Throughput Control Method between Different TCP variants based on SP-MAC over WLAN

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***Abstract*—We have proposed the Media Access Control method based on the Synchronization Phenomena of coupled oscillators (SP-MAC) to improve a total throughput of wireless terminals connected to a Access Point. SP-MAC can avoid the collision of data frames that occur by applying Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) based on IEEE 802.11 in Wireless local area networks (WLAN). Furthermore, a new throughput guarantee control method based on SP-MAC has been proposed. This method enable each terminal not only to avoid the collision of frames but also to obtain the requested throughput by adjusting the parameters of SP-MAC. In this paper, we propose a new throughput control method that realizes the fairness among groups of terminals that use the different TCP versions, by taking the advantage of our method that is able to change acquired throughput by adjusting parameters. Moreover, we confirm the effectiveness of the proposed method by the simulation evaluation.**

***Keywords*—WLAN, Media access control, Synchronization phenomena of Coupled oscillator, CUBIC-TCP, Compound TCP**

I. Introduction

Wireless local area networks (WLAN) based on IEEE 802.11 usually employ carrier sense multiple access with collision avoidance (CSMA/CA) for media access control. For the CSMA/CA mechanism, data frame collisions frequently occur if the number of wireless terminals increases. To address this problem, a media access control method based on the synchronization phenomena of coupled oscillators [1] (SP-MAC) has been proposed [2]. In addition, a new throughput control method [3] has been proposed as a QoS control by developing SP-MAC, and has advantages that it can suppress the occurrence of data frame collisions and guarantee the throughput required by each terminal. In this paper, as an application example that takes these advantages of our proposed method, we propose the throughput control method that realizes the fairness among groups of terminals that use the different TCP versions.

II. Media access control method based on synchronization phenomena of coupled oscillators

SP-MAC [2] uses the synchronized phase with phase shifting equation (1) based on the *Kuramoto model* [1] to set the back-off time for CSMA/CA.

$$\frac{d\theta_i}{dt} = \omega_i + \frac{K}{N}\sum_{j=1}^{N}\sin(\omega_j - \omega_i) \quad (i = 1, 2, \cdots, N). \tag{1}$$

First, Access Points (APs) send the control parameters that are terminal ID i, the natural frequency ω_i, the coupling strength K, an initial phase $\theta_i(0)$, control interval Δt and the number of terminals N for all terminals by using a beacon signal. When receiving the beacon signal, each wireless terminal immediately begins calculation of the phase $\theta_i(t)$ for $\forall i$ using the control parameters. The back-off time for sending the data frame is as follows:

$$\text{Backoff}_i(t) = Amp_i \times ((|\cos\theta_i(t)| \times \alpha) \bmod N) \times \text{ST}, \tag{2}$$

where ST and α ($\alpha = 100$ [2]) are the Slot Time (ST) interval specified in IEEE 802.11 and a coefficient for obtaining the normalized phase, respectively. In this paper, Amp_i is set according to [3] and ST is 9 μsec. If the wireless terminal detects data frame collisions, it calculates the new back-off time by (2) using the phase when a collision is detected.

Throughput guarantee control [3] has been proposed based on SP-MAC. Priority terminals can transfer data more preferentially than non-priority terminals by setting the amplitude Amp_i in (2) to a smaller value. The proposed back-off time can be applied to the guarantee of the target throughput for the priority terminal.

III. Proposed throughput control method

In this section, we explain the throughput control method that a group of terminals using a specific TCP version can send data frame preferentially when the different TCP versions coexist in the network.

Our proposed method is performed by dividing the range of the cosine wave used for calculation of the backoff time. Specifically, the priority and the non-priority terminals use a range in which the value of the cosine wave is small and large, respectively. Thus, the priority terminal can always acquire the more transmission right because of getting the smaller backoff-time. Our proposed method by extending (2) is as follows:

$$\text{Backoff}_i(t) = (Amp_i \times ((|\cos\theta_i(t)| \times \alpha) \bmod N) + AC) \times \text{ST} \tag{3}$$

Let us explain our proposed method by Fig.1 that is a example of back-off time image: priority terminal A and non-priority terminal B use $AC = 0$ and $AC = 1$ in the back-off time calculation (3), respectively. Since the back-off time of terminal A is smaller than one of terminal B due to the difference of AC, A can transmit the data frame more preferentially than B. Currently, most terminals use the loss-based CUBIC-TCP used in Linux OS and the delay-based Compound TCP used in Microsoft Windows OS as a TCP protocol in the current wireless LAN environment. Let us focus on these two TCP versions and consider a throughput control method that makes the total throughput of terminals using CUBIC-TCP equal to the total throughput of terminals

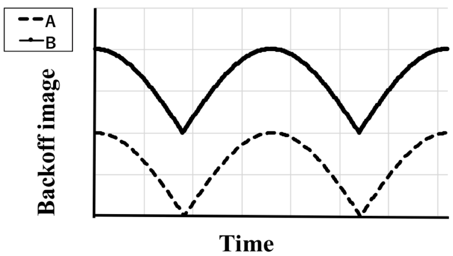

Fig. 1. A example of back-off time image for our proposed method.

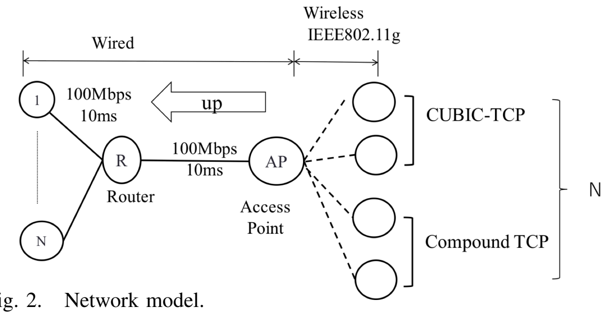

Fig. 2. Network model.

using Compound TCP. We define AC used in (3) as

$$AC = x \times {N_r}^y,$$

$$x \simeq 0.0086 \times N^{2.3713}, \;\; y \simeq 0.6681 \times \log N - 3.3150, \quad (4)$$

where N is the total number of terminals and N_r is the ratio of the number of terminals that use Compound TCP to the total number of terminals. This equation and its coefficients are obtained from preliminary experiments, and details on the derivation procedure are not described in this paper. The total transmission opportunities of CUBIC-TCP terminal group is equal to that of the Compound TCP terminal group by setting the obtained AC to CUBIC-TCP terminal group, and the fairness between terminal groups using the different TCP versions can realize. Moreover, it is expected that the total throughput is maintained since data frame collision can be avoided by the synchronization effect of SP-MAC.

IV. Simulation evaluations

In this section, we evaluate our proposed method by the ns2 network simulator. Figure 2 shows the network model which uses IEEE 802.11g (PHY) for the WLAN environment. In our simulation, we assume that none of terminals move. Wireless terminals are senders and send the TCP (CUBIC-TCP and Compound TCP) flow data using FTP among 60 seconds. Note that each wireless terminal generates only one flow. Parameters except for AC used in our proposed method are as follows: the initial phase $\theta_i(0)$ and the initial natural frequency $\omega_i(0)$ are the random values in the ranges $(0, 1.0)$ and $[0, 2.0]$, respectively. The coupling strength K is set to 5.0 and the total number of terminals is 40. Each evaluation result indicates the mean value obtained from 10 trials.

Figure 3 shows the result for the normal SP-MAC without priority control. The vertical axis and the horizontal axis show the total throughput and the terminal ratio N_r that is the ratio of the number of Compound TCP terminals to the total number of terminals, respectively. We can see from this figure that the total throughput of terminal group using Compound TCP increases as the ratio of the number of Compound TCP terminals increases. Especially, in case that the number of Compound TCP terminals is the same as that of CUBIC-TCP terminals (that is, the terminal ratio is 20/40), the throughput of Compound TCP is slightly less than that of CUBIC-TCP. This unfairness problem of throughput in the environment where the CUBIC-TCP and Compound TCP coexist has been reported in [4].

On the other hand, Fig. 4 shows the result that applied throughput control of (4). This figure suggests that terminals using CUBIC-TCP acquire the total throughput equal to that of Compound TCP regardless the terminal ratio. This is because AC is adjusted according to the situation: when the number of

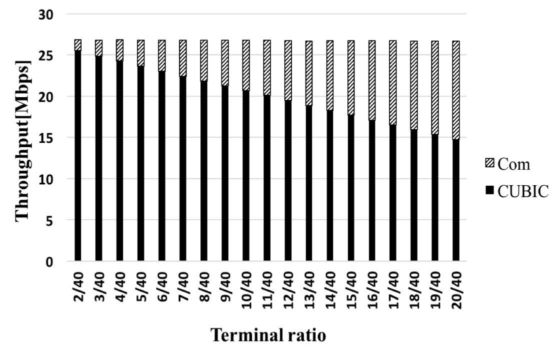

Fig. 3. Terminal ratio v.s. total throughput for normal SP-MAC.

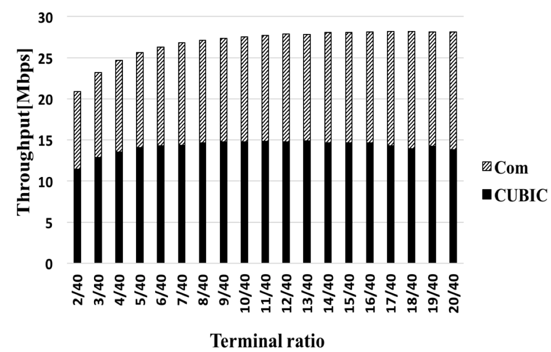

Fig. 4. Terminal ratio v.s. total throughput for the proposed method.

Compound TCP terminals is smallCompound TCP terminals have higher priority of the transmission opportunity than CUBIC-TCP terminals. When the terminal ratio is 20/40, the number of the transmission opportunity of TCP versions are almost equal, that means the unfairness problem is solved.

V. SUMMARY

In this paper, we proposed a new throughput control method that realizes the fairness among groups of terminals that use the different TCP versions, CUBIC-TCP and Compound TCP. The findings obtained in this paper suggest that similar priority control is possible even in other TCP versions because the acquired throughput can be freely changed by properly and adaptively adjusting the parameter of the proposed method.

REFERENCES [1] Y. Kuramoto, "Chemical Oscillations, Waves, and Turbulence, Springer", 1984. [2] H. Obata et al., "SP-MAC: A Media Access Control Method Based on the Synchronization Phenomena of Coupled Oscillators over WLAN," IEICE Transactions on Information and Systems, E98-D, 12, pp.2060-2070, 2015. [3] Y.Yamamoto et al., "Control Method to Guarantee Throughput based on Media Access Control Method SP-MAC over WLAN," Proc. 13th IEEE Consumer Communications and Networking Conference (CCNC2016), pp.657–662, 2016. [4] H. Itsumi et al., "Improving Fairness between CUBIC and Compound TCP ,"IEICE Tech. Rep, NS2010-160, 2011.