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Title	**Packing Multiple Higher Layer SDUs into a Single MAC PDU**
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Re:	IEEE 802.16.1-01/02 : Call for Comments on IEEE 802.16.1/D1-2000
Abstract	A proposal for packing multiple higher layer SDUs into a single MAC PDU in a manner that supports both fixed length (e.g., ATM) and variable length (e.g., Ethernet) packets without knowing the specific higher layer protocol but while working hand in hand with fragmentation.
Purpose	This document is the supporting text for a separately submitted comment to add a section "6.2.1.5 Packing" to IEEE 802.16.1/D1-2000.
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Packing Multiple Higher Layer SDUs into a Single MAC PDU

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Motivation

A number of scenarios have been identified that indicate a benefit in being able to pack multiple higher layer SDUs into a single MAC PDU (i.e., behind one MAC header). For instance, at session 10, there was a TG3 contribution on the applicability of the TG1 MAC that indicated the desire to be able to pack multiple variable length packets behind a single MAC header. Additionally, IEEE 802.16.1c-00/15 proposed packing multiple ATM cells behind a single MAC header. Clearly, packing multiple SDUs from the same connection behind a single MAC header saves bandwidth over attaching a separate MAC header to each. This is particularly true when the SDUs are small. For instance, the uplink MAC header is more than 16% of the size of an ATM payload.

Explanation

Goals

- Support packing both on connections that carry fixed length packets and on those that carry variable length packets.
- No packing related overhead on connections on which packing is not turned on.
- Minimize packing related overhead in general and particularly at those times when packing cannot be accomplished on a connection on which packing is turned on.
- Coordinate packing and MAC level fragmentation so that packing does not create excessive delays due to fragmentation and reassembly.

To meet these goals, this paper proposes that a uniform method for packing multiple higher layer SDUs in a single MAC PDU be defined for the MAC layer rather than separately for the convergence sublayers.

Indicating Packing

Whether or not packing is allowed on a connection should be an attribute of the connection when it is created and should stay unchanged for the life of the connection. This helps minimize any overhead associated with packing.

Packing Fixed Length SDUs

Packing fixed length SDU connections, such as ATM, can be very simple. The MAC simply needs to know that the connection carries fixed length SDUs and the size of those SDUs. For instance, based on the concurrently submitted ATM convergence sublayer proposal IEEE 802.16.1c-01/04r0, SDUs from an ATM connection would always be 53, 50, or 48 bytes depending upon whether payload header suppression is turned on for the connection, and if so, whether the connection is VC switched or VP switched. If the SDU size = n bytes, the receiving side can unpack simply by knowing that the length field in the MAC header will be k*n, where k is the number of SDUs packed into the MAC PDU. A MAC PDU containing a packed sequence of fixed length SDUs would be constructed as in Figure 1. Note that there is no added overhead due to packing and a single SDU is simply a packed sequence of length 1.

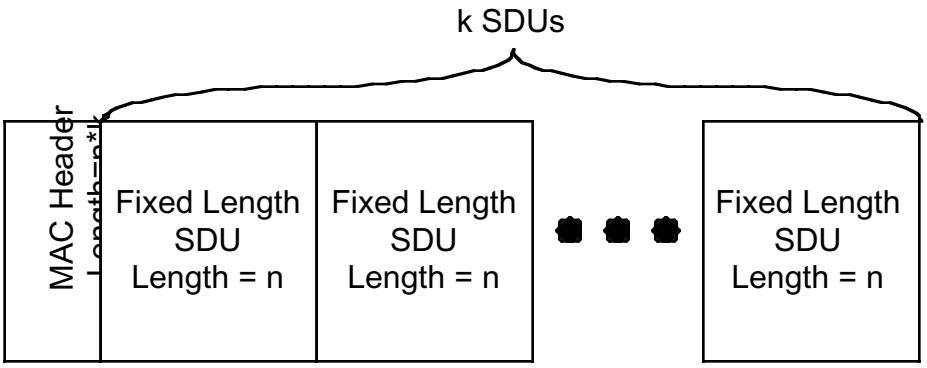

Figure 1: Packing Fixed Length SDUs into a Single MAC PDU

Packing Variable Length SDUs

Packing variable length SDU connections, such as Ethernet, is more difficult. We no longer have the k*n relationship between the MAC header's length field and the length of an SDU. This necessitates some indication of where one SDU ends and another begins. The MAC attaches a packing sub-header (PSH) to each SDU. This header can have 2 forms as shown in Figure 2.

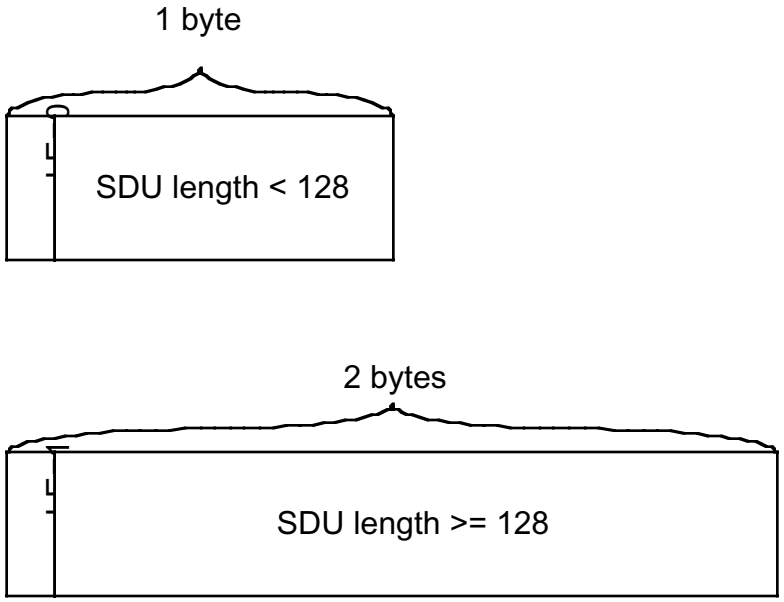

Figure 2: Packing Sub-header for Variable Length PDUs

The packing sub-header starts with a single length extension (LE) bit which is set to 0 if the length field in the packing sub-header is 7 bits or set to 1 if it is 15 bits. This allows small SDUs less than 128 bytes in length to be packed more efficiently while still supporting larger SDUs.

A MAC PDU containing a packed sequence of variable length SDUs would be constructed as shown in Figure 3. Note that packing sub-headers with LE=0 and packing sub-headers with LE=1 may both be present in the same MAC PDU.

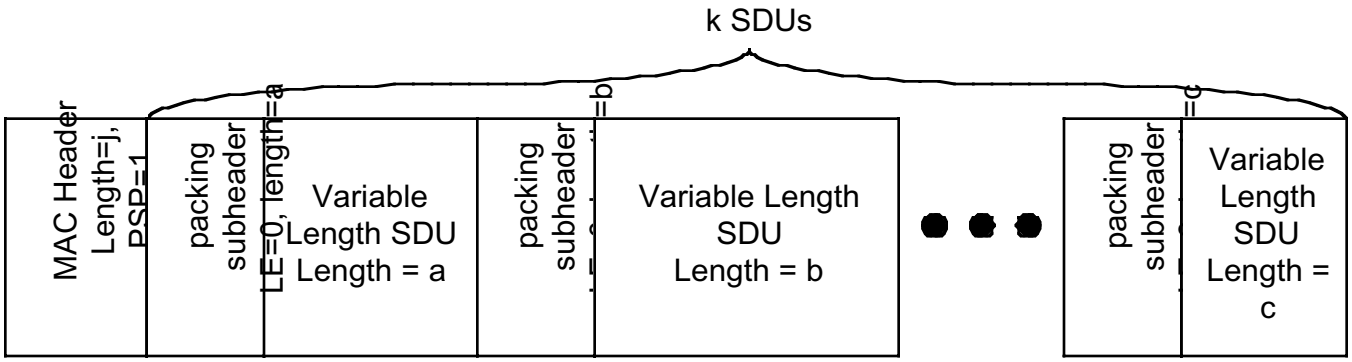

Figure 3: Packing variable Length SDUs into a Single MAC PDU

Since the packing sub-header adds a small amount of packing related overhead, it is beneficial to have special treatment of SDUs that are, for some reason, sent unpacked. One of the reserved bits in the MAC header is changed to be a packing sub-header present (PSP) bit. If more than one SDU is packed into the MAC PDU, the PSP bit is 1 aswas shown in Figure 3. If only one SDU (or fragment thereof) is present in a MAC PDU, the PSP bit is 0. This is shown in Figure 4.

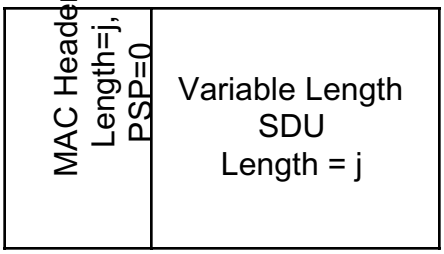

Figure 4: Packing a Single Variable Length SDU into a MAC PDU

Interaction With Fragmentation

Rules for interacting with fragmentation must be observed. In fact, packing must be performed simultaneously with fragmentation in order to maximize the benefits of both. In fact, packing done without knowledge of fragmentation may be negated by fragmentation. This is why packing cannot be done in the convergence sublayer. The convergence sublayer doesn't have the proper fragmentation state information for the connection and does not know how much bandwidth will be available for the connection in any given frame or scheduling interval.

There are 2 ways to handle the interaction between packing and fragmentation. The simplest would be to require that a MAC PDU that contains packed SDUs cannot fragment those SDUs and to require that a MAC PDU that contains a fragment of an SDU not contain packed SDUs. This is shown in Figure 5.

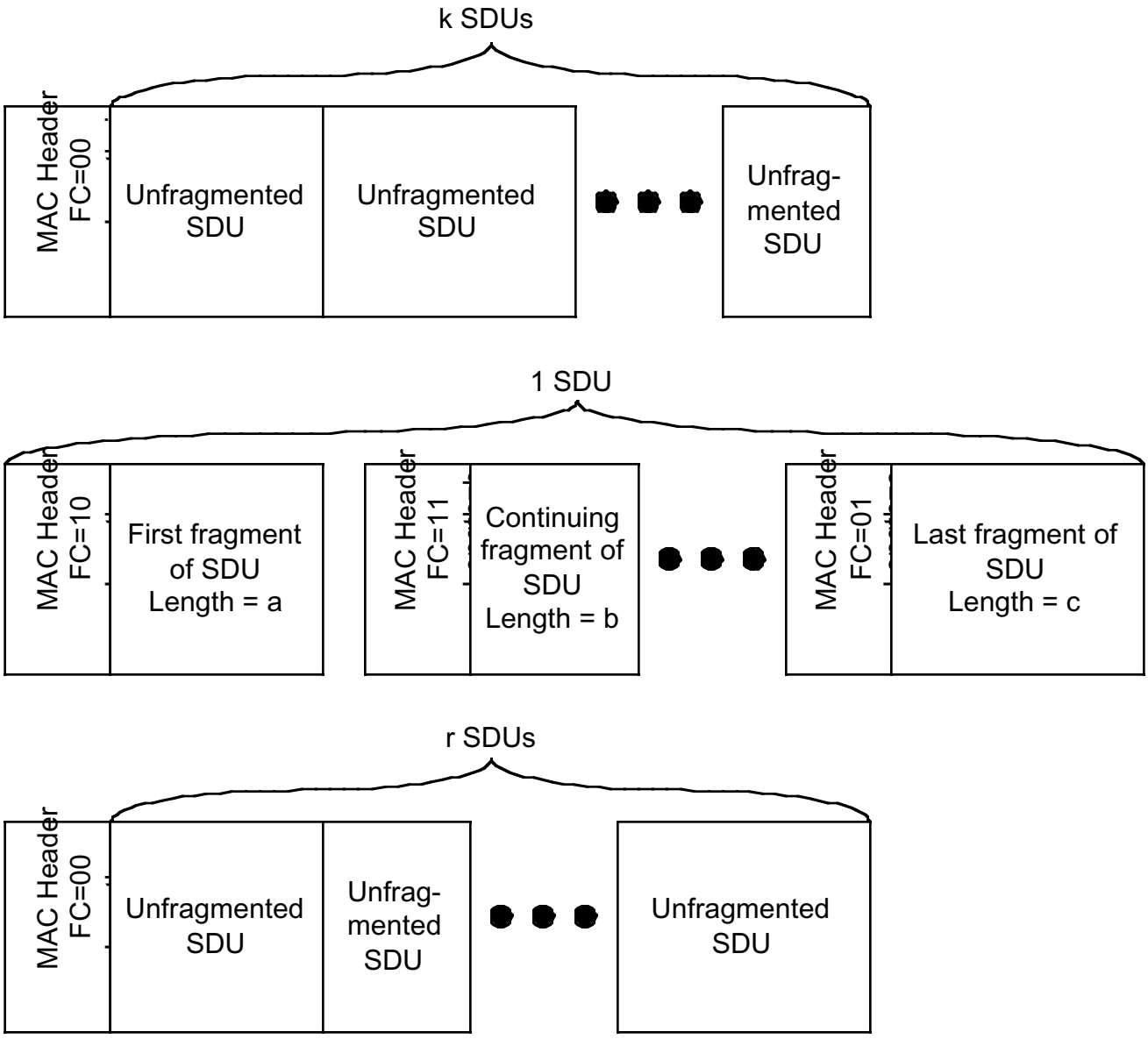

Figure 5: Packing Without Fragmentation

A more complex, but more efficient way to implement simultaneous fragmentation and packing is to have the fragmentation information in the MAC header pertain to the last packed SDU if it is a FIRST fragment. It would pertain to the first packed SDU if it is a LAST fragment. CONTINUING fragments would still only carry a single SDU fragment. Fragmentation bits set to UNFRAGMENTED would indicate that every SDU packed in the MAC PDU are complete and unfragmented. This is shown in Figure 6.

In this more complex method, if the connection carries variable length SDUs, the length of each individual SDU and any fragments of SDUs is explicitly carried in the SDU's (or fragment's) packing sub-header. If the connection carries fixed length SDUs, the presence of a fragment and the length of that fragment is implied by a non-zero remainder when dividing the length specified in the MAC header by the length of the fixed size SDU.

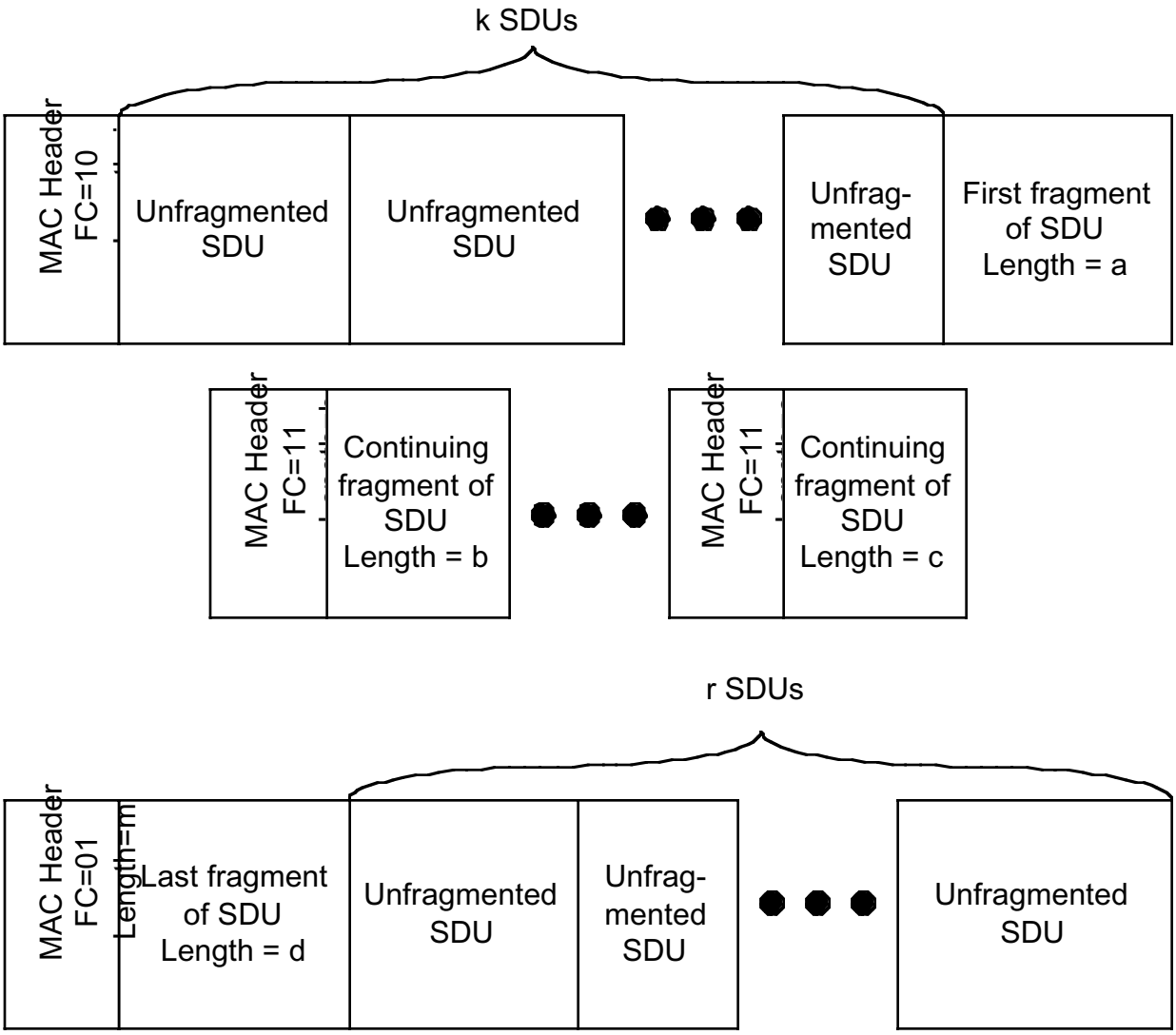

Figure 6: Packing With Fragmentation

Specific Modifications to Draft Air Interface Standard

This section lists explicit line by line comments for updating IEEE 802.16.1/D1-2000. They are here for completeness of the idea presented, and are also submitted using the comment form.

Acronyms and Definitions

1. On page 19, line 41 add the following definition:

Concatenation: Concatenation is the act of combining multiple MAC PDUs into a single TDM or TDMA burst.

2. On page 20, line 44 add the following definition:

Packing: packing is the act of combining multiple SDUs from a higher layer into a single MAC PDU.

3. On page 20, line 28 add he following acronym definition:

LE Length Extension

4. On page 22, line 51 add the following acronym definitions:

PSH Packing Sub-Header
PSP Packing Sub-header Present

SAP

1. On page 28, line 61 add:

Packing on/off indicator,
Fixed or variable length SDU indicator,
SDU length (only needed for fixed length SDU connections),

MAC Header

In Figure 6 on page 37, replace one of the reserved bits with a PSP bit.

On page 37, line 14 add the following row to the table:

PSP	1	Packing Sub-header Present Indicator 0 = no packing sub-header is present 1 = packing sub-headers are present

Packing Section

On page 90, line 11 add the following section:

6.2.1.5 Packing

If packing is turned on for a connection, the MAC may pack multiple SDUs into a single MAC PDU. Packing makes use of the connection attribute indicating whether the connection carries fixed or variable length packets.

6.2.1.5.1 Packing Fixed Length SDUs

When packing fixed length SDU connections, such as ATM, the MAC needs to know that the connection carries fixed length SDUs and the size of those SDUs. This information is included in the setup information for the connection. The length field of the MAC header implicitly indicates the number of SDUs packed into a single MAC PDU. If the SDU size = n bytes, the receiving side can unpack simply by knowing that the length field in the MAC header will be k*n, where k is the number of SDUs packed into the MAC PDU. A MAC PDU containing a packed sequence of fixed length SDUs would be constructed as in Figure 7. Note that there is no added overhead due to packing in the fixed length SDU case and a single SDU is simply a packed sequence of length 1.

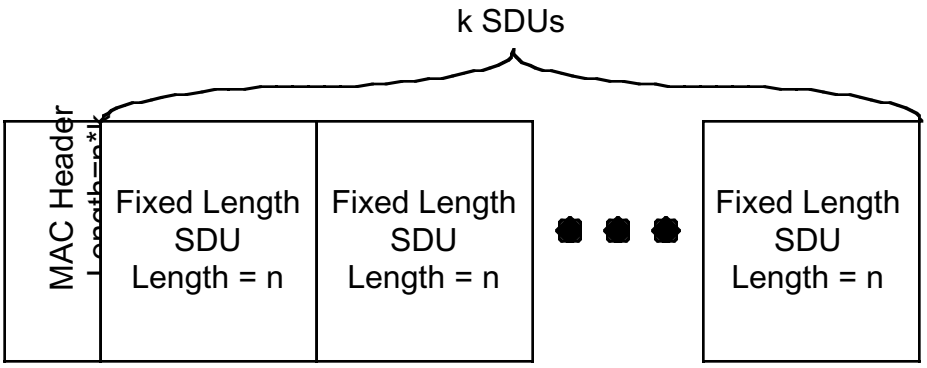

Figure 7: Packing Fixed Length SDUs into a Single MAC PDU

6.2.1.5.2 Packing Variable Length Packets

When packing variable length SDU connections, such as Ethernet, the k*n relationship between the MAC header's length field and the higher layer SDUs no longer holds . This necessitates indication of where one SDU ends and another begins. In the variable length SDU case, the MAC attaches a packing sub-header (PSH) to each SDU. This header can have 2 variants as shown in Figure 8.

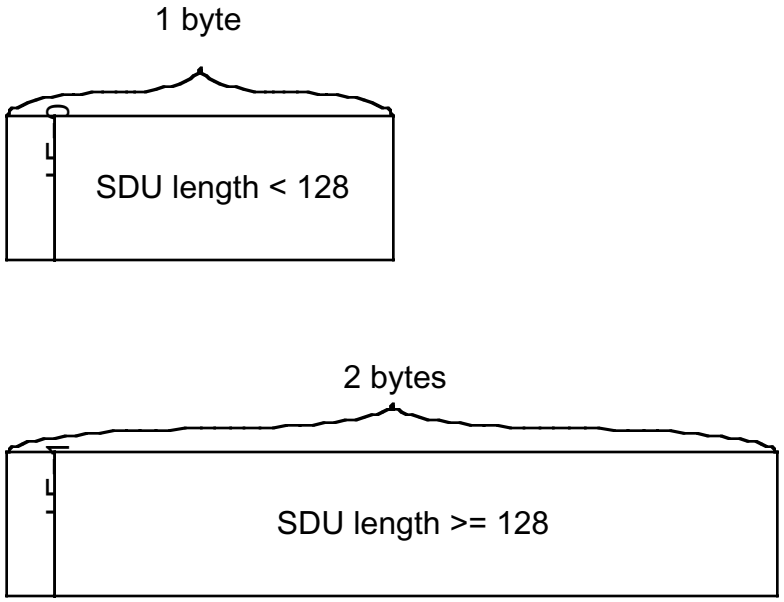

Figure 8: Packing Sub-header for Variable Length PDUs

The packing sub-header starts with a single length extension (LE) bit which is set to 0 if the length field in the packing sub-header is 7 bits or set to 1 if it is 15 bits. The 8 bit form of the packing sub-header is used for SDUs shorter than 128 bytes. The 16 bit form is used for SDUs at least 16 bits in length.

A MAC PDU containing a packed sequence of variable length SDUs is constructed as shown in Figure 9. If more than one SDU is packed into the MAC PDU, the PSP bit is 1. Note that packing sub-headers with LE=0 and packing sub-headers with LE=1 may both be present in the same MAC PDU.

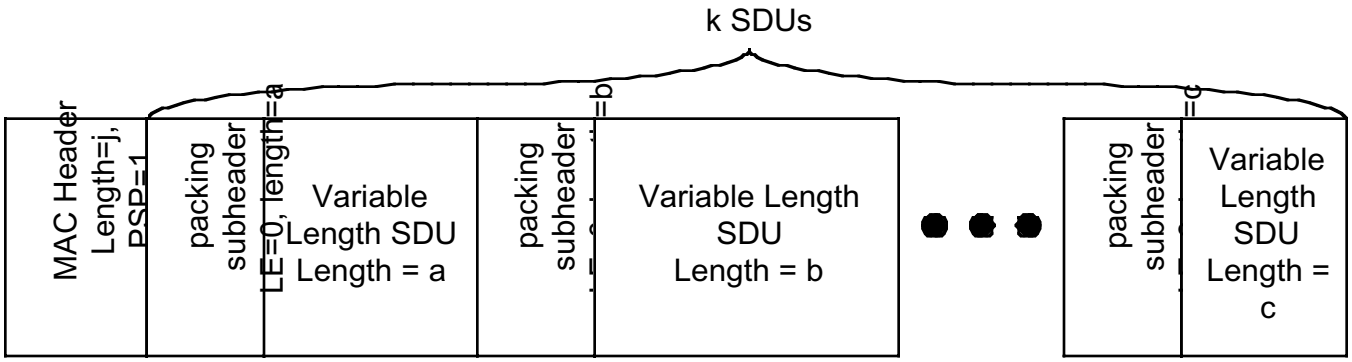

Figure 9: Packing variable Length SDUs into a Single MAC PDU

If only one SDU (or fragment thereof) is present in a MAC PDU, the PSP bit is 0. This is shown in Figure 10.

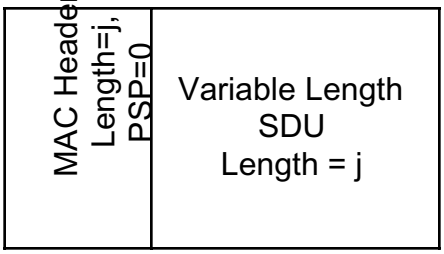

Figure 10: Packing a Single Variable Length PDU into a MAC PDU

6.2.1.5.3 Interaction With Fragmentation

Simultaneous fragmentation and packing allows efficient use of the airlink, but requires guidelines to be followed so it is clear which SDU is currently in a state of fragmentation. To accomplish this, the fragmentation information in the MAC header pertains to the last packed SDU if it is a FIRST fragment. It would pertain to the first packed SDU if it is a LAST fragment. CONTINUING fragments would still only carry a single SDU fragment. Fragmentation bits set to UNFRAGMENTED would indicate that every SDU packed in the MAC PDU are complete and unfragmented. This is shown in Figure 11.

If the connection carries variable length SDUs, the length of each individual SDU and any fragments of SDUs is explicitly carried in the SDU's (or fragment's) packing sub-header. If the connection carries fixed length SDUs, the presence of a fragment and the length of that fragment is implied by a non-zero remainder when dividing the length specified in the MAC header by the length of the fixed size SDU.

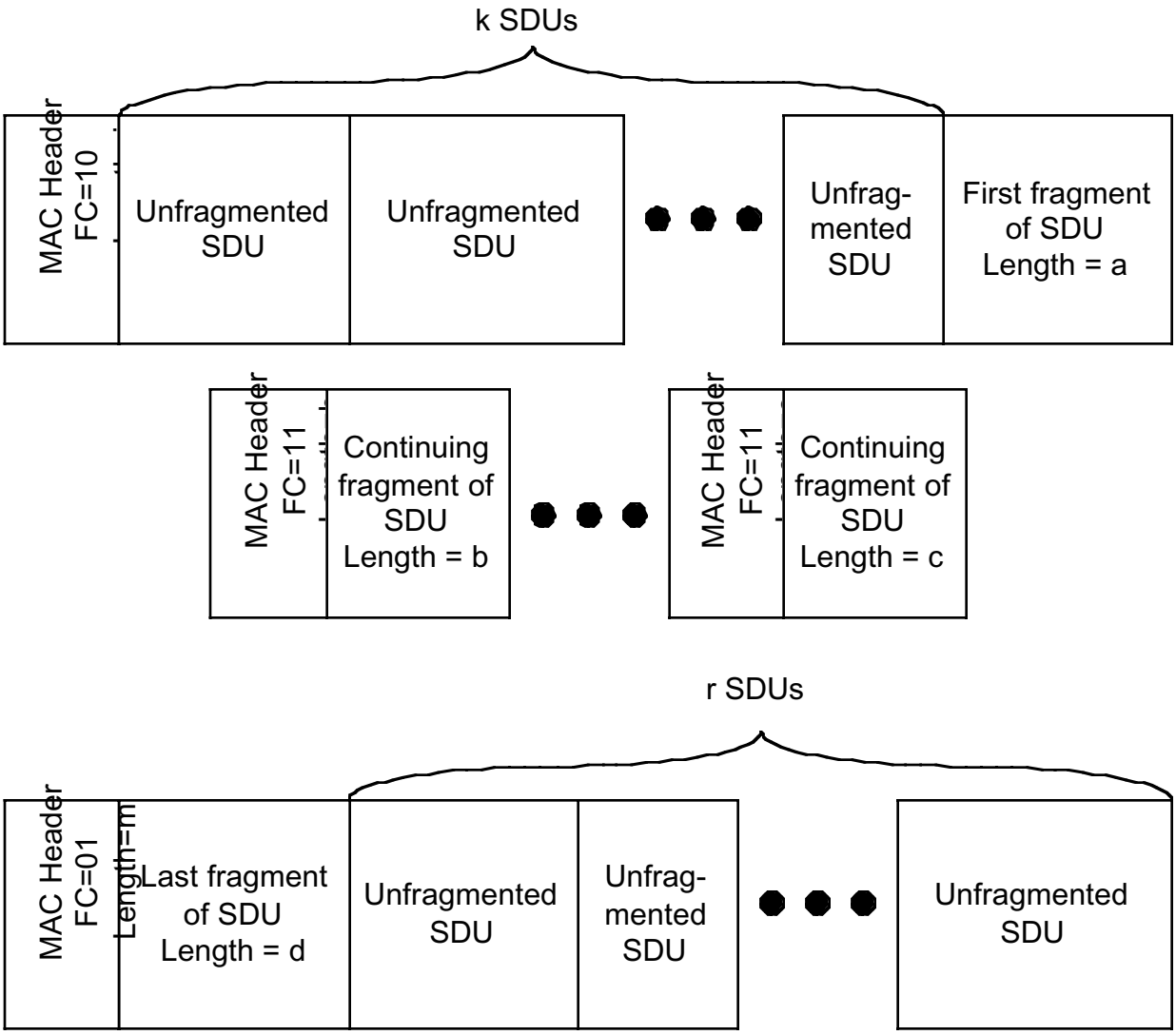

Figure 11: Packing With Fragmentation

TLVs

The following TLV sections should be added on or around page 335, line 17:

11.4.12.x Packing On/Off Indicator

The value of this parameter specifies whether or not packing is turned on or off for a connection. The default is off.

Type	Length	Value	Scope
[24/5].x	1	0 = packing off 1 = packing on default = 0	Configuration File REG-REQ REG-RSP DSx-REQ DSx-RSP DSx-ACK

11.4.12.y Fixed vs. Variable Length SDU Indicator

The value of this parameter specifies whether the SDUs on the service flow will be fixed length or variable length. The parameter is only used if packing is on for the service flow. The default value is 0 = variable length SDUs.

Type	Length	Value	Scope
[24/5].y	1	0 = variable length SDUs 1 = fixed length SDUs default = 0	Configuration File REG-REQ REG-RSP DSx-REQ DSx-RSP DSx-ACK

11.4.12.z SDU Length

The value of this parameter specifies the length of the SDU for a fixed length SUD service flow. This parameter is only used if packing is on and if the service flow is indicated as carrying fixed length SDUs. The default value is 48.

Type	Length	Value	Scope
[24/5].z	1	Bytes Default = 48	Configuration File REG-REQ REG-RSP DSx-REQ DSx-RSP DSx-ACK