# Characterizing Reservation Management for Media Gateway Controller
## (Performance and Reliability)

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**Abstract**

*In this paper, analysis and simulation of Media Gateway Controller (MEGACO) based COPS (Common Open Policy Server) which is a protocol defined in IETF (Internet Engineering Task Force) to transport configuration requests and deliver the policies is presented. For this scenario, three queuing models include M/M/1, M/M/c and M/D/c were applied . Then, some of the key performance benchmarks look likes mean response time to process the MEGACO calls and mean number of MEGACO calls in the system was reviewed. In the following, the comparison between them was performed.*

***Keywords:*** *MEGACO, COPS, Reliability, queuing models*

## 1. Introduction

Voice over IP (VoIP) means that voice calls are transmitted over an IP network such as the Internet instead of Public Switched Telephone Networks (PSTN). Since access to the Internet is available at more and more places in the world, it is possible to use VoIP in a higher degree. The focus on this paper is to study performance from the viewpoint of VoIP about MEGACO call flow. VoIP’s Benefits and disadvantages are considered and future panorama is given. At the beginning an overview to VoIP is given: history, protocols and standards, technical aspects, advantages and disadvantages. Secondly future visions and few implementations are described.

In recent years, The MEGACO/H.248 signaling protocol employs a call control concept. The call control “intelligence” or the master server resides in the Media Gateway Controller (MGC), while the Media Gateway (MG) serves as the slave device (dumb terminal). This concept reduces the complexity of the gateway and making it simpler and more suitable for mass deployment. six MEGACO commands are implemented which are: Add, Audit Capabilities, Audit Value, Modify, Notify, Service Change, and simultaneously.

We verified some signaling commands and simulated the MG registration and call-establishment scenarios. According to the simulation of an M/M/1 queuing model which was proposed in [1,2], we obtained the bandwidth management results of our proposed call flow and considered a single MGC in this model to avoid the propagation delay between the MGCs.

parameters such as Call Set-up Delay (CSD), call misrouting probability and call set-up failure probability [3], which are mainly dependent on call processing nodes' performance.

In this paper we present signaling call flows based on the architecture proposed by ITU for different resource control schemes. The CSD is simulated and the resource control schemes are compared based on their performance in various network traffic. Following this, the optimum points for choosing the best scheme can be found.

According to the aim of research, the paper is structured as follows: Section 2 covers existing work related to queuing models in network. Section 3 provides a brief background on the history of MEGACO network and presents an infrastructure model with MEGACO commands. Section 4 describes an architecture model for MEGACO. Section 5 introduces a mechanism for resource management by COPS protocol. Section 6 details the comparative study of the results of the MEGACO models. Finally, in conclusion, research observations and future work in this area in addition to the results from the performance analysis were summarized.

## 2. Related Work

Hajipour [4] analyzed security model for MEGACO with variation arrival rate in M/M/1 queuing model. Dehestani [5] analyzed Quality of call setup in two different domains by M/M/1 and $M/E_r/1$ queuing delay models. Wu et al. [2] analyzed the queuing delay and queuing delay variation using embedded Markov chains in an M/G/1 queuing model. Our work, by contrast, analyzes performance under varying service rates and network delays of an end-to-end native MEGACO network.

Gurbani and et.al [1] 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 calls in the system. They modeled a SIP proxy server as an open feed forward queuing network. Also, they analyzed the queuing delay and queuing delay variation using embedded Markov chains in the M/M/1 queuing model for Performance and Reliability in SIP network. Suresh Kumar and et.al [6] analyzed the queuing delay and queuing delay variation using embedded Markov chains in the M/M /1 queuing model and M/M/c queuing model of the SIP Proxy Server.

The main part of current international research activities in this field is being actively discussed in ITU.T, ETSI and IETF. Also some individual projects have been defined and executed . The following subsections give an overview of the main activities in ETSI and IETF.

**ETSI:** ETSI NGN architecture is based on the IMS (IP multimedia subsystem) specification delivered by 3GPP (The 3rd Generation Partnership Project), which is the 3rd generation mobile network organization.

Telecommunications and Internet converged Services and Protocols for Advanced Networking (TISPAN) as a technical and standardization body of ETSI, developed the IMS architecture to fit the specific requirements of

fixed-line networks. TISPAN presented a functional architecture for network resource management in the access and aggregation networks called Resource and

Admission Control Subsystem (RACS).

The RACS is responsible for elements of policing control, including resource reservation and admission control in the access and aggregation networks [7].

**IETF:** In the Internet Engineering Task Force (IETF), current QoS control work is focused on resource management and QoS signaling protocol completion, deployment, operation and refinement. Two framework QoS solutions were proposed by IETF: resource reservation (Integrated Services - IntServ) and service classification

(Differentiated Services -Diffserv). QoS signaling mechanisms were developed inside these frameworks. Currently, the IETF QoS policy framework considers policies of the network operator aimed at automated DiffServ and IntServ configurations [8].

## 3. MEGACO/H.248 Protocol

The MEGACO definition is recommendation H.248.1. MEGACO defines the protocol for Media Gateway Controllers to control Media Gateways to support multimedia streams across computer networks. It is typically used to provide Voice over Internet Protocol (VoIP) services (voice and fax) between IP networks and PSTN, or entirely within IP networks. The protocol was the result of collaboration of the MEGACO working group of the Internet Engineering Task Force (IETF) and International Telecommunication Union (ITU) Study Group 16. The IETF originally published the standard as RFC 3015 which was later replaced by RFC 3525.

## 4. Design Architecture

We have designed two core modules for the MEGACO/H.248protocol: MGC and MG [9].

### *4.1 MG Architecture*

As you seen in Figure1, The MG consists of five components: Message Receiver (MR), Message Processor (MP), Message Sender (MS), User Interface (UI) and Voice Generator (VG). Figure 6 illustrates the architecture of the MG.

The Message Processor is built to handle any commands sent from the MGC. The User Interface component initiates various events, such as off-hook, flash-hook, and on-hook. Once an event is initiated the corresponding event notification message is sent to the MGC via the Message Processor and the Message Sender.

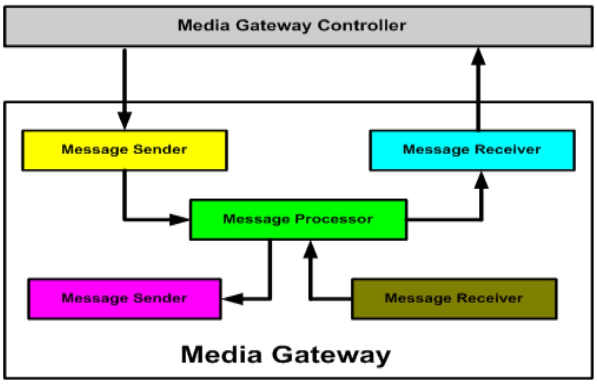


***Figure 1. MG Design Architecture[8]***

The Voice Generator is responsible for generating voice packets upon call establishment. Then, these voice packets are encapsulated into the RTP payload and sent over the network .Similar to the MGC, communications between MG components are accomplished through local function calls.

### *4.2 MGC Architecture*

The MGC consists of three main components as shown in Figure2, Message Receiver (MR), Message Processor (MP), and Message Sender (MS).

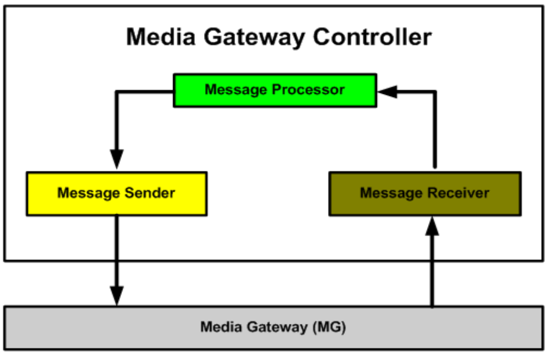


*Figure 2. MGC Design Architecture[8]*

### *4.3 MEGACO/H.248 Command Set: The commands supported by the MEGACO/H.248 protocol are[9,10]*

[MGC↔ MG]

- Service Change – Notify the responder of the new service state

[MGC ↔MG]

- Audit Value – Determine the characteristics of an endpoint
- Audit Capabilities – Determine the capability of an endpoint
- Add – Add a connection
- Modify – Change a connection characteristic
- Subtract – Tear down a connection
- Move – Move an endpoint from one connection to another connection (call-waiting)

[MG ↔ MGC]

- Notify – Notify the responder of an event (on hook)

## 5. COPS Protocol (Bandwidth Manager)

As seen in Figure 3, The Common Open Policy Service (COPS) protocol has been defined in the context of the IETF RAP working group as mean to support policy control in an IP Quality of Service (QoS) environment.

The COPS protocol is a protocol to create policy for reservation of resources. This process begins with a NOTIFY Request from MG1 to MGC to establish a call. For this purpose, MG1 sends Off-hook signal to MGC, then MGC sends NOTIFY Reply for MG1.

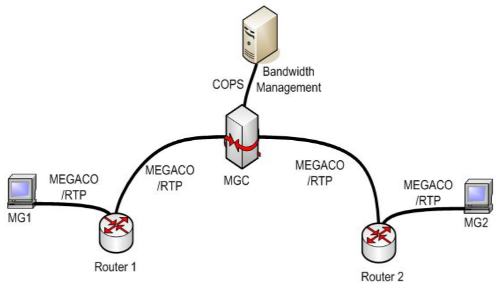


***Figure 3. MEGACO Call with Bandwidth management in different domain***

## 6. Call Flow Scenarios

In this section, we want to evaluate MGC in stateless and stateful situations:

As seen in Figure 4 , This model due to MGC database has not prior information about signaling MG2. Thus, MGC does not act for processing on the MG1 messages and it sends directly to the MG2. All messages which are received from the MG2 will forward directly to the MG1.

There are two different kinds of MGCs, i.e. stateful and stateless. A stateless proxy is a “simple message forwarder", as described in the MEGACO standard. When receiving a request, the stateless MGC forwards the message in a stateless fashion; without saving any transaction context. This means that once the message is forwarded the MGC “forgets” ever handling this message [12,13]. These kinds of MGCs typically are used in offices and enterprise solutions.

When stateful, the MGC processes transactions rather than individual messages. The MGC manages two types of transactions; server transactions to receive requests and return responses, and client transactions to send requests and receive responses. An incoming request is processed by a server transaction and then forwarded downstream by one or more client transactions. An incoming response is received by the matching client transaction and forwarded back to the MGC.

Since their input and output processes traffic in one direction and according to Markov model, their previous values are not dependent. We use the M/M/1 queue model to analyze call setup scenario. The traffic model is considered in each process requiring information processing. this model has been considered for establishing a call between the Media Gateways with Bandwidth Management caused by COPS.

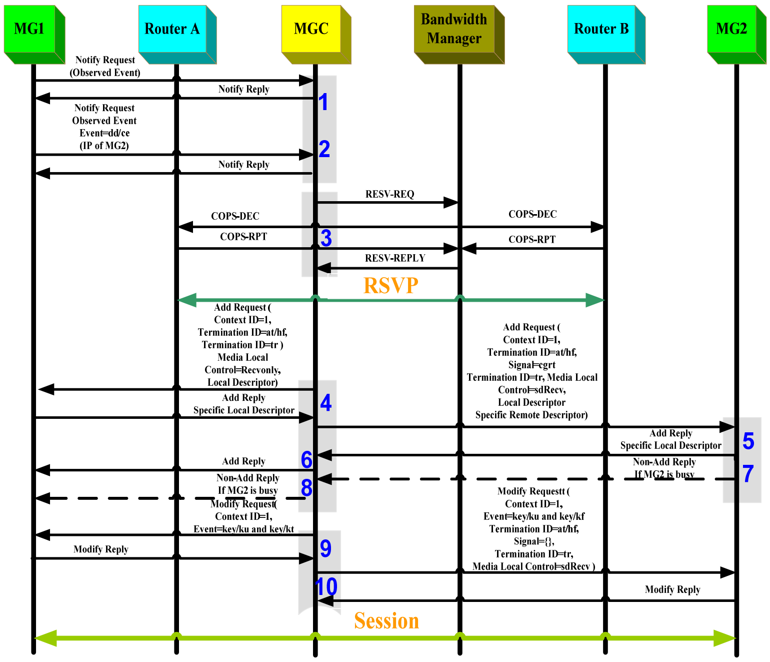

*Figure 4. Stateless call flow base MEGACO[17]*

As you seen in Figure 5, This model due to the MGC‘s database has prior information about signaling MG2. Therefore, in status which systems or call flow scenario is serving, it is better to use stateful model, because, mean response of time will be less and performance of call flow will be better. Also, system will

have better MOS than stateless from subscriber view. Before sending each message to MG1, MGC checks signaling status; If MG2 is busy, MGC will send message to MG1 for this reason and if establishing time is finished for a call, MGC will inform both MGs.

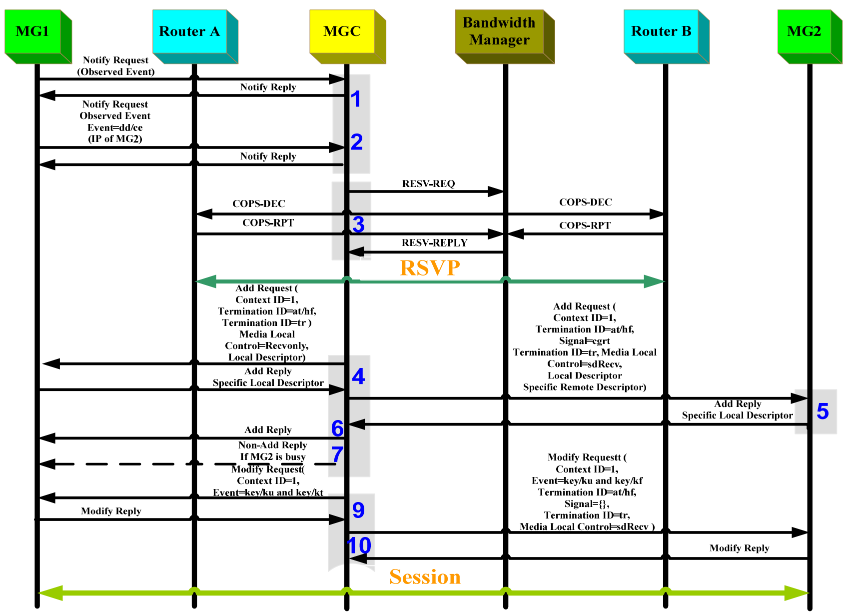

*Figure 5. Stateful call flow base MEGACO[17]*

### *6.1 Queuing model based in Stateless and Stateful situation*

Most of the researches in VoIP related to MEGACO are focused on engineering principles, protocol definitions, enhancement and other improvement [10, 13]. A few researches are done in the area of performance modeling of MEGACO. Many of IP telephony industries have been focusing on various MEGACO and MGC performance metrics. Here we propose analytical queuing models which there are *n* successive queues in order to process various MEGACO packets with deterministic service time. They primarily considered the mean response time and the mean number of jobs in the system to analyze performance and reliability of MEGACO protocol. Mean response time of a MGC is the difference between the time it takes for an NOTIFY Request sent from MG1 to reach MGC until the final response is sent by MGC to MG1. Mean number of jobs is defined as the mean number of sessions which are currently in the system. They modeled a MEGACO as an open feed forward queuing network. The MGC is modeled as queuing with *n* queues.

Each queuing station is modeled as an M/M/1 queue. The first M, which represents the arrival distribution, is memory less. The arrival of one call request is independent of other requests. The second M, representing the serving distribution, also is memory less. The serving time of a message is independent of all other messages. The 1 means there is only one server in a system. This model is an open, feed forward queuing network, since jobs arrive from an outside source, and there is no feedback among queuing stations in the queuing network.

The service rate of each queue ($\mu_i$) depends on the processing performance of the related node (proxy) and the message type. The arrival rate ($\lambda_i$) depends on the number of network subscribers, offered traffic per subscriber and mean call holding time.

In the next subsections, the queuing model and the simulation results for two different modes i.e., stateful and stateless are presented.

"In equation"(1)", Mean number of jobs for the M/M/1 queuing based MEGACO model can be obtained from any standard work [14] and is as follow:

$$N = \sum_{K=1}^{J} \frac{r_K}{(1-r_K)} where\ r_k = \frac{\lambda_k}{m_k} \qquad (1)$$

$$l_j = \sum_{k=1}^{j-1} (l_k Q[k,j]) \qquad for \qquad 1 < j \leq J \qquad (2)$$

*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. The mean response time for calls is by Little's law R=N/λ. They assumed the service rate is fixed at $0.5ms^{-1}$ and the arrival rate at 0.3 $ms^{-1}$ (Alouf et al) [13,14,15].

In this time a new implementation based on a single queue with multiple servers was introduced that each packet is run through the entire processing before the next one is picked up. In other words, the entire processing for one packet is performed in one thread of execution. This is exactly amenable to modeling by an M/M/*c* queue, where c represents number of threads used and it is a constant value. All the incoming MEGACO packets are processed by different threads (allocated randomly) in parallel and forwarded to the queue until each MEGACO sessions is setup and tear down.

In equations (3,4), The mean response time and the mean number of calls for the M/M/c queuing based MEGACO model can be obtained from any standard work [7] and are as follows:

$$W = \frac{1}{m} + [l / m)^{c} . \frac{m}{(c-1)!(cm - l)^{2}}]P_0 \quad (3)$$

$$L = \frac{l}{m} + [l / m)^{c} . \frac{m}{(c-1)!(cm - l)^{2}}]P_0 \quad (4)$$

$$P_0 = [1 + \sum_{n=1}^{c-1} \frac{(c\rho)^{n}}{n} + \frac{(c\rho)^{c}}{c!} . \frac{1}{1-\rho}]^{-1} \quad (5)$$

The mean response time, the mean number of jobs and server utilization data are calculated by providing appropriate input values such as $\lambda$, $\mu$ and $c$ (only in case of *M/M/c*) based on the M/M/1 and M/M/c MGC and DIAMETER server models. We considered c = 3 (number of threads) in our M/M/c model calculations [14,15].

In this section, M/D/c was described based on MEGACO model. For all the MEGACO request and response messages, using standard approaches, arrival times are exponentially distributed. Service time have no variance and the average queue length is exactly half of M/M/c for a M/D/c queuing model [14, 15, 16].

"In equations"(6,7)", The mean response time and the mean number of calls for the M/D/c queuing based on MEGACO model can be obtained from any standard work and are as follows: ($\rho=\lambda/c\mu<1$)

$$W = \frac{1}{2mC} + [1 + \frac{cm + \lambda Cs^{2}}{(cm - \lambda)}] \quad (6)$$

$$L = \frac{l}{mC} + [2 + \frac{\lambda + \lambda Cs^{2}}{(2cm - 2\lambda)}] \quad (7)$$

Where $C_s$ the coefficient of variation is, $C_s$ is zero for the deterministic distribution M/D/c queue.

Only 80 percent of the NOTIFY Request messages will be successful in getting the NOTIFY Reply (Observed Event) and 90 percent of those Add Request (MG1, MG2) responses will get the Add Reply (MG1, MG2) responses. Remaining 20 percent of the Notify Request message will get a non- NOTIFY Reply and 10 percent of the Add Request (MG1, MG2) responses will receive a Add Reply (MG1, MG2) responses MG.

1. Queuing models are assumed as 0.5/μ for sending the Add Request followed by Add Reply, Modify Request and Modify Reply with 0.3 /μ.

2.Queuing models(Single phase and Two phases) only 80 percent of the Add Request messages will be successful in getting the Add Reply response and 90 percent of that Modify Request responses will get the Modify Reply responses (Figures 6,7).

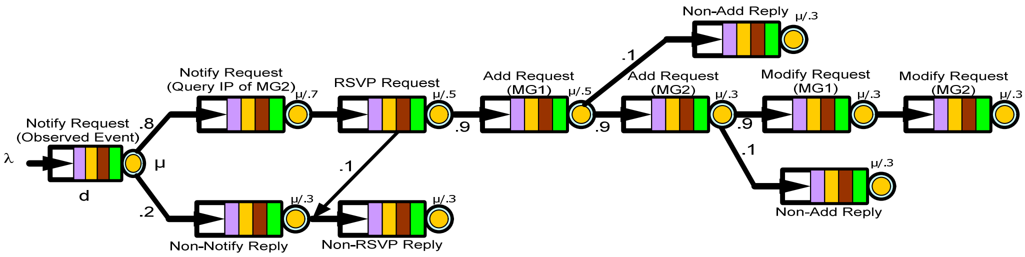


*Figure 6. Stateless Queue model*

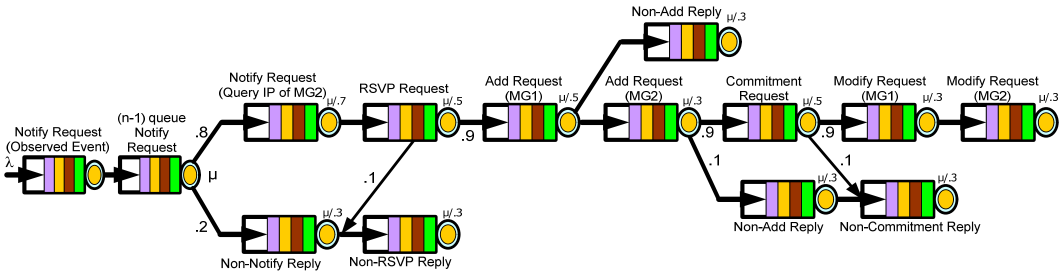


*Figure 7. Stateful Queue model*

## *6.2 Calculated results in MEGACO network with Propagation delay*

As we seen in Figures (8, 9, 10, 11), each 100 miles is assumed to be equivalent with 1ms delay. As seen, the mean response time with variation of arrival rate is approximately linear. The mean response time increases with publication delay.

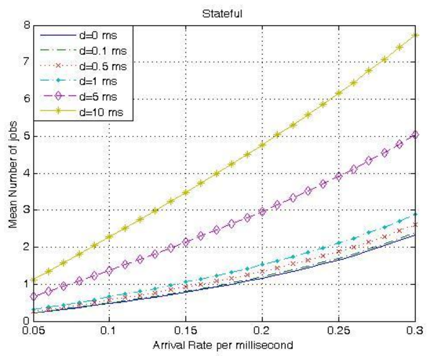


*Figure 8. Mean number of jobs base on arrival rate changes with different delays in stateful model*

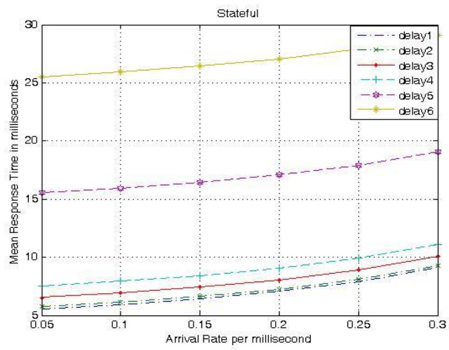


*Figure 9. Mean response time base on arrival rate changes with different delays in stateful model*

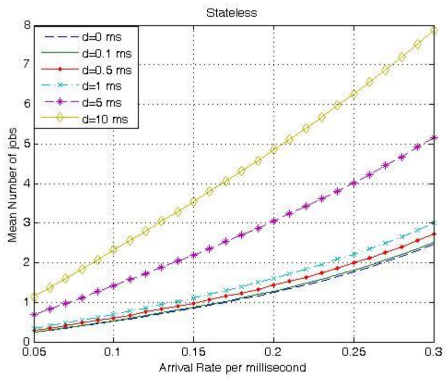


***Figure 10. Mean number of jobs base on arrival rate changes with different delays in stateless model***

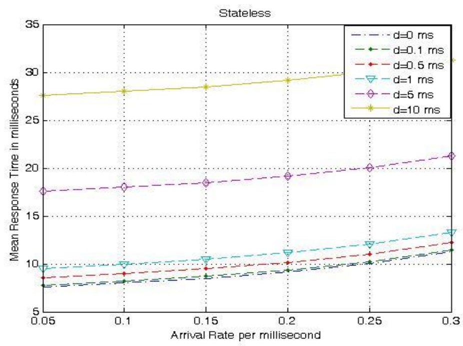


***Figure 11. Mean response time base on arrival rate changes with different delays in stateless model***

### *6.3 Comparison between stateful and stateless traffic Model in our call flow*

1. During the experiments, we observed that in the stateless model, the mean response time is much smaller when the arrival rate of the incoming packets increases compared to stateless model.

2. In both models the mean number of jobs and the mean response time increases when the call arrival rate increase. second MG does not Off-hook, access to resources is not available. Therefore, there isn’t traffic between the Media Gateway Controller and Bandwidth Manager, so there isn’t delay between two packages which send to each other node. If the call signaling in network is sent with Best Effort service quality, we can accept the correct conclusion that the delay between routers with network traffic is direct ratio[14,15].

## 7. Single and Two phase call flow

In this section, we are going to introduce two scenarios of resource reservation. **Resource control schemes:** According to the diversity of application characteristics and performance requirements, the Resource and Admission Control Functions (RACF) supports two different schemes of resource control:

**1.Single-phase scheme:** Authorization, reservation and commitment are performed in one step. The requested resource is immediately committed after a successful authorization and reservation.

**2.Two-phase scheme:** Authorization and reservation are performed in one step followed by commitment in another step. Alternatively authorization is performed in one step, followed by reservation and commitment in another step [21].

In this section, we want to evaluate resource reservation of behavior through call setup which the MGC prepare resource for communication between MGs in two different situations.

MG1and MG2 have the advantage of knowing all acceptable codec, and thus can make informed assumptions about the bandwidth to be reserved. For RSVP, each party can submit revised PATH requests should an earlier one fail.

When the MG2 is assured that the data path has been reserved in both directions, it responds with a “Modify Request” message and starts alerting the MG2.

In this and all schemes below, the resource reservation has to time out if it does not get committed.

Otherwise, malfunctioning or malicious end systems could reserve resources indefinitely and block other MG1 from using the network. Also, the network will likely have to impose a per-subscriber limit of reserved but uncommitted resources.

Ergo, resource reservation and providing resources is done at the same time.

Figure 12 illustrates the stages of the proposed scenario for call setup between two Media Gateways by MEGACO network. The scenario is composed of the following stages. This model hasn't prior information about signaling MG2 due to MGC database. Thus, MGC doesn't act for processing on the MG1messages and it sends directly to the MG2. All messages received from the MG2 will forward directly to the MG1.

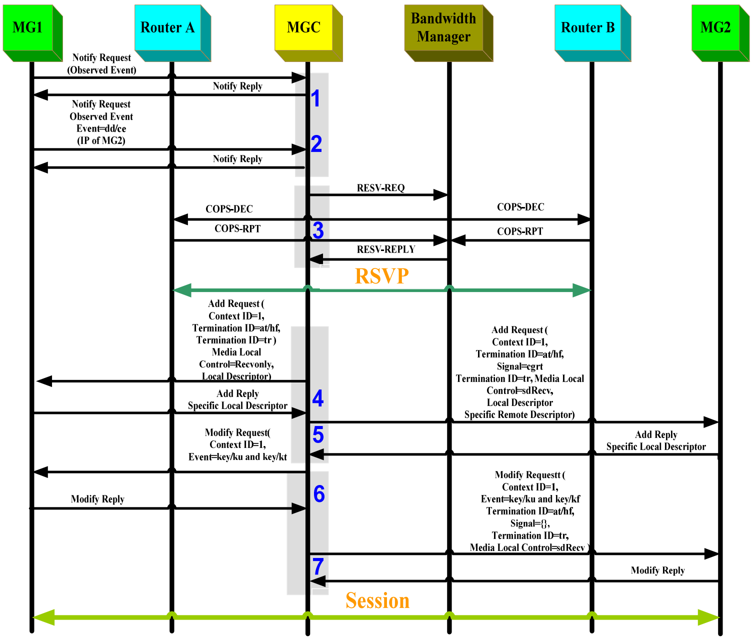


***Figure 12. Single phase MEGACO call flow base resource reservation[19,20]***

Figure 13, illustrates stages of the proposed scenario for call setup between two different domains by MEGACO network. The scenario is composed of the following stages. This model has prior information about signaling MG2 due to the MGC database. Before sending each message to MG1, MGC checks signaling status and if MG2 is busy, MGC will send message for MG1 for this reason and if establishing time is end for a call, MGC will announce to both sides of MGs.

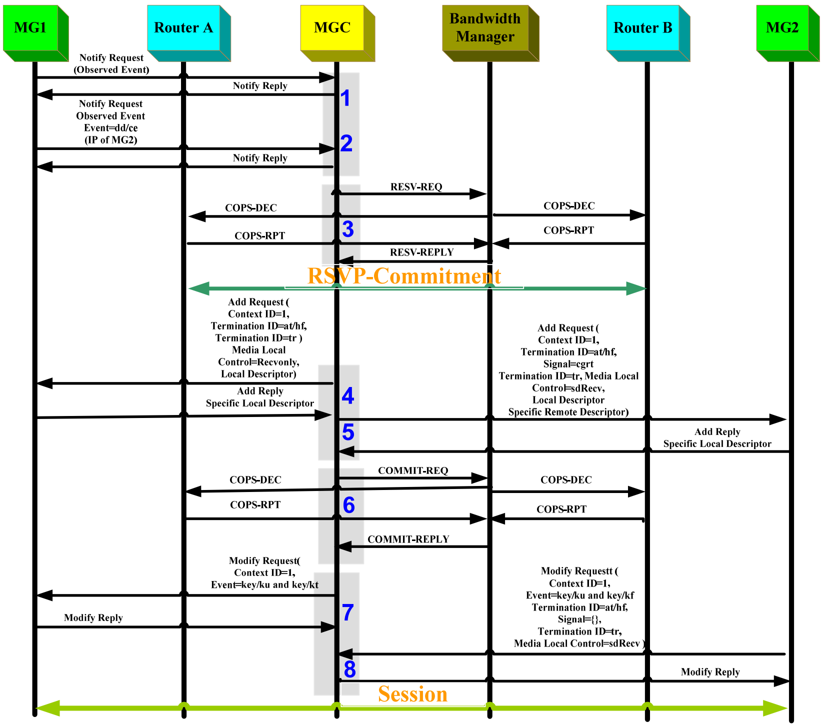

*Figure 13. Two phases MEGACO call flow base resource reservation[19,20]*

### 7.1 Queuing model based Single phase and two phases Models

Each queuing station is modeled as an M/M/1 queue. The first M, which represents the arrival distribution, is memory less. The arrival of one call request is independent of other requests. The second M, representing the serving distribution, also is memory less. The serving time of a message is independent of all other messages. The 1 means there is only one server in a system. This model is an open, feed forward queuing network, since jobs arrive from an outside source, and there is no feedback among queuing stations in the queuing network.

1. Queuing models (Single phase and two phases) are assumed as 0.5/μ for sending the Add Request followed by Add Reply, Modify Request and Modify Reply with 0.3-/μ.

2.Queuing models(Single phase and Two phase) only 80 percent of the Add Request messages will be successful in getting the Add Reply response and 90 percent of that Modify Request responses will get the Modify Reply response (Figures 14,15).

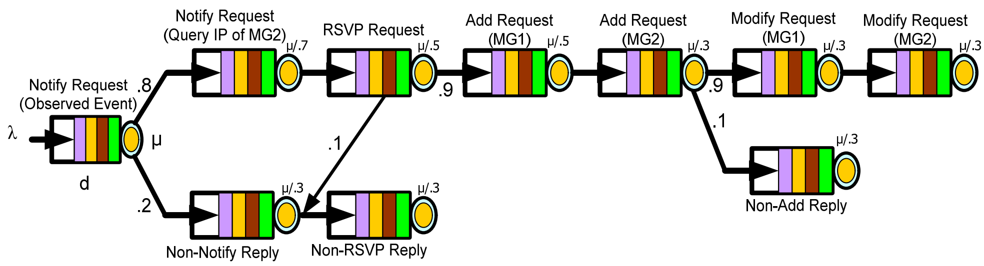


*Figure 14. Single phase Queue model*

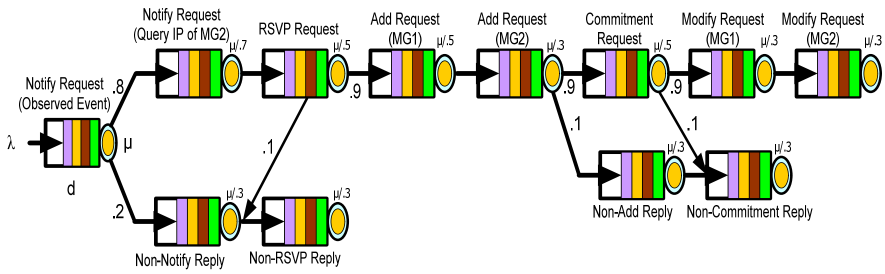


*Figure 15. Two phases Queue model*

## 7.2 Calculated results in Single phase and two phases base MEGACO network

In This paper, former assumption was considered with μ= 0.5, in order to calculate system's mean response time with publication delay varying between 0 - 10 ms where the distance between MG and MGC is 0-1000 miles (Figures16,17,18).

Each 100 miles is assumed to be equivalent with 1ms delay. As seen in figures, the mean response time with variation of arrival rate is approximately linear and the mean response time increases with publication delay.

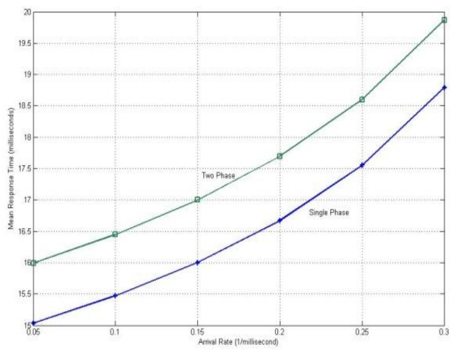


*Figure 16. Mean response time base on arrival rate changes (Comparative single phase& two phases*

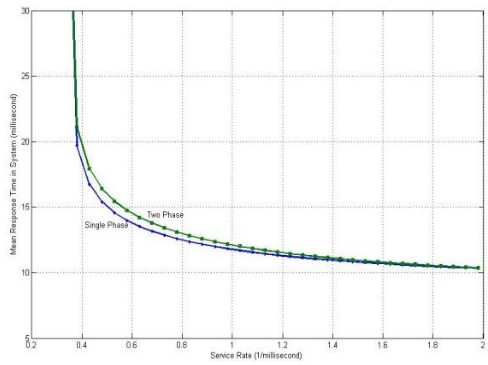


*Figure 17. Mean response time base on service rate changes (Comparative single phase& two phases)*

As our observation, the maximum average number of jobs is less than 10 in maximum distance of 1000 miles.

The results of Mean number of jobs and mean response time are obtained by changing base service rate delay while λ (λ = 0.3) is supposed constant.

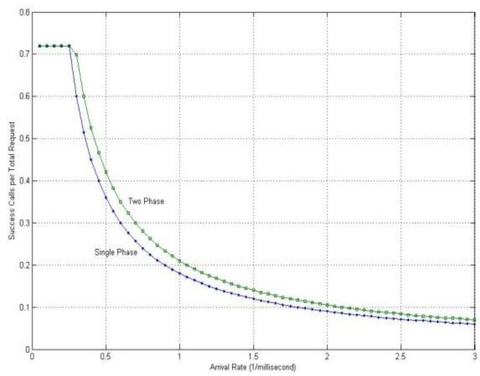


*Figure 18. Success calls per request on arrival rate changes (Comparative single phase& two phases)*

There are some advantages in two phase model and single phase model which in this section, some of them are described. In single phase flow model, less signaling will be exchanged between network equipment and this will cause acceleration the call connection. In the two phase model, network recourses are used in optimized manner and till the second MG does not Off-hook, the bandwidth is not busy and the resources are not accessible for subscribers. But, each model can be used depending to the network structure. In common networks, signal phase model can be used. In this model, establishment of a call is faster. In the networks with high traffic, it is better to use the two phase model in order to use the resources efficiently. Even, in the networks with high traffic, acceleration of call establishment in two phase model is more than single phase model which is depending to the average of talk time, in special states due to the appropriate use of resources.

## 8. Performance Model for Multiple MGCs

We now extend the model and analysis in two ways: first, to hosts running multiple MGCs for scalability, and second, to a network of MGCs [1].

We provide Performance results for a multi-server host. We extend the model of Figure 19 to queue networks with the same structure, but with each M/M/1 queue replaced by M/M/c and M/D/c queues. The equations for computing the mean response time and mean number of jobs in system are standard. Figure 30 illustrates the performance results, where the number of servers "c" is varied between 3 and 10, and the propagation delay is set to zero. A key observation is that below a certain threshold for the service rate (i.e. 0.3 NOTIFY $ms^{-1}$), the mean response time to process requests can grow significantly even under small changes in the service rate.

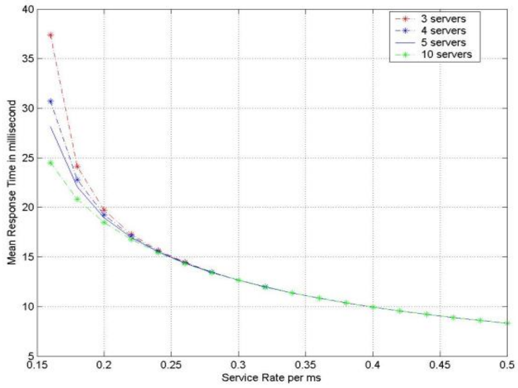


***Figure 19. Mean response time of multiple server host under varying service rates (M/D /c Queuing Model)***

### *8.1 Chain of Media Gateway Controllers*

We next extend our analysis of a single server host in an orthogonal direction: namely, to a network of proxy servers modeling multiple hops in an end to end network. We thus extend our performance measures of interest of mean response time and mean jobs in system to reflect the end to end network. In particular, the mean end to end response time is defined as the mean elapsed time from the time *t*1 an NOTIFY request from an MG1 arrives at the MGC until the time *t*2 that the MGC sends a final response to the MG2; this mean response time now includes the time taken by all the intermediate MGCs and the far end MG2 to set up the call. Similarly, the mean number of jobs in system is now defined as the mean number of calls being set up or waiting to be set up by any of the intermediate MGCs involved in setting up the call [1].

In order to do this analysis, this model is depicted in Figures 20, 21 for establishing a call, Client will send a NOTIFY message for MGC. In this stage, MGC process above message and with pay attention to each process, we assume a queue for this reason. In this model, (n-1) queues apply for sending NOTIFY message from MGC to MG. other section queuing proxy chains model is look like to simple queuing model.

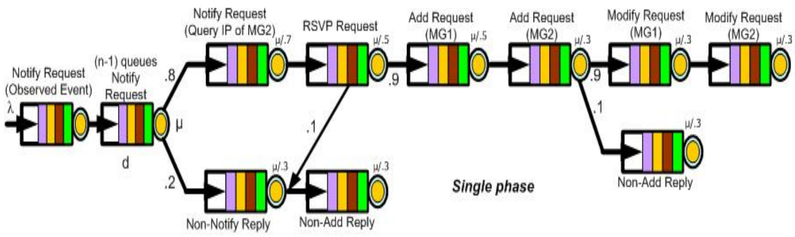


*Figure 20. Single phase Queue model base chain of MGCs*

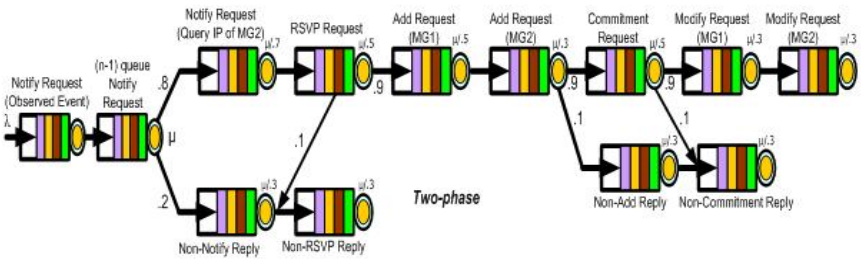


*Figure 21. Two phases Queue model base chain of MGCs*

## *8.2 Calculated results base chain of MGCs*

As shown in Figures (22, 23), the mean response time and the mean number of job with variation of length of proxy chain are linear. Also the mean response time and the mean number of job increases with publication delay.

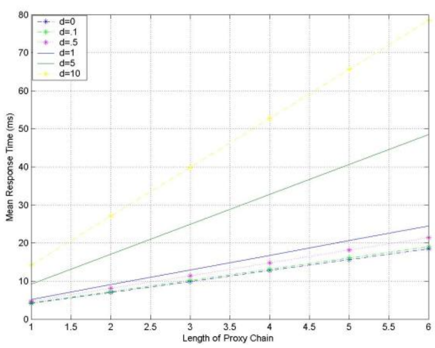


*Figure 22. Mean Response Time base Length of Proxy Chain*

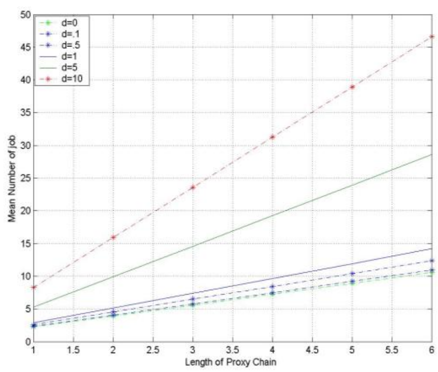


*Figure 23: Mean Number of jobs base Length of Proxy Chain*

## 9. Conclusion and Future Work

Based on the measurements and analysis, we have modeled Bandwidth management scenario in MEGACO with queuing models. With the predicted and experimental results, we has shown that the average response time, mean number of calls and server utilization factor of the M/M/1 model can produce a more predictable model with significant performance improvements and also met the ITU-T standards[19,20]. In future, we intend to extend our work with considering multiple Media Gateway Controllers located in various remote locations and carrying out a comparative study of performance effects when network delays are introduced into these models.

In particular, our results show that for single server hosts and service rates of 0.5 NOTIFY $ms^{-1}$, mean response times are less than 10ms. Furthermore, service rates greater than 1 $ms^{-1}$ does not yield significant improvements in mean response time. Similarly, for multiple server hosts and service rates of 0.3 $ms^{-1}$, response times remain acceptable. Second, our results indicate that in steady state there are very few jobs in the system that is in a setup state. For example, in the steady state we observe that single server hosts with service rates greater than 0.5 requests per ms, there are no more than 10 jobs in the setup state in a single MGC. For chains of single MGCs up to length 6, there are no more than 50 jobs in the setup state across all MGCs in a MEGACO network. Given these results, we question whether it is necessary to add check pointing in a MEGACO network. However, as mentioned before, if the delay representing the time taken by the user to answer the call is included in the analysis there will be more jobs in the system in a ringing state. Our future work will extend the performance analysis to multiple servers on hosts. Our future work will also extend this aspect of our analysis with multiple servers on hosts.

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