Influence of Interference with Moving Terminal in Wireless LAN Environment and Evaluation of Behavior of QoS-TCP

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Abstract—In late years, the demand for multimedia communication has been raised extensively. In this environment, to guarantee the QoS is extremely important . While various control mechanisms have already been realized about the QoS control in each protocol layer, a QoS-guaranteed TCP (QoS-TCP) has been proposed. The QoS-TCP tries to guarantee a specified bandwidth against competing background TCP traffic. Previous researches reveal that the QoS-TCP is effective in wired networks, fixed wireless networks, and wireless network with handover.

Recently, a mobile router has spread quickly. Therefore, we should assume the environment where an access point (AP) and portable terminals move together, and investigate the use of QoS-TCP in such an environment. In this paper, we investigate the behavior of QoS-TCP caused by radio interference when 2 QoS-TCPs come close together.

Keywords-wireless LAN, QoS guarantee, mobile, interference

I. Introduction

In recent years, a demand for multimedia communications including video stream communications and/or voice (VoIP) communications has been raised extensively. For such multimedia communications, it is important to guarantee a certain level of Quality of Service (QoS). We here aim at guaranteeing constant bandwidth as one of QoS criteria.

In IEEE802.11 wireless LAN, QoS control on an uplink, which is a link directed from wireless terminals to an access point (AP), is very difficult because an autonomous distributed control[1] is employed to access the uplink. In order to control uplink traffic for a specific QoS, many previous works including IEEE802.11e (EDCA)[4] have been done. They could work well if we can modify IEEE802.11 MAC protocol or can add dedicated functions in both mobile terminals and APs. In practice, however, it is difficult to modify MAC, because MAC protocols in many implementations are run in LSI chips except some API[2][3]. Even if we can complete to deploy EDCA in any wireless terminals and APs, QoS control of EDCA still has difficulties in a control of a level of QoS differentiation and in a parameter tuning to obtain a specific QoS values.

In order to avoid such difficulties, QoS control mechanism by TCP has been introduced. A TCP protocol, which is a variant of a traditional TCP (TCP-Reno) and can control QoS by using congestion control mechanisms, is here called a QoS-TCP. It is developed to guarantee a certain bandwidth for multimedia communications. One of advantages of QoS-TCP is that no modification is needed to guarantee bandwidth in any network devices except TCP behaviors of sending terminals, nor additional any control overhead. The performance evaluation of QoS-TCP [6] reveals that QoS-TCP can guarantee a specific bandwidth, but also cannot if competing background traffic increases.

On the other hand, a mobile router has spread quickly in recent years. In this paper, a mobile router means that it is connected by a wireless LAN with portable terminals at the front-end, and connected with WiMAX, LTE, and so on at the back-end. Thus an environment is assumed in which data is exchanged between a mobile router and terminals. If a lot of APs exist in this environment, radio interference occurs in the same channnel because unused channel's automatic setting does not function. In such a case, it is supposed the link capacity is decreasing.

For this reason, QoS control is needed in a mobile wireless environment. The characteristics of QoS-TCP is clarified in wired networks, fixed wireless networks, and wireless networks with handover. However, we still need to know the performance of QoS-TCP in a mobile wireless environment. Therefore, we evaluate an influence of radio interference with mobile router and terminals in a wireless LAN environment and behavior of QoS-TCP.

The rest of this paper is organized as follows. In Section II, Related works are described as well as QoS-TCP technologies and CSMA/CA. Evaluation models and experiment results are discussed in Section III. The concluding remarks are stated in Section IV.

II. Related Works and Technologies

A. Previous Researches

As addressed in the previous section, QoS-TCP has been developed guaranteeing a certain bandwidth for multimedia communications. Results of computer simulations and real terminal experiments have shown that QoS-TCP is effective within a number of competing background TCP flows in wired networks[6].

It has aloso been evaluated for QoS-TCP in wireless networks, such as IEEE802.11 LANs(WLANs). In WLAN, performance of QoS-TCP is reported in a fixed environment (Fig.1) and an environment with handover (Fig.2) [7]. In fixed wireless networks, it has been proven QoS-TCP can guarantee about 2 times bandwidth compared with conventional TCP. In addition, in WLAN with handover, QoS-TCP is likely to have a possibility to guarantee a target bandwidth in indoor.

However, QoS-TCP has not been investigated in an environment with mobile router. In this environment, there is a possibility of influencing Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA), that is the MAC protocol in IEEE802.11, by the influence of radio interference because two or more routers come close together.

This paper is devoted for investigating characteristics of QoS-TCP in the case that terminals and router move together. Fig.3 shows an environment assumed in this study.

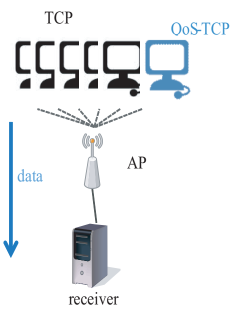

Figure 1. fixed wireless environment

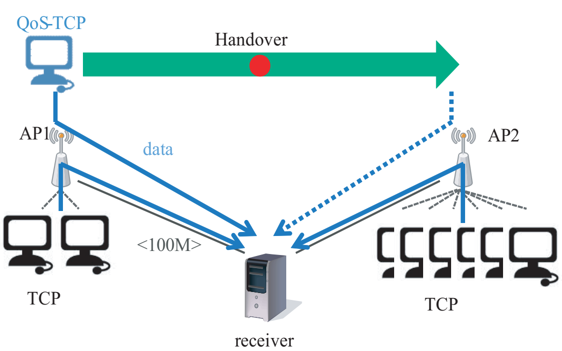

Figure 2. wireless environment with handover

B. QoS-Guaranteed TCP

Several QoS-TCP instances have been introduced [5][6]. They are developed for aiming at quality improvement of streaming communications, and designed to assure a designated bandwidth. Protocols of the QoS-TCP expand the congestion control mechanism of existing TCP, and adopt a retransmission behavior to improve burst packet loss tolerance.

TCP-AV[6] is one of the QoS-TCP instances. TCP-AV modifies slow start threshold according to a target bandwidth that a user specifies, and improves congestion window behaviors in temporal congestion. Larger slow start threshold in TCP-AV than that in a conventional TCP (TCP-Reno) result in an advantage of obtaining more bandwidth. Congestion window of TCP-AV is aggressively kept large to obtain more bandwidth, and is also carefully controlled to avoid congestion collapse. Thus, TCP-AV eventually gives up guaranteeing the specified bandwidth when competing background TCP flows are strong enough to cause congestion collapse.

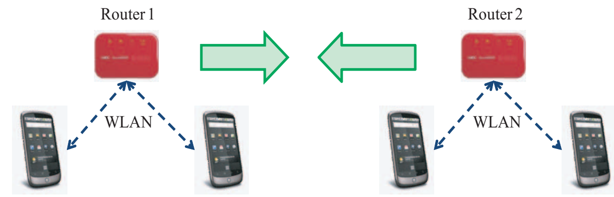

Figure 3. Assumed Environment

C. CSMA/CA(Carrier Sense Multiple Access/Collision Avoidance)

CSMA/CA is used as MAC protocol in IEEE802.11. Unlike CSMA/CD (Carrier Sense Multiple Access/Collision Detection) which deals with transmission after a collision has occurred, CSMA/CA acts to prevent collisions before they occured.

In CSMA/CA, as soon as a node receives a packet that is to be sent, it checks to be sure the channel is clear. If the channel is clear during the time called DIFS (Distributed InterFrame Space), then the packet is sent. If the channel is not clear, the node waits for a randomly chosen period of time, and then checks again to see if the channel is clear. This period of time is called the backoff time. An overview of CSMA/CA is shown in Fig.4.

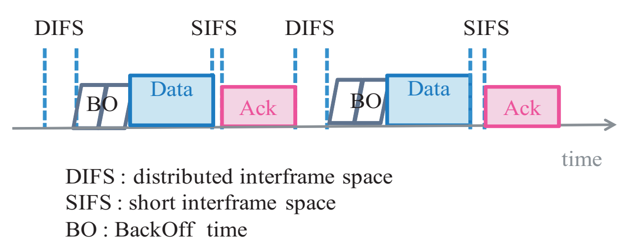

Figure 4. CSMA/CA

In the case of CSMA/CA, if a lot of APs exist in this environment, radio interference should be occurred in the same channnel because unused channel's automatic setting does not function. Thus it is supposed the link capacity is decreasing. Fig.5 shows the appearance of CSMA/CA when the routers come close together.

In State 1, the distance between routers is enough. This means radio interference hardly influences them. Therefore, it does not influence the bit error though there is a noise from other systems.

In State 2, routers come close together. The error occurs in MAC frame because noise from other systems is large compared with that in state 1. Therefore, ACK does not return, and the data is necessary to be retransmitted. Moreover, if noise from other systems is larger, it is recognized as a carrier, and the system becomes "wait" state.

In State 3, the distance between routers reach to the level in which both carriers can be sensed almost equally with each other. In this case, though the influence of a few noises is received, other systems are completely recognized as a carrier, and the system becomes "wait" state. In addition, ACK of other systems is recognized as a carrier. For this reason, in state 3, 2 systems are supposed to become 1 CSMA/CA domain.

We confirme this by experiments.

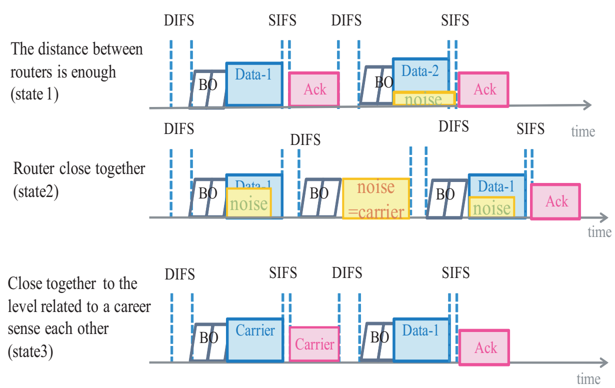

Figure 5. CSMA/CA

III. Evaluation

In a mobile environment, there are various matters we have to investigate. For example, influences of change in a radio environment (interference and radio field strength), the number of terminals connected with 1 router, and the situation in which two or more QoS-TCP communicates at the same time.

Radio interference occurs when the distance between 2 mobile routers change. In this study, we focus on the point how much throughput decreases by this interference. Thus, we investigate the influence of interference in the following 3 environments.

- mutual interference of TCP/TCP
- mutual interference of TCP/TCP-AV
- mutual interference of TCP-AV/TCP-AV

A. Experimental equipment

In this experiment, we use IEEE802.11g as WLAN. Although data transfer rate of 11g is 54Mbps theoretically, it actually communicates with about 20Mbps. Therefore, for example, fair-share (=value that total bandwidth is divided by the number of transmission terminals) becomes 4Mbps when 5 terminals connect with 1 router.

We use 2 mobile routers (NEC Aterm WM3500R). They are interfered by using the same channel number. When this router is used actually, the default radio output is 25% so as not to interfere with each other, thus we use the radio output as 25%.

We use Android smartphone (Nexus one, Galaxy S) as mobile terminals. While these terminals behave as TCP (Cubic) usually, they behave as TCP-AV when the module of TCP-AV is loaded. In this time, TCP-AV is mounted as proxy(Fig.6).

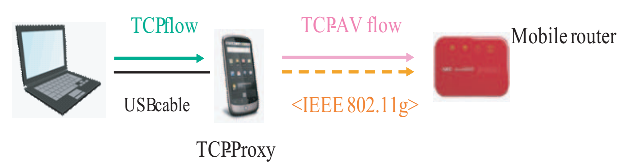

Figure 6. TCP-AV(proxy)

B. Evaluation Model

Fig.7 and Fig.8 show evaluation models. Fig.7 is an environment that connects 1 terminal to each router, and these systems come close together. In this case, terminals A and B are TCP and TCP-AV respectively, and we investigate the influence of each interference. Each sending terminal sends an uplink TCP flow to the receiving terminal.

Fig.8 is an environment that connects 5 terminal to each router, and these systems come close together. In this case also, terminals C and D are TCP and TCP-AV respectively, and we investigate the influence of each interference. All other background terminals are TCP.

C. experimental results

1) mutual interference of TCP/TCP: Fig.9 and Fig.10 show experimental results, in the environment of model 1 and environment of model 2, respectively. In model 1, when the distance between routers is 20m or more, each terminal can communicate with 20Mbps. When throughput is gradually lowered as the routers come close together, and throughput degraded to be about half compared with that of 20m by radio interference. In the case of model 2,

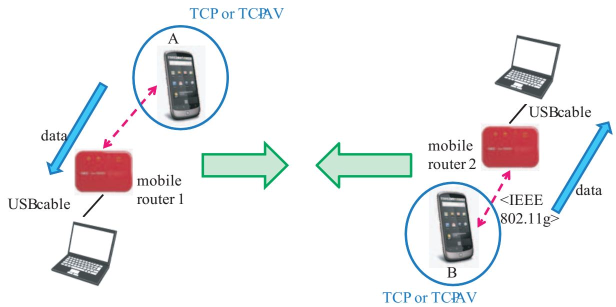

Figure 7. Evaluation Model 1

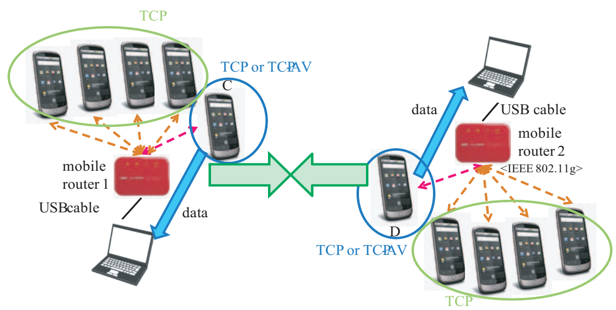

Figure 8. Evaluation Model 2

throughput becomes the result of model 1 divided by 5 that is the number of the sending terminals.

In both environments, as the routers come close together, throughput decreases by recognizing the other communication as a noise. When the routers come close together more, each data can be recognized as a carrier, throughput decreases further.

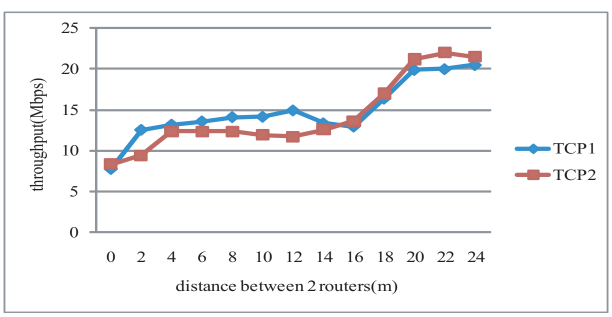

Figure 9. TCP/TCP(model 1)

2) mutual interference of TCP/TCP-AV: Fig.11 and Fig.12 show experimental results of model 1 and model 2, respectively. These results also, in model 1, when the distance between routers is 20m or more, terminals can communicate with 20Mbps. In the case of model 2, throughput becomes the result of model 1 divided by 5 that is the number of the sending terminals.

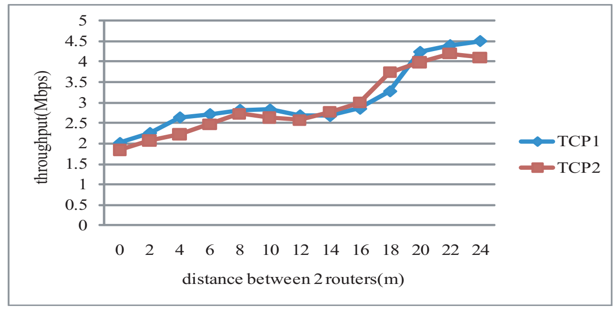

Figure 10. TCP/TCP(model 2)

In these environments also, as the routers come close together, throughput decreases by recognizing other communication as a noise. However, throuthput of TCP-AV is higher than that of TCP because TCP-AV is strong at the packet loss.

When routers come close together, since each data can be recognized as a carrier, TCP throughput decreases further. However, TCP-AV does not decrease throughput so much because TCP-AV can get the sending opportunity easily compared with TCP.

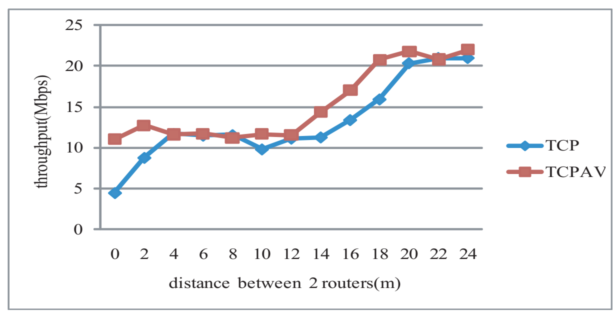

Figure 11. TCP/TCP-AV(model 1)

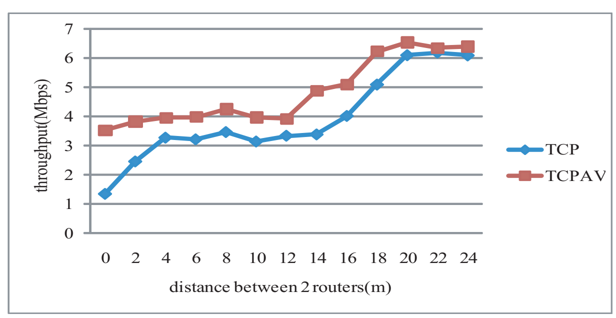

Figure 12. TCP/TCP-AV(model 2)

3) mutual interference of TCP-AV/TCP-AV: Fig.13 and Fig.14 show experimental results of model 1 and model 2, respectively. In these results also, in model 1, when the

distance between routers is 20m or more, terminals can communicate with 20Mbps. In model 2, Throughput of TCP-AV is about 1.5 times value of fair-share.

In model 2, TCP-AV can keep throughput high because of the grab of the bandwidth from background TCP. However, TCP-AV can not guarantee fair-sahre under strong interference.

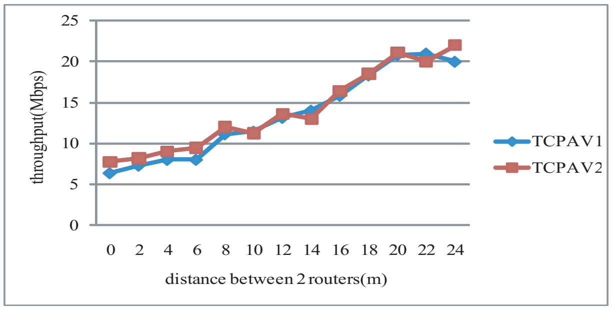

Figure 13. TCP-AV/TCP-AV(model 1)

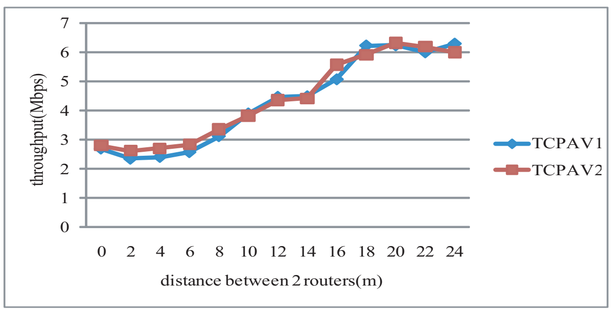

Figure 14. TCP-AV/TCP-AV(model 2)

As shown in above, we can confirme the transition of state 1 → state 2 → state 3. When TCP-AV communicates with other TCP, though TCP-AV can guarantee fair-share in the case of 10m 24m, it cannot guarantee fair-share in 0m 10m. However, TCP-AV is effective about 1.5 2.0 times compared with using TCP in these environments.

D. Analysis of performance evaluation results

Transferred packets are analyzed in MAC layer to know what occured in state 1, 2, and 3.

In state 2, packets of terminal connected with router 1 and 2 collapse. There are 2 kinds of collisions. First, packet is received as another frame because the bit changes by this collision. Second, packet is received as a noise because the frame is broken by this collision. The error rate in the MAC layer increases rapidly because these phenomena occur frequently.

In state 3, most packets are recognized as a carrier though these errors occured. This means 2 separate systems become 1 CSMA/CA domains. Thus, the MAC error rate decreases as shown in Fig.15.

In real terminal, state 1, 2 and 3 are smoothy transited (States 1, 2, and 3 do not occur at a precise distance between 2 routers) by noise and an individual equipment characteristic.

Figure 15. Error rate of MAC

IV. Conclusion

QoS-TCP bandwidth guarantee performance is investigated in mobile environment (router and terminals move together). QoS-TCP [6] was proposed, which tries to guarantee a target bandwidth and has a limitation of the guarantee because of avoiding congestion collapse.

Through our experiments, in IEEE802.11 mobile networks, many wireless factors such as radio interferences, change of the number of terminals connected with 1 router, and two or more QoS-TCP communicates at the same time are proved to significantly effect on the QoS-TCP performance. Especially, radio interferences from other system contribute QoS-TCP in its guarantee performance.

Therefore, we investitage degradation of throughput by the change of the distance between 2 mobile routers. As a result, we proved that there were states 1, 2, and 3.

In state 1, the distance between routers is enough. Therefore, the routers do not interfere with each other.

In state 2, the routers come close together. Although radio of each router reaches as the routers come close together, these packets collapse and it is recognized as a noise for the other router. For these reasons, retransmission occurs frequently in MAC layer, and MAC error rate increases in state 2 while throughput decreases.

In state 3, the distance between routers to the level a career can be sensed with each other. In this case, most packet are recognized as a carrier though these errors occured. For this reason, 2 separate systems become 1 CSMA/CA domains, throughput becomes about half compared with that of satate 1.

Acknowledgement

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