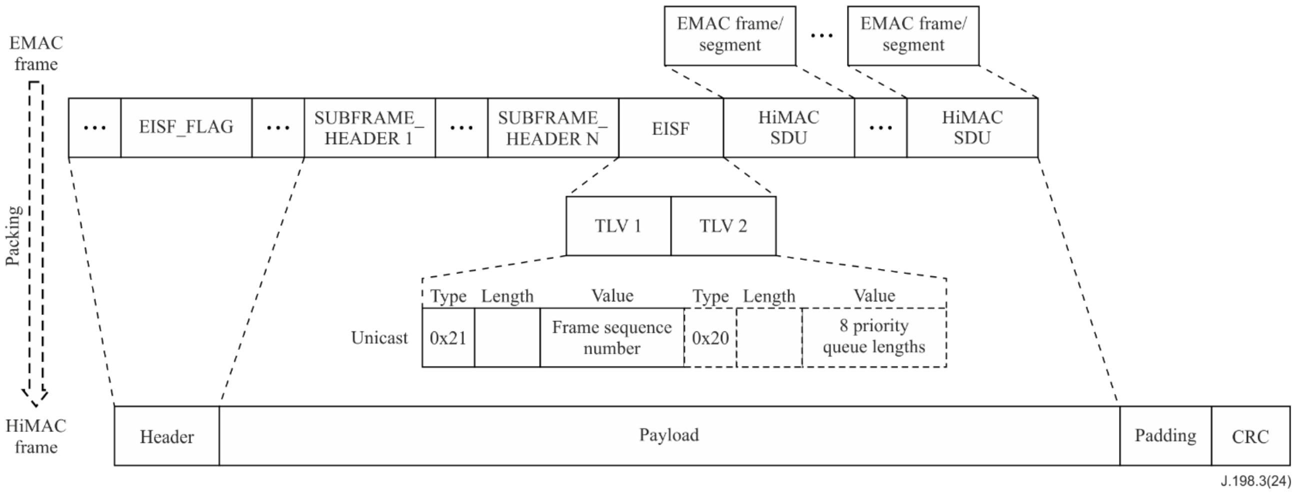

Figure 9 – Example of a HiMAC3.0 unicast data frame

b) Framing/deframing function for Multicast transmission mode

The data frame framing function for multicast transmission mode is to encapsulate one or more EMAC multicast frames/EMAC multicast frame segments and an EISF to be sent to the same multicast address with the same priority into a HiMAC3.0 data frame which is a multicast frame.

The value of the NODE_ID field in the multicast frame header is required to be a fixed value 0x49.

The priority (Pri) field of the first extended frame header in the multicast frame header indicates the priority of the multicast frame.

The HiMAC3.0 multicast data frame is required to contain an EISF, so the value of the EISF_FLAG field in the multicast frame header is required to be 1.

The multicast transmission mode includes simple mode and complex mode. The contents of EISF in the frame structure are different for the two modes.

In the simple mode of multicast transmission, the EISF in the multicast data frame is required to contain the multicast receiving member list information in the TLV/TLVs, which indicates the multicast members that will receive the multicast frames on the current channel. If there are any other information to be transmitted, it can also be filled into the EISF in the form of TLV.

An example of a HiMAC3.0 multicast data frame in simple mode is shown in Figure 10. In this example, the EISF includes a TLV indicating the multicast receiving member list information.

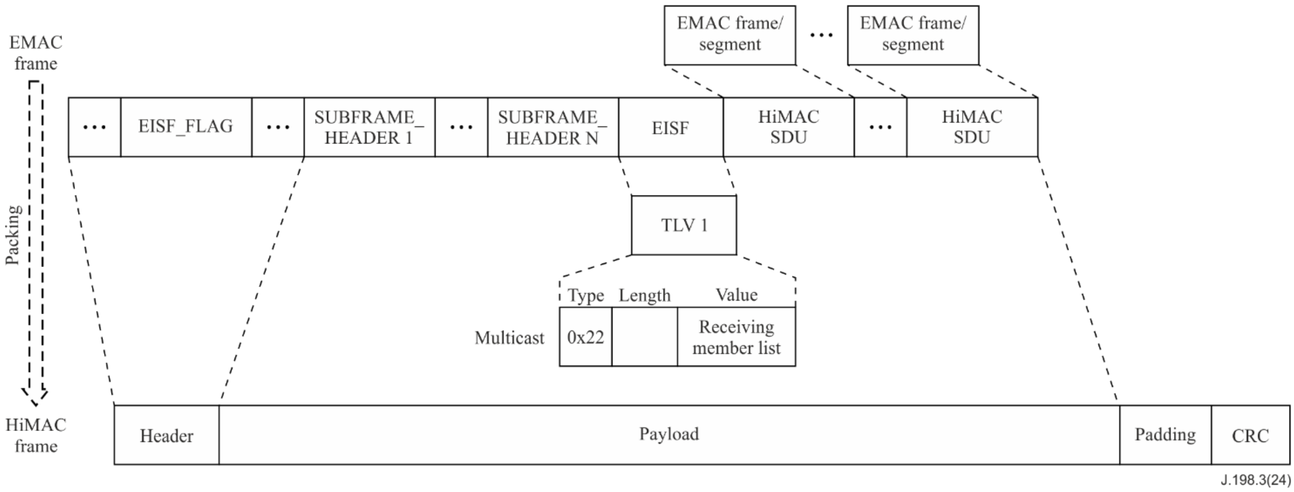

Figure 10 – Example of a HiMAC3.0 multicast data frame in simple mode

In the complex mode of multicast transmission, the EISF in the multicast data frame is required to contain the multicast data frame sequence number, the multicast receiving member list information and the multicast group ID, and each information of them is filled into a TLV. The TLV of multicast group ID uniquely identifies the multicast group to which the frame belongs. The value is the lower 24 bits of the multicast address in EMAC frames carried by it. For the TLV of multicast data frame sequence number, the frame sequence number of each HiMAC3.0 multicast data frame destined for the same multicast group should remain continuous (to wrap around to 0 when the frame sequence number reaches the maximum value). For HiMAC3.0 multicast data frames destined for different multicast groups, their frame sequence numbers are required to be generated independently. The TLV of multicast receiving member list indicates the receiving members of the multicast frames on this channel. If there are any other information to be transmitted, it can also be filled into the EISF in the form of TLV.

An example of a HiMAC3.0 multicast data frame in complex mode is shown in Figure 11. In this example, the EISF includes a TLV of multicast frame sequence number, a TLV of multicast receiving and a TLV of multicast group ID.

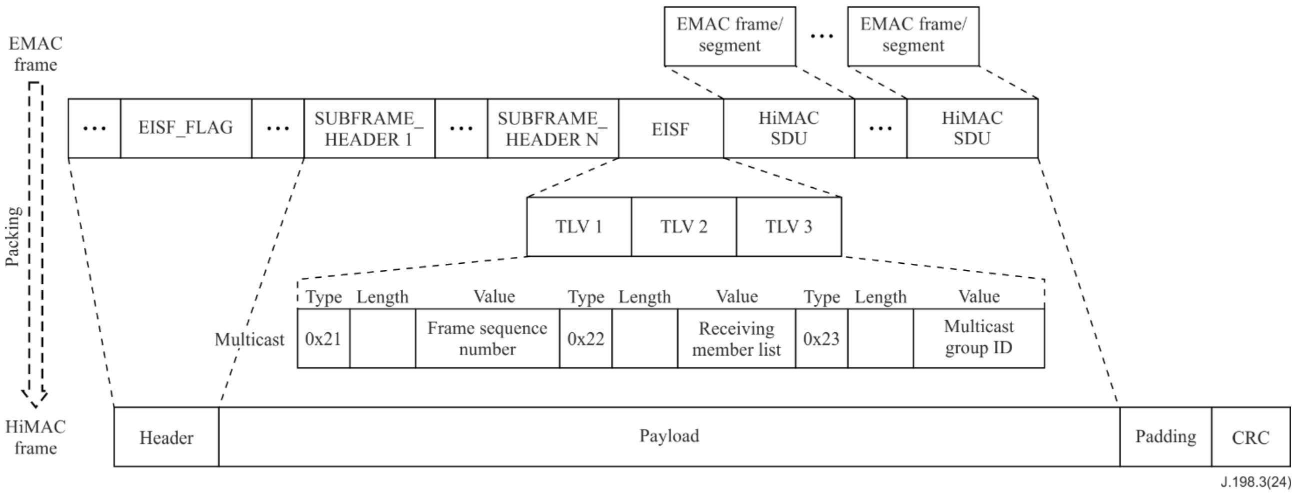

Figure 11 – Example of a HiMAC3.0 multicast data frame in complex mode

c) Framing/deframing function for broadcast transmission mode

The data frame framing function for broadcast transmission mode is to encapsulate one or more EMAC frames/EMAC frame segments and an optional EISF to be sent to all HM nodes with the same priority into a HiMAC3.0 data frame which is a broadcast frame.

The value of the NODE_ID field in the broadcast frame header is required to be a fixed value 0x4A.

The priority (Pri) field of the first extended frame header in the broadcast data frame header indicates the priority of the frame.

EISF is optional in the HiMAC3.0 broadcast data frame. If an EISF is included, the value of the EISF_FLAG field in the broadcast data frame header is required to be 1.

The transmitted HiMAC3.0 data frames which have already been framed will be defamed (unpacked and reassembled) when they come to the CS of the destination node, and the EMAC frames and EISF will be recovered.

9 Common part sublayer

9.1 Media access control and channel allocation

9.1.1 Overview

The main mechanisms of HiNoC 3.0 medium access control and channel allocation are as follows:

a) The spectrum for HiNoC 3.0 is divided into N channels in the frequency domain, where $1 \leq N \leq 8$, and one channel is defined as a continuous 128 MHz spectrum. HB and HM can operate on multiple channels simultaneously.

b) Each HM is required to be admitted to a certain channel before accessing it.

c) Once the HM is admitted, its access to each channel is entirely under the centralized control of the HB.

d) In the time domain, HiNoC 3.0 uses Pd cycle as the time period and the time within each Pd cycle is divided into several MAP cycles. On each channel, the HiNoC 3.0 system performs access control and channel allocation based on MAP cycles.

e) Each HM is required to adopt the report-authorization mechanism to access its channels. Each HM is required to report its own uplink bandwidth requirement to the HB in its R frame transmission slot. Based on the information provided by each HM on all the channels and HB's local downlink queues information, the HB should generate the channel allocation scheme for each channel, and announce the channel allocation scheme for the next MAP cycle to each HM through the MAP frames on each channel. HB and each HM transmit data according to the channel allocation scheme in the MAP frame.

f) The channel bonding mechanism is required to be supported. HB and each HM can communicate using multiple channels to increase the data transmission rate.

g) The profile group transmission mechanism is required to be supported. After allocating a profile group transmission opportunity, HB can use it to transmit downlink data frames to one or more HMs within that profile group, thereby reducing the downlink data transmission latency.

h) During the process of channel allocation, the quality of service (QoS) guarantee based on priority is required to be supported.

i) Ranging and delay compensation are required to be supported.

j) HiNoC 3.0 is backward compatible with HiNoC 2.0. HiNoC 3.0-compliant HB is required to support access from HiNoC 2.0 HMs.

This section specifies the medium access control and channel allocation mechanism of the HiNoC 3.0 MAC layer protocol, mainly including the Pd cycle and MAP cycle structure, MAP cycle allocation, channel bonding and profile group transmission mechanism.

The constants referred to in clause 9.1, such as T_{P_IFG} are defined in Table B.2.

9.1.2 Pd cycle and MAP cycle

HiNoC 3.0 HB and HM can work simultaneously on multiple channels. On each channel of HiNoC 3.0 system, the Pd cycle is used as the time period and the time within each Pd cycle is divided into MAP cycles. In HiNoC 3.0 system MAP cycle is used for channel allocation.

a) Pd cycle

On each channel of HiNoC 3.0 system, the Pd frames are required to be transmitted periodically at the PHY layer and the time interval between the start time of two adjacent Pd frames is called a Pd cycle which is equal to 65536 μs. The start time of each Pd cycle refers to the time that HB starts to send the Pd frame at the PHY layer. The Pd cycles on each channel are required to be strictly aligned in transmission time and the network synchronization between different channels is required to conform to clause 9.5. It is required to take the start time of a Pd frame as the HiNoC 3.0 network starting time in each Pd cycle.

The Pd cycles on each channel are shown in Figure 12. Each Pd cycle is required to contain a fixed Pd frame time slot and a fixed uplink probe (Pu) frame group time slot. The Pu frame group time slot is required to consist of nine continuously accommodated Pu frame time slots and their inter-frame gaps (IFGs) wherein the fifth Pu frame time slot is in the middle of the Pd cycle and the time interval between the start time of the fifth Pu frame and an adjacent Pd frame is 32768 μs. An IFG is required to be reserved following each Pd/Pu frame, the value of which is provided by T_{P_IFG}. Each Pd or Pu frame time slot is used to transmit one Pd or Pu frame. The MAC layer downlink/uplink signalling frames are carried by Pd/Pu frames.

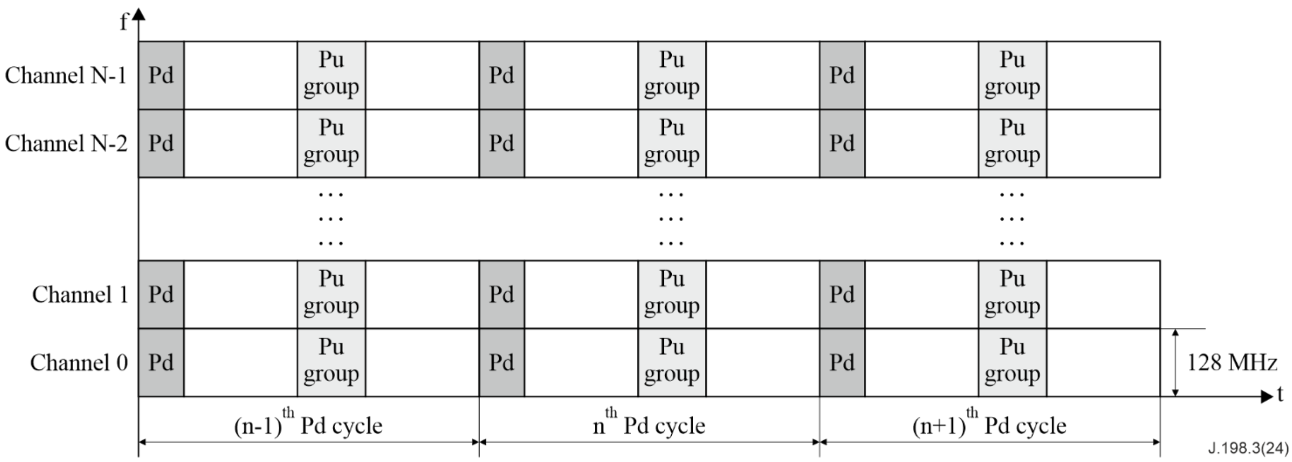

Figure 12 – Pd cycles on each channel

b) MAP cycle

On each channel of HiNoC 3.0 system, the time of each Pd cycle except for the fixed Pd frame time slot and Pu frame group time slot is divided into continuous and non-overlapping MAP cycles. The relationship between MAP cycles and Pd cycles on one channel is shown in Figure 13. The start time and end time of each MAP cycle refer to offset time relative to the network starting time. A MAP cycle is prohibited from being split by a Pd or Pu frame. A MAP cycle includes N_{MAP_SYMBOL} OFDM symbols and the value of N_{MAP_SYMBOL} can be configured and is required to be noticed by Pd frames on each channel.

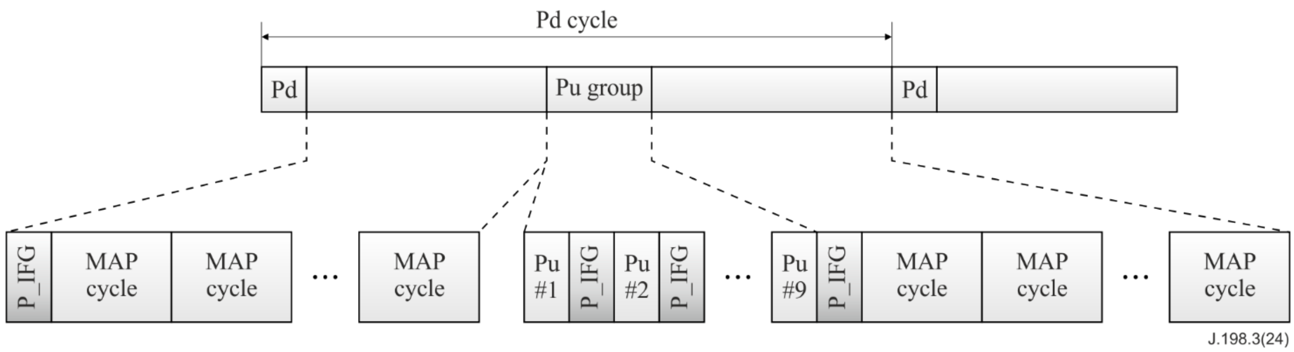

Figure 13 – Relationship between MAP cycles and Pd cycles on a channel

The MAP cycles on each channel are required to be strictly aligned in transmission time. Each MAP cycle on each channel has a MAP frame and the MAP frames within the same MAP cycle on different channels are independent. On any one channel, the allocation scheme of each MAP cycle is required to be scheduled by the MAP frame in the previous MAP cycle, that is, the allocation scheme of the channel in the n^{th} MAP cycle is required to be scheduled by the MAP frame in the $(n-1)^{th}$ MAP cycle, as shown in Figure 14.

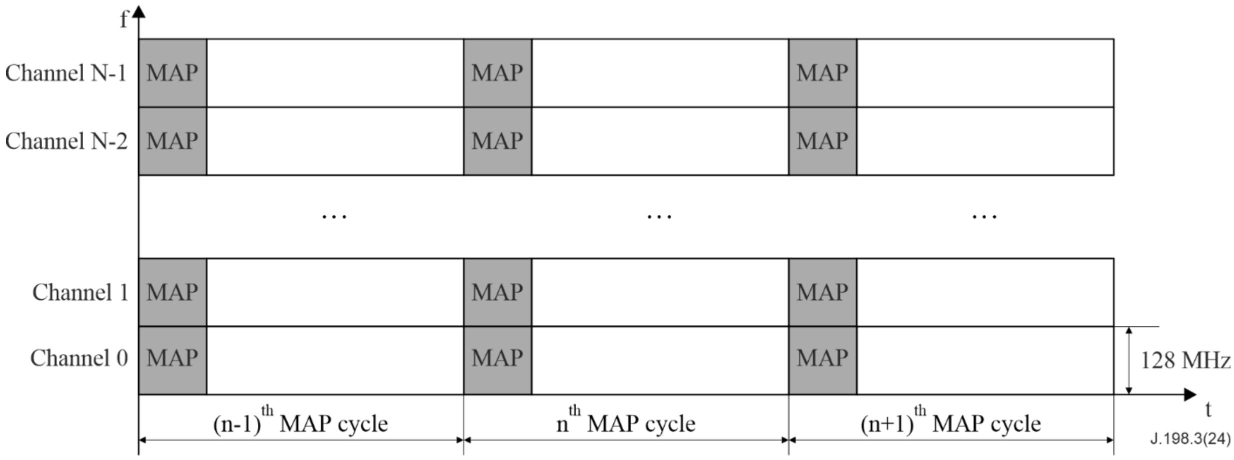

Figure 14 – MAP cycles on each channel

Within each MAP cycle on a certain channel, HB uses one or multiple consecutive OFDM symbols to carry MAP frames, where the length and start position of MAP frame occupying OFDM symbols are announced by the downlink signalling frames on the channel. As a default setting, the first two OFDM symbols in each MAP cycle are used to carry MAP frame. Within each MAP cycle on a certain channel, HMs on the channel share one or multiple consecutive OFDM symbols to carry R frames respectively, where the length and start position of R frame occupying OFDM symbols are announced by the downlink signalling frames on the channel. As a default setting, the last OFDM symbol in each MAP cycle is used to carry R frames.

Each MAP cycle is divided into a downlink period, an uplink period and two reverse intervals between two adjacent periods. The downlink period is used to transmit downlink control frames and data frames, and the uplink period is used to transmit uplink control frames and data frames. Within each MAP cycle, the downlink period precedes the uplink period. The length of downlink period and uplink period are variable. It is prohibited that one OFDM symbol is used to transmit downlink frames and uplink frames simultaneously. The reverse interval between two adjacent periods which is also the inter-frame gap between two adjacent downlink and uplink symbols or between two adjacent uplink and downlink symbols is defined as R_IFG with the value of T_{R_IFG}. The MAP cycle structure is shown in Figure 15.

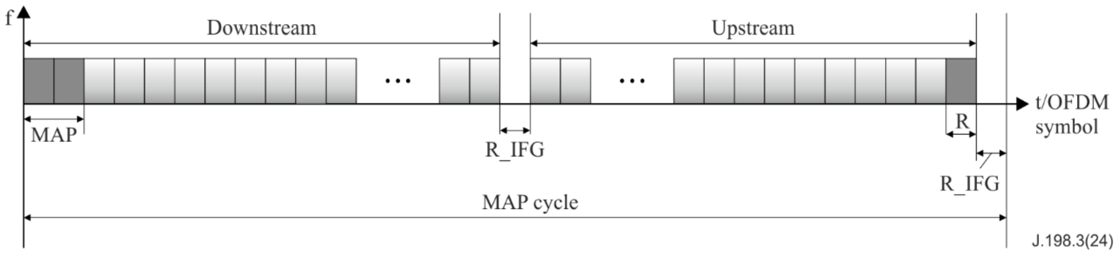

Figure 15 – MAP cycle structure

9.1.3 Allocation of MAP cycle

HiNoC 3.0 specifies the report-authorization mechanism to allocate channel resources of each MAP cycle to HB and HMs. The basic process is as follows: Each HM is required to utilize any one R frame slot allocated to it on its working channels to send an R frame to report bandwidth requirements for each of its priority queues. Furthermore, each HM can also use the EISF of its uplink data frame to report detailed queue information. Based on the information provided by each HM and local downlink queues information, the HB should separately generate a channel allocation scheme of a MAP cycle for each channel. The HB should send MAP frames separately on each channel to announce the channel allocation scheme for the corresponding channel, and the MAP frame in the current MAP cycle indicates the channel allocation scheme of the next MAP cycle. The HB and HMs are required to transmit data according to the scheme indicated in the MAP frames.

Each HM can send R frames to HB on any one of its working channels and the R frame is carried by the Ru frame at PHY layer. Each R frame has a length of L_{R_FRAME} bits, with an 8-bit Q_FLAG field designated to indicate the information of eight queues respectively. The configuration method for the Q_FLAG field is not covered in this Recommendation. Additionally, each HM can report its detailed queues information using the TLV field in the EISF carried by its uplink data frame.

Based on the information provided by each HM and the local downlink queues information, HB should send independent MAP frames on each channel. The length of a MAP frame is related to the number of OFDM symbols it occupies, and it is configured through the downlink signalling frame. A MAP frame consists of MAP cycle ID (MAP_ID), the number of allocation units (AU_NUM), MAP frame length (MAP_LENGTH), SSC pattern (SSC_MAP), padding (optional), HM online status (HM_STATE), reserved (RSVD), and CRC fields. The definition of these fields is as follows:

– MAP_ID (8 bits): ID number of the next MAP cycle scheduled by this MAP frame within its Pd cycle (numbering from 1), wherein, the ID number denotes which MAP cycle it is within its Pd cycle. Each HM can determine the starting time of the MAP cycle scheduled by this MAP frame through the MAP_ID.
– AU_NUM (8 bits): The number of allocation units (AUs) in the SSC_MAP field of the current MAP frame.
– MAP_LENGTH (16 bits): The length of the MAP frame, measured in bytes.
– SSC_MAP (variable length): This field sequentially indicates the allocation of each SSC in the next MAP cycle on the current channel, excluding the time slots of the MAP frame and R frame. The number of subcarriers contained in an SSC is configured by the downlink signalling frame, with a minimum of 16 and a maximum of 2048. The detailed definition of SSC_MAP can be found in the content below within this section.
– Padding (variable length): A padding field. Its length is related to the MAP frame length to ensure that the sum of the lengths of all fields in the current MAP frame reaches a pre-configured MAP frame length.
– HM_STATE (64 bits): The online status of the HM admitted on the current channel.
– RSVD (64 bits): Reserved.
– CRC (32 bits): Cyclic redundancy check.

The detailed definition of SSC_MAP field in a MAP frame is as follows:

The SSC_MAP consists of AU_NUM allocation units (AUs). The MAP frame uses AUs for channel allocation, and each AU indicates the purpose and the length or position of one or more consecutive SSCs in the MAP cycle. Consecutive AUs in the SSC_MAP correspond to continuous SSCs in the MAP cycle. Each AU consists of an AU type (AU_TYPE) field and an AU function (FUNCTION) field. The AU_TYPE represents the function of the AU field, and the FUNCTION indicates the value corresponding to the AU function. The definition and functional description of the AU fields are shown in Table 4.

Table 4 – Definition and Function Description of AU Field

Value of AU_TYPE	Usage of AU_TYPE	Usage of FUNCTION
0x00	This AU indicates idle SSCs.	The number of idle SSCs
0x01-0x40	This AU allocates SSCs to an HM with Node ID ranging from 0x01 to 0x40 on the current channel.	The number of SSCs allocated
0x41-0x48	This AU allocates SSCs to a profile group with Profile Group Identifier (PGID) ranging from 0x41 to 0x48 on the current channel.	The number of SSCs allocated
0x49	This AU allocates SSCs for multicast frames.	The number of SSCs allocated
0x4A	This AU allocates SSCS for broadcast frames.	The number of SSCs allocated
0x7F	This AU indicates the position of reverse interval between downlink period and uplink period.	The position of the reverse interval

The detailed functions of AUs in the SSC_MAP are defined as follows:

a) **AU_TYPE value is 0x00**: This AU allocates idle SSCs, which means the SSCs indicated by this AU are not allocated to any node. The FUNCTION field of this AU represents the number of idle SSCs.

b) **AU_TYPE value is 0x01-0x40**: This AU allocates SSC resources to an HM with Node ID of 0x01 ~ 0x40 on the current channel for receiving/transmitting downlink/uplink unicast data frames. The FUNCTION field of this AU represents the number of SSCs allocated to this HM.

c) **AU_TYPE value is 0x41-0x48**: This AU allocates SSC resources to a profile group with Profile Group ID (PGID) of 0x41 ~ 0x48 and the SSCs will be used for transmitting downlink unicast data frames to any HMs of this profile group. The FUNCTION field of this AU represents the number of SSCs allocated to this profile group.

d) **AU_TYPE value is 0x49**: This AU allocates SSC resources to HB for transmitting downlink multicast data frames. The FUNCTION field of this AU indicates the number of SSCs allocated for transmitting multicast data frames.

e) **AU_TYPE value is 0x4A**: This AU allocates SSC resources to HB for transmitting downlink broadcast data frames. The FUNCTION field of this AU indicates the number of SSCs allocated for broadcasting data frames.

f) **AU_TYPE value is 0x7F**: This AU is used to indicate the position of the downlink/uplink reverse interval. The FUNCTION field of this AU indicates which OFDM symbol is the reverse interval within this MAP cycle.

The number of sub-carriers occupied by an SSC in an OFDM symbol is configured by the downlink signalling frame, and the length of an SSC determines the granularity of bandwidth allocation.

HiNoC 3.0 specifies time division multiple access (TDMA) mode and orthogonal frequency division multiple access (OFDMA) mode for data frame transmission, with TDMA mode being mandatory and OFMDA mode being optionally supported. The granularity and result of bandwidth allocation differ between the two modes. For TDMA mode, channel allocation is required to be conducted based on OFDM symbols, so the SSC is required to be configured as 2048 successive sub-carriers, meaning that one SSC is equivalent to one OFDM symbol. In this mode, different HMs transmit or receive data using different OFDM symbols. For OFDMA mode, the number of sub-carriers occupied by one SSC can be configured to different values, with a minimum of 16. In this mode, multiple HMs can share the same OFDM symbol to transmit data.

Examples of channel allocation of a MAP cycle using MAP frame in TDMA and OFDMA mode are illustrated in Figure 16 and Figure 17 respectively.

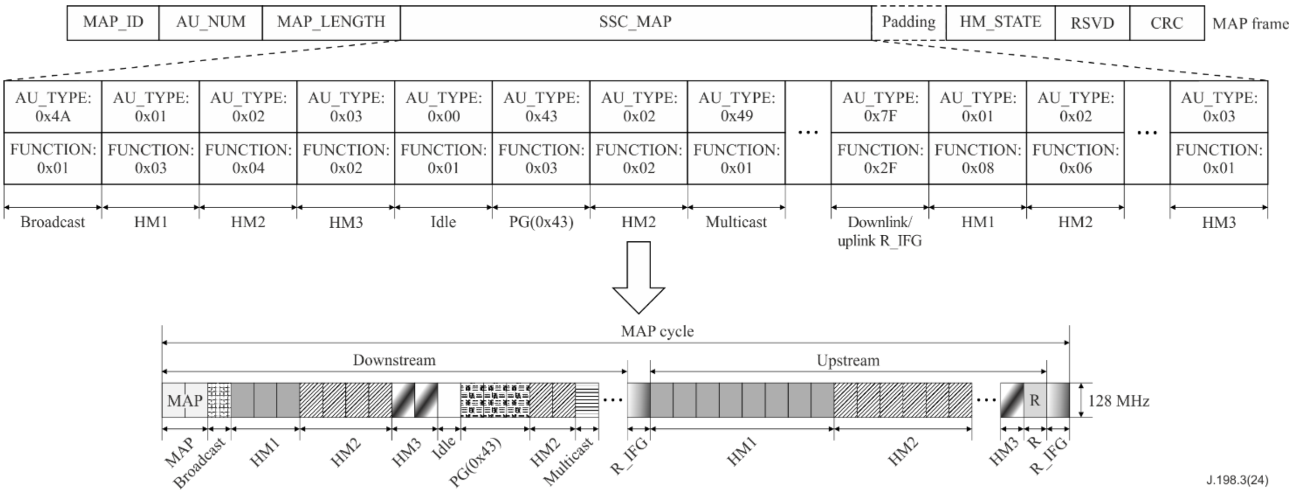

Figure 16 – Example of correspondence between SSC_MAP and channel allocation scheme of a MAP cycle in TDMA mode

Figure 16 illustrates an example of SSC_MAP encoding in the MAP frame on one channel and its corresponding channel allocation of the MAP cycle in TDMA mode. Each SSC in the SSC_MAP corresponds to one OFDM symbol. In this example, the first two OFDM symbols of the MAP cycle is used to transmit the MAP frame, so in the SSC_MAP, the channel is allocated from the third OFDM symbol of the MAP cycle and each AU sequentially indicates the allocation scheme for each SSC (OFDM symbol) excluding the SSCs used for MAP frame, R frame and the last reverse interval within the MAP cycle.

As shown in the figure, first it is the downlink transmission period:

– The first OFDM symbol after the MAP frame (which is the 3rd symbols of the MAP cycle) is used to transmit broadcast data frames.

– The next three symbols (from the 4th to the 6th symbols of the MAP cycle) are for transmitting unicast data frames to HM1.

– The following four symbols (from the 7th to the 10th symbols of the MAP cycle) are for downlink unicast data frames to HM2.

– The next two symbols (from the 11th to the 12th symbols of the MAP cycle) are for downlink unicast data frames to HM3.

– The following OFDM symbol (the 13th symbol) is idle.

– The next three symbols (from the 14th to the 16th symbols) are allocated to the profile group with PGID of 0x43, used for transmitting unicast data frames to one or more HMs belonging to this group.

– The following two symbols (the 17th and the 18th symbols) are for transmitting unicast data frames to HM2 again.

– The next symbol (the 19th symbol) is for transmitting downlink multicast data frames, and so on.

Following the downlink period, there is a reverse interval with a length of one OFDM symbol, located at the 47th OFDM symbol of this MAP cycle.

Then comes the uplink transmission period:

– The first eight symbols (from the 1st to the 8th symbol of the uplink period) are allocated to HM1 for transmitting uplink data frames.

– The next six symbols (from the 9th to the 14th symbols of the uplink period) are for HM2's uplink data frame transmission.

– The last symbol before the R frame is allocated to HM3 for transmitting uplink data frames, and so on.

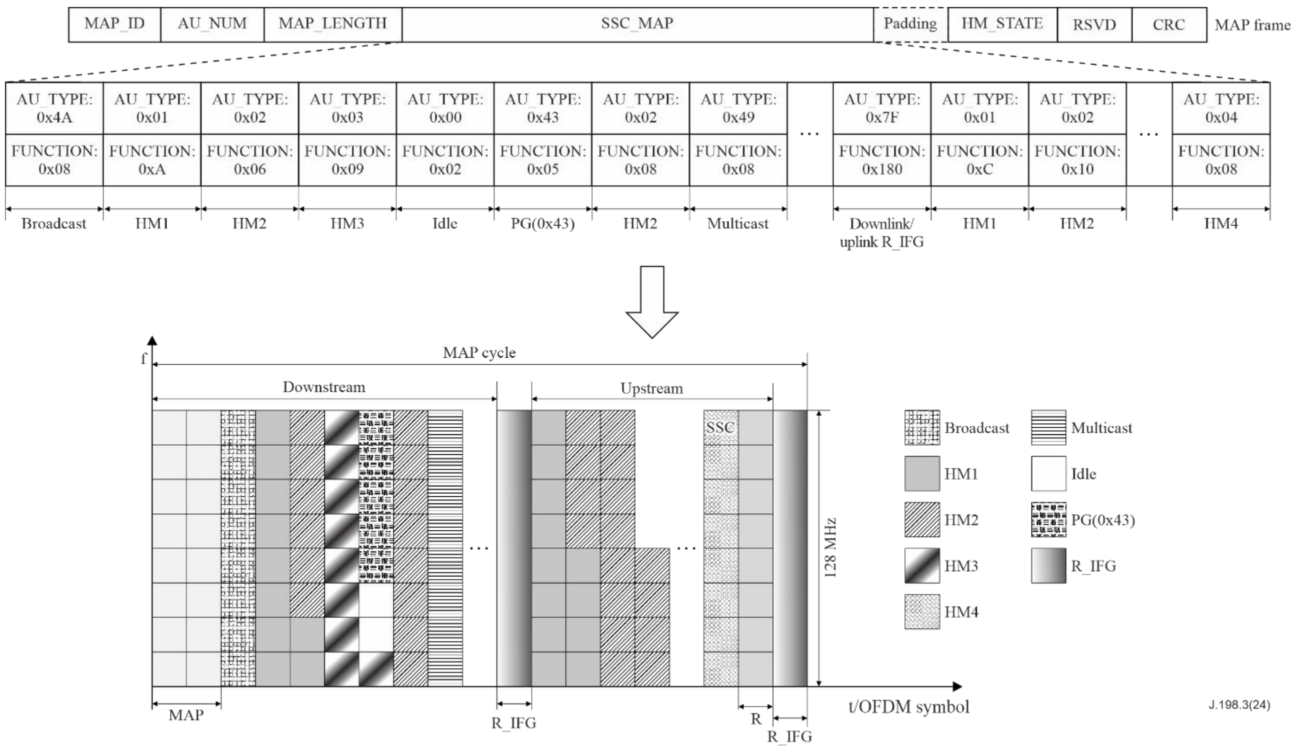

Figure 17 – Example of correspondence between SSC_MAP and channel allocation scheme of a MAP cycle in OFDMA mode

Figure 17 illustrates an example of SSC_MAP encoding in the MAP frame on one channel and its corresponding channel allocation of the MAP cycle in OFDMA mode. In the SSC_MAP, each SSC consists of 256 sub-carriers, which means that each OFDM symbol includes 8 SSCs. Similarly in this example, in the SSC_MAP, the channel is allocated from the 3rd OFDM symbol of the MAP cycle, and each AU sequentially indicates the allocation scheme for each SSC excluding the SSCs used for MAP frame, R frame and the last reverse interval within the MAP cycle. Distinct from the illustration in Figure 16, in the OFDMA mode, the SSCs of the same OFDM symbol can be allocated to multiple HMs.

As shown in the figure, first, it is the downlink transmission period:

– The 8 SSCs after the MAP frame (corresponding to the 3rd OFDM symbol of the MAP cycle) are used for transmitting broadcast data frames.

– The next 10 SSCs (corresponding to the 4th symbol and the first two low-frequency SSCs of the 5th symbol) are allocated for downlink unicast data frame transmission to HM1.
– The following 6 SSCs (corresponding to the remaining SSCs of the 5th symbol) are for downlink unicast data frame transmission to HM2.
– The next 9 SSCs (corresponding to the 6th symbol and the first low-frequency SSC of the 7th symbol) are for downlink data frame transmission to HM3.
– The following 2 SSCs (corresponding to the 2nd and 3rd SSCs of the 7th symbol) are idle.
– The next 5 SSCs (corresponding to the remaining 5 SSCs of the 7th symbol) are allocated to the profile group with PGID of 0x43 for transmitting downlink unicast data frames to one or more HMs belonging to the profile group.
– The next 8 SSCs (corresponding to the 8th symbol) are for downlink data frame transmission to HM2 again.
– The next 8 SSCs (corresponding to the 9th symbol) are for transmitting multicast data frames, and so on.

Following the downlink transmission period, there is a reverse interval with a length of one OFDM symbol, located at the OFDM symbol that contains the 384th SSC of this MAP cycle (corresponding to the 48th symbol of the MAP cycle).

Then comes the uplink transmission period:

– The first 12 SSCs (corresponding to the first uplink symbol and the first 4 low-frequency SSCs of the 2nd uplink symbol) are allocated to HM1 for uplink unicast data frame transmission.
– The following 16 SSCs (from the last 4 high-frequency SSCs of the 2nd uplink symbol to the first 4 low-frequency SSCs of the 4th uplink symbol) are allocated to HM2 for uplink data frame transmission.
– The final 8 SSCs before the R frame (equivalent to one symbol) are allocated to HM4 for uplink data frame transmission, and so on.

Each HM is required to get the channel allocation scheme of the next MAP cycle from the received MAP frames on each channel it is admitted. When the MAP cycle arrives, HB and each HM are required to transmit data according to the channel allocation scheme in the MAP frame on each channel.

When a new HM's node admission is complete, the HB is required to set the corresponding bit to 1 in the HM_STATE field. If the HB does not receive the R frames from one HM in the continuous N_{NO_R} MAP cycles on any one of the channels it is admitted, the HB is required to delete the HM from the network and not to allocate any channel resource to it. If an HM does not receive its HM_STATE indication in the MAP frame transmitted by the HB for the time duration of T_{KA} on a certain channel, it is required to consider itself as being deleted from the channel by the HB. Then, the HM can only rejoin the channel through the node admission process.

9.1.4 Channel bonding

In the frequency domain, HiNoC 3.0 divides the spectrum into 128 MHz segments, and each continuous 128 MHz segment is defined as a channel. Both HiNoC 3.0-compliant HB and HM are required to support channel bonding and can work on multiple channels at the same time. Channel bonding is defined as a mechanism used by HB and HMs to transmit upper-layer service flows (i.e., EMAC frames) over multiple channels to increase the overall transmission rate of the HiNoC system.

HiNoC 3.0 defines two types of identifiers for each HM. One type is the system-unique HM identifier known as Device ID, and the other type is the unique identifier associated with each channel it operates on, known as Node ID. For instance, if an HM operates on n bonded channels, there will be n Node IDs, each corresponding to a single channel, and one Device ID for this HM. There is a correspondence between the n Node IDs and the Device ID since they belong to the same HM. Each HM's Device ID and Node IDs on each channel are assigned by HB during the node admission process, as detailed in clause 9.2. Similarly for HB, the Device ID and Node IDs on each channel are also defined, with the values all set to 0 by default.

HiNoC 3.0 is required to support a maximum of eight channels for bonding. Figure 18 shows an example of channel bonding. In this scenario, the HB works on channel 0 (CH0) to channel 7 (CH7), a total of 8 channels, and each HM node works on multiple channels. For instance, HM1 works on CH4, CH5 and CH7; HM2 works on CH4 and CH6; HM3 works on CH0, CH1, CH2 and CH3, and so on. This enables HB and each HM node to utilize the multiple channels they have joined to transmit upper-layer service flows concurrently, resulting in higher transmission rate compared to using a single channel.

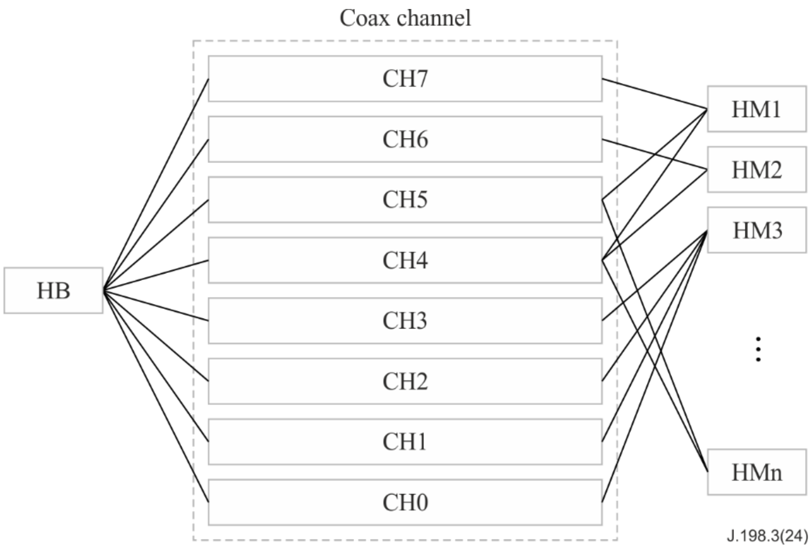

Figure 18 – Example of channel bonding

For the three data transmission modes of unicast, multicast, and broadcast, the operations of channel bonding are different, as specified below.

a) Channel bonding for unicast transmission

By utilizing channel bonding for transmitting unicast service flows, HiMAC3.0 unicast data frames that are destined for the same HiNoC node (with the same Device ID) and have the same priority can be transmitted over one or multiple channels.

The framing method of unicast data frame is required to conform to clause 8.4. To support channel bonding, each unicast data frame is required to inherently contain an EISF including its frame sequence number information in the frame structure, thereby allowing the receiving nodes to reconstruct the unicast service flow sequentially from multiple channels. For HiMAC3.0 unicast data frames that are transmitted to the same HiNoC node and have the same priority, their frame sequence numbers are required to remain continuous (looping back to 0 when reaching the maximum value). For HiMAC3.0 unicast data frames sent to different nodes or with different priorities, the frame sequence numbers are independent of each other.

The sending node should send HiMAC3.0 unicast data frames within the corresponding transmission window according to the channel allocation schemes of the MAP cycle on each working channel. After receiving the HiMAC3.0 unicast data frames destined for the receiving node from various working channels, it should reconstruct the carried unicast service flow according to the priority and frame sequence number information.

Figure 19 shows an example of channel bonding for unicast data transmission. Both HM1 and HM2 operate simultaneously on channel 1 (CH1) and channel 2 (CH2), and HB uses these two channels to transmit downlink unicast data frames to them. For instance, two HiMAC3.0 unicast data frames destined for HM1 and having the same priority have frame sequence numbers i and i+1. These two unicast data frames are transmitted separately on CH1 and CH2 by HB. HM1 receives the data frames from both channels and reconstructs the upper-layer EMAC frames based on their frame sequence numbers. Similarly, HM2 receives unicast data frames with frame sequence numbers j and j+1 on both CH1 and CH2 and reconstructs them accordingly.

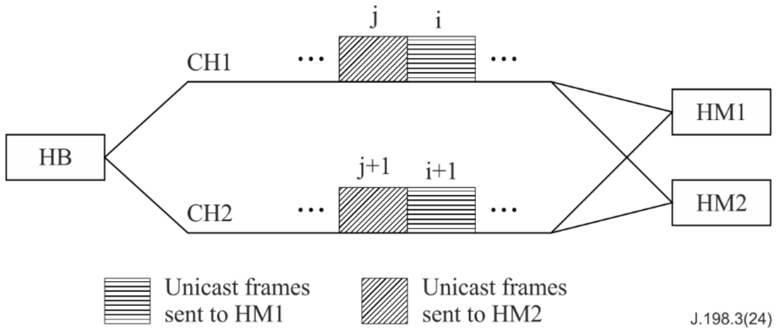

Figure 19 – Example of channel bonding for unicast transmission

b) Channel bonding for multicast transmission

HiMAC3.0 multicast data frames with the same multicast EMAC address and the same priority belong to the same multicast group. Using channel bonding to transmit multicast services refers to scheduling HiMAC3.0 multicast data frames destined for the same multicast group to be transmitted over a single or multiple channels. It is required to use the broadcast modulation profile for each multicast data frame to be transmitted on each channel to ensure that the multicast frames can be correctly received by each receiving member.

Two modes are specified for multicast transmission using channel bonding: simple mode and complex mode.

In the simple mode of channel bonding for multicast transmission, HiMAC3.0 multicast data frames destined for the same receiving members of the same multicast group can only be scheduled for transmission on the same channel. The simple mode emphasizes that the HiMAC3.0 multicast data frames destined for the same receiving members of the same multicast group should be transmitted sequentially on the same channel. The purpose is to allow the multicast receiving members to sequentially receive all the multicast data frames intended for their multicast group from a single channel. Each receiving member of a multicast group may operate on different working channels. In such case, multicast data frames destined for the same multicast group will be duplicated and transmitted over multiple channels. The receiving members on different channels vary to ensure that multicast frames are received by all members of that multicast group without redundancy.

In the simple mode, the framing method of multicast data frames is required to conform to clause 8.4. The HiMAC3.0 multicast data frame is required to inherently contain the EISF in the frame structure and the EISF should include the list of multicast frame receiving members on the channel to which the frame is intended to be transmitted.

Figure 20 shows an example of channel bonding for multicast transmission in simple mode. Nodes HM1 and HM2 operate on channel 1 (CH1) and channel 2 (CH2) respectively, while HM3 and HM4 operate concurrently on CH1 and CH2. HM1, HM2, and HM3 have joined multicast group 1, while HM2, HM3, and HM4 have joined multicast group 2.

In the designated multicast frame transmission slot, HB sends multicast frames for multicast group 1 on CH1 and CH2 respectively. The receiving members of multicast frames transmitted on CH1 are

HM1 and HM3, while on CH2 the receiving member is HM2. Except for the differing receiving members, the multicast frames for multicast group 1 transmitted on both channels are identical. HB sends multicast data frames for multicast group 2 to HM2, HM3 and HM4 on CH2. Each HM node receives all the multicast frames for the same multicast group from a designated channel and reconstructs the corresponding multicast service flow. Therefore, HM1 and HM3 receive the multicast service flow for multicast group 1 from CH1, and HM2 receives the multicast service flow for multicast group 1 from CH2. HM2, HM3, and HM4 all receive the multicast service flow for multicast group 2 from CH2.

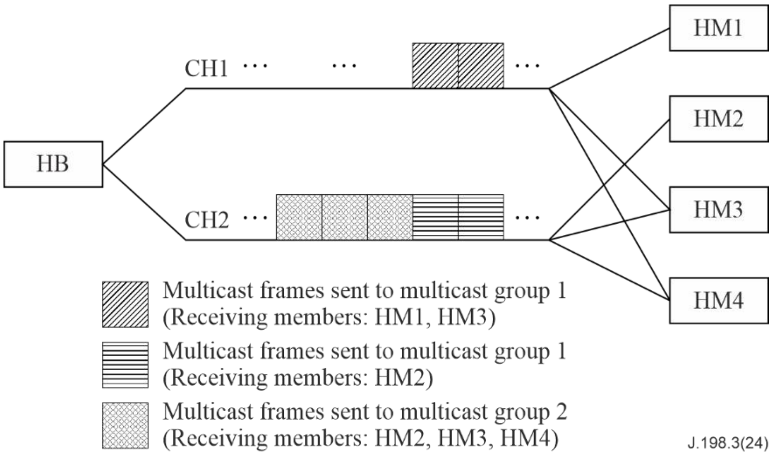

Figure 20 – Example of channel bonding for multicast transmission in simple mode

In the complex mode of channel bonding for multicast transmission, HiMAC3.0 multicast data frames destined for the same receiving members of the same multicast group can be scheduled for transmission over two or more channels. In this mode, the HiMAC3.0 multicast data frames destined for a certain receiving member of a multicast group can be partially transmitted on one channel and partially transmitted on the other channel. In this situation, a multicast receiving node should use multiple channels to receive all the multicast data frames destined for the multicast group to which it belongs.

In the complex mode, the framing method of multicast data frames is required to conform to clause 8.4. The HiMAC3.0 multicast data frame is required to inherently contain the EISF in the frame structure and the EISF should include the multicast group ID, the multicast data frame sequence number, and the list of multicast receiving members on the channel to which the frame is intended to be transmitted.

Figure 21 shows an example of channel bonding for multicast transmission in complex mode. Nodes HM1 to HM4 work on channel 1 (CH1) and channel 2 (CH2). HM1 and HM2 have joined multicast group 1, and HM2, HM3 and HM4 have joined multicast group 2. In the designated multicast frame transmission slot, HB sends multicast data frames of multicast group 1 with frame sequence number i to i+3 to HM1 and HM2, and sends multicast data frames of multicast group 2 with frame sequence number j to j+1 to HM2, HM3 and HM4 on CH1 and CH2. Each multicast frame contains the multicast group ID, the multicast frame sequence number, and the receiving member list. HM1 and HM2 respectively receive the multicast frames of multicast group 1 from the two channels and combine them in sequence to reconstruct the multicast service flow. Similarly, HM2, HM3 and HM4 receive the multicast frames of multicast group 2 from the two channels and combine them in sequence to reconstruct the multicast service flow.

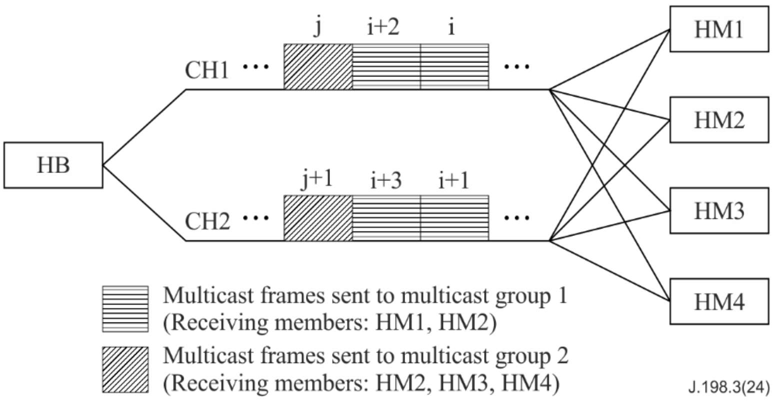

Figure 21 – Example of channel bonding for multicast transmission in complex mode

HB is required to send HiMAC3.0 multicast data frames in the corresponding transmission window according to channel allocation scheme of the MAP cycle on each working channel. Each HM node receives multicast frames in multicast frame transmission window on their respective channels, and checks the list of receiving members in the multicast frames. If there's a match, the HM then reconstructs the multicast service flow. In complex mode, HM can receive HiMAC3.0 multicast data frames of its multicast group from multiple channels and reconstruct each multicast EMAC frame according to the multicast frame sequence number.

HiNoC 3.0 is required to support simple mode, and can optionally support complex mode. If the system supports both modes, only one mode can be selected as the system working mode. The multicast transmission capability announcement and mode selection between HB and HMs are realized through the interaction of signalling frames in the node admission process.

c) Channel bonding for broadcast transmission

Utilizing channel bonding for broadcasting transmission refers to that HB duplicates each HiMAC3.0 broadcast data frame to each channel for broadcast transmission, which is, the HiMAC3.0 broadcast data frames transmitted on each channel are identical. Each HM can receive all the HiMAC3.0 broadcast data frames on any channel it operates on.

Figure 22 shows an example of channel bonding for broadcast transmission. Nodes HM1 and HM3 work on channel 1 (CH1) and channel 2 (CH2) respectively, while HM2 works on CH1 and CH2 simultaneously. In the specified broadcast transmission, HB sends the same broadcast data frames on CH1 and CH2. HM2 receives broadcast frames from either of CH1 and CH2, while HM1 and HM3 receive broadcast frames from CH1 and CH2 respectively because they only join one channel.

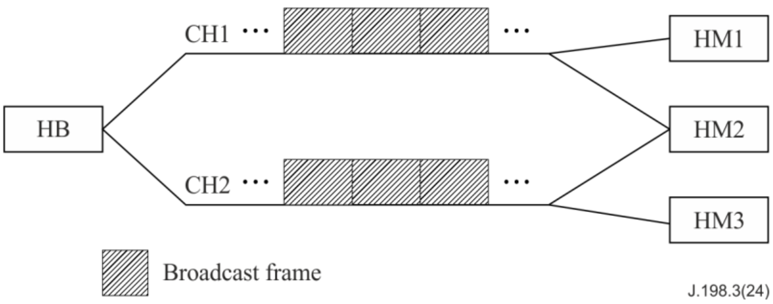

Figure 22 – Example of channel bonding for broadcast transmission

9.1.5 Profile group transmission mechanism

In HiNoC 3.0, HB supports setting multiple HM nodes with similar downlink channel conditions on the same channel as a group, and generating a unified downlink modulation profile for the group. This group is defined as a profile group (PG), where its modulation profile is a list of modulation modes for each OFDM sub-carrier. In the HiNoC 3.0 system, up to 8 profile groups can be established on one channel, identified by the Profile Group ID (PGID). Its value range is defined as 0x41～0x48.

In HiNoC3.0, profile group transmission mechanism is defined as: when planning and allocating channel for downlink transmission, the HB proactively plans transmission opportunities for a specific profile group or groups. Subsequently, within each profile group's transmission window, the HB sends downlink unicast data frames to one or more HM nodes in that group, utilizing the modulation profile designated for that group. The purpose of profile group transmission is to further reduce the transmission latency of downlink unicast services.

During the node admission process on each channel, the HB divides HM nodes into profile groups and generates the corresponding modulation profiles. When an HM is in the node admission process on a channel, the HB classifies it into a profile group (either a new group or an existing one) based on its downlink channel training information. Subsequently, the HB generates a new modulation profile for this profile group according to all HMs' downlink channel information within this profile group. This modulation profile, Profile Group ID (PGID) and the members of this profile group are broadcasted via a downlink signalling frame. Since channel conditions can vary over time, the HB can adjust the profile groups through the link maintenance process on each channel. This includes updating the modulation profiles and/or members of profile groups, and reorganizing HM nodes to form new profile groups and generating the corresponding new modulation profiles. The information of adjusted profile groups are broadcasted through downlink signalling frames. The detailed operations are specified in clauses 9.2 and 9.3.

In HiNoC3.0, the profile group transmission mechanism is implemented through the MAP frame, specifically using the channel allocation unit AU in the MAP frame to allocate SSC resources for profile groups. On a certain channel, HB uses the MAP frame to plan and allocate several SSCs in the downlink transmission period of the next MAP cycle for a specific profile group (or groups). To do this, the SSC_MAP field in the MAP frame is required to contain the AU for the profile group, in which the value of AU_TYPE field should be the PGID of the profile group, and the FUNCTION field should indicate the number of allocated SSCs, as detailed in clause 9.1.3. When the MAP cycle arrives, HB can use the SSCs of the profile group to send downlink unicast data frames to one (or more) HM nodes that belong to this profile group. At this moment the NODE_ID which is the destination address in each downlink data frame is required to be HM's Node ID on this channel, and the modulation profile of each data frame is required to be the modulation profile of the profile group, so as to ensure that the data frame can be correctly received by the corresponding HM node.

An example of profile group transmission in TDMA mode is illustrated in Figure 23. The profile group with PGID of 0x41 comprises four members, HM1～HM4. In the MAP frame of the (n-1)th MAP cycle, 4 SSCs (1 SSC corresponds to 1 OFDM symbol) are assigned to this profile group by the first AU of the SSC_MAP. Before the arrival of the nth MAP cycle, downstream data destined for HM1, HM2 and HM4 respectively arrives at HB. When the n^{th} MAP cycle arrives, HB can use the SSCs assigned to the profile group to send downlink unicast data frames. In the figure, 1, 2 and 1 OFDM symbols are used to send unicast data frames to HM1, HM2 and HM4, respectively. The modulation profile of the profile group is used for each data frames to ensure that each data frame can be correctly received by the members of this group, i.e., HM1, HM2 and HM4. Since SSC resources are planned in advance for the profile group, the downlink transmission delay is reduced.

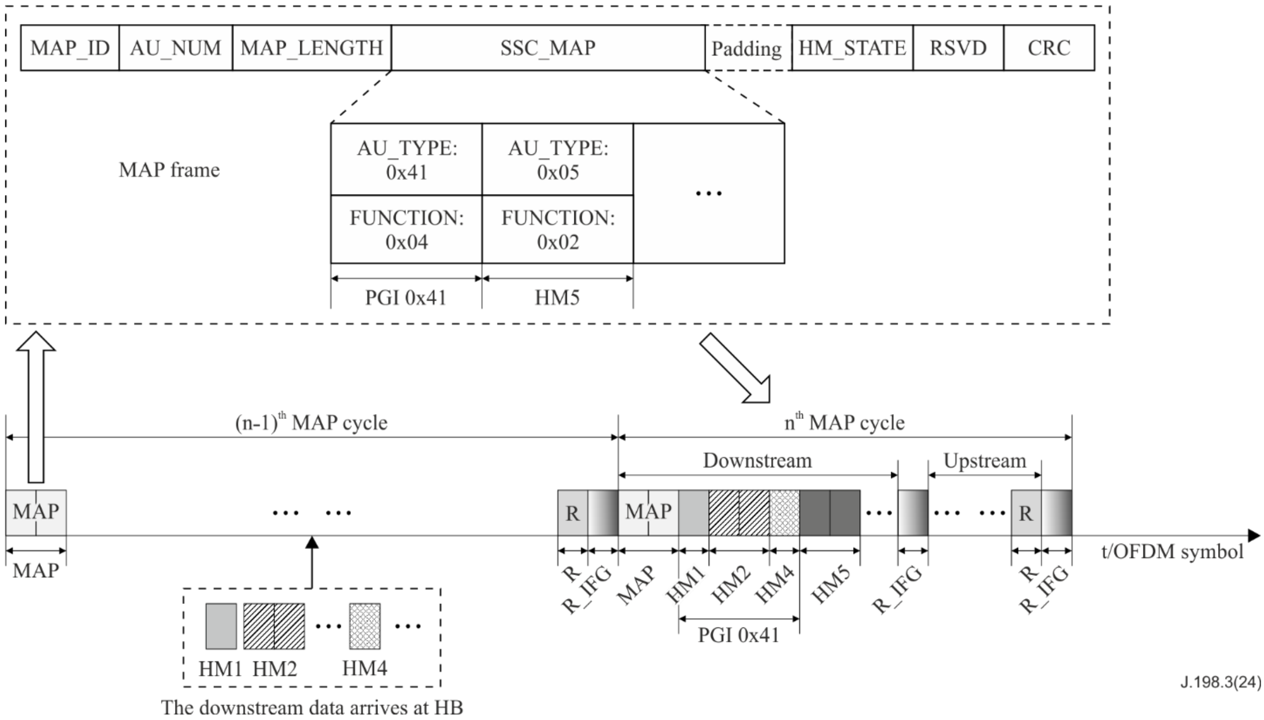

Figure 23 – An example of profile group transmission

9.2 Node admission

9.2.1 Overview

Node admission is the process in which a new HiNoC modem (NHM) joins an existing HiNoC 3.0 system through the interaction of signalling frames with HB after power-on initialization (or reset).

For HiNoC 3.0 channel, the node admission process is specified as below. For HiNoC2.0+ channel, the node admission process is required to conform to clause 9.2 of [ITU-T J.196.3].

a) Correspondence between MAC layer signalling frames and PHY layer Pd/Pu frames

The MAC layer signalling frames are carried by PHY layer Pd/Pu frames. The correspondence between them and the temporal relation of Pd/Pu frame slots are shown in Figure 24. The characteristics are as follows:

1) One Pd cycle is required to contain 1 Pd frame slot and 9 Pu frame slots.

2) The position of the Pd/Pu frame slots are fixed. Wherein, Pu frame slots are accommodated continuously, and the start time of the fifth Pu frame slot is at the middle of the Pd cycle, i.e., 32768 μs to the start time of the current Pd cycle.

3) The Pd slots are required to be used for transmitting downlink signalling frames.

4) In the Pu slots, the fifth slot is required to be used by HM for transmitting uplink signalling frames. The remaining eight Pu slots are required to be used by HM for uplink training and can optionally be used for transmitting uplink signalling frames. The default option is not to transmit any uplink signalling frames.

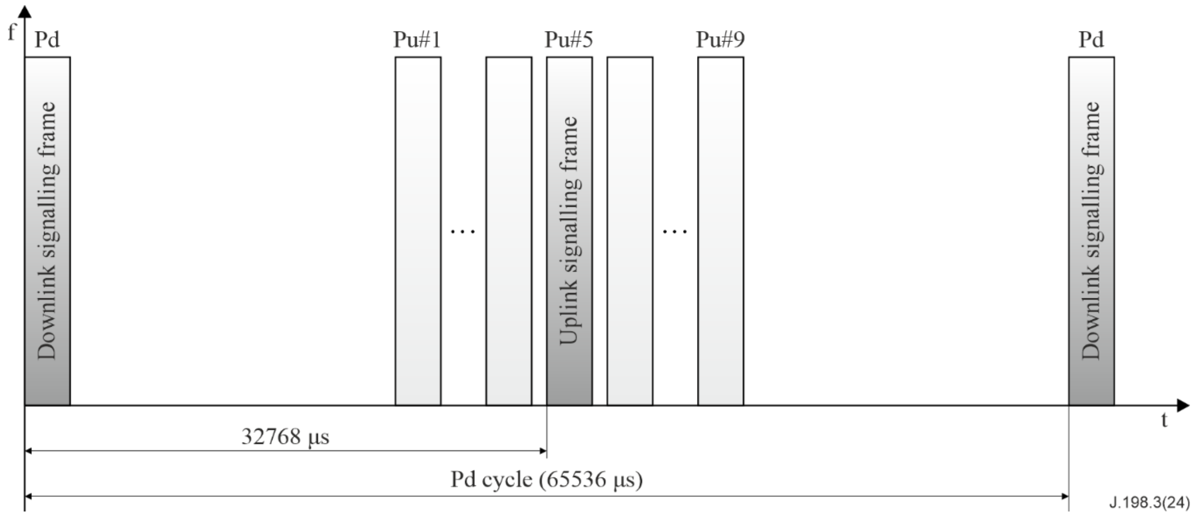

Figure 24 –The relation between MAC layer signalling frames and PHY layer Pd/Pu frame slots

b) Node admission process

HiNoC 3.0 support channel bonding mechanism that the HB and HMs can work on multiple channels at the same time. For each HM, both the Device ID and each Node ID for each working channel are allocated by HB during the node admission process.

When an HM works on multiple channels, it is required that the HM performs node admission process separately on each channel. Firstly, the HM is required to choose a channel as the first channel and to start node admission on this channel to obtain Device ID and the Node ID corresponding to this channel from HB. Then, the HM is required to use the Device ID to perform node admission on the other channels. The procedure of node admission on each channel is basically the same except for getting the Device ID on the first channel.

For each channel, the interaction of signalling frames in the node admission process is shown in Figure 25. The process consists of six steps as follows:

1) Step 1: Network searching, downlink power control and downlink training.

2) Step 2: Interaction of ADM_REQ/ADM_RES/ADM_ACK frames.

3) Step 3: Interaction of DLINK_REPORT.

4) Step 4: Uplink power control, uplink training and ranging.

5) Step 5: Interaction of ULINK_REPORT.

6) Step 6: CMP_REPORT and LINK_UPDATE transmission.

The HB can perform ranging and power control with the HM/NHM through the node admission and/or link maintenance process; the detailed procedure is defined in clauses 9.5 and 9.6.

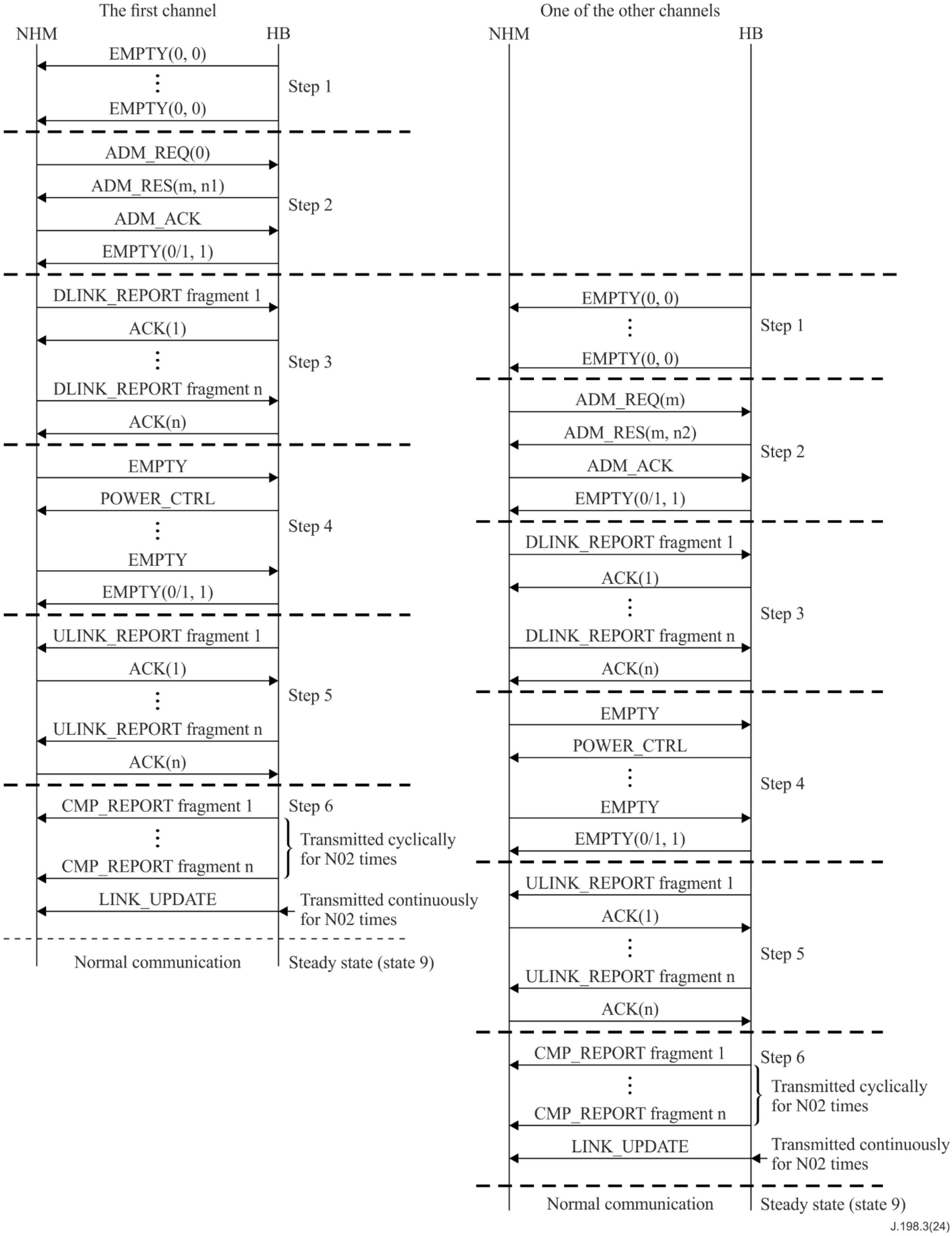

Figure 25 – Interaction of signalling frames in the node admission process

The parameters x and y of EMPTY(x, y) in Figure 25 are defined as follows: x represents the value of the ADM_FLAG field in the header of the downlink EMPTY frame, and y represents the value of the HINOC_STATE field in the header of the downlink EMPTY frame. The "0/1" in EMPTY(0/1, 1) indicates that the value of the ADM_FLAG field is required to be set to "1" or "0" by the HB, based on whether the current network allows the admission of a new node or not.

The parameter n of ACK(n) represents the value of the ACK_SN field in the uplink/downlink ACK frame.

The parameter x of ADM_REQ(x) represents the value of the Device ID indicated by the corresponding TLV.

The parameters x and y of ADM_RES(x, y) are defined as follows: x represents the value of the Device ID indicated by the corresponding TLV, and y represents the value of the ASSIGNED_HM_NODE_ID field.

Node admission process includes ten relative states presented as follows:

1) State 0 (S0): network searching

2) State 1 (S1): downlink power control and downlink training

3) State 2 (S2): ADM_REQ/ADM_RES frames interaction

4) State 3 (S3): ADM_RES/ADM_ACK frames interaction

5) State 4 (S4): DLINK_REPORT fragments interaction

6) State 5 (S5): uplink power control

7) State 6 (S6): uplink training and ranging

8) State 7 (S7): ULINK_REPORT fragments interaction

9) State 8 (S8): CMP_REPORT and LINK_UPDATE frames transmission

10) State 9 (S9): steady state.

An example of a normal state transition diagram in the node admission process of the HB and the NHM on each channel is shown in Figures 26 and 27, respectively. After the node admission process has finished, both the NHM and HB are required to advance to steady state (state 9) and begin to transmit and receive data normally.

In the node admission process, the HB/NHM can optionally start the node quitting/deletion process, as specified in clause 9.4, to terminate node admission.

The constants referred to in this clause 9.2, for example, TL1, are defined in Table B.3.

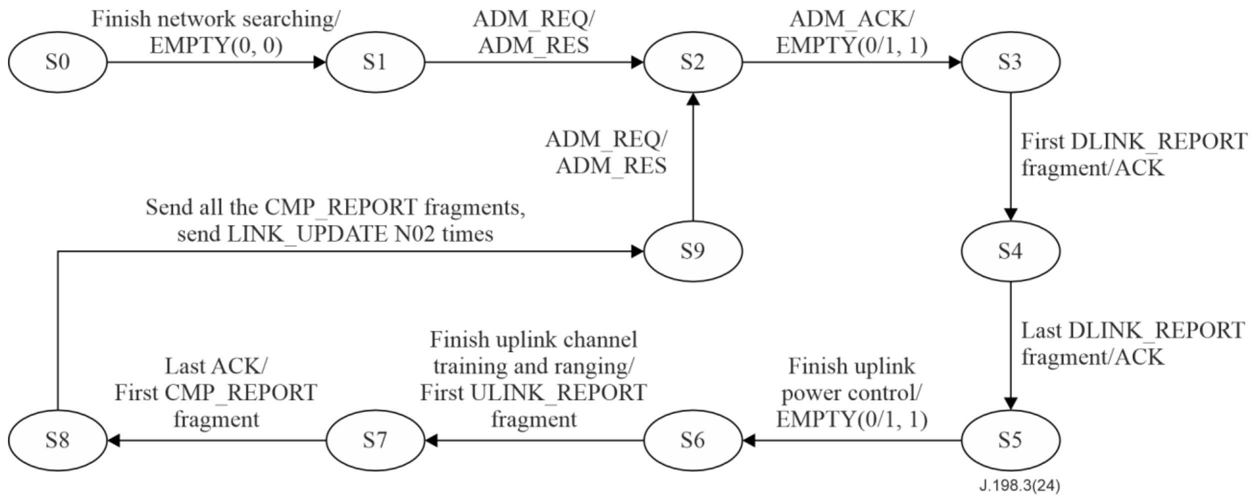

Figure 26 – An example of normal state transition diagram in node admission process of HB on each channel

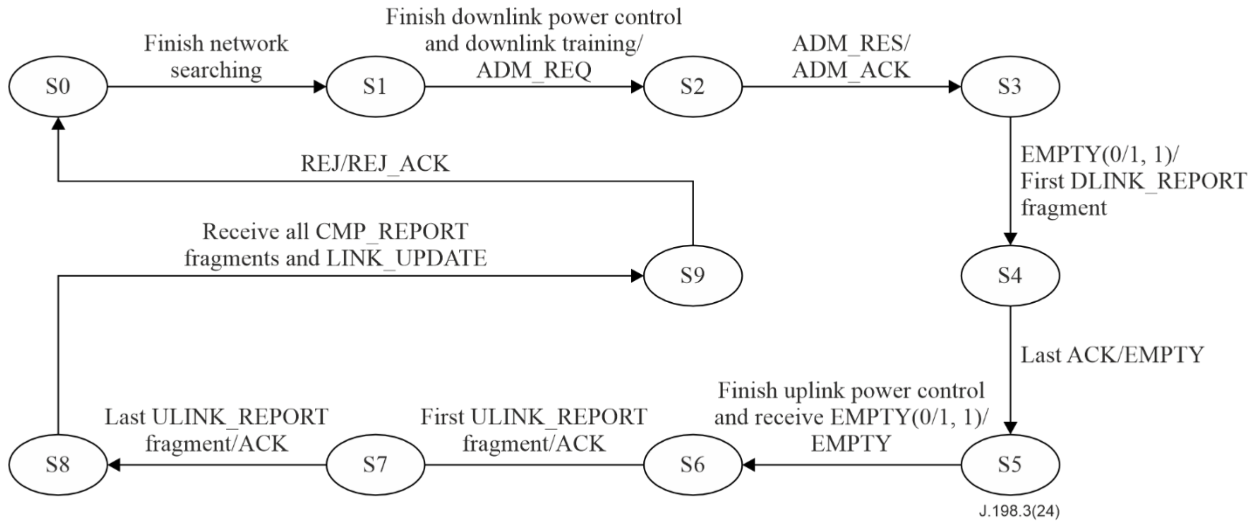

Figure 27 – An example of normal state transition diagram in node admission process of HM on each channel

9.2.2 Step 1

Step 1 consists of two states: network searching (state 0), and downlink power control and downlink training (state 1). After power-on initialization (or reset), the HB and NHM are required to be in state 0 on each channel and network searching is required to be executed. After joining one channel, the NHM is required to execute downlink power control and downlink training by receiving downlink signalling frames on the current channel.

In network searching state (state 0), the HB and NHM are required to search an available channel to build a network.

Operations of the NHM: after powering up, the NHM is required to operate in the preset frequency, set the initial receive power gain to the maximum, and set timer TL1.

1) If a downlink signalling frame with an error CRC checksum or no downlink signalling frame is received within a Pd cycle, the NHM is required to reduce receive power gain and wait to receive the downlink signalling frame in the next Pd cycle.
2) If a downlink signalling frame with a correct CRC checksum is received within a Pd cycle but indicates a mismatched network ID or no admission to the network, the NHM is required to switch to another frequency and reset timer TL1 to restart the network searching process.

If there is no frequency available, the NHM is required to terminate network searching and quit the node admission process.

3) If a downlink signalling frame with a correct CRC checksum is received within a Pd cycle and indicates the network ID matched and new nodes admissible, the NHM is required to cancel timer TL1 and network searching is required to be completed. After that, the NHM is required to set timer TL2 and enter state 1 to conduct downlink power control and downlink training.

4) If timer TL1 expires, the NHM is required to switch to another frequency, reset timer TL1 and restart the network searching process. If there is no frequency available, the NHM is required to terminate network searching and quit the node admission process.

Operations of the HB: after powering up, the HB is required to operate in the preset frequency, set timer TL1, and then begin to monitor downlink signalling frames.

1) If a downlink signalling frame is received, the HB is required to cancel timer TL1, switch to another frequency and reset timer TL1 to restart network searching. If there is no frequency available, the HB is required to terminate network searching and quit the node admission process.

2) If timer TL1 expires, which means that the channel is available, the HB is required to enter state 1 and transmit EMPTY(0, 0) frames on this channel periodically.

After network searching is completed, the NHM/HB starts downlink power control and downlink training (state 1) on the current channel.

Operations of the NHM:

a) The NHM is required to receive downlink signalling frames repeatedly to execute downlink power control, that is, to adjust the receive power gain accordingly. The maximum number of adjustments is N03:

   1) If downlink power control is completed within N03 adjustments, the NHM continues to receive downlink signalling frames to execute downlink training.

   2) If downlink power control is not completed after N03 adjustments, the NHM is required to terminate downlink power control and keep receiving downlink signalling frames to execute downlink training.

b) When downlink power control and downlink training are completed and the HB is in admissible steady state (state 9), the NHM is required to cancel timer TL2, transmit the ADM_REQ frame: if the current channel is the first one that the NHM was admitted, the Device ID indicated by the corresponding TLV in ADM_REQ frame is required to be set to 0, while if the current channel is not the first one for the NHM, the Device ID indicated by the corresponding TLV in ADM_REQ frame is required to be set to the value of the NHM's Device ID obtained on the first channel. Then the NHM is required to set timers TA1 and T01 and enter state 2.

c) If timer TL2 expires, the NHM is required to enter state 0 and quit the node admission process.

Operations of the HB:

a) HB is required to transmit EMPTY(0, 0) frames repeatedly with the HINOC_ID field indicating the network ID.

b) If an ADM_REQ frame is received,

   1) If the value of Device ID indicated by the corresponding TLV in ADM_REQ frame is 0:

      – If the NHM is admissible to the network, the HB is required to transmit an ADM_RES frame to assign a system unique Device ID and also a Node ID corresponding to the current channel for the NHM, set timers TA1 and T01, and enter state 2.

– If it is not allowed to admit the NHM, the HB is required to transmit an REJ frame (with the REASON field giving reasons for the rejection), quit the node admission process on the current channel, and then enter state 9.

2) If the value of Device ID indicated by the corresponding TLV in ADM_REQ frame is not 0:

– If the NHM is admissible to the network, the HB is required to transmit an ADM_RES frame to assign a Node ID corresponding to the current channel for the NHM, set timers TA1 and T01, and enter state 2.

– If it is not allowed to admit the NHM, the HB is required to transmit an REJ frame (with the REASON field giving reasons for the rejection), quit the node admission process on the current channel, and then enter state 9.

9.2.3 Step 2

The interaction of ADM_REQ/ADM_RES/ADM_ACK frames is executed on the current channel in step 2. This step consists of two states: ADM_REQ/ADM_RES frames interaction (state 2) and ADM_RES/ADM_ACK frames interaction (state 3).

Operations of the NHM:

a) After an ADM_REQ frame is transmitted, the NHM is required to enter state 2.

1) If an ADM_RES frame is received before timer T01 expires:

– If the NHM has not obtained a Device ID yet, the NHM is required to get the Device ID and the Node ID corresponding to the current channel from the ADM_REQ frame, transmit an ADM_ACK frame and enter state 3.

– If the NHM has obtained the Device ID, the NHM is required to get the Node ID corresponding to the current channel from the ADM_REQ frame, transmit an ADM_ACK frame and enter state 3.

2) If an REJ frame is received, the NHM is required to transmit an REJ_ACK frame, cancel timer TA1 and T01, enter state 0 and quit the admission process.

3) If an EMPTY(0, 0) frame is received or timer T01 expires, the NHM is required to assume that a collision occurred to the ADM_REQ frame and execute the truncated binary exponential backoff operation. The node is required to set the backoff number K, which represents the number of Pd cycles the NHM has to wait before retransmitting the ADM_REQ frame. K is assigned a random integer value between 0 and $2^M - 1$, where M is the number of times the ADM_REQ frame has been transmitted before and the value of M is required to satisfy 0 < M < NA1. The NHM is required to reset timer TA1 every time after retransmitting the ADM_REQ frame. Once the backoff process is finished, the NHM is required to retransmit the ADM_REQ frame and retry the above operation 1). In the backoff process, if an ADM_RES frame for the NHM is received, the NHM is required to transmit an ADM_ACK frame and enter state 3; if a downlink signalling frame to admit/maintain another NHM/HM is received, the NHM is required to enter state 0 and quit the admission process.

4) If no ADM_RES frame is received after the ADM_REQ frame has been transmitted NA1 times, the NHM is required to enter state 0 and quit the admission process.

5) If an EMPTY(1, 0) frame is received, the NHM is required to enter state 0 and quit the admission process.

b) After an ADM_ACK frame is transmitted, the NHM is required to enter state 3.

   1) If an EMPTY(0/1, 1) frame is received, the NHM is required to transmit a DLINK_REPORT frame, set timer T01 and enter state 4. If this current working channel is the first channel for the NHM to be admitted, the NHM can start the node admission process on the other channels.
   2) If an ADM_RES frame is received, the NHM is required to transmit an ADM_ACK frame.
   3) If an EMPTY(0/1, 0) frame is received, the NHM is required to enter state 0 and quit the admission process.
   4) In other cases, the NHM is prohibited from transmitting any uplink signalling frames.

c) If timer TA1 expires in state 2 or state 3, the NHM is required to enter state 0 and quit the admission process.

Operations of the HB:

a) After an ADM_RES frame is transmitted, the HB is required to enter state 2.

   1) If an ADM_ACK frame is received before timer T01 expires, the HB is required to transmit an EMPTY(0/1, 1) frame, reset timer T01 and enter state 3.
   2) If an ADM_REQ frame is received before timer T01 expires:
      – If the value of Device ID indicated by the corresponding TLV in ADM_REQ frame is 0:
         • If the NHM is admissible to the network, the HB is required to transmit an ADM_RES frame to assign a system unique Device ID as well as a Node ID corresponding to the current channel for the NHM, and reset timer T01.
         • If it is not allowed to admit the NHM, the HB is required to transmit an REJ frame (with the REASON field giving reasons for the rejection), quit the node admission process on the current channel, and then enter state 9.
      – If the value of Device ID indicated by the corresponding TLV in ADM_REQ frame is not 0:
         • If the NHM is admissible to the network, the HB is required to transmit an ADM_RES frame to assign a Node ID corresponding to the current channel for the NHM, and reset timer T01.
         • If it is not allowed to admit the NHM, the HB is required to transmit an REJ frame (with the REASON field giving reasons for the rejection), quit the node admission process on the current channel, and then enter state 9.
   3) If timer T01 expires, the HB is required to retransmit the ADM_RES frame and reset timer T01.
   4) If no ADM_ACK frame is received after the ADM_RES frame has been transmitted N01 times, the HB is required to quit the admission process on the current channel for this node, transmit an EMPTY(0/1, 0) frame, enter state 9 and quit the admission process.

b) After an EMPTY(0/1, 0) frame is transmitted, the HB is required to enter state 3.

   1) If the first DLINK_REPORT fragment from the NHM is received before timer T01 expires, the HB is required to transmit the ACK(1) frame, reset timers T01 and TA2, and then enter state 4.
   2) If timer T01 expires, the HB is required to transmit an EMPTY(0/1, 1) frame, reset timer T01, and keep waiting for the first DLINK_REPORT fragment.

c) If timer TA1 expires in state 2 or 3, the HB is required to enter state 9 and quit the admission process.

9.2.4 Step 3

The interaction of DLINK_REPORT is executed on the current channel in step 3. This step consists of one state: DLINK_REPORT fragments interaction (state 4).

Operations of the NHM: after a DLINK_REPORT fragment is transmitted, the NHM is required to enter state 4.

a) If an ACK(n) frame is received before timer T01 expires, where n is the maximum sequence number among all consecutive sequence numbers of the fragments that the HB has received correctly, the NHM is required to transmit the DLINK_REPORT fragment n+1 and reset timer T01.

b) If the ACK frame for the last DLINK_REPORT fragment is received before timer T01 expires, the NHM is required to transmit an EMPTY frame, reset timer T01, set timer TA3 and enter state 5.

c) If timer T01 expires, the NHM is required to retransmit the DLINK_REPORT fragment. The maximum number of DLINK_REPORT fragment transmissions is N01.

d) If the corresponding ACK frame is not received after the DLINK_REPORT fragment has been transmitted N01 times, the NHM is required to enter state 0 and quit the admission process.

e) If an EMPTY(0/1, 0) frame is received, the NHM is required to enter state 0 and quit the admission process.

f) If timer TA1 expires, the NHM is required to enter state 0 and quit the admission process.

Operations of the HB: after an ACK(1) frame is transmitted, the HB is required to enter state 4.

a) If a DLINK_REPORT fragment is received before timer T01 expires, regardless of whether the fragment is a correct fragment, an error fragment, or a retransmitted fragment, the HB is required to transmit an ACK(n) frame and reset timer T01, where n is the maximum sequence number among all consecutive sequence numbers of the fragments that the HB has received correctly.

b) If timer T01 expires, the HB is required to retransmit the ACK(n) frame and reset timer T01, where n is the maximum sequence number among all consecutive sequence numbers of the fragments that the HB has received correctly.

c) If the last DLINK_REPORT fragment is received before timer T01 expires, HB is required to cancel timers TA1 and T01, transmit the corresponding ACK frame, set timers TA3 and T01 and enter state 5.

d) If timer TA2 expires, the HB is required to enter state 9 and quit the admission process.

e) If timer TA1 expires, the HB is required to enter state 9 and quit the admission process.

9.2.5 Step 4

Uplink power control, uplink training and ranging are executed on the current channel in step 4. This step consists of two states: uplink power control (state 5) and uplink training and ranging (state 6).

Operations of the NHM:

a) When executing the uplink power control process, the NHM is required to be in state 5.

   1) If a power control frame is received before timer T01 expires, the NHM is required to adjust the transmit power gain, transmit an EMPTY frame and reset timer T01.

   2) If an EMPTY(0/1, 1) frame is received before timer T01 expires, the NHM is required to transmit an EMPTY frame, reset timer T01 and enter state 6 to start uplink training and ranging.

3) If an ACK frame for the last DLINK_REPORT fragment is received before timer T01 expires, the NHM is required to transmit an EMPTY frame and reset timer T01.

4) If timer T01 expires, the NHM is required to continue to transmit the EMPTY frame and reset timer T01.

b) When executing the uplink training and ranging process, the NHM is required to be in state 6.

1) If an EMPTY(0/1, 1) frame is received before timer T01 expires, the NHM is required to transmit an EMPTY frame and reset timer T01.

2) If the first ULINK_REPORT fragment is received before timer T01 expires, the NHM is required to cancel timer TA3, transmit the ACK(1) frame, set timer TA4 and enter state 7.

3) If timer T01 expires, the NHM is required to continue to transmit the EMPTY frame and reset timer T01.

c) If an EMPTY(0/1, 0) frame is received in state 5 or 6, the NHM is required to enter state 0 and quit the admission process.

d) If timer TA3 expires in state 5 or 6, the NHM is required to enter state 0 and quit the admission process.

e) If timer TA1 expires in state 5 or 6, the NHM is required to enter state 0 and quit the admission process.

Operations of the HB:

a) When executing the uplink power control process, the HB is required to be in state 5.

After the HB transmits the ACK frame for the last DLINK_REPORT fragment:

1) If an EMPTY frame is received before timer T01 expires, the HB is required to transmit the corresponding power control frame and reset timer T01 to start uplink power control.

2) If the last DLINK_REPORT fragment is received before timer T01 expires, the HB is required to transmit the corresponding ACK frame and reset timer T01.

3) If timer T01 expires, the HB is required to transmit the ACK frame for the last DLINK_REPORT fragment and reset timer T01.

After uplink power control begins, the HB is required to keep receiving the EMPTY frames and transmitting the corresponding power control frames. The maximum number of power control frame transmissions is N03.

1) If an EMPTY frame is received before timer T01 expires, the HB is required to transmit the corresponding power control frame and reset timer T01.

2) If timer T01 expires, the HB is required to retransmit the power control frame and reset timer T01. The maximum number of power control frame transmissions is N01. If no EMPTY frame is received after the power control frame has been transmitted N01 times, the HB is required to enter state 9 and quit the admission process.

3) If uplink power control is completed within N03 times, the HB is required to transmit an EMPTY(0/1, 1) frame, reset timer T01 and enter state 6 to start uplink training and ranging.

4) If uplink power control is not completed after N03 times, the HB is required to terminate the uplink power control process, transmit an EMPTY(0/1, 1) frame, reset timer T01 and enter state 6 to start uplink training and ranging.

b) When executing uplink training and ranging process, HB is required to be in state 6.

1) If an EMPTY frame is received before timer T01 expires, the HB is required to transmit an EMPTY(0/1, 1) frame and reset timer T01.

2) If timer T01 expires, the HB is required to transmit an EMPTY(0/1, 1) frame and reset timer T01.

3) After uplink training and ranging is completed, the HB is required to cancel timer TA3, transmit the first ULINK_REPORT fragment, set timer T01 and enter state 7.

c) If timer TA3 expires in state 5 or 6, the HB is required to enter state 9 and quit the admission process.

d) If timer TA1 expires in state 5 or 6, the HB is required to enter state 9 and quit the admission process.

9.2.6 Step 5

The ranging report transmission and interaction of the ULINK_REPORT is executed on the current channel in step 5. This step consists of one state: ULINK_REPORT fragments interaction (state 7).

Operations of the NHM: after an ACK(1) frame is transmitted, the NHM is required to enter state 7.

a) If a ULINK_REPORT fragment is received, regardless of whether the fragment is a correct fragment, an error fragment, or a retransmitted fragment, the NHM is required to transmit an ACK(n) frame, where n is the maximum sequence number among all consecutive sequence numbers of the fragments that the NHM has received correctly.

b) If the last ULINK_REPORT fragment is received, the NHM is required to cancel timer TA4, transmit the corresponding ACK frame, set timer TC1 and enter state 8.

c) In other cases, the NHM is prohibited from transmitting any uplink signalling frames.

d) If an EMPTY(0/1, 0) frame is received, the NHM is required to enter state 0 and quit the admission process.

e) If timer TA4 expires, the NHM is required to enter state 0 and quit the admission process.

f) If timer TA1 expires, the NHM is required to enter state 0 and quit the admission process.

Operations of the HB: after a ULINK_REPORT fragment is transmitted, the HB is required to enter state 7.

a) If an ACK(n) frame is received before timer T01 expires, where n is the maximum sequence number among all consecutive sequence numbers of the fragments that the NHM has received correctly, HB is required to transmit ULINK_REPORT fragment n+1 and reset timer T01.

b) If the ACK frame for the last ULINK_REPORT fragment is received before timer T01 expires, the HB is required to cancel timer T01, transmit the first CMP_REPORT fragment and enter state 8.

c) If timer T01 expires, HB is required to retransmit the ULINK_REPORT fragment. The maximum number of ULINK_REPORT fragment transmissions is N01.

d) If the corresponding ACK frame is not received after the ULINK_REPORT fragment has been transmitted N01 times, the HB is required to enter state 9 and quit the admission process.

e) If timer TA1 expires, the HB is required to enter state 9 and quit the admission process.

9.2.7 Step 6

In step 6, the HB is required to advertise the new broadcast parameters and profile group parameters to the NHM and all other existing HMs on this current channel, and indicate the update of link parameters exchanged by DLINK_REPORT, ULINK_REPORT, and CMP_REPORT frames. This step consists of one state: CMP_REPORT and LINK_UPDATE frames transmission (state 8).

Operations of the NHM and each HM:

a) In state 8, the NHM is first required to continue receiving CMP_REPORT fragments. When all CMP_REPORT fragments are received, the NHM is required to cancel timer TC1, set timer T02 and wait for the LINK_UPDATE frame. For all the existing HMs, when the first CMP_REPORT fragment is received, they are required to enter state 8 from state 9 and set timer TC1; when all CMP_REPORT fragments are received, the HMs are required to cancel timer TC1, set timer T02 and wait for the LINK_UPDATE frame.
   1) If a LINK_UPDATE frame is received before timer T02 expires, the NHM/HM is required to cancel timer T02 and TA1 (TA1 only for NHM) and enter state 9. From the first MAP cycle following the last LINK_UPDATE frame, all HMs are required to utilize new parameters to transmit control frames and data frames.
   2) If an EMPTY(0/1, 0) frame is received before T02 expires, the NHM/HM is required to enter state 9 and transmit control frames and data frames with new parameters.
   3) If timer T02 expires, the NHM is required to cancel timer TA1. The NHM/HM is required to enter state 9 and transmit control frames and data frames with new parameters.

b) In this state, if an EMPTY(0/1, 0) frame is received before timer TC1 expires, the NHM is required to enter state 0 and quit the admission process, while the existing HMs are required to enter state 9.

c) If not all CMP_REPORT fragments are received after timer TC1 expires, the NHM is required to cancel timer TA1, enter state 0, and quit the admission process, while the existing HMs are required to enter state 9.

d) If the last ULINK_REPORT fragment is received before timer TC1 expires, the NHM is required to transmit the corresponding ACK frame and reset timer TC1.

e) If timer TA1 expires, the NHM is required to enter state 0 and quit the admission process.

f) In other cases, the NHM is prohibited from transmitting any uplink signalling frames.

Operations of the HB:

a) The HB is required to broadcast each CMP_REPORT fragment in sequence to all nodes (both the NHM and the existing HMs) on this current channel, and repeat this operation N02 times, as shown in Figure 25.

b) After that, the HB is required to broadcast a LINK_UPDATE frame N02 times to all nodes on this current channel. From the first MAP cycle after the last LINK_UPDATE frame, the HB is required to utilize new link parameters to transmit control frames and data frames.

c) The HB is then required to cancel timer TA1, set timer TM0 (only when the admission of the first NHM in the network is finished), and enter state 9.

d) If timer TA1 expires, the HB is required to enter state 9 and quit the admission process.

9.2.8 Steady state

State 9 is the steady state. In state 9, an NHM becomes an HM for the current channel, and the HB is required to communicate with all HMs with new link parameters on this current channel.

Operations of an HM:

a) If an HM receives an EMPTY(0/1, 2) frame with the DESTINATION_NODE_ID field matching its own ID, it is required to set timers TM2 and TM5 and enter state 10 to start downlink power control and uplink training.

b) If a CMP_REPORT fragment is received where the value of the HINOC_STATE field is 0x1, the HM is required to set timer TC1 and enter state 8; whereas if the value of the HINOC_STATE field is 0x2, the HM is required to set timer TC1 and enter state 16.

c) If the HM executes the node quitting process, it is required to execute the operations specified in clause 9.4.

d) In other cases, the HM is prohibited from transmitting any uplink signalling frames.

Operations of the HB:

a) If the HB receives an ADM_REQ frame:
   - If the value of Device ID indicated by the corresponding TLV in ADM_REQ frame is 0:
     - If the NHM is admissible to the network, the HB is required to transmit an ADM_RES frame to assign a system unique Device ID as well as a Node ID corresponding to the current channel for the NHM, set timers TA1 and T01, and enter state 2.
     - If it is not allowed to admit the NHM, the HB is required to transmit an REJ frame (with the REASON field giving reasons for the rejection), quit the node admission process on the current channel, and remain in state 9.
   - If the value of Device ID indicated by the corresponding TLV in ADM_REQ frame is not 0:
     - If the NHM is admissible to the network, the HB is required to transmit an ADM_RES frame to assign a Node ID corresponding to the current channel for the NHM, set timers TA1 and T01, and enter state 2.
     - If it is not allowed to admit the NHM, the HB is required to transmit an REJ frame (with the REASON field giving reasons for the rejection), quit the node admission process on the current channel, and remain in state 9.

b) If timer TM0 or TM1 expires, the HB is required to transmit an EMPTY(0/1, 2) frame, set timers TM2 and TM5 and enter state 10.

c) If timer TM3 expires, the HB is required to transmit the first CMP_REPORT fragment and enter state 16.

d) If the HB executes node quitting/deletion process, it is required to execute the operations specified in clause 9.4.

e) In other cases, the HB is required to transmit the EMPTY(0/1, 0) frame periodically.

9.3 Link maintenance

In the HiNoC 3.0 system, the characteristics of each working channel between the HB and each HM may vary over time. Link maintenance estimates and exchanges the link parameters of each working channel to adapt to the variation of channel characteristics and ensure that the system runs steadily.

For each working channel, there are two types of link maintenance in the HiNoC 3.0 system:

a) Periodical link maintenance between the HB and all the HMs

For each channel, HB periodically performs a round of link maintenance with all the HMs working on the channel one by one. The time interval of periodical link maintenance is TM0, which means that the HB is required to select an HM to start a new round of periodical link maintenance after a period of TM0 following the completion of the previous link maintenance. To start link maintenance with a certain HM working on the current channel, the HB is required to set the value of DESTINATION_NODE field to the HM's Node ID for the channel, and set the value of the HINOC_STATE field to 0x2 in EMPTY frame and send the EMPTY frame several times to the HM to inform it to start link maintenance with the HB. After completing link maintenance with an HM (not the last one in a round), the HB is required to enter steady state for a period of TM1 and then select another HM to execute link maintenance. After completing link maintenance with the last HM working on the current channel in a round, the HB is required to enter steady state, stay for a period of TM3 and inform every HM on the current channel of the new broadcast parameters, profile group parameters and the moment to update link parameters. After that, a round of periodical link maintenance on the current channel is finished.

The HB is required to enter steady state (state 9) after completing link maintenance with an HM. During this period, if there is an NHM admission request on the same channel, the HB is required to execute the node admission process first. After that, the HB is required to continue link maintenance with the next HM.

b) Single link maintenance between the HB and a certain HM

The HB can optionally start the link maintenance process according to the variation of the current channel. Similarly, when an HM detects that the characteristics of one channel vary, it can optionally send R frames on this channel to the HB to request link maintenance by setting the value of the LM_REQ field to 0x1, and then the HB starts link maintenance on this channel with the HM. After unicast parameters between the HB and the certain HM are updated, the HB is required to stay in steady state for a period of TM3 and inform every HM on this current channel of the new broadcast parameters, profile group parameters and the moment to update link parameters.

It is required to utilize MAC layer signalling frames to execute link maintenance process. For each working channel, the link maintenance process is independent, but the procedure of signalling frames interaction in the link maintenance process is the same. The interaction of signalling frames on one channel is shown in Figure 28. The link maintenance process consists of the following five steps:

1) Step 1: downlink power control and downlink training
2) Step 2: DLINK_REPORT interaction
3) Step 3: uplink power control and uplink training and ranging
4) Step 4: ULINK_REPORT interaction and LINK_UPDATE transmission for unicast parameters updating
5) Step 5: CMP_REPORT and LINK_UPDATE transmission.

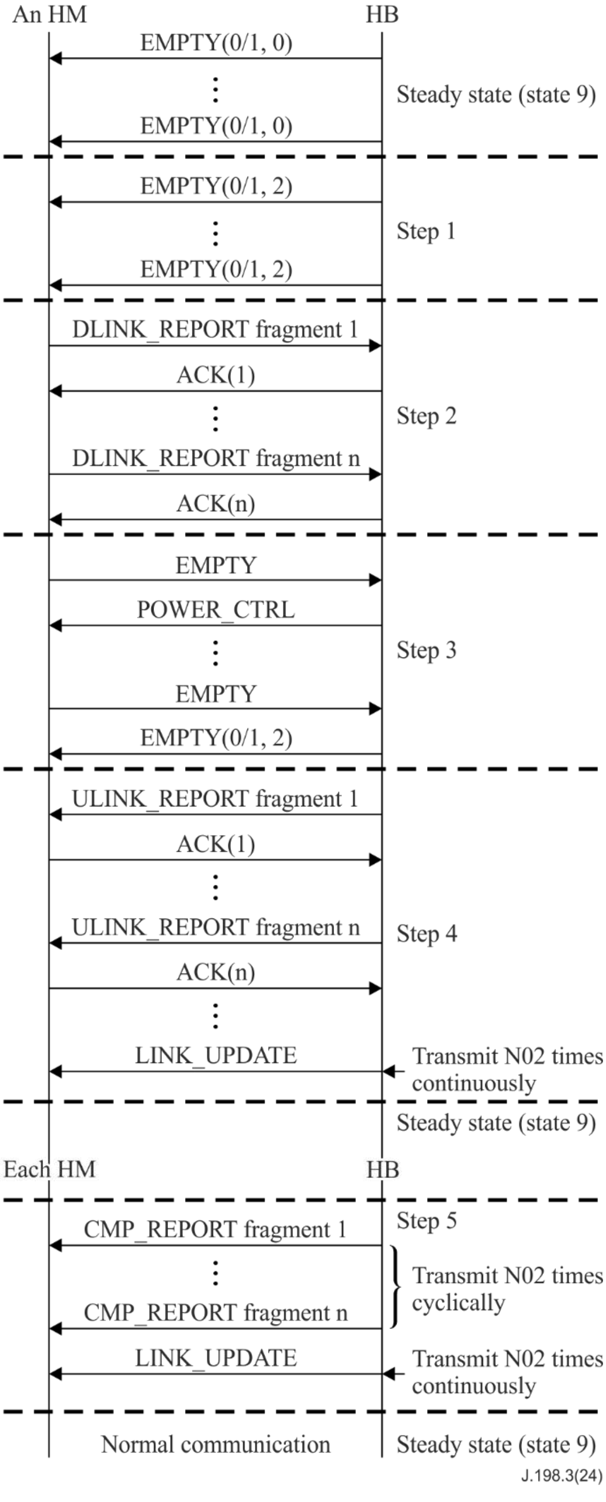

Figure 28 – Interaction of signalling frames in the link maintenance process on one channel

The parameters x and y of EMPTY(x, y) in Figure 28 are defined as follows: x represents the value of the ADM_FLAG field in the header of the downlink EMPTY frame, and y represents the value of the HINOC_STATE field in the header of the downlink EMPTY frame. The "0/1" in EMPTY(0/1, 0) and EMPTY(0/1, 2) indicates that the value of the ADM_FLAG field is required to be set to "1" or "0" by the HB, based on whether the current network allows the admission of a new node or not.

The parameter n of ACK(n) represents the value of the ACK_SN field in the uplink/downlink ACK frame.

The detailed specification of steps 1 to 5 in the link maintenance process are required to conform to clauses 9.3.2 to 9.3.6 of [ITU-T J.196.3].

9.4 Node quitting/deletion

9.4.1 Overview

Node quitting/deletion refers to the NHM/HM quits from a working channel or from the HiNoC 3.0 network. The node quitting/deletion process consists of two situations: active quitting and passive quitting of the NHM/HM. For HiNoC 3.0 channel, the node quitting/deletion process is specified as below. For HiNoC2.0+ channel, the node quitting/deletion process is required to conform to clause 9.4 of [ITU-T J.196.3]. It is required to execute the node quitting/deletion process independently on each working channel. So, the NHM/HM can quit or be deleted from a working channel through the node quitting/deletion process on this channel. Also the NHM/HM can quit or be deleted from the HiNoC 3.0 network which means all the working channels through the node quitting/deletion process on any HiNoC 3.0 channel.

Node quitting/deletion process includes three relative states presented as follows:

1) State 0 (S0): network searching;
2) State 9 (S9): steady state;
3) State 17 (S17): node quitting.

9.4.2 Active quitting of the NHM/HM

Operations of the NHM/HM on one channel:

a) When the NHM/HM is in the process of node admission or link maintenance on the channel, it is required to transmit a QUIT frame on the same channel to inform the HB that it requests to quit and the REASON field in the QUIT frame indicates that it will quit from this channel or from the network. And then it is required to set timer T01 and enter node quitting state (state 17) as shown in Figure 29.
    1) If a QUIT_ACK frame is received before timer T01 expires, the NHM/HM is required to cancel timer T01, enter state 0 on this channel and quit from this channel, or enter state 0 on all the working channels and quit from the network, accordingly.
    2) If timer T01 expires, the NHM/HM is required to retransmit the QUIT frame. The maximum number of QUIT frame transmissions is N01.
    3) If the QUIT_ACK frame is not received after the QUIT frame has been transmitted N01 times, the NHM/HM is required to enter state 0 on this channel and quit from this channel, or enter state 0 on all the working channels and quit from the network, accordingly.
    4) If an EMPTY(0/1, 0) frame is received before timer T01 expires, the NHM/HM is required to cancel timer T01, enter state 0 on this channel and quit from this channel, or enter state 0 on all the working channels and quit from the network, accordingly.
b) When the HM is in steady state, it is required to utilize the R frame on this channel to inform the HB that it will quit instead of transmitting a QUIT frame, where the value of QUIT_IND field in the R frame is required to be 0x1 and the value of QUIT_FLAG field in the R frame depends on whether the HM will quit from this channel or from the network. After that, the HM is required to enter state 0 on this channel and quit from this channel, or enter state 0 on all the working channels and quit from the network, accordingly.

Operations of the HB on one channel:

a) If a QUIT frame from the NHM/HM on this channel is received, the HB is required to transmit a QUIT_ACK frame, delete the NHM/HM from this channel or from the network according to the value of REASON field in the QUIT frame, and then enter state 9.

b) If an R frame with the value of QUIT_IND field set to 0x1 from an HM on this channel is received, the HB is required to delete the HM from this channel or from the network according to the value of QUIT_FLAG field in the R frame, and then enter state 9.

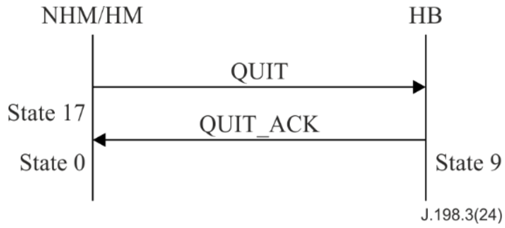

Figure 29 – Active quitting of the NHM/HM

9.4.3 Passive quitting of the NHM/HM

Operations of the NHM/HM:

a) If an NHM/HM receives an REJ frame on one of the working channel and the value of DESTINATION_NODE_ID field of the REJ frame matches its own Node ID corresponding to this channel, it is required to transmit the REJ_ACK frame on this channel to the HB, and then enter state 0 on this channel and quit from the this channel, or enter state 0 on all the working channels and quit from the network according to the value of REASON field in the REJ frame.

b) If an NHM/HM receives an REJ frame on any working channel from the HB in broadcast mode (with the value of the DESTINATION_NODE_ID field set to 0xFF), it is required to enter state 0 on this channel and quit from the this channel, or enter state 0 on all the working channels and quit from the network according to the value of REASON field in the REJ frame.

Operations of the HB:

a) Passive quitting of a certain NHM/HM

When the HB is in the process of node admission or link maintenance with a NHM/HM on a channel, if the HB needs to execute passive quitting procedure on this channel, it can only be executed to the NHM/HM which is in the process. The HB is required to transmit the REJ frame to the NHM/HM on this channel and the REASON field in the REJ frame indicates that the NHM/HM will be deleted from this channel or from the network. And then the HB is required to set timer T01 and enter node quitting state (state 17), as shown in Figure 30.

1) If an REJ_ACK frame is received on the same channel before timer T01 expires, the HB is required to cancel T01, delete the NHM/HM from this channel or from the network accordingly, and enter state 9.

2) If timer T01 expires, the HB is required to retransmit the REJ frame on this channel. The maximum number of REJ frame transmissions is N01.

3) If the REJ_ACK frame is not received on this channel after the REJ frame has been transmitted N01 times, the HB is required to delete the NHM/HM from this channel or from the network accordingly, and enter state 9.

When the HB is in steady state, it can optionally execute the passive quitting procedure with any HM in the network. The operations are the same as when the HB is in the process of node admission or link maintenance.

b) Passive quitting of all NHM/HMs on one channel

Whichever state the HB is in, to delete all HMs on one channel simultaneously, it is required to broadcast the REJ frame on this channel and the REASON field in the REJ frame indicates that all the NHM/HMs on this channel will be deleted from this channel or from the network. When the HB begins to transmit the first REJ frame, it is required to enter state 17. The HB is required to transmit the REJ frame N02 times, and then enter state 9.

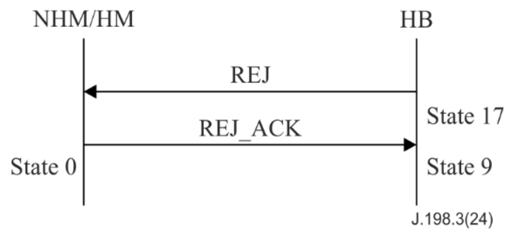

Figure 30 – Passive quitting of the NHM/HM

9.5 Network synchronization and ranging

In HiNoC 3.0 system, the length of Pd cycle is determined as the time cycle, and the start time of each Pd cycle refers to the time that HB starts to send the Pd frame in PHY layer. In each Pd cycle, the HB and HMs are required to take the start time of Pd cycle as the system start time. All HMs are required to regard the HB's clock as the reference time. In HiNoC 3.0 system, it is required that the Pd cycle on each channel is strictly aligned in terms of transmission time, which means that the HB is required to send Pd frames on all working channels synchronously. Each HM is required to perform network synchronization and ranging with the HB on the first channel to which the HM is admitted during the node admission process. Each HM can optionally perform network synchronization and ranging on any channel during the link maintenance process. The specification of network synchronization and ranging is required to conform to clause 9.5 of [ITU-T J.196.3].

9.6 Power control

In the HiNoC 3.0 system, it is required to realize power control independently on each channel. The specification of power control is required to conform to clause 9.6 of [ITU-T J.196.3].

10 Compatibility with HiNoC 2.0

This Recommendation specifies HiNoC 3.0 protocol. HiNoC 3.0 is backward compatible with HiNoC 2.0. HiNoC 3.0-compliant HBs seamlessly support to interoperate with HiNoC 2.0 HMs. In order to achieve compatibility with HiNoC 2.0, the work channels are divided into HiNoC 2.0+ channel(s) and HiNoC 3.0 channel(s) in the HiNoC 3.0 protocol. HiNoC 2.0+ channel should support both HiNoC 2.0 HMs and HiNoC 3.0 HMs, and HiNoC 3.0 channel only supports HiNoC 3.0 HMs. HiNoC 3.0-compliant HMs should support to access HiNoC 2.0+ channel(s). Before a HiNoC 3.0 HB and HiNoC 2.0 HM(s) build a network, it is required to configure one or more of the HiNoC 3.0 HB's working channels to be HiNoC 2.0+ channel(s) with the number of HiNoC 2.0+ channels depending on the number of HiNoC 2.0 HMs intended for connection.

Figure 31 provides an example of a mixed networking scenario of HiNoC 3.0 HB with HiNoC 2.0 HMs and HiNoC 3.0 HMs. As shown, the eight 128 MHz channels of HiNoC system are divided into two HiNoC 2.0+ channels and six HiNoC 3.0 channels. Among them, channel 2 and channel 6 are HiNoC 2.0+ channels in which both HiNoC 3.0 HMs (indicated as HMx(3.0)) and HiNoC 2.0 HMs (indicated as HMx(2.0)) are connected, and the rest of the channels are HiNoC 3.0 channels in which all of the HMs connected are HiNoC 3.0 HMs.

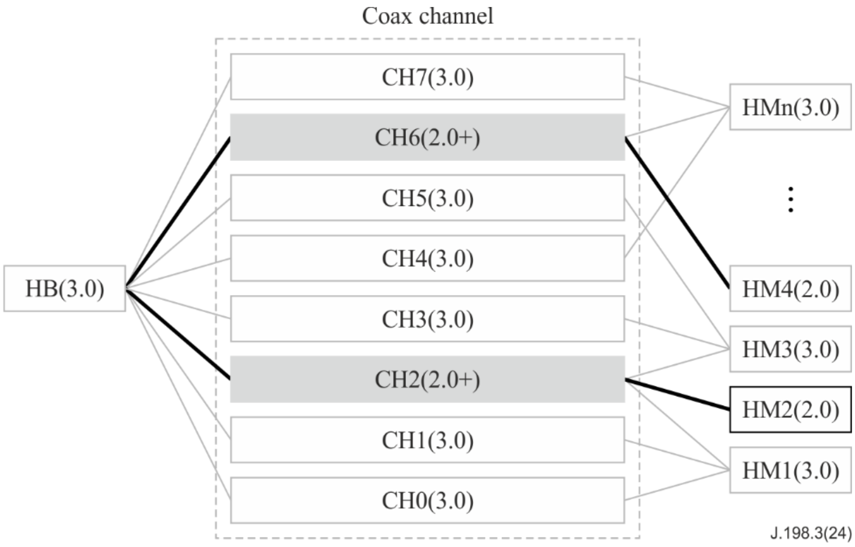

Figure 31 – An example of a mixed networking scenario of HiNoC 3.0 channels and HiNoC 2.0+ channels

The compatible requirements for HB and HMs working on the HiNoC 2.0+ channel are specified as follows:

a) On the HiNoC 2.0+ channel, HiNoC 3.0 HB is required to send downlink signalling frames according to the HiNoC 2.0 protocol and complete the node admission process with both HiNoC 2.0 HMs and HiNoC 3.0 HMs as specified in the same protocol.

b) HiNoC 3.0 HB is required to divide the channel into MAP cycles and perform channel allocation for each MAP cycle following the HiNoC 2.0 protocol, meaning the structure of the MAP cycle and MAP frame should conform to clauses 9.1.2 and 9.1.3 in [ITU-T J.196.3].

c) On the HiNoC 2.0+ channel, the interaction of signalling frames and control frames and the transmission of data frames between HiNoC 3.0 HB and HiNoC 2.0 HMs are required to be carried out following the HiNoC 2.0 protocol.

d) To access the HiNoC 2.0+ channel, HiNoC 3.0 HM is required to perform the node admission process as speicified in the HiNoC 2.0 protocol.

e) On the HiNoC 2.0+ channel, HiNoC 3.0 HM should be capable of sending the R frames and receiving the MAP frames compliant with the HiNoC 2.0 protocol and transmit data using the channel resources allocated to this node.

f) On the HiNoC 2.0+ channel, HiNoC 3.0 HB and HiNoC 3.0 HMs are required to apply the data frame format specified by the HiNoC 3.0 protocol for uplink and downlink unicast data transmission.

g) On the HiNoC 2.0+ channel, the group broadcast frame specified in HiNoC 2.0 protocol are required to be supported between HiNoC 3.0 HB and HiNoC 3.0 HMs, but the multicast frame, broadcast frame, and Profile Group transmission mechanism specified in the HiNoC 3.0 protocol are not supported between them.

h) When a HiNoC 3.0 HM, which accesses a HiNoC 2.0+ channel, also connects to other HiNoC 2.0+ or HiNoC 3.0 channel(s), it should support the channel bonding mechanism for unicast data transmission with HiNoC 3.0 HB.

Annex A

Format of MAC layer frames

(This annex forms an integral part of this Recommendation.)

A.1 Signalling frame format

A.1.1 Downlink signalling frame format

The structure of fixed part of the downlink signalling frame header is shown in Table A.1.

Table A.1 – Downlink signalling frame header

Field	Length (bit)	Function
DESTINATION_NODE_ID	8	Destination node ID: 0x01-0x40 – Node ID of a HM node on current channel 0xFF – Node ID of broadcast address All other values reserved
SOURCE_NODE_ID	8	Source node ID (HB's Node ID): 0x0
FRAME_LENGTH	8	Frame length (including the header and the payload), in bytes
FRAME_TYPE	4	Downlink signalling frame type: 0x1 – EMPTY frame 0x2 – ADM_RES frame 0x3 – REJ frame 0x4 – ULINK_REPORT frame 0x5 – ACK frame 0x6 – CMP_REPORT frame 0x7 – LINK_UPDATE frame 0x8 – QUIT_ACK frame 0x9 – POWER_CTRL frame All other values reserved
VERSION	4	Supported HiNoC protocol version types, one bit corresponding to one HiNoC version Bit 0 – For HiNoC 1.0, setting 1 indicates to support HiNoC 1.0, setting 0 indicates not to support HiNoC 1.0 Bit 1 – For HiNoC 2.0, setting 1 indicates to support HiNoC 2.0, setting 0 indicates not to support HiNoC 2.0 Bit 2 – For HiNoC 3.0, setting 1 indicates to support HiNoC 3.0, setting 0 indicates not to support HiNoC 3.0 Bit 3 – Reserved
FF	1	FRAGMENT FLAG: 0x0 – Do not fragment 0x1 – Fragment
LFF	1	LAST FRAGMENT FLAG: 0x0 – Not the last fragment 0x1 – Last fragment
FSN	6	FRAGMENT SEQUENCE NUMBER, beginning with 1

Table A.1 – Downlink signalling frame header

Field	Length (bit)	Function
HINOC_ID	8	ID of the HiNoC network built by the current HB
HM_NUM	8	Number of HM nodes in the HiNoC channel
ADM_FLAG	1	Whether the channel allows a new node to be admitted: 0x0 – Admissible 0x1 – Inadmissible
HINOC_STATE	3	Current state of the channel: 0x0 – Steady state 0x1 – Node admission 0x2 – Link maintenance
PREEQ_EN	2	Pre-equalization supported flags: 0x0 – Not to support pre-equalization 0x1 – To support pre-equalization 0x2 – Decided by HM 0x3 – Reserved
EXT_HEADER_INFO	1	Whether there is extended part after fixed part in the header: 0x0 – No 0x1 – Yes
EXT_PAYLOAD_INFO	1	Whether there is extended part after fixed part in the payload: 0x0 – No 0x1 – Yes
ARQ_SPTD	1	Whether to support ARQ protocol: 0x0 – Not to support ARQ protocol 0x1 – To support ARQ protocol
EISF_SPTD	1	Whether to support EISF: 0x0 – Not to support EISF 0x1 – To support EISF
TERMINAL_SPTD	3	The maximum bandwidth of HM supported by current channel: 0x7 – Supporting an HM with maximum bandwidth of 128 MHz All other values Reserved
CP_MODE	2	The cyclic prefix (CP) length used in transmitting data frame: 0x0-0.5 μs 0x1-1 μs 0x2-2 μs All other values reserved
RSVD	5	Reserved
FEC_SPTD	4	The forward error correction (FEC) format supported by HB: setting 1 indicates to support the corresponding FEC format and setting 0 indicates not to support the corresponding FEC format

Table A.1 – Downlink signalling frame header

Field	Length (bit)	Function
		Bit 0 – (1920, 1744) truncated Bose-Chaudhuri-Hocquenghem (BCH) code Bit 1 – (1920, 1040) truncated BCH code Bit 2 – (1920, 1728) LDPC code Bit 3 – (3840, 3456) LDPC code Others – Reserved
MAP_OFDM_NUM	8	Number of OFDM symbols for transmitting a MAP frame
MAP_MAX_MODU_MODE	8	Mode of the highest-order sub-carrier modulation for transmitting a MAP frame
MAP_FRAME_OFFSET	24	Time from the beginning of this Pd frame to the beginning of the transmission of the first MAP frame, in TICK_TIMEs. If this field is 0, it indicates that there is no transmission of MAP frames during this Pd cycle
OFDMA_SPTD	1	Whether to support OFDMA mechanism to transmit data frame: 0x0 – Not to support OFDMA 0x1 – Support OFDMA
CHANNEL_NUM	3	The downlink signalling frame channel number to transmit this downlink signalling frame
FEC_MODE	4	The FEC format used by Dd/Du frames: 0x0 – No FEC 0x1 – (508, 472) truncated BCH code 0x2 – (504, 432) truncated BCH code All other values reserved

The structure of the downlink signalling frame tail is shown in Table A.2.

Table A.2 – Downlink signalling frame tail

Field	Length (bit)	Function
CRC	32	Cyclic redundancy check

The structure of the fixed part in the downlink signalling frame payload is shown in Tables A.3 to A.12.

Table A.3 – EMPTY frame payload

Field	Length (bit)	Function
NOTE – This type of downlink signalling frame does not have fixed part in payload.		

Table A.4 – ADM_RES frame payload

Field	Length (bit)	Function
ASSIGNED_HM_NODE_ID	8	Node ID assigned to this HM by current channel
HM_GUID	48	Hardware address of this HM
ULINK_TRAIN_CHANNEL	8	Pu frame slots used by this HM to make uplink channel training, except for the 5th Pu frame. Bit 7-4 – Each bit corresponds to the 9th~6th Pu frame time slot respectively. Bit 3-0 – Each bit corresponds to the 4th~1st Pu frame time slot respectively. Setting to 1 indicates that the corresponding time slot is available to make uplink channel training and setting to 0 indicates that this time slot is not available to make uplink channel training
RSVD	4	Reserved
FEC_MODE_2	4	The FEC format used by Dd/Du frames: 0x0 – No FEC 0x1 – (1920, 1744) truncated BCH code 0x2 – (1920, 1040) truncated BCH code 0x3 – (1920, 1728) LDPC code 0x4 – (3840, 3456) LDPC code All other values reserved

Table A.5 – REJ frame payload

Field	Length (bit)	Function
REASON	8	Reasons that the HB rejects the HM: 0x1 – Password error 0x2 – Channel capacity is full 0x3 – Channel condition is bad 0x4 – MAC (GUID) address conflict 0x5 – Device ID error The above values indicate that the HM quits the current channel 0x81 – Indicate the HM to quit the entire network All other values reserved
HM_GUID	48	Hardware address of the HM When the DESTINATION_NODE_ID field in the header is 0xFF, each bit in this field should be set to '1'

Table A.6 – ULINK_REPORT frame payload

Field	Length (bit)	Function
PE_NUM	8	Number of parameter elements
for (i=0; i< PE_NUM; i++) {		
PE	variable[a)]	Parameter element
}		
[a)] The PE is specified in Table A.12. And the value of its length depends on the parameter content.		

Table A.7 – ACK payload

Field	Length (bit)	Function
RSVD	2	Reserved
ACK_SN	6	Sequence number of the ACK frame

Table A.8 – CMP_REPORT frame payload

Field	Length (bit)	Function
PE_NUM	8	Number of parameter elements
for (i=0; i<PE_NUM; i++) {		
PE	variable[a)]	Parameter element
}		
[a)] The PE is specified in Table A.12. And the value of its length depends on the parameter content.		

Table A.9 – LINK_UPDATE frame payload

Field	Length (bit)	Function
LINK_UPDATE_SN	8	Sequence number of LINK_UPDATE frame, with a maximum value of 0x3: 0x3 – First LINK_UPDATE 0x2 – Second LINK_UPDATE 0x1 – Third LINK_UPDATE All other values reserved
RSVD	48	Reserved

Table A.10 – QUIT_ACK frame payload

Field	Length (bit)	Function
NOTE – This type of downlink signalling frame does not have fixed part in payload.		

Table A.11 – POWER_CTRL frame payload

Field	Length (bit)	Function
Action	2	Indicates the power adjustment scheme. The magnitude of the adjustment is determined by the value of Range A and Range B: 0x2 – Increase power 0x3 – Reduce power All other values reserved
Range A	3	Adjustment magnitude (on a large scale). (Recommendation: use 3 dB as the basic unit)
Range B	3	Adjustment magnitude (on a small scale). (Recommendation: use 0.5 dB as the basic unit)

Table A.12 – PE (parameter element)

Field	Length (bit)	Function
CODE	8	Type of parameters transmitted: 0x1 – OFDM modulation parameters 0x2 – Power control parameters and time and frequency offset 0x3 – Delay compensation value 0x4 – SCG_Ru position of R frame 0x5 – Data frame retransmission (ARQ) enable flag 0x6 – Profile Group information All other values reserved
LENGTH	16	Total length of this PE, in bytes
CONTENT	Specified as below	Specific parameter content corresponding to the value of CODE field, defined as below.
If CODE = 1		
CONTENT	480	Bit 3-0 – Effective sub-carrier group 1 0x2 – QPSK 0x3 – 8 QAM 0x4 – 16 QAM 0x5 – 32 QAM 0x6 – 64 QAM 0x7 – 128 QAM 0x8 – 256 QAM 0x9 – 512 QAM 0xa – 1024 QAM 0xb – 2048 QAM 0xc – 4096 QAM 0xd – 8192 QAM 0xe – 16384 QAM All other values reserved ……

Table A.12 – PE (parameter element)

Field	Length (bit)	Function
		Bit 479-476 – Effective sub-carrier group 120 0x2 – QPSK 0x3 – 8 QAM 0x4 – 16 QAM 0x5 – 32 QAM 0x6 – 64 QAM 0x7 – 128 QAM 0x8 – 256 QAM 0x9 – 512 QAM 0xa – 1024 QAM 0xb – 2048 QAM 0xc – 4096 QAM 0xd – 8192 QAM 0xe – 16384 QAM All other values reserved
If CODE = 2		
CONTENT	32	Bit 7-0 – Power Bit 15-8 – Time offset Bit 31-16 – Frequency offset
If CODE = 3		
CONTENT	16	Delay compensation value for HM (in unit of TICK_TIME, 1/128 μs)
If CODE = 4		
CONTENT	32	SCG_RU number used in R frame transmission for the HM Bit 7-0 – The value of m in the first scheduled SCG_Ru(m, n) Bit 15-8 – The value of n in the first scheduled SCG_Ru(m, n) Bit 23-16 – The value of m in the second scheduled SCG_Ru(m, n) Bit 31-24 – The value of n in the second scheduled SCG_Ru(m, n)
If CODE = 5		
CONTENT	7	Reserved
	1	Data frame retransmission (ARQ) enabled flag: 0x0 – Disable data frame retransmission function 0x1 – Enable data frame retransmission function
If CODE = 6		
CONTENT	480	Profile Group modulation information Bit 3-0 – Subcarrier group 1 0x2 – QPSK 0x3 – 8 QAM

Table A.12 – PE (parameter element)

Field	Length (bit)	Function
		0x4 – 16 QAM 0x5 – 32 QAM 0x6 – 64 QAM 0x7 – 128 QAM 0x8 – 256 QAM 0x9 – 512 QAM 0xa – 1024 QAM 0xb – 2048 QAM 0xc – 4096 QAM 0xd – 8192 QAM 0xe – 16384 QAM All other values reserved …… Bit 479-476 – Subcarrier group 120 0x2 – QPSK 0x3 – 8 QAM 0x4 – 16 QAM 0x5 – 32 QAM 0x6 – 64 QAM 0x7 – 128 QAM 0x8 – 256 QAM 0x9 – 512 QAM 0xa – 1024 QAM 0xb – 2048 QAM 0xc – 4096 QAM 0xd – 8192 QAM 0xe – 16384 QAM All other values reserved
	64	HM nodes contained in the current Profile Group. If a node is within the current Profile Group, the corresponding bit value is 1, otherwise the corresponding bit value is 0. Bit 63~0 corresponds to HM nodes on the current channel with Node ID 64~1
	3	Profile Group indication, with values of 0-7 indicating profile groups with PGID of 0x41-0x48 correspondingly
	5	Reserved

The structure of the downlink/uplink signalling frame header/payload expansion section is shown in Table A.13.

Table A.13 – Downlink/uplink signalling frame header/payload expansion section

Field	Length (bit)	Function
TLV_NUM	8	Number of TLV-coded fields
for (i=1; i≤TLV_NUM; i++) {		
TYPE	8	Type
LENGTH	8	Length
VALUE	Variable[a)]	Value
}		
[a)] The TLV coding format is specified in Table A.14. And the length of the VALUE field depends on the information Type indicated by the TYPE field.		

The TLV coding format involved in downlink/uplink signalling frames and data frames is shown in Table A.14.

Table A.14 – TLV code

Field	Length (bit)	Function
TYPE	8	Information type: System defined types: 0x00-0xBF 0x00-0x0E – Reserved 0x0F – Device ID assigned 0x10 – Transmitting power and receiving gain 0x11 – Indication of Pu frame slot 0x12 – FEC format supported 0x13 – FEC format adopted 0x14 – The maximum interleaving depth supported 0x15 – The interleaving depth adopted 0x16 – Number of subcarriers that SSC contains 0x17 – Channel frequency list 0x18 – OFDMA mode enable flag 0x20 – Detailed report of queues information 0x21 – Frame sequence number 0x22 – Receiving member list of the frame 0x23 – Multicast group identification 0x30 – MAP cycle length 0x31 – Starting position of the MAP frame time slot relative to the MAP period 0x32 – Starting position of the R frame time slot relative to the MAP period 0x33 – Number of OFDM symbols occupied by MAP frame 0x34 – Number of OFDM symbols occupied by R frame 0x35 – Length of the FUNCTION field in the AU unit 0x36 – Complex mode support capability of channel bonding multicast transmission

Table A.14 – TLV code

Field	Length (bit)	Function
		0x37 – Complex mode enable flag of channel bonding multicast transmission All other values reserved User defined types: 0xC0-0xFF
LENGTH	8	Length of VALUE field (in bytes)
VALUE	Specified as below	The detailed content corresponding to the value of TYPE field, specified as below
If TYPE = 0x0F		
VALUE	8	The value of 0 indicating that no Device ID has been assigned to the HM or the HM hasn't obtained a Device ID The value of 1-128 indicating the Device ID assigned by the system to the HM
If TYPE = 0x10		
VALUE	32	Bit 31-16 – HB transmitting power Bit 15-0 – HB receiving gain
If TYPE = 0x11		
VALUE	8	Pu frame time slots used by this HM to make uplink channel training Bit 7-4 – Corresponding to Pu frame time slot 9 ~ time slot 6 Bit 3-0 – Corresponding to Pu frame time slot 4 ~ time slot 1 Setting to 1 indicates that the time slot can be used for uplink channel training on the HM, and setting to 0 indicates that the slot cannot be used for uplink channel training on the HM
If TYPE = 0x12		
VALUE	8	The FEC format supported by the node: setting to 1 indicates to support the corresponding FEC format and setting to 0 indicates not to support the corresponding FEC format. Bit 0 – (1920, 1744) truncated BCH code Bit 1 – (1920, 1040) truncated BCH code Bit 2 – (1920, 1728) LDPC code Bit 3 – (3840, 3456) LDPC code Others – Reserved
If TYPE = 0x13		
VALUE	8	The FEC format used by the PHY layer. 0x0 – No FEC 0x1 – (1920，1744) truncated BCH code 0x2 – (1920，1040) truncated BCH code 0x3 – (1920，1728) LDPC code 0x4 – (3840，3456) LDPC code

Table A.14 – TLV code

Field	Length (bit)	Function
		Others – Reserved
If TYPE = 0x14		
VALUE	8	The maximum interleaving depth supported by the current node, setting to 0 indicates that interleaving is not supported
If TYPE = 0x15		
VALUE	8	Interleaving depth of PHY layer Adopted. Setting to 0 indicates that no interleaving is used
If TYPE = 0x16		
VALUE	8	Number of subcarriers within an SSC. 0x04 – 16 0x05 – 32 0x06 – 64 0x07 – 128 0x08 – 256 0x09 – 512 0x0A – 1024 0x0B – 2048 Others – Reserved
If TYPE = 0x17		
VALUE	8	List of available channel frequencies for the current device, as an extension of the payload in the ADM_RES, ADM_REQ and REJ frame
If TYPE = 0x18		
VALUE	8	OFDMA mode enable flag for data transmission. Bit 0: Setting to 1 indicates OFDMA mode is enabled, and setting 0 indicates OFDMA mode is not enabled. Others – Reserved
If TYPE = 0x20		
VALUE	128	Report of 8 priority queues information in this HM, definition is specified as below, in granularity of 16 bytes (rounded up to an integer): Bit 127-112 – the length of queue 7 Bit 111-96 – the length of queue 6 Bit 95-80 – the length of queue 5 Bit 79-64 – the length of queue 4 Bit 63-48 – the length of queue 3 Bit 47-32 – the length of queue 2 Bit 31-16 – the length of queue 1 Bit 15-0 – the length of queue 0
If TYPE = 0x21		
VALUE	16	The sequence number of the current HiMAC3.0 data frame: 0-65535

Table A.14 – TLV code

Field	Length (bit)	Function
If TYPE = 0x22		
VALUE	64	The receiving member list of the frame. Bit 0-63 – Corresponding to HM nodes with the current channel Node ID of 1~64 respectively. Setting to 1 indicates that the corresponding HM should receive the current frame. and setting to 0 indicates that the corresponding HM should not receive the current frame
If TYPE = 0x23		
VALUE	24	Multicast group identifier, with a value of the lower 24 bits of the multicast address of the EMAC frame carried by the current HiMAC3.0 multicast frame
If TYPE = 0x30		
VALUE	16	The length of the MAP cycle (N_{MAP_SYMBOL}) in the Pd cycle. 0x01 – 32 OFDM symbols 0x02 – 64 OFDM symbols 0x03 – 128 OFDM symbols 0x04 – 256 OFDM symbols Others – Reserved
If TYPE = 0x31		
VALUE	16	The start position of the MAP frame time slot relative to the MAP period in which it is located, in units of OFDM symbols, with a value of ≥ 1
If TYPE = 0x32		
VALUE	16	The start position of the R frame time slot relative to the MAP period in which it is located, in units of OFDM symbols, with a value of ≥ 1
If TYPE = 0x33		
VALUE	8	The number of OFDM symbols occupied by MAP frame
If TYPE = 0x34		
VALUE	8	The number of OFDM symbols occupied by R frame
If TYPE = 0x35		
VALUE	8	The length of the AU unit FUNCTION field in a MAP frame, in bits
If TYPE = 0x36		
VALUE	8	Channel bonding multicast transmission complex mode support capability. Bit 0 – Whether the current node supports channel bonding multicast transmission complex mode. Setting to 1 indicates the mode supported, and setting to 0 indicates the mode not supported. Bit 7-1 – Reserved

Table A.14 – TLV code

Field	Length (bit)	Function
If TYPE = 0x37		
VALUE	8	Complex mode enable flag of channel bonding multicast transmission. Bit 0 – Whether to enable complex mode function of channel bonding multicast transmission. Setting to 1 indicates the function enabled, and setting to 0 indicates the function not enabled. Bit 7-1 – Reserved

A.1.2 Uplink signalling frame format

The structure of the fixed part in the uplink signalling frame header is shown in Table A.15.

Table A.15 – Uplink signalling frame header

Field	Length (bit)	Function
DESTINATION_NODE_ID	8	Destination node ID: 0x0 – HB's Node ID
SOURCE_NODE_ID	8	Source node ID (HM's Node ID)
FRAME_LENGTH	8	Frame length (including the header and payload), in bytes
FRAME_TYPE	4	Uplink signalling frame type: 0x1 – EMPTY frame 0x2 – ADM_REQ frame 0x3 – ADM_ACK frame 0x4 – REJ_ACK frame 0x5 – ACK frame 0x6 – DLINK_REPORT frame 0x7 – QUIT frame All other values reserved
VERSION	4	HiNoC version supported by the HM, one bit corresponding to a HiNoC version Bit 0 – For HiNoC 1.0, setting 1 indicates to support HiNoC 1.0, setting 0 indicates not to support HiNoC 1.0 Bit 1 – For HiNoC 2.0, setting 1 indicates to support HiNoC 2.0, setting 0 indicates not to support HiNoC 2.0 Bit 2 – For HiNoC 3.0, setting 1 indicates to support HiNoC 3.0, setting 0 indicates not to support HiNoC 3.0 Bit 3 – Reserved

Table A.15 – Uplink signalling frame header

Field	Length (bit)	Function
FF	1	FRAGMENT FLAG: 0x0 – Do not fragment 0x1 – Fragment
LFF	1	LAST FRAGMENT FLAG: 0x0 – Not the last fragment 0x1 – Last fragment
FSN	6	FRAGMENT SEQUENCE NUMBER
PREEQ_EN	2	Pre-equalization supported flags: 0x0 – Not to support pre-equalization 0x1 – To support pre-equalization All other values reserved
CHANNEL_NUM	3	The uplink signalling frame channel number to transmit this uplink signalling frame
RSVD	1	Reserved
EXT_HEADER_INFO	1	Whether there is extended part after fixed part in the header: 0x0 – No 0x1 – Yes
EXT_PAYLOAD_INFO	1	Whether there is extended part after fixed part in the payload: 0x0 – No 0x1 – Yes

The structure of the uplink signalling frame tail is shown in Table A.16.

Table A.16 – Uplink signalling frame tail

Field	Length (bit)	Function
CRC	32	Cyclic redundancy check

The structure of the fixed part of the uplink signalling frame payload is shown in Tables A.17 to A.23.

Table A.17 – EMPTY frame payload

Field	Length (bit)	Function
NOTE – This type of uplink signalling frame does not have fixed part in payload.		

Table A.18 – ADM_REQ frame payload

Field	Length (bit)	Function
USER_ID	96	User identification
PASSWORD	96	User password
ARQ_SPTD	1	Whether to support ARQ protocol: 0x0 – Not to support ARQ protocol 0x1 – To support ARQ protocol
EISF_SPTD	1	Whether to support EISF: 0x0 – Not to support EISF 0x1 – To support EISF
OFDMA_SPTD	1	Whether to support OFDMA mechanism to transmit data frame: 0x0 – Not to support OFDMA 0x1 – Support OFDMA
TERMINAL_TYPE	3	Type of HM: 0x0 – 128 MHz HM 0x1 – 256 MHz HM 0x2 – 384 MHz HM 0x3 – 512 MHz HM 0x4 – 640 MHz HM 0x5 – 768 MHz HM 0x6 – 896 MHz HM 0x7 – 1024 MHz HM
RSVD	2	Reserved
NODE_PROTOCOL_SUPPORT	8	The higher layer protocol supported by this node: Bit 0 – 0x1, indicates to support Ethernet protocol Bit 7:1 – Reserved
HM_GUID	48	Hardware address of this HM

Table A.19 – ADM_ACK frame payload

Field	Length (bit)	Function
NOTE – This type of uplink signalling frame does not have fixed part in payload.		

Table A.20 – REJ_ACK frame payload

Field	Length (bit)	Function
NOTE – This type of uplink signalling frame does not have fixed part in payload.		

Table A.21 – ACK frame payload

Field	Length (bit)	Function
RSVD	2	Reserved
ACK_SN	6	Sequence number of the ACK frame

Table A.22 – DLINK_REPORT frame payload

Field	Length (bit)	Function
PE_NUM	8	Number of parameter elements
for (i=0; i< PE_NUM; i++) {		
PE	variable[a)]	Parameter element, with the same definition as that in downlink signalling frame
}		
a) The PE is specified in Table A.12. And the value of its length depends on the parameter content.		

Table A.23 – QUIT payload

Field	Length (bit)	Function
REASON	8	Reasons an HM quits the HiNoC network: 0x1 – Quit normally 0x2 – Channel condition is bad The above values indicate that the HM quits the current channel. 0x81 – Quit the entire network All other values reserved
HM_GUID	48	Hardware address of this HM

A.2 Control frame format

The structure of the MAP control frame is shown in Tables A.24 and A.25.

Table A.24 – MAP frame

Field	Length (bit)	Function
MAP_ID	8	The number of this MAP cycle in the Pd cycle
AU_NUM	8	The number of channel allocation units in this MAP cycle
MAP_LENGTH	16	MAP frame length, in bytes
SSC_MAP{		SSC usage pattern, composed of AU_ NUM channel allocation units (AUs)
for (i=0; i<AU_NUM; i++) {		

Table A.24 – MAP frame

Field	Length (bit)	Function
AU	Variable[a)]	The definition of channel allocation unit (AU): AU_TYPE (8bit): The type of current channel allocation unit 0x00 – Idle SSC 0x01-0x40 – HM's Node ID 0x41-0x48 – Profile Group ID 0x49 – Multicast transmission 0x4A – Broadcast transmission 0x7F – Downlink/uplink reverse interval Other values – Reserved FUNCTION (variable length): When AU_TYPE is 0x7F, this field represents the offset of the reverse interval relative to the starting position of the MAP cycle, in SSCs; When AU_TYPE is a different value, this field represents the number of SSCs assigned to it or idle SSCs
}		
}		
Padding	Variable[b)]	Padding, to ensure that the length of all fields in the current MAP frame reaches the specified MAP frame length
for (i=0; i<64; i++) {		
HM_STATE	1	The $(i+1)^{th}$ HM's online state: 0x0 – Offline (not admitted or deleted) 0x1 – Online (admitted)
}		
RSVD	64	Reserved
CRC	32	Cyclic redundancy check

a) The length of AU field is equal to the sum of the lengths of sub-fields AU-TYPE and FUNCTION. The length of FUNCTION sub-field is variable and noticed by TLV coding block in signalling frame.

b) The length of Padding field is equal to the MAP frame length minus the length of all the other fields.

Table A.25 – R frame

Field	Length (bit)	Function
for (i=7; i>0; i--) {		
Q_FLAG#i	1	Queue information of queue i
}		
QUIT_IND	1	Quitting indication. A value of 0x1 indicates to the HB that the HM is quitting from the channel

Table A.25 – R frame

Field	Length (bit)	Function
LM_REQ	1	Request for link maintenance, setting 1 indicates that HM requests link maintenance
QUIT_FLAG	1	Indicates whether to quit the current channel, effective when QUIT_IND is 1 0x1 – Quit the current channel 0x0 – Quit the entire network
RSVD	3	Reserved
CRC	4	Cyclic redundancy check

A.3 Data frame format

The structure of the data frame is shown in Tables A.26 to A.29.

Table A.26 – HiMAC3.0 data frame header

Field	Length (bit)	Function
NODE_ID	8	Node ID of the node transmitting this HiMAC3.0 frame: For Du frame, this field represents the source Node ID. For Dd frame, this field represents the destination Node ID. Value: 0x01-0x40 – Node ID of a specified HM node 0x49 – Multicast data frame 0x4A – Broadcast data frame All other values reserved
EH_FLAG	1	Extended header flag: 0x0 – The byte following the header is not an extended header byte 0x1 – The byte following the header is an extended header byte
SUBFRAME_NUM	3	The value is n ($n \geq 0$), indicating the number of encapsulated subframes
F_SEGMENTATION_H_FLAG	1	The first EMAC subframe segmentation (header) flag, setting to 1 indicates that the first EMAC subframe (i.e., not including EISF) contains an EMAC header
F_SEGMENTATION_E_FLAG	1	The first EMAC subframe segmentation (tail) flag, setting to 1 indicates that the first EMAC subframe contains an EMAC tail
L_SEGMENTATIONT_H_FLAG	1	The last EMAC subframe segmentation (header) flag, setting to 1 indicates that the last EMAC subframe contains an EMAC header

Table A.26 – HiMAC3.0 data frame header

Field	Length (bit)	Function
L_SEGMENTATION_E_FLAG	1	The last EMAC subframe segment (tail) flag, setting to 1 indicates that the last EMAC subframe contains an EMAC tail
EH_FLAG (optional)	1	Extended header flag: 0x0 – The byte following this byte is not an extended header byte 0x1 – The byte following this byte is an extended header byte
EISF_FLAG (optional)	1	Whether the first subframe is EISF or not: 0x0 – The first subframe is not EISF 0x1 – The first subframe is EISF
RSVD (optional)	2	Reserved
VERSION (optional)	1	Data frame version 0x0 – This data frame is a HiNoC 2.0 data frame 0x1 – This data frame is a HiNoC 3.0 data frame
Pri (optional)	3	Priority, setting 0 indicates the lowest priority, and setting 7 indicates the highest priority

Table A.27 – HiMAC3.0 data frame payload

Field	Length (bit)	Function
for (i=0; i<N; i++) {		N is the number of subframes
SUBFRAME_LENGTH	8	The length of the corresponding subframe (in bytes)
}		
for (i=0; i<N; i++) {		N is the number of subframes
SUBFRAME	Indicated by the corresponding SUBFRAME_LENGTH field	The content of a subframe
}		
PADDING	≥ 0	Padding field, the content is all 0s

Table A.28 – HiMAC3.0 data frame tail

Field	Length (bit)	Function
CRC	16	Cyclic redundancy check

Table A.29 – EISF format

Field	Length (bit)	Function
for (i=1; i≤N; i++) {		N is the number of TLV code fields (N ≥ 1). The definition of TLV is shown in Table A.14
TYPE	8	Type
LENGTH	8	Length
VALUE	variable[a)]	Value
}		
CRC	32	Cyclic redundancy check
a) The TLV coding format is specified in Table A.14. And the length of the VALUE field depends on the information Type indicated by the TYPE field.		

Annex B

MAC layer constants

(This annex forms an integral part of this Recommendation.)

The constants and their values used in the MAC layer are specified in this annex. The constants used in the MAC layer frame structure are specified in Table B.1, and the constants used in medium access control and channel allocation are specified in Table B.2. The constants used in the node admission process are specified in Table B.3.

Table B.1 – MAC layer frame structure constants

Constant	Value	Explanation
N_{SF}	For HiNoC 2.0+ channels: 496 For HiNoC 3.0 channels: 3968	The length of downlink/uplink signalling frame (in bits)
L_{MAP_FRAME}	For HiNoC 2.0+ channels: 744 For HiNoC 3.0 channels: 1984*number of MAP frame symbols	The length of the MAP frame (in bits)
L_{R_FRAME}	18	The length of the R frame (in bits)
L_{HIMAC}	Conform to Table B.1 in Annex B of [ITU-T J.196.3]	The length of HiMAC3.0 data frame (in bits)

Table B.2 – Medium access control and channel allocation constants

Constant	Value	Explanation
T_{R_IFG}	1 OFDM symbol (the length of OFDM symbol is calculated based on the CP length of data frame)	The length of the frame gap between adjacent downlink/uplink frames and uplink/downlink frames
T_{P_IFG}	3 OFDM symbols (the length of an OFDM symbol is calculated based on the CP length of Pd/Pu frame)	The length of the frame gap following Pd/Pu frames
N_{NO_R}	Recommended value: 1000	The maximum times for the HB to continuously not to receive one HM's R frame
T_{KA}	Recommended value: 2 s	The maximum time duration for an HM not to receive online state indication in a MAP frame transmitted by the HB

Table B.3 – Node admission constants

Constant	Value	Explanation
TL1	3 s	Maximum time for the HB and an NHM to monitor the downlink signalling frame in each channel during network searching
TL2	12 s	Maximum time for an NHM to complete downlink power control and downlink training

Table B.3 – Node admission constants

Constant	Value	Explanation
NA1	6	Maximum number of ADM_REQ frames an NHM transmits
TA1	8 s	Maximum time to admit a new node after HB/NHM completes downlink training
TA2	2 s	Maximum time for the HB to receive all DLINK_REPORT fragments
TA3	5 s	Maximum time for the HB/NHM to complete uplink power control, uplink training and ranging
TA4	2 s	Maximum time for an NHM to receive all ULINK_REPORT fragments
N01	3	Maximum number of times to transmit a signalling frame
N02	3	Number of times for the HB to broadcast/grouping-broadcast the LINK_UPDATE/CMP_REPORT/REJ frame
N03	30	Maximum number of adjustments for an HB/NHM/HM to execute uplink/downlink power control
TC1	600 ms	Maximum time to wait for CMP_REPORT fragments
T01	40 ms	Recommended time for an HB/NHM/HM to wait for the next uplink/downlink signalling frame after transmitting a downlink/uplink signalling frame
T02	600 ms	Maximum time for an HM to wait for the LINK_UPDATE frame after receiving all CMP_REPORT fragments

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