

Uplink Scheduling and TXOP Sharing Activated by Downlink Traffic Delivery

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Introduction

- **Timely Low-Latency (LL) traffic transmission and achieving higher throughput are among the key design goals of UHR**
- **For scheduled UL and P2P transmissions:** The use of SCS and QoS Characteristics allows non-AP STAs to specify their needs for periodic/semi-periodic UL, DL, and P2P transmissions [IEEE P802.11be/D7.0]
- **For priority-aware DL transmissions:** Using Mirrored SCS, the AP can rely on the TID of UL traffic to mark the TID of DL streams; this ensures the use of proper AC for DL transmissions
- **For event-driven and trigger-based LL UL and P2P traffic, UHR introduces [P802.11bn D1.0]:**
 - **P-EDCA:** STAs are permitted to use P-EDCA after experiencing a certain number of collisions
 - **LL Indication (LLI):** A non-AP STA can use LLI in M-BA frame to indicate the existence of UL or P2P LL traffic [11-25/0931]
 - This method has several shortcomings: **(1) does not provide the non-AP STA with enough time to process the DL data and generate LL traffic before sending the M-BA frame, (2) it cannot be used for non-LL traffic, (3) does not allow specifying the characteristics of response traffic**
- **In this contribution, we propose Downlink-activated UL scheduling and TXOP sharing**
 - It is an enhancement of SCS and QoS Characteristics
 - **Allows a non-AP STA to request UL scheduling or TXOP sharing from the AP whenever the AP sends specific DL streams to the STA**

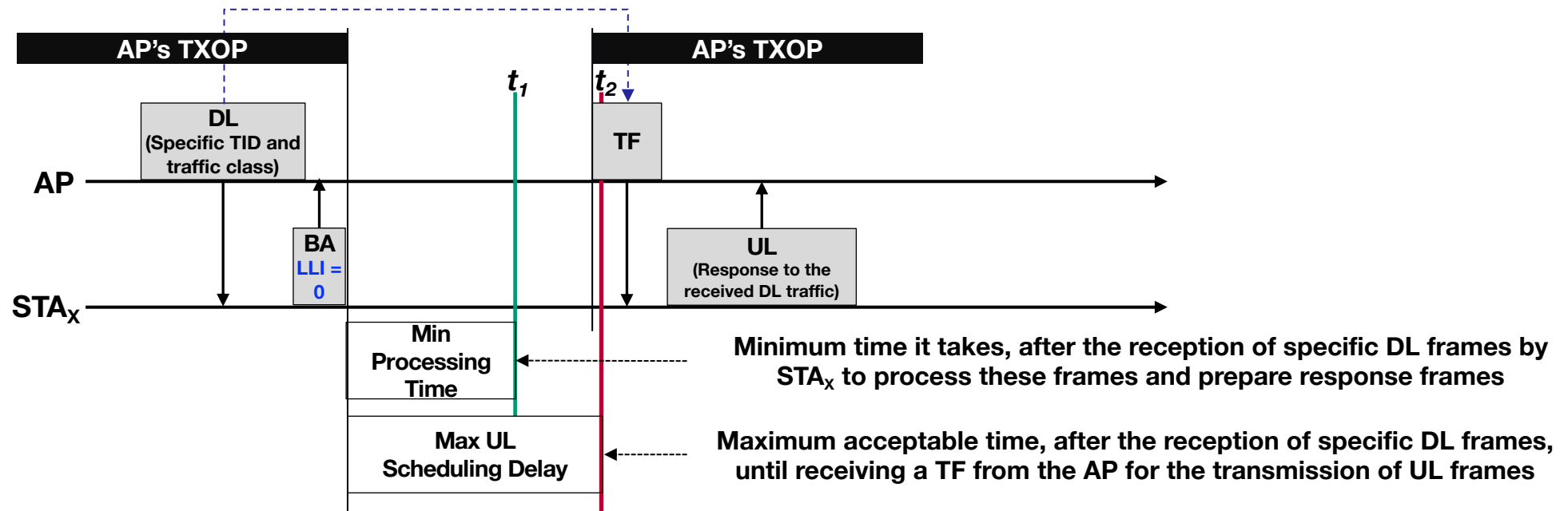
Problem Statement

- **There are cases where the generation and transmission of UL/P2P traffic by a STA is triggered by the reception of DL traffic from the AP**
- **Examples:**
 - A controller sends a command; the robot replies with sensor readings, confirmation, or status updates
 - A smart sensor node sends measurements only when queried by a controller or gateway
 - A user or controller sends a capture command; the camera responds by transmitting image or video data
 - A PLC (Programmable Logic Controller) sends a control signal; the actuator responds with feedback data confirming execution
- **For these cases, since there is not enough time for the STA (between the reception of DL traffic and the transmission of the M-BA frame) to process the DL traffic and generate response traffic, the LLI method cannot be used to request resource allocation from the AP**
- **To enhance UL/P2P transmission efficiency and timeliness, the AP should allocate transmission resources after a certain time interval following the transmission of such DL traffic**
 - The current SCS and QoS Characteristics methods do not support this operation

Downlink-Activated UL Scheduling

- We propose enhancements of SCS and QoS Characteristics to allow UL traffic scheduling after the delivery of specific DL traffic streams (specified by TIDs and/or traffic classes)
- A non-AP STA establishes a SCS agreement with the AP, where it informs the AP that it is requesting for UL scheduling after the delivery of specific DL traffic frames

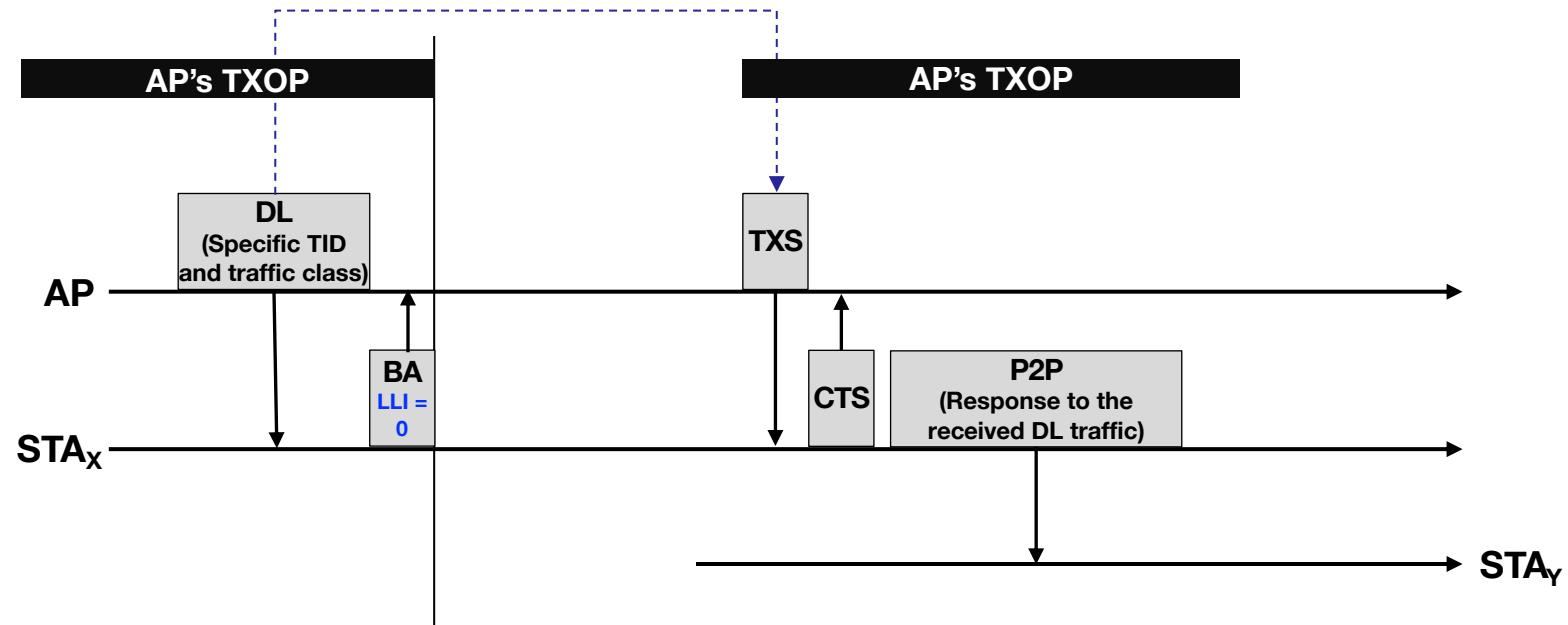
After the delivery of frames, belonging to a particular TID and/or traffic class, to STA_x, the AP announces UL scheduling to STA_x within a specific time interval



Downlink-Activated TXOP Sharing

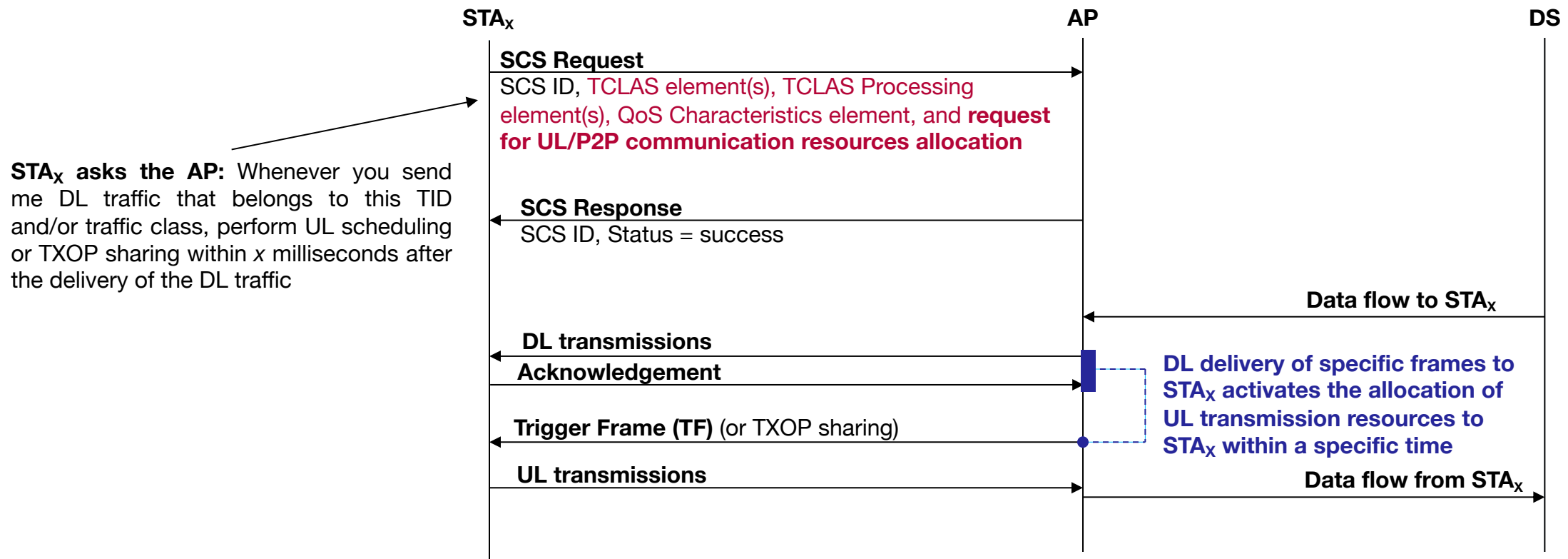
- For Downlink-Activated **TXOP Sharing**, a non-AP STA establishes an SCS agreement with the AP, indicating that it requests TXOP sharing for **P2P communication following the delivery of specific DL traffic**

After the delivery of frames, belonging to a particular TID and/or traffic class, to STA_x, the AP announces TXOP sharing to STA_x within a specific time interval



Signaling Procedure

- A non-AP STA sends an SCS Request to the AP to request UL scheduling or TXOP sharing after the delivery of specified DL frames
 - The parameters of the request are specified within the QoS Characteristics element



❑ Using SCS and QoS Characteristics to Specify the Request Type

- Using the **SCS Request**, to specify a DL-activated UL scheduling or DL-activated TXOP sharing request, the **Direction** subfield of the Control Info field of **QoS Characteristics** element is used

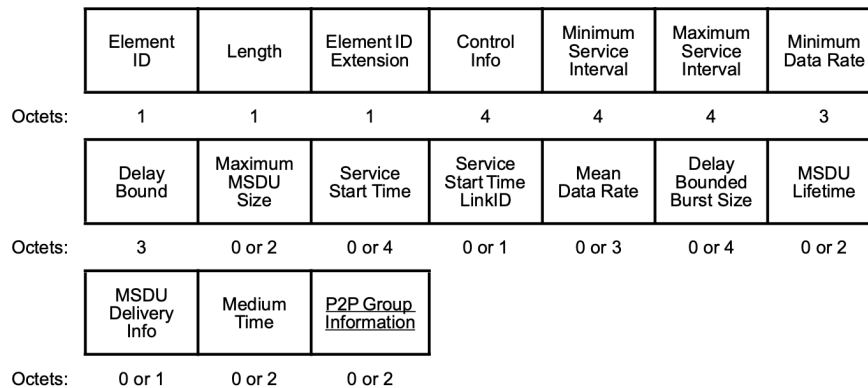


Figure 9-1074bc—QoS Characteristics element format

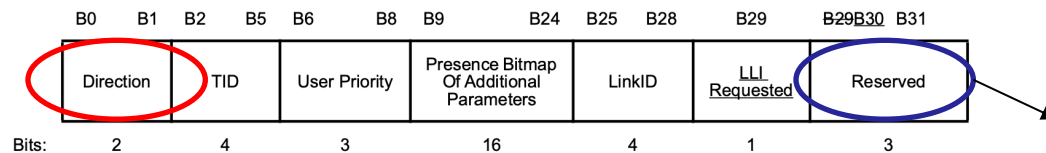


Figure 9-1074bd—Control Info field format

Table 9-417w—Direction subfield encoding

Direction	Usage
0	Uplink, defined as follows: — MSDUs or A-MSDUs are sent from the non-AP STA to the AP.
1	Downlink, defined as follows: — MSDUs or A-MSDUs are sent from the AP to the non-AP STA.
2	Direct link (MSDUs or A-MSDUs are sent over a peer-to-peer link).
3	Reserved

- If the value of the Direction subfield is 0 (UL) or 2 (Direct Link), a reserved bit in the Control Info field is used to indicate that it is a request for DL-activated UL scheduling or DL-activated TXOP sharing

- Example: bit 30 of Control Info field

❑ Using SCS and QoS Characteristics to Specify the Request Type

- In the QoS Characteristics element, the **TID subfield** of the Control Info field **specifies the flows (MSDUs) that would activate UL scheduling or TXOP sharing actions by the AP**
- Additionally, the **TCLAS element(s)** of the SCS Descriptor element can be used to further **specify these flows**

Using TID to specify the DL traffic that activates scheduling/sharing

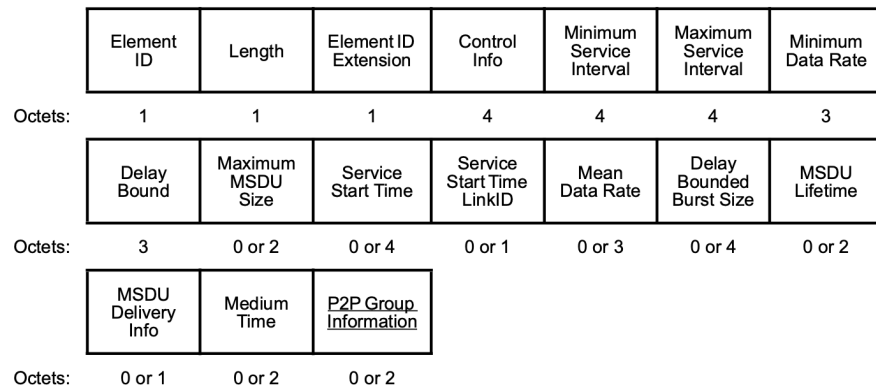


Figure 9-1074bc—QoS Characteristics element format

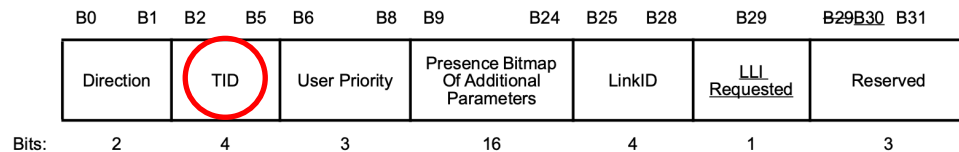


Figure 9-1074bd—Control Info field format

Using TCLAS to specify the DL traffic(s) that activates scheduling/sharing

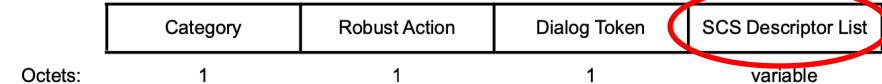


Figure 9-954—SCS Request frame Action field format

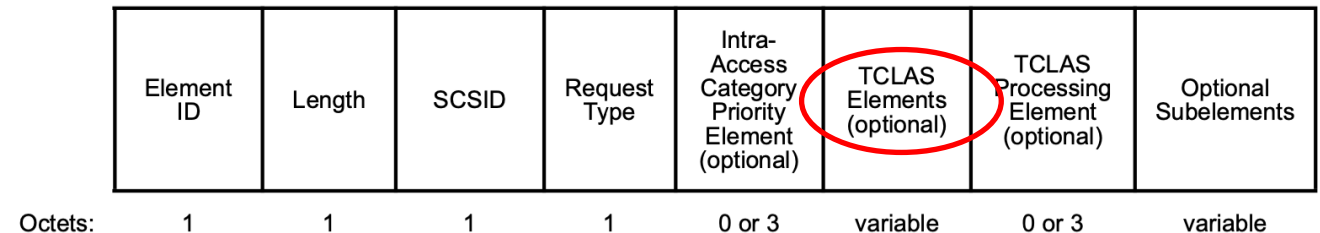


Figure 9-541—SCS Descriptor element format

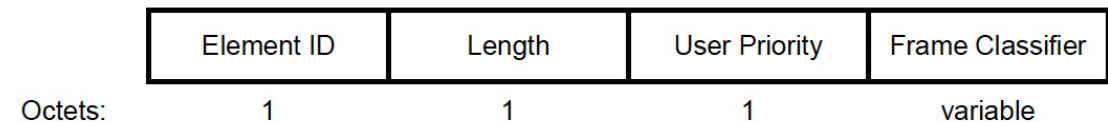


Figure 9-382—TCLAS element format

❑ Using SCS and QoS Characteristics to Specify the Request Type

- The **existing fields of the QoS Characteristics** element can be used as follows to specify the parameters of UL scheduling or TXOP sharing
- **Service Start Time:** The requested start of UL scheduling or TXOP sharing after the delivery of the specified DL frames
- **MSDU Lifetime:** The lifetime of UL scheduling or TXOP sharing
 - **= 0:** A **one-time** UL scheduling or TXOP sharing
 - **> 0 :** The duration of UL scheduling or TXOP sharing procedure in milliseconds after the delivery of specific DL frames to a STA
 - In this case, parameters such as Minimum Service Interval and Maximum Service Interval specify the periodicity of UL scheduling or TXOP sharing

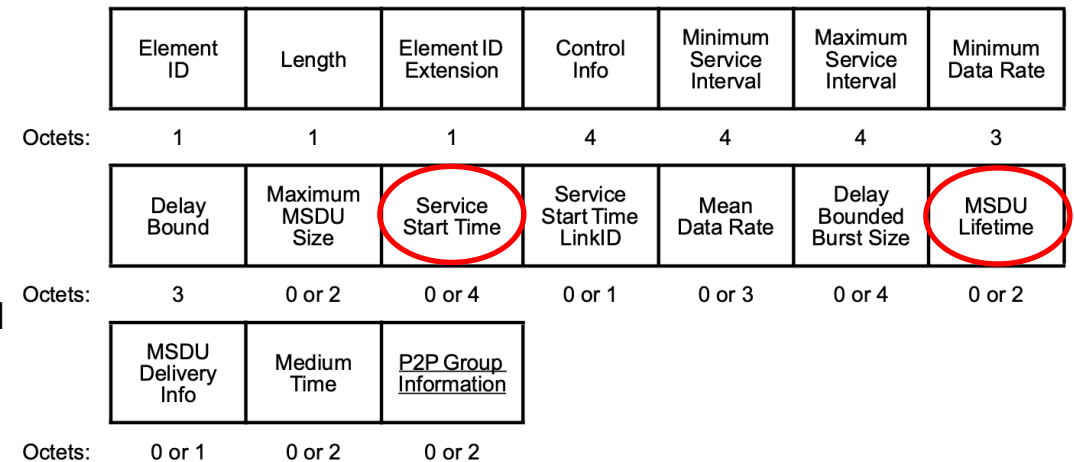
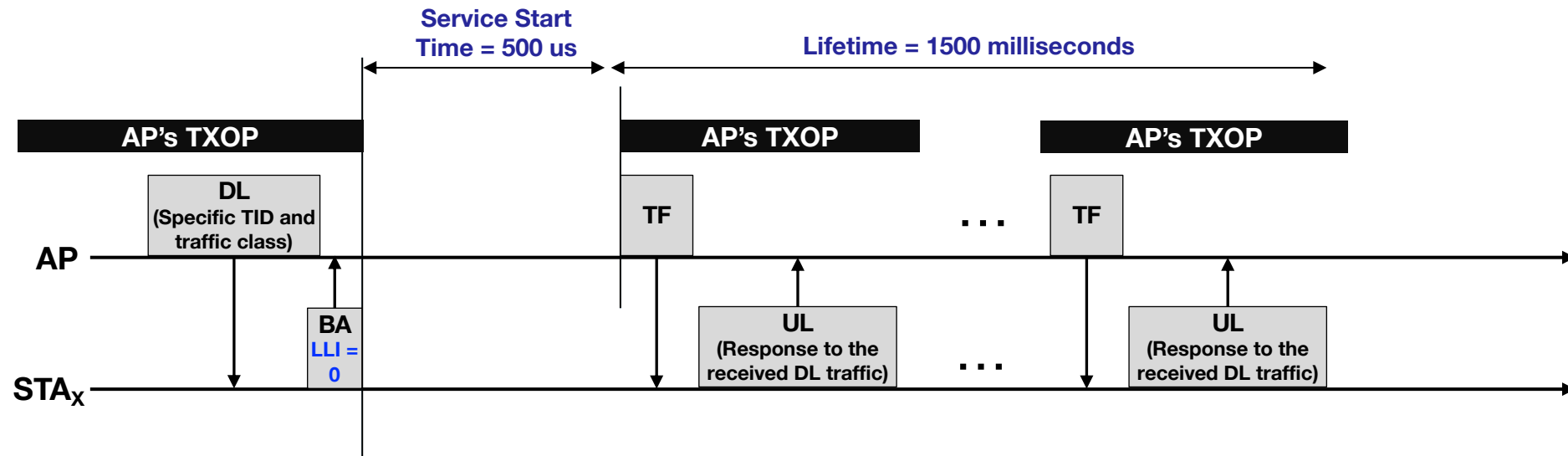


Figure 9-1074bc—QoS Characteristics element format

❑ Using SCS and QoS Characteristics to Specify the Request Type

• Example:

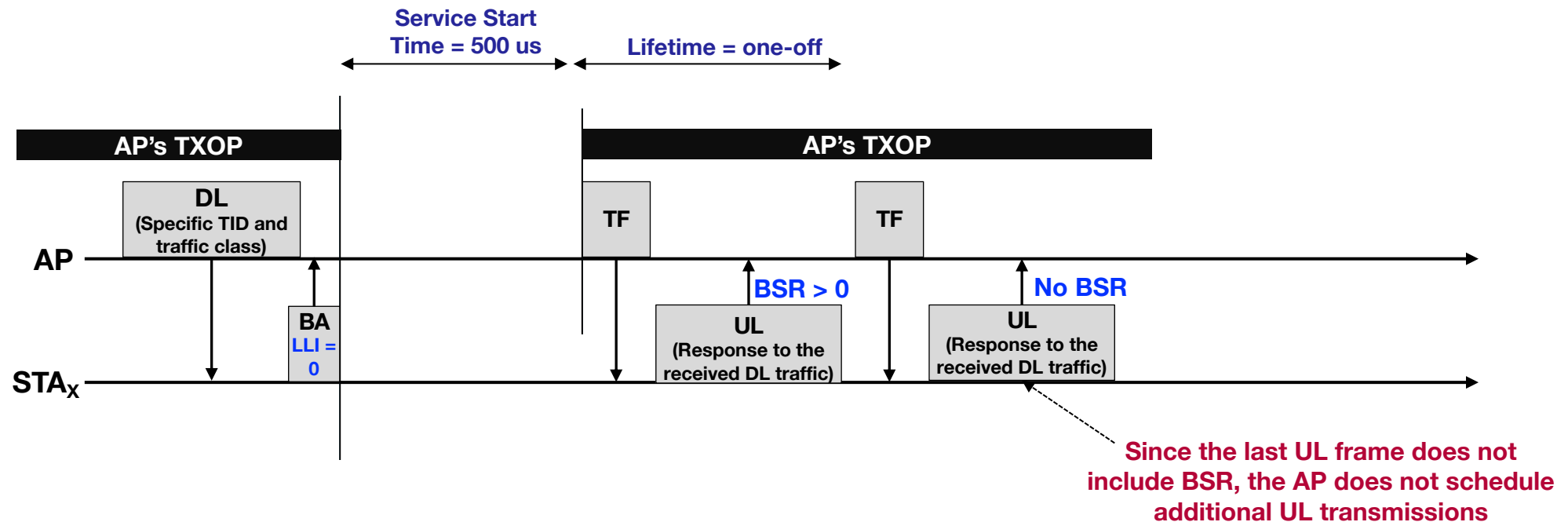
- **Service Start Time** is 500 microseconds after the delivery of specified DL frames
- The **lifetime** of action is 1500 milliseconds, which requests for UL scheduling for the specified duration
 - This means, whenever frames belonging to a specific stream are delivered to a STA, the AP starts UL scheduling in about 500 us after the delivery of DL frames and continues the UL scheduling for 1500 milliseconds



❑ Using SCS and QoS Characteristics to Specify the Request Type

• Example:

- **Service Start Time** is 500 microseconds after the delivery of specified DL frames
- The **Lifetime** of action is 0, which requests a one-off UL scheduling
 - Note: the one-off scheduling may be repeated if the STA requests for additional UL scheduling using methods such as including buffer size, BSR or EBSR in data frames sent to AP



Conclusion

- In this contribution, we highlighted the importance of performing UL scheduling or TXOP sharing by AP **after the delivery of specific DL streams to a non-AP STA**
 - Various real-world applications justify the importance of this need
 - Such DL streams are identified using TID, traffic class, or both
- **We proposed to enhance SCS with QoS Characteristics to support downlink-activated UL scheduling and TXOP sharing**
- By scheduling UL transmissions or performing TXOP sharing, a non-AP STA will be able to send its data (to the AP or P2P) within the specified time frame
 - **Prevents the need for channel access contentions using EDCA/P-EDCA**
 - **Enhances the benefits of OFDMA, MU-MIMO, and TXS Mode 1/2 sharing**
 - **Improves the efficiency and timeliness of UL and P2P traffic delivery**

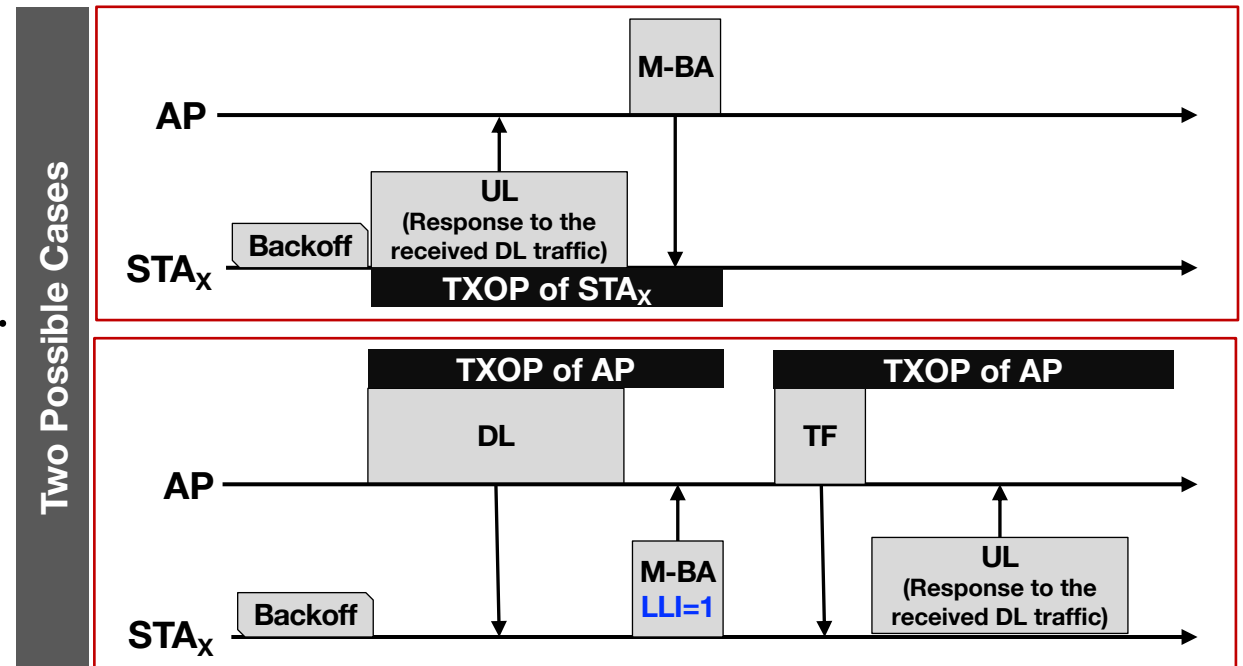
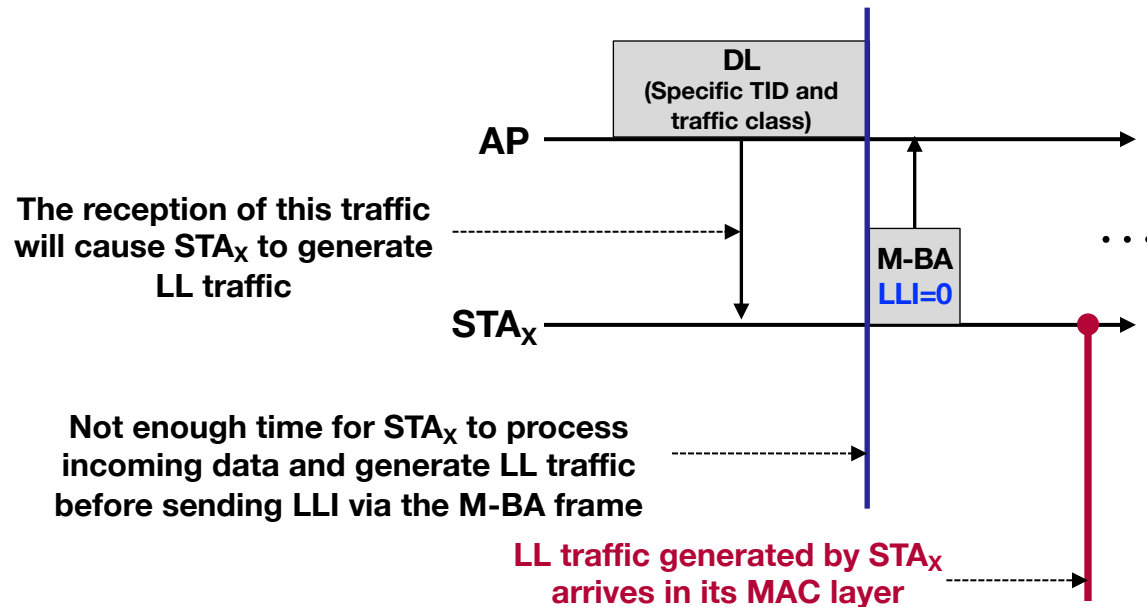
Appendix:

Why not using the LLI method?

Differences from Low-Latency Indication (LLI)

(A) Downlink-activated scheduling/sharing provides the receiving STA with sufficient time to process the incoming traffic and subsequently transmit the UL/P2P response

- With LLI, the receiving STA does not have enough time to process the incoming frames and present LLI based on the processing of newly-received DL frames
- In contrast, downlink-activated scheduling/sharing allows the non-AP STA to inform the AP that it will have LL (or non-LL traffic) for the AP or another STA imminently



❑ Differences from Low-Latency Indication (LLI)

(B) Downlink-activated scheduling/sharing can be used for both LL and non-LL traffic scheduling

- With LLI, a non-AP STA informs the AP that it has LL traffic for AP or another non-AP STA
 - The AP needs to consider the LLI as **urgent** data that must be sent asap, therefore, the AP is not provided with an acceptable interval to address the need of the non-AP STA(s)
- In contrast, the downlink-activated scheduling/sharing method can be used for both LL and non-LL traffic; enhancing channel access efficiency for various traffic types

(C) Downlink-activated scheduling/sharing allows for specifying traffic characteristics and better scheduling

- Downlink-activated scheduling/sharing allows the non-AP STA to specify traffic characteristic such as Delay Bounded Burst Size, Mean Data Rate, and Maximum MSDU Size; these parameters enhance the efficiency of UL scheduling by the AP

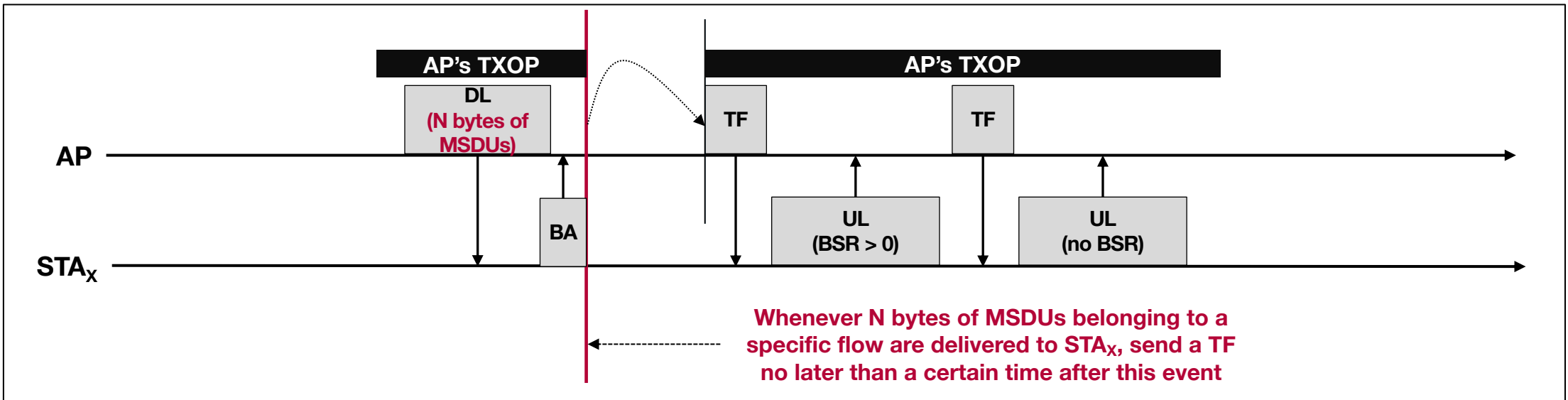
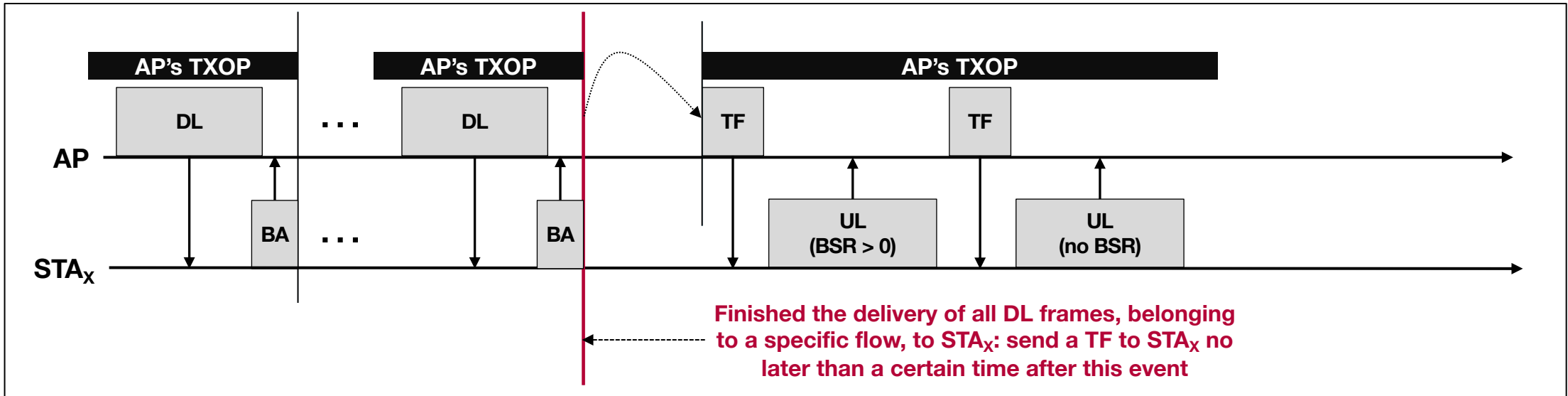
Appendix:

When does the AP activate UL scheduling or TXOP sharing?

□ Resource Allocation by the AP

- For a specific DL traffic flow that would activate UL scheduling or TXOP sharing:
 - If the **AP delivers all the buffered frames to a STA**, then it can activate the scheduling action after receiving the BA frame from the STA
 - If the AP does not deliver all the buffer frames to the STA within one TXOP:
 - The AP may trigger the scheduling action **after the delivery of all the buffered frames in a subsequent TXOP**
 - The AP may activate the scheduling action **after the delivery of a certain number of bytes (certain number of MSDU bytes)**
- In a generic case, a non-AP STA may request for UL scheduling or TXOP sharing after the DL delivery of a certain number of MSDU bytes that belong to specific TID and/or traffic class

Resource Allocation by the AP



Appendix:

An alternative method to specify the request type

❑ Using SCS and QoS Characteristics to Specify the Request Type

- To specify the parameters of UL scheduling or TXOP sharing, another option is to define a new subfield within the QoS Characteristics element†

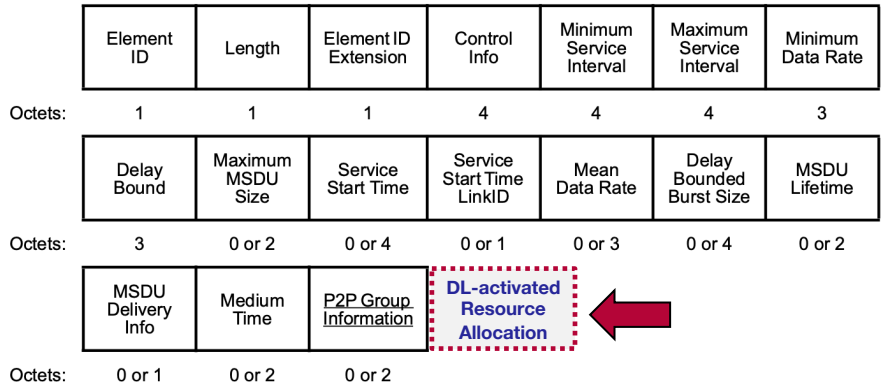


Figure 9-1074bc—QoS Characteristics element format

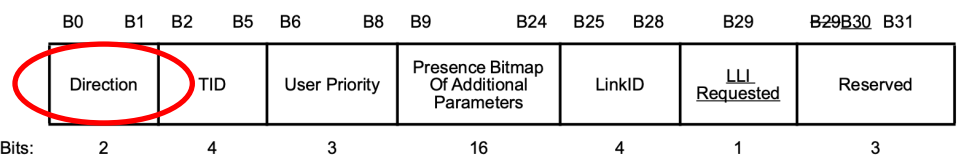


Figure 9-1074bd—Control Info field format

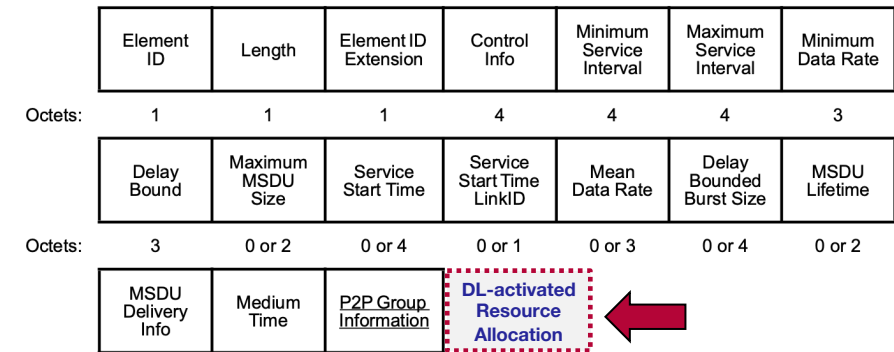
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2	Direct link (MSDUs or A-MSDUs are sent over a peer-to-peer link).
3	Reserved

- If the value of the Direction subfield is 0 (UL) or 2 (Direct link), a new field of the QoS Characteristics element, named *DL-activated Resource Allocation*, is used
- If a flag within this subfield is set, the value of the **Direction** subfile specifies DL-activated UL scheduling or DL-activated TXOP sharing

❑ Using SCS and QoS Characteristics to Specify the Request Type

- The parameters of the UL scheduling operation are conveyed by using the newly-defined DL-activated Resource Allocation subfield
- The following subfields could be defined within this subfield



DL Activated Resource Allocation	0: The DL Activated Resource Allocation operation is not used 1: This is a request for resource allocation after the delivery of DL frames belonging to specific TID/flows; the value of the Direction field of the Control Info field of the QoS Characteristics element specifies if this is a request for UL scheduling or TXOP sharing
Min Start Time	The minimum amount of time needed by the non-AP STA before resources that allow the non-AP STA to perform UL or P2P transmissions are announced by the AP
Max Start Time	The maximum amount of time acceptable by the non-AP STA before resources that allow the non-AP STA to perform UL or P2P transmissions are announced by the AP
Avg Start Time	The average amount of time acceptable by the non-AP STA before resources that allow the non-AP STA to perform UL or P2P transmissions are announced by the AP
Lifetime	= 0: A one-time UL scheduling or TXOP sharing; > 0: The duration of UL scheduling or TXOP sharing procedure in milliseconds after the delivery of specific DL frames to a STA
MSDU Bytes	The number of MSDU bytes that belong to the specified flows and are delivered by the AP to the non-AP STA before the AP allocates resources to the non-AP STA to perform UL or P2P transmissions. After the delivery of each set of MSDU Bytes, the AP performs resource allocation for UL or P2P transmission, depending on the request type.
Buffer Action	Specifies if the non-AP STA requires the AP to fully deliver all the buffered frames belonging to the specified traffic flows before activating resource allocation for UL or P2P transmissions.