Performance Analysis of QTP-based S2S Transmission in IEEE 802.11ax WLANs

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***Abstract*— The Quiet Time Period (QTP) is a new feature introduced in IEEE 802.11ax standard to support the coexistence of the Station-to-Station (S2S) and uplink/downlink in a WLAN. However, according to the standard, an AP has a restriction that it should accept QTP procedure only if the introduction of QTP would benefit the network performance. Therefore, prior to the designing a practical QTP control scheme, it is necessary to analyze the effect of QTP on network performance. For this purpose, this paper evaluates the performance of QTP, Uplink OFDMA Random Access (UORA), and MU DL (Multi-User Down Link) in terms of throughput and transmission delay, respectively, by simulation.**

Keywords—IEEE 802.11ax, quiet time period, WLAN, QTP

I. INTRODUCTION

In Wireless Local Area Networks (WLANs), since Station-to-Station (S2S) transmission does not go through an Access Point (AP) unnecessarily, it is possible to obtain the performance gain in terms of both a transmission delay and a throughput. However, if S2S transmission is allowed without any control scheme, it causes interference to other transmissions of adjacent STAs. As a result, the S2S might cause deterioration of the overall network performance.

The Quiet Time Period (QTP) [1] is a new feature introduced in IEEE 802.11ax standard [2] to support the coexistence of the S2S and other transmissions (i.e., uplink and downlink) in a WLAN environment. In the QTP, when the S2S STA requests the QTP procedure from the AP, the AP and the S2S STA negotiate the QTP parameters. And then, the AP determines to allow a dedicated transmission period (i.e., QTP duration) to the S2S STA if the QTP procedure will be beneficial to the network.

Therefore, for the AP to decide whether to allow QTP, it needs a criterion to determine whether the QTP procedure is helpful for the network or not. However, how to set this criterion is not defined in the standard and remains an implementation issue. In other words, to design a technique for operating QTP in the IEEE 802.11ax WLAN environment, it is necessary to check the effect of the existence of QTP on network performance.

For this reason, in this paper, to investigate the effect of the QTP procedure, we evaluate the network performance in terms of throughput and delay based on a simulation scenario where

	Dialog Token	Quiet Period Offset	Quiet Period Duration	Quiet Period Interval	Repetition Count	Service Specific Identifier
Octets:	2	1	2	1	1	2

(a) QTP request

	Dialog Token	Status Code	Quiet Period Offset	Quiet Period Duration	Quiet Period Interval	Repetition Count	Service Specific Identifier
Octets:	2	1	1	2	1	1	2

(b) QTP response

	Quiet Period Duration	Service Specific Identifier
Octets:	1	2

(c) QTP setup

Fig. 1. Action Frames for QTP procedure.

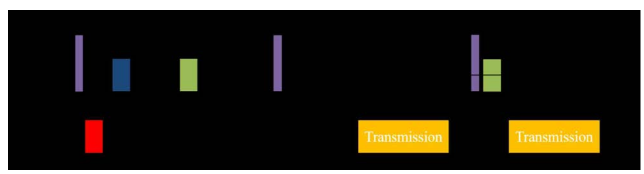

Fig. 2. Basic operation of QTP prodecure.

both UORA (Uplink OFDMA Random Access) and MU DL (Multi-User Down Link) operate in WLAN.

The rest of this paper is organized as follows. Section II describes QTP parameters and QTP procedure. In Section III, we evaluated the effect of QTP on the network performance by simulation. Lastly, we conclude in Section IV.

II. QUIET TIME PERIOD IN IEEE 802.11AX

The standard defines three action frames (QTP request, QTP respond, and QTP setup) to control the operation of the QTP. The QTP-requester STA sends the QTP request frame, and it has the information regarding a periodic sequence of QTP.

The AP broadcasts a QTP response message to announce whether the QTP procedure has been permitted or not. If the QTP procedure is allowed and the QTP-requester STA receives the QTP setup frame from the AP, the QTP-requester STA may transmit data using the S2S link during the QTP period.

The information field of each QTP action frame is shown in Fig. 1, and their details are as below.

- Dialog Token: Since the AP issues several QTP respond messages for many QTP request messages, the requester-STA needs to distinguish between request messages to the corresponding response messages, and vice versa. For this purpose, the QTP request message has a dialog token element to distinguish its corresponding QTP respond. After the requester-STA set the dialog token to a specific value and sends the QTP request, the AP sets the dialog token to the same value of it when it transmits QTP respond.
- Quiet Period Offset: This information defines the duration of a QTP period that the QTP-requester STA needs to acquire for its transmission. The unit is 32 μsec.
- Quiet Period Duration: This information defines the duration of a QTP period that the QTP-requester STA needs to acquire for its transmission. The unit is 32 μsec.
- Quiet Period Interval: The interval between the start of two consecutive QTP is defined from this element, which is expressed in TUs.
- Repetition Count: This element defines the number of QTP periods. If its value is 0, the QTP period operates only one time.
- Service Specific Identifier: This element is an identifier assigned by a P2P application. The AP identifies the type of P2P service that requires the QTP from the service specific identifier of the QTP request message. Besides, the AP uses this element of a QTP response/setup to specify the type of P2P service supported via QTP.
- Status Code: In the QTP response message, the status code indicates the result of the QTP request of the STA. If the status code is *SUCCESS*, the QTP-requester STA can begin the QTP procedure. If the status code is *REJECTED*, the QTP procedure is not allowed. If the status code is *COUNTERED*, the QTP request is denied by the AP. However, the AP suggests the recommended QTP-related values to the QTP-requester STA by sending the QTP response message. The QTP-requester STA refers to the recommended values and can send a new QTP request message immediately with modified QTP values to set another QTP procedure.

Fig. 2 shows the basic operation of QTP procedure. The QTP is set up between an AP and a STA. A STA that desires an S2S link sends a request message to an AP, and then the AP broadcasts a success message as a response to the STA if the build of the S2S link is beneficial to the network. After the STA which has requested the S2S link, receives the success message it has a dedicated duration (i.e., the quiet time period)

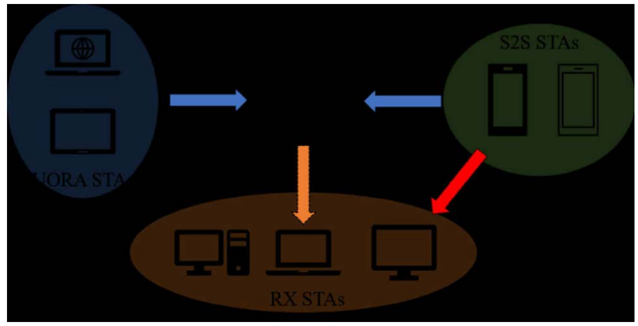

Fig. 3. Simulation environment.

for transmission, and other STAs may be forced to silence for this duration.

III. SIMULATION STUDY

This section investigates the effect of QTP on network performance by the simulation in terms of throughput and delay.

Fig. 3 describes our simulation scenario, which operates both UORA and MU-DL. Here, the UORA STAs transmit their traffic based on UORA, and the AP access to the channel to send traffic to RX STAs. The S2S STA has two ways to send traffic to the RX STA. One is UORA, the S2S STA should contend to access a RU with other UORA STAs by UORA rule, and traffic is delivered to RX STAs via the AP. Another is QTP, the S2S STA should contend to access a channel with the AP by EDCA rule, and traffic is delivered to RX STAs directly.

And also, we observed the throughput and delay of each transmission procedure when the number of RX STAs and S2S STAs is fixed to 5 in simulation, but the number of UORA STAs increases from 5 to 20. Thus, the level of channel access contention in the UORA procedure will be more severe as UORA STAs increase. The other major simulation parameters for our simulation are shown in Table 1.

Fig. 4 and Fig. 5 show the performance for each transmission procedure in terms of throughput and delay, respectively. First, when the QTP was disabled so that the S2S

TABLE I. SIMULATION CONFIGURATIONS

Parameters	Value
Bandwidth	20 MHz
number of RUs	1~9
OCWmin, OCWmax	7, 31
MCS	5
aSlotTime	9 μsec
SIFS	16 μsec
QTP offset	10 TUs (10.2 msec)
QTP duration	3 msec
QTP interval	371 TUs (380 msec)
MPDU length	6400 Bytes
Paket arrival interval	38 msec
Trigger frame interval	30 msec
number of MU DL(RX STA)s	5
number of S2S STAs	5
number of UORA STAs	5~20

STAs should deliver their traffic by UORA, the throughput of UORA increased from 2.8 to 4.1 Mb/s. In contrast, throughputs of MU DL and S2S decreased from 9.7 to 7.8 Mb/s and decreased from 2.9 to 1.0 Mb/s, respectively.

In the case where the QTP was enabled, the throughput of UORA was ranged from 4.8 to 5.8 Mb/s, so its throughput was increased by 1.5 times on average. The throughput of S2S also increased up to 6.5 times as well. The reason the throughputs of UORA and S2S were increased is S2S's traffic was offloaded. In other words, the contention level was mitigated in UORA, and S2S could avoid severe channel access contention because of their dedicated channel resources.

Although the throughput of MU DL decreased somewhat when QTP was enabled, it was 79% on average compared to the throughput of MU DL when QTP was disabled. Besides, assuming the decreased throughput of MU DL still satisfy QoS (Quality of Service) of traffic, it might not be a critical problem in the QTP-enabled scenario.

Meanwhile, we observed that the QTP is more effective for performance enhancement in terms of delay. In Fig. 5, when QTP was enabled, the maximum reduction amount of UORA's delay was 1436 msec. In QTP, the delay was reduced from 3678 up to 4 msec on average. The average increased amount of MU DL's delay was only 3.7 msec.

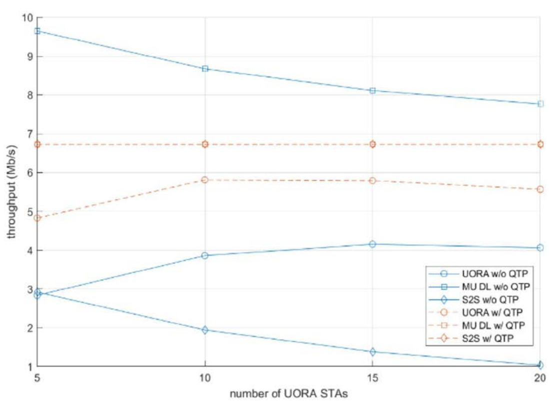

Fig. 4 Effect of QTP on on network performance in terms of throughput

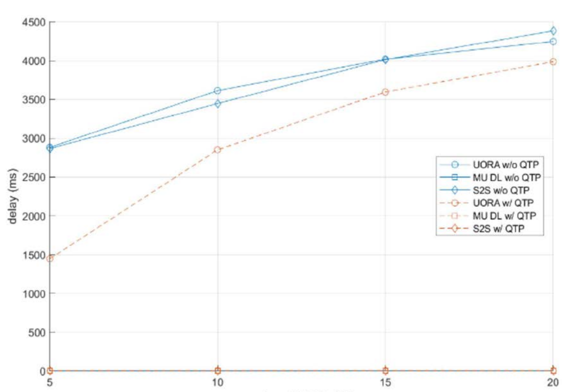

Fig. 5 Effect of QTP on network performance in terms of delay.

IV. CONCLUSION

In this paper, we evaluated the impact of QTP on network performance in terms of throughput and latency. However, our simulation scenario was only a fractional case. The network situation in which QTP could contribute to that performance improvement might be very extensive. So, it is necessary to analyze the effect of more various QTP parameters and network environment in future works.

ACKNOWLEDGMENT

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (No. 2021R1I1A1A01047630).

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. NRF-2020R1C1C1010692).

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (No. 2018R1D1A1B07049758).

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government(MSIT) (No. 2021R1F1A1061514).

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