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Architecture and Performance of Satellite Configurations in Different Orbits

Pedram Hajipour

Faculty member Young Researchers and Elite Club, Islamic Azad University, Shahrerey Branch, Tehran, Iran

Hajipour@itrc.ac.ir

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Abstract

In this paper, new features of satellite configuration, Such as IP network based infrastructure and separated signaling and media are considered to propose a variety of satellite configurations in different orbits. Because of their different altitude in space such as Low Earth Orbit(LEO) and Geostationary orbit (GEO). A test bed used to test call setup delay in a one space link to process the Media Gateway Control protocol calls was reviewed. Furthermore, three different call flows is presented by M/M/1 queuing model that can be used for deploying and evaluating Next Generation Network for satellite configurations. These call flows help to verify Media Gateway Controller protocol and also allow testing and evaluating in various call set up delay time for different satellite configurations . In these simulations, a 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.

Keywords: *MEGACO, Queuing Model, SLA, FLA, HLA*

1. Introduction

The growth in use of Internet-based applications in recent years has led to telecommunication networks transporting an increasingly large amount of Internet Protocol (IP)-based traffic. Proposed satellite configurations, currently under development will be required to transport IP traffic. A case can be made for implementing IP routing directly within the satellite configuration, in order to transport IP traffic well and to provide good support for emerging IP-based Quality of Service (QoS) guarantees. This paper designs different constellation for simulation IP routing effectively within different altitudes, given known constraints on the configurations resulting from satellite mobility, global visibility, routing and addressing.

Therefore, more and more satellite providers have deemed that next generation satellite constellation would be constructed based on satellite. Considering the forthcoming popularity of satellite configurations, satellite technologies have shown its importance. While current research mainly focuses on satellite interconnection protocols and corresponding performance analysis.

A signaling protocol can be specifically optimized for the satellite configuration. Such a Media Gateway Control Protocol (MEGACO) can avoid transmitting unnecessary routing information while propagating other useful network -specific information such as internal delay, expected traffic load or instantaneous traffic load.

Internet Engineering Task Force (IETF) and ITU-T standards, has been considered a promising signaling protocol for the current and future IP services due to its simplicity and flexibility built in its security features. Most of the recent researchers like the true promise of VoIP resides with MEGACO and its ability to create and access innovative IP service applications. If IP service along with MEGACO signaling is the modern day replacement for PSTN, it should meet the same level of Quality of Service and security. There are several ongoing discussions on the QoS of IP services and MEGACO within the IETF and other research communities.

This paper is organized as follows. In section 2, addresses the related research work done in this area. In sections 3,The provides detailed MEGACO protocol history, functions and commands .In section 4, three kinds of satellite constellation are distinctively introduced as well as their applicability and performance. In Sections 5, satellite configurations are presented by queuing models and then in sections 6, Future work and addresses the concluding remarks is proposed.

2. Related Work

Hajipour [1] 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).

Wu et al. [2] analyzed the queuing delay variation using embedded Markov chains in a M/G/1 queuing model.

Lipson [3] proposed an approach to use model checking of Markov Reward Models to analyze properties of a simple SIP network. It focuses on transient properties related to the number of calls processed before system failure or system repair. Rewards are expressed as simple rates of incoming requests for call setups.

V.K.Gurbani, L. Jagadeesan, V.B. Mendiritta, [4] came up with an analytical Session Initial Protocol (SIP) based on performance and reliability model in which they primarily considered the mean response time and the mean number of calls in system. They modeled a SIP proxy server as an open feed forward queuing network and they analyze the queuing delay variation using embedded Markov chains in a M/M/1 queuing model for Performance and Reliability in SIP network.

Suresh Kumar V. Subramanian, Rudra Dutta [5], analyzed the queuing delay variation using embedded Markov chains in a M/M/1 and M/M/c queuing model of the SIP Proxy Server. Raja opal et al. [6] analyzed and proposed the IP Multimedia Services (IMS) network based on the SIP signaling delay predicted performance of the network, which allowed them to choose parameter values optimally. Their model was based on queuing model for the IMS network that characterizes the SIP server workload.

S.V.Subramanian, R.Dutta [7] designed an alternative M/D/1 performance model that enhances the SIP Proxy Server performance.

3. MEGACO Protocol

In traditional circuit-switched networks, call setups are performed primarily through the backbone of the telephone network. As a result, a proprietary signaling protocol can be used for establishing and deleting connections. Although, a well defined signaling protocol is required for VoIP because VoIP traffic is routed through the public network infrastructure. Various signaling protocols have been designed to control VoIP traffic. peer-to-peer protocols, such as SIP and H.323, have been introduced. However, for large scale deployments, these protocols have scalability problems. Hence, a new architecture for signaling protocols was proposed. The control and the media gateway components were redefined using the master/slave architecture. Figure 1 shows the evolution of the MEGACO/H.248 protocol [8, 9].

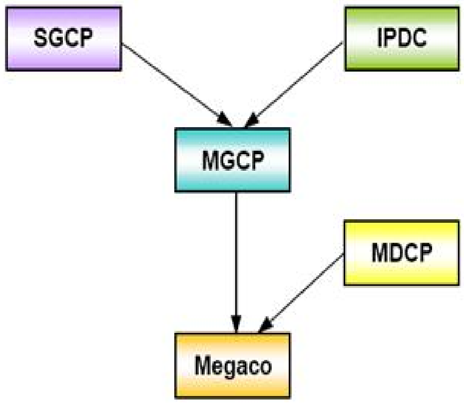

Figure 1: Evolution of the MEGACO/H.248 Protocol

As shown in Figure (2), MEGACO (officially H.248) is an implementation of the MEGACO architecture [10,11] for controlling Media Gateways on the IP networks and the Public Switched Telephone Network (PSTN). The total basic architecture and programming interface was originally described in RFC 2805 and the current specific MEGACO definition is recommendation H.248.1. It is typically used to provide VoIP services (voice and fax) between IP networks and PSTN, or entirely within IP networks.

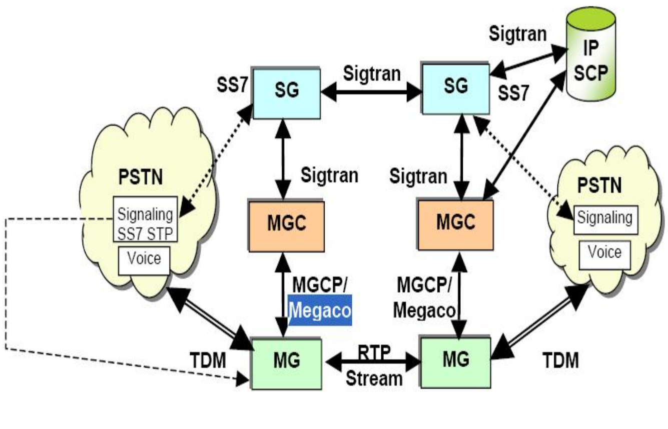

Figure 2: The MEGACO Architecture

4. Satellite Constellation Architecture

Satellite-based networking has developed in complexity over the years, rising up and building upon established work at the various networking layers as described by the (Open Systems Interconnection) OSI reference model [12].

4.1 The Comparison between LEO and GEO orbits

In order to improve the IP packet transfer performance, LEO satellite constellation by orbits much lower than GEO have been proposed. This improvement results in global coverage, more frequency reuse of limited earth-space communication spectrum and as a consequence higher system capacity, reduction in propagation delay in comparison with GEO, Although this advantages may not be significant or quantifiable in some special applications.

Use of non-geostationary orbits results in demand for satellite-to-satellite handover even for fixed ground stations. Use of inter-satellite links (ISLs) in the constellation leads to a complex orbiting mesh network topology, where permanent ISLs are established between satellites following each other in the same circular orbital plane. ISLs have added direction to illustrate crossing of orbital planes at highest latitudes, where neighbors swap places.

The trend toward complex switching and routing onboard satellite, and the network topologies created by an orbiting constellation of broadband satellites with ISLs, have produced demand for constellation networks to be able to route traffic internally over multiple satellites between sources and destinations on the ground. Although unicast transmissions, such as those for (Transport Control Protocol)TCP virtual circuits, can be supported end-to-end across any proprietary network by tunneling, implementing support for other protocols in the TCP/IP suite, particularly multicast, is less straightforward, requiring routing support in the new constellations that are described below.

The development of multiple spot beams per satellite led to on-board switching, with control of capacity allocated via circuits and a logical link control (LLC) sub layer. Development of ISLs between satellites and the design of constellations utilizing ISLs, such as Iridium, Eledesic and Space way has led to different connectivity of signaling and media between satellites and ground stations.

In order to extend the coverage area of the satellite constellation ,is analyzed following three structures:

1) Single Layer Architecture (SLA);
2) Fully Layered Architecture (FLA);
3) Hybrid Layered Architecture (HLA) [13].

4.2 Single Layer Architecture (SLA)

In SLA, every Satellite in constellation could perform signaling routing independently. Thus they have to manage signaling routing for all ground stations in configuration. A typical SLA Satellite network is shown in figure 3.

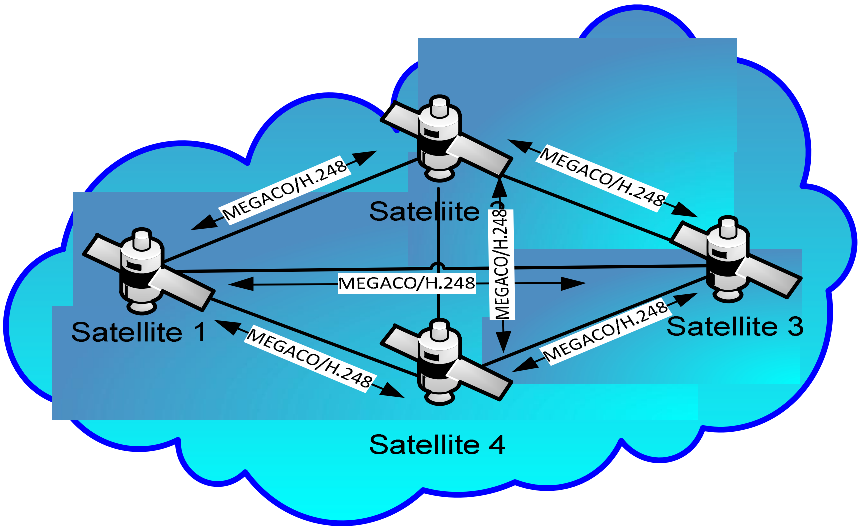

Figure 3: SLA scenario

Single layer Satellite constellation is the simplest one in all the configurations presented in this paper both on signaling and media management.
On the aspect of signaling, call setup delay takes just one hop in SLA, and signaling routing can be performed locally.
However, to support this configuration, all satellites have to maintain signaling routing for all ground stations in satellite configuration. Once a new ground station connects to the satellite network, all databases in all satellites should be updated. At the same time, signaling connection among each pair of satellite is always carried in a dedicate space link base IP for signaling connection's tremendous importance. When the number of satellites in the satellite constellation keeps growing, the number of IP tunnels will have to increase exponentially.
To analyze the performance of certain satellite configuration, a universal satellite functional block diagram is proposed shown in figure 4.

Figure 4: Universal Satellite Functional Block Diagram

In figure 4, Call state machine, with which consecutive call control operations can be organized, and following which a certain call control message can be correctly processed, is implemented in Call Control (CC). Call Control is the central part of a satellite. Ground Station Management & Routing (GSMR) will fulfill ground station authentication, authorization and signaling routing. Then the queuing constellation model for diagram in figure 4 can be composed as shown in figure 5.

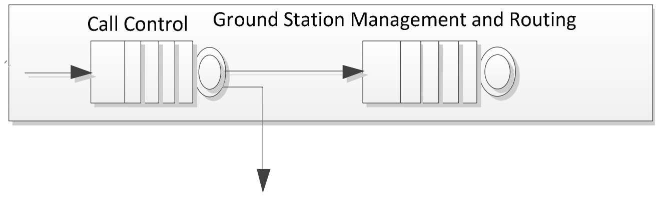

Figure 5: Queuing Network Model for satellite

In figure 5, CC queue is assumed to be an M/M/1 queuing model. Although the input process of GSMR which is the out put process of call control is no longer poissonous, since many different traffic streams are usually superimposed in the subsequent queuing models, the Poisson approximation can still be used and leads to sufficiently reliable results[14].
To calculate the call setup delay by satellite, the average service time of CC is assumed to be C; that of GSMR is τ. τ will increase along with the increase of the ground stations managed by a satellite. Then it can be given than τ=f(m), where m is the number of ground stations. The performance of SLA is analyzed in the scenario shown in figure 6.

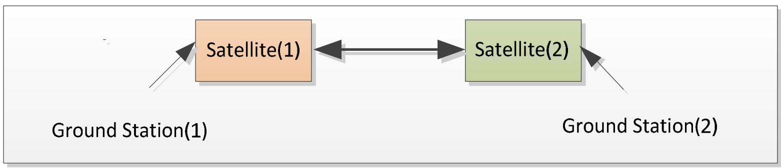

Figure 6: Example OF SLA

Now, let

1) The rate for call setup delay requests arriving at a satellite will linearly increase according to the increasing of the ground stations directly connected to a satellite.
   Let λ denote the rate for call setup delay requests, then $\lambda=\alpha.m$, where m is the number of ground stations.
   Furthermore, base on the traffic theories of telecommunication networks, α cab be given by
   α=(Traffic $_{\text{Single Subscriber}}$/Time Length $_{\text{Average Call}}$)where Traffic $_{\text{Single Subscriber}}$ is the traffic of a single ground station and Time Length $_{\text{Average Call}}$ is the average length of time for a call[15].
2) R is the ratio of the number of outgoing calls to the total number of calls.
3) The number of ground stations directly connected to both satellite 1 and satellite 2 is m.
4) The transfer delay of signaling messages over IP backbone is d.
5) The total number of ground stations in satellite network M.

Base on above assumptions, the queuing model for the scenario shown in figure 6 is produced. In figure 7, the dashed line illustrates the path of a call setup delay message to pass the soft switch network. Then, the call setup delay T is given by equation”(1)”:

$$T = T_{CC\ 1} + T_{SMR\ 1} + T_{CC\ 2} + d \tag{1}$$

Where T_{CC1}, T_{GMSR1}, T_{CC2} are the delay of CC1, GMSR1 and CC2.

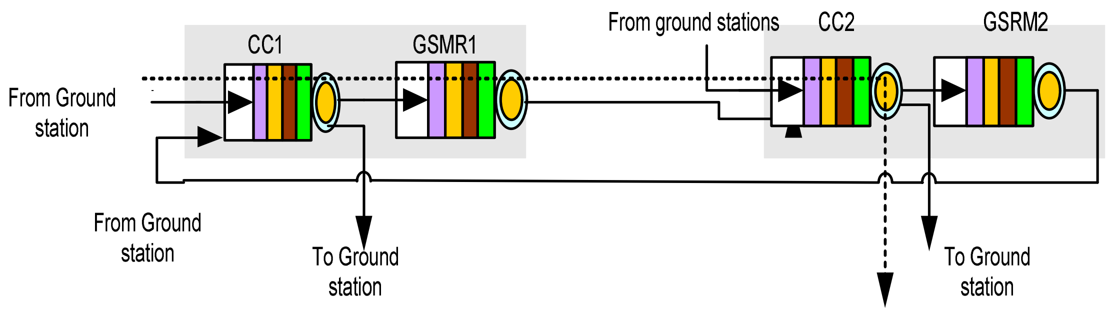

Figure 7: SLA Queuing Model for Satellite

The arriving rate and the service rate for each queue in figure 5 are summarized in table 1 and table 2.

Table1: Arriving rate of each queue (SLA)

λ_{CC1}	λ_{SMR1}	λ_{CC2}	λ_{SMR2}
(1+r)αm	rαm	(1+r)αm	rαm

Table 2: Service rate of each queue (SLA)

μ_{CC1}	μ_{SMR1}	μ_{CC2}	μ_{SMR2}
1/C	1/f(M)	1/C	1/f(M)

It is known from [16] that the delay of CC1 as an M/M/1 queuing model can be given by equation"(2)":

$$T_{CC\,1} = \frac{1}{\mu_{CC\,2} - \lambda_{CC\,2}} = \frac{C}{1 - C(r+1)\alpha m} \tag{2}$$

Similarly, T_{SMR1} and T_{CC2} are given by equations"(3,4)":

$$T_{SMR\ 1} = \frac{1}{\mu_{SMR\ 1} - \lambda_{SMR\ 1}} = \frac{f(M)}{1 - ramf\ (M)} \tag{3}$$

$$T_{CC2} = \frac{1}{\mu_{CC2} - \lambda_{CC2}} = \frac{C}{1 - C(1+r)\alpha m} \tag{4}$$

4.3 Fully Layer Architecture call flow

Figures 8 illustrate stages of the Fully Layer Architecture scenario for call setup delay between many different domains by satellite configuration.

In FLA, satellite is organized hierarchically based on the range ground stations it managed and capabilities on signaling routing. Low orbit satellite manages ground stations directly connecting to it, while high orbit satellite manages ground stations connecting to all its subordinate satellite. Being alike to routing servers, high orbit satellite could manage ground stations and signaling routing information in a larger granularity than low orbit satellite. In FLA, both signaling connection and media connection between two low orbit satellites will be via their higher orbit satellite as shown in figure 8. FLA is exactly the same as the architecture of existing satellite networks. Although this architecture might lose some advantages of satellite, such as a single hop media connection, existing techniques and tools, especially on billing and network management, can be inherited into satellite network.

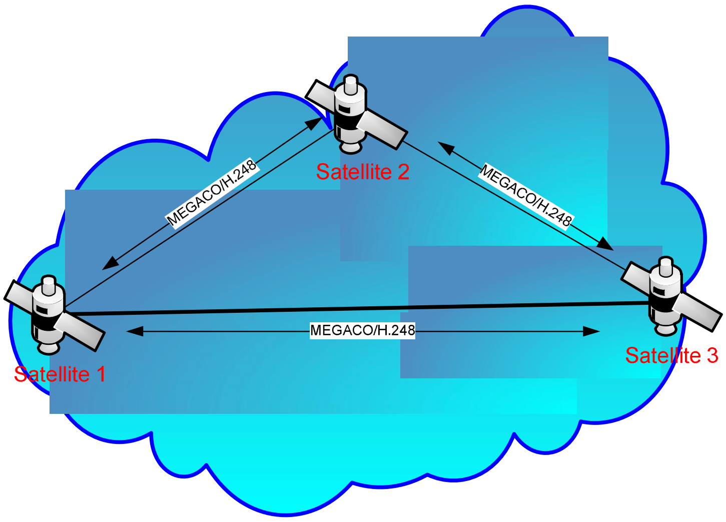

Figure 8: FLA scenario

In figure 9, satellite 0 is a high level satellite, which does not access ground stations directly, but has to perform call processing.

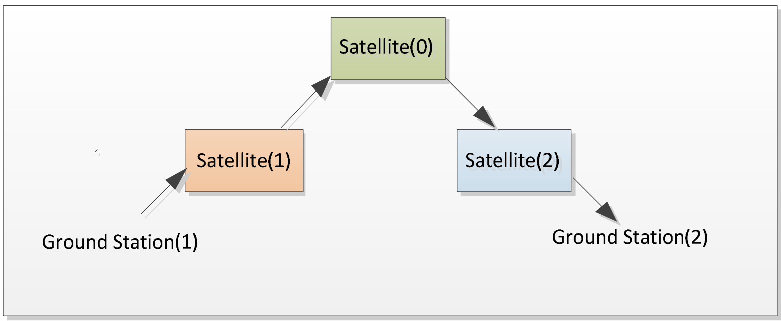

Figure 9: Example OF FLA

There for, the queuing constellation model can be adopted for satellite 0.The queuing model for FLA is shown in figure 10.

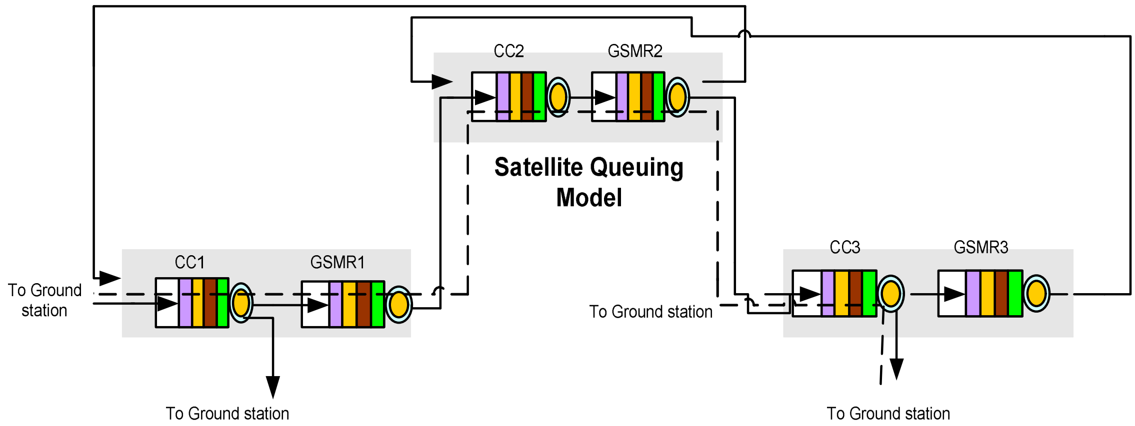

Figure 10: FLA Queuing Model for Satellite

In figure 10, the dashed line illustrates the path of a call setup delay message to pass a Satellite configuration. Then, the call setup delay T is given by equation"(5)":

$$T = T_{CC1} + T_{SMR1} + T_{CC0} + T_{SMR0} + T_{CC2} + 2d \tag{5}$$

Where T_{CC1}, T_{GSMRI}, T_{CC0}, T_{GSMR0}, T_{CC2}, T_{GSMR} are the delay of CC1, GSMR1, CC0, SMR0, CC2 and GSMR2. The arriving rate and the service rate for each queue in figure 10 are summarized in table 3 and table 4.

Table 3: Arriving rate for each queue(HLA)

λ_{CC1}	λ_{SMR1}	λ_{CC0}	λ_{SMR0}	λ_{CC2}	λ_{SMR2}
(1+r)αm	rαm	2rαm	2rαm	(1+r)αm	rαm

Table 4: Service rate of each queue (HLA)

μ_{CC1}	μ_{SMR1}	μ_{CC0}	μ_{SMR0}	μ_{CC2}	μ_{SMR2}
1/C	1/f(m)	1/C	1/f(M,m)	1/C	1/f(m)

With the same methodology used to calculate the call setup delay for FLA, the call setup delay for the example shown in figure 9 can be given by equation"(6)":

$$T = \frac{2C}{1 - C(r+1)\alpha m} + \frac{f(m)}{1 - r\alpha m f(m)} + \frac{C}{1 - 2Cr\alpha m} + \frac{f(M,m)}{1 - 2r\alpha m f(M,m)} + 2d \tag{6}$$

4.4 Hybrid Layer Architecture call flow

Figure 11 illustrate stage of the HLA scenario for call setup delay between many satellites by MEGACO network.
The concepts of "domain" and "region" are introduced into the HLA. A satellite manages all ground stations and signaling routing information in domain it resides. In a satellite domain, SLA is adopted. And a satellite region is composed of many satellite domains. Two satellites residing in same satellite region but two different domains will rely on routing server or high orbit satellite for signaling routing.

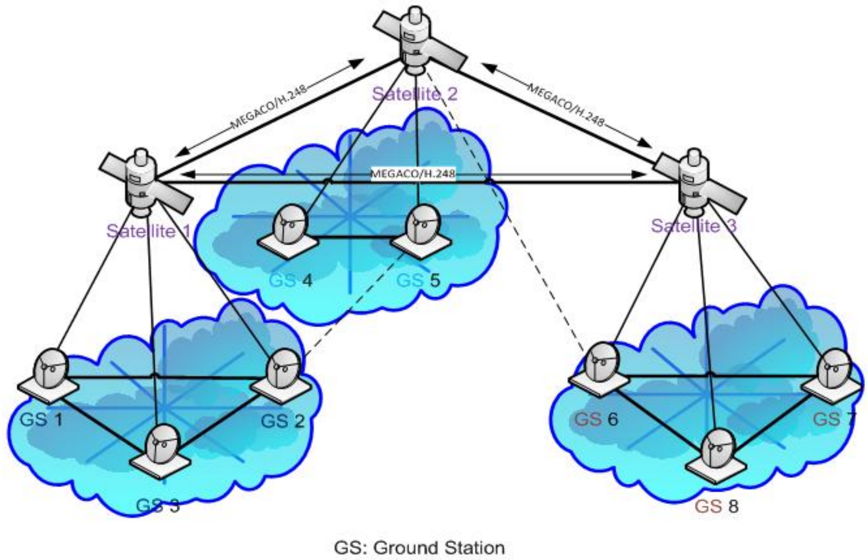

Figure 11: HLA scenario

The queuing model for HLA is shown in figure 12.

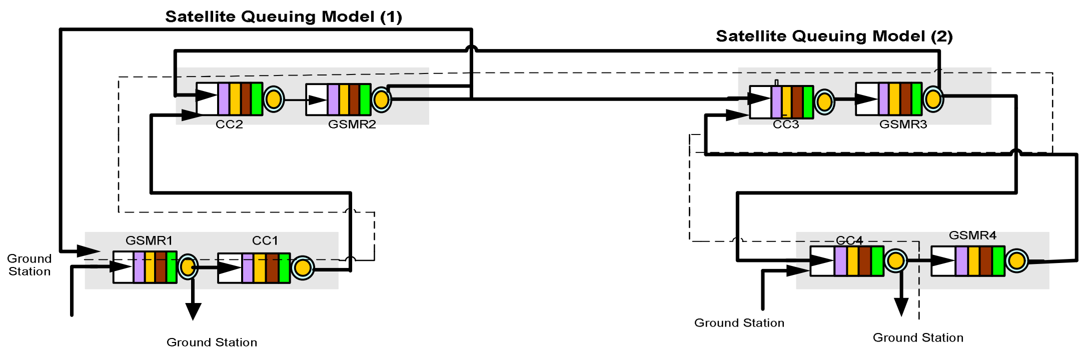

Figure 12: HLA Queuing Model for Satellite

5. Numeric Analysis based different satellite configurations

1. The input and output of Markov processes are one directional and independent to the previous values. Call setup delay was analyzed by M/M/1 queuing model.
The Call setup delay is based on equation"(7)":

$$T = \frac{1}{\mu - \lambda} \tag{7}$$

Which μ is arrival rate and λ is service rate.
2. In queuing model are assumed as 0.5/μ for sending the request followed by reply and modify request and modify reply with 0.3/μ.
3. Up to 10000 ground stations could directly connect to a single satellite, m is 10000.
4. 20 percent of calls are outgoing calls, r is 0.2.

5. The average service time for call control module is 0.03s, C is 0.03s.
6. The average time used to inquire a subscriber in a satellite will linearly increase according to the increasing of the size of subscriber database. It means τ=f (m), where $\alpha=4.3\times10^{-8}$.
7. d is 0.025s
In order to calculate system's call setup delay and mean number of ground station with propagation delay varying between 0-10 ms (Figures 13,14).
Each 100 miles is assumed to be equivalent with 1ms delay. As one can see the call setup delay with variation of number is approximately linear for HLA, FLA but SLA is exponential behavior with increasing ground station numbers.

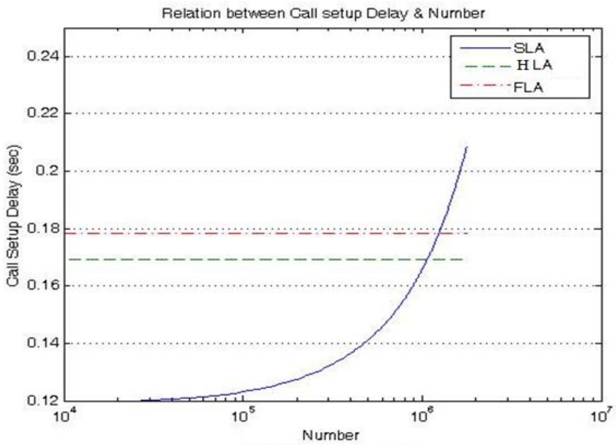

Figure13: Call setup delay based on ground station

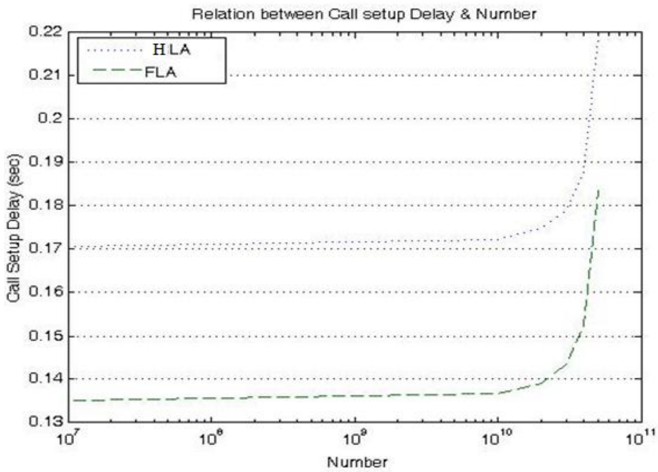

Figure14: Comparative between HLA and FLA base ground station

6. Conclusion and Future works

Based on the measurements and analysis, satellite network architecture was modeled by three different models with presence of propagation delay in queuing model. Therefore we understand the call setup delay for SLA is much smaller than HLA and FLA and the HLA and FLA models have approximately the same behavior. In future, we continue to work on redesigning this queuing model based on the multi threaded program model, that is instead of M/M/1 or M/D/1 queuing model, we intend to focus on M/M/C or M/D/C or the combination of both. Also intend to expand the study by redesigning the performance model with multiple satellite located in remote locations and factor the network delays.

7. References

[1] P. Hajipour, K. Abbasi shahkoh,"Characterizing Reservation Management for Media Gateway Controller (Performance and Reliability)", Journal of Advances in Computer Research (JACR), ISSN 2008-6148,pp. 73-89,August 2012.

[2] V.K.Gurbani, L. Jagadeesan, V.B. Mendiritta,"Characterizing the Session Initiation Protocol (SIP) network (Performance and Reliability)", ISAS 2005: LNCS 3694, pp. 196-211, April 2005.

[3] J-S. Wu and P-Y Wang, "The performance analysis of SIP-T signaling system in carrier class VoIP network", proceedings of the 17th IEEE international conference on Advanced Information Networking and Applications (AINA), 2003.

[4] F.Lipson,"Verification of Service Level Agreements with Markov Reward Models, south african telecommunications networks and applications conference, September2003.

[5] S. kumar, V. Subramanian, R. Dutta," Measurements and Analysis of M/M/1 and M/M/C Queuing Models of the SIP Proxy Server IP Communication Business Unit", CISCO systems, Research Triangle Park ,USA, 2008.

[6] N. Rajagopal, M. Devetsikiotis, "Modeling and optimization for the design of IMS Networks", proceedings of 39th Annual. Simulation symposium. (ANSS06), Huntsville, Alabama, USA, April 2006.

[7] S. V. Subramanian, R. Dutta, "Comparative Study of M/M/1 and M/D/1 Models of a SIP Proxy Server", australasian telecommunications networking and application conference. (ATNAC), Adelaide, Australia, December 2008.

[8] T.Taylor, "MEGACO/H.248: a new standard for Media Gateway Control," IEEE Communications Magazine, pp.124-132, October 2000.

[9] N. Greene, M. Ramalho and B. Rosen, "Media Gateway Control Protocol architecture and requirements", RFC 2805,April 1999.

[10] F. Cuervo, N. Greene, A. Rayhan, C. Huitema, B. Rosen and J. Segers, "MEGACO protocol version 1.0", RFC 3015,November 2000.

[11] N. Greene, M. Ramalho, B. Rosen, RFC 2805, "Media Gateway Control Protocol Architecture and Requirements", IETF, April 2000.

[12] ISO. Basic reference model for Open Systems Interconnection. ISO7498, Recommendation X.200 of the International Telecommunications Union, 1984.

[13] X. Peng, S.Sen C. Junliang, "Architecture and Performance of Soft switch Networking," proceeding of International Symposium on Communications and Information Technologies (ISCIT), pp. 54- 59, 2005.

[14] G. Willmann, P.Kuhn, **"**Performance Modeling of Signaling System No.7**"**, IEEE Communication Magazine, July 1990.

[15] Z. Jiongpan, "Theory of Telecommunication Networks", ISBN:7-115-04600-X, 12, 1991.

[16] G. Bolch, S. Greiner, S. Trvedi, "Queuing Networks and Markov Chains", John Wiley& Sons, Inc, 1998.