An Asynchronous Burst Time Plan Generation Method for Broadband Satellite Multimedia System

Shaodong Feng[1,2], Fan Wang[3], Yuan Lin[1] , Liang Gou[1] and Guangxia Li[1]
[1]Institute of Communication Engineering, PLA University of Science and Technology,
Nanjing 210007, China
[e-mail: 86431043@qq.com]
[2]People's Liberation Army 96610 Troop, Beijing 102208 , China
[e-mail: fengshaodong1981@gmail.com]
[3]People's Liberation Army 73682 Troop, Xuzhou 221006, China
[e-mail: wangfan19841116@gmail.com]
*Corresponding author: Shaodong Feng

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Abstract

In broadband satellite multimedia (BSM) system, burst time plan (BTP) is always periodically generated. We find that this method can have a great effect on the system response ability to bandwidth requests. A general analysis model of BTP generation method is given. An optimized BTP generation (O-BTPG) method is presented by deducing the optimal bandwidth allocation period (BAP) and bandwidth allocation latency (BAL) without considering the signaling overhead caused by BTP. Then a novel asynchronous BTP generation (A-BTPG) method in which the BTP is generated asynchronously according to the traffic load from users' bandwidth requests is proposed. Simulation results show that A-BTPG can flexibly realize a trade-off between the system response ability and BTP signaling overhead. What's more, it can be widely used in various regenerative onboard switching BSM systems.

Keywords: Broadband Satellite Multimedia (BSM); bandwidth allocation; multiple access; burst time plan (BTP)

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1. Introduction

Broadband Satellite Multimedia (BSM) systems [1][2] have gained increased popularity and played an important role in the global information infrastructure. The bursty multimedia applications (for example the military applications) need the system to respond to their instantaneous bandwidth requests (BRs) quickly. Considerable research has been carried out to deal with this problem by predicting the varying trend of multimeida traffic。Zhang et al.[3] gave a wavelet packet decomposition method to predict the variable video traffic. Lygizou et al.[4] used normalized least mean square algorithm to predict the video traffic in joint WiMAX/Satellite networks. Williams et al. [5] studied various traffic prediction methods in satellite networks and found that packet traffic is not very predictable in most cases. Bisio et.al [6] modeled the problem by Multi-Objective Programming (MOP) method. Unhee Park et.al [7][8] exploited convex optimization to minimize the differences between the traffic demand and allocated capacity. However, the performances of these methods heavily depend on the input traffic pattern.

In order to satisfy the dynamic traffic demand, cross-layer design [9][10] is introduced. Castro et.al [11] proposed cross-layer design for Quality-of-Service (QoS) of interactive services in the second generation of the Digital Video Broadcasting standard for satellite transmission. The cross-layer approach exploited the satellite channel characteristics of space-time correlation via a cross-layer queueing architecture and an adaptive cross-layer scheduling policy. Diffserv architecture is another way to guarantee the QoS of multimedia applcaiton. Rendon-Morales et.al [12] gave a DiffServ model that includes a modified queuing mechanism in the forward link to enhance the goodput of the assured forwarding traffic class. The modified DiffServ model was simulated and tested, considering the interaction of the selected TCP variants. The best TCP variant was obtained. However, these methods can only be effective with specific transport protocol. The features of return link (or uplink) from User terminal （UT） to Gateway (or satellite) is not concerned.

In BSM system, burst time plan (BTP) is generated after the completion of bandwidth allocation algorithm to indicate the UTs' transmission. In order to simplify the implementation, the BTP is always periodically generated [13][14][15][16] at the beginning of every superframe. Here we call it periodical BTP generation (P-BTPG) method. We have found that by using P-BTPG method, the system response ability depends on the bandwidth allocation period (BAP) and bandwidth allocation latency (BAL) heavily. So the long superframe will have an effect on the system response ability. Yet few researchers have paid attention to that. To overcome this problem, Pietrabissa et.al [17] gave a dyncmic uplink frame optimization scheme in which BTP is generated every frame instead of every superframe. Nevertheless, the BTP signalling overhead was increased a lot by doing so. Kim et al. [18] focused on superframe length optimization to reduce the scheduling-waiting-time. However, the research was carried out under the assumption that the superframe structure is fixed. The optimization method can be hardly extended to other systems with various frame structures.

Different from the previous studies, a more general model to analyze the BTP method is given in this paper. To overcome the aforementioned shortcomings, system response ability and BTP efficiency are both taken into consideration. In order to realize a balance betwteen these two metrics, the BTP generation is not periodical but dynamically activated according to the system traffic load.

Our main contributions can be summarized as the follows.

1) The general analysis model of BTP generation method is given based on the bandwidth on demand (BoD) model. The model is independent of the traffic pattern and frame structure. Two key parameters BAP and BAL which can affect the system response ability are defined.

2) The cost function of BTP generation method both taking system respnose ability and BTP efficiency is proposed. The close-form expression of optimal scheduling length which can minimize the cost function is derived. Optimal scheduling length is the key parameter of A-BTPG method. The effectiveness of A-BTPG method is proven through extensive simulation results.

The remainder of the paper is organized as follows. In Section 2, BSM system under consideration and the BoD mechanism are briefly introduced. In Section 3, the general analysis model of BTP generation mehod is given, the performance of P-BTPG method is analyzed. In Section 4, O-BTPG method is introduced . In Section 5, A-BTPG method is given and the performance is analyzed. In Section 6, extensive simulation is carried out to evaluate the performance of various BTP generation methods. The simulation results are discussed. The conclusion is given in Section 7.

2. BSM system and BoD mechanism

The BSM system structure is shown in **Fig.1**. Satellite is equipped with multiple spot beams and onboard switching units. UTs are connected to the satellite through Multi-Frequency-Time Division Multiple Access (MF-TDMA) links on the uplink and Time Division Multiple (TDM) link on the downlink. Gateways are connected to the satellite using very high speed point-to-point bi-directional TDM links. The Network Control Center (NCC) is in charge of control and management of the whole system.

Bandwidth management module (BMM) onboard the satellite is in charge of allocating bandwidth to UTs according to their bandwidth requests (BRs). Bandwidth on demand (BoD) is the most widely used bandwidth allocation scheme. Various BoD algorithms such as Combined Free/Demand Assignment Multiple Access-Piggy Backed (CFDAMA-PB) [19], FIFO Ordered Demand Assignment (FODA) [20] were proposed in the past years. Almost all of them adopted P-BTPG method. **Table 1**. shows the parameters we will mention in the following.

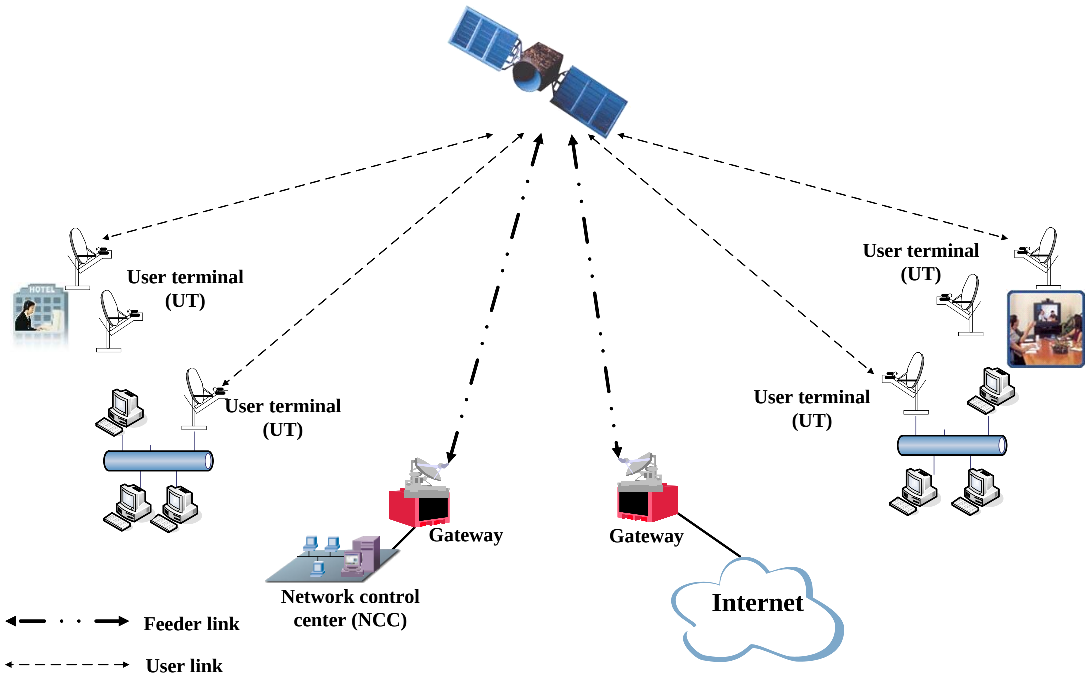


Fig. 1. BSM system architecture

Table 1. Parameter definition

Parameters	Definition
SRL(s)	T_{SRL}
BAP(s)	T_{BAP}
BAL(s)	T_{BAL}
Request waiting delay(s)	D_{rw}
RTT(s)	T_{RTT}
Maximum RTT(s)	$T_{\text{RTT\_max}}$
Onboard processing delay(s)	D_{op}
Transmission preparation delay(s)	D_{tp}
Uplink frame length(s)	D_{uframe}
Uplink slot length(s)	D_{uslot}
BAP of P-BTPG method(s)	$T_{\text{P-BAP}}$
BAP of O-BTPG method(s)	$T_{\text{O-BAP}}$
BAL of the *k*th timeslot of P-BTPG method(s)	$T^{k}_{\text{P-BAL}}$
BAL of O-BTPG method(s)	$T_{\text{O-BAL}}$
BAL of the *k*th timeslot of A-BTPG method(s)	$T^{k}_{\text{A-BAL}}$
Next scheduling instant(A-BTPG)(s)	$T_{\text{A-next}}$
Current scheduling instant(A-BTPG)(s)	$T_{\text{A-curr}}$
SRL of P-BTPG(s)	$T_{\text{P-SRL}}$
SRL of O-BTPG(s)	$T_{\text{O-SRL}}$
SRL of A-BTPG(s)	$T_{\text{A-SRL}}$
Scheduling length(A-BTPG)(s)	l_{sch}

Fig.2 gives a general model of BoD process. The main entities involved are the BMM onboard the satellite and bandwidth management agent (BMA) at the UT. Firstly, BMA sends a bandwidth request BR(1) at t_1 when there are new packets arrived at t_0 . BR(1) reaches BMM at t_2 after a half round trip time (RTT). For P-BTPG method, the bandwidth allocation algorithm is invoked periodically. At t_3, the bandwidth allocation algorithm starts to process BRs which come from UTs based on a certain scheduling discipline. At t_4 the bandwidth allocation is completed and BTP(1) that contains the allocation information for BR(1) is constructed and broadcasted to UTs. At t_5, BTP(1) arrives at the UT which has sent BR(1). The UT computes the next transmission time (t_6 in this paper) based on the indication of BTP(1). At t_6, the BR(i) is generated and piggybacked on the traffic packets.

BAP (T_{BAP}) and BAL (T_{BAL}) are two important parameters of the system response ability.

T_{BAP}: The duration between successive startup of bandwidth allocation algorithms. It is obvious that BAP equals to the BTP generation period for P-BTPG method.

T_{BAL}: The interval from each timeslot to its corresponding BTP. For P-BTPG method, T_{BAL} is different for each timeslot.

System response ability is defined as how fast the system can react to dynamic bandwidth requests from UTs. In this paper we take system response latency (SRL T_{SRL}) as our most concerned parameter. T_{SRL} shown in Fig.2 is the duration between UT transmitting BR and the UT transmitting in the timeslots that the exact BR has required.

It can be expressed by

$$\begin{aligned} T_{\text{SRL}} &= T_{\text{RTT}}/2 + D_{\text{rw}} + D_{\text{op}} + T_{\text{RTT}}/2 + D_{\text{tp}} \\ &= T_{\text{RTT}}/2 + D_{rw} + D_{\text{op}} + T_{\text{BAL}} - T_{\text{RTT}}/2 \\ &= D_{\text{rw}} + T_{\text{BAL}} + D_{\text{op}} \end{aligned} \tag{1}$$

The intrinsic delay during BoD process contains T_{RTT}, D_{op} and D_{tp}. Assuming T_{RTT}, D_{op} and D_{tp} are fixed, we can find that T_{SRL} depends on D_{rw} and T_{BAL} from the equation (1).

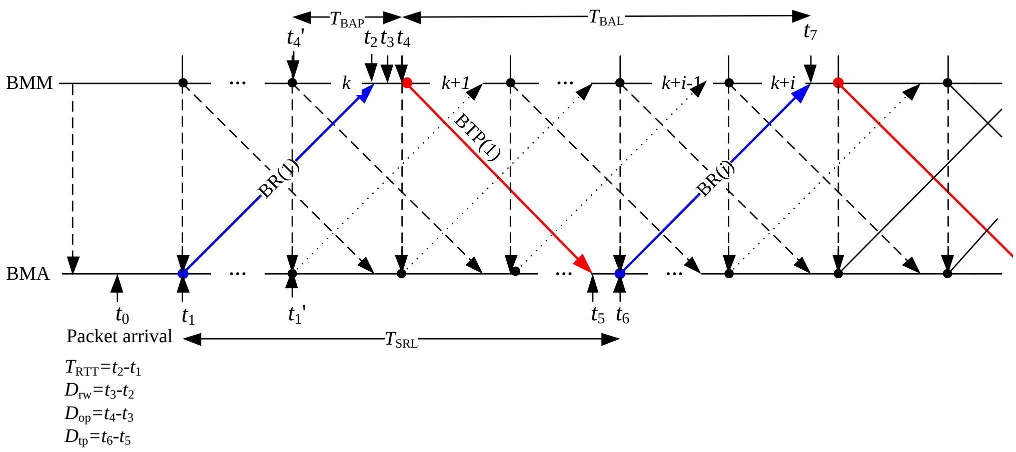


Fig. 2. General model of BoD process

3. P-BTPG Method Performance Analysis

Assuming that BRs from UTs are uniformly distributed, the mean value of D_{rw} can be obtained from [18].

$$E(D_{\text{rw}}) = T_{\text{P-BAP}}/2 \tag{2}$$

Fig.3 gives an illustration of P-BTPG method with k timeslots per uplink frame. From the figure we can find that each BTP is sent at the beginning of the downlink frame. Each BTP defines an assignment of a contiguous block of timeslots of a relevant uplink frame [16]. For example, in Fig.3 the nth BTP denoted by $B(n)$ is sent at the beginning of the nth downlink frame. $B(n)$ contains the timeslot assignment information of the k timeslots of the mth uplink frame. For most bandwidth allocation algorithm using P-BTPG, the $T_{\text{P-BAP}}$ equals to the uplink frame length.

$$T_{\text{P-BAP}} = D_{\text{uframe}} \tag{3}$$

From **Fig.3** we can find that the BAL of each timeslot differs from each other. The BAL of the first timeslot of the mth frame is

$$T^{1}_{\text{P-BAL}} = \left\lceil \frac{(T_{\text{RTT\_max}} + D_{\text{op}} + D_{\text{tp}})}{T_{\text{P-BAP}}} \right\rceil \times T_{\text{P-BAP}} \tag{4}$$

where $\lceil X \rceil$ gives the smallest integer greater than or equal to X. $T_{\text{RTT\_max}}$ is maximum RTT value in the satellite coverage. Because $B(n)$ contains assignment information for k timeslots of the mth uplink frame, the BAL of the kth (k>1) timeslot of the mth uplink frame is

$$T^{k}_{\text{P-BAL}} = T^{1}_{\text{P-BAL}} + (k-1) \times D_{\text{uslot}} \qquad k=(1,\ldots,\lceil T_{\text{P-BAP}} / D_{\text{uslot}} \rceil) \tag{5}$$

where k is the number of timeslots a BTP schedules. Assuming D_{uslot} is fixed, from (5) we can find that $T^{1}_{\text{P-BAL}}$, $T_{\text{P-BAP}}$ and k can have an effect on the BAL of timeslots. The more timeslots a BTP schedules, the larger BAL each timeslot has.

Furthermore, from (1), (4) and (5) we can find that the value of T_{SRL} depends on $T_{\text{P-BAP}}$ and $T^{k}_{\text{P-BAL}}$. In the next section we will give the optimal value of BAP and BAL in order to let T_{SRL} reach the optimal value.

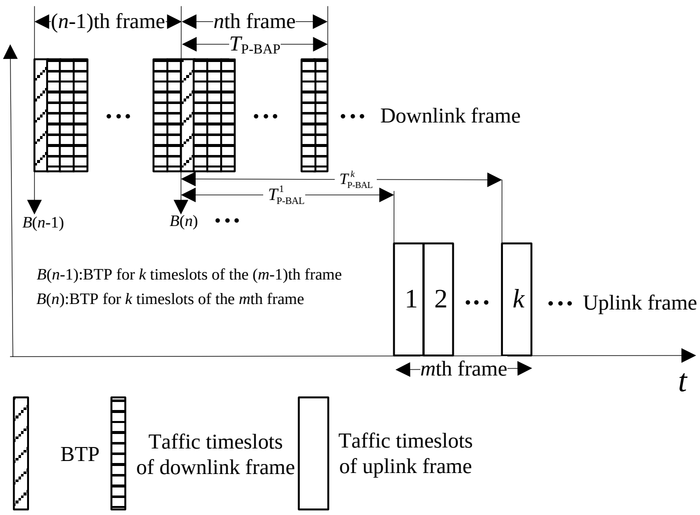


Fig. 3. P-BTPG method

4. O-BTPG Method

In this section we will show an optimal BTP generation (O-BTPG) method which can get the optimal value of BAP and BAL. The minimum scheduling unit in MF-TDMA BSM system is one timeslot. Therefore, the optimal value of BAP is the duration of one timeslot.

$$T_{\text{O-BAP}} = D_{\text{uslot}} \tag{6}$$

From (3) and (6) we can find

$$T_{\text{P-BAP}} \geq T_{\text{O-BAP}} \tag{7}$$

From (5) we can find that each timeslot can get an optimal BAL when k=1. That means each BTP schedules only one timeslot. From (4) we can get the BAL of each timeslot of O-BTPG method $T_{\text{O-BAL}}$.

$$T_{\text{O-BAL}} = \left\lceil \frac{(T_{\text{RTT\_max}} + D_{\text{op}} + D_{\text{tp}})}{T_{\text{O-BAP}}} \right\rceil \times T_{\text{O-BAP}} \tag{8}$$

From (5) and (8) we can find

$$T^{k}_{\text{P-BAL}} > T_{\text{O-BAL}} \quad (k>1) \tag{9}$$

Fig.4 shows an illustration of O-BTPG method, we can find that the O-BTPG method allocates the uplink timeslots one by one. Each timeslot in the uplink frame has an exclusive BTP in the downlink frame. For example in **Fig.4**, $B(1)$ contains the assignment information of the first timeslot of the mth uplink frame, $B(2)$ contains the assignment information of the second timeslot of the mth uplink frame and so on. By this way the BAL is minimized. In fact, O-BTPG is a special case of P-BTPG in which the BAP is equal to the timeslot duration. It has the optimal sysetm response ability as a result of the optimized BAP and BAL. However, it is evident that the number of BTPs increases a lot. The number of BTPs in one downlink frame should be equal to the number of timeslots in the corresponding uplink frame. In order to decrease the signalling overhead caused by BTP in the downlink frame. A-BTPG method is proposed in Section 5 to make a trade off between system response ability and BTP signaling efficiency.

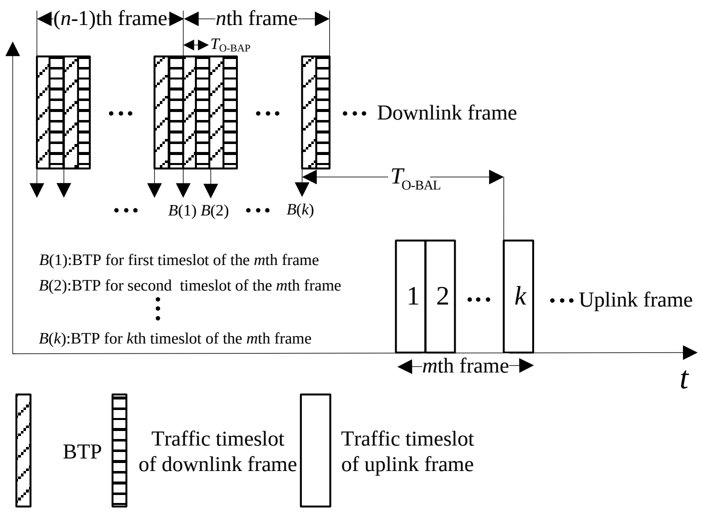


Fig. 4. O-BTPG method

5. A-BTPG Method

P-BTPG method comes from TDMA transparent satellite system in which the bandwidth allocation algorithm should be invoked periodically at the beginning of each frame in order to send the BTP through the reference burst [21]. While for BSM system with onboard switching unit and BMM, BTP can be inserted into the downlink by BMM flexibly. A possible structure is shown in **Fig.5**. The BRs and traffic are processed in the uplink porcessing unit. BRs are switched to BMM according the onboard swithcing strategy. After processing, BTPs generated can be asynchronously inserted into the downlink with traffic according to A-BTPG method.

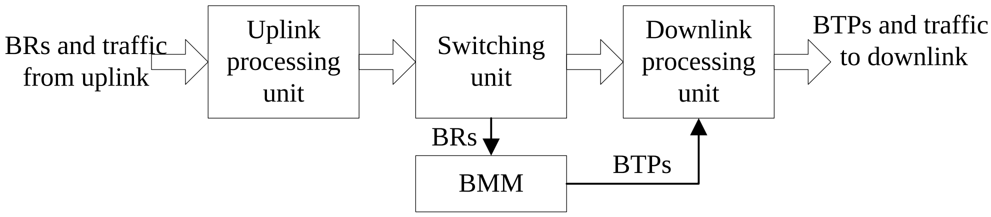


Fig. 5. A possible onboard processing structure of A-BTPG

The main idea of A-BTPG method is to generate the BTP when it is needed according to the traffic load from BRs. In order to assure all of the UTs have enough time to prepare transmission after BTP is received, the BTP generation of A-BTPG method is not periodical but determined by the generation instant and scheduling length of the previous BTP. So once a BTP generates, the next BTP generation instant $T_{\text{A-next}}$ is determined by

$$T_{\text{A-next}} = T_{\text{A-curr}} + l^{*}_{\text{sch}} \tag{10}$$

where $T_{\text{A-curr}}$ is the generation instant of the current BTP. l_{sch} which is called scheduling length is the value of the number of timeslots scheduled in the current BTP. l^{*}_{sch} is the optimal value of l_{sch}. l^{*}_{sch} can be obtained by minimizing the cost fuction $C(l_{\text{sch}})$.

$$C(l_{\text{sch}}) = C_{\text{waiting}}(l_{\text{sch}}) + C_{\text{btp}}(l_{\text{sch}}) \tag{11}$$

From (11) we can find that cost function consists of bandwidth request waiting delay cost function $C_{\text{waiting}}(l_{\text{sch}})$ and BTP signaling efficiency cost function $C_{\text{btp}}(l_{\text{sch}})$. $C_{\text{waiting}}(l_{\text{sch}})$ can be obtained from (2)：

$$C_{\text{waiting}}(l_{\text{sch}}) = \begin{cases} c_{\text{w}} \dfrac{l_{\text{sch}}}{2}, & 0<l_{\text{sch}} \le l_{\max} \\ \infty, & l_{\text{sch}} > l_{\max} \end{cases} \tag{12}$$

where l_{sch} is a variable needed to be optimized. $l_{\max}$ is a limitation that represents the maximum allowable scheduling length, c_{w} is a unit cost for D_{rw} , l_{sch} /2 is the average waiting time of BR arriving after the current BTP. BTP efficieny $P\%$ can be obtained by

$$P\% = \frac{S}{l_{\text{sch}} \times R + S} \times 100\% \quad (0 < P\% \le P_{\max}\%) \tag{13}$$

where S is the BTP signaling overhead, R is the sum of BRs (represented by rate), $P_{\max}\%$ is maximum BTP signaling efficiency allowed by the system. From (13) we can find that

$$0<l_{\text{sch}} \le \frac{S - S \times P_{\max}\%}{R \times P_{\max}\%} \tag{14}$$

The BTP signaling efficiency cost function $C_{\text{btp}}(l_{\text{sch}})$ can be represented by

$$C_{\text{btp}}(l_{\text{sch}}) = \begin{cases} c_{\text{b}} \dfrac{S}{S + R \times l_{\text{sch}}}, & 0<l_{\text{sch}} \le \dfrac{S - S \times P_{\max}\%}{R \times P_{\max}\%} \\ 0, & l_{\text{sch}} > \dfrac{S - S \times P_{\max}\%}{R \times P_{\max}\%} \end{cases} \tag{15}$$

where C_b is a unit cost for BTP signaling efficiency.

From (12) and (15) we can get the cost function

$$C(l_{sch})=\begin{cases} c_w\dfrac{l_{sch}}{2}+c_b\dfrac{S}{S+R\times l_{sch}}, & 0< l_{sch}<\min\left\{\dfrac{S-S\times P_{max}\%}{R\times P_{max}\%}, l_{max}\right\} \\ c_w\dfrac{l_{sch}}{2}, & \dfrac{S-S\times P_{max}\%}{R\times P_{max}\%}\le l_{sch}\le l_{max} \\ \infty, & \text{otherwise} \end{cases} \quad (16)$$

When $\dfrac{S-S\times P_{max}\%}{R\times P_{max}\%}>l_{max}$, l_{sch} can reach the optimal value by (17).

$$\frac{d(c_w\dfrac{l_{sch}}{2}+c_b\dfrac{S}{S+R\times l_{sch}})}{dl_{sch}}=0 \quad (17)$$

When $0<\dfrac{S-S\times P_{max}\%}{R\times P_{max}\%}\le l_{max}$,from (16) we can find that the minimum value of $C(l_{sch})$ can be obtained by

$$l_{sch}=\frac{S-S\times P_{max}\%}{R\times P_{max}\%} \quad (18)$$

Timeslot duration is the minimum scheduling length in MF-TDMA system, the value of l_{sch}^* should be multiple timeslot length. Therefore we can get the optimal scheduling length l_{sch}^* from (17) and (18).

$$l_{sch}^*=\begin{cases} \left\lceil \dfrac{S-S\times P_{max}\%}{R\times P_{max}\%\times D_{uslot}} \right\rceil\times D_{uslot}, & 0<\dfrac{S-S\times P_{max}\%}{R\times P_{max}\%}\le l_{max} \\ \left\lceil \min\left\{\dfrac{\sqrt{\dfrac{2RSc_b}{c_w}}-S}{R}, l_{max}\right\}/D_{uslot} \right\rceil\times D_{uslot}, & \dfrac{S-S\times P_{max}\%}{R\times P_{max}\%}>l_{max} \end{cases} \quad (19)$$

When $c_b>\dfrac{(Rl_{max}+S)^2\times c_w}{2RS}$

$$l_{sch}^*=\lceil l_{max}/D_{uslot}\rceil\times D_{uslot} \quad (20)$$

From (19), we can find that l_{max} is the overload threshold. When $(S-S\times P_{max}\%)/(R\times P_{max}\%)\le l_{max}$, l_{sch}^* depends on R. c_b, c_w, S, $P_{max}\%$ and D_{uslot} are all predetermined. R can be obtained by summing the BRs that have been received. Therefore l_{sch}^* can be computed within accepted complexity and implemented online.

The interval between two successive BTPs is

$$T_{\text{A-next}}-T_{\text{A-curr}}=l_{sch}^* \quad (21)$$

From (19) and (21) we can find that instead of the fixed interval between successive BTPs of P-BTPG and O-BTPG method, the interval of successive BTPs of A-BTPG is dynamically changed according to the BRs. What's more, from (3), (6), and (19) we can find

$$T_{\text{P-BAP}}\ge l_{sch}^*\ge T_{\text{O-BAP}} \quad (22)$$

The BAL of the first timeslot of A-BTPG method can be obtained by

$$T^{1}_{\text{A-BAL}} = \left\lceil \frac{(T_{\text{RTT\_max}} + D_{\text{op}} + D_{\text{tp}})}{D_{\text{uslot}}} \right\rceil \times D_{\text{uslot}} \tag{23}$$

The BAL of the qth timeslot can be obtained by

$$T^{q}_{\text{A-BAL}} = T^{1}_{\text{A-BAL}} + (q-1) \times D_{\text{uslot}} \qquad q=(1,\ldots,\lceil l^{*}_{\text{sch}} / D_{\text{uslot}} \rceil) \tag{24}$$

From (1), (5), (8) and (24) we can find

$$E(T_{\text{P-SRL}}) \geq E(T_{\text{A-SRL}}) \geq E(T_{\text{O-SRL}}) \tag{25}$$

6. Simulation and Analysis

An extensive simulation is carried out by network simulator OPNET. **Table 2** shows the simulation parameters. The satellite is at the Geostationary orbit. The onboard processing structure is shown in **Fig.5**. During the simulation, we assume the number of UTs is constantly 16. In order to show the performance of different BTP methods, only one spot beam is focused. There is one TDMA uplink and one TDM downlink channel in this spot beam. Possion and ExpONOFF are chosen as the traffic source. Possion is a traditional traffic source in which the interval of packets arrival is exponential distributed. ExpONOFF is always used to capture the burst phenomenon of multimeida traffic.It has two staus ON and OFF. Each status is exponential distributed. Therer is no packets for OFF status. Packets are generated exponentially for ON status. Thus, the sequence of traffic is viewed as the interchanging of ON and OFF periods. CFDAMA-PB [19] and FODA[20] which were mentioned in Section 2 have been adopted as the bandwidth allocation algorithm. By using CFDAMA-PB algorithm, BMM onboard the satellite maintains a BR table and a free assignment table separately. Each time when the bandwidth allocation algorithm is invoked, BMM will serve BR table first. In the absence of any queued BRs, the BMM will freely assign the remaining timeslots in a round robin manner. BR is accompanied with the traffic in the uplink timeslot according to the buffer status. Different from CFDAMA-PB, FODA serves the BR in a First In First Out(FIFO) manner without free assignment. UT sends BR in the preassigned timeslot. By using different bandwidth allocation algorithms and traffic sources we could comapre the performances of the BTP methods in a more general way.

The performance metrics we evaluated are SRL, average buffer queue size of UT, free assignment proportion and BTP efficiency. SRL is defined in (1). Free assignment proportion is the number of timeslots being freely assigned versus the number of timeslots being totally assigned. This metric is only for CFDAMA-PB algorithm because there is no free assignment timeslots for FODA algorithm. BTP efficiency is the number of BTP packets versus whole packets transmitted in downlink channel during the simulation for both CFDAMA-PB and FODA algorithms.

Table 2. Simulation parameters

Parameters	Value
Satellite altitude(km)	35786
Number of carriers in uplink channel	1
Number of carriers in downlink channel	1
Number of UTs	16
Uplink channel information rate(kbps)	2048
Downlink channel information rate(kbps)	8192
Normalized system load	0.1-0.92

BAP of P-BTPG(s)	0.192/0.384
BAL(s)	0.3
Number of packets per timeslot	1
Traffic model	Possion ExpONOFF
Bandwidth allocation algorithm	CFDAMA-PB FODA

Fig.6–**Fig.9** show performance comparison of various BTP generation methods using CFDAMA-PB algorithm with possion and ExpONOFF traffic source under the normalized system load 0.1-0.92. For P-BTPG method, SRL is larger when BAP equals to 0.384s than the value when BAP equals to 0.192s. It shows that BAP has an effect on SRL for P-BTPG method. It verifies our analysis in Section 3. SRL of O-BTPG performs best among the three BTP generation methods for both possion and ExpONOFF traffic source. This is because its optimal BAP and BAL guarantee the best SRL performace. The difference of SRL between A-BTPG and O-BTPG is no more than 0.002s for both possion and ExpONOFF traffic. It is observed that A-BTPG improves SRL compared with P-BTPG. This is because the bandwidth allocation algorithm is invoked according to the current needs of BRs. The results verify our analysis in expression (25). The SRL of A-BTPG is 0.02s better than P-BTPG with ExpONOFF traffic under the system load 0.92. For possion traffic source the reduced SRL is only 0.01s. The results show that A-BTPG method is particularly suitable for bursty multimedia traffic.

From **Fig.7** we can find that average buffer size of UT has increased with the normalized system load for both possion and ExpONOFF traffic source. A-BTPG method performs obviously better than P-BTPG method and almost the same as O-BTPG method. This is because with asynchronously generated BTP, more timeslots have been allocated to the packets needed to transmit at the buffer queue of UT, thus the average buffer size has been reduced.

From **Fig.8** we can find that the free assignment proportion of P-BTPG when BAP equals to 0.384s is the highest with both possion and ExpONOFF traffic among various BTP generation method. It is because most of timeslots have been freely assigned for the large BTP generation interval. The efficiency of free assignment is not as good as demand assignment [19]. This is also the reason why SRL of P-BTPG is larger than the values of O-BTPG and A-BTPG methods.

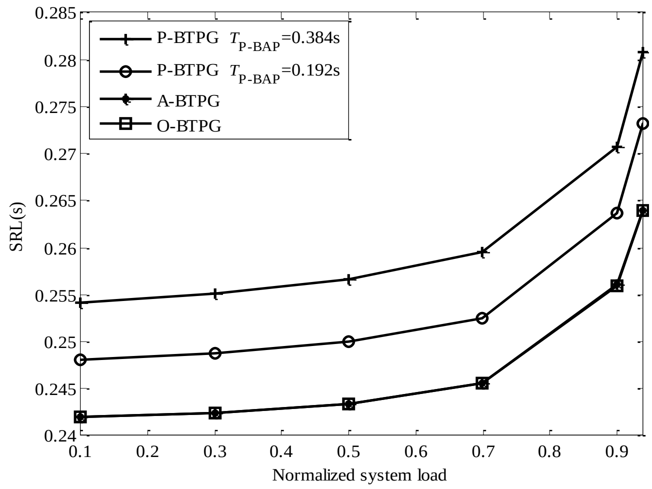
From **Fig.9** we can find that BTP efficiency is constantly 25% for O-BTPG method with possion and ExpONOFF traffic sources. This is because system generates BTP for each timeslot of the uplink for O-BTPG method. The BTP generation rate is equal to the uplink channel rate. From **Table 2** we can find that the downlink channel rate is four times than uplink channel rate in our simulation. Therefore the BTP efficiency which is equal to the BTP generation rate versus downlink channel rate is 25%. The BTP efficiency of A-BTPG is almost the same as O-BTPG method when the system load is low. However it has been reduced with increment of the normalized system load. This is because the traffic density for each UT has been increased.The number of BRs has been reduced. A BTP can schedule several timeslots together for one BR. Therefore the number of BTPs is also reduced. The BTP efficiency of A-BTPG is about 0.7% lower than the value of O-BTPG with possion traffic when the normalized system load is 0.92. With ExpONOFF traffic the difference between the values of the two methods is about 3.5% . We can find that the asynchrously BTP generation mechanism is suitable for bursty multimedia traffic.

All BTP generation methods performe better with possion traffic than they do with

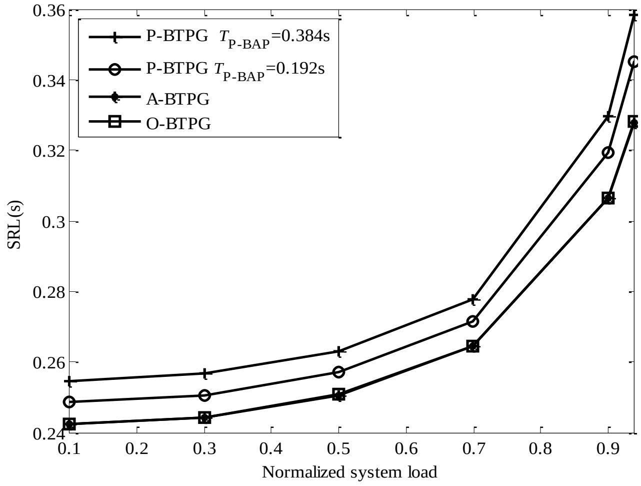
ExpONOFF traffic in terms of SRL, average buffer size, free assignemnt proportion and BTP efficiency. It is because the bursty feature of ExpONOFF traffic deteriorate the performance of all BTP generation methods.

Fig.10-**Fig.12** show performance comparison of various BTP generation methods using FODA algorithm with possion and ExpONOFF traffic sources under the normalized system load 0.1-0.92.

From **Fig.10** and **Fig.11** we can get the same conclusion as we obtained from **Fig.6** and **Fig.7**. All of the BTP generation methods perform better with Possion traffic than they do with ExpONOFF traffic . SRL and average buffer queue size of A-BTPG method outperform the values of P-BTPG method and are almost the same as the values of O-BTPG method. The simulation result of BTP efficiency of A-BTPG method in **Fig.12** is more interesting. It should be noted that the remaining timeslots after demand assignment cannot be assigned freely for FODA method. Therefore from **Fig.12** we can find that with the increment of normalized system load from low to medium the BTP efficiency has also been increased. However, with the continuous increment of system load, the traffic density of each UT begins to impact the value of BTP efficiency. So the BTP efficiency has been reduced from medium to heavy system load. Compared with the other two methods, A-BTPG can realize a balance between system response ability and BTP efficiency.

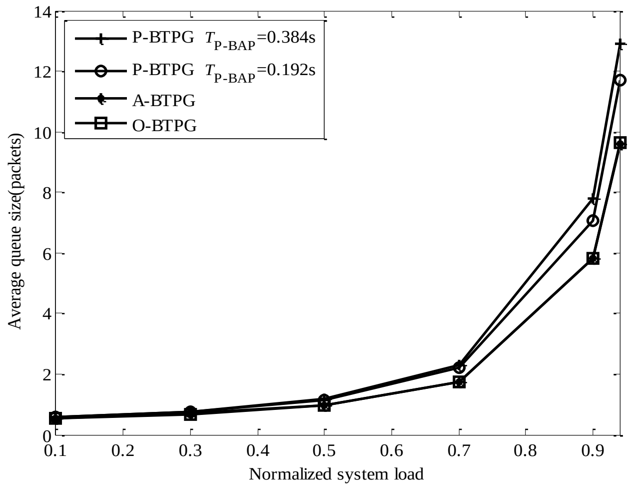


a) Possion traffic

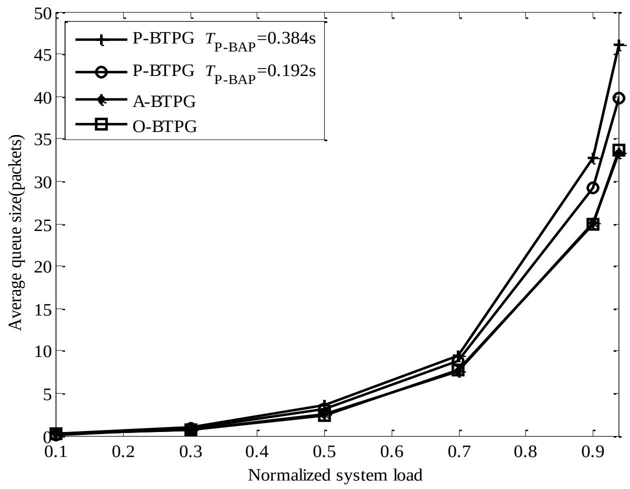


b) ExpONOFF traffic

Fig. 6. SRL comparison using CFDAMA-PB algorithm

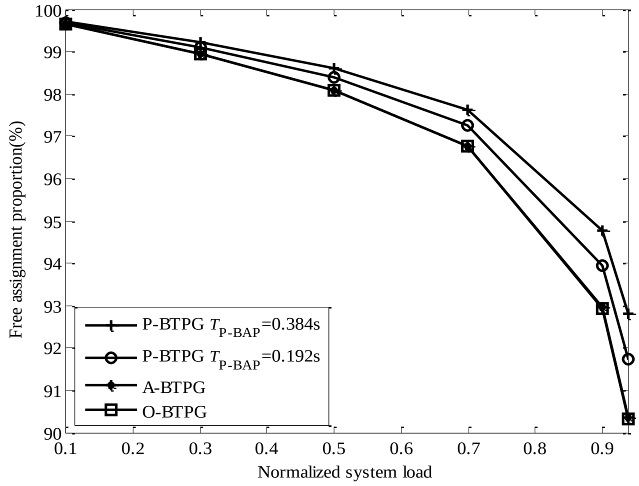


a) Possion traffic

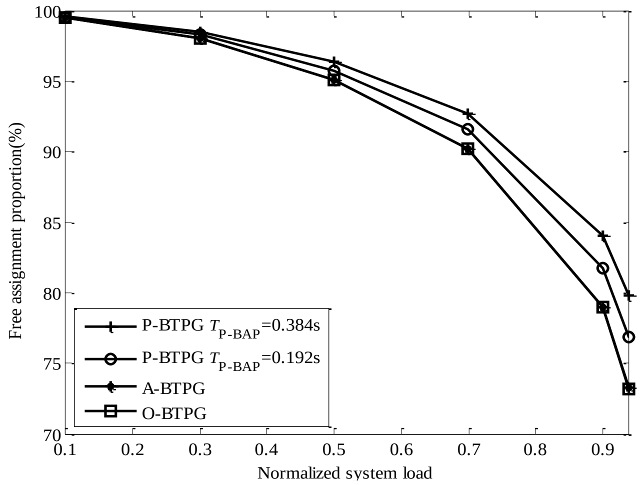


b) ExpONOFF traffic

Fig. 7. Average queue size comparison using CFDAMA-PB algorithm

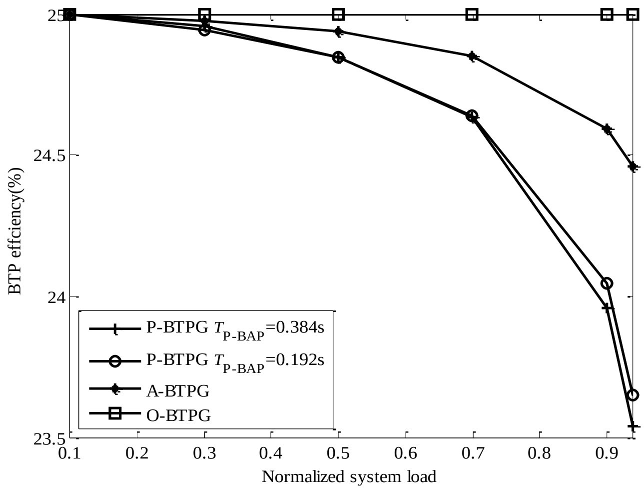


a) Possion traffic

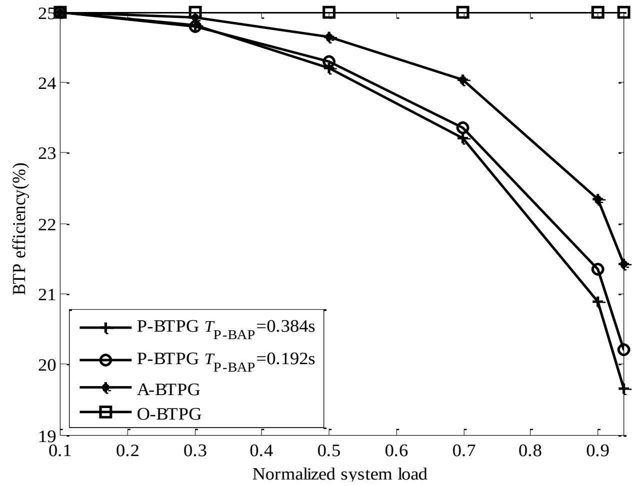


b) ExpONOFF traffic

Fig. 8. Free assignment proportion comparison using CFDAMA-PB algorithm

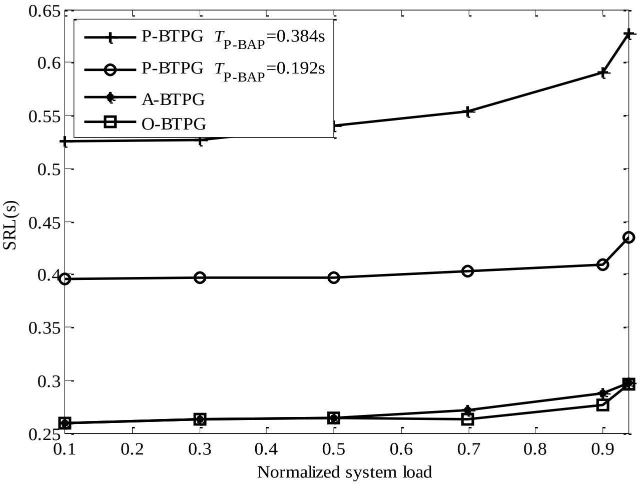


a) Possion traffic

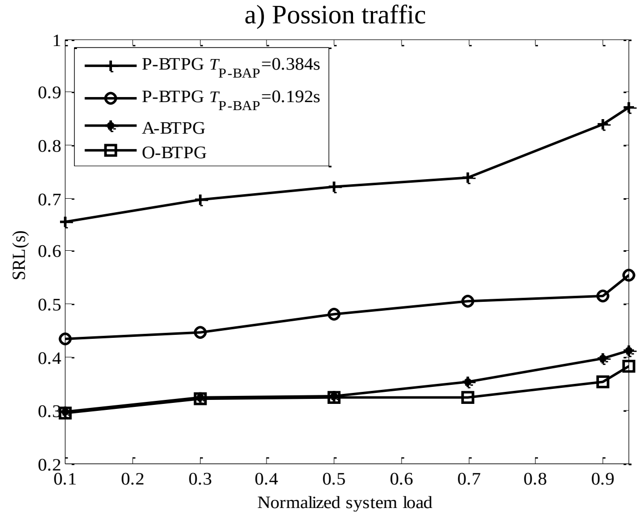


b) ExpONOFF traffic

Fig. 9. BTP efficiency comparison using CFDAMA-PB algorithm

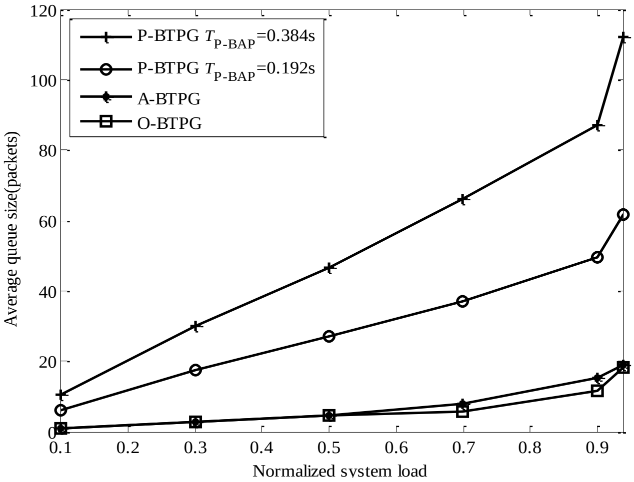


a) Possion traffic

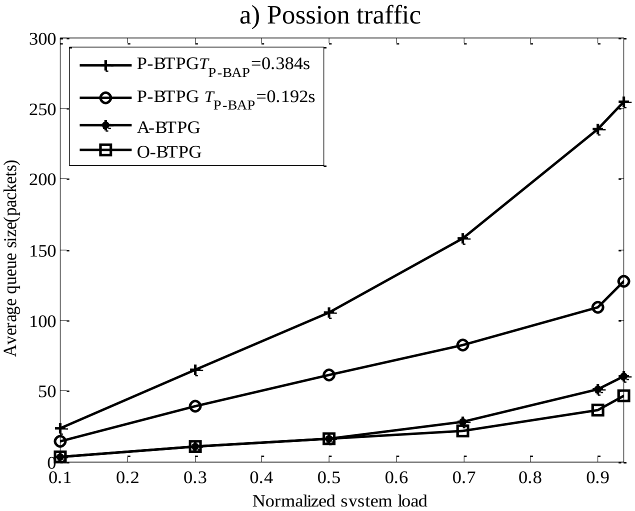


b) ExpONOFF traffic

Fig. 10. SRL comparison using FODA algorithm

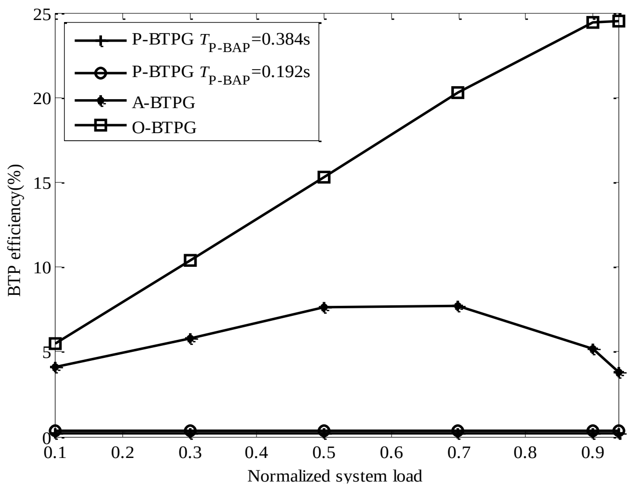


a) Possion traffic

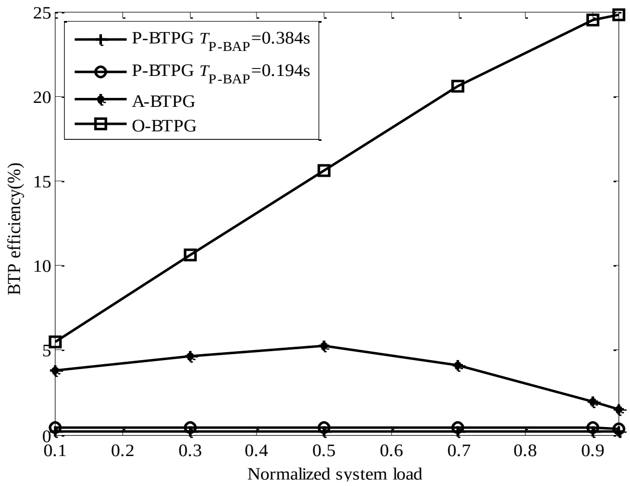


b) ExpONOFF traffic

Fig. 11. Average queue size comparison using FODA algorithm



a) Possion traffic



b) ExpONOFF traffic

Fig. 12. BTP efficiency comparison using FODA algorithm

7. Conclusion

This paper has investigated the performance of different BTP generation methods in BSM system with onboard switching in terms of SRL, free assignment proportion, average buffer size and BTP efficiency. The analysis of the general BTP generation methods shows that both BAP and BAL have an effect on the system response ability. The O-BTPG has been given to improve the system response ability by optimizing BAP and BAL. The main problem of O-BTPG is the large signaling overhead caused by frequent BTP generation. A-BTPG is proposed to optimize the interval between successive BTP generations. Extensive simulation results show that A-BTPG method can realize a trade-off between the system response ability and BTP signaling cost. Performance improvements of A-BTPG can be achieved with either bursty or none-bursty traffic source compared with other BTP methods. What's more A-BTPG method is not limited by a specific bandwidth allocation algorithm and can also be expanded to other regenerative BSM systems such as RSM-A [15]. Future study will be focused on the performance analysis combined with transport and application protocols.

References

[1] Y. F. Hu, M. Berioli, P. Pillai, H. Cruickshank, G. Giambene, K. Kotsopoulos, W. Guo and P.M.L. Chan, "Broadband satellite multimedia," *IET Communications,* vol.4, no.13, pp.1519-1531, September, 2010. Article (CrossRef Link)

[2] N. Anastasiadou, G. Gardikis, A. Nikiforiadis and S. Pangalos, "Adaptive Coding and Modulation-enabled satellite triple play over DVB-S2 (Digital Video Broadcasting - Satellite - Second Generation): a techno-economic study," *International Journal of Satellite Communications and Networking*, vol.30, Issue 3, pp. 99–112, May/June 2012. Article (CrossRef Link)

[3] A. Lygizou, N. Passas, S. Xergias, and L. Merakos, "Effective Prediction for Video Traffic in Joint WiMAX/Satellite Networks," *Wireless Personal Communications*, June 2012. Article (CrossRef Link)

[4] S. Zhang, J. Chen, L.H. She and X. R. Bao, “Use of optimal wavelet packet decomposition for the long-term prediction of variable-bitrate video traffic,” *IET Communications*, vol. 4, no. 11, pp. 1277-1287, July 2010. Article (CrossRef Link)
[5] M. Williams, and K. Nichols, “The effect of packet traffic prediction limitations on DAMA schemes for future satellite packet networks,” *in Proc. of IEEE Milcom 2009*, pp. 1-7, October 2009. Article (CrossRef Link)
[6] I. Bisio , and M. Marchese, “Power Saving Bandwidth Allocation over GEO Satellite Networks,” *IEEE Communications Letters*, vol.16, no.5, pp.596-599, May 2012. Article (CrossRef Link)
[7] P. Unhee, W. K. Hee, S. O. Dae, and J. K. Bon, “A Dynamic Bandwidth Allocation Scheme for a Multi-spot-beam Satellite System,” *ETRI Journal*,vol.34, no.4 , pp.613-616, August 2012. Article (CrossRef Link)
[8] P. Unhee, W. K. Hee, S. O. Dae, and J. K. Bon, “Flexible Bandwidth Allocation Scheme Based on Traffic Demands and Channel Conditions for Multi-Beam Satellite Systems,” in *Proc. Of Vehicular Technology Conference IEEE*, pp.1-5, September 2012. Article (CrossRef Link)
[9] E. Rendon-Morales, J. Mata-Diaz, J. J. Alins, J. L. Muñoz, and O. Esparza, “QoSatAr: a cross-layer architecture for E2E QoS provisioning over DVB-S2 broadband satellite systems,” *EURASIP Journal on Wireless Communications and Networking*, vol.2012:302, September 2012. Article (CrossRef Link)
[10] E. Rendon-Morales, J. Mata-Diaz, J. J. Alins, J. L. Muñoz and O. Esparza, “Cross-layer packet scheduler for QoS support over Digital Video Broadcasting-Second Generation broadband satellite systems,” *International Journal of Satellite Communications and Networking*, October 2012. Article (CrossRef Link)
[11] M. Angeles Vazquez Castro, and F. Vieira, “DVB-S2 full cross-layer design for QoS provision,” *Communications Magazine, IEEE*, vol.50, no.1, pp. 128-135, January 2012. Article (CrossRef Link)
[12] E. Rendon-Morales, J. Mata-Diaz, J. J. Alins, J. L. Muñoz and O. Esparza, “Performance evaluation of selected Transmission Control Protocol variants over a digital video broadcasting-second generation broadband satellite multimedia system with QoS,” *International Journal of Communication Systems*. March 2012. Article (CrossRef Link)
[13] P. Chatziparaskevas, G. Koltsidas and F. N. Pavlidou, “On the fairness of return channel capacity allocation in DVB-RCS-based satellite networks,” *International Journal of Satellite Communications and Networking*, vol. 29, no.2, pp. 163-184, March/April 2011. Article (CrossRef Link)
[14] Antonio Pietrabissaa, Tiziano Inzerillia, Olivier Alphandb, Pascal Berthoub, Thierry Gayraudb,Michel Mazzellac, Eddy Fromentind and Fabrice Lucasd, “Validation of a QoS architecture for DVB–RCS satellite networks via the SATIP6 demonstration platform,” *Computer Networks*, vol.49, no.6, pp. 797-815, December 2005. Article (CrossRef Link)
[15] N. Iuoras and T. Le-Ngoc, “Dynamic capacity allocation for quality-of-service support in IP-based satellite networks,” *IEEE Wireless Communications*, vol.12, no.5, pp.14-20, October 2005. Article (CrossRef Link)
[16] ETSI EN 301 545-2 V1.1.1, “Digital Video Broadcasting (DVB): Second Generation DVB Interactive Satellite System (DVB-RCS2) Part 2: Lower Layers for Satellite standard,” January 2012. Article (CrossRef Link)
[17] A. Pietrabissa and A. Fiaschetti, “Dynamic uplink frame optimization with ACM in DVB-RCS2 satellite networks,” in *Proc. Of 2012 IEEE First AESS European Conference on Satellite Telecommunications (ESTEL)*, pp.1-7, October 2012. Article (CrossRef Link)
[18] D. Kim, D. H. Park and K. Lee, “Minimum length transmission scheduling of return channels for multicode MF-TDMA satellite interactive terminals,” *IEEE Transactions on Vehicular technology*, vol.54, no.5, pp. 1854-1862, September 2005. Article (CrossRef Link)
[19] T. Le-Ngoc and I. Mohammed Jahangir, “Performance analysis of CFDAMA-PB protocol for packet satellite communications,” *IEEE Transactions on Communications*, vol.46, no.9, pp. 1206-1214, September 1998. Article (CrossRef Link)
[20] N. Celandroni and E. Ferro, “The FODA-TDMA satellite access scheme: presentation, study of the

system and results," *IEEE Transactions on Communications*, vol.39, no.12, pp.1823-1831, December 1991. Article (CrossRef Link)

[21] N. Celandroni, E. Ferro and F. Potortì, "Comparison between distributed and centralized demand assignment TDMA satellite access schemes," *International Journal of Satellite Communications*, vol.14, no.2, pp. 95-111, March 1996. Article (CrossRef Link)

[22] R. Gopal, S. Arnold, L. Orr and S. Ali, "Network centric satellite communication with IP networks based on regenerative satellite Mesh-A (RSM-A) Ka band technology," in *Proc. Of IEEE Milcom 2008*, pp.1-6, November 2008. Article (CrossRef Link)

Shaodong Feng was born in Anyang, Henan Province, in 1981. He received the Ph.D. degree in PLA University of Science and Technology in 2011. He is now an engineer in People's Liberation Army 96610 Troop. His research interests include satellite communication and satellite navigation.

Fan Wang was born in Nanyang, Henan Province, in 1984. She received the PHD degree in PLA University of Science and Technology in 2011. She is now an assistant engineer in People's Liberation Army 73682 Troop. Her research interests include wireless communication and signal processing.

Yuan Lin was born in Lanzhou, Gansu Province, in 1986. She received the M.S.degree in PLA University of Science and Technology in 2009. Her research interests include satellite communication and satellite navigation.

Liang Gou was born in Hubei Province, in 1983. He received the M.S.degree in PLA University of Science and Technology in 2007. His research interests include satellite communication and satellite navigation.

Guangxia Li was born in Yongkang, Zhe Jiang Province, in 1964. He is a professor of PLA University of Science and Technology. His research interests include satellite communication and satellite navigation.