Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
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Re:	IEEE 802.16j-06/027: "Call for Technical Proposals regarding IEEE Project P802.16j"
Abstract	This contribution introduces a measurement of network congestion in 802.16j networks. It uses average transmission queue length and standard deviation as network load measurement. The measurement can be used as a metrics of network load and used for congestion control and radio resource management in a MR cell. Related information including the number of active service flows, average link qualities of the MSs and standard deviations are also reported.
Purpose	For discussion and approval of inclusion of the proposed text into the P802.16j baseline document.
Notice	
Release	
Patent Policy and Procedures	

Measurement method of the network congestion used for adjusting radio resources in a MMR cell

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Introduction

In a MR cell, the MR-BS controls how the radio resources are shared by different transmitting entities, including MR-BS and RSs in the DL, and the RSs and the MSs in the UL. Because the network load and the channel qualities of the access links change with time, the MR-BS need to perform load balancing in the MR-cell by adjusting the radio resources assigned to the relay links and the access links dynamically. In the case that each RS schedules its own transmissions (using radio resources assigned to it by the MR-BS), the MR-BS does not have the complete BW request information or channel quality information in the entire MR cell. It is more difficult for the MR-BS to estimate the network traffic in the UL direction than in the DL. It is also difficult for the MR-BS to know the detailed operation of the scheduling algorithm at the RS, i.e. the burst profiles scheduled by the RS on the access link and relay links. When the MR-BS and RS are from different vendors, the MR-BS may not be aware of the scheduling algorithm of the RS. The QoS experienced by a user service flow is determined by its traffic characteristics (average rate and bustyness), the channel quality of the links (access link and relay link), the radio resources assigned for its transmission and the scheduling algorithm of the RSs and the MR-BS, and different user service flows have different QoS requirements. The MR-BS needs a mechanism to monitor the network load in the MR-cell. In order provide useful information to the MR-BS without having to transmit all the information from the RSs to the MR-BS, we propose to use transmission queue size (mean and standard deviation) as an indication of the network congestion in the MR cell. This is because average transmission queue size is proportional to the transmission delay of the user service flows and reflects the combined effect of the bandwidth request of the service flow and the throughput delivered on the corresponding link. The latter (delivered throughput) is determined by the link quality, the radio resource used and the scheduling algorithm. So the transmission queue size is a universal congestion indicator and reflects the degree of QoS delivered to the service flow.

By collecting the average queue sizes at all the links (or aggregated links) and their standard deviations, the MR-BS can have a reasonable estimate of the network load and congestion in the MR-cell. Within an RS microcell, information regarding how many MSs have active service flows, and how many connections (flows) are active, as well as the link qualities of these MSs, are also useful information that can be reported to the MR-BS. The MR-BS can perform load balancing based on these information. By assigning the bandwidth to the access links and the relay links in the MR-cell, the MR-BS functions as the top layer of the radio resource management. The detailed scheduling algorithm of the MR-BS and the RSs is the bottom layer of the radio resource management in the MR cell (in the case the RSs generate their own schedules). Because the queue length reflects the outcome of the operation of the RS scheduling algorithm, the top layer of radio resource allocation scheme automatically takes into account of the lower layer scheduling algorithm at the RSs, the channel quality and the radio resources used, without having to know the algorithmic details of the RS. This allows integration of MR-BS and RS from different vendors without exposing the vendor-specific scheduling algorithm.

Because different traffic type have different traffic characteristics and different priorities, and they usually require different QoS, the queue length information should be reported to the MR-BS on a per QoS class basis.

Proposed text changes

***Insert the following as a new subclause 6.3.6.7**:*

6.3.6.7 Network congestion measurement and radio resource management in multihop relay networks.

In a MR cell where the RSs generate their own MAP messages, chunks of bandwidth are allocated to the access links and the relay links by the MR-BS. In order for the MR-BS to monitor the network load and congestion, the MR-RS requests the RSs to report the average transmission queue length and the standard deviation of the associated links (access links and relay links). They also report the average channel qualities of these links and the number of active service flows and MSs served. By monitoring the congestion level in the MR cell, the MR-BS may conduct load balancing and determine the radio resources allocated to the links by considering the congestion level in the entire network, as well as other factors like the average link qualities and number of MSs/service flows in the entire MR cell.

Possible methods of calculating the mean and standard deviation of the transmission queue lengths, the mean and standard deviation of the MS RSSI and CINR are provided in the appendix.

Insert the following as new subclause 6.3.2.3.62

6.3.2.3.62 Multi-hop relay network congestion measurement

If the MR-BS requests congestion measurement report from a RS, it shall send the Congestion Measurement Request message to the RS. Table 1 shows the format of the Congestion Measurement Request Message (CGT--MEA-REQ).

Table 1 -- MR congestion measurement request (CGT-MEA-REQ) message format

Syntax	Size	Note
CGT-MEA-REQ _message format(){		
Management Message Type = 66	8 bits	Type = 66
Report Request TLVs	variable	
}		

The CGT-MEA-REQ message shall contain the following TLV encoded parameters:

Congestion Measurement Report Request

These parameters may include average queue length and standard deviation of a QoS type on an aggregated access link or a relay link, the number of MSs with certain QoS service flows served by the RS, the number of active flows of the QoS type, and average RSSI and CINR of the MSs with the specified QoS traffic types and their standard deviation.

The MR Congestion Measurement Response (CGT-MEA-REP) message shall be used by the RS to respond to the congestion measurement request from the BS. The format of the CGT-MEA-REP message is shown in Table 2:

Table 2 -- MR congestion measurement response (CGT-MEA-REP) message format

Syntax	Size	Note
Congestion_Measurement_Response_Message_Format() {		
Management Message Type = 67	8 bits	Type=67
Report Response TLVs	variable	
}		

The CGT-MEA-REP message shall contain the following TLV encoded parameters:

Congestion Measurement Report Respond

Compound TLV that contains the measurement report in accordance with the measurement report.

Insert the following as new subclause 11.20

11.20 MR congestion measurement encoding.

11.20.1 CGT-MEA-REQ message encodings:

Name	Type	Length (bytes)	Value
Link Index		1	Index of the link measured
Measured QoS Type		1	Bit #0: include UGS Bit #1: include Rt-VT Bit #2: include NRT-VR Bit #3: include BE Bit #4: include ERT-VR Bit #5: include all QoS types
Congestion Measure Request Type		1	Bit #0: include average queue length Bit #1: include standard deviation Bit #2: include number of active flows Bit #3: include number of MSs Bit #4: include MS CINR report Bit #5: include MS RSSI report

11.14.1.2 CGT-MEA-REP message encodings:

CGT-MEA-	Name	Type	Length	Value

REQ type			(bytes)	
Bit #0 = 1	Mean queue length		2	Average queue length (bytes)
Bit #1 = 1	Queue length standard deviation		2	Standard deviation of queue length
Bit #2 = 1	Number of active flows		2	Number of active flows of the corresponding QoS class
Bit #3 = 1	Number of MSs		2	Number of MS with the QoS traffic type served by the RS
Bit #4 = 1	MS CINR report		2	1 byte: mean (dB) 1 byte: standard deviation (dB)
Bit #5 = 1	MS RSSI report		2	1 byte: mean (mW) 1 byte: standard deviation (dBm)

Appendix

The following provides sample algorithms that can be used to compute the required measurement entities.

When congestion measurement is mandated by the MR-BS, the RS shall measure average transmission queue length and standard deviation for each relay link and for all the access links, and for each QoS class. In order to reduce the communication and computation overhead, all the access links originated from (in DL direction) or terminated at (in the UL direction) the same RS is considered as a logical aggregated access link. Let A be a link (a relay link or an aggregated access link) which is consisted of a set of links L, and ($q^{t,d}_j(k)$) is the transmission queue length in direction d (uplink or downlink) of QoS type t at access link j at kth sampling time. The average queue length can be calculated as

$$\hat{\mu}_A^{t,d}(k) = \begin{cases} \frac{1}{|L|}\sum_{j\in L} q_j^{t,d}(0), k=0, \\ (1-\alpha^t)\cdot\hat{\mu}_A^{t,d}(k-1)+\alpha^t\cdot\frac{1}{|L|}\sum_{j\in L} q_j^{t,d}(k), k>0. \end{cases} \quad (1)$$

where the parameter α^t and the sampling period are specified by the MR-BS. To get the standard deviation, the second order momentum of the queue length on composite link $RS_i \rightarrow MS_{RSi}$ can be calculated as

$$\hat{x}_A^{t,d\,2}(k) = \begin{cases} \frac{1}{|L|}\left(\sum_{j\in L} q_j^{t,d}(0)\right)^2, k=0, \\ (1-\alpha^t)\cdot\hat{x}_A^{t,d\,2}(k-1)+\alpha_t\cdot\frac{1}{|L|}\left(\sum_{j\in L} q_j^{t,d}(k)\right)^2, k>0. \end{cases} \quad (2)$$

The standard deviation of queue length is

$$\sigma_A^{t,d}(k) = sqrt(\hat{x}_A^{t,d\,2}(k) - (\hat{\mu}_A^{t,d}(k))^2). \quad (3)$$

For the access links, the RS has direct access to the queue length information in the downlink direction. In the uplink direction, because the queues are located at the MSs, the RS uses the bandwidth request information it receives from the MSs. Note that with the definition of aggregated access link, a RS only has one aggregated access link. For the relay links, a RS only calculates and reports the queue length information in the outgoing direction.

When mandated by the MR-BS, each RS should also report the number of MSs, the number of active flows of each QoS class it serves, and the mean and standard deviation of the RSSI and CINR of access links. For a RS, the mean RSSI of all its access links (aggregated access link *A*) of a particular QoS class *t,* $\hat{\mu}^t_{A,RSSI}$, can be computed as

$$\hat{\mu}^t_{A,RSSI} = \frac{1}{|L_t|}\sum_{j\in L_t}\hat{\mu}^j_{RSSI} \quad \text{(mW)}, \quad (4)$$

Where L_t is the set of access links of the RS that have active traffic flows of QoS class *t*, and $\hat{\mu}^j_{RSSI}$ is the mean RSSI of the access link *j*. The standard deviation of the access links, $\sigma^t_{A,RSSI}$, can be computed as

$$\sigma^t_{A,RSSI} = 5\log(\frac{1}{|L_t|}\sum_{j\in L_t}(\hat{\mu}^j_{RSSI})^2 - (\hat{\mu}^t_{A,RSSI})^2) \quad \text{(dBm)}. \quad (5)$$

The mean CINR of all the access links (aggregated access links A) of a particular QoS class *t* $\hat{\mu}^t_{A,CINR,dB}$, can be computed as

$$\hat{\mu}^t_{A,CINR} = \frac{1}{|L_t|}\sum_{j\in L_t}\hat{\mu}^j_{CINR}, \quad (6)$$

$$\hat{\mu}^t_{A,CINR,dB} = 10\log(\hat{\mu}_{A,CINR}) \quad \text{(dB)}. \quad (7)$$

The standard deviation $\sigma^t_{A,CINR,dB}$ can be computed as

$$\sigma^t_{A,CINR,dB} = 5\log(\frac{1}{|L_t|}\sum_{j\in L_t}(\hat{\mu}^j_{CINR})^2 - (\hat{\mu}^t_{A,CINR})^2) \quad \text{(dB)}. \quad (8)$$