Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Rate based bandwidth request mechanism**
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Re:	IEEE 802.16j-06/027: "Call for Technical Proposals regarding IEEE Project P802.16j"
Abstract	A rate-based bandwidth request mechanism is proposed in this contribution to reduce the number of bandwidth request headers disseminated on the relay links of MR networks.
Purpose	For discussion and approval of inclusion of the proposed text into the P802.16j baseline document.
Notice	
Release	
Patent Policy and Procedures	

Rate-Based Bandwidth Request Mechanism

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In this contribution a rate-based bandwidth request (BR) mechanism is proposed to reduce the number of BR headers disseminated on the relay links of MR networks. The contribution works with [1] in a complementary manner such that this contribution provide further performance enhancement in addition to [1].

1. Problems of existing bandwidth request mechanisms in MR networks

The existing BR mechanism incurs significant overhead as being applied to MR networks. In particular, control message overhead and long latency could create a huge impact to the performance of MR networks.

1) Heavy control overhead of the existing BR headers on the relay links: When an RS receives a BR header from its SSs, it needs to forward the BR header to the MR-BS and asks for resource from the MR-BS. Without any processing or aggregation of these BR headers at RSs, the overhead of BR headers is huge as they consume resource at both relay links and access links. In such a case, the number of BR headers sent by an RS over the relay link is doubled compared to that sent by an SS on the access link as the RS relays the BRs from the SS and sends the corresponding BR headers for the relay link as well.
2) Potential long latency for the UL transmissions: In MR networks, the latency from the time when an SS sends a BR via an RS to the time when the SS receives the grant from the RS could be much longer than the latency in the single hop networks.

2. Introduction of the proposed rate-based bandwidth request mechanism

In this contribution, a rate-based bandwidth request (RBR) mechanism is proposed to reduce the number of BR headers disseminated on the relay links and shorten the latency before data being granted in MR networks.

The RBR mechanism is to calculate the average data rate of a connection at an RS periodically based on the received BR headers (i.e. conventional BR headers) from an SS. SSs do not need to make any modification on the BR mechanism. The period of evaluating the average data rate shall be much longer than the inter-arrival time between two BR headers from an SS. That is, the average date rate represents the long term statistics of the BRs from a connection. The message overhead of the RBR mechanism is much reduced because of less BR headers are disseminated over the relay link.

The purpose of introducing a RBR message is simply to reduce but not to eliminate the number of conventional BR headers disseminated over relay links. To be more specific, the conventional BR headers are still required in the following three scenarios to cover the deficiency of the RBR mechanism.
1) Initial stage: In the first period of evaluating the average data rate, RSs still need to relay conventional BR headers to the MR-BS. Then data grant based on the conventional BR headers can be allocated to an SS before an RS generates the first RBR message.

2) Overflow: In the events of abrupt increase in the BRs (in terms of total requested amount) from an SS or buffer overflow at the RS, the RS may send a conventional BR header to ask for additional resource from the MR-BS.
3) Disconnect stage: If an uplink connection no longer exists, an RS may send a conventional BR header with the value of BR equal to zero to inform the MR-BS of the discontinuity of this connection.

Note that the RBR 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. Specific text changes

Insert the following text at the end of Table 14:

Type	Message name	Message description	Connection
67	RBR	Rate-based Bandwidth Request	Basic

Insert a new subclause 6.3.2.3.62:

6.3.2.3.62 Rate-based bandwidth request

A rate-based bandwidth request (RBR) message may be sent by an RS (or an SS) at a periodic interval $\boldsymbol{T_d}$ (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 in 6.3.6.7.1. An RS shall generate RBRs in the format shown in Table 109z, including all of the following parameters:

CID *(in the generic MAC header)*
RS's Basic CID.
DIUC/UIUC
Uplink or downlink interval usage code used in the request connection. Depending on the direction of the connection, either DIUC or UIUC is reported.
Progressive rate
Average data rate of the CID with the progressive resolution unit. It is set according to Table 109aa.
Request CID
The CID indicates the connection for which uplink (or downlink) bandwidth is requested.

Table 109z – Rate-based bandwidth request (RBR) message format

Syntax	**Size**	**Notes**
RBR_message format(){	—	

Management Message Type = 67	8 bits	
DIUC/UIUC	4 bits	
Progressive rate	12 bits	
Request CID	16 bits	
}	—	

The filed of Progressive rate represents the average data rate (with the unit of bit 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 7m. 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 7m 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 rage 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 7m 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 (i.e. Multiply of Unit and Magnitude) (Bps)
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 a new subclause 6.3.6.7:

6.3.6.7 Bandwidth allocation and request mechanisms for MR

Insert a new subclause 6.3.6.7.1:

6.3.6.7.1 Rate-based bandwidth request mechanism for MR

Bandwidth request mechanism described in 6.3.6.1 is an on-demand protocol. That is, a BR header is sent from an SS to its BS to inform the BS of the amount of data in the unit of byte it would send to the BS. The BR header defined from 6.3.2.1.2.1.1 to 6.3.2.1.2.1.6 indicates the byte count of the data belonging to a connection (identified by the CID) buffered in the queue. The on-demand BR mechanism is designed to update the BR information of connections frequently.

In this subclause, a rate-based BR (RBR) mechanism is presented. RBR message is described in 6.3.2.3.62. 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. Moreover, because the RBR message carry the interval usage code (UIUC/DIUC) that a connection uses, the MR-BS can know which burst profile is used for the delivery of this connection. Therefore, the MR-BS can accurately estimate the amount of resource needed over the access link, especially when the access link and relay link use different burst profiles.

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.

Insert a new subclause 6.3.6.7.2.1:

6.3.6.7.1.1 Derivation of average data rate from bandwidth request headers

This subclause provides a method of deriving the average data rate of a connection over the access link based on the BRs received from an SS. Data rate is evaluated periodically at an RS. The interval of evaluation period is a system parameter denoted as T_d (Table 342). For the traffic transmitted over the downlink access link, an RS knows that the amount of data of a downlink connection with CID i during the t_{th} period is $din_i(t)$. The average data rate $r_i(t)$ can be easily derived using Equation (8a)

$$r_i(t)=\begin{cases} din_i(t)/T_d & t=0 \\ (1-a_{avg})\cdot r_i(t-1)+a_{avg}\cdot din_i(t)/T_d & t>0 \end{cases} \quad (8a)$$

where a_{avg} ($0 \le a_{avg} \le 1$) is another system parameter representing the weight of the current statistics.

For the traffic transmitted over the uplink access link an RS needs to interpret the average data rate based on the BR headers from SSs. Still, the RS evaluates the data rate in a period of T_d, which in general is much longer than the interval between two BR headers of the same connection from an SS. RSs need to keep three sets of information: (1) the latest BR amount from connection ***i***, ***req$_i$(t)***, (2) the amount of data from connection ***i*** arriving at the RS since the previous check point, ***dout$_i$(t)***, and (3) the amount of data from connection ***i*** arriving at the RS since reception of the last BR header from connection ***i***, *d****out$_i$(t)***, where ***t*** is the index representing the ***t$_{th}$*** evaluation period of the average data rate. Figure 43a illustrates the relationship between these three sets of information and their corresponding points at the time domain. Note that only the latest BR header prior to the check point at the period of T_d is relevant and other BR headers can be ignored when an RS calculates the average data rate.

At each check point of period T_d, for instance at the time $t\cdot T_d$, an RS starts to count the amount of data from connection ***i*** and resets the variable ***dout$_i$(t)*** to be zero. *d****out$_i$(t)*** is a temporary variable recording the amount of data from connection ***i*** received between two BRs. Upon reception of a data packet from connection ***i***, an RS adds the byte number of the new received data packet to *d****out$_i$(t)***. Upon reception of a BR header from connection ***i***, the RS adds the value of *d****out$_i$(t)*** to ***dout$_i$(t)*** and reset the value of *d****out$_i$(t)*** to be zero.

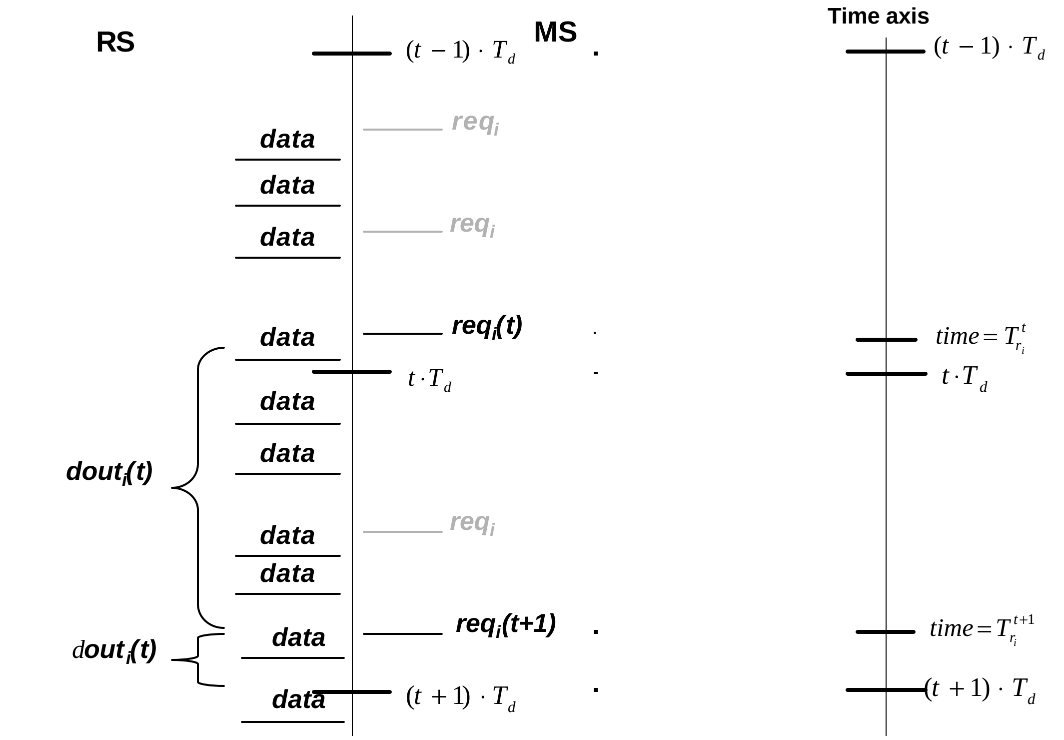

Figure 43a Relationship between *req$_i$(t)*, *dout$_i$(t)*, and *dout$_i$(t)*

The amount of data of connection ***i***, ***din_i(t)***, entering an SS during the interval between two BR headers ***req_i(t)*** and ***req_i(t+1)*** can be derived using Equation (8b):

$$din_i(t) = req_i(t+1) - req_i(t) + dout_i(t) \qquad (8b)$$

Note that the two BR headers, ***req_i(t)*** and ***req_i(t+1),*** are the arrived BR headers priori to the check points, i.e. $t \cdot T_d$ and $(t+1) \cdot T_d$, respectively. The arrival time of ***req_i(t)*** and ***req_i(t+1)*** are denoted as $T_{r_i}^t$ and $T_{r_i}^{t+1}$, respectively. Thus, the average data rate entering the SS during this period is $din_i(t)/(T_{r_i}^{t+1} - T_{r_i}^t)$.

Similar to Equation (8a), the average data rate of an uplink connection ***i*** can be derived using Equation (8c):

$$r_i(t) = \begin{cases} din_i(t)/T_{r_i}^1 & t = 0 \\ (1-a_{avg}) \cdot r_i(t-1) + a_{avg} \cdot din_i(t)/(T_{r_i}^{t+1} - T_{r_i}^t) & t > 0 \end{cases} \qquad (8c)$$

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	-

4. References

[1] M. Okuda, "Fast Bandwidth request scheme for Relay Station", IEEE C802.16j-06/125, IEEE 802.16 meeting #46, Dallas, November 2006.