Low-Latency Indication (LLI) with Delayed LL Traffic Generation

October 2025

Authors:

Name	Affiliations	Address	Phone	email
Behnam Dezfouli	Nokia	520 Almanor, Sunnyvale, CA		behnam.dezfouli@nokia.com
Klaus Doppler	Nokia	520 Almanor, Sunnyvale, CA		klaus.doppler@nokia.com
Prabodh Varshney	Nokia			prabodh.varshney@nokia.com

Introduction

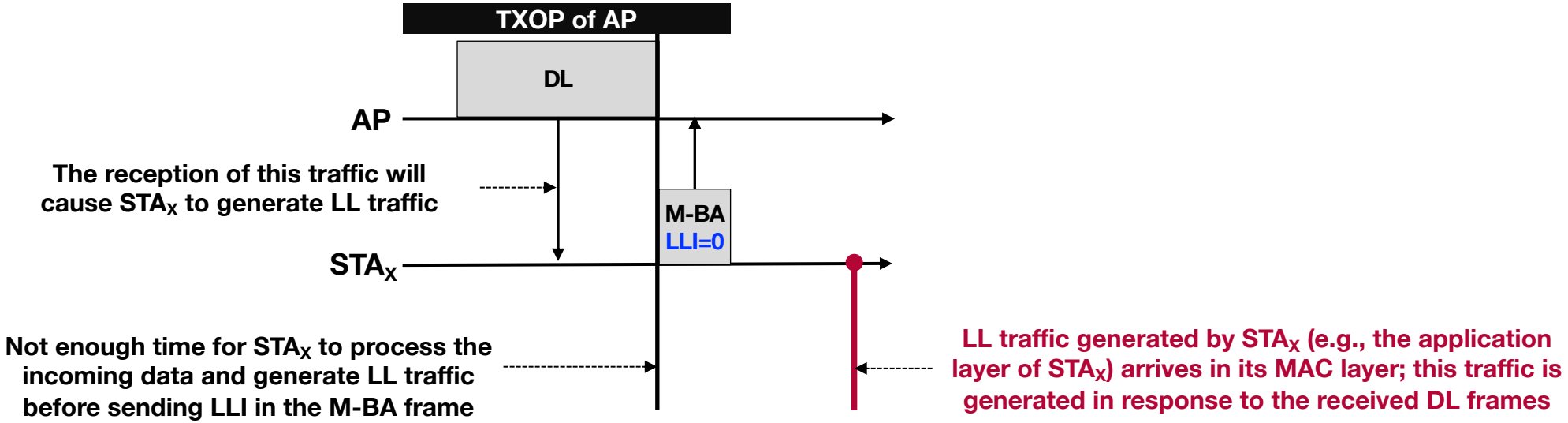
- In Wi-Fi networks, APs usually have a higher chance of capturing the channel (shorter AIFS, MU-EDCA, etc.)
  - Using AP-based resource allocation for UL/P2P transmissions leads to higher transmission efficiency for non-AP STAs compared to using EDCA for channel access contention

- For transmission of **periodic (semi-periodic)** UL/P2P traffic, non-AP STAs can use SCS with QoS Characteristics to request for periodic allocation of resources
- **For non-periodic UL/P2P traffic, UHR proposes two new methods to enhance the transmission of Low-Latency (LL) traffic from non-AP STAs** [IEEE P802.11bn/D1.0]:
  - **P-EDCA:** Used when non-AP STAs experience severe collisions when using EDCA
  - **Low-Latency Indication (LLI): When the AP is the TXOP holder and the receiving non-AP STA has LL traffic** [11-25/0931] [P802.11bn D1.0]
    - **The current LLI method does not support timely transmission of LL traffic when such traffic is generated in response to received DL traffic**

- **In this contribution, we propose to use LLI with delayed LL traffic generation: Allows a non-AP STA to use the LLI method for the transmission of LL traffic that will be generated imminently in response to the reception of DL traffic**

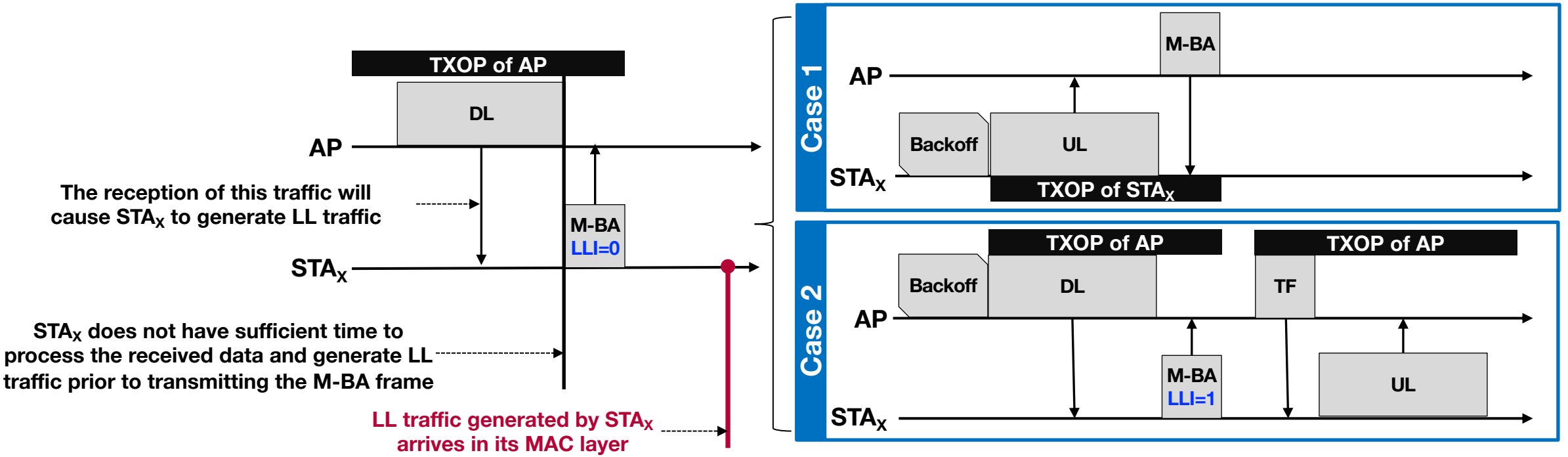
Shortcomings of the Low-Latency Indication (LLI) Feature

- With LLI [IEEE P802.11bn/D1.0], the receiving STA does not have sufficient time to process the incoming DL frames and send an LLI based on the processing of the newly received frames
- Consider the following case: After the transmission of DL frames to STA_X, this STA needs some time to process these frames and generate LL frames in response
- Examples:
  - **Commands sent to a robot, and reception of sensing or confirmation of actions in response**
  - **Sending a request to a camera to immediately capture and transmit images**
- **Therefore, the M-BA frame sent by this STA does not use LLI**



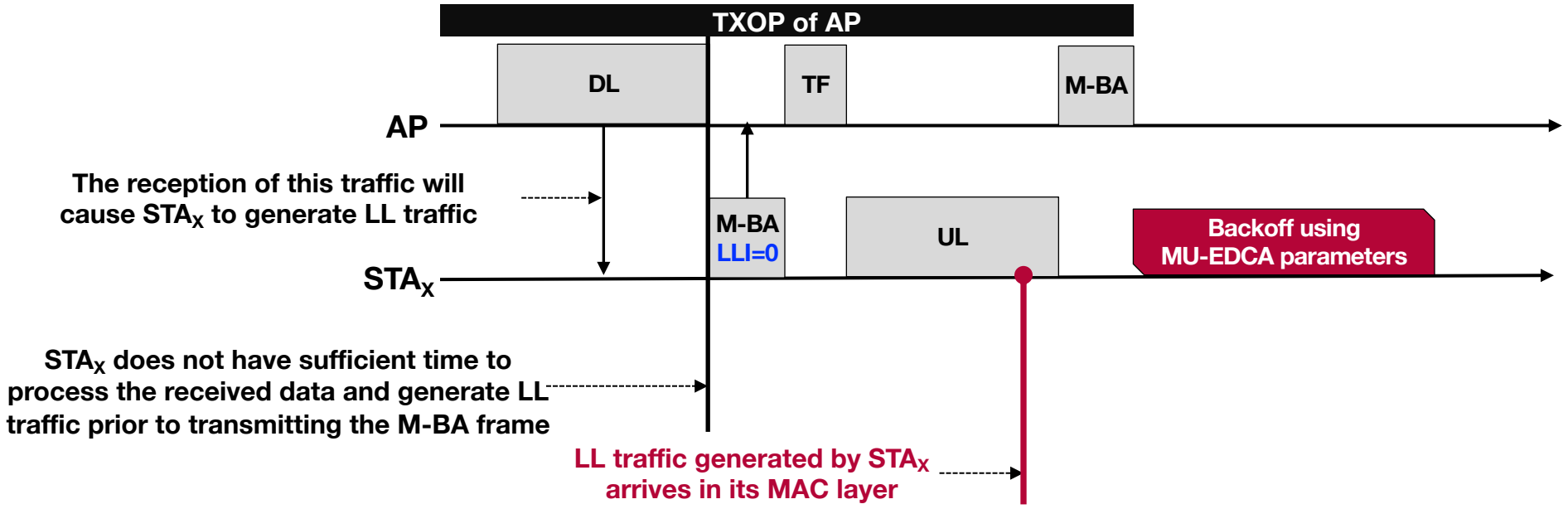
❑ Shortcomings of the Low-Latency Indication (LLI) Feature

- STA_X generates **LL traffic** at a later point, after which, one of the following two cases will occur:
  - **Case 1:** STA_X uses EDCA and captures the channel before the AP, then, STA_X sends its UL LL traffic to the AP
  - **Case 2:** The AP uses EDCA and captures the channel before STA_X
    - Through a method such as LLI, the AP is informed about the LL traffic of STA_X
    - Subsequently, the AP shares TXOP with STA_X using TF or TXS Mode 1/2
- **In both cases, LLI did not help with preventing EDCA channel contention by STA_X**



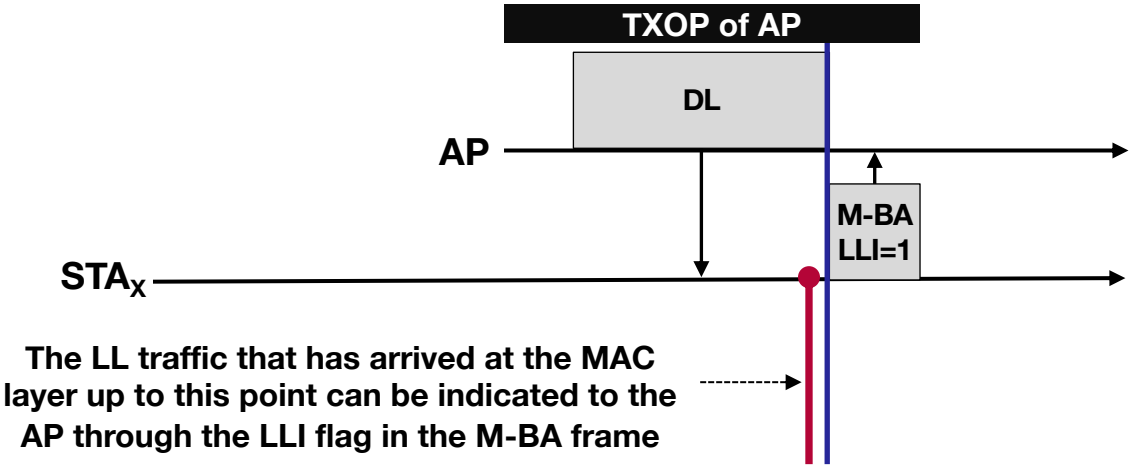
❑ Shortcomings of the Low-Latency Indication (LLI) Feature

- If the AP assigns resources to STA_X to send UL transmissions (before the generation of LL traffic by STA_X), then STA_X will need to use MU-EDCA parameters to compete for channel access to send its LL traffic
  - **STA_X will have a lower chance of capturing the channel compared to other STAs**



❑ Shortcomings of Low-Latency Indication (LLI)

- **In summary,** the LLI flag sent in an M-BA frame cannot be used to inform the AP of LL traffic that is generated in response to the delivery of DL frames received immediately before the transmission of the M-BA frame
- **The LLI flag is useful when LL traffic arrives in the MAC of the non-AP STA within a specific interval before the transmission of the M-BA frame**



- **The use of LLI for the transmission of non-periodic, event-triggered events is limited**
  - We note that the reception of DL traffic is a major cause of generating LL UL/P2P traffic
- **LLI must allow non-AP STAs to request for resource allocation from the AP based on: (1) current availability of LL traffic, and (2) generation of imminent LL traffic**

Delayed LLI

- In this work, we propose **delayed LLI as a method for a non-AP STA to inform the AP about imminent generation of LL traffic in response to the reception of DL traffic**

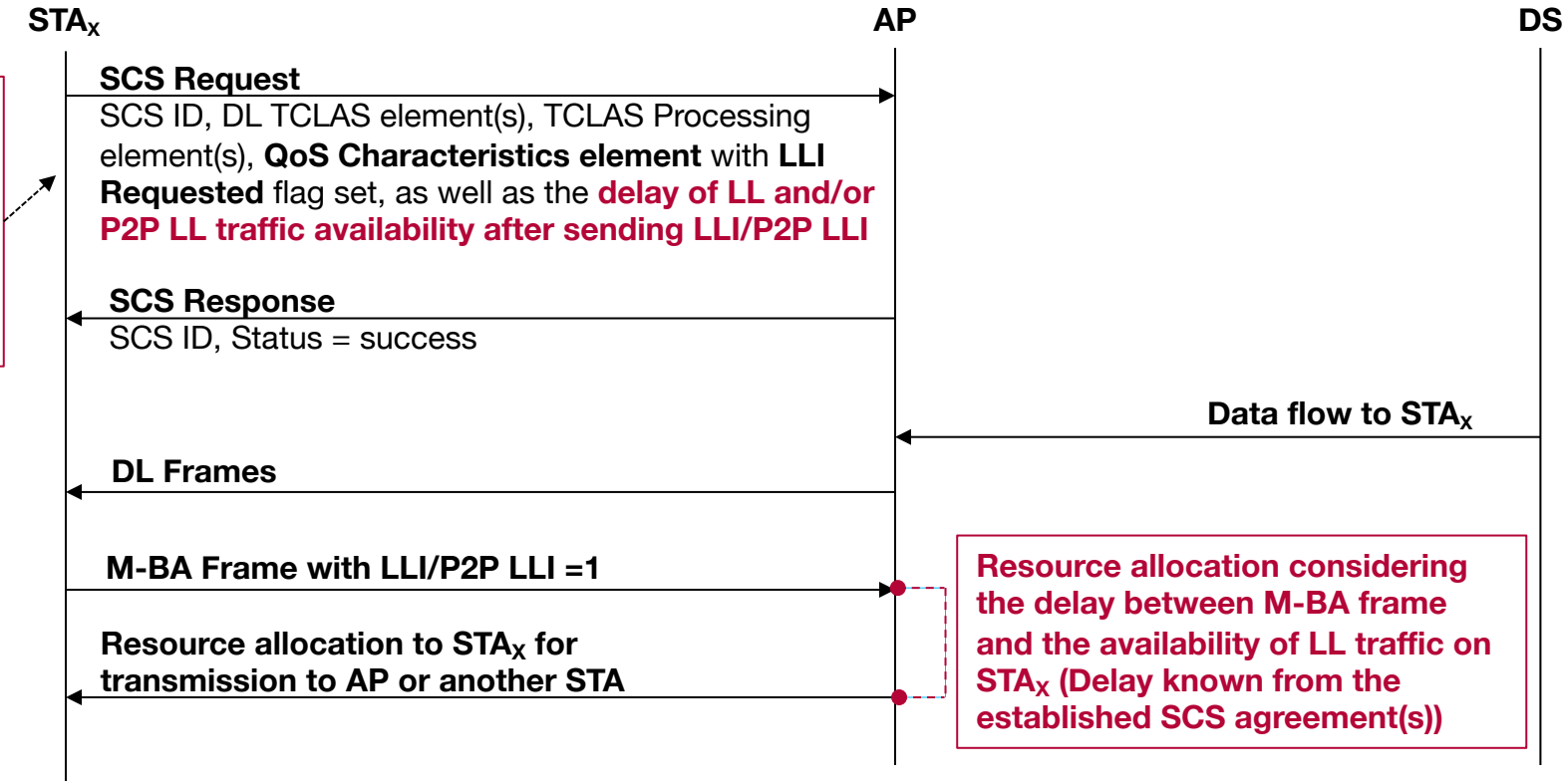
- Various methods can be used to support such behavior:
  - **Using SCS:** When a non-AP STA uses SCS to request for the enablement of LLI for a specific traffic TID/flow, **the SCS request also includes the delay between the transmission of M-BA frame with LLI/P2P LLI and availability of LLI/P2P on the STA**
  - **Using M-BA frame:** When a non-AP STA sends an M-BA frame**, the frame may include the delay until the availability of the indicated LL traffic on the STA**

❑ Using SCS for Specification of the Delay of LL Traffic Availability

- A non-AP STA establishes an **SCS agreement** with the AP (where the LLI Requested subfield of Control Info field of the QoS Characteristics element is being requested for the traffic of the SCS stream described by the QoS Characteristic element)
- The QoS Characteristics element of the SCS Request frame **includes information about the delay between the transmission of M-BA frame and availability of LL traffic at the STA**

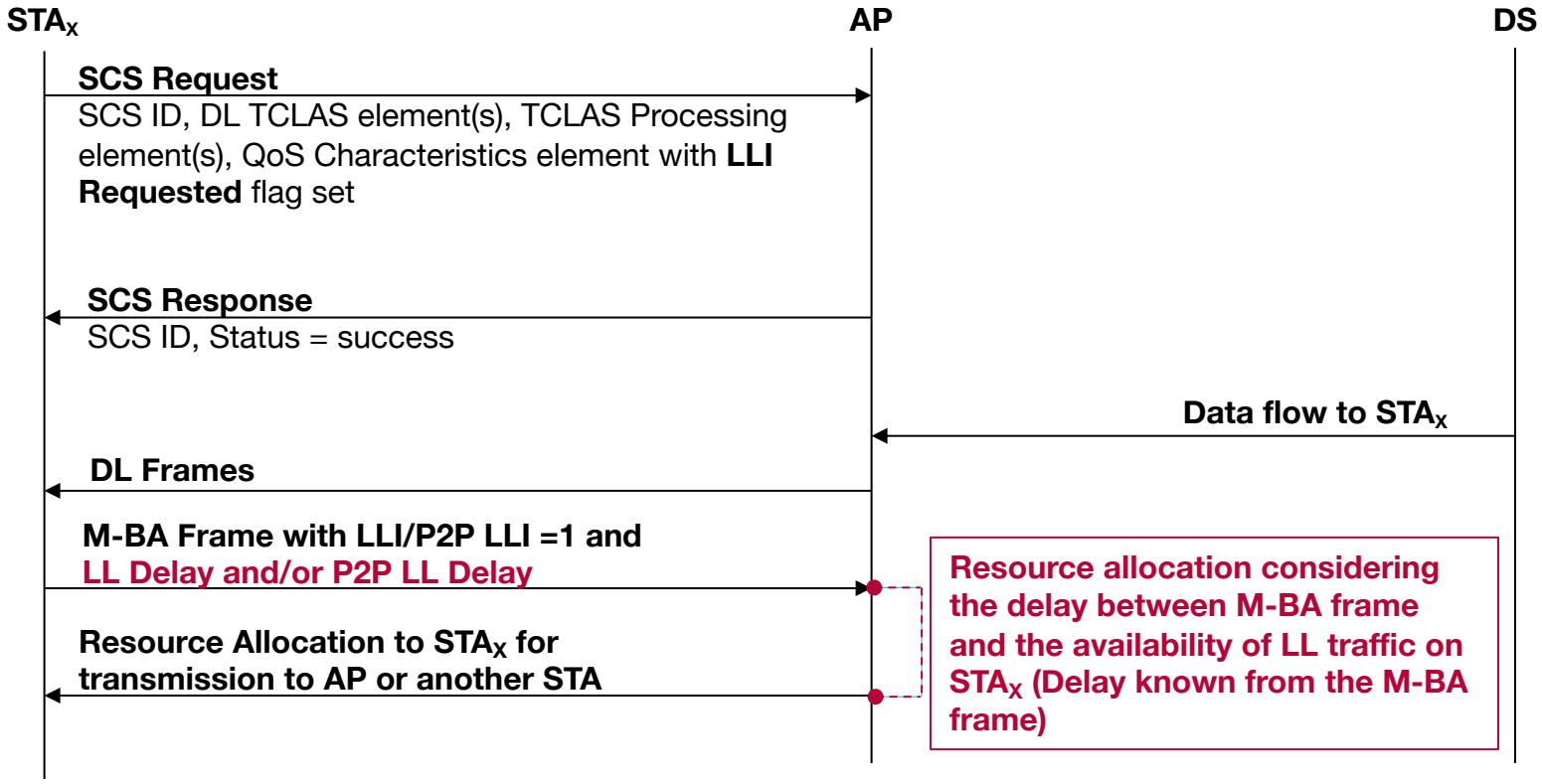
A subfield of the QoS Characteristics element could be used to convey the delay; e.g., Service Start time

Alternatively, a new subfield may be defined in the QoS Characteristics element for this purpose



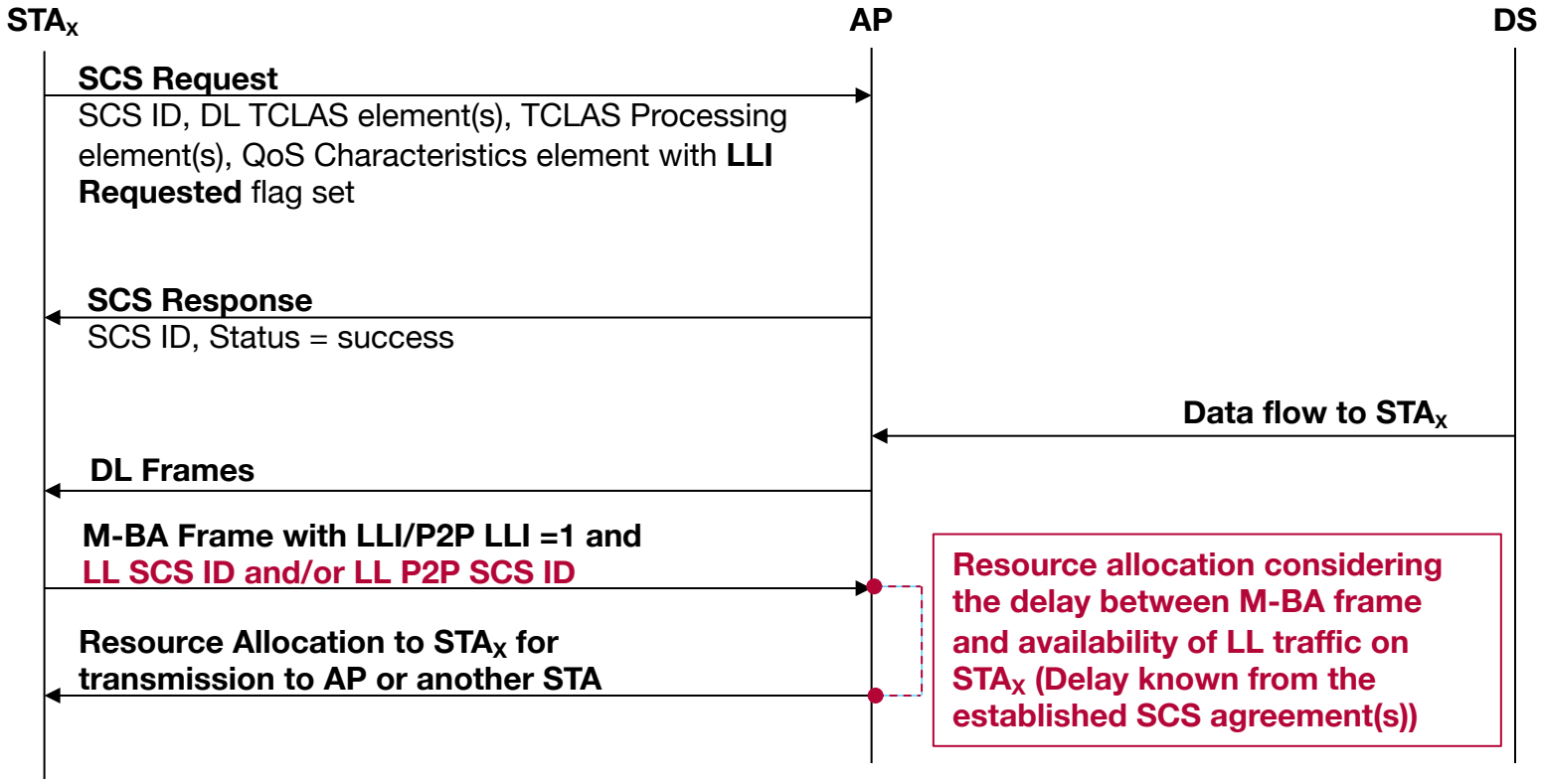
❑ Using M-BA Frame for Specification of the Delay of LL Traffic Availability

- An STA sending an **M-BA** frame may use the **Feedback subfield** of the Per AID TID Info subfield **to inform the AP about the delay between the transmission of LLI or P2P LLI and generation of LL traffic for AP or other STAs**



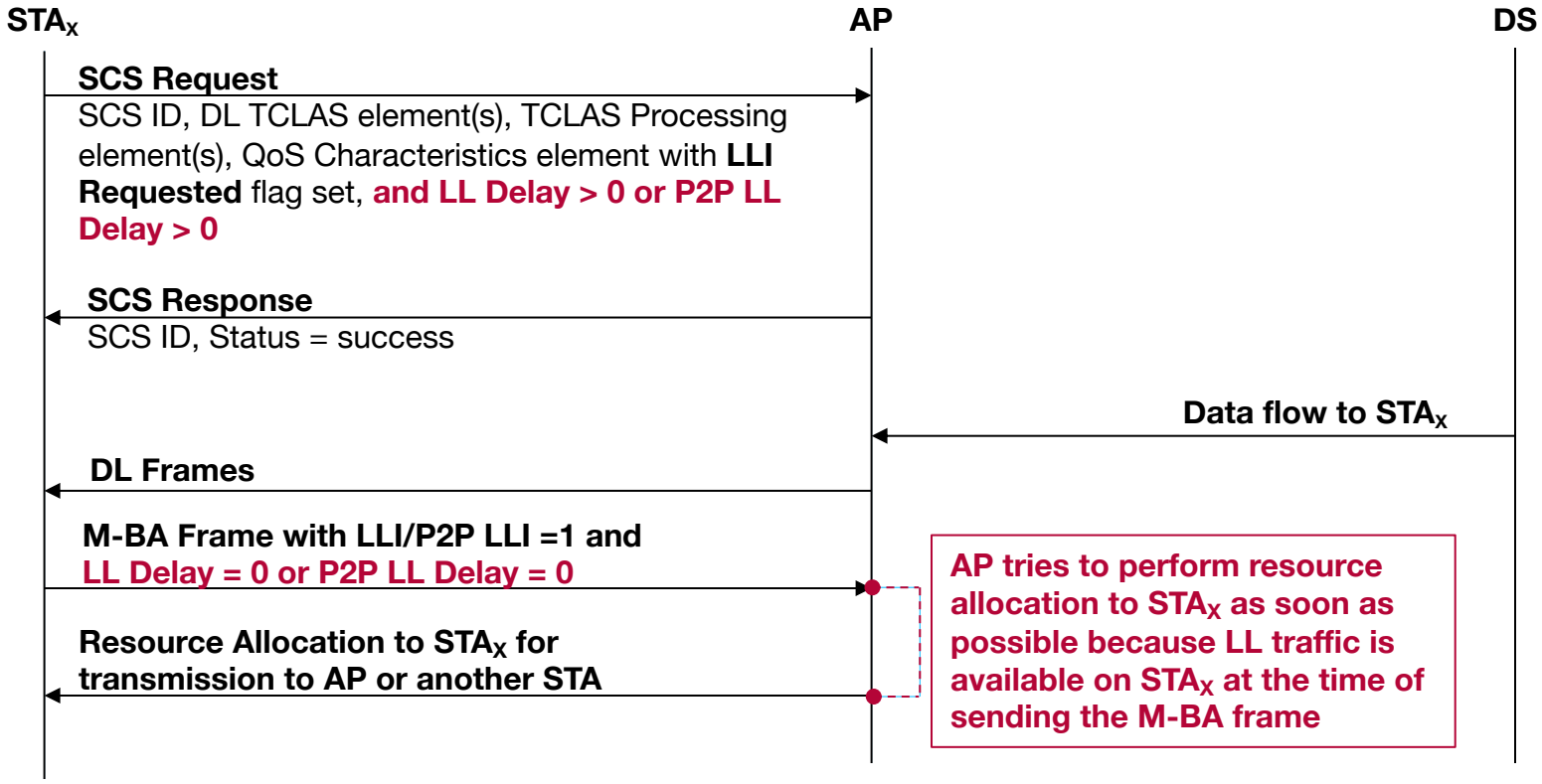
❑ Using SCS and M-BA Frame for Specification of the Delay of LL Traffic Availability

- An STA sending an **M-BA** frame may use the **Feedback subfield** of the Per AID TID Info subfield of the M-BA frame **to inform the AP about the SCS ID of the stream that caused LLI or P2P LLI**



❑ Overriding Previously-Announced Delay Values

- If a STA includes LL Delay or P2P LL Delay values within its M-BA frame, the values of these subfields override the values previously shared with the AP during the SCS negotiation



Conclusion

- Processing incoming DL frames and generating LL UL or LL P2P traffic in response to the received DL frames is a major cause of generating LL traffic
- The current LLI method does not allow a non-AP STA to indicate to the AP the imminent generation of LL traffic generated in response to the reception of DL traffic

- This contribution proposes methods that enable non-AP STAs to send LLI or P2P LLI when LL traffic will be imminently generated by the STA
  - The STA can use SCS negotiation or M-BA frame to inform the AP about the delay between the transmission of LLI and availability of LL traffic on the STA

- With the proposed method, non-AP STAs can rely more on resource allocations by the AP (OFDMA, MU-MIMO), rather than using EDCA for channel access.
  - **Results in better channel usage efficiency, lower EDCA collisions, and lower communication delay**