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Wireless RANs

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| MAC PDU Construction & Subheader Management | | | | |
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Abstract

This contribution provides resolutions to the MAC PDU Construction and Subheader handling issues (i.e. 1.D.3, 1.D.5, 1.E.2) brought up in DCN 22-14/82r0.

R0: initial version of this contribution

R1: Second version, some minor edits

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# Introduction

In Sections 1.D and 1.E of DCN 22-14/82r0, issues regarding how MAC PDUs are processed and how subheaders are handled were discussed. These procedures have some security sublayer related dependencies, and this contribution provides text to resolve them. In particular this contribution provides text to cover recommendations 1.D.3, 1.D.5, and 1.E.2.

# 1. Recommendation 1.D.3

Recommendation 1.D.3 in DCN 22-14/82r0 is as follows:

***“1.D.3: Clearly define what Subheaders are applicable to S-CPEs that talk through a distributed R-CPE. This list should be as follows: BR, Packing/Fragmentation, GMSH, and ARQ feedback. Existing rules in section 7.6.1.2 of 802.22-2011 should be followed when determining the order. The order should be as follows: BR 1st if no GMSH, GMSH then BR if GMSH present, then Extended Type/Channel Aggregation, then ARQ feedback and finally the Fragmentation subheader. Packing subheader is added before each packed SDU”***

There has been discussion (during TGb telecons) on this issue and the following text is proposed to resolve this issue.

***Modify the text in 7.6.1.2 in base standard as follows***

***<Start of modification>***

Five types of subheaders may be present. These subheaders can be categorized into two types, subheaders attached per-PDU and subheaders that are attached to each packed SDU (per-SDU). The Fragmentation/Packing subheader is considered to be a per-PDU when the “Purpose” bit in Table 6 is set to 0 (e.g. set to Fragmentation). The other ~~The~~ per-PDU subheaders ~~(i.e.,~~ are the Bandwidth Request, ~~Fragmentation/Packing~~Extended Subheader, the Grant Management Subheader, and the ARQ Feedback subheader. The per-PDU subheaders may be inserted in MAC PDUs immediately following the generic MAC header.

If indicated, the Bandwidth Request (BR) subheader shall always follow the Generic MAC header. In the upstream, if both the Grant Management subheader and Fragmentation/Packing subheader (set to Fragmentation) are indicated, the Grant Management subheader shall come first. If both the Grant Management subheader and Bandwidth Request subheader are indicated, the Grant Management subheader shall come first. If Extended Subheader and BR request subheader are both present, the Extended Subheader comes first.

For the upstream, the following order for per-PDU subheaders, when multiple subheaders are present in the same MAC PDU, shall be followed: Grant management subheader, Extended subheader, Bandwidth request subheader, and Fragmentation/Packing subheader (set to Fragmentation), and ARQ feedback payload. For the downstream, the following order of per-PDU subheaders shall be followed: Extended subheader, Fragmenation/Packing (set to Fragmentation), and ARQ Feedback.

The only per-SDU subhdeader is the Fragmentation/Packing subheader set to packing. There can be more than one Fragmentation/Packing subheader in a MAC PDU, all configured for packing. There can only be one Fragmentation/Packing subheader in the MAC PDU if configured for fragmentation. The Fragmentation/Packing subheader may be inserted before each MAC SDU if so indicated by setting Bit 1 in the Type field of the generic MAC Header and by setting the “Purpose bit” in 250HTable 6 to 1.

When present, per-PDU subheaders shall always precede the first per-SDU subheader.

***<End of modification>***

# 1. Recommendation 1.D.5

Recommendation 1.D.5 in DCN 22-14/82r0 is as follows:

***“1.D.5: We need to define a clear procedure for how PDUs are formatted & transmitted when using both & distributed R-CPE. The procedure defiend above should be a good start. It handles what to do when CPEs are configured to use encryption/authentication or not. “***

There has been discussion (during TGb telecons) on this issue and the following text is proposed to resolve this issue.

***Add a new subsection, 7.8.8 “MAC PDU Construction for A-CPE” after section 7.8.6 in 802.22-2011, with the following text***

***<Start of modification>***

### 7.8.8 MAC PDU Construction for A-CPE

In the relay network, a centralized scheduling A-CPE will not be doing any additional fragmentation and/or packing of PDUs exchanged between the A-BS and the S-CPE. The procedures defined in sections 7.8.1 – 7.8.6 shall be followed by the A-BS and S-CPE when exchanging MAC PDUs in either the DS or US, through a centralized scheduling A-CPE. These procedures are applicable to connections between the S-CPE and A-BS that use ARQ and those connections that do not use ARQ.

Distributed scheduling A-CPEs have the ability to locally make decisions with regard to allocating bandwidth and scheduling resources for S-CPEs that are attached to it. Procedures defined in this section describe how the distributed scheduling A-CPE processes MAC PDUs being exchanged through it between the A-BS and S-CPE. These procedures take into account the configuration of the security sublayer for the S-CPE, and whether or not ARQ is enabled for FIDs associated with a particular S-CPE. Indication of encryption/authentication being configured for the S-CPE is given when the EC bit in the GMH is set to 1.

### 7.8.8.1 MAC PDU Construction for Distributed scheduling A-CPE on non-ARQ connections

In this section, procedures for construction of MAC PDUs that may or may not require further Fragmentation/Packing on non-ARQ connections are defined. The four procedures defined in this section are as follows:

1. Security enabled, no further fragmentation/packing by A-CPE of MAC PDUs
2. Security enabled, A-CPE will further fragement/pack MAC PDUs
3. Security disabled, no further fragementation/packing by A-CPE of MAC PDUs
4. Security disabled, A-CPE will further fragment/pack MAC PDUs

Procedure 1 on non-ARQ connections: The following procedure shall be used when the security sublayer for the S-CPE is configured to provide authentication/encryption of MAC PDUs exchanged between the A-BS and S-CPE, and the distributed scheduling A-CPE will not further fragment/pack PDUs:

* 1. When a distributed scheduling A-CPE receives MAC PDU from a S-CPE or A-BS, the subheaders attached to the PDU are processed as necessary. In the US, this may include the BR subheader and Grant management subheader (GMSH).
  2. The A-CPE forwards the MAC PDU as is, i.e. it does not modify the MAC PDU contents (GMH, subheaders, payload).
  3. Upon reception of the MAC PDU at the intended destination the GMH and non-Fragmentation/Packing subheaders are processed first as follow:
     1. In the US: When the A-BS receives a MAC PDU that was relayed by A-CPE for an attached S-CPE with EC bit set to 1 in the GMH and the Type field indicating the presence of the BR and/or GMSH subheaders:
        1. the BR/GMSH subheader will be ignored, because those subheaders will have been processed by the A-CPE.
     2. In the DS: When the S-CPE receives a MAC PDU that was relayed by A-CPE on behalf of the A-BS with the EC bit set to 1 in the GMH, the PDU will be authenticated/decrypted
  4. A-BS/S-CPE will then go on to process the Fragmentation/Packing subheaders (included by the S-CPE or A-BS that sent the MAC PDU) as necessary:
     1. will then process the fragmentation subheader before decrypty/authenticating the MAC PDU payload
     2. proceed to decrypt/authenticate the PDU prior to processing each packed SDU.

Procedure 2 on non-ARQ connections: The following procedure shall be used when the security sublayer for the CPE is configured to provided authentication/encryption of the MAC PDUs exchanged between A-BS and S-CPE, and the A-CPE will further fragment/pack PDUs:

1. When a distributed scheduling A-CPE receives MAC PDU from a S-CPE or A-BS, the subheaders attached to the PDU are processed as necessary. In the US this may include the BR subheader and/or GMSH.
2. If the A-CPE has to pack multiple PDUs to transmit to the A-BS that come from one or more S-CPEs in the US:
   1. The A-CPE will bundle those PDUs into a Container Message (See 7.7.26) and transmit the burstof MAC PDUs containing the Container Message to the A-BS
   2. When the A-BS receives the packed PDU, it will unpack each of the S-CPE’s MAC PDUs from the Container Message.
   3. For each unpacked MAC PDU, it will be processed as indicated in “Procedure 1 on non-ARQ connections”
3. If the A-BS packs multiple PDUs destined for one or more S-CPEs in the DS:
   1. It will bundle those PDUs into a Container Message (see 7.7.26) and send it to the A-CPE
   2. The A-CPE will begin to process the Container Message.
      1. For each S-CPE that has >1 MAC PDUs bundled within the Container Message; S-CPE will pack each of those PDUs into one new MAC PDU setting the EC bit in the GMH set to 0 and send it to the intended S-CPE
      2. For CPEs that only have one MAC PDU in the container message, the A-CPE will copy it out of Container Message and forward it to the destination S-CPE
   3. For each MAC PDU received at the S-CPE, it will be processed as indicated in “Procedure 1 on non-ARQ connections”
4. If the A-CPE has to fragment a MAC PDU, that it is forwarding in the US:
   1. It will form a new MAC PDU with a GMH that has EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, finally attaching a CRC.
   2. The A-CPE will bundle fragments from multiple S-CPEs into a Container Message and forward the Container Message to A-BS
   3. When the A-BS receives the Container Message, it will unpack and store the PDU fragment for each S-CPE indicated in the Container Message.
   4. It will continue to do this until it receives all fragments from the A-CPE
   5. Once it receives all the fragments of the S-CPEs PDU, A-BS will process the MAC PDU and subheaders as defined in “Procedure 1 for non-ARQ Connections”
5. If the A-CPE has to fragment a MAC PDU, that it is forwarding in the DS:
   1. It will form a new MAC PDU with a GMH that has EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, finally attaching a CRC.
   2. The A-CPE will send each S-CPEs MAC PDU fragments to the S-CPE
   3. The S-CPE will continue to receive all the fragments
   4. Once it receives all the fragments sent by the A-CPE PDU, the S-CPE will process the MAC PDU and subheaders as defined in “Procedure 1 for non-ARQ Connections”

Procedure 3 on non-ARQ connections: When S-CPE encryption/authencation disabled & A-CPE will not further fragment/pack PDUs:

1. When a distributed scheduling A-CPE receives MAC PDU from a S-CPE or A-BS, the subheaders attached to the PDU are processed as necessary. In the US this may include the BR subheader and/or GMSH
2. If the A-CPE receives a MAC PDU from one or more S-CPEs in the US:
   1. The A-CPE will process subheaders as necessary.
   2. After processing the subheaders the A-CPE will generate a new MAC PDU by:
      1. Strip out the BR and/or GMSH subheader if present, also strip out CRC
      2. Create a new MAC PDU that has GMH with the BR/GMSH indicators in Type field set to 0, and packing/fragmentation subheader, recalculate the HCS of the GMH
      3. Append new CRC to paylaod
   3. The A-CPE forwards the new MAC PDU as currently defined. If transmission of PDUs from >1 S-CPEs is occurring repeat step (2.a-2.c) of this procedure and bundle the MAC PDU of each S-CPE into a Container Message to forward to A-BS
3. If the A-CPE receives a MAC PDU or Container Message in the DS:
   1. It will unpack each PDU from the Container Message and forward it to intended S-CPE.
4. In the US, when A-BS receives the Container Message,
   1. It will unpack each S-CPE’s MAC PDU from the Container Message, then
   2. Process the Fragmentation/Packing subheaders that are part of the original MAC PDU originated by S-CPE
5. In the DS, when the S-CPE receives a PDU transmission from A-CPE:
   1. Process the Fragmentation/Packing subheaders that are part of the original MAC PDU originated by A-BS

Procedure 4 on non-ARQ connections: When S-CPE encryption/authencation disabled & A-CPE will further fragment/pack PDUs:

1. When a distributed scheduling A-CPE receives MAC PDU from a S-CPE or A-BS, the subheaders attached to the PDU are processed as necessary. In the US this include the BR subheader and/or GMSH .
2. In the US, for each S-CPE’s PDU that is received at the A-CPE, and packing is to be used, each PDU is first transformed by the procedure defined in steps 2.a and 2.b of “Procedure 3 for non-ARQ Connections”
   1. It will form a new MAC PDU with a GMH that has EC bit set to 0, indicating packing subheader for each packed PDU from a S-CPE, finally attaching a CRC. The A-CPE forwards the new MAC PDU as currently defined.
      1. Repeat for each S-CPE that has one or more PDUs that can be packed
   2. Bundle the new PDUs from one or more S-CPEs in a Container Message and forward the Container Message to A-BS
   3. When the A-BS receives the Container Message it unpacks each S-CPEs burst and processes it according to Step 4 of “Procdure 3 for non-ARQ Connections”
3. In the DS, when the A-CPE receives the Container Message with one or more bursts associated with a particular S-CPE
   1. each PDU associated with a particular S-CPE is first transformed by the procedure defined in steps 2.a and 2.b of “Procedure 3 for non-ARQ Connections”
   2. A-CPE will form a new MAC PDU with a GMH that has EC bit set to 0, indicating packing subheader for each packed PDU from an S-CPE, finally attaching a CRC. The A-CPE forwards the new MAC PDU to the S-CPE.
4. If the A-CPE has to fragment a MAC PDU, that it is forwarding in the US:
   1. It will form a new MAC PDU with a GMH that has EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, finally attaching a CRC.
   2. The A-CPE will bundle fragments from multiple S-CPEs into a Container Message and forward Container Message to A-BS
   3. When the A-BS receives the Container Message, it will unpack and store the PDU fragment for each S-CPE indicated in the Container Message.
   4. It will continue to do this until it receives all fragments from the A-CPE
   5. Once it receives all the fragments of the S-CPEs PDU, A-BS will process the MAC PDU and subheaders of the constituted/complete MAC PDU originated by the S-CPE associated with the burst in the Container Message
5. If the A-CPE has to fragment a MAC PDU, that it is forwarding in the DS:
   1. It will form a new MAC PDU with a GMH that has EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, finally attaching a CRC.
   2. The A-CPE will send each S-CPEs MAC PDU fragments to the S-CPE
   3. The S-CPE will continue to receive all the fragments
   4. Once it receives all the fragments sent by the A-CPE PDU, the S-CPE will process the MAC PDU and subheaders as defined in Step 5 of “Procedure 3 for non-ARQ Connections”

### 7.8.8.2 MAC PDU Construction for Distributed A-CPE on ARQ connections

Procedures 1-4 outlined in section 7.8.8.1 are applicable to the exchange of MAC PDUs on ARQ connections between the A-BS and S-CPEs through a distributed scheduling A-CPE, as defined by the conditions in this section.

Procedure 1 for ARQ Connections: The following procedure shall be used when the security sublayer for the S-CPE is configured to provide authentication/encryption of MAC PDUs exchanged between the A-BS and S-CPE, and the distributed scheduling A-CPE will not further fragment/pack PDUs

1. In the US and DS the ARQ Feedback subheader can be attached to MAC PDUs
2. Follow “Procedure 1 for non-ARQ Connections” using the adjustements for ARQ connections in the US and DS as listed in steps 3 and 4 of this procedure
3. In the US:
   1. If end-to-end ARQ is used:
      1. the A-CPE will ignore the ARQ feedback subheader (attached to MAC PDU received from S-CPE) and forward the MAC PDU to the A-BS as is (i.e. forwarding the MAC PDU without altering the GMH, the ARQ Feedback IE, or the contents).
      2. When the A-BS receives the MAC PDU, it will process the ARQ Feedback IE attached to the MAC PDU
   2. If two-link ARQ is used:
      1. the A-CPE will process the ARQ feedback subheader (attached to MAC PDU received from the S-CPE)
      2. The A-CPE will then wrap the MAC PDU (i.e. without altering the GMH, the ARQ Feedback IE, or the payload) in a new MAC PDU and attach an ARQ feedback IE to represent the ARQ process on the A-CPE/A-BS link
      3. then forward the MAC PDU to the A-BS
      4. When the A-BS receives the MAC PDU first process the outer MAC PDU and ARQ feedback IE, but will ignore the ARQ Feedback IE attached to the original MAC PDU
4. In the DS:
   1. If end-to-end ARQ is used:
      1. the A-CPE will ignore the ARQ feedback subheader (attached to MAC PDU received from A-BS)
      2. and forward the MAC PDU to the S-CPE as is (i.e. forwarding the MAC PDU without altering the GMH, the ARQ Feedback IE, or the pay).
      3. When the S-CPE receives the MAC PDU, it will process the ARQ Feedback IE attached to the MAC PDU
   2. If two-link ARQ is used:
      1. the A-CPE will process the ARQ feedback subheader (attached to MAC PDU received from the A-BS)
      2. The A-CPE will then wrap the MAC PDU (i.e. without altering the GMH, the ARQ Feedback IE, or the payload) in a new MAC PDU and attach an ARQ feedback IE to represent the ARQ process on the A-CPE/S-CPE link
      3. then forward the MAC PDU to the S-CPE
      4. When the S-CPE receives the MAC PDU first process the outer MAC PDU and ARQ feedback IE, but will ignore the ARQ Feedback IE attached to the original MAC PDU

Procedure 2 for ARQ Connections: The following procedure shall be used when the security sublayer for the CPE is configured to provided authentication/encryption of the MAC PDUs exchanged between A-BS and S-CPE, and the A-CPE will further fragment/pack PDUs:

1. In the US and DS the ARQ Feedback subheader can be attached to MAC PDUs
2. Follow Procedure 2 for non-ARQ Connections using the adjustements for ARQ connections in the US and DS as listed in steps 3 and 4 of this procedure
3. In the US:
   1. If the A-CPE must pack multiple MAC PDUs:
      1. If end-to-end ARQ is used:
         1. the A-CPE will ignore the ARQ feedback subheader (attached to MAC PDU received from S-CPE).
         2. It will then bundle the MAC PDUs as is (i.e. forwarding the MAC PDU without altering the GMH, the ARQ Feedback IE, or the contents) from one or more S-CPEs into a Container Message.
         3. The A-CPE will forward the Container Message to the A-BS.
         4. When the A-BS receives the Container Message it will unbundle each S-CPEs MAC PDU, it will process the ARQ Feedback IE attached to the MAC PDU
      2. If two-link ARQ is used:
         1. the A-CPE will process the ARQ feedback header attached to a MAC PDU received from each S-CPE.
         2. It will then bundle the MAC PDUs as is (i.e. without altering the GMH, the ARQ Feedback IE, or the payload) from one or more S-CPEs into a Container Message. The MAC PDU that encapsulates the Container Message shall have a ARQ Feedback IE added to to indicate the ARQ process for the A-BS/A-CPE link.
         3. Successful delivery of the MAC PDU that encapsulates the Container Message is dependent upon the ARQ process on the A-BS/A-CPE link. When the A-BS receives the Container Message it will process the ARQ Feedback IE attached to the Container Message
         4. The A-BS will the process the Container Message and unbundle each S-CPEs MAC PDU
         5. For each received S-CPE MAC PDU, the A-BS will ignore the ARQ Feedback IE attached to the original MAC PDU
   2. If the A-CPE must fragment MAC PDUs:
      1. If end-to-end ARQ is used:
         1. The A-CPE will ignore the ARQ feedback IE attached to MAC PDU by the S-CPE
         2. If fragmentation necessary, the A-CPE will form a new MAC PDU with a GMH that has EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, finally attaching a CRC. When creating the fragments it will not alter the contents (e.g. GMH, subheaders, payload) of the original MAC PDU
         3. The A-CPE will bundle fragments from multiple S-CPEs into a Container Message and forward the Container Message to A-BS
         4. When the A-BS receives the Container Message, it will unpack and store the PDU fragment for each S-CPE indicated in the Container Message.
         5. It will continue to do this until it receives all fragments from the A-CPE
         6. Once it receives all the fragments of the S-CPEs PDU, A-BS will process the MAC PDU, including the processing the ARQ Feedback subheader of the original MAC PDU.
      2. If two-link ARQ is used
         1. The A-CPE will process the ARQ feedback IE attached to MAC PDU by the S-CPE
         2. If necessary, the A-CPE will form a new MAC PDU with a GMH that has EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, finally attaching a CRC. When doing this it will not alter the original contents (e.g. GMH, subheaders, payload) of the MAC PDU
         3. It will then bundle the MAC PDU fragments from one or more S-CPEs in to a Container Message. The MAC PDU that encapsulates the Container Message shall have an ARQ Feedback IE added to to indicate the ARQ process for the A-BS/A-CPE link.
         4. Successful delivery of the MAC PDU that encapsulates the Container Message is dependent upon the ARQ process on the A-BS/A-CPE link.
         5. When the A-BS receives the Container Message, it will first process the ARQ feedback IE attached to the MAC PDU encapsulating the Container Message, then it will unpack and store the PDU fragment for each S-CPE indicated in the Container Message.
         6. It will continue to do this until it receives all fragments from the A-CPE
         7. Once A-BS receives all the fragments of the S-CPEs PDU, the A-BS will process the MAC PDU; this also includes that the A-BS shall ignore the ARQ Feedback subheader of the original MAC PDU that it reassembles for each S-CPE.
4. In the DS:
   1. If the A-BS must pack multiple MAC PDUs destined for one or more S-CPEs in the DS:
      1. If end-to-end ARQ is used:
         1. The A-BS will bundles pack PDUs for each S-CPE into its’ own MAC PDU and adds the ARQ feedback subheader.
         2. Insert generated MAC PDUs into a Container Message and send it to the A-CPE
         3. The A-CPE receives the Container Message and begins to process it
            1. Unbundle a PDU destined for the S-CPE
            2. Forward the PDU to the S-CPE as is (i.e. the A-CPE shall ignore the ARQ feedback IE)
            3. Repeat until all PDUs in Container Message have been forwarded
         4. When S-CPE receives the MAC PDU it will process the attached ARQ feedback subheader
      2. If two-link ARQ is used:
         1. The A-BS will bundles pack PDUs for each S-CPE into its’ own MAC PDU
         2. Insert generated MAC PDUs into a Container Message and send it to the A-CPE. The MAC PDU that encapsulates the Container Message shall have a ARQ Feedback IE added to to indicate the ARQ process for the A-BS/A-CPE link.
         3. Successful delivery of the MAC PDU that encapsulates the Container Message is dependent upon the ARQ process on the A-BS/A-CPE link. When receiving the Container Message, the A-CPE will first process the ARQ Feedback IE attached to MAC PDU that encapsulates the Containre Message.
         4. The A-CPE receives the Container Message and begins to process it
            1. Unbundle a PDU destined for the S-CPE
            2. Encapsulate the unbundled PDU in a new MAC PDU (w/ EC bit set to 0 in GMH) with an ARQ feedback subheader (this represents the ARQ process on the S-CPE/A-CPE link)
            3. Repeat until all PDUs in Container Message have been forwarded
         5. When S-CPE receives the MAC PDU it shall process the attached ARQ feedback subheader as defined, then unbundle the original (packed) PDU
         6. The ARQ Feedback IE attached to the original (packed) PDU shall be ignored by the S-CPE
   2. If the A-BS has PDUs to send to S-CPEs attached to an A-CPE, and the A-CPE must fragment MAC PDUs:
      1. If end-to-end ARQ is used:
         1. The A-BS will create the MAC PDU and add the ARQ feedback subheader
         2. Then the A-BS bundles MAC PDUs for multiple S-CPEs into a Container Message and send it to the A-CPE
         3. The A-CPE will process each contained MAC PDU in the Container Message
            1. The A-CPE will unbundle the MAC PDU from the Container Message
            2. If necessary the A-CPE will fragment the PDU: form a new MAC PDU with a GMH that has EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, finally attaching a CRC. When this is done, the contents of the original MAC PDU will not be altered
            3. The A-CPE will send each fragment to the destination S-CPE
         4. Each S-CPE will collect those fragments, processing the new fragmentation subheader.
         5. Once an S-CPE has collected all of the fragments, and has resassembled the original MAC PDU, it will process the ARQ feedback subheader of the original MAC PDU
      2. If two-link ARQ is used
         1. The A-BS shall not add ARQ feedback subheader to MAC PDUs it’s transmitting in the DS
         2. The A-BS will create a Container Message to bundle MAC PDUs to be transmitted to S-CPEs that are attached to an A-CPE. The MAC PDU encapsulating the Container Message shall have an ARQ feedback subheader (related to the A-BS/A-CPE ARQ process)
         3. The A-BS then sends the Container Message to the A-CPE
         4. Successful delivery of the MAC PDU that encapsulates the Container Message is dependent upon the ARQ process on the A-BS/A-CPE link.
         5. The A-CPE will process each contained MAC PDU in the Container Message
            1. The A-CPE will unbundle the MAC PDU from the Container Message
            2. If necessary the A-CPE will fragment the PDU:

The new form a new MAC PDU with a GMH that has EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, finally attaching a CRC. When this is done the contents of the original MAC PDU will not be altered

Each new fragment will have the ARQ feedback subheader attached to it, before being sent to S-CPE

* + - 1. Each S-CPE will collect those fragments, processing the new fragmentation subheader and the attached ARQ feedback subheader.
      2. Once an S-CPE has collected all of the fragments, and will reassemble the original MAC PDU

Procedure 3 on ARQ connections: When S-CPE encryption/authencation disabled & A-CPE will not further fragment/pack PDUs:

1. In the US and DS the ARQ Feedback subheader can be attached to MAC PDUs
2. Follow Procedure 3 for non-ARQ Connections using the adjustements for ARQ connections in the US and DS as listed in steps 3 and 4 of this procedure
3. In the US:
   1. If end-to-end ARQ is used:
      1. the A-CPE will ignore the ARQ feedback subheader (attached to MAC PDU received from S-CPE), but process any other subheaders attached.
      2. The A-CPE will strip out the other subheaders and create a new MAC PDU, and copy the ARQ feedback header and forward the MAC PDU to the A-BS
      3. When the A-BS receives the MAC PDU, it will process the ARQ Feedback IE attached to the MAC PDU
   2. If two-link ARQ is used:
      1. the A-CPE will process the ARQ feedback header (attached to MAC PDU received from the S-CPE)
      2. It will process the ARQ feedback header (as received from the S-CPE) as well as any other subheaders.
      3. It will strip out the existing subheaders and create a new MAC PDU
      4. The new MAC PDU will have a new ARQ feedback subheader to indicate the ARQ process between the A-CPE and A-BS
      5. The A-CPE will then forward the MAC PDU to the A-BS
      6. When the A-BS receives the MAC PDU, it will processthe ARQ Feedback IE attached to the MAC PDU
4. In the DS:
   1. If end-to-end ARQ is used:
      1. the A-CPE will ignore the ARQ feedback subheader (attached to MAC PDU received from A-CPE), but process any other subheaders attached.
      2. The A-CPE will strip out the other subheaders and create a new MAC PDU, and copy the ARQ feedback header and forward the MAC PDU to the A-BS
      3. When the S-CPE receives the MAC PDU, it will process the ARQ Feedback IE attached to the MAC PDU
   2. If two-link ARQ is used:
      1. the A-CPE will process the ARQ feedback header (attached to MAC PDU received from the A-BS)
      2. It will process the ARQ feedback header (as received from the A-BS) as well as any other subheaders.
      3. It will strip out the existing subheaders and create a new MAC PDU
      4. The new MAC PDU will have a new ARQ feedback subheader to indicate the ARQ process between the A-CPE and S-CPE
      5. The A-CPE will then forward the MAC PDU to the S-CPE
      6. When the S-CPE receives the MAC PDU, it will processthe ARQ Feedback IE attached to the MAC PDU

Procedure 4 on ARQ connections: When S-CPE encryption/authencation disabled & A-CPE will further fragment/pack PDUs:

1. In the US and DS the ARQ Feedback subheader can be attached to MAC PDUs
2. Follow Procedure 4 for non-ARQ Connections using the adjustements for ARQ connections in the US and DS as listed in steps 3 and 4 of this procedure
3. In the US:
   1. If the A-CPE must pack multiple MAC PDUs:
      1. If end-to-end ARQ is used:
         1. the A-CPE will ignore the ARQ feedback subheader (attached to MAC PDU received from S-CPE).
         2. It will process any of the other subheaders and strip them out of the MAC PDU
         3. The A-CPE will then create a new MAC PDU, add the original ARQ Feedback IE and MAC PDU payload (without modifying it). Do this for each S-CPE sending a MAC PDU in US.
         4. It will then bundle the MAC PDUs from one or more S-CPEs in to a Container Message.
         5. The A-CPE will forward the Container Message to the A-BS.
         6. When the A-BS receives the Container Message it will unbundle each S-CPEs MAC PDU, it will process the ARQ Feedback IE attached to the MAC PDU
      2. If two-link ARQ is used:
         1. the A-CPE will process the ARQ feedback header attached to a MAC PDU received from each S-CPE.
         2. It will process any of the other subheaders and strip them out of the MAC PDU
         3. The A-CPE will then create a new MAC PDU, and copy the original and MAC PDU payload. Do this for each S-CPE sending a MAC PDU in US.
         4. It will then bundle the MAC PDUs in to a Container Message. The MAC PDU that encapsulates the Container Message shall have a ARQ Feedback IE added to to indicate the ARQ process for the A-BS/A-CPE link.
         5. Successful delivery of the MAC PDU that encapsulates the Container Message is dependent upon the ARQ process on the A-BS/A-CPE link.
         6. When the A-BS receives the Container Message it will first process the ARQ feedback IE attached to the MAC PDU that encapsulates the Container Message, then unbundle each S-CPEs MAC PDU
   2. If the A-CPE must fragment MAC PDUs:
      1. If end-to-end ARQ is used:
         1. the A-CPE will process the ARQ feedback header attached to a MAC PDU received from each S-CPE.
         2. It will process any of the other subheaders and strip them out of the MAC PDU
         3. If necessary it will fragment the MAC PDU payload and form a new MAC PDU with a GMH that has EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, finally attaching a CRC. When creating the fragments it will not alter the contents (e.g. ARQ Feedback IE and payload) of the original MAC PDU
         4. The A-CPE will bundle fragments from multiple S-CPEs into a Container Message and forward Container Message to A-BS
         5. When the A-BS receives the Container Message, it will unpack and store the PDU fragment for each S-CPE indicated in the Container Message.
         6. It will continue to do this until it receives all fragments from the A-CPE
         7. Once it receives all the fragments of the S-CPEs PDU, A-BS will process the MAC PDU, including processing the ARQ feedback IE attached to the original MAC PDU
      2. If two-link ARQ is used
         1. the A-CPE will process the ARQ feedback header attached to a MAC PDU received from each S-CPE.
         2. It will process any of the other subheaders and strip them, as well as the ARQ feedback IE, out of the MAC PDU
         3. If necessary it will fragment the MAC PDU payload and will form a new MAC PDU with a GMH that has EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, finally attaching a CRC. When doing this it will not alter the original contents (e.g. payload) of the MAC PDU
         4. It will then bundle the MAC PDU fragments from one or more S-CPEs in to a Container Message. The MAC PDU that encapsulates the Container Message shall have a ARQ Feedback IE added to to indicate the ARQ process for the A-BS/A-CPE link.
         5. Successful delivery of the MAC PDU that encapsulates the Container Message is dependent upon the ARQ process on the A-BS/A-CPE link.
         6. When the A-BS receives the Container Message, it will first process the ARQ Feedback IE attached to the MAC PDU that encapsulates the Container Message, then unpack and store the PDU fragment for each S-CPE indicated in the Container Message.
         7. It will continue to do this until it receives all fragments from the A-CPE
         8. Once A-BS receives all the fragments of the S-CPEs PDU, the A-BS will process the MAC PDU
4. In the DS:
   1. If the A-BS must pack multiple MAC PDUs destined for one or more S-CPEs in the DS:
      1. If end-to-end ARQ is used:
         1. The A-BS will bundles pack PDUs for each S-CPE into its’ own MAC PDU and adds the ARQ feedback subheader.
         2. Insert generated MAC PDUs into a Container Message (see xxx) and send it to the A-CPE
         3. The A-CPE receives the Container Message and begins to process it
            1. Unbundle a PDU destined for the S-CPE
            2. Forward the PDU to the S-CPE as is w/o modification (i.e. the A-CPE shall ignore the ARQ
            3. Repeat until all PDUs in Container Message have been forwarded
         4. When S-CPE receives the MAC PDU it will process the attached ARQ feedback subheader
      2. If two-link ARQ is used:
         1. The A-BS will bundles pack PDUs for each S-CPE into its’ own MAC PDU
         2. Insert generated MAC PDUs into a Container Message (see xxx) and send it to the A-CPE. The MAC PDU that encapsulates the Container Message shall have a ARQ Feedback IE added to to indicate the ARQ process for the A-BS/A-CPE link.
         3. Successful delivery of the MAC PDU that encapsulates the Container Message is dependent upon the ARQ process on the A-BS/A-CPE link.
         4. The A-CPE receives the Container Message and begins to process it
            1. Unbundle a PDU destined for the S-CPE
            2. Encapsulate the unbundled PDU in a new MAC PDU (w/ EC bit set to 0 in GMH) with an ARQ feedback subheader (this represents the ARQ process on the S-CPE/A-CPE link)
            3. Repeat until all PDUs in Container Message have been forwarded
         5. When S-CPE receives the MAC PDU it shall process the attached ARQ feedback subheader as defined, then unbundle the original (packed) PDU
   2. If the A-BS has PDUs to send to S-CPEs attached to an A-CPE, and the A-CPE must fragment MAC PDUs:
      1. If end-to-end ARQ is used:
         1. The A-BS will create the MAC PDU and add the ARQ feedback subheader
         2. Then the A-BS bundles MAC PDUs for multiple S-CPEs into a Container Message and send it to the A-CPE
         3. The A-CPE will process each contained MAC PDU in the Container Message
            1. The A-CPE will unbundle the MAC PDU from the Container Message
            2. If necessary the A-CPE will fragment the PDU: form a new MAC PDU with a GMH that has EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, finally attaching a CRC. When this is done, the contents of the original MAC PDU will not be altered
            3. The A-CPE will send each fragment to the destination S-CPE
         4. Each S-CPE will collect those fragments, processing the new fragmentation subheader.
         5. Once an S-CPE has collected all of the fragments, and has resassembled the original MAC PDU, it will process the ARQ feedback subheader of the original MAC PDU
      2. If two-link ARQ is used
         1. The A-BS shall not add ARQ feedback subheader to MAC PDUs it’s transmitting in the DS
         2. The A-BS will create a Container Message to bundle MAC PDUs to be transmitted to S-CPEs that are attached to an A-CPE. The MAC PDU encapsulating the Container Message shall have an ARQ feedback subheader (related to the A-BS/A-CPE ARQ process)
         3. The A-BS then sends the Container Message to the A-CPE
         4. Successful delivery of the MAC PDU that encapsulates the Container Message is dependent upon the ARQ process on the A-BS/A-CPE link. When the A-CPE first receives the Container Message it will process the ARQ feedback IE attached to the MAC PDU that encapsulates the Container Message
         5. The A-CPE will process each contained MAC PDU in the Container Message
            1. The A-CPE will unbundle the MAC PDU from the Container Message
            2. If necessary the A-CPE will fragment the PDU:

The new form a new MAC PDU with a GMH that has EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, finally attaching a CRC. When this is done the contents of the original MAC PDU will not be altered

Each new fragment will have the ARQ feedback subheader attached to it, before being sent to S-CPE

* + - 1. Each S-CPE will collect those fragments, processing the new fragmentation subheader and the attached ARQ feedback subheader.
      2. Once an S-CPE has collected all of the fragments, and will reassemble the original MAC PDU

***<End of modification>***

**References:**

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[4] Reddy, Ranga, “Security Recommendations for TGb”, DCN 22-14/82r0, <https://mentor.ieee.org/802.22/dcn/14/22-14-0082-00-000b-security-recommendations-for-tgb.docx>