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Source(s)	Ismail Guvenc, Moo-Ryong Jeong, Fujio Watanabe, and Chia-Chin Chong DoCoMo USA Labs 3240 Hillview Ave, Palo Alto, CA, 94304 E-mail: iguvenc@docomolabs-usa.com
Re:	To provide some clarification on the benefit of using ARQ in pre-transmissions in MBS.
Abstract	This contributions provides some clarification on the benefit of employing ARQ in MBS pre-transmissions (related to comments 816-820 to the P802.16j/D1)
Purpose	To enhance the reliability of pre-transmissions in MBS for IEEE 802.16j.
Notice	
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Patent Policy	

Technical Comments to P802.16j Baseline Document: 6.3.23.3 - Use of ARQ in MBS

Ismail Guvenc, Moo-Ryong Jeong, Fujio Watanabe, and Chia-Chin Chong
DoCoMo USA Labs

I. Introduction

This document provides some simple simulation results showing the benefit of using ARQ in MBS pre-transmissions. The contribution is a clarification on the comments # 816, 818, 819, 820.

The MBS in the current baseline document requires pre-transmissions to the RS for synchronization purposes. The pre-transmissions may possibly be achieved using unicast transmissions or multicast transmissions. Moreover, ARQ may be employed for pre-transmissions for improving the reliability. For multicast pre-transmission MBS, use of ARQ is not easy with the current baseline document, and requires significant changes. However, we think that ARQ can be utilized for unicast pre-transmissions (UP). In certain scenarios, it can even be employed for certain RSs without introducing any additional delay to the target transmission time.

Table 1 Possible pre-transmission options in IEEE 802.16j

Pre-transmission type	Summary
Unreliable UP-MBS	- The packets are pre-transmitted through unicast connections and no ARQ is used for any of the pre-transmissions.
Reliable UP-MBS	- The packets are pre-transmitted through unicast connections and ARQ is used for pre-transmissions of some selected RSs. - No additional delay is introduced with respect to the default mode since idle periods of some RSs are utilized.
Unreliable MP-MBS	- The packets are pre-transmitted through multicast connections and no ARQ is used for any of the pre-transmissions. - The spectrum is better utilized compared to UP-MBS since the packets are pre-transmitted to different RSs using the same frequency bands; however, no reliability is guaranteed.
Reliable MP-MBS	- The packets are pre-transmitted through multicast connections and ARQ is used for pre-transmissions of some selected RSs. - The reliability of the selected RSs are improved; however, the re-transmissions may slow down the other RSs under the same parent node, which receive the packets as duplicate packets rather than new packets. - Not possible with the current baseline document of IEEE 16j and requires significant modifications.

Fig. 1(a) illustrates an example for the operation of the UP-MBS based on the current baseline document of the IEEE 802.16j for a simple topology. In order to achieve synchronization, firstly, the BS pre-transmits the packets to all the RSs in the 1-hop distance in its downlink portion of the first frame. While RS-2 and RS-3 successfully receive the packets, the RS-1's packets are corrupted, and hence they are dropped. In the downlink portion of the second frame, RS-2 pre-transmits the packets to RS-4 (which is the children node of RS-2). Since RS-3 does not have any other children nodes, it waits in idle state in the second frame for the pre-transmissions to complete. In the third frame, once the pre-transmissions are finished, RS-2, RS-3, RS-4, and the BS synchronously transmit the packets to the MS. Note that RS-1 does not participate in synchronous transmission since the corrupted packets were dropped in the first frame.

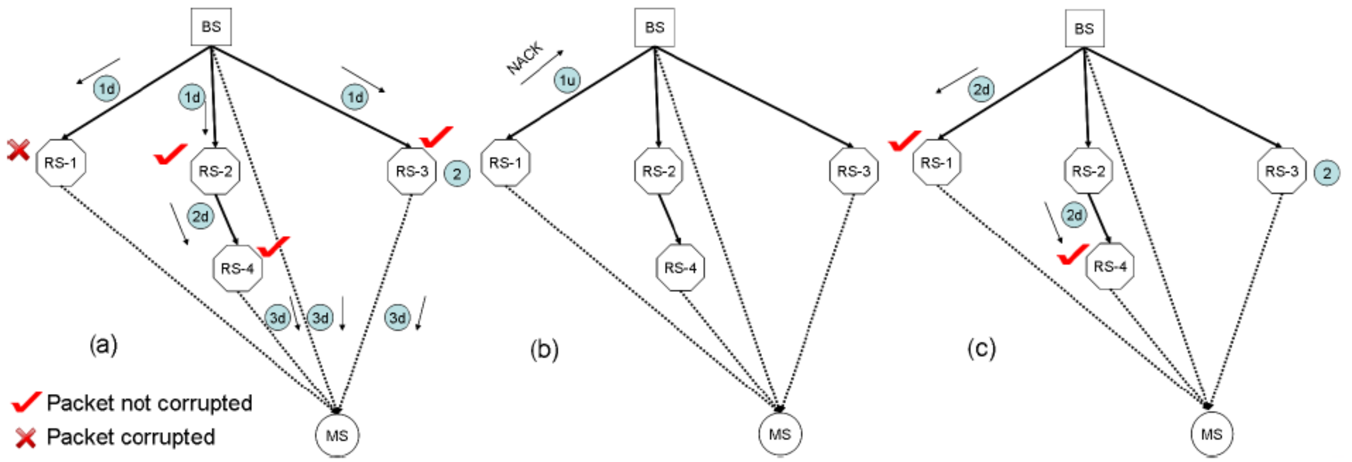

Figure 1 An example for improved pre-transmissions with using unicast-ARQ for some selected RSs. (a) Pre-transmissions in MBS without ARQ. (b) The uplink portion of the first frame when RS-1 is allowed to use ARQ. (c) Downlink portion of the second frame when RS-1 is allowed to use ARQ.

An example on how ARQ can be used to improve the reliability in UP-MBS without introducing any additional delay is illustrated in Fig. 1(b) and Fig. 1(c). The RS-1 and RS-3 are selected as ORSs since there is an opportunity (idle wait period) for these RSs where they may employ ARQ to improve the link-level reliability (it is assumed that the NACK message can be sent in the uplink portion of the same frame, and the parent node may re-transmit in the downlink portion of the next immediate frame). First, as in Fig. 1(a), the BS pre-transmits the packets to RS-1, RS-2, and RS-3 in the downlink portion of the first frame. RS-1 checks the packets and figures out that they are corrupted. When no ARQ is used, these packets are dropped at RS-1 and would not be forwarded to the MS. However, RS-1 still has some time period before the target transmission frame, which can be utilized using ARQ. Hence, as illustrated in Fig. 1(b), it sends back a NACK message to the BS in the uplink portion of the first frame, requesting a retransmission. In this example, RS-2 simply does not operate in the ARQ mode; hence, it waits for the next frame for transmitting the packets to its children node (i.e., RS-4). RS-3 also operates in ARQ mode; however, it receives the packets correctly as opposed to RS-1. In Fig. 1(c), transmissions that occur in the downlink portion of the second frame are illustrated. The BS responds to the NACK message of RS-1, and re-transmits the packets. They are received successfully at the RS-1 in the second attempt. At the same time, RS-2 forwards the packets to RS-4, which are received successfully. Since RS-3 received the packets successfully during the first frame, it waits in idle state during the downlink portion of the second frame. Finally, in the third frame, all the RSs (including RS-1, which could not participate in the MBS transmission in the default mode) and the BS may synchronously transmit the packets to the MS.

Note that if ACK can not be sent at the immediate next frame, above solution is still useful to add minimum delay to the target transmission time while employing ARQ.

II. Simulation Results

Monte Carlo simulations are performed to evaluate the improvements when ARQ is used for pre-transmissions in MBS. We consider the simulation topology illustrated in Figure 2. For the sake of obtaining the MBS topology, we assume that the BS may connect to all the MSs within a *5* mile radius, while a RS may connect to all the MSs within a *3.5* mile radius. Also, we position *16* MSs on a grid as illustrated in Figure 2, where some MSs may receive MBS packets from more than one RS/BS. For example, MS-5 receives the MBS packets from both RS-2 and RS-3, while MS-10 receives the MBS packets from RS-2, RS-3, and RS-4.

We generate the received signal based on the Jake's fading model using a mobile speed of *3* Km/h and a central frequency of f_c=*2500* MHz. Power per occupied subcarrier is *28.1* dBm, transmitter antenna gain is *15* dB, receiver antenna gain is *-1* dB, receiver noise figure is *10* dB, noise level is taken as *-98* dBm, and an uncoded BPSK modulation is considered for MBS transmissions (since it is more robust compared to other higher-order modulation options). The free-space path loss for a certain link is taken as

$$\mathrm{PL} = 10\log_{10}\{f_c\} + 20\log_{10}\{d\} + 36.6 \ (\mathrm{dB})$$

where f_c is the central frequency of transmission (in MHz) and *d* is the distance between a transmitter and a receiver (in miles). Based on the path loss model and the link budget constraints, we evaluate the SNR for each link between a pair of transmitter and a receiver. Then, we fix the noise level, and scale the signal energy to generate the received signals. For the MSs receiving signals from multiple parent nodes, the received signals are simply summed in order to obtain the aggregate SNR. Considering that the received symbol duration is 102.9×10^{-6} μsec and assuming perfect knowledge of the channels, each of the received symbols are sampled and demodulated. When a symbol error occurs, the packet that contains the symbol is considered as corrupted, and a retransmission is requested from the parent RS/BS if there is any retransmission opportunity available.

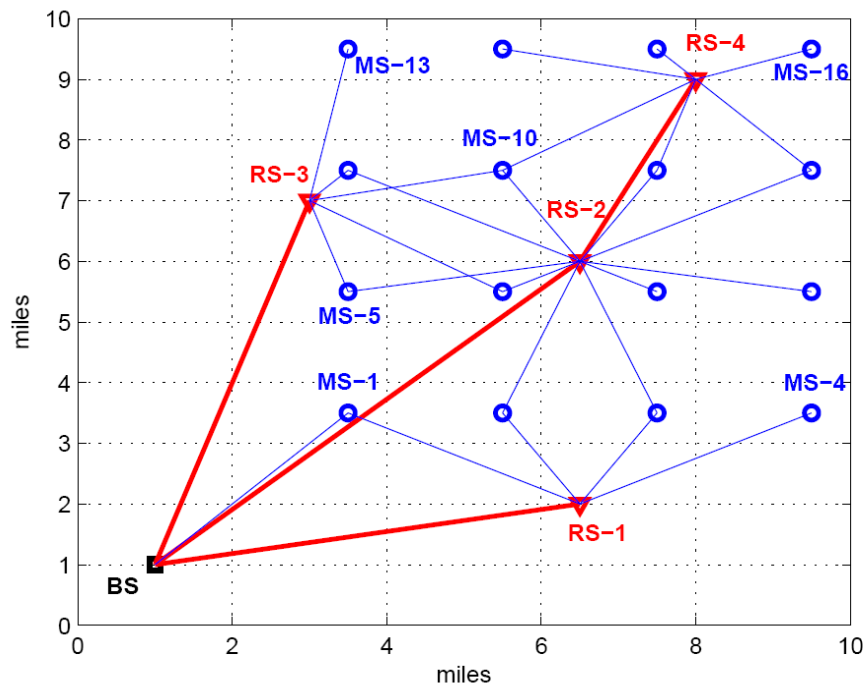

Figure 2 Simulation topology.

If ARQ is allowed for a certain RS, then, we simulate the realistic receiver/transmitter state machines for that RS and its parent node. Both the transmitter and the receiver keep track of the received packets, using a window of *10* packets. If a packet is not received after its maximum number of allowed retransmissions, it is dropped. We define a retransmission vector $\mathbf{r}=[r_1,r_2,r_3,r_4]$, where r_i denotes the maximum number of retransmissions allowed for RS-*i*. Note that r_i may delay the target transmission frame F_{tar} for the MBS packets due to extra delay caused by retransmissions. For example, for $\mathbf{r}=[0,0,0,0]$, the target transmission frame is *3*; the first two frames are used for pre-transmitting the packets to all the RSs, while simultaneous transmission to the MS happens in frame *3*. On the other hand, for $\mathbf{r}=[0,1,0,1]$, the target transmission frame becomes *5* due to the delay budget allocated for the retransmissions of RS-*2* and RS-*4*.

With a total number of *10000* symbols and a packet length of *50* symbols, we evaluate *200* packets per received signal. Moreover, the simulations are repeated over *240* different signal realizations for each link to populate the obtained PERs. The CDF of the PERs at different MSs and over different realizations are plotted in Figure 3 for different scenarios. We can observe that using ARQ improves the PER performance in all cases. Note that gains in the PER when allowing ARQ for RS-2 and RS-4 are much more significant than when allowing ARQ for RS-1 and RS-3; this is because RS-2 and RS-4 serves to a much larger number of MSs, and the link between RS-2 and the BS is relatively weaker than the other links due to larger path-loss, and using ARQ helps strengthening the link.

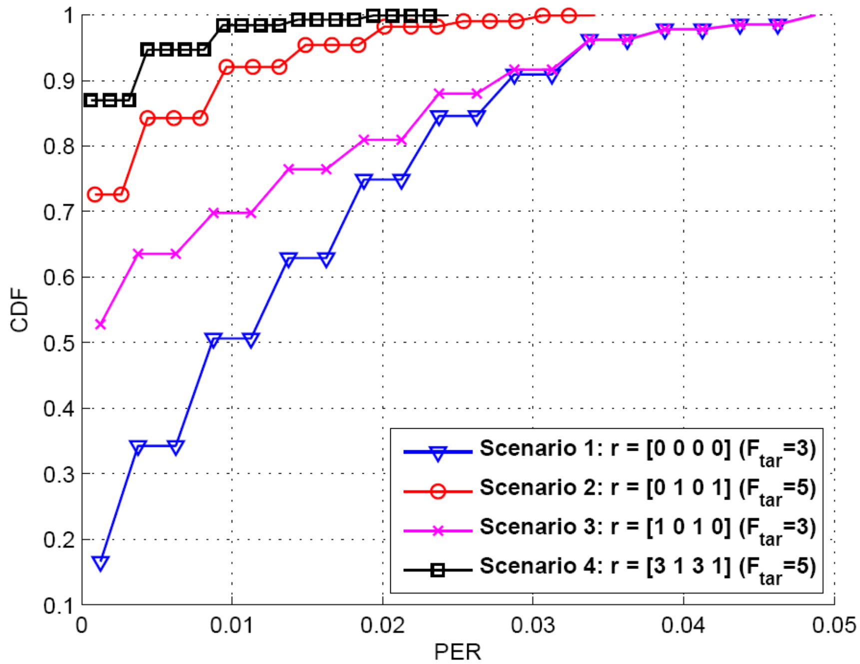

Figure 3 CDF of the PER for the simulation topology in Figure 2.