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Resource Management for 5G-satellite Communication Systems based on Queuing Theory

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Abstract

Nowadays, with the advent of new satellite services, the need for resource management in the emerging fifth generation satellite systems (5G-satellite) is inevitable. Thus, to solve this problem, the Bandwidth Manager for resource reservation in satellite link is mandatory. On the other hand, due to limited resources, their resource management is essential. In order to resource management in 5G-satellite systems, can be applied in one phase or many phases. In this paper, resource management for 5G-satellite services is evaluated. The proposed problem is to obtain mean response time under the propagation delay constraints in different satellite orbits. We solve the considered problem via the single phase and two phase algorithms. Finally, through simulation, the proposed algorithms are investigated and confirmed. In our scenarios, satellite is a central node in call flows and ground stations are end nodes in 5G-satellite based on Internet protocol. So, we simulated all of scenarios in MATLAB software for this reason.

Keywords: 5G-satellite, Signaling Protocol; Bandwidth Manager; M/M/1; Single phase; Two phase

1. Introduction

This paper looks at resource management for space links into the 5G-satellite systems that will provide communications based on Internet protocol (IP) which simulated by MATLAB software. A recent European Space Agency (ESA) study considered the integration of satellite and other networks and found many opportunities where they can work together to enhance the end user experience. Today we are at the start of working towards the next generation-5G, which is likely to be standardized by 2016 and be rolled out from 2020. The EU has set up a 5G-PPP research program to fund research towards this new standard which will commence in 2015.

Satellite systems are fundamental components to deliver reliably 5G services not only across the whole of Europe but also in all regions of the world, all the time and at an affordable cost. Satellite component will contribute to augment the 5G service capability in relation to the support of IP traffic growth whilst optimizing the value for money to the end users.

Today, 4.3% of the European population live in areas without access to wire or Internet. Moreover, a growing number of people expect to access to the satellite services they have

at home even while traveling, flights and so on. Furthermore, it is expected that 5G-satellite systems will also provide machine-to machine communication [1].The main contribution of satellite transmissions, thanks to their broadcast/multicast and broadband capabilities, is the off-loading of terrestrial 5G networks [2].
Therefore, different scenarios need to be evaluated to achieve effective satellite communications. But a challenge is related to the propagation delay of the satellite link [3-4] which requires that the resource management along space link.
Propagation delay plays an important role in Quality of Service (QoS). The 5G-satellite systems have great advantages to support signaling protocol as a technology that allows universal access to services. Satellites today provide diverse services to air, sea and remote land areas via GEO operators (e.g Inmarsat, Thuraya) and non-geostationary orbit (GEO) operators (e.g. Iridium, Globalstar, O3b). The role of satellite in 5G networks is still under discussion [5], nevertheless, the scientific community will intend to design a satellite system based on IP which can be a part of the terrestrial IP network or be standalone satellite network with satellites participating as sources, processors, and consumers of data.
Due to the wide coverage area, satellite constellations are also expected to play a vital role as a reservation node in IP satellite networks. The main concern investigated in this paper is the resource management over space link, which poses two scenarios based on queuing theory to be measured some key parameters such as mean response time. A flowchart of the proposed algorithm presented in Fig. (1).
In this algorithm, each of the node displays as a queuing node which includes managing and routing paths. According to queuing theory, the input and output queuing node have statistical distribution which include Poisson distribution and exponential distribution.

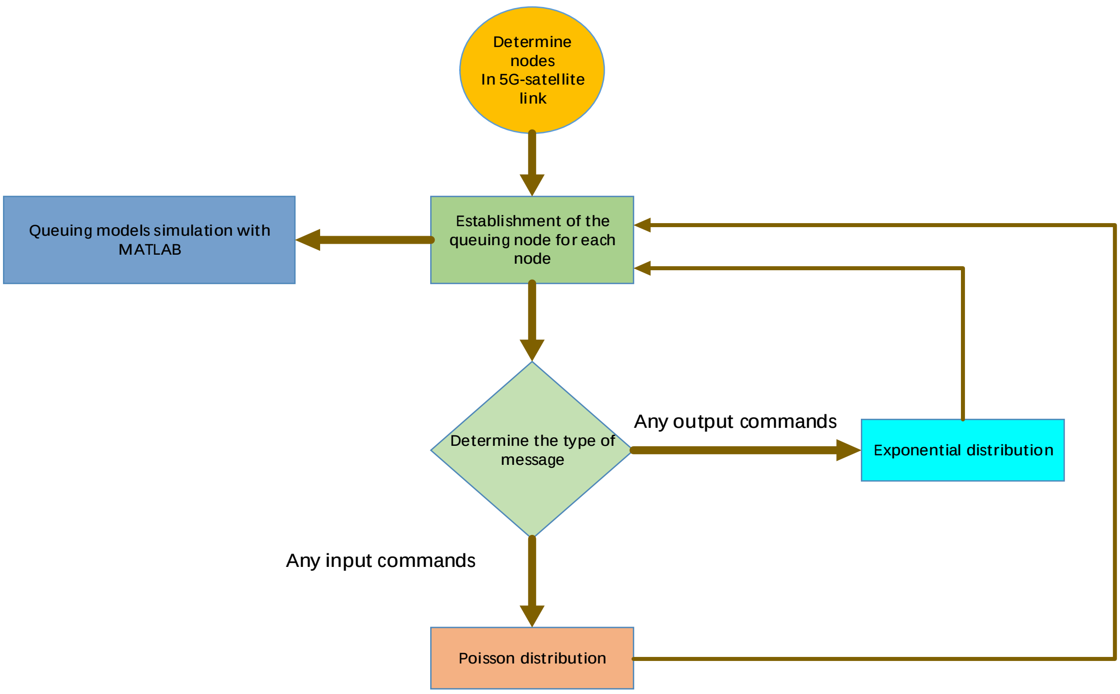

Fig. 1. Algorithm model for 5G-satellite

The National Aeronautics and Space Administration (NASA) have been experimenting with the use of Internet protocols for satellite communications [6-7]. However, a number of issues have to be resolved before IP can be efficiently used in satellite networks. However, there exists a substantial challenge to be faced and overcome in supporting system performance, reliability, and resource management that are significant for IP-enabled satellites. In this paper, Signaling protocol was introduced by working group of the Internet Engineering Task Force (IETF) and International Telecommunication Union (ITU) Study Group [8-11]. There are several ongoing discussions on the QoS in Signaling protocol base Network within IETF and other research communities. QoS provides control over congestion management, Queue management, Traffic shaping and policy and Link efficiency. As show in Fig.(2), for call setup over satellite, Key contribution in this paper is obtaining a better understanding of the performance of the signaling protocol structure with presence bandwidth manager. V.K.Gurbani, L. Jagadeesan, V.B. Mendiritta, [12] came up with an analytical SIP based performance and reliability model, in which they primarily considered the mean response time and the mean number of jobs in the system. They modeled a Session Initiation Protocol (SIP) proxy server as an open feed forward queuing network and analyze the queuing delay and queuing delay variation using embedded Markov chains in a M/M/1 queuing model for Performance and Reliability in SIP network.Wu et al. [13] analyze the queuing delay and queuing delay variation using embedded Markov chains in a M/G/1 queuing model under varying service rates and network delays of an end-to-end native SIP network.

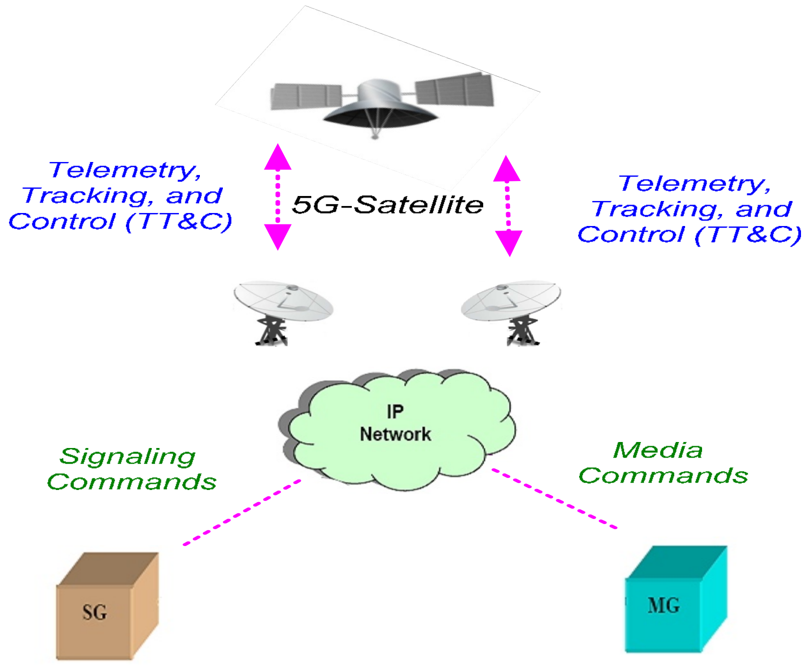

Fig. 2. Voice calls through satellite network

Ross [14] treated an M/G/1 queue with the per rule and server breakdowns having exponential inter-breakdowns and general repair times. Towsley [15] studied an M/G/1 priority queue with server failures having exponential inter failures and general repair times.

Lipson [16] presents an approach for using model checking of Markov Reward Models to analyze properties of a simple (Session Initial Protocol) SIP network. The focus is on transient properties related to the number of jobs processed prior to system failure or system repair. Rewards are expressed as simple rates of incoming requests for call setups. Suresh Kumar V. Subramanian, Rudra Dutta [10], analyze the queuing delay and queuing delay variation using embedded Markov chains in a M/M/1 queuing model and M/M/c queuing model of the SIP Proxy Server. Raja opal et al. [11] analyzed and proposed the IP Multimedia Services (IMS) network based on the SIP signaling delay predicted performance trends of the network, which allowed them to choose parameter values optimally, the proposed models were based on queuing models for the IMS network that characterizes the SIP server workload. Hajipour [17] analyzed and simulated the queuing models for different scenarios such as stateless/stateful, single/two phase call flows base on MEGACO with presence Common Open Policy Server (COPS). Hajipour [18] presented the satellite is a media gateway controller node for receiving and transmitting IP messages in a space link and a ground stations is Media Gateway node. Hajipour [19] analyzed security model for MEGACO with variation arrival rate in M/M/1 queuing model. Hajipour et al. [20] measured and compared different scenarios based on queuing theory for resource management in satellite systems.

In this paper, the new considered system model and the main assumptions are presented based on MATLAB software. The bandwidth management for security problem is developed in Section 3 where the Quality of Service (QoS) are also obtained by IETF standard. Signaling commands for the proposed system is presented in Section 4. Simulation results are provided in Sections 5 and 6 based on queuing theory which these models have two algorithms for resource allocation in middle nodes.Comparsion between different scenarios and simulation result are provided in Sections 7, 8 and. Finally, Section 9 concludes the paper.

2. Signaling protocol

As shown in Fig.(3), Signaling protocol (officially H.248) is an implementation of the Media Gateway Control Protocol architecture[10] for controlling End users on Internet Protocol (IP) networks and the Public Switched Telephone Network(PSTN). The general base architecture and programming interface was originally described in RFC 2805 and the current specific signaling protocol definition is recommendation H.248.1. Signaling protocol defines the protocol for satellite processing server to control end users for the support of multimedia streams across satellite networks. It is typically used to provide Voice over Internet Protocol (VoIP) services between IP-enabled satellites and the other configurations in space. The protocol was the result of collaboration of the Signaling protocol working group of the IETF and (International Telecommunication Union) ITU. The IETF originally published the standard as RFC 3015, which was later replaced by RFC 3525.

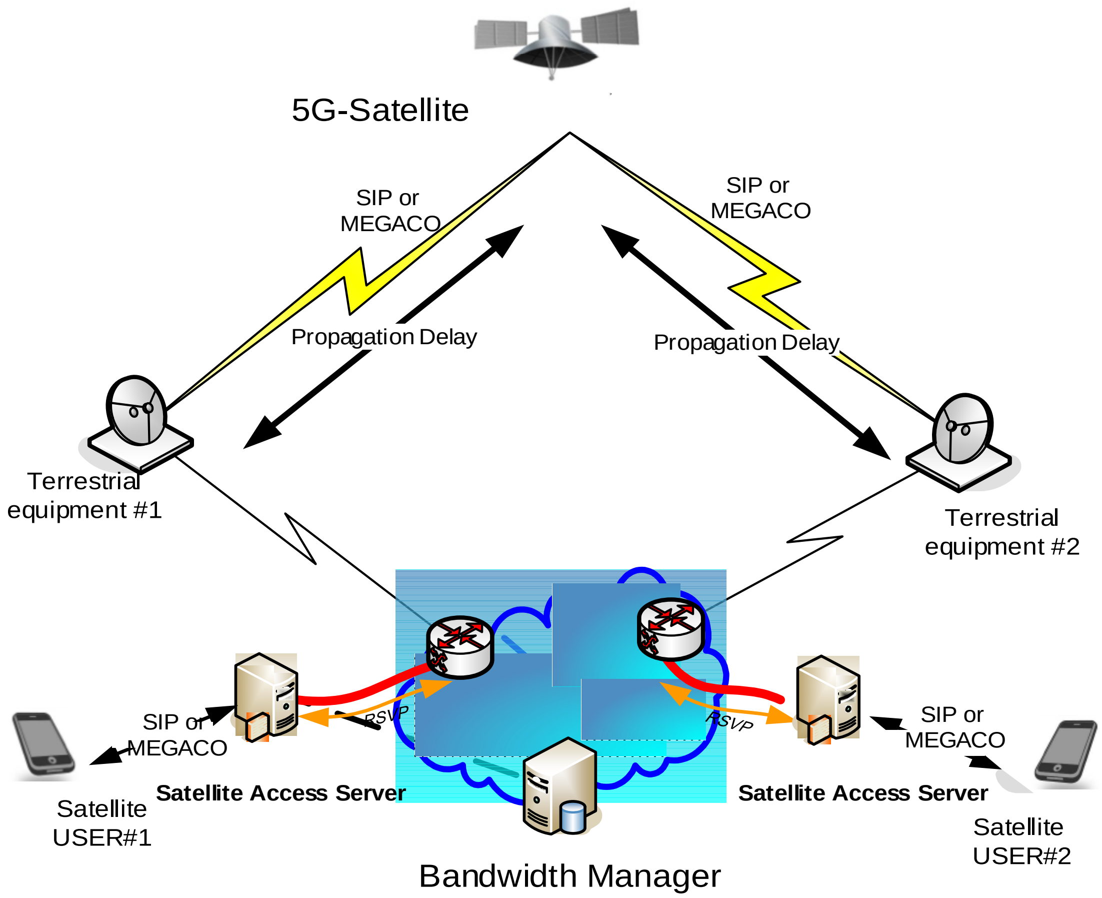

Fig.3. Satellite system with presence the Signaling Protocol

3. Using Bandwidth Manager for security policy provisioning

Bandwidth manager has been defined in the context of the IETF working group as mean to support policy control in an IP Quality of Service QoS environment and communicate policy bandwidth manager can used to carry QoS or Security information between satellite management entities and satellite terminals [21]. The underlying architectural model foresees that policy servers administrate the network communicating decision to policy clients (e.g., network elements) where the policy decisions are enforced. In particular, if IP-enabled satellites are deployed, the users can access different transport services, and this access must be administratively regulated. The topic of QoS can be found in [22-24], where the two approaches are described and compared.

4. Signaling protocol Command Set

Commands supported by the Signaling protocol are:

[Call server« satellite user]

- INVITE initiates a session between two participants.
- 100 Trying is the initial message from 5G- satellite system (IP-enabled satellite node) to satellite users for responding INVITE command.

- 183 Session Progress indicates that information about the call state is present in the message body media information.
- RESV_REQ is the initial message from 5G-satellite to Bandwidth Manager.
- RESV_UPDATE is the second message to dedicate bandwidth allocation from 5G-satellite to bandwidth management.
- RESV_OK is the second message to reserve bandwidth allocation from bandwidth management to 5G-satellite.
- COPS-RSV is the initial message to reserve bandwidth allocation from 5G-satellite to Bandwidth management.
- COPS-OK is the second message to dedicate bandwidth allocation from bandwidth management to terrestrial router.
- 200 ok is the final message.
- UPDATE is the message for any variations.
- 180 Ringing is a provisional or an informational response used to indicate that the INVITE message has been received by the satellite user and that alerting is taking place.

5. Call Flow Scenarios base resource management scenarios

5.1. Single phase call flow

In single phase model, the resource reservation and providing resources is done by the same time. In two phase model, firstly resource reservation is done and as the second satellite user is not off-hook. There isn't an available resource. Now the assumption that the routing distance of each other is so long that it can be embedded a heavy delay in queuing model for request/response commands for each scenario. Therefore, there is a heavy traffic between call server and Bandwidth Manager. If the call signaling in network sent with Best Effort service quality, we can be accepted the correct conclusion that the delay between routers with network traffic is direct ratio. Fig. (4) Illustrates stages of the proposed scenario for call setup between two satellite users. The scenario is composed of the following stages.

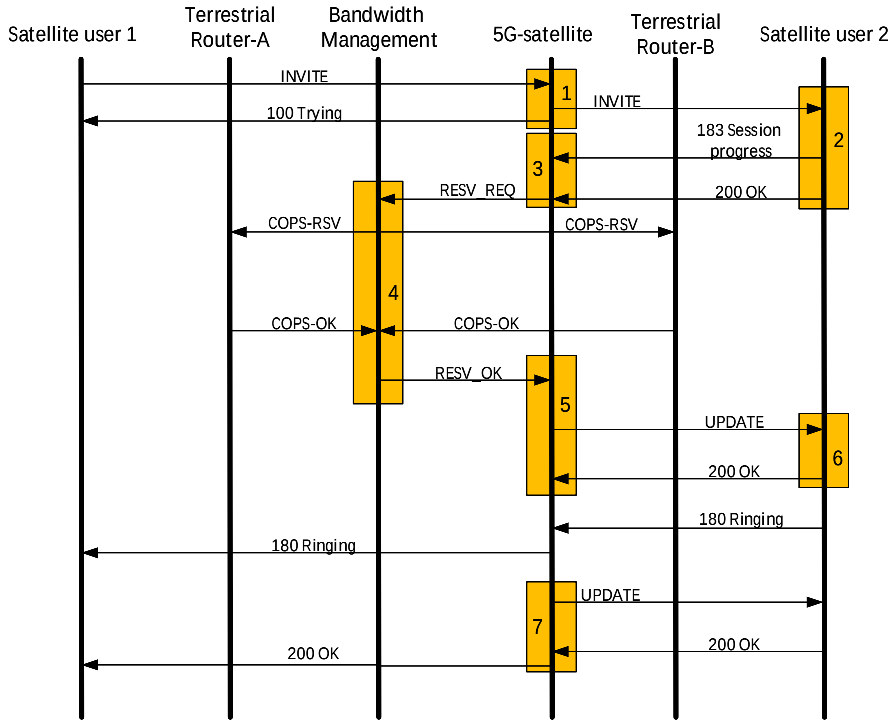

Fig. 4. Single phase call flow in 5G-satellite network

5.2. Two phase call flow

Fig. (5) Illustrates stages of the two phase scenario for call setup between two different domains in satellite system. The scenario is composed of the following stages.

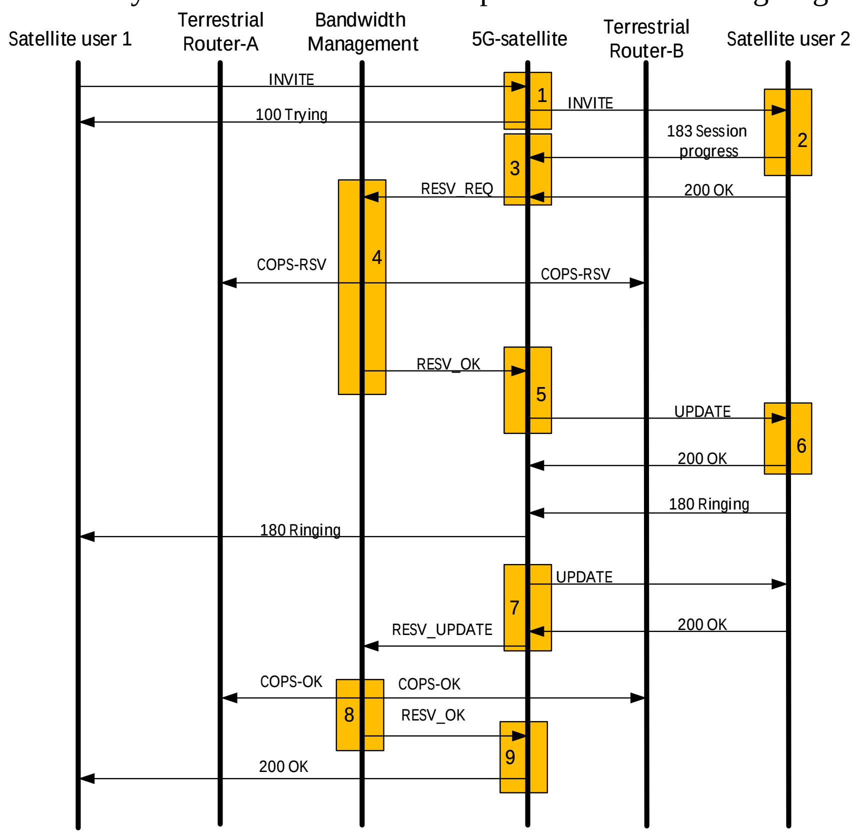

Fig. 5. Two phase call flow in 5G-satellite network

6. M/M/1 queuing model based Satellite system and Bandwidth Manager

In general, in the care of identical temporal distribution of the network tasks, increasing network capacity can decrease the number of queuing connections. On the other hand, under the condition of certain network capacity, increasing network task generation rate will lead to a boost of the queuing delay. Distribution of the arrival time determines the amount of connection requests per unit duration, while service time distribution affects the operating speed of connection requests. To build a reasonable temporal distribution model of network tasks, arrival time and service time of connection requests generated on certain distributions should be considered. Actually, plentiful approaches have been proposed in order to model large network flows as well as their superposition properties [25].In this paper, arrival times with Poisson distribution [26] and service times with lognormal distribution [27] were chosen both for their simplicity and because they provide rather general and realistic representation of large network systems.

As shown in Figs. (6, 7), To assess the usefulness of the queuing model proposed by Gurbani et al[12], we simulated this model with the heavy propagation delay for each command in call flow for up/down links in our scenarios.

1. The aggregate arrival processes are approximately by a Poisson process. this is due to the well-known property that any process which results from the superposition of a large number of independent point processes approaches a markov process, if each individual point process" thins out" within the result process.

2. The input and output processes traffic in one direction and according to Markov model, their previous values are not dependent. Call setup scenario was analyzed by M/M/1 queuing model.

3. Performance of signaling protocol was analyzed by the mean response time and the mean number of jobs in the system. "Equation (1) is", Mean response time (the difference between the times it takes for an event) sent from End user to reach call server until the final response is sent by call server to End user. Refer to "(2)", Mean number of calls is defined as the mean number of sessions that are currently in the system.

Mean number of jobs N (random variable) in the system at study state is given by the system at study state is given by currently in the system [28-31].

$$N = \sum_{k=1}^{J} \rho_k / (1 - \rho_K) \qquad \text{Where} \qquad \rho_k = \lambda_k / \mu_k \tag{1}$$

$$\lambda_j = \sum_{k=1}^{j-1} (\lambda_k Q[k, j]) \qquad \text{for} \qquad 1 < j \le J \tag{2}$$

"J" is equal to the number of stations in the queuing model. "Q" is the one step probability matrix corresponding to the queuing model; that is, "Q [i,j]" the probability that a job departing station i goes to station j. We obtained the mean response time for calls by Little's law which it is equivalent to:

$R = N/\lambda$.

4. In queuing models, only 80 percent of the INVITE messages will be successful in getting the 200 ok and 90 percent of that 183 Session progress response will get the PRACK response.

5. Queuing models are assumed as $0.5/\mu$ for sending the INVITE followed by 100 Trying, 180 Ringing and 200 ok with $0.3/\mu$ and so on.

6. The larger of two ways delay component in a satellite access system due to the location of the GEO Stationary orbit and the speed of light is the propagation delay between the satellites and the ground equipment, i.e.

6.1. Propagation delay versus Satellite Orbits

The GEO orbit is by far the most popular orbit used for IP-enabled satellites. A GEO satellite is located in a circular orbit in tee equatorial plane, at a nominal of 36000 km at a stable point, which sees the satellite at a fixed location in the sky. The propagation delay for GEO is between 220~240 (ms) which can affect network synchronization or impact voice communication.

The Medium Earth Orbit (MEO) MEO orbit is in a higher orbit, 1600 to 4200 km. However propagation delay is bigger than from previous orbits. The propagation delay over the radio link for MEO is between 64~68 (ms).

The low earth orbit (LEO), which is a circular orbit nominally 160 to 640 km above the earth. The delay is approximately 10 ms, however the satellite moves across the sky. The propagation delay over the radio link for LEO is between 8~12 (ms) [32].

7. Comparative between single phase with two phase scenario

Each of the two phase and single phase models has certain advantages. In single phase flow model exchange less signaling between network equipment and this will cause acceleration in establishing a call. While the two phase model is used to optimize network resource management and as the second end user is not off-hook, hasn't occupied bandwidth and resources providing. Depending the satellite system can be used any of the two models. In satellite system with high traffic, the two phase model is suitable because it allow better use of resources. (Figs.7,8).

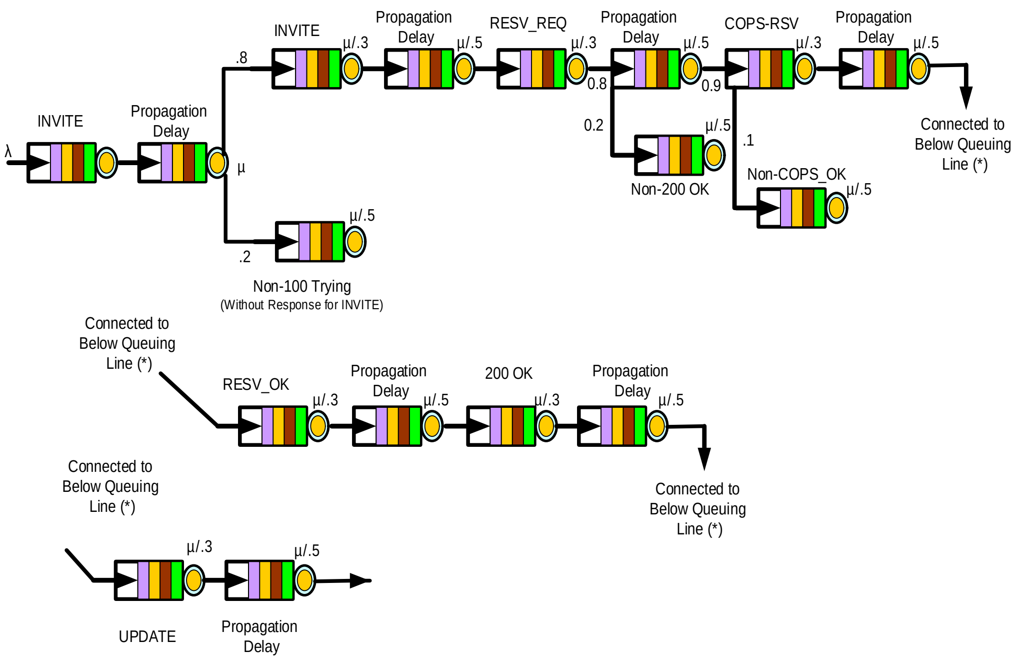

Fig. 6. Single phase queuing mode in 5G-satellite network, (μ = 0.5)

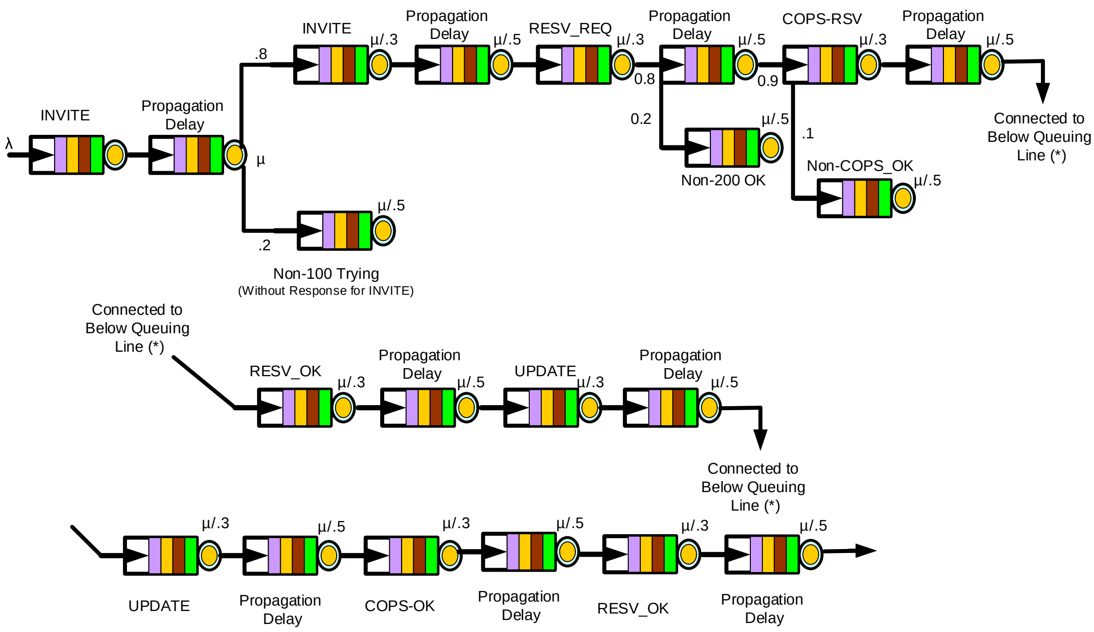

Fig. 7. Two phase queuing model in 5G-satellite network, (μ = 0.5)

8. Calculated results in 5G-Satellite networks

This paper was considered former assumption mentioned and was assumed μ = 0.5, in order to calculate system's mean response time with a propagation delay which can vary between 10 ~240 ms where the distance between end user and satellite system is different from 160 to 36000 km (Figs.8).

As one can see in Fig.9, the mean response time with variation of arrival rate is approximately linear. Also, the mean response time increases with propagation delay.

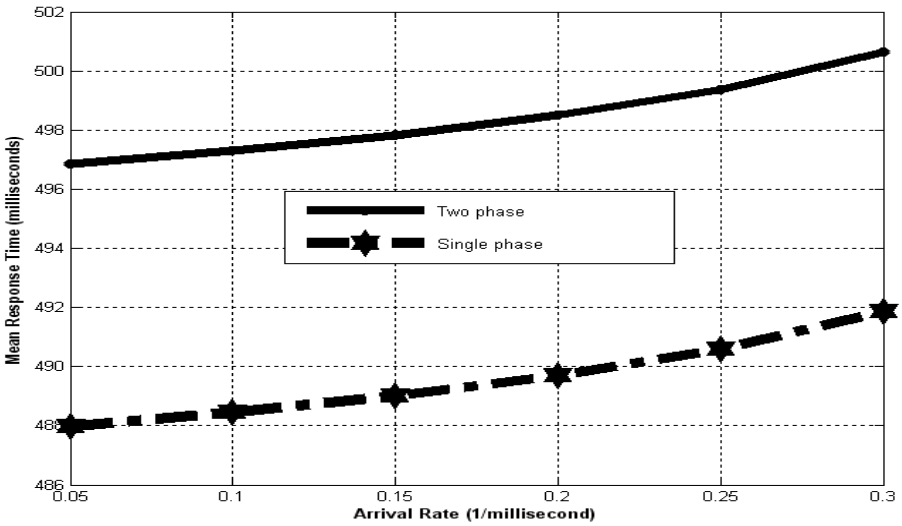

Fig. 8. Mean response time based on arrival rate (for GEO satellite system)

Mean response for Single phase (millisecond)						
Arrival rate	**0.05**	**0.1**	**0.15**	**0.2**	**0.25**	**0.3**
GEO	**488**	**488.7**	**489**	**489.7**	**490.8**	**492**
MEO	**316**	**316.7**	**317**	**317.7**	**318.8**	**320**
LEO	**260**	**260.7**	**261**	**261.7**	**262.8**	**264**
Mean response for Two phase (millisecond)						
Arrival rate	**0.05**	**0.1**	**0.15**	**0.2**	**0.25**	**0.3**
GEO	**497**	**497.65**	**497.9**	**498.3**	**499.7**	**500.4**
MEO	**325**	**325.65**	**325.9**	**326.3**	**327.7**	**328.4**
LEO	**269**	**269.65**	**269.9**	**270.3**	**271.7**	**272.4**

Fig. 9. Comparison Mean response time based on arrival rate in different orbits

9. Conclusions and Future works

In this paper, a new method for the improvement of the link based IP-enabled satellite systems was evaluated and simulated for both single phase and two phase algorithms. The proposed objective function is to qualify the arrival rates under the propagation delay constraints. The considered problem was analyzed via queuing theory. Finally, the performance of the proposed system was simulated for different orbits.

Based on the simulation and analysis, Signaling protocol was modeled by single phase or two phase with propagation delay and computed delay budget for call setup between satellite user and satellite system and used from an M/M/1 model to calculate the delay budget and key metrics that were analyzed include (end-to-end) mean response times, mean number of jobs in the system. In particular, the results show that for single server hosts and service rates of 0.5 ms^{-1}, mean response times are Incident from satellite height. Two phase model is much better than one phase model when arrival rate changed because the mean number of jobs is low but the mean response time in two models is approximately equal together when service rate changed [21].

The average response time, success call and server utilization factor of the M/M/1 model were a predictable model with significant performance improvements and also met the ITU-T standards. In future, for completing and getting most result can continue to work on redesigning this queuing model based on the multi-threaded program model. Also new work was expanded the study by redesigning the performance model with multiple satellite systems located in remote locations with respect to the propagation delays.

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