A proposal on dynamic bandwidth allocation for one-dimensionally moving mobile entities

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***Abstract*— Recent years, with the introduction of 5th generation mobile communication networks, bursty traffic and upstream traffic characteristics have changed significantly. The deployment of small cells and passive optical networks for high-speed broadband services are considered. Passive optical network technology can apply to multiplex many small cells. The authors have proposed BCOM as a bandwidth control scheme for uplink traffic and have carried out bandwidth allocation, assuming the case where mobile vehicles pass according to schedule. In this paper, BCOMs evaluate assuming that mobile vehicles do not arrive on schedule.**

Keywords— optical access, Passive Optical Network, Bandwidth control, 5th Generation Mobile Communication System, broadband mobile infrastructure

I. INTRODUCTION

5G is expected to be implemented in various industries and fields as a comprehensive social infrastructure in the IoT era. 5G is mainly based on optical communications using small cells and optical fibers to realize three critical requirements of 5G: enhance Mobile Broadband (eMBB), massive-Machine Type Communication (mMTC), and Ultra Reliable Low Latency Communication (URLLC)[1].

As a method of multiplexing a large number of small cells, accommodation by Passive Optical Network (PON) has been proposed from the viewpoint of operational cost and flexibility[2]. Therefore, authors built an evaluation platform [3] with functions for 5G traffic simulation, PON system simulation, and server simulation, and add a traffic control algorithm to devise bandwidth control based on online monitoring (BCOM) [4].

Therefore, the authors propose BCOM+[5], an extension of BCOM that can cope with the rapid increase in traffic. The purpose of this study is to evaluate the practicality of BCOM+.

II. OVERVIEW OF BCOM AND RELATED WORKS

This section provides an overview of the BCOM developed by the authors and the results of the BCOM evaluation.

A. Research on bandwidth allocation schemes

Traffic bandwidth allocation schemes have studied. Bandwidth control schemes using mobile edge computing (MEC) [6] have studied in [7]. Bandwidth allocation using MEC based on a specified traffic model. However, with the evolution from 4G to 5G, the traffic on the Internet has changed to have irregular burstiness, making it unsuitable for use on the Internet. Various studies have been conducted on bandwidth allocation using PON, such as [8][9].

Figure 2.1 shows how traffic monitored in a PON. In a PON, and the OLT sends a transmission permission message, the ONU that receives the message sends the measured incoming traffic results to the OLT, which allocates bandwidth to each ONU based on the measurement results. Three exchanges make between the OLT and the ONU before the bandwidth allocation is made.

However, if many small cells multiplexed, a large amount of bandwidth may be used just to exchange between the OLT and ONU. Therefore, the authors devise a method to use the network more efficiently to spread 5G.

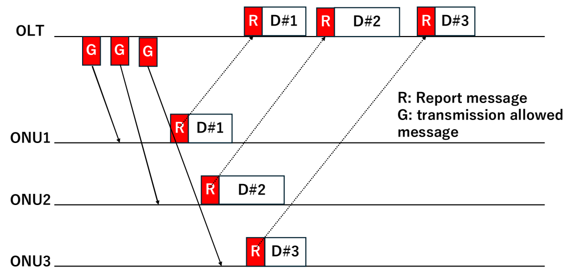

Fig.2.1 PON traffic monitoring

B. Overview of BCOM

BCOM is one of the bandwidth control methods for upstream traffic. The 5G traffic flowing into the ONU is first monitored and measured, and the OLT predicts the subsequent incoming traffic by extrapolating the bandwidth after one second to the regression line obtained by linear regression analysis. After the bandwidth allocation decision, the ONU Management and Control Interface (OMCI) is used to inform each ONU of its bandwidth allocation [10]. The BCOM allows bandwidth to allocated dynamically and enables efficient use of the network. The calculation of the allocated bandwidth uses the R language, which is suitable for statistical processing.

Figure 2.2 shows a detailed implementation of the BCOM, which consists of two types of ports: traffic monitoring ports and bandwidth allocation ports. Traffic is monitored in YAF [11], and the monitored results stored in a database in Silk, for communication between YAF and Silk, IP Flow Information Export (IPFIX) [12][13], an extension to NetFlow v9, is used. It measured from database information stored in Silk on the server. It is the client that allocates the bandwidth.

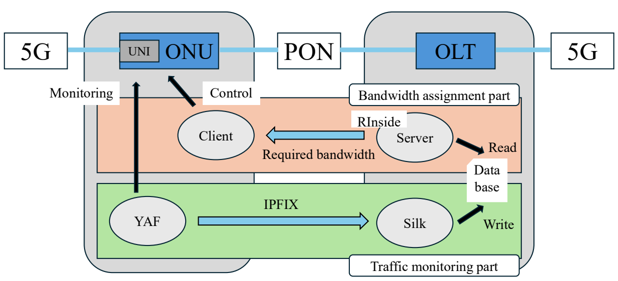

Fig.2.2 Functional blocks of BCOM

This section describes the linear regression model used to predict the bandwidth. If traffic X_i measured i, the allocated bandwidth Y_1 is as in equation (1)

$$Y_i = \beta_0 + \beta_1 X_i + \varepsilon_i \quad (i = 1,2,\cdots,n) \qquad (1)$$

β and β_1 are estimated as continuous-time information when the error coefficients ε_i minimized in Equations 2 and 3.

$$\widehat{\beta_1} = \frac{\sum_i (X_i - \bar{X})(Y_i - \bar{Y})}{\sum_i (X_i - \bar{X})^2} \qquad (2)$$

$$\widehat{\beta_0} = \bar{Y} - \widehat{\beta_1}\bar{X} \qquad (3)$$

The characteristics of the predicted bandwidth for bandwidth allocation by BCOM vary significantly with the reference time. Figure 2.3 shows the differences in BCOM traffic forecasts according to reference time. Shorter reference times result in more significant fluctuations in predicted traffic. When the reference time lengthened, the predicted traffic fluctuation becomes slower, but the OLT cannot cope with the sudden increase in traffic, and the response performance degrades because the bandwidth cannot increase instantaneously. The degradation of response performance increases the risk of communication failures.

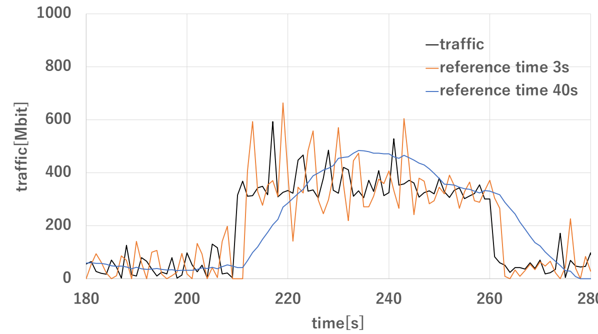

Fig. 2.3 Example of actual incoming traffic of ONU and predicted traffic with reference time

C. Related works

To solve this problem, authors devise BCOM+, which is an advanced version of BCOM. Figure 2.4 shows BCOM+ improves the response performance of BCOM by adding α% of the predicted traffic to the predicted traffic when mobile vehicles are passing. when no moving objects are passing through, β% of the predicted traffic subtracted from the predicted traffic. β is calculated from the following equation. BCOM+ will consider train operations.

$$\beta = \frac{\alpha}{Number\ of\ ONUs\ connected\ to\ PON - 1}$$

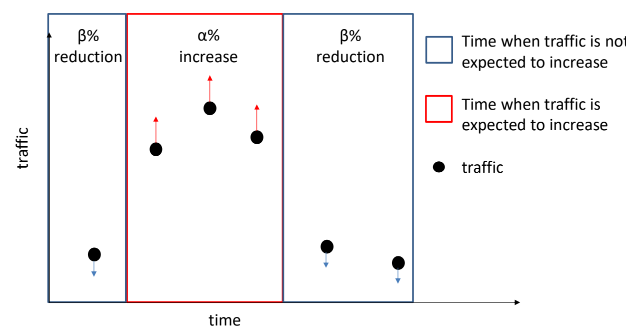

Fig.2.4 Correction by BCOM+

Figure 2.5 shows the assumed network model. Eight ONUs connect to one PON interface. The parameters are the speed of the train (36 km) and the distance between ONUs (500 m), considering small cells. For the train, a Poisson distribution is used as the traffic generation model, producing an average traffic rate of 300 Mbps. The train is emitting traffic only to the ONUs it is passing. For this verification, authors assume a neighborhood that constantly generates traffic. An exponential distribution is used as the traffic generation model for the neighbors, generating an average traffic rate of 50 Mbps[14]. Traffic send to all ONUs in the neighborhoods, the capacity of the PON interface is 1 Gbps, and the net utilization is 70%. No oncoming traffic assumed in this verification.

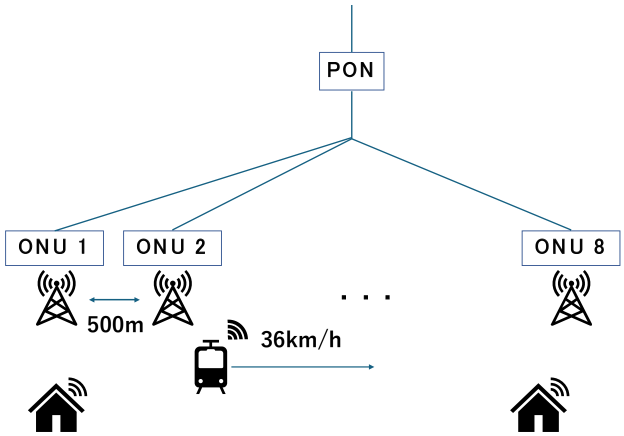

Fig2.5 Assumed network model

The network model in Figure 2.5 has been used to evaluate BCOM+. Figure 2.6 shows the behavior of BCOM and BCOM+ with 30% over-allocation, where the reference time set to 40-seconds. In BCOM, the predicted traffic is sufficient at 225-seconds, 15-seconds after the time of the traffic spike. In BCOM, the predicted traffic becomes sufficient at 225-seconds, 15-seconds after the traffic spike. On the other hand, in the case of BCOM+ with 30% over-allocation, the predicted traffic becomes sufficient at 219-seconds, 9-seconds after the traffic spike, indicating that the response performance is 6-seconds better than that of BCOM.

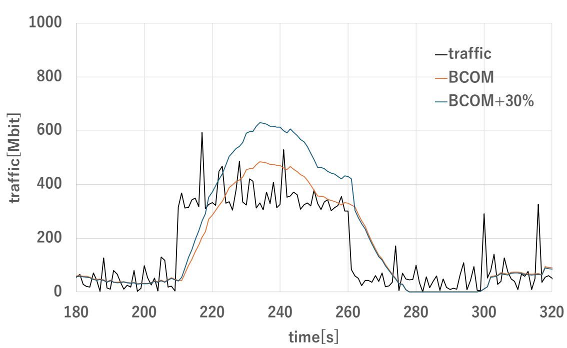

Fig.2.6 BCOM+ behavior

Next, to verify the performance of BCOM+, authors compare the amount of over-bandwidth and under-bandwidth during the mobile transit time period. Figure 2.7 shows the safe and danger values for the period, time when a mobile passes through. The safe value is the sum of the over-bandwidth traffic when the mobile passes divided by the sum of the traffic measured at the ONU when the mobile passes. The danger value is the sum of the under-bandwidth traffic when the mobile unit passes divided by the sum of the traffic measured at the ONU when the mobile unit passes. From Figure 2.5, BCOM+ has a safe value about 2.5 times higher and a danger value about 0.4 times lower than BCOM.

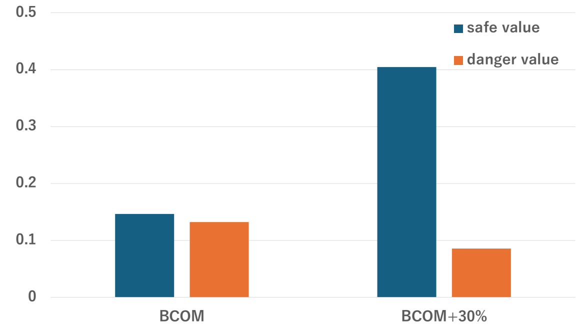

Fig.2.7 Safe and danger value

III. Ploposed Method for Delay

The authors have conducted their research assuming a Schedule model, in which mobile vehicles pass according to schedule. However, there may be cases where mobile aircraft delayed and do not pass according to schedule. This case evaluated in this section as a delayed tolerant model. It also assesses how the performance of BCOM+ changes as the speed of the mobile object has increased.

A. BCOM+ Issue and Solution

As described in Section 2, BCOM+ allocates an excessive amount of bandwidth at a given time and is considered for use with trains. A model with no train delays have used as the schedule model in this verification.

However, when adapted to trains, it is possible that there may be a delay of several tens of seconds in departures due to congestion or other reasons. The delayed tolerant model have used when trains are delayed.

Figure 3.1 shows the behavior of BCOM+ when a train delayed by 40-seconds. It can seen that when there is a delay in train departure, the current BCOM+ reduces the allocate bandwidth when the train is passing, which increases the risk of communication failure. Also, the response performance, which was the purpose of using BCOM+, cannot be expected to improve.

Figure 3.2 shows the safe and danger values of BCOM+ in normal behavior and when a train is delayed. It can see that the safe value of BCOM+ is significantly reduced by a factor of 0.25 and the danger value is increased compared to the normal behavior. The safety value is lower than the existing BCOM, so measures need to take in the event of a mobile delay.

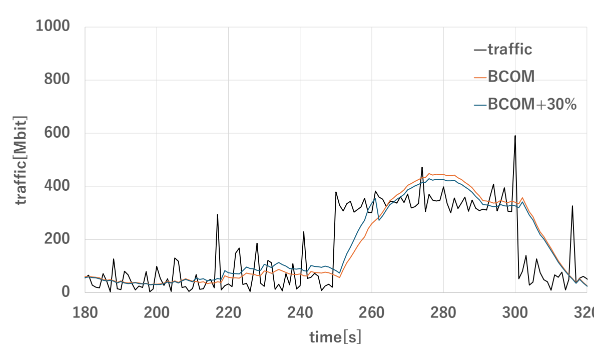

Fig 3.1 BCOM+ behavior when a train delayed by 40-seconds

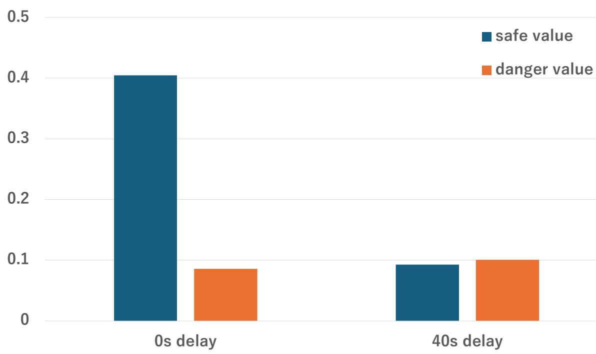

Fig 3.2 Safe and danger value of BCOM+30% when a train delayed by 40-seconds

This paper proposes to increase the bandwidth allocation range of BCOM+ as a response to mobile delays, as shown in Figure 3.3. Lengthening the BCOM+ over-allocation by 30-seconds increases the safe value and reduces the danger value during train delays. For this verification, authors do not consider train delays longer than 60-seconds because authors assume that delays longer than 60-seconds allow the system to be changed before the train departs.

Figure 3.4 shows the assumed network model. The network model is the same as in Figure 2.5, but in this verification, a delay is assumed for the delay tolerant mode, so the train is delayed. The speed of the train is assumed to remain constant despite the delay and no oncoming trains are assumed to pass.

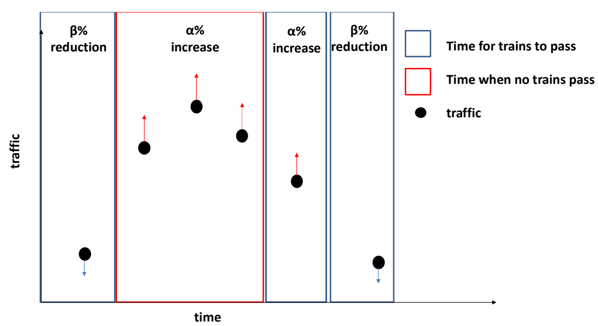

Fig.3.3 Proposed method of increasing over-allocation range

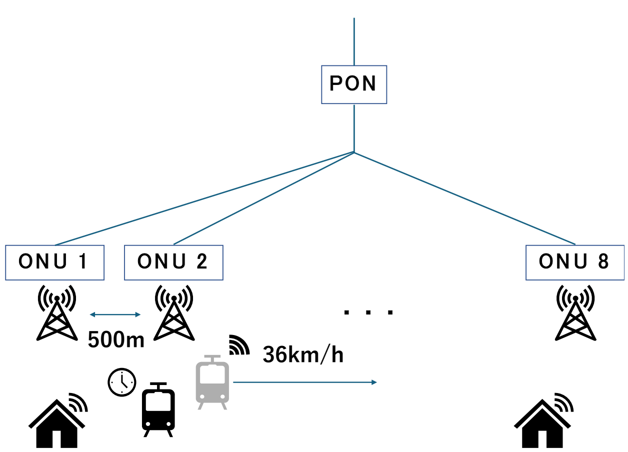

Fig3.4 delayed tolerant model

Figure 3.5 shows the behavior of BCOM+ when the 30-seconds over-allocation range increased. Compared to Figure 3.1, increasing the over-allocation range allocates more bandwidth when mobile traffic is passing through.

Figure 3.6 shows the safe and danger values for BCOM+ when the over-allocation range increased by 30-seconds. By increasing the over-allocated range, the safe value increased by a factor of 3. Compared to the case where the train do not delay, the decrease in safe value is 0.75 times more significant. The danger value was equivalent to the case where the train do not delay. These results indicate that increasing the over-allocation range can reduce performance degradation in the case of train delays.

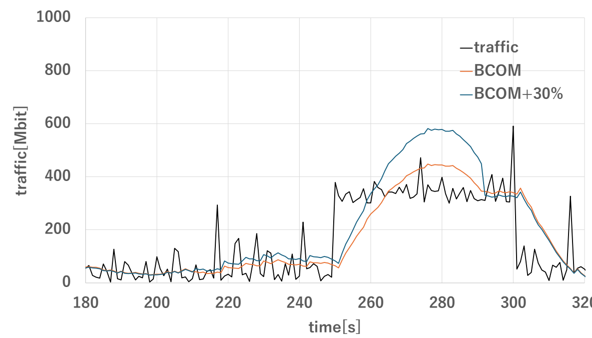

Fig 3.5 BCOM+ behavior when increasing the 40-seconds over-allocation range

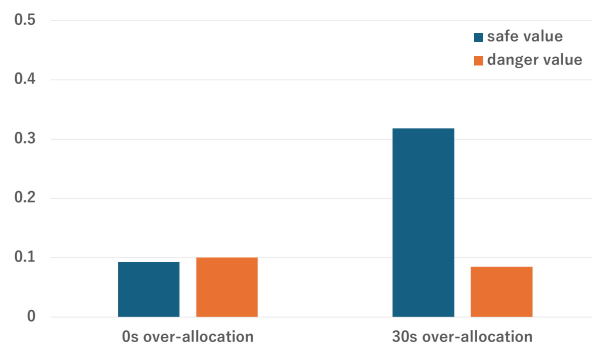

Fig 3.6 Safe and danger value of BCOM+30% when increasing the 40-seconds over-allocation range

B. BCOM+ behavior at a higher speed

In this verification, it found that increasing the over-allocation range reduces the performance degradation of BCOM+ when trains are late.

Other issues can consider for the practical use of BCOM+. Because train speeds vary from railroad to railroad, further verification conduct at 72 km/s. The appropriate reference time may change as the increased speed shortens the time that a train passes within a single ONU.

Figure 3.6 shows the behavior of the BCOM at a speed of 72 km/s with reference times. If the reference time is longer than required to pass through the ONU, the necessary bandwidth cannot allocate for the transit time.

Figure 3.7 shows the safe and unsafe values of BCOM when the reference time is at a speed of 72 km/s. At higher speeds, the safe value can be increased, and the danger value can be decreased by reducing the reference time.

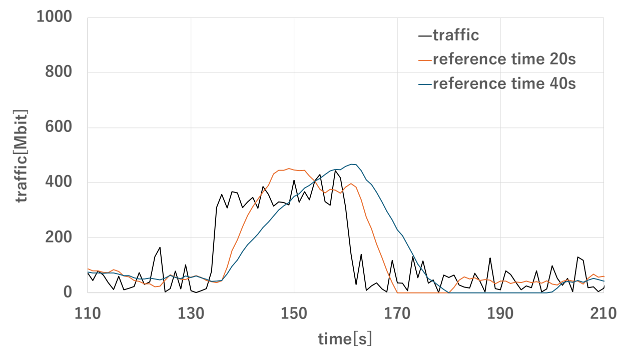

Fig. 3.6 BCOM behavior by reference time when train speed is 72 km/s

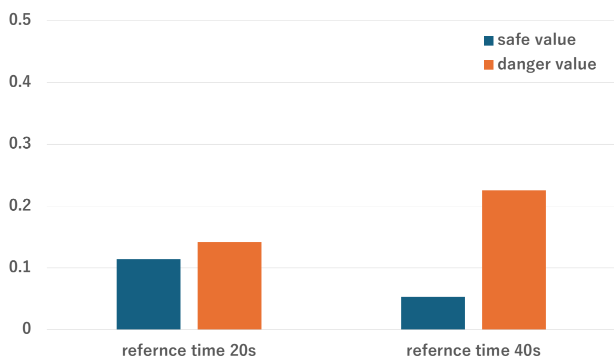

Fig. 3.7 Safe and danger values by reference time when train speed is 72 km/s

Figure 3.8 shows the behavior of BCOM+ when increasing the over-allocation range when the train is delayed by 40-seconds at a speed of 72 km/s. Even at higher speeds, increasing the over-allocation range reduces the degradation of response performance.

Figure 3.9 shows the safe and danger values of BCOM+ when the over-allocation range increase when the train delay for 40-seconds at a speed of 72 km/s. Increasing the over-allocation range increases the safe value by a factor of 2.5 and decreases the danger value.

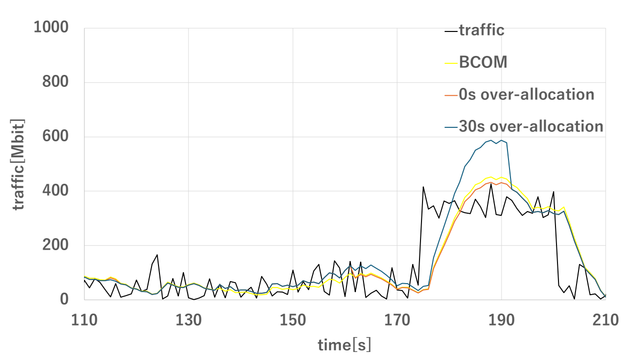

Fig.3.8 BCOM+ behavior when increasing the 40-seconds over-allocation range when train speed is 72 km/s

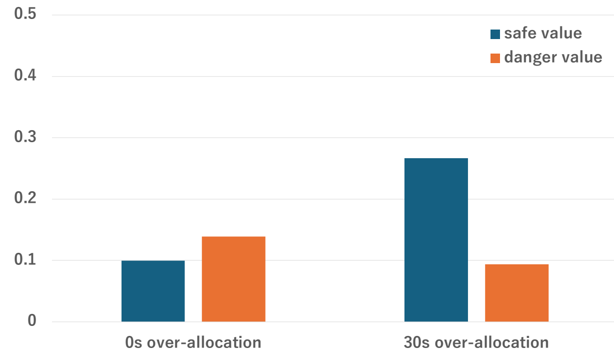

Fig 3.9 Safe and danger value of BCOM+30% when increasing the 40-seconds over-allocation range when train speed is 72 km/s

C. Consideration

The methods for increasing the over-allocation range have been evaluated in this chapter. As a summary, the safe and danger values of normal BCOM and BCOM+ are compared, as well as the safe and danger values when the over-allocation range is increased by 30-seconds.

Figure 3.10 shows the safe and danger values for BCOM and BCOM+, as well as the safe and danger values when the over-allocation range has increased by 30-seconds. Comparing BCOM+ and the increased over-allocation range, the danger values are almost identical.

However, the safe value of increasing the over-allocation range was approximately 0.75 times higher than for BCOM+. This is thought to be due to the delay not being fully covered. The safe value is higher if the delay of the mobile is smaller than the increase time of the over-allocation range. The safe value was higher than the BCOM for both BCOM+ and increased over-allocation range. This shows the effectiveness of the method of increasing the over-allocated range.

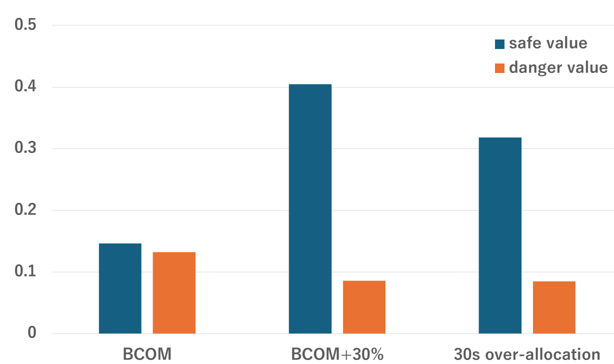

Fig.3.10 Safe and danger value of BCOM, BCOM+30%, and over-allocation

IV. Conclusions

Authors proposed BCOM+, a more advanced version of BCOM, which was proposed as a bandwidth allocation scheme to accommodate traffic in 5G and verified it under realistic practical conditions. This verification showed that the performance degradation of BCOM+ can be mitigated by increasing the excess allocation range. In the future, authors intend to incorporate the BCOM+ system into actual PONs for more accurate verification.

V. References

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