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Re: A response to a Call for Technical Comments and Contributions regarding IEEE Project 802.16j, http://wirelessman.org/relay/docs/80216j-07_007r2.pdf

Abstract This contribution proposes the use of dedicated uplink channel as a bandwidth resource for RS to transmit upstream control signaling and data traffic. This dedicated channel simplifies operation, minimizes delay and protocol overhead when compared with extending the existing bandwidth request and allocation mechanism for MMR network operation. The dedicated channel is also an effective control and transport mechanism for support of minimum delay in centralized multi-hop relay networks.

Purpose To incorporate the proposed text into the P802.16j Baseline Document (IEEE 802.16j-06/026)

Dedicated Resource Assignment for RS

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1. Introduction

The control information exchanged between an MR-BS and RSs includes channel quality information, bandwidth requests, topology change information, ranging information, and other control signaling. Excessive delay in this information transfer will have an adverse effect on the performance of the network. For efficient operation of the network (e.g., handover, improved throughput, backward compatibility with legacy MSs, etc), RSs should be able to deliver information to the MR-BS in a timely manner.

The basic mechanism by which bandwidth is allocated between the MR-BS and the RS is the contention bandwidth request and allocation procedure. The basic design of the bandwidth request and allocation procedure for 802.16e is based on the characteristics and requirements of MS. As an RS will be serving a number of MS(s), (and perhaps also a number of RSs) it will require frequent UL transmission to service the concentration of traffic and changing requirements of the subtending MSs or RSs. The RS behavior and traffic requirements are different from that of an MS.

The transport mechanisms for control messages currently provided by the IEEE 802.16e are adequate for the operation of single hop access networks, but are less well suited for the purpose of relay networks. Figure shows an example message flow chart, where an MS is taking a contention based bandwidth request procedure defined in Section 6.3.6.7.2 of 802.16j-06/026r2 (See also C802.16j-07/039r3.). In Figure , the CDMA code transmitted by the RS is not very reliable since the transmission can be involved in a collision. For the purpose of transporting management messages, a more reliable mechanism is required.

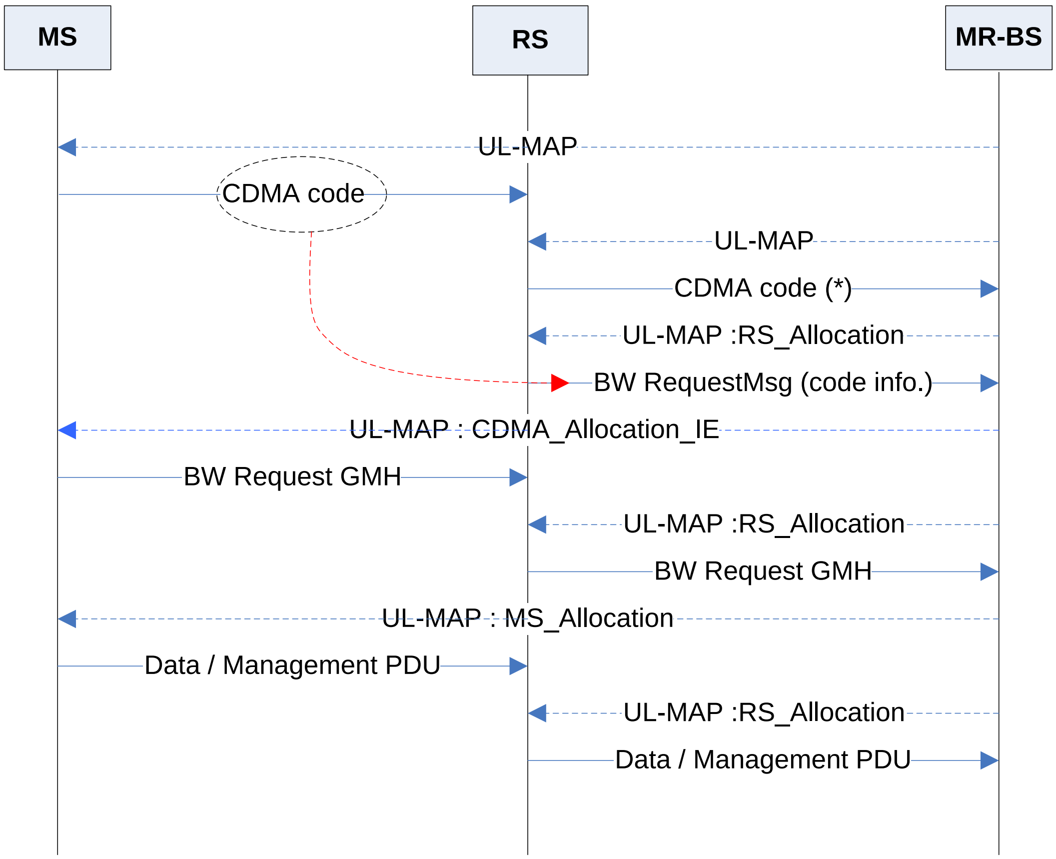

Figure 1 Contention based bandwidth request and allocation.

Contention based packet transmission scheme is event driven. This is efficient in terms of resource utilization for traffic from individual MSs. However, contention based bandwidth allocation is not as efficient for aggregated traffic from multiple MSs across RS to MR-BS links. When an RS needs to transmit many control messages occurring periodically or randomly in time to the MR-BS, the need to send bandwidth request for every single control message is highly inefficient.

2. Proposed Solution

The proposed solution to the problem is to allocate a dedicated resource between an MR-BS and an RS for the purpose of transporting control messages or data traffic. By allocating uplink bandwidth to an RS, the RS can transmit control messages whenever necessary to the MR-BS without having to request bandwidth. Figure 2 illustrates this dedicated resource for a multi-hop network.

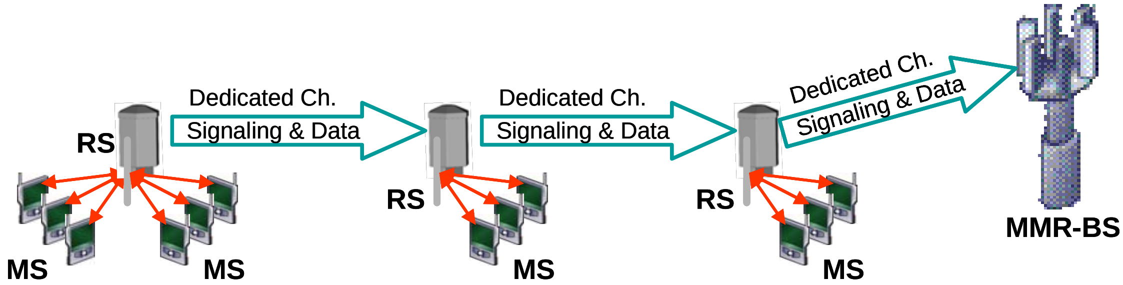

Figure 2: Multi-hop uplink transmission through dedicated channel allocation

The dedicated uplink channel enables a tight coupling between MMR-BS with its RS(s) to serve MS effectively. It is applicable to both distributed and centralized resource management. For centralized management, it is more like a backhaul of control signaling messages and data traffic to the MMR-BS. For distributed management, signaling that can be handled locally is managed by the RS and requests to the MR-BS can be aggregated to further reduce the amount of signaling messages needed to go through the RS hops towards the MR-BS.

Resource Allocation at RS Network Entry

After initial network entry procedure of an RS, a dedicated control channel will be allocated to the RS at the request of the RS or the MR-BS. If the MR-BS does not allocate a dedicated control channel to an RS, the RS can request an allocation.

The RS will be assigned the minimum or larger size of dedicated resource by its upstream serving station (MR-BS or RS). The minimum size is large enough for a signaling message, it is available once every N frames. This initial resource is used by the RS to initiate the continuous operations of the dedicated channel. For example, the size can be updated, when appropriate, to a larger (or smaller) size for both signaling and data traffic according to the BW requirement of the RS. The BW requirement can be computed by the RS, periodically or as needed by traffic and signaling events, to ensure adequate signaling and data traffic flows. For centralized resource management, the initial assignment and all subsequent updates are done by the MMR-BS only.

The dedicated channel allocation is assigned through R-MAP IE within the RS-Zone. The allocation is available starting in the same frame when the R-MAP IE is received by the RS. The R-MAP IE is the MAP information element used to allocate resources for the relay link.

If traffic conditions do not warrant the continued allocation of the dedicated resource, the MR-BS can terminate or decrease the bandwidth of the dedicated resource without request from the RS. The RS may request a decreased bandwidth or return the resource if it is no longer necessary.

The following figure 3 illustrates the allocation of the dedicated resource between an MR-BS and an RS. This figure indicates that a dedicated resource allocation is performed as part of the procedure whereby the RS joins the network. There is thereafter a persistent scheduling of the resource between the MR-BS and the RS. This resource may used by the RS to respond to subsequent events with its subtending MSs.

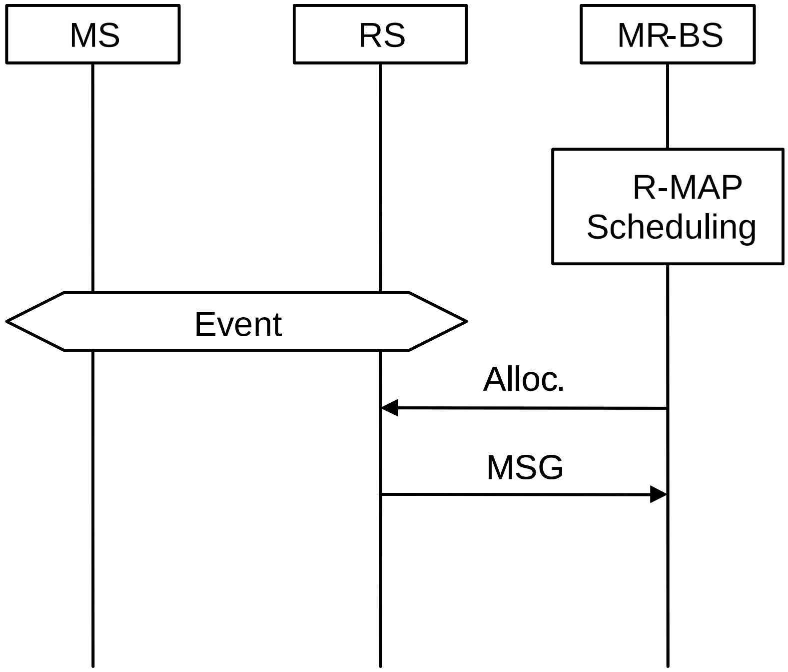

Figure 3: Allocation of dedicated resource between MR-BS and RS.

Variable Resource Allocation

The bandwidth of the dedicated resource can be updated, when appropriate, to a larger (or smaller) value according to the BW requirements of the relay. The BW requirement can be computed or estimated, periodically or as needed by events, by the RS to ensure adequate signaling and data traffic flows. These events may include, for example: changes in traffic flows, changes in signaling requirements, detection of possible handover due to approaching MS, association of new MS (etc.).

Rate based allocation

An RS may calculate the average data rate of a connection based on the traffic from the MSs. That is, the average data rate may be used to represent the long term statistics of the MSs. The dedicated resource may be set initially based on the measured statistics or adjusted at other times to match changing traffic statistics.

Due to fluctuations in the traffic there will be cases when the dedicated resource does not perfectly accommodate the traffic needs. When the dedicated resource is not large enough to handle the traffic, the bandwidth request procedure will be used to request and allocate additional resources. If the dedicated resource is greater than required, the MR-BS or the RS may reduce or return the dedicated allocation.

Note that the rate based allocation mechanism is particularly useful to the near-constant bit rate connections such as rtPS, ertPS, and nrtPS. On the other hand, since a bursty connection (e.g. a BE connection) might show a large fluctuation in BR, an RS may aggregate BRs of bursty connections from the same class.

3. Delay Analysis: Multihop Delay Benefit with Dedicated Allocation

The following analysis provides some guidelines on how dedicated resources are allocated at MRBS as well as for the multihop relays. It also demonstrates the delay benefit for best effort traffic when comparing with BW request mechanisms described in the baseline text.

Resources Availability at MRBS and Relay

The simplified illustration in Figure 4 describes the resources availability at both the MRBS and relay for supporting multihop UL data transfer. The MRBS is serving four 1st hop relays, whereas RS_{12} is serving two 2nd hop relays (RS_{21} & RS_{22}).

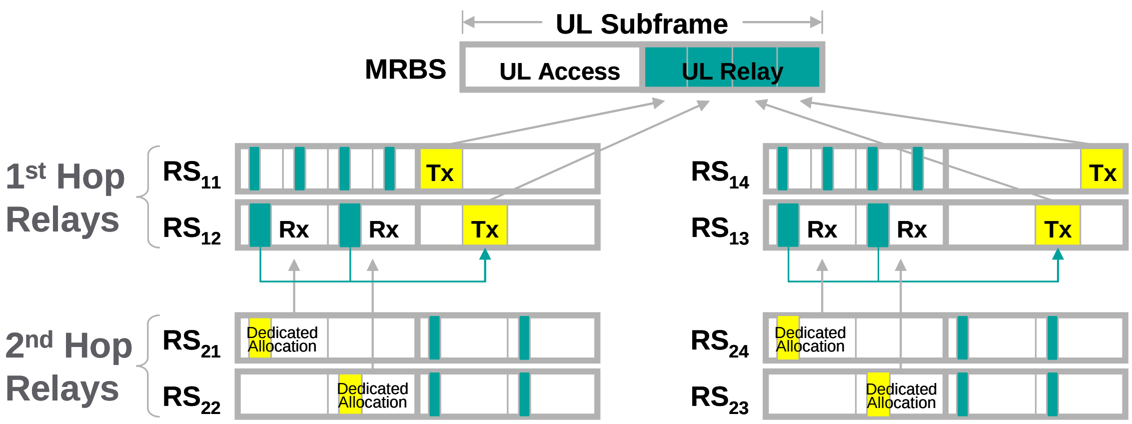

Figure 4: Resources Availability at MRBS and Relay.

The size of the colored blocks depicts the actual average resources used by each relay for data traffic upload. Each of the four 1st hop relays contributes, on average, a quarter of the traffic to fill up the UL relay resource at MRBS. As indicated, the second hop relays (RS_{21} & RS_{22}) are allocated four times the resources needed by their parent RS_{12} and the overall throughput capacity is not impacted even when the 2nd hop relays, on average, only use one quarter of the allocated bandwidth. As such it is possible for loosely dedicated resource allocation at the relay to its child relays. In terms of aggregate capacity, BW resources are not wasted unless they are wasted at the MRBS. Hence, a tighter UL dedicated resources management can be applied to the first hop when needed.

Analysis Assumptions

The following are the assumption used for the analysis:

- Best effort traffic: single burst upload.
- Three hops connection.
- First hop UL dedicated resources are allocated once every frame but enough for a BW request header. After receiving a BW request header, the MRBS can allocate additional resources as requested. As the first hop link is the final concentrated link to the MRBS, the dedicated resources are expected to be filled when the network is loaded.
- All subsequent hops, the UL dedicated resources are also allocated once every frame but for both signaling and data traffic.
- For dedicated resource under centralized allocation, each RS that serves mobiles has dedicated resources already pre-allocated by the MRBS to the RS to serve its mobiles. The RS can use these pre-allocated resources to grant BW request to any of its mobiles.

Analysis Results

The flow of signaling and data burst based on the dedicated resource allocation and BW request in the baseline text are shown in Figure 5 and 6 respectively.

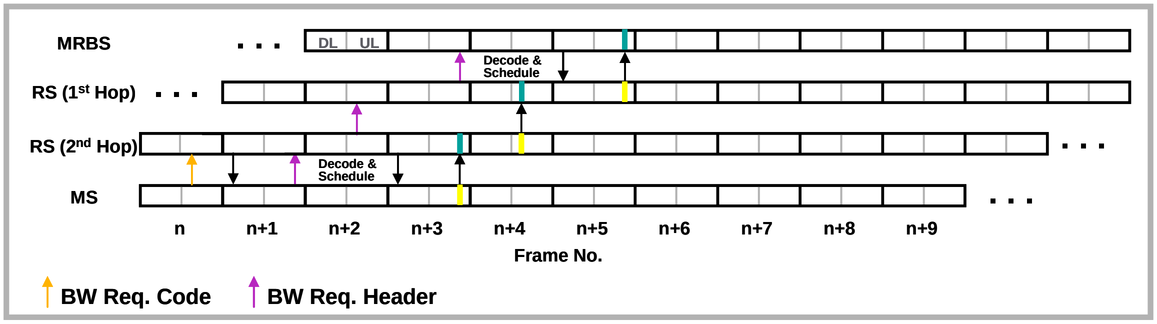

Figure 5: Delay Analysis for Dedicated Resource Allocation.

With dedicated resource allocation, shown in Figure 5 for a three hops link, the MS UL delay to transmit a burst of data is 6 frames from the first frame when the MS sends in the BW request ranging code. The MS UL delay can be generalized to the following:

MS Tx Delay for UL burst = H + 3, where H is the number of hops the MS is from the MRBS.

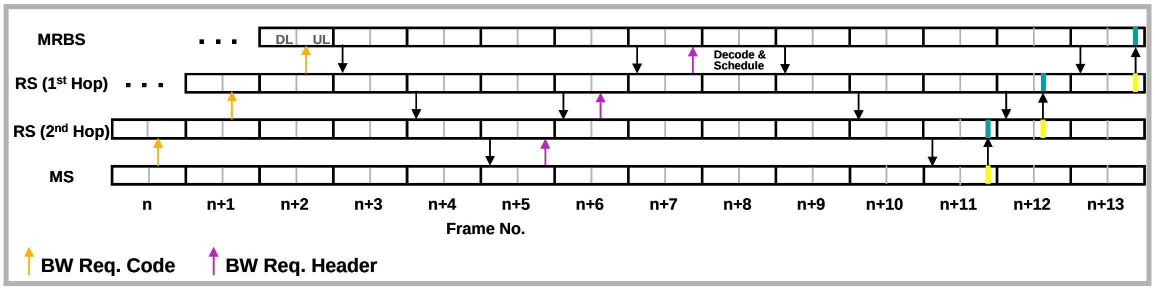

Figure 6: Delay Analysis for BW Request in Baseline Text.

For the case with the BW request in the baseline text, shown in Figure 6 for the same three hops link, the MS UL delay to transmit a burst of data is 14 frames. The MS UL delay can be generalized to the following:

MS Tx Delay for UL burst = 5H - 1, where H is the number of hops the MS is from the MRBS.

The results summary of the delay analysis is shown in Figure 7. When comparing the BW request in the baseline text with the dedicated approach, the baseline BW request incurs 5 : 1 in additional delay for each additional hop added to the path.

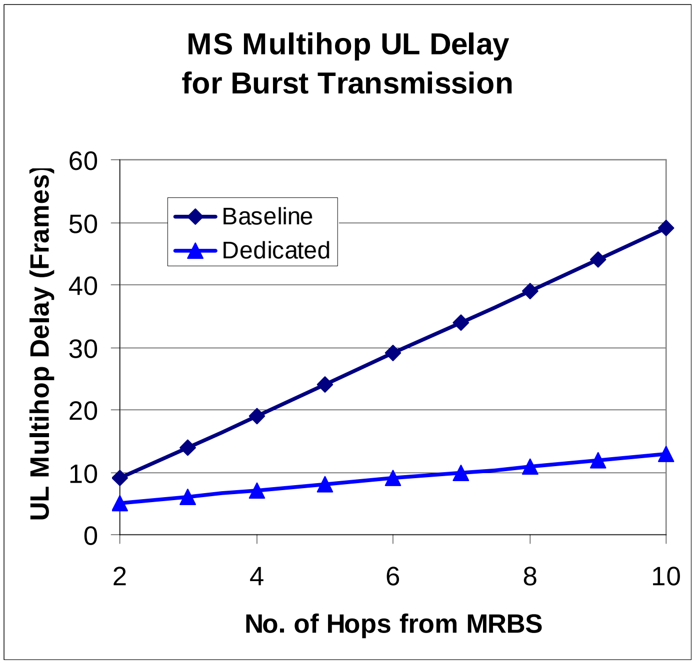

Figure 7: Summary of Delay Analysis.

With dedicated resource allocation, the MS Multihop UL delay can be significantly improved for both control and data traffic.

4. Text Proposal

4.1 Dedicated relay uplink channel allocation using request header

+++++++++++++++ Start Text Proposal +++

[Change subclause 6.3.2 as indicated]

6.3.2 MAC PDU Formats

6.3.2.1 MAC Header Format

6.3.2.1.1 Generic MAC header

6.3.2.1.1.2 Relay Mac PDU header format (UL)

6.3.2.1.1.2.1 RS UL DCH Request Header

The RS requests a dedicated uplink resource through the RS UL request header.   This header is as follows:

<table>
<tr><td colspan="2">RMI = 0b1110
(4)</td><td>HT = 1
(1)</td><td>TYPE
(5)</td></tr>
<tr><td></td><td>DCH TYPE
(2)</td><td colspan="2">Header Content
(4)</td></tr>
<tr><td colspan="4">Header Content
(8)</td></tr>
<tr><td colspan="4">Header Content
(8)</td></tr>
<tr><td colspan="4">Header Content
(8)</td></tr>
<tr><td colspan="4">HCS (8)</td></tr>
</table>

Syntax	Size	Notes
MAC Header() {		
RMI	4 bits	Relay mode indication: "1110" = this MPDU uses 802.16j relay format, others = this MPDU uses legacy 802.16e format
if (RMI == 1110) {		If ***relay MAC PDU format*** will be used
HT	1 bit	0 = Relay MAC PDU with payload 1 = Relay MAC PDU without payload
if (HT == 1) {		If ***no payload*** is attached
TYPE	5 bits	00000 = DCH Request 00001 to 11111 = Reserved
if (TYPE == 00000) {		If ***DCH Request***
DCH TYPE	2 bits	00 = DCH Request Incremental 01 = DCH Request Aggregate 10 = DCH Request Rate Based 11 = Reserved
if (DCH TYPE == 00) {		If ***DCH Request Incremental***
Bandwidth Request	16 bits	Number of bytes requested by the RS. Zero in this field indicates DCH release request
N	4 bits	Allocation repeats once every N frames
} else (DCH TYPE == 01) {		If ***DCH Request Aggregate***
Bandwidth Request	16 bits	Number of bytes requested by the RS. Zero in this field indicates DCH release request
N	4 bits	Allocation repeats once every N frames
} else (DCH TYPE == 10) {		If ***DCH Request Rate Based***
Progressive rate	12 bits	Average data rate with the progressive resolution unit.
Reserved	8 bits	Reserved
}		
RS CID	8 bits	Reduced Basic CID of RS
}		
}		
HCS	8 bits	Header check sequence
}		
}		

[Change subclause 6.3.6 as indicated]

6.3.6 Bandwidth allocation and request mechanism

During network entry and initialization every SS is assigned up to three dedicated CIDs for the purpose of sending and receiving control messages. These connection pairs are used to allow differentiated levels of QoS to be applied to the different connections carrying MAC management traffic. Increasing (or decreasing) bandwidth requirement is necessary for all services except incompressible constant bit rate UGS connections. The needs of incompressible UGS connections do not change between connection establishment and termination. The requirements of compressible UGS connections, such as channelized T1, may increase or decrease depending on traffic. Demand Assigned Multiple Access (DAMA) services are given resources on a demand assignment basis, as the need arises.

When an SS needs to ask for bandwidth on a connection with BE scheduling service, it sends a message to the BS containing the immediate requirements of the DAMA connection. QoS for the connection was established at connection establishment and is looked up by the BS.

There are numerous methods by which the SS can get the bandwidth request message to the BS. The methods are listed in 6.3.6.1 through 6.3.6.6.

The method by which an RS requests a dedicated uplink resource can be the bandwidth request R-MAC header RS UL DCH Request Header or the MAC Management message DCH REQ.

6.3.6.7 Relay bandwidth request and allocation mechanisms

[Add the following section]

6.3.6.7.3 Dedicated relay uplink channel allocation for control signaling and data transmission

After the RS network entry and initialization, the RS can be assigned the minimum or larger size of uplink dedicated channel (RS_UL_DCH) resource by its upstream serving station (MMR-BS or RS). If the MR-BS does not allocate an uplink dedicated channel to an RS, the RS may request an allocation.

The minimum size is large enough for a signaling message, it is available once every N frames. This initial resource is used by the RS to initiate the continuous operations of the dedicated channel. For example, the size can be updated, when appropriate, to a larger (or smaller) size for both signaling and data traffic according to the BW requirement of the relay. The BW requirement can be computed, periodically or as needed by events, by the RS to ensure adequate signaling and data traffic flows. For centralized resource management, the initial assignment and all subsequent updates are done by the MMR-BS only.

The dedicated channel allocation is assigned through MAP IE within the RS-Zone, i.e. R-MAP. The allocation is available starting in the same frame when the R-MAP IE is received by the RS.

4.2 R-MAP IE definition for dedicated relay uplink channel allocation

[Add the following section]

8.4.5.9 MAP IE (within R-MAP)

8.4.5.9.1 RS_UL_DCH assignment IE

This IE is used for the initial allocation and subsequent updates of the uplink dedicated channel on the R-link. The channel can be used to transmit uplink control signaling messages and data traffic.

Table XXX. RS_UL_DCH assignment IE format.

Syntax	Size	Notes
RS_UL_DCH assignment IE {		
Type	4 bits	
RSCID	8 bits	Reduced basic CID of the RS
UL Resource allocation	x bits	Resources allocated to DCH
Frequency (N)	4 bits	Allocation repeats once every N frames
}		

The coding for the UL resource allocation to the DCH is TBD

4.3 Dedicated relay uplink channel allocation using MAC management messages

6.3.2.3 MAC Management messages

[Change Table 14 as indicated:]

66	MOB_ASC-REP	Association result report message	primary management
67	DCH-REQ	Dedicated channel request message	basic
68	DCH-RSP	Dedicated channel response message	basic
69	RBR	Rate-based Bandwidth Request	basic
~~67~~70-255		Reserved	–

[Insert new subclause 6.3.2.3.62:]

6.3.2.3.62 Dedicated channel request (DCH-REQ) message

A DCH-REQ is sent by an RS to an MMR-BS to request, change, or release a dedicated channel allocation.

Table xxx – DCH-REQ message format

Syntax	Size	Note
DCH-REQ_Message_format() {		
Management Message Type = 67	8 bits	
Frame Number	24 bits	
Bandwidth Request	16 bits	0 = Release request of the allocation
Allocation Interval	8 bits	Set to zero when the bandwidth request field is set to zero.
}		

An RS shall generate DCH-REQ messages in the form shown in Table xxx, including the following parameters:

Frame Number

The frame number of the first allocation of the dedicated channel. In case the DCH-REQ is a release request, Frame Number indicates the frame from which on the RS requests to release the bandwidth allocation.

Bandwidth Request

The number of bytes of the single uplink bandwidth allocation requested by the RS. Zero in this field indicates the DCH-REQ is a bandwidth release request.

Allocation Interval

The interval of the periodic bandwidth allocation in number of frame. This field is set to zero when the Bandwidth Request field is zero.

[Insert new subclause 6.3.2.3.63:]

6.3.2.3.63 Dedicated channel response (DCH-RSP) message

A DCH-RSP shall be generated in response to a received DCH-REQ, or to terminate a dedicated channel allocated to an RS.

Table xxx – DCH-RSP message format

Syntax	Size	Note
DCH-RSP_Message_format() {		
Management Message Type = 68	8 bits	
Frame Number	24 bits	
Allocated Bandwidth	16 bits	0 = Indicates release of the allocation
Allocation Interval	8 bits	Set to zero when the bandwidth request field is set to zero.
}		

An MMR-BS shall generate DCH-RSP message in the form shown in Table xxx, including the following parameters:

Frame Number

The frame number of the first allocation of the dedicated channel. In case the DCH-RSP is the response to a bandwidth release request, Frame Number indicates the frame from which on the MMR-BS stops the bandwidth allocation.

Allocated Bandwidth

The number of bytes of the allocated single uplink bandwidth. When DCH-RSP is a response to a DCH-REQ requesting non-zero bandwidth, zero in this field indicates failing to allocated bandwidth.

Allocation Interval

The interval of the periodic bandwidth allocation in the number of frame. This field is set to zero when the Allocated Bandwidth field is set to zero.

[Insert new subclause 6.3.2.3.64:]

6.3.2.3.64 Rate-based bandwidth request (RBR) message

A rate-based bandwidth request (RBR) message may be sent by an RS at a periodic interval Td (Table 342) to inform its MR-BS (or RS) of the average data rate of a connection. The procedure of how to estimate the average data rate is outside the scope of the standard.

Table xxx – Rate-based bandwidth request (RBR) message format

Syntax	Size	Notes
RBR_message format(){	—	
Management Message Type = 69	8 bits	
Progressive rate	12 bits	
Request CID	16 bits	
}	—	

An RS shall generate RBRs in the format shown in Table xxx, including the following parameters:

Progressive rate

Average data rate of the CID with the progressive resolution unit. It is set according to Table yyy.

Request CID

The CID indicates the connection for which uplink (or downlink) bandwidth is requested.

The field of Progressive rate represents the average data rate (with the unit of byte per second) of the connection measured at an RS (or an SS). It contains the information of both the unit and the magnitude of the average data. The encodings and decoding of Progressive rate filed is based on Table yyy. In particular, the unit value is not a fixed value but with the progressive resolution. When the value of data rate is low, a smaller unit with higher resolution is adopted to encode the data rate. On the other hand, if the data rate value is large, a large unit with coarse resolution is adopted to represent the data rate. For instance, if the data rate is between 2 kBps (kilobyte per second) and 4 kBps, the encoding rule of the second entry (101x xxxxxxxx) in Table yyy is used. The first two MSB of Progressive rate field are used to indicate that the Unit is 2^2 (=4) Bps (byte per second) while the next 10 LBS are used to represent the magnitude of the data rate. The allowed magnitude range is between 2^9 and 2^{10}-1 as the most significant bit in these 10 bits is specified as "1". Therefore, the range of the data rate value (i.e. the multiply of the Unit and Magnitude) is between 2^{11} and 2^{12}-2^2.

Table yyy Encodings of Progressive rate field

Bitmap of Progressive rate field (x: don't care)	# of MSB bits for Unit	Unit	Magnitude	Range of overall value (Bps) (i.e. Multiple of Unit and Magnitude)
0xxx xxxxxxxx	1	2^0	$0 \sim 2^{11} - 1$	$0 \sim 2^{11} - 2^0$
101x xxxxxxxx	2	2^2	$2^9 \sim 2^{10} - 1$	$2^{11} \sim 2^{12} - 2^2$
1101 xxxxxxxx	3	2^4	$2^8 \sim 2^9 - 1$	$2^{12} \sim 2^{13} - 2^4$

1110 1xxxxxxx	4	2^{6}	$2^{7} \sim 2^{8} - 1$	$2^{13} \sim 2^{14} - 2^{6}$
1111 01xxxxxx	5	2^{8}	$2^{6} \sim 2^{7} - 1$	$2^{14} \sim 2^{15} - 2^{8}$
1111 101xxxxx	6	2^{10}	$2^{5} \sim 2^{6} - 1$	$2^{15} \sim 2^{16} - 2^{10}$
1111 1101xxxx	7	2^{12}	$2^{4} \sim 2^{5} - 1$	$2^{16} \sim 2^{17} - 2^{12}$
1111 11101xxx	8	2^{14}	$2^{3} \sim 2^{4} - 1$	$2^{17} \sim 2^{18} - 2^{14}$
1111 111101xx	9	2^{16}	$2^{2} \sim 2^{3} - 1$	$2^{18} \sim 2^{19} - 2^{16}$
1111 1111101x	10	2^{18}	$2^{1} \sim 2^{2} - 1$	$2^{19} \sim 2^{20} - 2^{18}$
1111 11111101	11	2^{20}	1	$\geq 2^{20}$

[Insert new subclause 6.3.6.8:]

6.3.6.8 Bandwidth request and allocation mechanisms for MMR

6.3.6.8.1 Dedicated channel between MMR-BS and RS

An RS shall request a dedicated channel using DCH-REQ message (see 6.3.2.3.62) for the purpose of transporting control messages and data from the RS to the MMR-BS. A dedicated channel is a periodic allocation of uplink bandwidth.

To reduce the overhead of allocating a dedicated channel to an RS, a dedicated channel can be allocated, changed, and released based on the expected demand of the uplink bandwidth.

MMR-BS may allocated a dedicated channel to an RS without an explicit request from the RS by sending a DCH-RSP (6.3.2.3.63) message to the RS.

If necessary, an MMR-BS can terminate or decrease the bandwidth and/or the allocation interval of the dedicated channel without request from an RS.

If the uplink path from an RS to an MMR-BS includes other RSs, the MMR-BS shall allocated dedicated channel for each hop within the path in response to an DCH-REQ.

6.3.6.8.2 Rate-based bandwidth request mechanism for MMR

In this subclause, a rate-based BR (RBR) mechanism is presented. RBR message is described in 6.3.2.3.64. An RBR carries the average data rate of a connection (also identified by the CID) in the unit of bytes per second (Bps).

The connection in an RBR could be a connection, a set of connections related to a station, a set of connections related to a service QoS class, a virtual group of stations, or any combination of the aforementioned groups. The utilization of the aggregation level is implementation specific.

Compared to the short-term statistics of BR mechanism in 6.3.6.1, the RBR message carries the information of statistics in a much longer duration. The interval between two RBR messages, T_d, is defined in Table 342. Since the transmission number of RBR messages is much less than that of BR headers, the control overhead of BRs can be much reduced. On the other hand, since an RS updates the value of data rate of RBR in a longer period, the RBR information is more suited to the resource allocation scheme with a longer adjustment period.

In the case of abrupt increase of traffic demand happening between two periodical RBR messages, the BR header defined from 6.3.2.1.2.1.1 to 6.3.2.1.2.1.6 may be used by an RS to ask for additional resource from the MR-BS.

10.1 Global values

[Insert the following text at the end of Table 342:]

System	**Name**	**Time Reference**	**Minimum value**	**Default value**	**Maximum value**
MR-BS, RS	T_d	Time interval of measuring the average data rate	10s	30s	-

+++++++++++++++ End Text Proposal +++