2017 International Symposium on Nonlinear Theory and Its Applications,
NOLTA2017, Cancun, Mexico, December 4-7, 2017

An Adaptive Throughput Guarantee Method based on SP-MAC for WLAN

Hiroyasu Obata[†], Chisa Takano[†], Yuuki Yamamoto[†]

[†]Graduate School of Information Sciences, Hiroshima City University,
Hiroshima-shi, Hiroshima 731-3194, Japan

Abstract—Along with the spread of mobile terminals, applications such as streaming services that require a lot of stable throughput are being widely used on wireless LAN. In order to respond to such a request, we have proposed the throughput guarantee control method based on the Synchronized Phase Media Access Control (SP-MAC). In this paper, we propose an adaptive control method based on the SP-MAC which guarantees the throughput of transmitting terminals for the environment where the number of terminals and requested throughput dynamically change.

1. A Throughput Guarantee Control Method

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

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

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:

$$\mathrm{Backoff}_i(t) = A_i\left((|\cos\theta_i(t)| \times \alpha) \bmod N\right) \times \mathrm{ST}, \quad (2)$$

where ST and α ($\alpha = 100$ [1]) are the Slot Time (ST) interval specified in IEEE 802.11 and a coefficient for obtaining the normalized phase, respectively. If the wireless terminal detects data frame collisions, it calculates the new back-off time using Eq.(2) and the phase when a collision is detected again. 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 A_i in Eq.(2) to a smaller value. The proposed back-off time can be applied to the guarantee of the target throughput for the priority terminal. If the number of all terminals N and the target throughput *Thr* are specified, we can calculate the amplitude A_i satisfying the target throughput of the priority terminals from Eq.(3) [3] . Note that the value of γ varies according to the kind of the transport protocol (UDP, TCP), and $\gamma = -10.0/\log(41.0N)$ especially when it is UDP.

$$A_i = \left(\frac{Thr \cdot N^{0.8}}{16.0}\right)^{\gamma} \quad (3)$$

In this study, we refer to Eq.(3) as the *QoS parameter control equation* (QPCE).

By using the synchronization phenomenon of oscillators by the *Kuramoto model*, the proposal can avoid collision of packets which occurs in CSMA/CA. In addition, it is a throughput control method that can obtain the required throughput by appropriately selecting the amplitude A_i in QPCE.

2. An Adaptive Throughput Guarantee Control Method

As described in Sec.1, the amplitude A_i is obtained by the number of priority terminals and the target throughput and the kind of transport protocols. However, there are cases where the target throughput does not be completely achieved even if the A_i derived by Eq.(3) is used because of the other factors of the network. In this section, we describe the proposed adaptive throughput control method in which the value of A_i varies depending on a change of the communication environment.

For the proposed method, the amplitude A_i for priority terminals is basically decided by Eq.(3). The difference from the QPCE is that *Thr* in Eq.(3) is not the target throughput of priority terminals but the value calculated according the actual acquisition throughput. A concrete algorithm of the proposed adaptive throughput control is shown in **Algorithm 1**.

Thr is the target throughput of priority terminals and *Per_Comp* is the parameter to close the gap between *Thr* and the actual acquisition throughput (the initial value of *Per_Comp* is 1.00). The actual acquisition throughput is sequentially calculated by using both the long-term average *Long_Thr* and the short-time average *Short_Thr* of the observed throughput

Algorithm 1 Algorithm of Proposal

```
if $Thr \geq Long\_Thr$ then
    if $Thr \geq Short\_Thr$ then
        $Per\_Comp = Per\_Comp + Pit$
    end if
else
    if $Thr \quad Short\_Thr$ then
        $Per\_Comp = Per\_Comp - Pit$
    end if
end if
$Thr_{Tem} = Thr \times Per\_Comp + (Thr - Long\_Thr)$
```

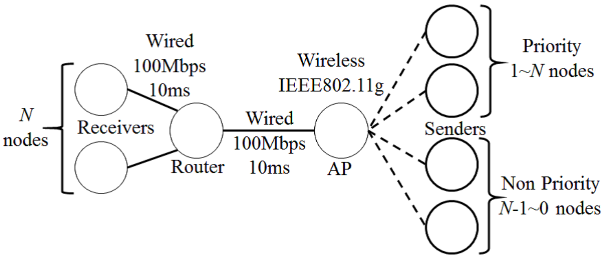

Figure 1: Network model

and we refer to the actual acquisition throughput as Thr_{Tem}. Note that the long-term and short-term for calculations of the throughput average are the elapsed time from a start of the communication for each terminal and the wireless LAN beacon signal reception interval (0.1 second), respectively. The change width of the parameter Per_Comp is Pit. The interval of calculation of Thr_{Tem} is equal to the wireless LAN beacon signal reception interval. In the proposed adaptive throughput control method, using A_i obtained by substituting the Thr_{Tem} for the Thr in Eq.(3), priority terminals can achieve the throughput closer to the target throughput.

3. Evaluations

In this section, we evaluate the performance of the proposed adaptive throughput control by using the network simulator ns2 [4]. Figure 1 shows the network model in which data flows from the wireless environment to the wired one, and the wireless LAN standard is IEEE802.11g (54 Mbps). We use UDP (the segment size of the data is $1,000$ Bytes) as the transport protocol and generate traffic with the constant bitrate which is 30 Mbps for 60 seconds. For the parameters of SP-MAC, we assume that the coupling strength $K = 5.0$ and the control interval $\Delta t = 10$ ms. The initial phase $\theta_i(0)$ and natural frequencies ω_i are defined by uniform random numbers in the range of $(0, 1)$ and $[0, 2]$, respectively. The number of all terminals in communication and the coordinates of terminals are not changed during the experiment, and for the number of all terminals N, the number of the priority terminals is between 1 and N. Priority terminals use the shown in Sec. 2 The result is the average value for ten trials.

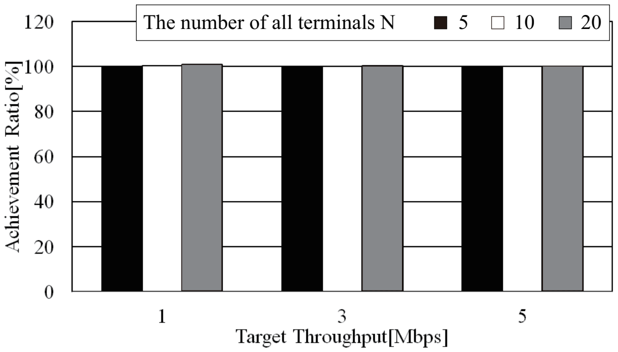

Figure 2: Throughput achievement ratio for the target throughput of priority terminals (the number of priority terminals is 5).

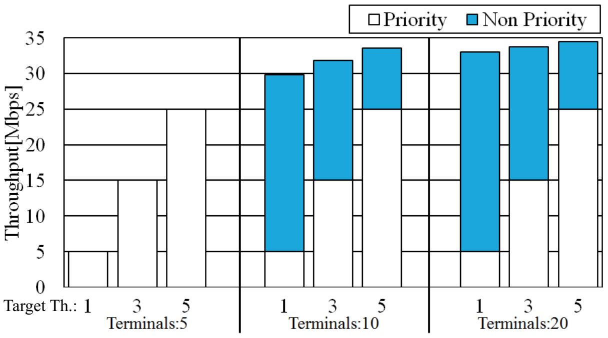

Figure 3: Total throughput for target throughput and the number of all terminals (the number of priority terminals is 5)

Figure 2 shows the throughput achievement ratio for the priority terminals which number is 5. The throughput achievement ratio is defined by the ratio of the actual acquisition throughput for the target throughput of priority terminals. We can see from this figure that the achievement ratio is close to 100% regardless of the number of all terminals and the target throughput of priority terminals.

Next, we evaluate the total throughput of all terminals for the target throughput and the number of terminals, and the result is shown in Fig. 3. While the theoretical value of the total throughput of terminals in this environment is about 30 Mbps, this result shows that the proposal can control the throughput of priority terminals without depriving the throughput of the non-priority terminal regardless of the number of all terminals and the target throughput of priority terminals.

4. Conclusions

In this paper, we proposed an adaptive control method which guarantees the target throughput of priority terminals. The proposal is based on the SP-MAC which can avoid collision of packets which occurs in CSMA/CA by using the synchronization phenomenon of oscillators by the *Kuramoto model*, and realizes high throughput guarantee by adjusting the parameters of the proposal according to the network environment. We confirmed that evaluation results show the achievement ratio is close to 100% regardless of the number of all terminals and the target throughput of priority terminals.

Acknowledgments

This work was partly supported by JSPS KAKENHI Grant Numbers JP15K00431, JP15H02688, and Hiroshima City University Grant for Special Academic Research.

References

[1] H. Obata, R. Hamamoto, C. Takano, and K. Ishida, "SP-MAC: A media access control method based on the synchronization phenomena of coupled oscillators over WLAN," *IEICE Trans. Inf. & Syst.*, E98-D, 12, pp.2060–2070, 2015.

[2] Y. Kuramoto, *Chemical oscillations, waves, and turbulence*, Springer, 1984.

[3] Y. Yamamoto, R. Hamamoto, H. Obata, C. Takano, and K. Ishida, "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] Network Simulator - ns (version 2), available at `http://nsnam.sourceforge.net/wiki/index.php/Main_Page`, 2017.