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Title	**Distributed Bandwidth Request and Allocation in Multi-Hop Relay**
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~~Re:~~	~~This is a response to the call for proposals 80216j-06_034.pdf.~~
~~Abstract~~	~~This contribution proposes a mechanism for requesting bandwidth allocation.~~
~~Purpose~~	~~Add proposed spec changes in P802.16j Baseline Document (IEEE 802.16j-06/026)~~

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Distributed Bandwidth Request and Allocation in Multi-Hop Relay

1 Introduction

In systems with distributed bandwidth allocation, each infrastructure station determines the bandwidth allocations on the links it controls (i.e. downlinks to and uplinks from its immediate downstream stations) and creates it own MAPs reflecting these decisions. The services they support are the same as those defined in 802.16e (i.e. UGS, rtPS, ertPS, nrtPS, and BE).

When relay is introduced into a network, the process of forwarding a packet to its destination incurs greater overhead and delay regardless of the bandwidth request and allocation method used. The bandwidth request methods available in relay networks are the same as those defined in 802.16e, i.e. a stand-alone BW request header, a piggybacked BW request, or a contention based CDMA BW request defined for WirelessMAN-OFDMA.

This contribution discusses protocols that reduce the delay and overhead in requesting and allocating BW in relay networks.

2 Delays in BW request and allocation without modifications to 802.16e

Based on the current 802.16e standard, the message flow required to transmit a packet from an MS to the MR-BS using the contention based method is depicted in Fig 1. This message flow is based on the in-band relay frame structure depicted in Fig 2. It is assumed that the time required to process a packet at the RS is no longer than the length of a frame. As the figure indicates, there will be large delays in forwarding packets if the process is not updated in some respect. The same holds true for other forms of BW request and allocation.

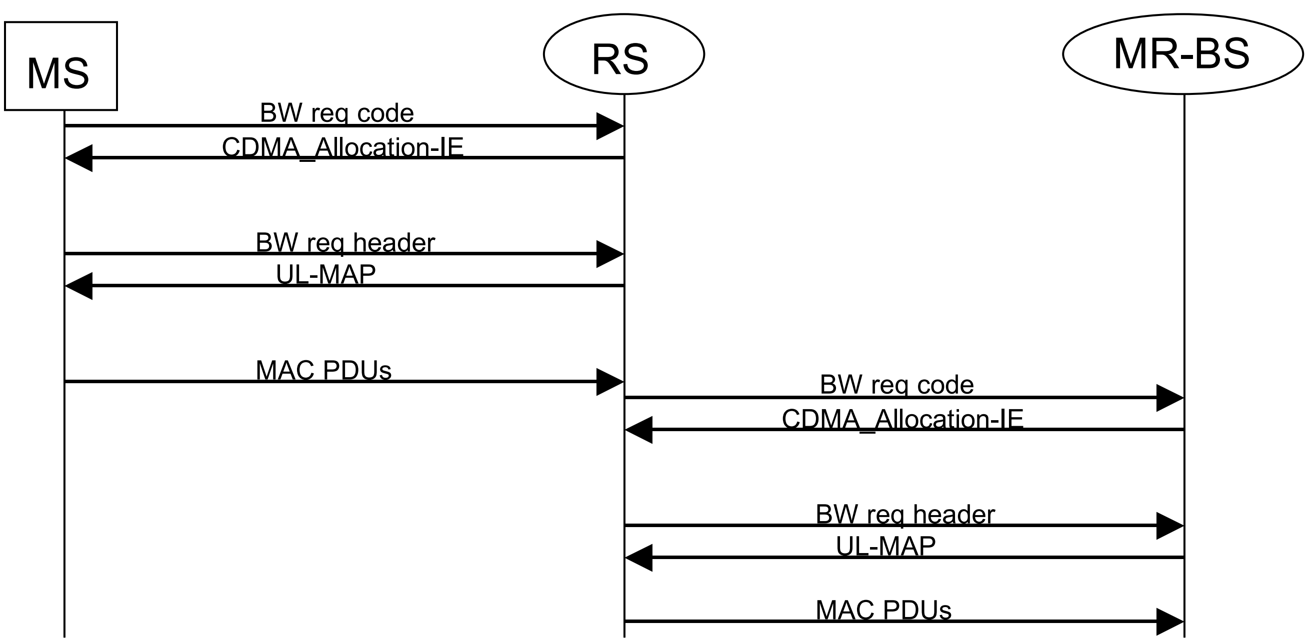

Figure 1 BW request and allocation in 802.16e systems using CDMA ranging codes

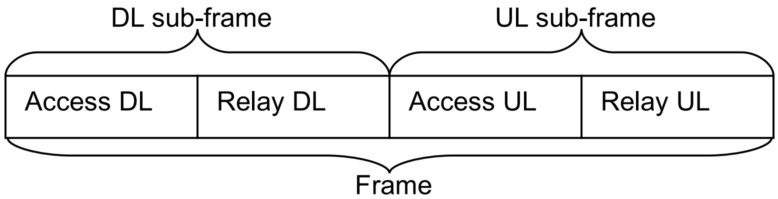

Figure 2 In-band relay frame structure

3 Proposal

As Figure 1 shows, when the signaling required to forward a packet from an MS to the MR-BS is transmitted sequentially, there is a long delay between when the MS first begins the process of requesting bandwidth for a data packet and when that packet arrives at the MR-BS (and this message flow assumes successful reception of all transmissions, unsuccessful transmissions would incur further delay). The latency in this process can be reduced significantly if the signaling used to acquire bandwidth on relay links is initiated sooner. It can be reduced further if the RS is instructed to aggregate bandwidth requests from its downstream stations. Doing so *also* reduces overhead. These delay and overhead reduction techniques are described in the next two sections.

3.1 Advancing the start time of relay link transmissions to reduce latency

There are several ways to advance the start time of relay link transmissions. These are outlined in the next few subsections.

3.1.1 Advancing the start time of the BW request process

The RS can reduce end-to-end packet transmission delay by advancing the start time of the BW request process with its upstream station.

For example, if the RS is polled or if it has uplink data transmissions, it can transmit or piggyback a BW request header soon after it receives a BW request header from one of its downstream stations (timed to yield an uplink allocation sequential to the arrival of those packets) instead of waiting for the actual packets to arrive. It must first check that is has resources on the uplink it controls before requesting BW on the uplink to its upstream station. This process is depicted in Figure 3.

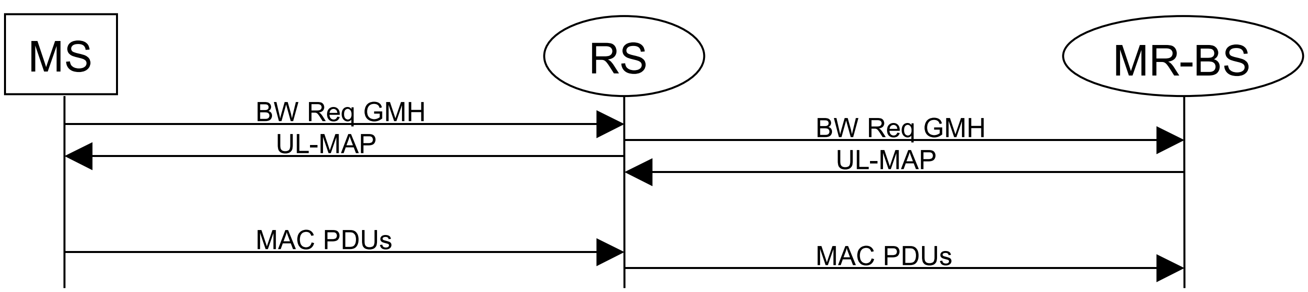

Figure 3 Advancing start time of BW request process on R-UL when RS is polled or can piggyback BW request

If the RS is not polled and does not have data transmissions on which to piggyback BW requests, the RS can reduce delay by starting the contention based BW request process with its upstream station soon after it receives a BW request code (or a BW request header when there is polling or piggybacking on the downstream station) from one of its downstream stations instead of waiting for the actual data packets to arrive. This assumes that the RS has resources to give to its downstream station on which to transmit data packets.

The resulting signaling in the case of contention based BW requests on both the access and relay links is depicted in Figure 4. As this figure shows, if the start time is calculated properly (taking into account when the BW request header is estimated to arrive from the downstream station, time required to process the BW request header, and time to successfully receive a CDMA_Allocation-IE from the upstream station), there should be an uplink allocation on which to transmit a BW request header to the RS's upstream station soon after the BW request arrives from the downstream station. Then, assuming the bandwidth request process is successful, there should be a bandwidth allocation on the uplink to the RS's upstream station shortly after the packet arrives from the downstream station and is processed by the RS.

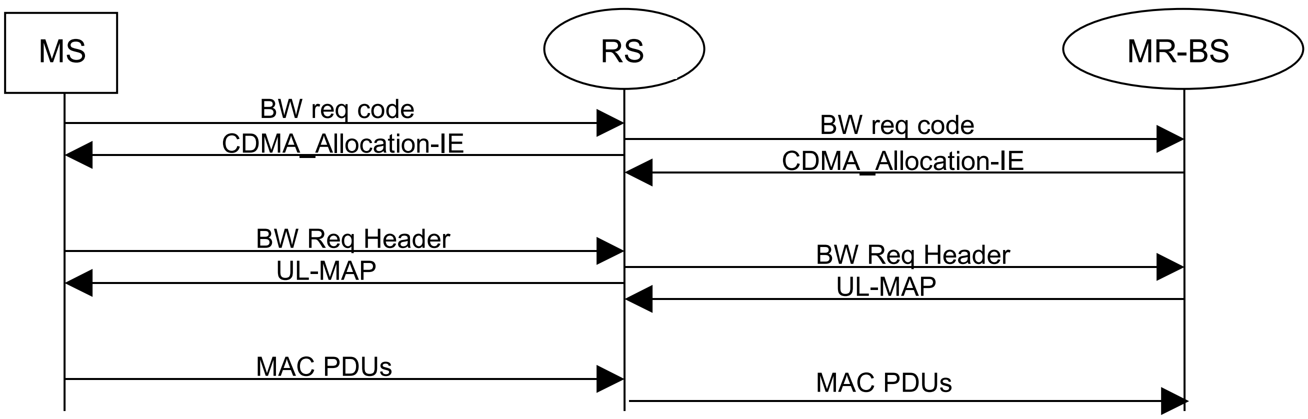

Figure 4 Advancing start time of BW request process on R-UL when RS uses contention based BW request

3.1.1Continuously polling RSs

Another method that will reduce end-to-end packet delay in multi-hop relay networks is to continuously poll the RSs in the network so that they can transmit a bandwidth (BW) request header as soon as they receive a packet or a bandwidth request header from one of their downstream stations. This signaling is depicted in Figure 5.

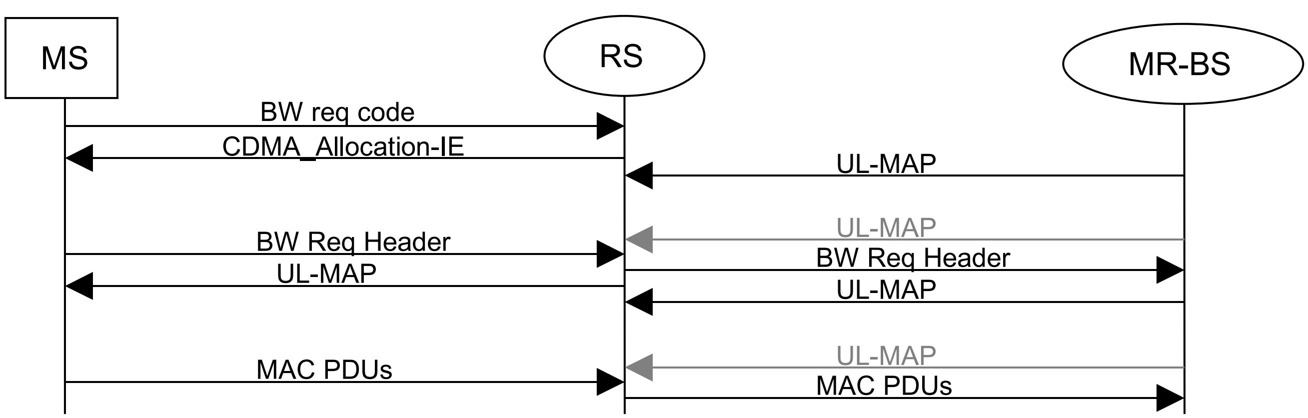

Figure 5 BW request and allocation with RS polling

3.2 Aggregating BW requests to reduce latency and overhead

In many cases, the RS will have many downstream stations composed of both SSs and other RSs. In order to reduce overhead and delay, the RS should aggregate the bandwidth requests it receives from downstream stations along with the bandwidth requirements of packets in queue.

In response to this aggregated bandwidth request, the RS will be allocated an R-UL burst with CID set to its basic RS CID. However, the RS may transmit SS or downstream RS MAC PDUs in this allocated region, setting the CID in the Generic MAC header to that of the transport CID to which the payload corresponds. To clarify this process, some text is proposed.

The RS may aggregate its received bandwidth requests based on QoS demands and send aggregated bandwidth requests to its upstream MR-BS/RS using CIDs that inform the upstream station of the required QoS. The aggregation of bandwidth requests by the RS is depicted in Figure 5.

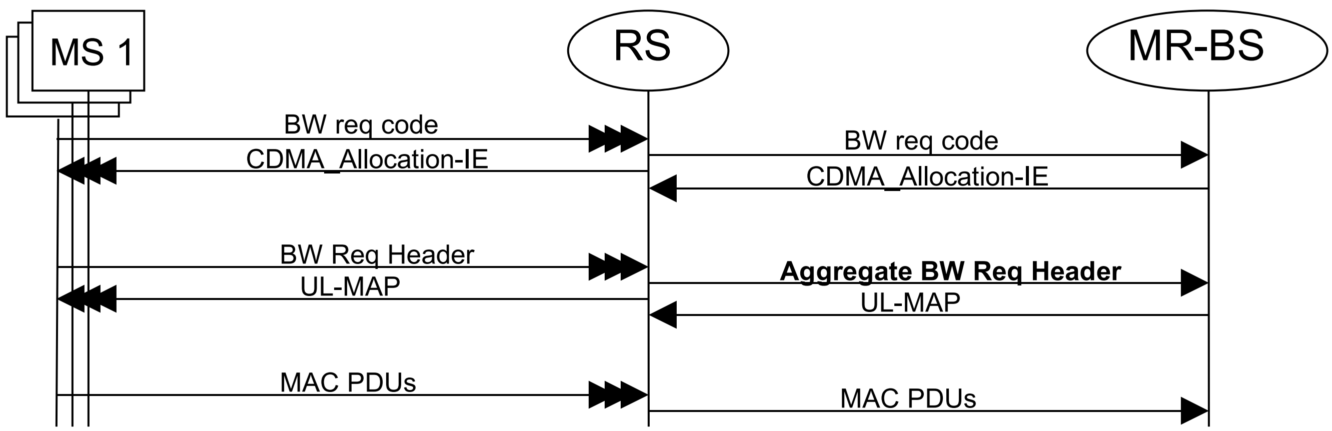

Figure 5 Aggregation of bandwidth requests by the RS

In summary, the RS will use the methods already available in IEEE Std 802.16 to request BW on the R-UL. Based on the case of the MAC signaling header Type 1 with the largest BR field of 19bits, this gives the total request size per header of 524288 bytes. Based on a maximum frame size of 20ms and minimum frame size of 2ms this enables the RS to request a maximum rate of 26.21Mbytes/s and 262Mbytes/s, respectively, based on sending a header in every frame. Therefore, this should be sufficient for the RS to indicate its bandwidth needs to the MR-BS.

4 Specification changes

[Edit 6.3.6.7 title as follows]

6.3.6.7 Relay~~ing support for scheduling~~ bandwidth request and allocation mechanisms

[Edit 6.3.6.7.1 title as follows]

6.3.6.7.1 Distributed ~~scheduling~~ bandwidth request and allocation

[Add following text to 6.3.6.7.1:]

In relay systems with distributed bandwidth request and allocation, each MR-BS and RS individually determines the bandwidth allocations on the links it controls (i.e. downlinks to and uplinks from its immediate downstream stations) and creates it own MAPs reflecting these decisions.

Bandwidth request and allocation procedures on the access link (i.e. between the SS and its access RS or MR-BS) are the same as those outlined in 6.3.6.1-6.3.6.3 and 6.3.6.5.

The following subclauses specify bandwidth request and allocation procedures for the relay link (i.e. between an RS and its upstream RS or MR-BS) in relay systems with distributed control. <Section note: additional BW request and allocation mechanisms may be defined for the relay link to improve its BW utilization. This is TBD.>

6.3.6.7.1.1 Bandwidth requests

The bandwidth request from an RS may come as a stand-alone bandwidth request header or piggybacked on other MAC PDUs. If it is a stand-alone bandwidth request header, it may come as a response to a poll (see 6.3.6.7.1.1.3) or as a result of a contention-based CDMA bandwidth request process (see 6.3.6.7.1.1.4). Because the uplink profile can change, all requests shall be made in terms of the number of bytes needed to carry the MAC header and payload, but not the PHY overhead. The bandwidth request header may be transmitted during any relay uplink allocation, except during initial ranging.

An RS may combine the bandwidth requests that arrive from downstream stations during a given period of time along with the bandwidth needs of packets in queue into one BW request header per QoS class. When resources are available, the upstream station will allocate bandwidth using the RS's Basic CID. The upstream station shall expect to receive concatenated (see Section 6.3.3.2) MAC PDUs with CIDs of transport connections from stations further down the tree.

In addition, the RS can transmit an aggregate or incremental bandwidth request. When the upstream station receives an incremental bandwidth request, it shall add the quantity of bandwidth requested to its current perception of the bandwidth needs of the connection. When the upstream station receives an aggregate bandwidth request, it shall replace its perception of the bandwidth needs of the connection with the quantity of bandwidth requested. The Type field in the bandwidth request header indicates whether the request is incremental or aggregate. Since piggybacked bandwidth request do not have a type field, they shall always be incremental.

The RS may transmit a BW request header soon after it receives a BW request header from one of its downstream stations (timed to yield an uplink allocation sequential to the arrival of those packets) instead of waiting for the actual packets to arrive in order to reduce delay in relaying traffic (see Figure ***x.1***). <Section note: the BW request headers defined for the relay link may be different from those defined for the access link to improve its BW utilization. This is TBD.>

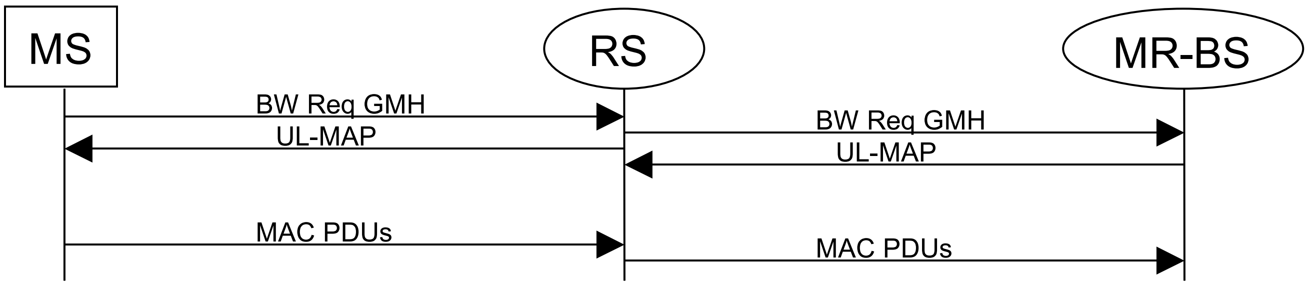

Figure *x.1* Reducing latency in relaying traffic by transmitting BW req. header on R-UL before packets arrive

6.3.6.7.1.2 Grants

RS bandwidth requests may reference specific connections, while each bandwidth grant an RS receives from its upstream station is addressed to the RS identifier. <Section note: identifier is TBD.>. The RS can schedule any MAC PDU on the bandwidth allocations it receives from its upstream station.

6.3.6.7.1.3 Polling

MR-BSs and RSs can allocate bandwidth to a downstream RS or a group of downstream RSs for the purpose of transmitting a bandwidth request header. This polling process on the relay link is the same as that defined for the access link in 6.3.6.3.

If the RS is regularly polled, it can transmit a bandwidth request header on the relay uplink as soon as it senses the lack of bandwidth for its subordinate MSs and RSs, thereby reducing relaying delay (see Figure ***x.2***).

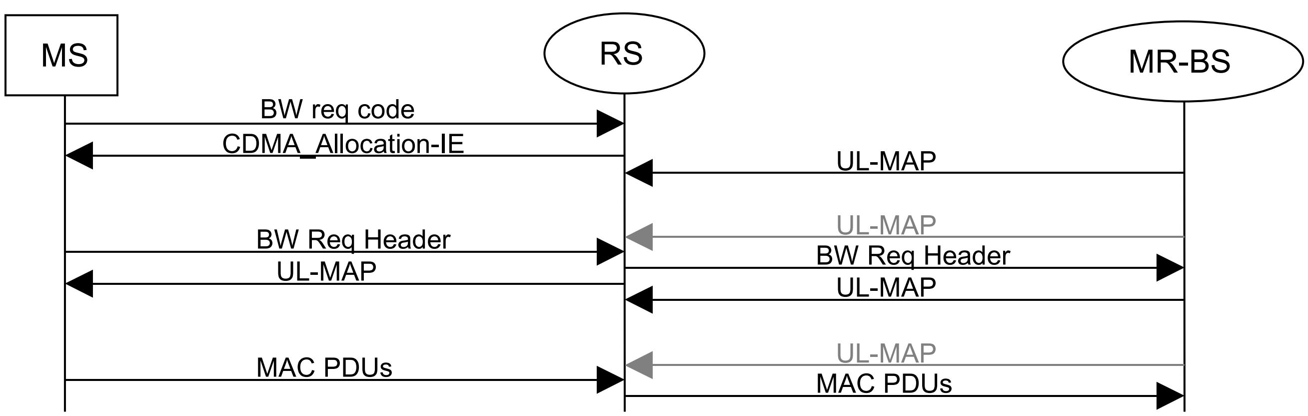

Figure *x.2* Reducing latency in relaying traffic via RS polling

6.3.6.7.1.4 Contention-based CDMA bandwidth requests

The contention-based CDMA bandwidth request process on the relay link is the same as that on the access link detailed in 6.3.6.5. The set of ranging codes used for bandwidth request on the relay link is the same as that used for the access link..

Upon needing bandwidth, the RS shall select a ranging code with equal probability from the code subset allocated for bandwidth requests. This ranging code shall be modulated onto the ranging subchannels and transmitted during the appropriate relay uplink allocation.

Upon detection of the ranging code, the RS's upstream station shall provide a relay uplink allocation using a CDMA_Allocation_IE specifying the transmit region and ranging code used by the RS. Once the RS determines it has been given an allocation by matching the transmit region and code it used against those specified by the CDMA_Allocation_IE, it shall use the allocation to transmit a bandwidth request header and/or data. If the upstream station does not issue a relay uplink allocation or if the bandwidth request header does not result in a bandwidth allocation, the RS shall assume a collision took place and follow the contention resolution specified in 6.3.8.

The RS may reduce the latency of relaying traffic by sending a bandwidth request CDMA ranging code as soon as it receives one from a downstream station instead of waiting for the actual packets to arrive (see Figure ***x.3***).

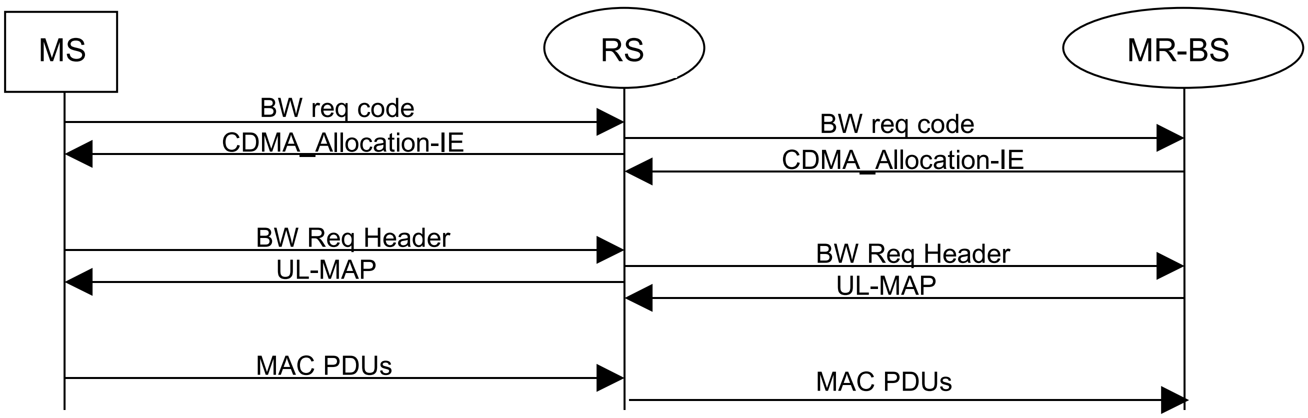

Figure x.3 Reducing latency in relaying traffic by early transmission of BW request ranging code on the R-UL