Novel throughput evaluation method of radio LAN systems based on occupied duration for individual UDP transmission

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Abstract: The instantaneous throughput is evaluated based on the communication traffic volume per fixed unit time. Although the conventional method can roughly evaluate it within unit time, it is difficult to evaluate the communication situation of each packet in detail. Therefore, the authors propose a method of deriving the throughput based on the occupied duration for one packet transmission. In the proposed method, not only throughput per packet but also throughput of other signals such as beacon signals and variation of Back-off Time can be evaluated. In this paper, we define the occupation duration for deriving throughput during individual UDP transmission, and show analysis examples compared with the conventional method.

Keywords: radio LAN, occupied duration, instantaneous throughput, UDP, packet capture analysis

Classification: Network

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1 Introduction

In recent years, demands for Radio LAN communications have increased, and communication quality is frequently evaluated. The instantaneous throughput, evaluating the throughput per unit time, is especially used to observe the communication situation and used for communication quality evaluation. However, there are cases where the throughput is not accurately evaluated by the conventional method. Therefore, the authors propose a throughput evaluation method based on an occupied duration for one packet transmission. In this paper as the simplest case, we define in various cases for individual UDP transmission in 802.11g mode, and examples applied to actual captured data are indicated.

2 Definition of throughput based on occupied duration in individual UDP transmission

The proposed throughput based on the occupied duration in individual UDP transmission is defined in detail in various cases.

2.1 Conventional instantaneous throughput

Fig. 1(a) shows the definition of the conventional instantaneous throughput. It is represented by how much data was captured per unit time. Since the throughput is based on the fixed duration, we call it Fixed Duration (FD) throughput in this paper. For example, if \( N \) packets of 1500 bytes exist in unit time \( t \) seconds, FD throughput is obtained by the following equation [1]:

\[
FD \text{ throughput (Mbit/s)} = \frac{1500 \times 8 \times N \times 10^{-6}}{t}.
\]  

Packet capture devices print a timestamp at the time of receiving the first or last bit. Therefore, in many analysis software, FD throughput is derived by the all information amount in which the timestamp exists in the unit time. So that means the shorter the unit time, the greater the influence of one packet. The number of packets included within a short unit time is determined for each transmission rate, and since the throughput is evaluated based on the number, the quantized result appears.

2.2 Definition of occupied duration for the proposed throughput

The authors propose a throughput evaluation method using Occupied Duration which is a duration when one packet occupies the communication path. Fig. 1(b) shows the its definition. 802.11 Data Frame (Data Frame) is one Radio LAN packet. 802.11 ACK Frame (ACK Frame) is the acknowledgement packet of the physical layer transmitted by a network interface card of a receiving device. Occupied Duration is defined by the sum of DIFS, Back-off Time with dynamic values by CSMA/CA, SIFS and Frame Length shown in the Fig. 1(b). Briefly, it is
from the last bit reception time of the previous ACK Frame to that time of ACK Frame of the target packet. Data Frame contains two physical layer headers of 802.11 and Logical Link Control headers [1], but they are excluded from Data Frame and let it be Payload. Since the proposed throughput is based on Occupied Duration for one packet transmission, it is called Occupied Duration (OD) throughput distinguished from FD throughput. OD throughput is obtained by the following equation:

\[
OD \text{ throughput (Mbit/s)} = \frac{\text{Payload}}{\text{Occupied Duration}}.
\]  

(2)

Since OD throughput is derived based on Occupied Duration, it can be analyzed that the difference in the throughput at the same transmission rate is the difference in Back-off Time changing dynamically.
2.3 Definition of occupied duration when other signals exist

Unit time used in the conventional method includes signal transmission durations other than Data Frame such as beacon signals. Therefore, FD throughput sometimes cannot indicate only Data Frame. OD throughput is derived more accurately than FD throughput by considering the other signal transmission durations. Fig. 1(c) shows the definition of Occupied Duration when other signals exist. Signal is other signal such as beacon, and it usually does not have ACK Frame. In this case, the transmission control start time cannot be specified. Therefore, it is necessary to define the start time of the Occupied Duration after Signal. Back-off Time by CSMA/CA differs each packet and it is difficult to measure its value, for that reason, it is employed its average value in this case. Hereat, there may be Idle Time that is not communicated between the capture completion time of Signal and the start time of Occupied Duration. In addition, as shown in Fig. 1(d), when the start time of Occupied Duration is before capture completion time of Signal, the start time is set as capture completion time of Signal. Furthermore, Signal’s OD throughput which was impossible by the conventional method can be derived. Signal’s Occupied Duration is from the capture completion time of the preceding ACK Frame to that of the Signal, and the information volume of the Signal is all bits.

2.4 Definition of occupied duration at retransmission occurrence

During communications, ACK Frame may not be returned and physical layer retransmissions may occur. Fig. 1(e) shows Occupied Duration in the case that physical layer retransmissions occur twice as an example. In this case, the Occupied Duration is the time interval from the preceding ACK Frame to the ACK Frame of the retransmission packet normally transmitted, and the information volume is one packet. If there are many physical layer retransmissions for a specific packet, the Occupied Duration increases and OD throughput decreases.

With the above detailed definition, comparisons of FD and OD throughput is summarized in Fig. 1(f), and OD throughput shows that communication situations which can not be analyzed by FD throughput can be visualized.

3 Application examples in individual UDP transmission

3.1 Experiment system

Fig. 2 shows an experiment system. UDP packets are transmitted from the Tx Personal Computer (PC) on which Ubuntu 14.04 [2] is installed to Rx Smartphone via the access point. iPerf 3 for iPhone [3] is installed in the Rx Smartphone. This can set a transmission data amount of UDP packets per unit time at transmitting devices, preset UDP transmission rate is set by 30 Mbit/s in this experiment. We employed iPhone 6 as the Rx Smartphone, the iOS was version 9.3.4, iPerf 3 for iPhone was version 3.0.9. In the wireless section, the Capture PC connected with AirPcap Nx [4] to capture the packets. Wireshark [5] is used for packet analysis. Occupied Duration and the throughputs were obtained from this capture data. Experiments were conducted at a laboratory of Toyo University.
3.2 Comparison between proposed and conventional method

Figs. 3(a) and (b) are examples in the other signals and the retransmission existences respectively. Both show the results of the proposed, conventional method unit time 10 msec and 1 msec in order from the top. The horizontal axis is time and the vertical axis is the FD or OD throughput. Black lines are the throughput of Data Frame, and reds are that of Signals. First, we discuss Fig. 3(a) in the other signals existence. Since OD throughput in the proposed method at the top is derived based on Occupied Duration per packet, the area of the rectangle indicates the communication traffic volume and the width indicates Occupied Duration. In other words, OD throughput becomes higher as Occupied Duration is shorter at the same transmission rate and Payload. In addition, if the transmission rate is the same, the Back-off Time dynamically changing can be evaluated by the difference in OD throughput. Furthermore, the Signal is visualized and Idle Time is confirmed between the Signal and the Data Frame. The middle at unit time 10 msec shows the change of the FD throughput is roughly understood, but compared to the proposed method, it is not shown in packet unit. The bottom at unit time 1 msec shows the FD throughput is shown only four values of 0, 12, 24 and 36 Mbit/s. Considering one packet transmission duration based on the 802.11g mode transmission rate at 54 Mbit/s, three packets are transmitted at most in 1 msec as described in section 2.1. Therefore, it is evaluated with four values. Next, we discuss Fig. 3(b) in the retransmission existence. As the result of the packet capture analysis, there was some influence on the transmission path in this section, and the transmission rate was 36 Mbit/s. The top in proposed method, the retransmission occurred once in the duration where the OD throughput was around 10 Mbit/s, and occurred twice around 5 Mbit/s. In the middle and bottom, FD throughput is declining, but it is difficult to analyze the communication situation such as the number of retransmissions. Particularly, in the vicinity of 31.892 and 31.895 seconds at unit time 1 msec, the FD throughput is 0 because one packet was transmitted across the unit time, since the OD throughput is obtained with the Occupied Duration, it is possible to accurately evaluate the communication situation such that retransmission occurs and it takes time to transmit one packet. In this way, OD throughput can be accurately analyzed even when other signals or retransmission occurs, and Back-off Time and communication situations can be estimated.
4 Conclusion

We proposed OD throughput based on Occupied Duration for one packet transmission in individual UDP Radio LAN transmission. Detailed analysis of other signals and retransmission existence that was difficult with the conventional method was facilitated by the proposed method. As further study, we will extend to 802.11n or ac that needs to consider frame aggregation etc., TCP and competitive transmissions.

Fig. 3. Application and analysis example.