OPNET Implementation of the Megaco/H.248 Protocol: Multi-Call and Multi-Connection Scenarios

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Abstract
In this paper, we describe the OPNET implementation of MEGACO/H.248 signaling protocol. The OPNET model allows for multi-call and multi-connection scenarios, where any number of Media Gateways (MGs) can simultaneously connect to the Media Gateway Controller (MGC). This design is important for simulations of simultaneous voice conversations. In our simulation scenario, multiple MGs can connect to one MGC via a router. We simulated the call-establishment, call-waiting, and call-release scenarios by employing a complete set of MEGACO/H.248 signaling commands. We also simulated voice transmission using packets encoded with the Real-Time Transport Protocol (RTP).

1. Introduction
Voice over IP (VoIP) technology is currently finding its place in the telecommunication market. It enables a telecommunication company to cut cost by allowing a single network to transmit both data and voice traffic. In addition, VoIP technology is gaining popularity in both commercial and residential markets because the voice quality resulting from packets transmitted over the IP network is comparable to the voice quality resulting from analog signals sent over the Public Switched Telephone Network (PSTN). The MEGACO/H.248 signaling protocol was introduced by the Internet Engineering Task Force (IETF) and International Telecommunication Union (ITU) to help control and manage the increasing volume of VoIP traffic.

With the emergence of VoIP technology, voice traffic is no longer restricted to the circuit-switched network. New IP-based products, such as IP phones and voice cable modems, have been introduced to integrate voice services over the data network. To properly manage and control these voice services, various signaling protocols have been developed. One of these protocols is MEGACO/H.248. It provides the master/slave architecture for controlling VoIP traffic.

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, making it easier and more suitable for mass deployment.

In this paper, we describe the implementation and simulation of the MEGACO/H.248 protocol using OPNET. All eight MEGACO commands are implemented: Add, AuditCapabilities, AuditValue, Modify, Move, Notify, ServiceChange, and Subtract. The OPNET implementation permits the addition of multiple MGs. This flexibility is important for realistic simulation scenarios where many voice conversations occur simultaneously. Several MGs are connected to a single MGC via a router. We verified all signaling commands and simulated the MG registration, call-establishment, call-waiting, and call-release scenarios. To verify that voice calls were actually established, we generated voice packets encoded using the RTP protocol.

Section 2 describes the history and basic architecture of the MEGACO/H.248 protocol. Sections 3 and 4 describe the design of the MEGACO/H.248 protocol, while Section 5 describes its OPNET implementation. Various call flow simulation scenarios are given in Section 6. Simulation results are presented in Section 7. We conclude with Section 8.

2. MEGACO/H.248 Protocol
2.1. History
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. However, 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 re-defined using the master/slave architecture. Figure 1 shows the evolution of the MEGACO/H.248 protocol.

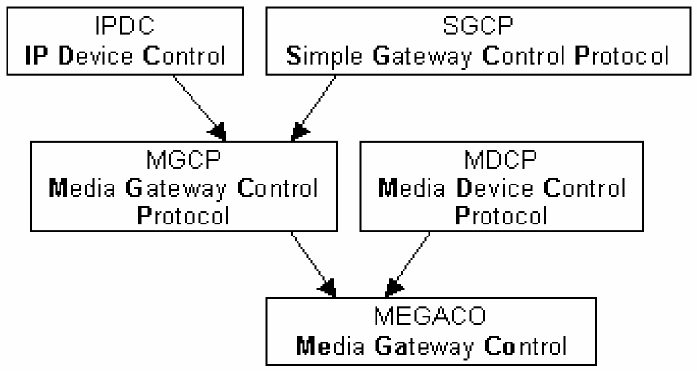

IPDC
IP Device Control
SGCP
Simple Gateway Control Protocol
MGCP
Media Gateway Control Protocol
MDCP
Media Device Control Protocol
MEGACO
Media Gateway Control

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

2.2. Gateway Architecture
The MEGACO/H.248 protocol employs the master/slave architecture, where the MGC acts as a master server, while the MG behaves like a slave device. Figure 2 illustrates the

simplified gateway architecture. In a deployed telecommunication network, one MGC may control multiple MGs.

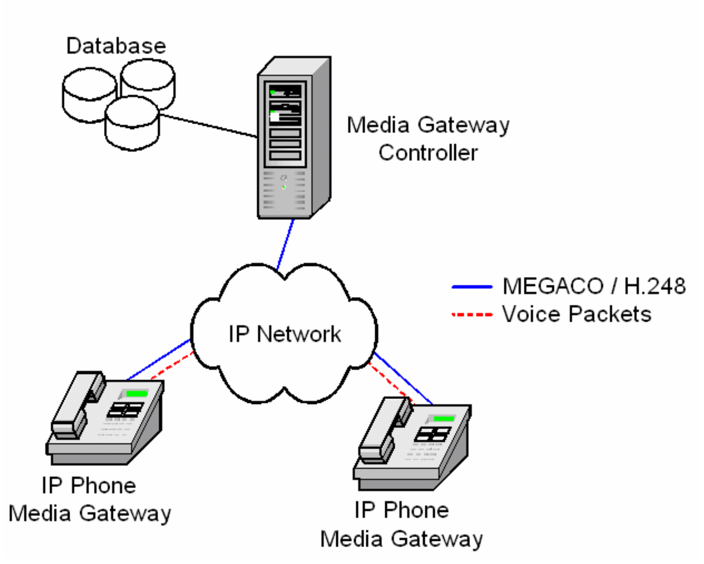


Figure 2: The Master/Slave Architecture.

2.3. Media Gateway Controller

The MGC is the central point of intelligence for call signaling. It maintains the states of each MG and responds appropriately to any event notification. For instance, upon receiving an off-hook event from an MG, the MGC instructs the MG to play the dial tone and listen for the dual tone multi-frequency (DTMF) tones.

2.4. Media Gateway

The master/slave architecture was designed to eliminate processor-intensive functionalities from the MG. Due to the reduced complexity, the cost of MG is much lower than the cost of MGC, making it more affordable to the commercial and residential markets. Essentially, the MG is a dumb terminal awaiting commands from the MGC for its next actions. Upon the successful creation of a connection, the MG is also responsible for streaming the voice packets over the IP backbone using various encoding/compression algorithms.

2.5. MEGACO/H.248 Command Set

The commands supported by the MEGACO/H.248 protocol are:

[MGC $\leftrightarrow$ MG]

• ServiceChange	– Notify the responder of the new service state

[MGC $\rightarrow$ MG]

• AuditValue	– Determine the characteristics of an endpoint
• AuditCapabilities	– 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 $\rightarrow$ MGC]

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

3. Design Architecture

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

3.1. MGC Architecture

The MGC consists of three main components as shown in Figure 3: Message Receiver (MR), Message Processor (MP), and Message Sender (MS).

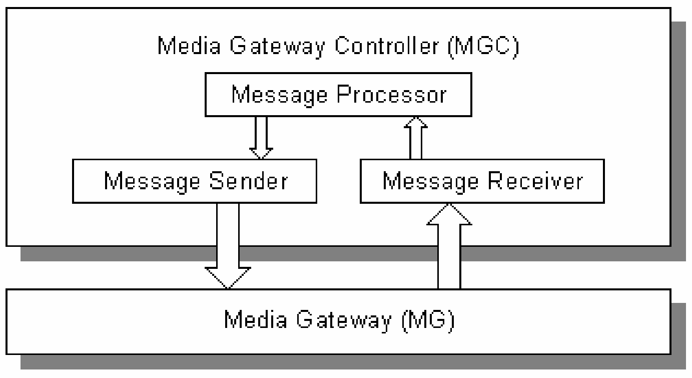


Figure 3: MGC Design Architecture [1].

The main responsibility of the Message Receiver is to parse the received messages. The Message Processor is built with the intelligence to handle all eight MEGACO/H.248 commands and to control all MGs in the system. The Message Sender is used to compose and transmit MEGACO messages to MGs.

In our implementation, communications among three components are achieved via local function calls. Upon receiving an event notification message from the MG, the MGC reads the statuses of the related MGs and instructs them with one or more MEGACO/H.248 commands. The responsibilities of each component are summarized in Table 1.

Component	Responsibility
Message Receiver	• Receive MEGACO messages from the MGs • Extract parameters from MEGACO messages • Redirect message parameters to MP
Message Processor	• Receive message parameters from MR • Read statuses of the related MGs • Determine actions for the related MGs • Request MS to compose response messages if necessary
Message Sender	• Receive requests from MP • Compose MEGACO messages • Send MEGACO messages to the MGs

Table 1: Component Responsibilities in the MGC.

3.2. MG Architecture

The MG consists of five components: Message Receiver (MR), Message Processor (MP), Message Sender (MS), User Interface

(UI), and Voice Generator (VG). Figure 4 illustrates the design architecture of the MG.

The functionalities of the Message Receiver and Message Sender in the MG are similar to those in the MGC. The Message Processor is built to handle any commands sent from the MGC. Upon receiving a command from the MGC, the Message Processor responds accordingly, as listed in Section 2.5.

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.

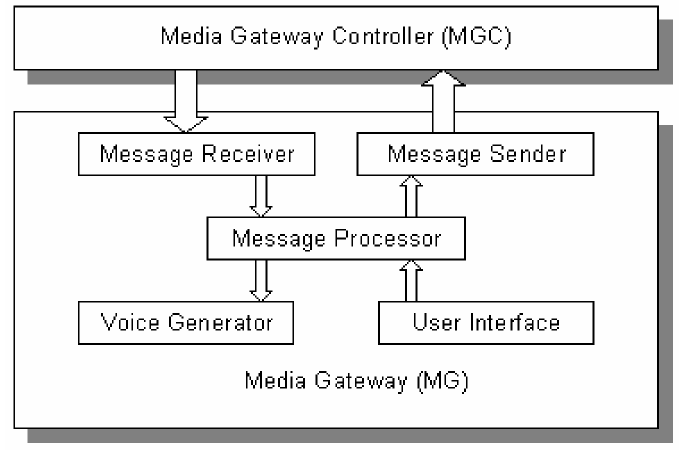


Figure 4: MG Design Architecture [1].

The Voice Generator is responsible for generating voice packets upon call establishment. These voice packets are then encapsulated into the RTP payload and sent over the network.

Similar to the MGC, communications between MG components are accomplished through local function calls. Table 2 summarizes the responsibilities of each component.

Component	Responsibility
Message Receiver	• Receive MEGACO messages from the MGC • Extract parameters from MEGACO messages • Redirect message parameters to the MP
Message Processor	• Receive message parameters from the MR • Respond according to Section 2.5 • Request the MS to compose response messages if necessary
Message Sender	• Receive requests from the MP • Compose MEGACO message • Send MEGACO messages to the MGC
User Interface	• Receive user request via the object attribute • Request the MS to compose transaction message
Voice Generator	• Generate voice packets • Encapsulate voice packet into RTP payloads • Send RTP messages to other MGs

Table 2: Component Responsibilities in the MG.

4. Design Considerations

4.1. Unlimited Number of MGs

In order to support the multi-call and multi-connection scenario, the MG architecture needs to support an unlimited number of MGs. Our implementation utilizes a linked-list to keep track of the MGs. This design enables an unlimited number of MG interconnections.

4.2. Control Intelligence in MGC

To illustrate the complexity in the multi-call and multi-connection scenarios, we describe three cases for the Subtract command:

Case 1: MG1 talks with MG2. Then, MG2 hangs up by sending the Notify command to the controller. Since MG1 is not involved in any other connection, the controller sends to both gateways the Subtract commands.

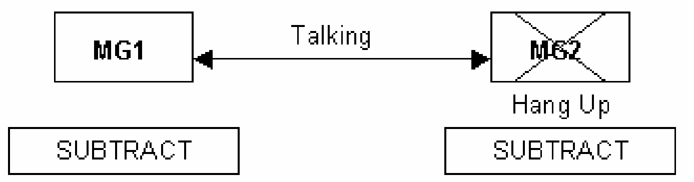


Figure 5: Call Release for the Connection of 2 MGs.

Case 2: Initially, MG1 talks with MG2. Then, MG3 calls MG2 and MG2 decides to switch line to talk with MG3. After a while, MG3 hangs up. Since an inactive connection still exists between MG1 and MG2, the controller will send to MG2 a Move command with the SendReceive parameter to activate the connection between MG1 and MG2. At the same time, the Subtract command is sent to MG3.

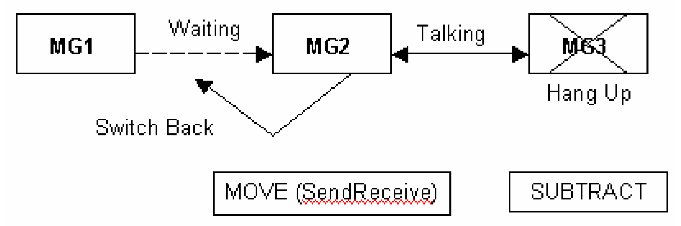


Figure 6: Call Release for the Connection of 3 MGs.

Case 3: First, MG2 talks with MG3. Then, MG1 calls MG2 and MG4 calls MG3. Both MG2 and MG3 switch line to create connections with the new callers. After a while, MG4 decides to hang up. Since MG2 is still talking with MG1, no active connection exists between MG2 and MG3. As a result, the controller needs to send MG3 a Move command with the ReceiveOnly parameter and the Subtract command to MG4. This case is different from the Case 2 because the controller does not send the Move command with the SendReceive parameter.

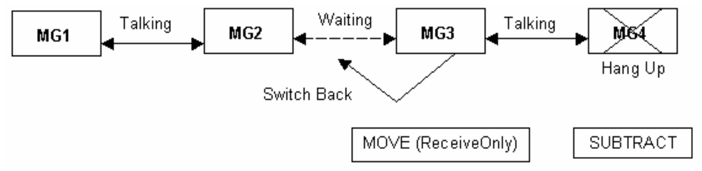
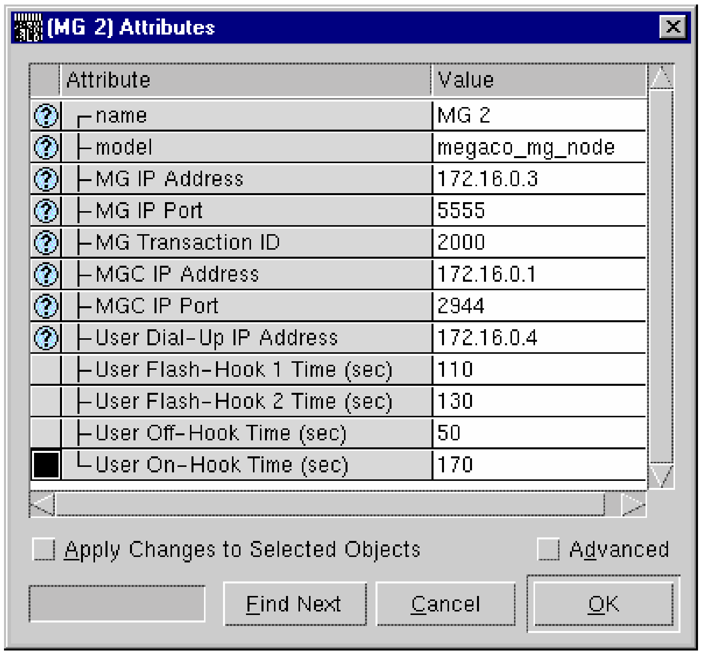


Figure 7: Call Release for the Connection of four MGs.

4.3. Object Attributes in MG

In order to support multi-call and multi-connection environment, the MG implementation is based on the object-oriented concept. Each MG stores its own data and contains its own object attributes. With such a design, any number of MGs can be added to the simulation scenario. Figure 8 shows the *Object Attributes* dialog box for the configurable data, such as IP address and IP port.


(MG 2) Attributes

Attribute	Value
name	MG 2
model	megaco_mg_node
MG IP Address	172.16.0.3
MG IP Port	5555
MG Transaction ID	2000
MGC IP Address	172.16.0.1
MGC IP Port	2944
User Dial-Up IP Address	172.16.0.4
User Flash-Hook 1 Time (sec)	110
User Flash-Hook 2 Time (sec)	130
User Off-Hook Time (sec)	50
User On-Hook Time (sec)	170

Figure 8: MG Object Attribute Dialog Box.

5. OPNET Implementation

The OPNET node model permits any number of MGs to be registered with the MGC. Therefore, a variety of network topologies can be readily configured. Various network topologies are used in our simulation. The simulation results are given in Section 7.

Three OPNET node models have been implemented: Router Node, MGC Node, and MG Node.

5.1. Router Node

As shown in Figure 9, the router node model consists of eleven transmitters, eleven receivers, and one router processor. The router processor is responsible for routing traffic from a receiver to a transmitter.

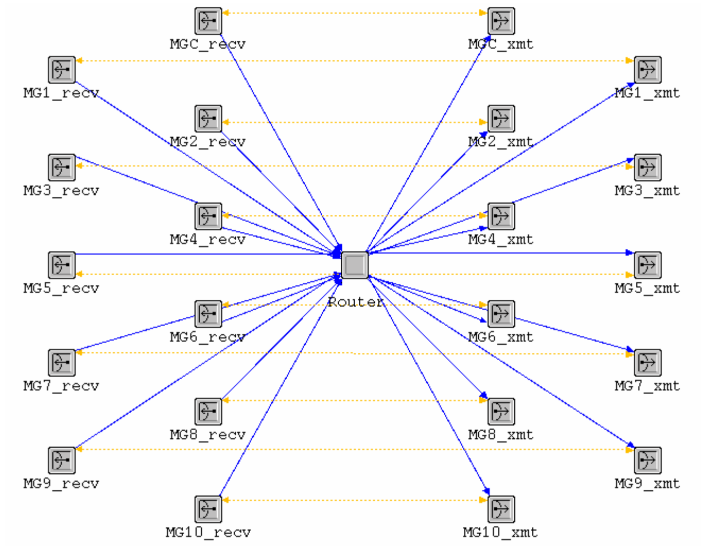


Figure 9: Router Node Model.

Figure 10 illustrates the state machine for the router processor, which consists of two states: *idle* and *route_pk*. The initial state of the router processor is the *idle* state, which waits for the arrival of packets. Upon receiving packets, the state machine proceeds to the *route_pk* state. In this state, the router processor relays packets to the appropriate recipients.

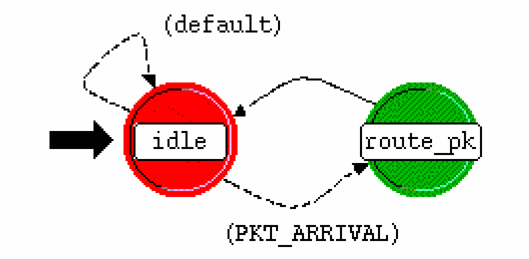


Figure 10: Router Process Model.

5.2. MGC Node

Figure 11 shows the node model of the MGC. The MGC node model consists of a transmitter, a receiver, and the MGC processor. The MGC processor is responsible for parsing MEGACO messages, determining necessary actions for the MGs, and composing the MEGACO messages.

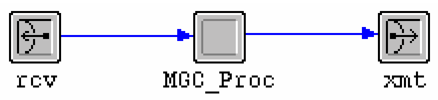


Figure 11: MEGACO MGC Node Model.

The MGC process model, shown in Figure 12, has four states: *init*, *idle*, *send*, and *process*. The *init* state initializes all the resources in the MGC. Upon successful initialization, the system proceeds to the *idle* state, where it either waits for the MGs to respond or for the MGs to send new MEGACO requests. The system enters to the *process* state when new MEGACO messages arrive. In this state, the received messages are parsed and appropriate responses to the MGs are generated. These responses are placed in an outgoing queue where they are periodically transmitted when the system enters the *send* state.

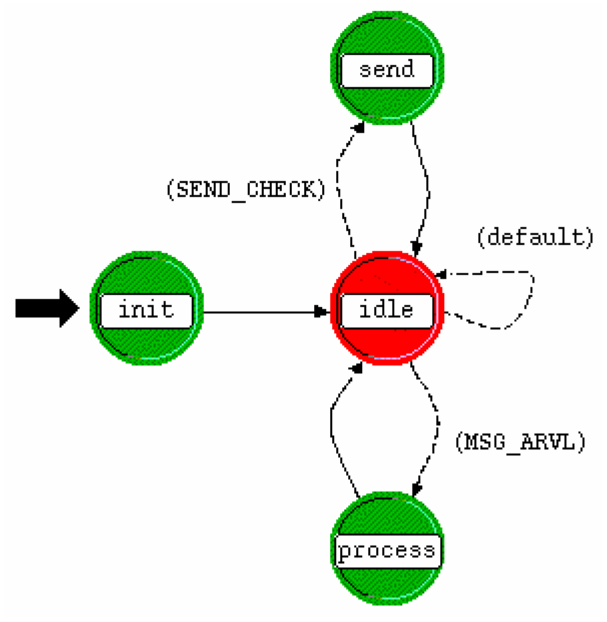


Figure 12: MGC Finite State Machine (Process Model).

5.3. MG Node

The MG node, shown in Figure 13, consists of a transmitter, a receiver, and the MG processor. The MG processor is responsible for handling MEGACO/H.248 commands sent from the MGC and detecting events initiated by the user. Furthermore, RTP packets are generated by the MG processor for voice transmission.

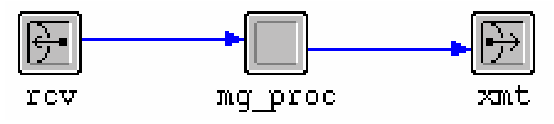


Figure 13: MEGACO MG Node Model.

Figure 14 shows the state machine of the MG processor, which consists of the *init*, *idle*, *msg_pr*, *mg_pr*, and *usr_pr* states. The MG objects are initialized in the *init* state. After the initialization, the state machine proceeds to the *idle* state. In this state, the process waits for the periodic interrupt and packet arrival. When the state machine receives a regular interrupt in the *idle* state, it enters the *usr_pr* state. The state machine checks whether an event was initiated by the user. If an event was initiated, a corresponding event notification message is sent to the MGC. In this state, the state machine also checks for call establishment. Once a call is established, the state machine generates an RTP voice stream to the corresponding MG. Upon receiving a message in the *idle* state, the state machine proceeds to the *msg_pr* state where the packet type is determined. If a signaling command is received, the state machine moves to the *mg_pr* state where the command gets processed. Alternately, if a RTP packet is received, the state machine moves to the *usr_pr* state where the MG object statistics are updated.

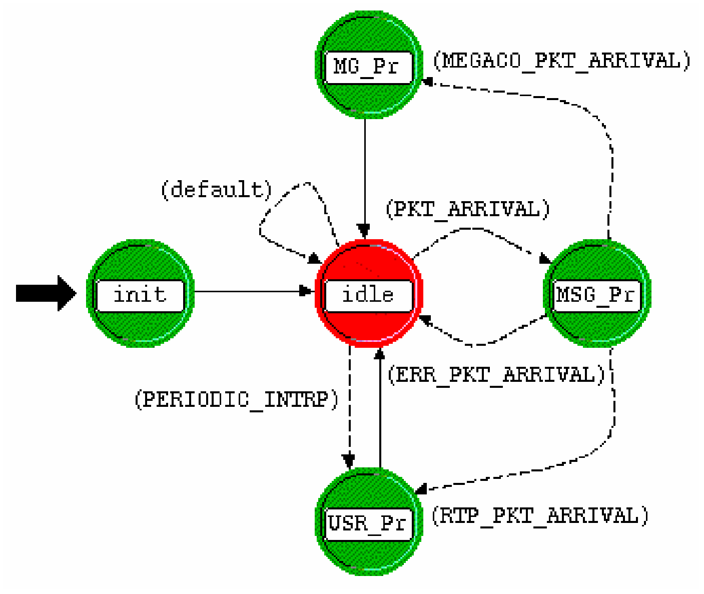


Figure 14: MG Finite State Machine (Process Model).

6. Call Flow Scenario

Four basic call flow scenarios were defined to validate the implementation of the eight MEGACO/H.248 commands. These scenarios are MG Registration Procedure, Call Setup Procedure, Call Waiting Procedure, and Call Release Procedure. These scenarios are described in the following subsections, where the MEGACO/H.248 commands and main parameters are included within the sequence diagrams.

6.1. MG Registration Procedure

The first procedure when the MG starts is to register with the MGC using the *ServiceChange* command (1). This command enables the MGC to detect and maintain the status of the MG. The MGC then issues the *AuditCapability* command (3) to determine what functionalities are available for the MG. The MGC also issues the *Modify* command (5) to request the notification of a key-down event or an off-hook event. The sequence diagram for the MG Registration Procedure is shown in Figure 15.

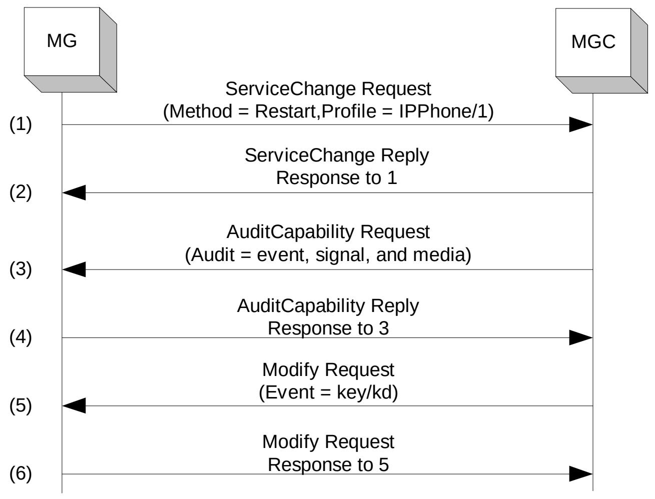


Figure 15: MG Registration Sequence Diagram.

6.2. Call Setup Procedure

When a user picks up the phone (MG1), a *Notify* command (1) is generated to the MGC. The MGC then requests MG1 to play a dial tone, to listen for the DTMF tones, and to detect the key down (on-hook) event via the *Modify* command (3). After the user specifies the remote location, the *Notify* command (5) with the destination address is forwarded to MGC. MGC then creates a connection between MG1 and MG2 with two *Add* commands (7) (9) and one *Modify* command (11). When the user at the remote end picks up the phone (MG2), a *Notify* command (13) is generated to the MGC. Finally, MGC sends each phone a *Modify* command to establish a media stream between the two gateways. Encapsulated within the *Modify* command (15) (17) is a request to stop the ringing signals and to set up the notification mechanism for an on-hook event. The flow diagram for the Call Setup Procedure is shown in Figure 16.

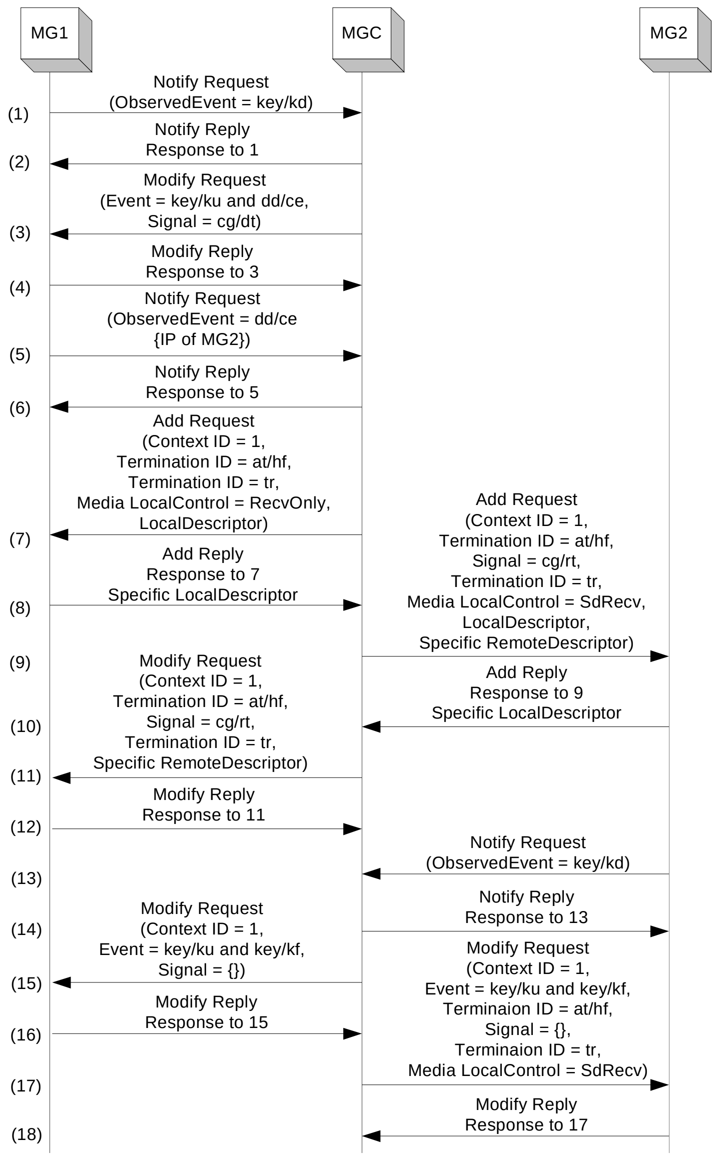

MG1
MGC
MG2
(1)
Notify Request (ObservedEvent = key/kd)
(2)
Notify Reply Response to 1
(3)
Modify Request (Event = key/ku and dd/ce, Signal = cg/dt)
(4)
Modify Reply Response to 3
(5)
Notify Request (ObservedEvent = dd/ce {IP of MG2})
(6)
Notify Reply Response to 5
(7)
Add Request (Context ID = 1, Termination ID = at/hf, Termination ID = tr, Media LocalControl = RecvOnly, LocalDescriptor)
(8)
Add Reply Response to 7 Specific LocalDescriptor
(9)
Add Request (Context ID = 1, Termination ID = at/hf, Signal = cg/rt, Termination ID = tr, Media LocalControl = SdRecv, LocalDescriptor, Specific RemoteDescriptor)
(10)
Add Reply Response to 9 Specific LocalDescriptor
(11)
Modify Request (Context ID = 1, Termination ID = at/hf, Signal = cg/rt, Termination ID = tr, Specific RemoteDescriptor)
(12)
Modify Reply Response to 11
(13)
Notify Request (ObservedEvent = key/kd)
(14)
Notify Reply Response to 13
(15)
Modify Request (Context ID = 1, Event = key/ku and key/kf, Signal = {})
(16)
Modify Reply Response to 15
(17)
Modify Request (Context ID = 1, Event = key/ku and key/kf, Terminaion ID = at/hf, Signal = {}, Terminaion ID = tr, Media LocalControl = SdRecv)
(18)
Modify Reply Response to 17

Figure 16: Call Setup Sequence Diagram.

6.3. Call Waiting Procedure

The Call Waiting Procedure is invoked when a third party wishes to call a party that is currently in-session. Following the steps similar to the Call Setup procedure, a receive-only connection is established (7) (9) (11) between the third party and the party in-session. Upon receipt of the Flash Hook notification (13), the MGC places the current active connection into the inactive mode with the *Modify* command (15).

Before MG2 switches lines, the MGC reads the statistics of MG2 using the *AuditValue* command (17). The MGC then sends to MG2 the *Move* command (19) to switch the connection to MG3. Finally, the MGC requests MG3 to stop playing signals and to set up the notification mechanism for an on-hook event via the *Modify* command (21). The flow diagram for the Call Waiting Procedure is shown in Figure 17.

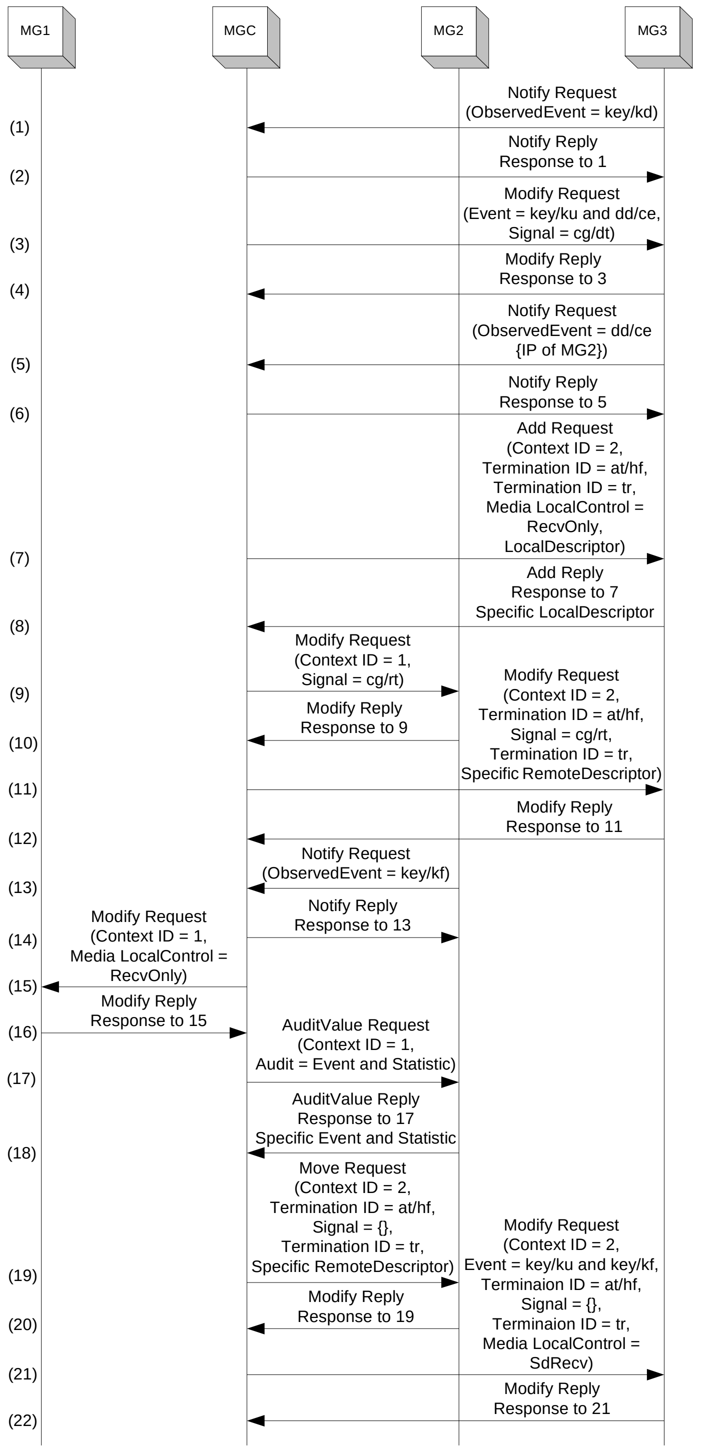

MG1
MGC
MG2
MG3
(1)
Notify Request (ObservedEvent = key/kd)
(2)
Notify Reply Response to 1
(3)
Modify Request (Event = key/ku and dd/ce, Signal = cg/dt)
(4)
Modify Reply Response to 3
(5)
Notify Request (ObservedEvent = dd/ce {IP of MG2})
(6)
Notify Reply Response to 5
(7)
Add Request (Context ID = 2, Termination ID = at/hf, Termination ID = tr, Media LocalControl = RecvOnly, LocalDescriptor)
(8)
Add Reply Response to 7 Specific LocalDescriptor
(9)
Modify Request (Context ID = 1, Signal = cg/rt)
(10)
Modify Reply Response to 9
(11)
Modify Request (Context ID = 2, Termination ID = at/hf, Signal = cg/rt, Termination ID = tr, Specific RemoteDescriptor)
(12)
Modify Reply Response to 11
(13)
Notify Request (ObservedEvent = key/kf)
(14)
Notify Reply Response to 13
(15)
Modify Request (Context ID = 1, Media LocalControl = RecvOnly)
(16)
Modify Reply Response to 15
(17)
AuditValue Request (Context ID = 1, Audit = Event and Statistic)
(18)
AuditValue Reply Response to 17 Specific Event and Statistic
(19)
Move Request (Context ID = 2, Termination ID = at/hf, Signal = {}, Termination ID = tr, Specific RemoteDescriptor)
(20)
Modify Reply Response to 19
(21)
Modify Request (Context ID = 2, Event = key/ku and key/kf, Terminaion ID = at/hf, Signal = {}, Terminaion ID = tr, Media LocalControl = SdRecv)
(22)
Modify Reply Response to 21

Figure 17: Call Waiting Sequence Diagram.

6.4. Call Release Procedure

When a user hangs up, a *Notify* command (1) is sent to the MGC. The MGC then issues the *Subtract* command (3) (7) (11), which tears down the connection with each MG. In preparation for the next call, the MGC sends to each MG a *Modify* command (5) (9) (13) for the detection of an off-hook event. The flow diagram for the Call Release Procedure is shown in Figure 18.

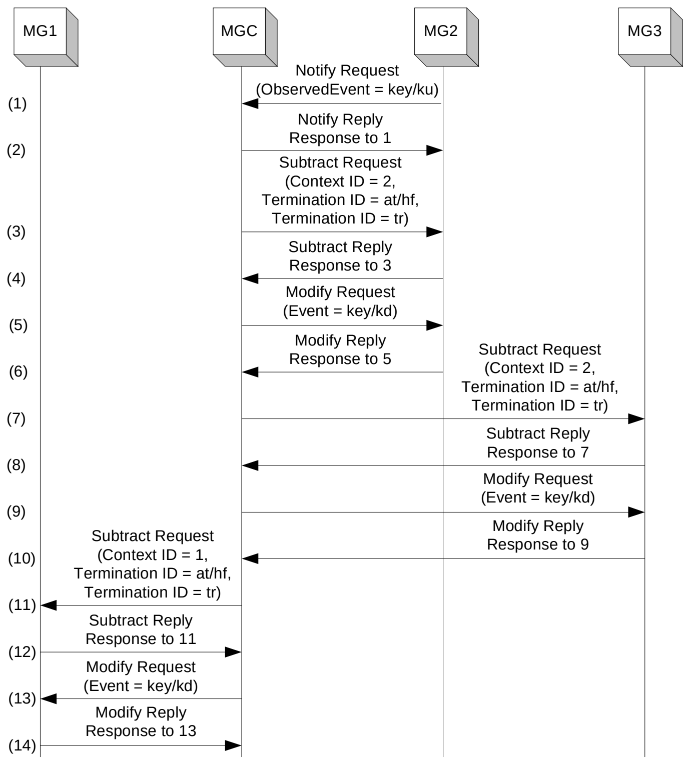

MG1
MGC
MG2
MG3
Notify Request (ObservedEvent = key/ku)
Notify Reply Response to 1
Subtract Request (Context ID = 2, Termination ID = at/hf, Termination ID = tr)
Subtract Reply Response to 3
Modify Request (Event = key/kd)
Modify Reply Response to 5
Subtract Request (Context ID = 2, Termination ID = at/hf, Termination ID = tr)
Subtract Reply Response to 7
Modify Request (Event = key/kd)
Modify Reply Response to 9
Subtract Request (Context ID = 1, Termination ID = at/hf, Termination ID = tr)
Subtract Reply Response to 11
Modify Request (Event = key/kd)
Modify Reply Response to 13
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
(10)
(11)
(12)
(13)
(14)

Figure 18: Call Release Sequence Diagram.

7. Simulation Results

The MEGACO/H.248 OPNET implementation was verified by employing a simple call-waiting scenario, a complex call-waiting scenario, as well as a multi-call and multi-connection scenario. Section 7.1, 7.2 and 7.3 discuss each scenario.

Due to the large volume of the simulation result, only subset of result in the simple call-waiting scenario is shown.

7.1. Simple Call-Waiting Scenario

In the simple call-waiting scenario shown in Figure 19, three MGs are connected to the MGC.

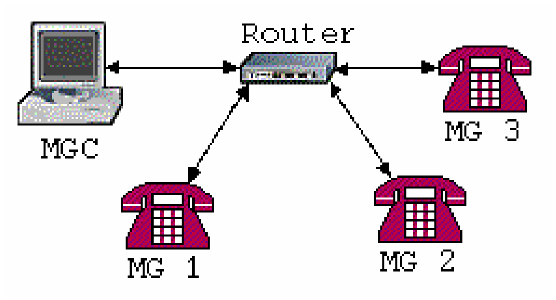


Figure 19: Simple Call-Waiting Topology.

In this simulation scenario, each command was used and the results were verified. The action sequence is:

1. MG1, MG2, and MG3 register with MGC
2. MG1 connects to MG2
3. MG3 calls MG2
4. MG2 switches to MG3, while MG1 is on hold
5. MG3 hangs up, and MG2 switches to MG1
6. MG2 hangs up.

In action sequence 1, the interaction between the MGC and the MGs is:

```
|-----------------------------------------|
| [1] MGC received the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.2]:5555
Transaction = 1000 {
Context = - {
ServiceChange = ROOT {
Service {
Method=Restart,
ServiceChangeAddress=5555,
Profile=IPPhone/1
}}}}
|-----------------------------------------|
| [2] MGC just sent MG (IP: 172.16.0.2)
|     the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.1]:2944
Reply = 1000 {
Context = - {
ServiceChange = ROOT {
Services {
ServiceChangeAddress=5555,
Profile=IPPhone/1
}}}}
|-----------------------------------------|
| [3] MGC received the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.3]:5555
Transaction = 2000 {
Context = - {
ServiceChange = ROOT {
Service {
Method=Restart,
ServiceChangeAddress=5555,
Profile=IPPhone/1
}}}}
|-----------------------------------------|
| [4] MGC just sent MG (IP: 172.16.0.3)
|     the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.1]:2944
Reply = 2000 {
Context = - {
ServiceChange = ROOT {
Services {
ServiceChangeAddress=5555,
Profile=IPPhone/1
}}}}
```

```
|-----------------------------------------|
| [5] MGC just sent MG (IP: 172.16.0.2)
|     the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.1]:2944
Transaction = 1 {
Context = - {
AuditCapabilities = ui {
Audit{Events, Signals}
}}}
|-----------------------------------------|
| [6] MGC received the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.4]:5555
Transaction = 3000 {
Context = - {
ServiceChange = ROOT {
Service {
Method=Restart,
ServiceChangeAddress=5555,
Profile=IPPhone/1
}}}}
|-----------------------------------------|
| [7] MGC just sent MG (IP: 172.16.0.4)
|     the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.1]:2944
Reply = 3000 {
Context = - {
ServiceChange = ROOT {
Services {
ServiceChangeAddress=5555,
Profile=IPPhone/1
}}}}
|-----------------------------------------|
| [8] MGC received the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.2]:5555
Reply = 1 {
Context = - {
AuditCapabilities = ui {
Event {key/kd,key/ku,key/kf,dd/ce},
Signal {cg/dt,cg/rt}
}}}
|-----------------------------------------|
| [9] MGC just sent MG (IP: 172.16.0.2)
|     the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.1]:2944
Transaction = 2 {
Context = - {
Modify = ui {
Events = 1 {key/kd}
}}}
|-----------------------------------------|
| [10] MGC received the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.2]:5555
Reply = 2 {
Context = - {
Modify = ui
}}
```

```
|-----------------------------------------|
| [11] MGC just sent MG (IP: 172.16.0.3)
|      the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.1]:2944
Transaction = 3 {
Context = - {
AuditCapabilities = ui {
Audit{Events, Signals}
}}}
|-----------------------------------------|
| [12] MGC received the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.3]:5555
Reply = 3 {
Context = - {
AuditCapabilities = ui {
Event {key/kd,key/ku,key/kf,dd/ce},
Signal {cg/dt,cg/rt}
}}}
|-----------------------------------------|
| [13] MGC just sent MG (IP: 172.16.0.3)
|      the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.1]:2944
Transaction = 4 {
Context = - {
Modify = ui {
Events = 2 {key/kd}
}}}
|-----------------------------------------|
| [14] MGC received the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.3]:5555
Reply = 4 {
Context = - {
Modify = ui
}}
|-----------------------------------------|
| [15] MGC just sent MG (IP: 172.16.0.4)
|      the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.1]:2944
Transaction = 5 {
Context = - {
AuditCapabilities = ui {
Audit{Events, Signals}
}}}
|-----------------------------------------|
| [16] MGC received the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.4]:5555
Reply = 5 {
Context = - {
AuditCapabilities = ui {
Event {key/kd,key/ku,key/kf,dd/ce},
Signal {cg/dt,cg/rt}
}}}
```

```
|-----------------------------------------|
| [17] MGC just sent MG (IP: 172.16.0.4)
|      the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.1]:2944
Transaction = 6 {
Context = - {
Modify = ui {
Events = 3 {key/kd}
}}}
|-----------------------------------------|
| [18] MGC received the following message:
|-----------------------------------------|
MEGACO/1 [172.16.0.4]:5555
Reply = 6 {
Context = - {
Modify = ui
}}
```

7.2. Complex Call-Waiting Scenario

In the complex call-waiting scenario, four MGs are connected to the MGC. The network topology of this simulation scenario is shown in Figure 20. The action sequence is:

1. All MGs register with MGC
2. MG2 connects to MG3
3. MG1 calls MG2, and MG4 calls MG3
4. MG2 switches to MG1, while MG3 switches to MG4
5. MG2 and MG3 switches back, while MG1 and MG4 are put on hold
6. MG3 hangs up
7. MG4 gets removed from the inactive connection
8. MG2 switches back to MG1
9. MG2 hangs up.

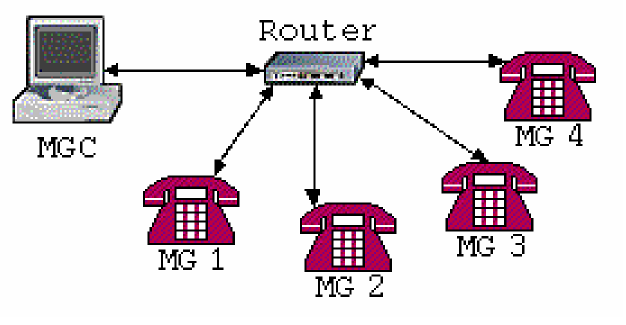


Figure 20: Complex Call-Waiting Topology.

7.3. Multi-Call and Multi-Connection Scenario

This simulation scenario is used to verify the OPNET implementation in a multi-call and multi-connection environment. Five MGs are connected to the MGC. The network topology is shown in Figure 21. The action sequence is:

1. All MGs register with MGC
2. MG1 connects to MG2, while MG4 connects to MG5
3. MG3 calls MG2
4. MG2 switches to MG3, while MG1 is put on hold
5. MG3 hangs up, and MG2 switches back to MG1
6. MG2 and MG4 hang up.

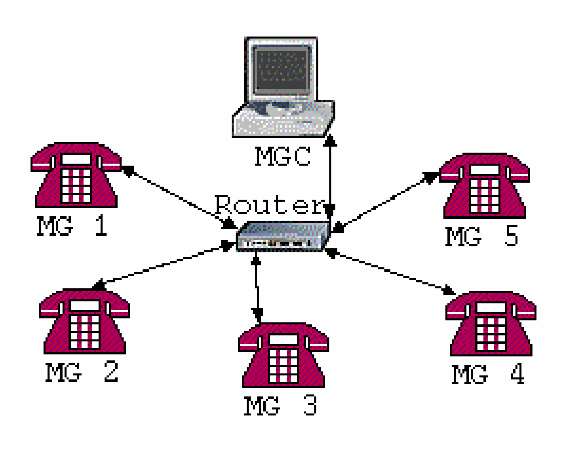


Figure 21: Multi-Call and Multi-Connection Topology.

8. Conclusion and Future Work

In this paper, we describe the OPNET implementation of the MEGACO/H.248 signaling protocol between the MGC and MG. We provide an overview of the MEGACO/H.248 signaling components and the commands. The OPNET implementation of the MEGACO/H.248 protocol supports an unlimited number of MG interconnections. We successfully implemented all MEGACO/H.248 commands. Several call scenarios between the MGC and MGs were simulated, which validated our implementation. Future development of this project would be implementation of the MEGACO/H.248 protocol over the IP network.

9. References

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