Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Enhanced piggyback request scheme**
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Re:	IEEE Working Group 802.16 Letter Ballot #26 as announced in IEEE 802.16-07/049
Abstract	This contribution proposes multiple piggyback requests for CIDs in a SS using extended subheader.
Purpose	Adopt the proposed change in IEEE802.16REV2/D2
Notice	
Release	
Patent Policy	

Enhanced piggyback request scheme

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1. Problem statement

If a SS has several CIDs, the SS should do BR (bandwidth request) individually for each CID. If a CID is sending packets in UL, the CID can use grant management subheader as piggyback for BR (PBR: PiggyBack Request). Other CIDs which is not sending packets in UL should send BR header individually by random access or polling process. If we can use multiple piggyback using extended subheader for CIDs in one SS instead of waiting for next polling period or attaching BR header of 6 bytes for each CID to BR or doing random access, we can reduce overhead and latency. CPE can be considered to the case that a SS has multiple CIDs.

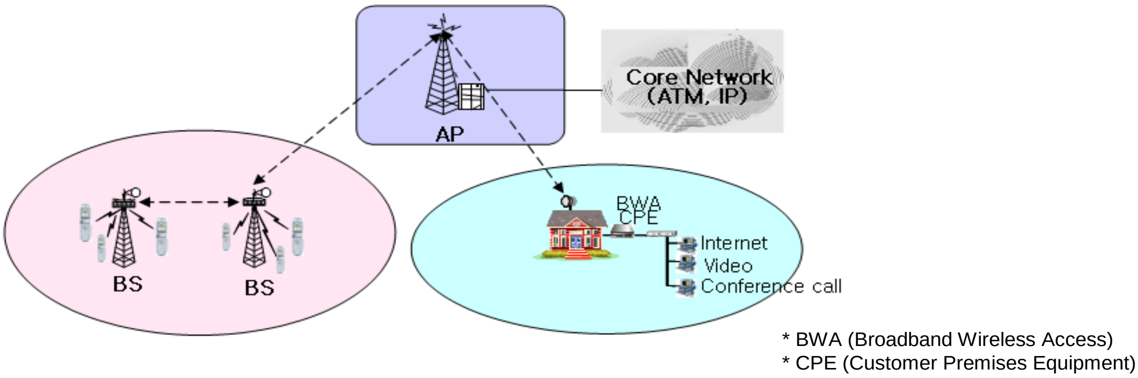

Figure A. An example of multiple CIDs in one SS - CPE

2. Proposed text change

[Modify Table 26 in the section 6.3 Description of extended subheaders types (UL) on Page 75 of IEEE802.16REV2/D2, as follows]

Extended Subheader type	Name	Extended subheader body size (byte)	Description
0	MIMO mode feedback extended subheader	1	See 6.3.2.2.7.4
1	UL Tx power report extended subheader	1	See 6.3.2.2.7.5
2	Mini-feedback extended subheader	2	See 6.3.2.2.7.6
3	PDU SN(short) extended subheader	1	See 6.3.2.2.7.8
4	PDU SN(long) extended subheader	2	See 6.3.2.2.7.8

5	e-PBR extended subheader	2	See 6.3.2.2.7.9
~~5~~ 6-127	*Reserved*	-	

[Insert new part in the section 6.3 of IEEE802.16REV2/D2, as follows]

"

6.3.2.2.7.9 e-PBR extended subheader

This subheader is sent from SS to BS to request bandwidth of UL for the CIDs in the same SS with a CID which serves generic MAC header.

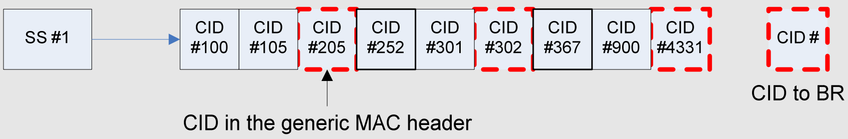

Figure 38 – A case for e-PBR extended subheader

This subheader can be used when the CID of generic MAC header is sending packets in uplink and the other CIDs in the same SS need BR. Set the ESF field to 1 in the generic MAC header and an extended subheader for e-PBR can be attached.

Table 35 – e-PBR extended subheader

Name	Size (bit)	Description
The number of PBR	5	The number of PBRs which are included in this extended subheader body.
PiggyBack Request	11	The number of bytes of UL bandwidth requested by the SS. The BR is for the CID in the generic MAC header. The request shall not include any PHY overhead.
PBR CID index	5	The order of CID for PBR in predetermined CID list of a SS.
PiggyBack Request	11	The number of bytes of UL bandwidth requested by the SS. The BR is for the private CID index. The request shall not include any PHY overhead.

The e-PBR extended subheader body length is decided by the number of PBR. When the BS receives this subheader, the BS can know the body length by the first field – twice of the number of PBR. Each PBR is composed of PBR CID index field and piggyback request field.

BS already knows all CIDs of each SS, so the same CID list can be made per SS in BS and SS with predetermined role such as ascending order. The SS can indicate the order of CID to BR from the CID list instead of CID itself. In the figure 38, CID number 302 want BR and the order of CID is 6 in the list, so PBR CID index is 6. If the BS receives this e-PBR extended subheader, the BS can know which CID of the SS want BR with combination of generic MAC header CID and the order of CID from the CID list.

For the case of the figure 38, the value of the number of PBR field is 3 and the followed Piggyback Request field is for the CID in the generic MAC header – CID 205. And first PBR CID index is attached with value of 6 and the followed Piggyback Request field is for CID 302. And second PBR CID index is attached with value of 9 and the followed Piggyback Request field is for CID 4331.

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Appendix A. Simple performance analysis

Overhead comparison can be showed easily. In e-PBR case of figure 38, the signaling overhead for BR is 14 bytes if one of the CIDs to BR is generic MAC header CID and other CIDs use conventional BR header. If there is no resource for BR header, then we should wait for next polling period or can do random access to request uplink resource to send BR header.

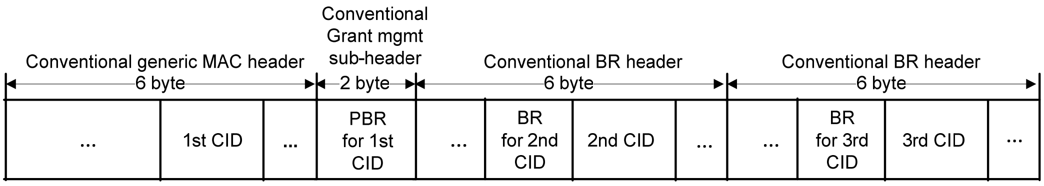

Figure A – Example of conventional scheme with BR header

If e-PBR extended subheader can be used, the signaling overhead for BR can be reduced to 8 bytes if there is no other extended subheader. If there is other extended subheader, signaling overhead for BR can be said to be 7 bytes because extended subheader group length of 1 byte can be considered as common overhead with other extended subheader. And the way using e-PBR extended subheader can have more possibility to reduce latency due to shorter message length than conventional scheme.

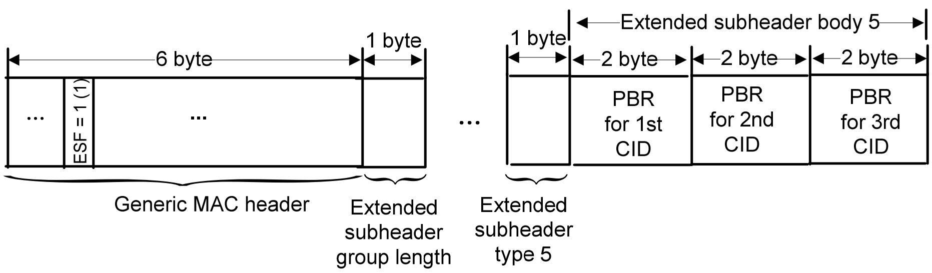

Figure B – Example of e-PBR extended subheader

Appendix B. Performance analysis with numerical formulas

- Frame structure
  - Frame Duration: 5ms
  - Downlink:Uplink symbols = 29:18
  - Bandwidth: 10 MHz
  - Number of DL Subchannels: 30 per 2 symbols
  - Number of UL Subchannels: 35 per 3 symbols

- Overhead analysis
  - Size of BR header: 6 bytes

- Grant mgmt sub-header: 2 bytes
- Overhead: overhead ratio for BR header and PBR in UL symbol
- Assumption
  - Polling periods for all CIDs are same.
  - BR is performed using only BRH & PBR
  - No padding (No other waste in UL resource)
- Conventional overhead

$$overhead(\%) = \frac{\left(BRH\_size * p + PBR\_size*(1-p)\right)*M*N}{\frac{T}{frame\_length}*(total\_number\_of\_slots)*(bytes\_per\_slot)}$$

where $p =$ probability using BRH when the CID tries BR

$M =$ Number of CIDs $= number\_of\_users * number\_of\_CIDs\_per\_user$

$N =$ total polling number in $T = T / polling\_period$,

$T =$ total simulation time,

$$\therefore overhead(\%) = \frac{\left(BRH\_size * p + PBR\_size*(1-p)\right)*M*frame\_length}{polling\_period*(total\_number\_of\_slots)*(bytes\_per\_slot)}$$

- Overhead with proposed e-PBR using extended subheader
  - q: probability that CIDs can use PBR
  - Extended sub-header group length (1 bye) & Extended sub-header type field(1 byte) are added per SS.

$$overhead(\%) = \frac{\left(\left(BRH\_size*(1-q) + PBR\_size*q\right)*M + 2*q*N\right)*L}{polling\_period*(total\_number\_of\_slots)*(bytes\_per\_slot)}$$

where $q =$ probability using proposed PBR instead of BRH

L = frame length

M = Number of CIDs = $K*(Number\_of\_users)$

N = number of users

- BR latency
  - From the point that the BS can know the SS need BR (point that the random access for BR is succeed) to the point that the SS can do BR (point that UL resource is allocated for BR).
  - Time for random access and TTI, scheduling latency are not included for BR latency.

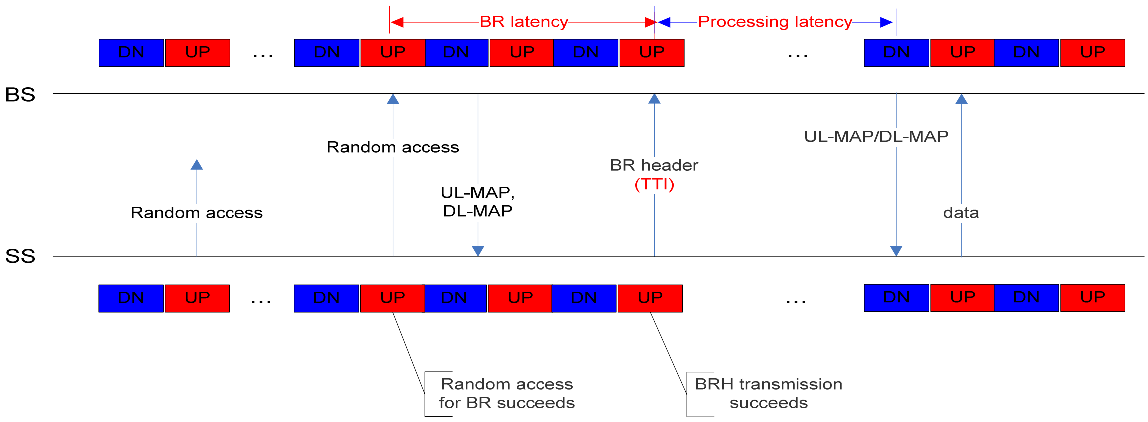

Figure C – BR latency

- Effect on latency due to slot padding
  - In case of no padding
    - A packet should be wait for fixed polling point

      τ_p : polling interval

      λ : packet arrival rate

      $\underset{\sim}{T_a}$: Random process of BR packet arrival time

      L_p : latency due to polling interval with no padding

      $$L_p = \tau_p \cdot P[\underset{\sim}{T_a} \le \tau_p] = \tau_p \cdot \left(1 - e^{-\lambda \tau_p}\right)$$
  - In case that padding exists,
    - A packet should be wait for next scheduling point and can use padding to send BRH or PBR.
    - Assumption: scheduling is performed per frame.

      τ_f : frame length

      L_f : latency due to fixed scheduling period

      $$L_f = \tau_f \cdot P[\underset{\sim}{T_a} \le \tau_f] = \tau_f \cdot \left(1 - e^{-\lambda \tau_f}\right)$$
  - Effect on latency due to slot padding
    - In case that padding exists,
      - If slot padding is enough for BRHs or PBRs

S_s : slot size, S_p : padding size

$\underset{\sim}{T_b}$: Random process for padding percentage of the slot

x : padding percentage - uniform distribution

$$f_{\underset{\sim}{T_b}}(x) = \begin{cases} 1, \text{if } 0 \le x \le 1 \\ 0, \text{otherwise} \end{cases}$$

r : probability that the size of

BRH or PBR for unexpected BR is equal or smaller than padding size

$$r = P[S_{BR} \le S_p] = P[S_{BR} \le x \cdot S_s] = P[x \ge S_{BR} / S_s]$$

Let $\text{A} = S_{BR} / S_s$, then $r = \int_A^1 f(x)dx = 1 - A$

Let r_p is occurence rate of padding.

$$\therefore Latency = L_f \cdot \left(1 - r_p \cdot (1 - A)\right)$$

- If slot padding is not enough for BRHs or PBRs, the remained BRHs or PBRs should be sent at the next scheduling point using padding.

  n : the number of frame to send all BRHs or PBRs

  (assumption : depends on only padding rate)

  $$\therefore Latency = L_f + n \cdot \tau_f$$

- Parameters
  - polling period: 20ms
  - The number of SS 100
  - The number of CID per SS 5
  - The probability that the SS can use proposed e-PBR scheme for BR (i.e. the SS has another connection & the connection is sending packets in UL) : 50%
  - Time for random access during BR is excluded when calculating BR latency.
  - The ratio of padding in slot: 20% (can be used for BR)

Table A – Performance comparison

		Overhead	Improvement rate of overhead	Latency	Improvement rate of latency
Number of CID per SS: 2	Conventional scheme	1.460%	-	2.06ms	-
	Proposed scheme	1.095%	25%	1.852ms	11.73%
Number of CID per SS: 5	Conventional scheme	3.651%	-	8.57ms	-
	Proposed scheme	2.556%	30%	3.73ms	56.47%