Evaluation of BCOM-based bandwidth allocation for predictable traffic

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SUMMARY The 5th-generation-mobile-communication-system (5G) is expected to operate high-capacity services such as 4K/8K video, VR, and AR. In line with this, user traffic flowing over the Internet will also increase significantly. Therefore, PONs that can accommodate many users with wide bandwidth are suitable for accommodating 5G traffic. We have been developing a scheme called BCOM, which accommodates 5G traffic from IoT devices via PON. In this paper, we evaluate BCOM+, an extension of BCOM to keep up with traffic growth to accommodate 5G mobile traffic.
keywords: *5G upstream traffic, PON, traffic prediction, bandwidth assignment*

1. Introduction

Internet traffic is increasing due to the emergence of 4K/8K video streaming, VR, and AR. The internet traffic flowing over 5G is said to increase 20 times compared to 4G. Especially for services that require real-time information such as VR, not only the downlink traffic but also the uplink traffic is expected to increase dramatically. For this reason, passive-optical-networks (PON), which can accommodate many users economically, are widely used on 5G [1].

Furthermore, since 5G traffic includes not only Internet traffic but also traffic with various requirements, such as low latency communication and massive machine-type communications, a control method for quality-of-experience (QoE) based on traffic monitoring and prediction is being considered [2].

Therefore, we have developed a BCOM focusing on bandwidth allocation, aiming at coordinated traffic control between 5G and PON. The basic principles of BCOM are described in ComEx [3]. In this paper, we provide a detailed evaluation of BCOM and propose an extension scheme for mobile entity accommodation.

2. Related works

In this section, we present our approach to bandwidth allocation and describe an overview of the BCOM we have developed.

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2.1 Approaches to bandwidth allocation

This section presents research and ideas on bandwidth allocation to accommodate 5G traffic.

The bandwidth allocation scheme using mobile-edge-computing (MEC) servers has been studied in [4], and the architecture of the bandwidth allocation scheme in PONs has been studied in [5]. These bandwidth allocation schemes can be classified into two categories: parametric and non-parametric approaches. Parametric approaches are methods that allocate bandwidth based on a specified traffic model, while non-parametric approaches are monitoring-based bandwidth allocation methods. These methods are described in [6].

The parametric approach is practical for traffic that occurs in a constant pattern, such as in factories but is not suitable for traffic that occurs irregularly, such as on the Internet. On the other hand, the non-parametric approach analyzes traffic in real-time and can handle various patterns of occurrence, but the processing time required for monitoring and computation is a bottleneck.

2.2 BCOM

To address both flexibility and response performance, we develop a non-parametric approach to bandwidth allocation, bandwidth-control-based-on-online-monitoring (BCOM) [3]. BCOM uses linear regression analysis for bandwidth allocation calculations. The calculation of allocated bandwidth uses the R language, which is suitable for statistical processing.

Figure 1 shows the network architecture when BCOM is applied to a PON: the amount of traffic flowing from the distributed-unit (DU) to the optical-network-unit (ONU) is monitored, and the bandwidth allocated to the ONU is determined at the optical-line-terminal (OLT). The bandwidth allocated is predicted by extrapolating the bandwidth one second later to the regression line obtained by linear regression analysis. After the bandwidth allocation is determined, the ONU-management-and-control-interface (OMCI), which is standardized in ITU-T, is used to notify the bandwidth allocation to each ONU [7].

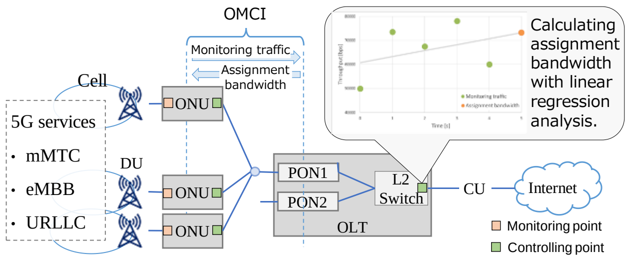

Fig. 1 BCOM architecture

The detailed implementation of BCOM is shown in Figure 2. It consists of two slices: a bandwidth allocation slice and a traffic monitoring slice. The traffic is monitored by the yet-another-flowmeter (YAF), and this information is stored in a database in Silk. IP-flow-information-export (IPFIX) [8], an extension of NetFlow v9, is used for communication between YAF and Silk. On the other hand, bandwidth estimation from the information in the database is done by the Server and bandwidth allocation is done by the Client.

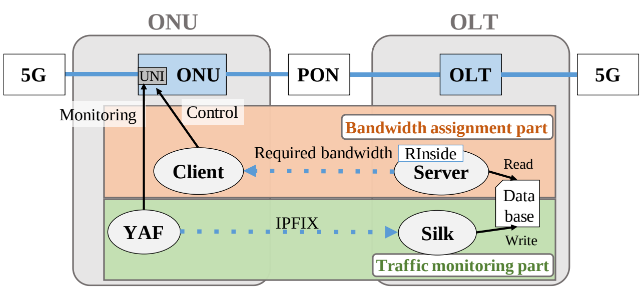

Fig.2 Functional blocks of BCOM

This section describes the linear regression model used to predict bandwidth. If traffic X_i is measured at time i, the allocated bandwidth Y_i is obtained as in Eq. 1.

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

In this case, β_0 and β_1 are estimated as continuous time information when the error factor ε_i is minimum in Eq. 2 and Eq. 3.

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

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

BCOM has as a parameter the reference time (the number of samples used in the regression analysis). When the reference time is small (i.e., the number of data used in the regression analysis is small), the predictions follow the fluctuations in traffic rapidly. On the other hand, when the reference time is large (more data is used in the regression analysis), the predictions can be moderately controlled.

Furthermore, the BCOM can be implemented in ONUs and OLTs in both PONs: wavelength-division-multiplexed (WDM) PON, which occupying bandwidth, and time-division-multiplexed (TDM) PON, which sharing bandwidth [1].

3. BCOM issues and the proposed method

This section describes the challenges of BCOM and proposes BCOM+, an extension of BCOM's functionality, as a solution.

3.1 BCOM issues and solutions

An example of burst-traffic accommodated by BCOM is shown in Figure 3. For the actual traffic shown by the black line, the predicted results when the reference time is 3 seconds are shown in red, and the results when the reference time is 20 seconds are shown in blue. The longer the reference time, the slower the predictions follow the rise of the traffic. Since the delay in the rise of the predictions leads to an increase in the frame loss rate, it is necessary to improve the tracking of the predictions.

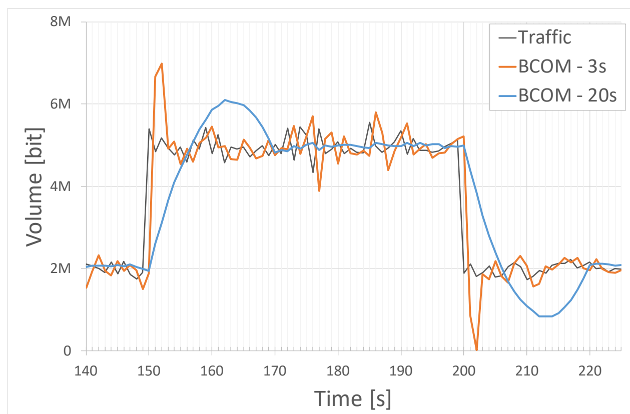

Fig. 3 An example of bandwidth assignment

To solve this problem, we assume a situation where the duration of burst-traffic is known and develop BCOM+ that increases the allocated bandwidth during times when traffic is increasing and decreases the bandwidth during other times.

3.2 Proposed method

BCOM+ operates based on the BCOM functionality. During the period when burst-traffic is generated, BCOM+ applies an incremental correction to the allocated bandwidth calculated by BCOM, and during other periods, BCOM+ provides a portion of its allocated bandwidth to other ONUs where burst-traffic is being observed. If the bandwidth of other ONUs on the PON is reduced by β[bit] to compensate for α[bit], the formula for the relationship between α and β is calculated as in Eq. 4.

$$\beta = \frac{\alpha}{\min(2, a\ number\ of\ onus)} \qquad (4)$$

Figure 4 shows an example of B COM+ operation when burst-traffic is observed at ONU3. This is expected to improve the tracking of predictions during periods of increased traffic.

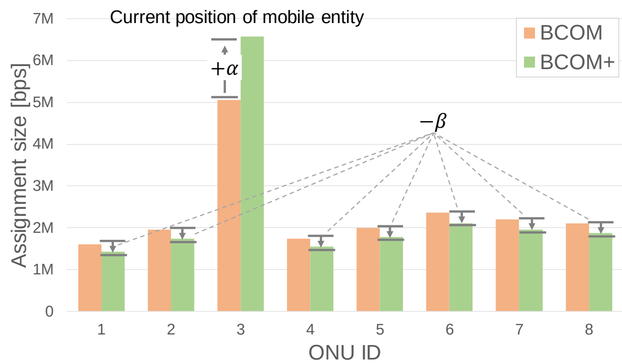

Fig. 4 An example of BCOM+ operation

4. Test modeling

To evaluate BCOM+, we use our simulator [3] to simulate a real environment. In this section, we describe the assumed logic model and the parameters and traffic model used in the evaluation.

4.1 Logical model

The test case assumed in this study is shown in Figure 5. A simple model is used to facilitate verification of BCOM+ characteristics in situations where traffic is generated in bursts; PON is applied to accommodate 5G, and the assumed user traffic is mobile traffic and neighboring traffic from fixed entities such as residences. The antenna installation spacing x [m], the number of ONUs n, and the speed of a mobile entity v [km/h] were variables.

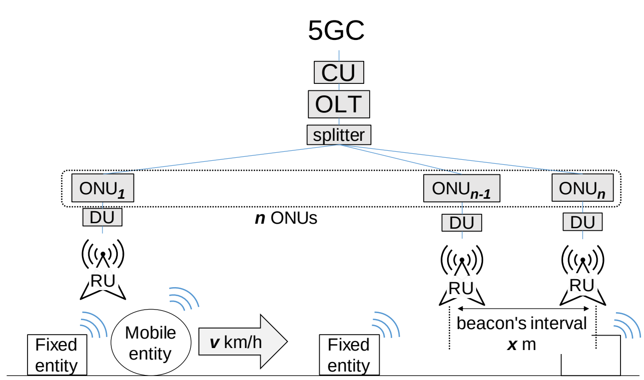

Fig. 5 Logical model

4.2 Modeling Parameters for Evaluation

Determine the traffic model to be used to evaluate BCOM+ and the set values for each variable. Assuming that all traffic from a mobile entity and neighbors is due to Internet service, the interval of traffic generation after multiplexing flowing between DU and ONU follows an exponential distribution [9]. In this case, frames from the mobile entity are generated according to a Poisson distribution with an average rate of 300 Mbps, and frames from the neighbors follow a Poisson distribution with an average rate of 200 Mbps per RU. The frame size is a fixed length of 10 kbit per frame.

The antenna spacing x is assumed to be 500 [m], the number of ONUs n is 8, and the mobile entity moves at a speed v of 36 [km]. The mobile entity shall follow a defined route, and only one mobile entity shall be traveling. The handover of a mobile entity is assumed to switch the RU to be communicated with every 500 [m] of the antenna installation interval; the ONU-ID is assigned a number from 1 to 8 in the order in which the mobile entity passes.

5. Evaluation

We evaluated BCOM+ based on the parameters presented in Section 4.2. Figure 6 shows the temporal variation of the predicted results for BCOM and BCOM+ at ONU3 when the reference time was set to 3 seconds (see Fig. 6.1) and 20 seconds (see Fig. 6.2). The correction value α for BCOM+ was set to 30% of the prediction obtained for BCOM.

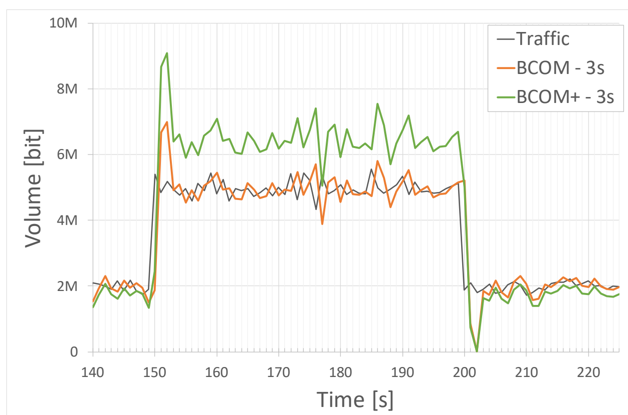

Fig.6.1 BCOM and BCOM+ prediction results at 3 seconds reference time.

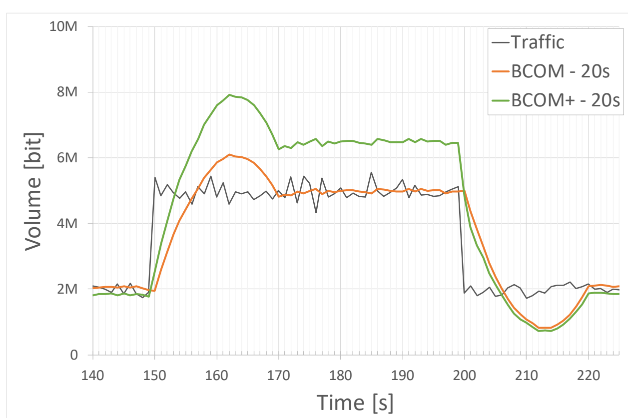

Fig.6.2 BCOM and BCOM+ prediction results at 20 seconds reference time.

Excessive bandwidth is allocated for a mobile entity, and bandwidth is also allocated for traffic not covered by BCOM. Also, in the case of longer reference times, the rise in predicted values is steeper with BCOM+ than with BCOM.

Next, to verify the effect of BCOM+, we focus on the time when a mobile entity is passing through and compare the sum of the missing bandwidth when the reference time is 3 seconds (see Fig. 7.1) and when the reference time is 20 seconds (see Fig. 7.2).

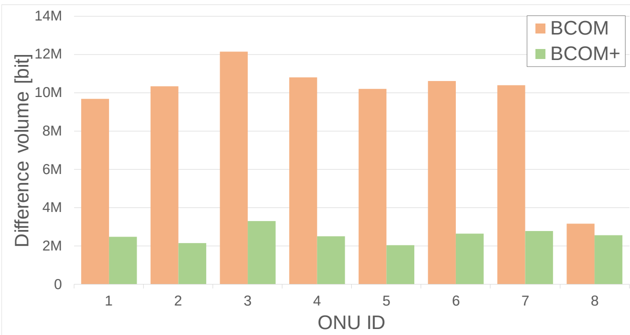

Fig.7.1 Insufficient bandwidth at reference time of 3 seconds

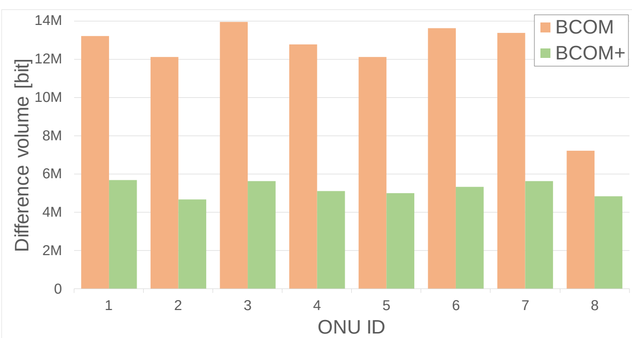

Fig.7.2 Insufficient bandwidth at reference time of 20 seconds

Comparing the amount of unallocated traffic between BCOM and BCOM+, the unallocated bandwidth was approximately 10 Mbit for each ONU in BCOM and 2.5 Mbit in BCOM+ when the reference time was 3 seconds. When the reference time was 20 seconds, the BCOM+ had 13 Mbit, and the BCOM+ had 5.5 Mbit. These results indicate that BCOM+ can reduce the frame loss rate at the time of passing a mobile position by about 60% compared to BCOM.

6. Conclusions

In this work, we proposed BCOM+, an extension of BCOM, which is one of our research assets, to accommodate large upstream traffic, such as 5G Internet traffic generated by mobile devices. We have evaluated BCOM+ by reproducing the actual environment in simulation and found that BCOM+ solved the problem that BCOM could not allocate enough bandwidth when passing through a mobile. Prospects for the future will be specific to use cases and a detailed evaluation of BCOM+.

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