PTT Service Interworking Between IMS Based Networks and P2P Overlay Networks

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Abstract

The demand for multimedia streaming services is increasing rapidly. To meet this demand, there has been much research and many practical developments for providing multimedia services. A push-to-talk (PTT) service is one of the multimedia streaming services that have been deployed not only over IP multimedia subsystem (IMS) but also in peer-to-peer (P2P) overlay networks. The benefit of PTT has been demonstrated in the literature. However, the need for using PTT service in communication can be arbitrary among users, regardless what kind of PTT services they use. This demand does not support current PTT systems, so an expansion of PTT services still be limited. Moreover, the combination of PTT services in IMS and P2P networks will help operators to provide more scalable PTT services. Therefore, in this paper, we proposed a model to support PTT service interworking between IMS and P2P overlay networks. We also introduced our system design and some interworking service scenarios. We confirmed our architecture through implementation and testing.

Keywords: Push-to-talk, PTT interworking, Peer-to-peer, IMS, PoC, Media floor control

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1. Introduction

Multimedia streaming services have been considered kill-apps for years.Currently, there are many multimedia streaming systems that are widely deployed both on P2P overlay networks and IMS network. One of these services is Push-to-talk (PTT) service, a walkie-talkie-like service defined by the Open Mobile Alliance (OMA) [1]. PTT allows several users to talk with each other using a single, half-duplex, communication channel. Therefore, only one user can talk at a time while the others listen.

PTT over cellular (PoC) in the IMS system was operated in centralized manner, while PTT in the P2P network is operated totally in a distributed manner. Each system provides PTT service to its own users. Therefore, in this paper, we propose a PTT system model to support multimedia PTT service interworking between P2P overlay and IMS networks. We introduce three service scenarios and analyze them to confirm session setup latency. Through real implementation and deployment, we demonstrate that the above demand is addressed to support arbitrary communication with good delay performance.

1.1 Push-to-Talk Service

In the OMA approach, a PoC server, playing the role of central arbitrator, is applied to coordinate the permission to talk among group members and to determine the member who is permitted to talk [1]. The research in [2] has proposed a solution for PTT service in the IMS mobile environment. It provides a powerful framework to easily deploy a service or application.

In an OMA-based PTT architecture, PoC server is central point of the PTT system. The PoC server has responsibility of managing the session, floor, and relaying media streams which causes several major issues. First, the burden at PoC will increase in proportion with the number of participants which limits the system capability. Second, PoC becomes a single failure point of the system means that when PoC's performance reduces, the PTT system's performance degrades. As a result, a P2P-based PTT approach appears as a suitable solution to supply a scalable and reliable PTT service.

In the P2P-based PTT architecture, there is no predefined PoC instead of that a participant will be selected as PoC and if the current PoC may disconnect, another participant will be selected to replace. More especially, in some P2P-based approaches, PoC does not exist in the system and determining who is permitted to speak is performed by propagating the requests among participants and basing on the particular mechanisms, participants will detect who is allowed to speak.

The paper [3] has designed and implemented the PTT service in ad hoc VoIP network. The PTT UA in their system has been implemented by extending SIP server with PTT server module to support PTT service in ad hoc environments. Each PTT UA has been equipped with both UA client and UA server abilities so they they can send the SIP signallings as well as respond the requests. The SIP signals and media streams will be relayed among participants.

The authors in [4] and [5] have proposed a PTT service for intelligent transportation systems. They have designed a distributed PTT mechanism called the learning interaction to determine who is permited to speak in a group without any central-arbitrator defined in OMA.

The paper [6] has discussed Push-to-talk applications in mobile ad hoc networks. They minimized the number of forwarding nodes by taking advantages of Optimized Link State Routing (OLSR) protocol for the mobile ad hoc networks.

Some studies [7], [8], [9] have focused on PTT service for wireless mesh network (WMN). The papers [7] and [8] have proposed an architecture of and protocol for a distributed PTT service for WMN. In paper [9], the authors have presented a multimedia PTT service in a home network. These studies had analyzed experimental results, and some were verified by real implementation.

The researches in [10], [11] have also proposed a distributed PTT service. The P2P PTT service, iPTT [10] was based on the serverless architecture with two floor control mechanisms: flooding-based floor control (FFC) and tree-based floor control (TFC) for the real time talk burst determination. The mechanisms were investigated through analytical and simulation models in terms of the determination latency and the number of floor-control message exchanges. Moreover, the ePTT [11] enhanced iPTT in terms of signaling costs for overlay network construction and call determination.

1.2 Interworking between P2P Overlay and IMS Networks

F. Belqasmi et al [12] proposed a P2P infrastructure for a universal presence service that enables users in multiple presence accounts in domains with difference technologies to publish and discover end-user context information through a single interface.

The proxy peer and relay agent [13] play main roles in interworking between P2P overlays and IMS systems. The Proxy Peer maintains signaling messages between the P2P overlay and IMS network, which has a similar role to the I-CSCF (Interrogating Call Session Control Function) in IMS, and needs to be registered with the public naming service (DNS) to get a unique identification for the overlay. The relay agent is responsible for transferring media streams to other domains, which are supposed to be used in conjunction with standard tools for network address translation (NAT) traversal (i.e., Session Traversal Utilities for NAT (STUN) [14], Traversal Using Relays around NAT (TURN) [15], and Interactive Connectivity Establishment (ICE) [16]).

An architecture using a gateway application server (AS) [17] has interfaces to both networks: the ordinary peer in the P2PSIP (Peer-to-Peer Session Initiation Protocol) network and the SIP AS in the IMS. To interconnect the P2PSIP and IMS networks, the gateway AS needs to register itself to the P2PSIP network, but only the host name part (for example, ims-domain.com). IMS users who want the ability to interconnect to the P2PSIP network have to set up appropriate initial filter criteria (iFC) in their user profile which is stored in the HSS. The appropriate iFC for P2PSIP interconnection contains the address of the gateway AS. Sessions can be established between P2PSIP and IMS via the gateway AS as soon as registration procedures on both sides are completes.

The proxy peer and gateway AS are the main components for interconnecting the P2P overlay with the IMS network. They both maintain a signaling level interconnection. However, registration procedures of the gateway AS are more convenient than the registration procedures of the proxy peer. Therefore, in this paper, we design and propose an interworking PTT gateway (IP-GW) component. Taking advantage of the previous work [18], our gateway is designed with the inclusion of the relay agent in terms of media and presence messages, and MBCP relay functions. We utilized strong points of the gateway AS as a gateway signaling controller, the relay agent as a gateway media controller, and MBCP relay functions as a gateway MBCP relay agent. The IP-GW plays an important role in interworking PTT service between the P2P PTT overlay network and the PoC server IMS network which is shown in **Fig. 1**.

2. System Architecture and Design

2.1 System Architecture

The system architecture in this paper is shown in **Fig. 1**Fig. 1. In this architecture, the RELOAD is used as P2PSIP protocol for the P2P overlay network. The P2P PTT service is built on the P2PSIP overlay network. We designed a P2P PTT overlay in which the P2P PTT peer plays the role of PTT server. **Fig. 1** shows the PTT peer functional components. The PoC server in IMS network provides PTT service for IMS user equipments (UEs). Both PTT services from two networks interconnect via the IP-GW.

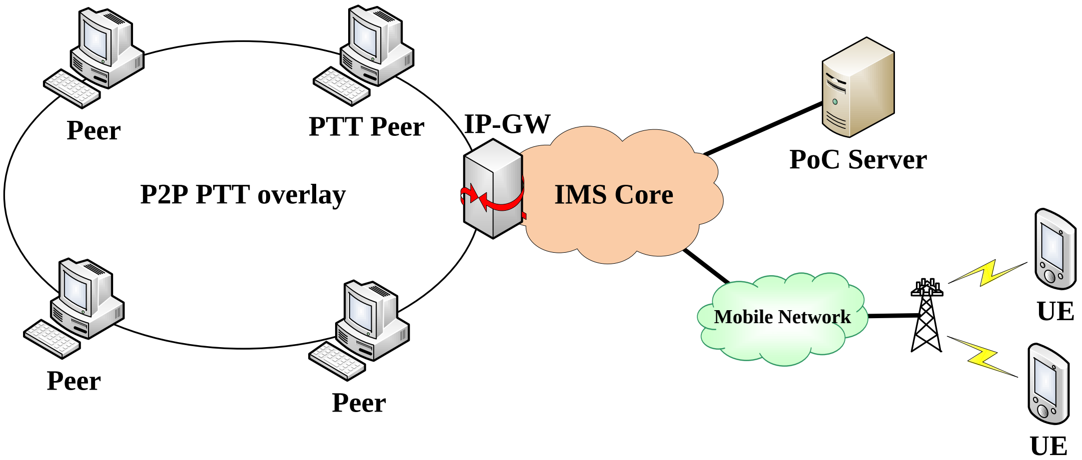


Fig. 1. Interworking PTT service architecture

2.2 System Design

2.2.1 P2P PTT Functional Components

Fig. 2 shows that the first component is the PTT application, where we designed user interface with the talk button to execute the PTT function. The second component is a Registrar which functions to register with the P2PSIP overlay. It maps the URI and IP address in the P2P overlay, then the P2P peer can route SIP messages via the P2PSIP overlay. The third component includes a Presence Controller and a Presence Translator. The Presence Controller performs presence functions and co-operates with the Presence Translator to translate another presence protocol to SIP presence protocol [12]. The fourth component is a SIP Stack that is responsible for exchanging SIP signaling and establishing the SIP session. The fifth component is the PTT component, which maintains PTT group member information, consisting of a member list and ongoing sessions of a PTT group. Based on this information, when a multimedia packet is received, the media data replicator simply copies and transmits the packet to each PTT group member (excluding the sender). On the other hand, Floor Control Logic component has a policy algorithm to determine who of candidates requesting the floor should be the floor owner. The RTP/RTCP multimedia component includes not only multimedia data transmission functions but also floor control functions (i.e., MBCP). The role of MBCP is handling the control messages in cooperation with the PTT component. The P2P middleware (DHT) and network transport protocol modules belong to the networking component, which maintains the topology information of the overall network.

Depending on the role of the peer in the system architecture, a peer activates function components, respectively. A P2P PTT must have a PTT component to perform the floor control and media relay.

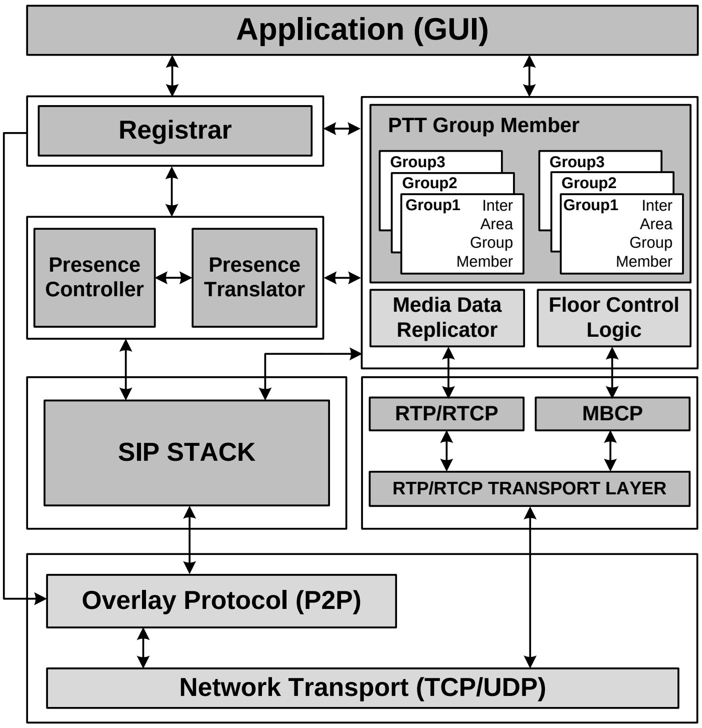


Fig. 2. P2P PTT functional components

2.2.2 The IP-GW Functional Components

Fig. 3 shows components of the IP-GW, which has both a SIP stack and an IMS stack to perform SIP and IMS functionalities. Moreover, it has interfaces to both networks: the P2P overlay network and the IMS network. The IP-GW must register itself with both P2P overlay and IMS network. Therefore, it has the basic functions of a P2P peer and an IMS user agent. Based on the previous work in [18], the IP-GW not only converts and forwards SIP messages to corresponding targets but alsoplays the role of the media relay, which is responsible for transferring media streams to other domains, MBCP relay and Presence relay. There are two approaches for gateway to operate the presence relay depending on the purpose of service provider. The first approach is that the gateway only forwards any subscribe, publich, notify message from one domain to the other. This helps the gateway to reduce the work load with regardless of managing any mapping information between an actual presentity and the identity which the gateway uses. The second one is that the gateway will act on behalf of any presentity and subscribe as well as publish using its identity whenever it receives a request from a presentity.

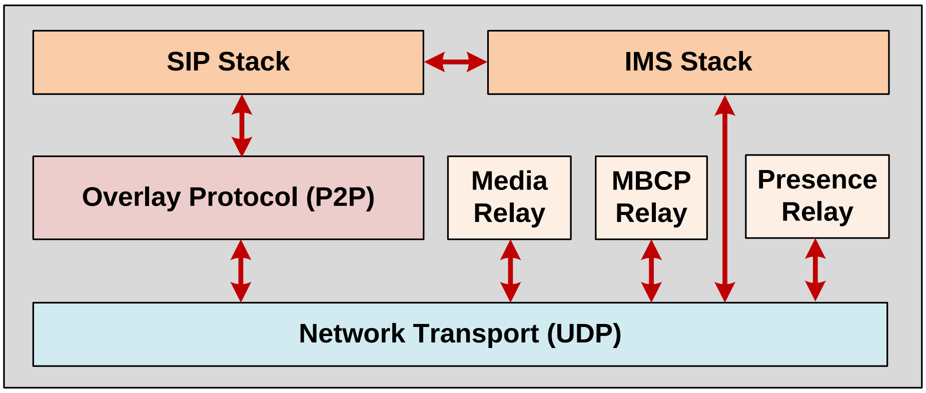


Fig. 3. IP-GW functional components

2.3 Service Scenarios

2.3.1 Interworking PTT Service in the IMS Network

Fig. 4 illustrates a scenario in which an IMS-aware UE-B wants to invite a P2P-aware peer-A in the overlay to join the PoC service through the IMS network, assuming that both the IMS UE-B and the P2P peer-A have completed registration within their own systems. The IMS UE-B registered with the IMS system and the P2P peer-A registered with the P2P overlay network.

From Step 1 to Step 4, the IMS UE-B joins the PoC service on the IMS system by sending an INVITE request. After negotiations in the IMS system are completed[15], the PoC server responds with the “200 OK” message, and then sends this message to the IMS UE-B as a final response to the INVITE request. As soon as the session between UE-B and the PoC server is established, they keep exchanging MBCP messages [20] to make the MBCP connection in Step 5.

From Step 6 to Step 8, the IMS UE-B invites the peer-A in the overlay network to the PoC service by the REFER procedure. The IMS UE-B sends a REFER message with the Refer-to field containing the PoC server URI. Additionally, the Refer-to with URI parameter indicates that the P2P peer-A is requested to send an INVITE request to this URI. The Call Session Control Functions (CSCFs) in the IMS system perform an analysis of the destination address, calculate and determine the best IP-GW (the middle entity, which knows both the P2P overlay and the IMS system), and forward the REFER message to it. Because the IP-GW has both interfaces - P2P overlay interface and IMS network interface - so as the REFER message arrives, it forwards this message to a corresponding peer-A via the routing mechanism in the P2PSIP overlay[21], [22].

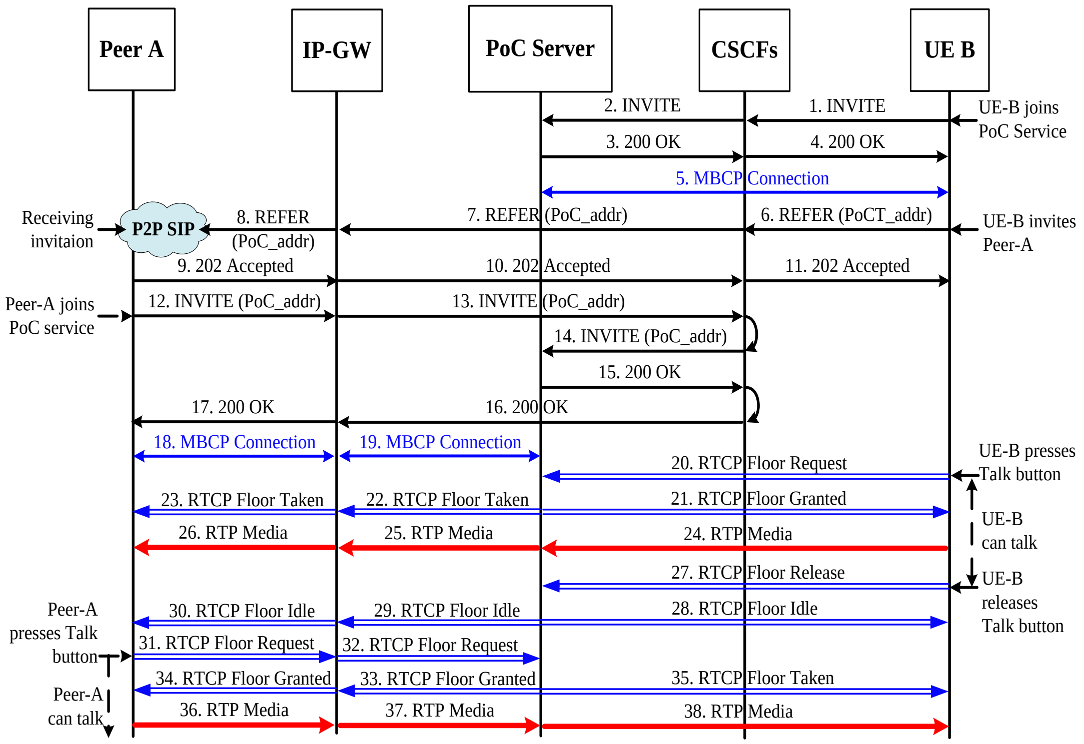


Fig. 4. Service scenario I: IMS UE-B invites peer-A to join PoC server

In Step 27, an RTCP Floor Release is sent to the PoC server when UE-B releases the Talk button, and then the PoC server responds with an RTCP Floor Idle to inform all group members that the media channel is available from Step 28 to Step 30. From Step 31 to Step 35 peer-A gets the right to talk by sending an RTCP Floor Request to the PoC server and receiving an RTCP Floor Granted from the PoC server, and then starts sending RTP media from Step 36 to Step 38.

We have two procedures for the P2P peer-A to join the PoC service: 1) the IMS UE-B knows the peer-A URI and uses a REFER message to invite peer-A to join the PoC service; or 2) peer-A in the overlay network knows the PoC server URI and wants to join the PoC service. The procedure we discussed above is Case 1. In Case 2, instead of the PoC server URI being learned from the REFER message, it may be learned by email, a web site, or in other ways; then, peer-A sends an INVITE message to the PoC server via the IP-GW.

Upon receiving the message, peer-A processes and decides to accept or not. From Step 9 to Step 11, peer-A accepts the REFER request and responds with a the “202 Accepted” message that informs UE-B that the REFER request is being processed. The P2P peer-A is aware of the PoC server URI by the REFER request. Then, from Steps 12 to Step 14, it enters the PoC service. A “200 OK” message is sent to peer-A, indicating that the P2P peer-A has successfully established the session with the PoC service from Step 15 to Step 17. To handle the right of sending RTP media, in Steps 18 and 19, peer-A exchanges the MBCP message with the PoC server via the IP-GW.

Step 20 shows that the IMS UE-B wants to talk, so a Talk button is pressed and a RTCP Floor Request is sent to the PoC server. Receiving the first RTCP Floor Request, the PoC server responds with a RTCP Floor Granted in Step 21, and sends an RTCP Floor Taken to peer-A via the IP-GW to announce that UE-B has granted the right to send RTP media. From

Step 24 to Step 26, UE-B sends RTP media to the PoC server where the RTP media will be replicated and transmitted to all joined members (excluding the sender).

2.3.2 Interworking PTT Service in the P2P Overlay Network

Fig. 5 illustrates a scenario in which peer-A wants to invite an IMS UE-B to join an established P2P PTT session. In Step 1, the joining peer-A in the overlay network intends to join an existing P2P PTT service. It sets up connection by sending an INVITE request message to the corresponding PTT peer via the routing mechanism in the P2PSIP overlay [21], [22]. Then, the PTT peer responds with a "200 OK" message in Step 2 as a final response to the INVITE request. In Step 3, peer-A and the PTT peer exchange MBCP messages to create an MBCP connection [20].

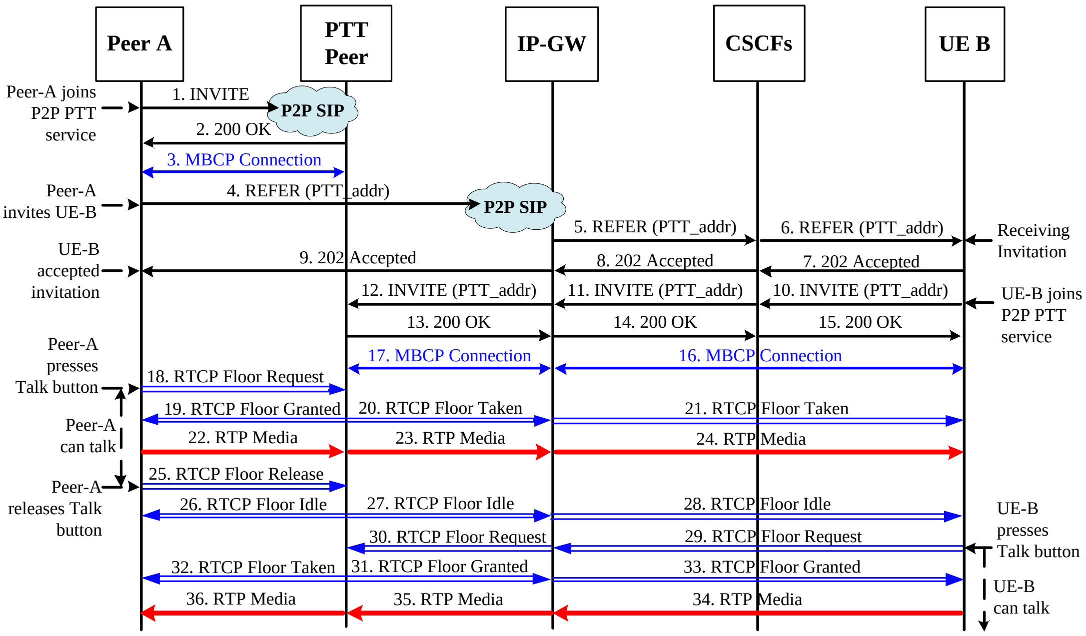


Fig. 5. Service scenario II: peer-A invites UE-B to join P2P PTT service

To invite the IMS UE-B to join the P2P PTT service, peer-A sends a REFER message to UE-B with the Refer-to field containing the P2P PTT peer URI. The REFER request firstly reaches the IP-GW by the P2PSIP routing mechanism, and the REFER request will the be forwarded and routed to UE-B via CSCFs in Step 4 to Step6. From Step 7 to Step 9, UE-B processes the REFER message and accepts the request by responding with a "202 Accepted" message.

The IMS UE-B is aware of the PTT peer URI by the REFER request. Then, from Step 10 to Step 12, it joins the PTT session by sending an INVITE request to the PTT peer. A "200 OK" message is sent back to UE-B, indicating that the UE-B has successfully established the session with the PTT peer from Step 13 to Step 15. In Steps 16 and 17, UE-B exchanges the MBCP message with the PoC server via the IP-GW.

From Step 18 to Step 24, peer-A has the right to talk by sending a message to the P2P PTT peer, which plays the role of PTT server, and replicates and transmits RTP media packets to all group members (except the sender).

From Step 25 to Step 28, peer-A releases the Talk button by sending an RTCP Floor Release message to the PTT peer, and then the PTT peer responds and broadcasts the RTCP Floor Idle to all group members. Step 29 to Step 36 show that UE-B has the right to talk by sending an RTCP Floor Request to the PTT peer and receiving an RTCP Floor Granted before starting to send RTP media.

2.3.3 Interworking PTT Service Between P2P Overlay and IMS Networks

Assume that we have an existing P2P PTT service with two joined P2P peers (A, C), and the PoC server with three established IMS UEs(B, D, E) (Steps 1 and 2).

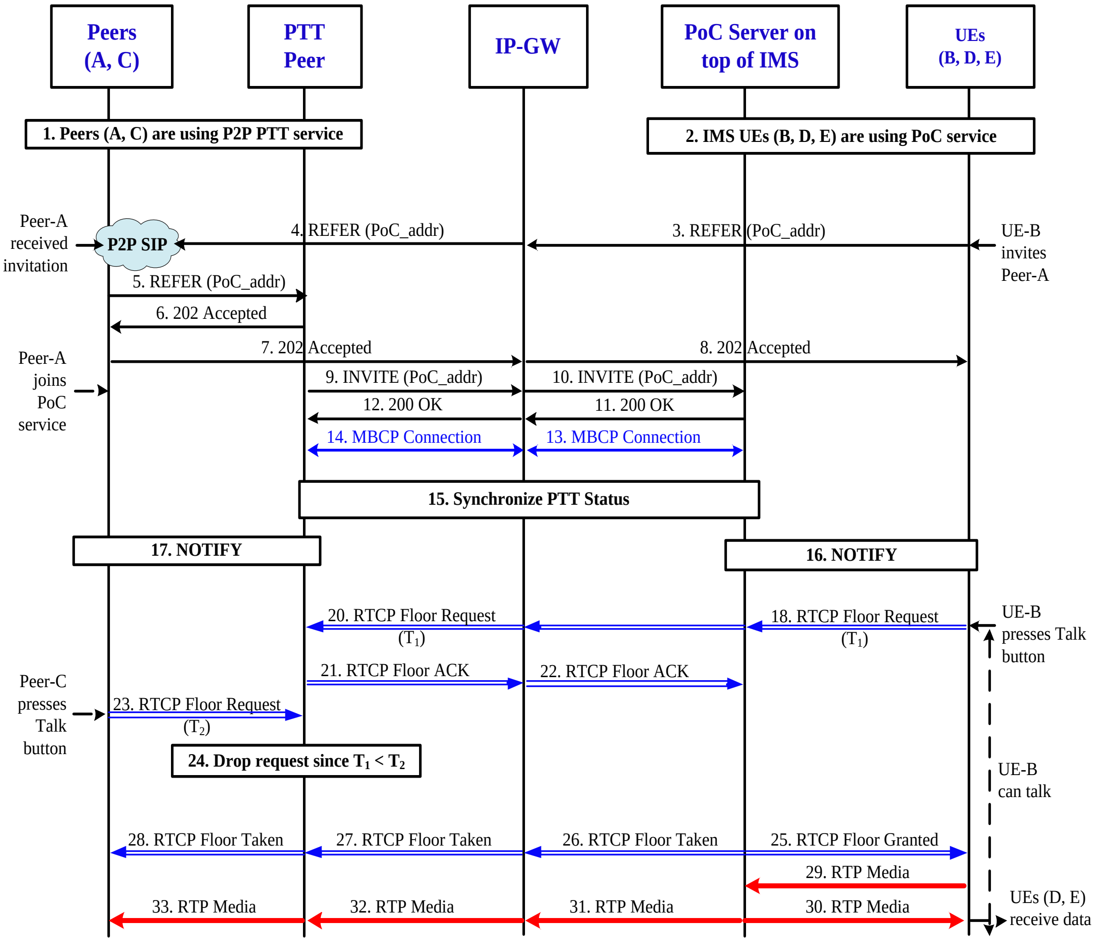


Fig. 6. Service scenario III: interworking PTT service between P2P overlay and IMS networks

Fig. 6 illustrates a scenario in which the IMS UE-B wants to invite a P2P-aware peer-A to the PoC service. From Step 3 to Step 4, UE-B sends a REFER request with the Refer-to field containing the PoC server URI to peer-A, which is now in the P2P PTT service. Therefore, it forwards the REFER request to the PTT peer with an aim to inform the the PTT peer that it has an interworking PTT service request in Step 5. From Step 6 to Step 8, the PTT peer responds with the "202 Accepted" to UE-B. The PTT peer is aware of the PoC server URI by the REFER request, and then it sends an INVITE request message to the PoC server in Steps 9 and 10. After the session between the PTT peer and the PoC server has been established, a "200 OK" response is sent by the PoC server to the PTT peer in Steps 11 and 12. From Step 13 to Step 14, both the PTT peer and the PoC server exchange the MBCP message to establish to an MBCP connection.

Because both PTT peer and the PoC server play the role of a floor controller they need a synchronized PTT service status procedure in Step 15. The purpose of this procedure is to ensure that only one granted user is able to send RTP media in the interworking PTT session. If there are two granted users, the procedure will grant sending rights to only one user based on the priorities of floor requests depending on their relative timestamp. The relative timestamp is the period between the time when the RTCP Floor Release is received and the subsequent time when the floor request is made [10]. In comparing two relative timestamp of two granted users that are stored in the PTT peer and the PoC server, whichever relative timestamp is smaller implies that the user is more eager to get the floor and hence a higher priority is set to that user. Consequently, that user becomes the unique granted user in the interworking PTT service.

After the synchronization procedure is done, the PoC server and the PTT peer inform their group members about the granted user and the status of the interworking PTT service by NOTIFY messages in Steps 16 and 17. From Step 18 to Step 20, UE-B presses the Talk button, and issues the RTCP Floor Request message with timestamp T_1. The floor request is routed to the PoC server and the PTT peer where it is stored for the future process of the interworking PTT service. In Steps 21 and 22, the PTT peer sends RTCP Floor ACK back to the PoC server. In Step 23, peer-A sends an RTCP Floor Request with relative timestamp T_2 to the PTT peer. Upon receipt of the request of peer-A, the PTT peer drops the floor request of the peer-A because $T_1 < T_2$. From Step 25 to Step 33, UE-B obtains the floor by receiving an RTCP Floor Granted and starting to send RTP media data to all members in the interworking PTT service (except itself).

3. Performance Evaluation

We analyzed three interworking scenarios and show the computation of service scenario I in detail below. With service scenarios II and III, we used the same method to analyze the final total delay time for the PTT service interworking invitation setup. Table 1 shows system parameters. The following parameters and equations were defined in [23] and refer from the methods used by the author in [18] to compute session setup delay time. $T_{wl\_X,Y}$ (resp. $T_{w\_X,Y}$) defines the one-way transmission delay of a message of size s between X and Y with a wireless (resp. wired) link.

Table 1. System Parameters

Parameters	Values
Wired link bandwidth (**B_w**)	100 Mbps
Wireless link bandwidth (**B_{wl}**)	11 Mbps
Wired link delay (**L_w**)	2 ms
Wireless link delay (**L_{wl}**)	10 ms
Message packet size (**S**)	600 bytes

$$T_{wl\_X,Y}(s) = d_{X,Y}\left(\frac{1+q}{1-q}\right)\left(\frac{s}{B_{wl}} + L_{wl}\right) \tag{1}$$

$$T_{w\_X,Y}(s) = d_{X,Y}\left(\frac{s}{B_w} + L_w + \omega_q\right) \tag{2}$$

The parameter q is the probability of a wireless link failure; ω_q ω_q is the average queuing delay (0.5ms) for each router on the Internet. B_w (resp. B_{wl}) is the bandwidth of a wired (resp. wireless) link, and L_w (resp. L_{wl}) is the wired (resp. wired) link delay. In addition, to get a total session setup delay time, one must consider the lookup delay. In this paper, we used the Kademlia [24] algorithm in order to organize the P2P overlay network. The average time for the Kademlia algorithm to lookup is $\log_2 N$, with N indicating the number of peers. If the IMS UE sends a REFER message to a peer, $T_{refer\_UE,peer}$ is computed as the following:

$$T_{refer\_UE,peer}(s) = T_{refer\_UE,pcscf}(s) + T_{refer\_pcscf,gw}(s) + T_{refer\_lookup}(s) + T_{refer\_gw,peer}(s) \tag{3}$$

According to message flows in service scenario I in **Fig. 4**, $T_{accepted\_peer,UE}$, $T_{invite\_peer,PoC}$, $T_{200ok\_PoC,peer}$, and $T_{mbcp\_peer,PoC}$ are computed respectively as the following:

$$T_{accepted\_peer,UE}(s) = T_{accepted\_peer,gw}(s) + T_{accepted\_gw,pcscf}(s) + T_{accepted\_pcscf,UE}(s) \tag{4}$$

$$T_{invite\_peer,PoC}(s) = T_{invite\_lookup}(s) + T_{invite\_peer,gw}(s) + T_{invite\_gw,pcscf}(s) + T_{invite\_pcscf,PoC}(s) \tag{5}$$

$$T_{200ok\_PoC,peer}(s) = T_{200ok\_PoC,pcscf}(s) + T_{200ok\_pcscf,gw}(s) + T_{200ok\_gw,peer}(s) \quad 6)$$

$$T_{mbcp\_peer,PoC}(s) = (T_{mbcp\_peer,gw}(s) + T_{mbcp\_gw,PoC}(s)) * 3 \tag{7}$$

We assume that only the link between IMS UE and Proxy Call Session Control Function (PCSCF) in the IMS network is the wireless link; after finishing the lookup procedure, the IP-GW has only one hop link to reach the corresponding peer. Thus, we can compute the total delay time for the invitation as the following:

$$T_{total}(s) = T_{refer\_UE,peer}(s) + T_{accepted\_peer,UE}(s) + T_{invite\_peer,PoC}(s) + T_{200ok\_PoC,peer}(s) + T_{mbcp\_peer,PoC} \tag{8}$$

We considered two factors and analyzed the session setup delay according to changes in two factors: q and the number of peers in the P2P overlay network. In **Fig. 7** we can see that the q factor is more influential in setting up an interworking PTT session than the P2P overlay network size is. Therefore, it is important to decrease the probability of wireless link failure in order to decrease the invitation PTT session setup delay.

We used the same method as in the first scenario to analyze the second and the third scenarios. We then computed the total setup time for the invitation respectively as the following:

$$T_{total}(s) = T_{refer\_peer,UE}(s) + T_{accepted\_UE,peer}(s) + T_{invite\_UE,PTT}(s) + T_{200ok\_PTT,UE}(s) + T_{mbcp\_UE,PTT} \tag{9}$$

$$T_{total}(s) = T_{refer\_UE,peer}(s) + T_{accepted\_PTT,UE}(s) + T_{invite\_PTT,PoC}(s) + T_{200ok\_PoC,PTT}(s) + T_{mbcp\_PTT,PoC} + T_{syn}(s) + T_{notify}(s) \tag{10}$$

In the formula (3-10), $T_{syn}(s)$ and $T_{notify}(s)$ are computed as the following:

$$\begin{aligned} T_{syn}(s) = T_{mbcp\_PTT,gw}(s) + T_{mbcp\_gw,PoC}(s) + T_{mbcp\_PoC,gw}(s) \\ + T_{mbcp\_gw,PTT}(s) + T_{ack}(s) * 2 \end{aligned} \quad (11)$$

$$T_{notify}(s) = T_{notify\_PTT,peer}(s) + T_{notify\_PoC,UE}(s) \quad (12)$$

From these formulas, we analyzed setup latency and archived the results in **Fig. 8** for service scenario II and **Fig. 9** for service scenario III.

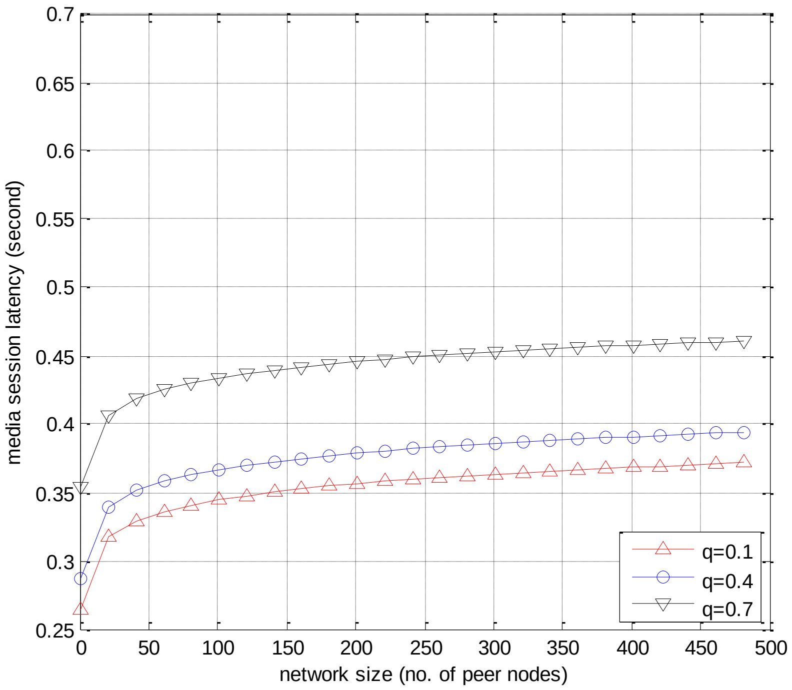


Fig. 7. Latency as network size of service scenario I

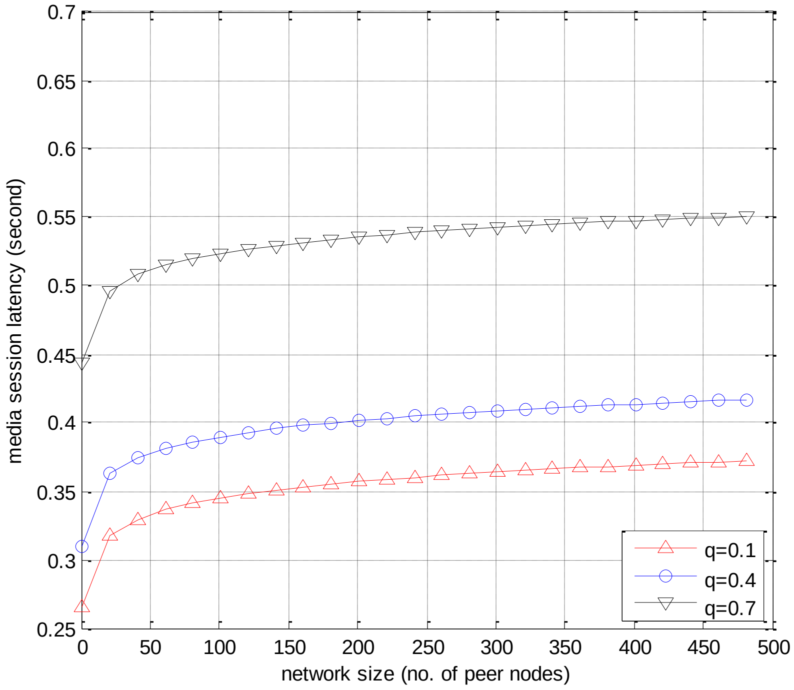


Fig. 8. Latency as network size of service scenario II

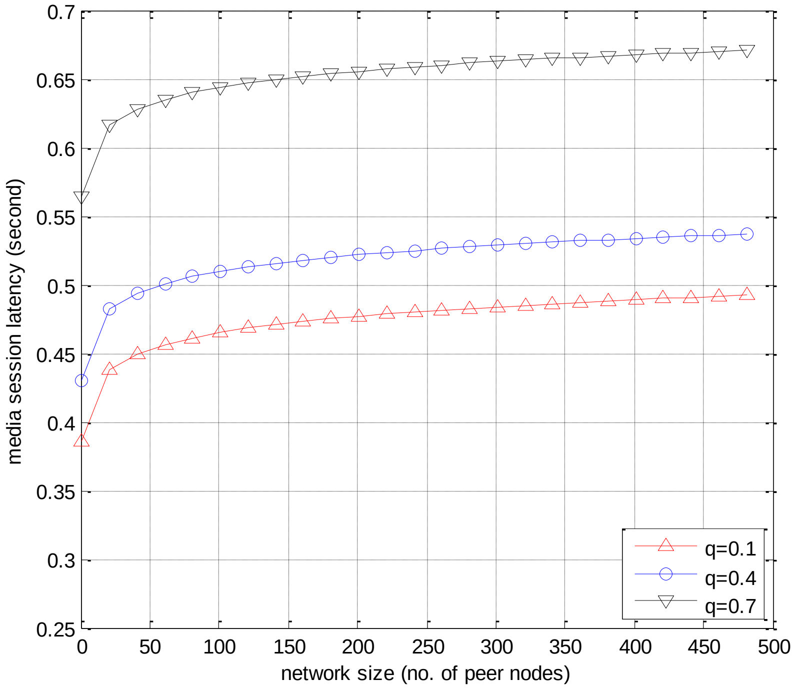


Fig. 9. Latency as network size of service scenario III

4. System Implementation and Test Results

This chapter illustrates our real implementation of the PTT service interworking between P2P overlay and IMS networks by using the IP-GW. To build a test-bed, we leverage the open-source SIP library and developed more functions to make the IMS user client and a PoC server. The IMS core network includes PCSCF and SCSCF, which were developed by customizing an SIP server. We also utilized the same SIP stack for developing normal and P2P PTT peer functions. For interworking, we focused on implementing the functions of the IP-GW, which were developed for both IMS and P2P interfaces. We used open-source DHT libraries, which implemented the Kademlia [24] algorithm and added modifications to create the P2P overlay. We set up our test-bed environment to study the underlying media packet's transmission. The scenario for our test is that we had a PTT service on a P2P overlay with one P2P PTT peer, and two normal peers (A and B) were simulated as shown in **Fig. 10**.

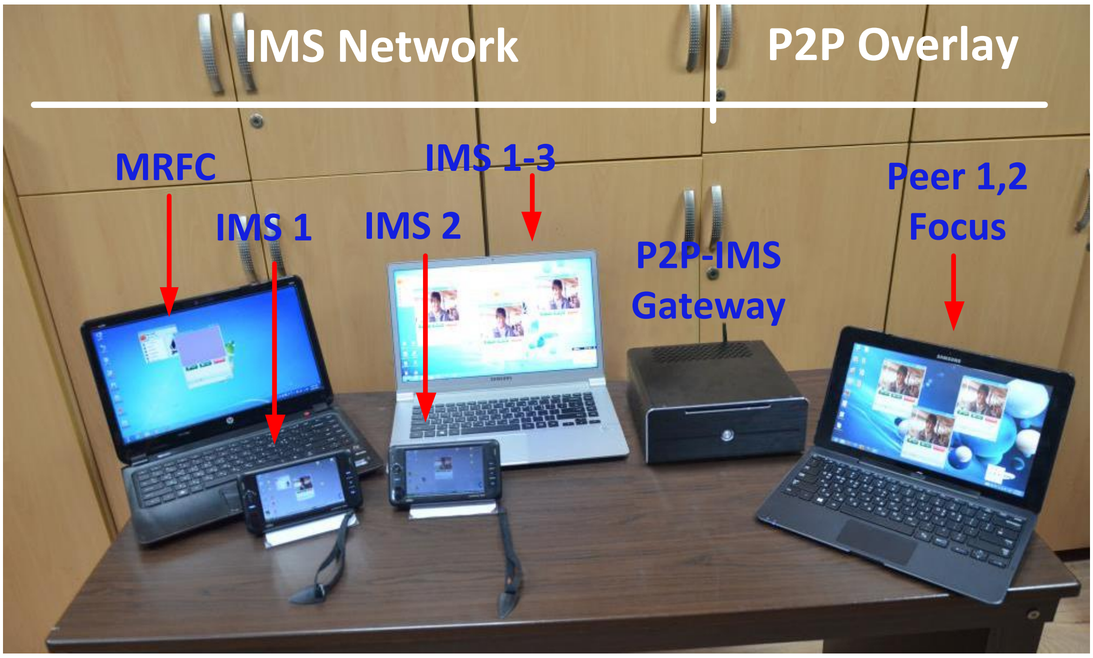
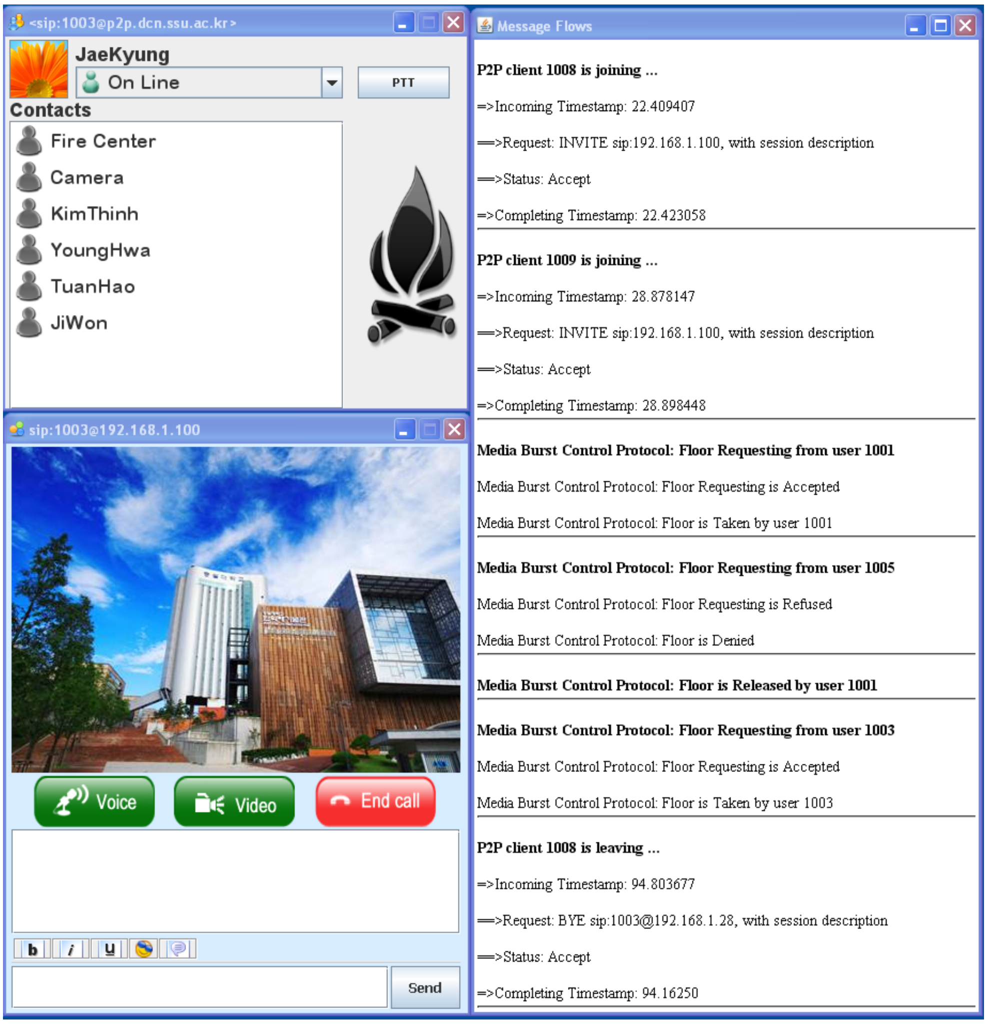


Fig. 10. Implemented results and test environment

In addition, **Fig. 11** shows the graphic user interface of the implemented interworking system, including a main screen with a list of buddies. It enables its user to start a PTT session with a specific user without regarding of the domain where that user locates. The **Fig. 11** is the out-of-session screen with no any video displayed. Moreover, a user can initiate a PTT session and invite the other to join later. Through the interface, the user can ask for a grant to send media resource via MBCP mechanism and display as illustrated in Message Flows dialog. The process of granting Floor Request in the case it is in available status as well as the case it is denied by the PTT server is also demostrated Message Flows window.



P2P client 1008 is joining ...

=>Incoming Timestamp: 22.409407

==>Request: INVITE sip:192.168.1.100, with session description

==>Status: Accept

=>Completing Timestamp: 22.423058

P2P client 1009 is joining ...

=>Incoming Timestamp: 28.878147

==>Request: INVITE sip:192.168.1.100, with session description

==>Status: Accept

=>Completing Timestamp: 28.898448

Media Burst Control Protocol: Floor Requesting from user 1001

Media Burst Control Protocol: Floor Requesting is Accepted

Media Burst Control Protocol: Floor is Taken by user 1001

Media Burst Control Protocol: Floor Requesting from user 1005

Media Burst Control Protocol: Floor Requesting is Refused

Media Burst Control Protocol: Floor is Denied

Media Burst Control Protocol: Floor is Released by user 1001

Media Burst Control Protocol: Floor Requesting from user 1003

Media Burst Control Protocol: Floor Requesting is Accepted

Media Burst Control Protocol: Floor is Taken by user 1003

P2P client 1008 is leaving ...

=>Incoming Timestamp: 94.803677

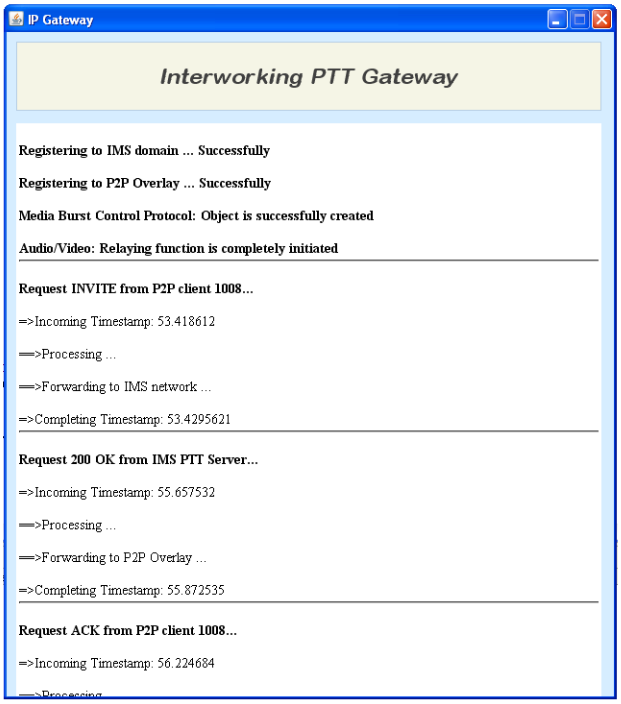
==>Request: BYE sip:1003@192.168.1.28, with session description

==>Status: Accept

=>Completing Timestamp: 94.16250

Fig. 11. Graphic User Interface of Interworking PTT System

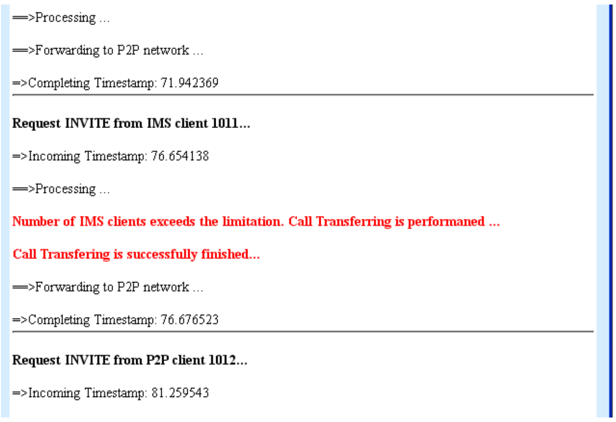
At the PTT-IMS gateway, the internal message flows are processed as shown in **Fig. 12**. Upon lauching, the gateway conducts the registration process to IMS network and P2P overlay. After registering succesfully to both domains, some components performing MBCP management and storing session information are initiated. The gateway contains a mapping table which is used to determine which target it should forward the message to in the case sender and receiver locate at different networks. Then it can act as a relay for both signaling plane and media plane. We also determine the timestamp when a message arrives at a certain interface and when it is completely processed to forward to the other domain. For instance, the delay for an INVITE message from IMS domain to P2P overlay or vice versa needed to be manipulated at gateway is about 0.2s ~ 0.4s. This value obtained on a common system can be acceptable in a delay-sensitive application but requires the real-time property like push-to-talk service.



```
Registering to IMS domain ... Successfully

Registering to P2P Overlay ... Successfully

Media Burst Control Protocol: Object is successfully created

Audio/Video: Relaying function is completely initiated
________________________________________________________
Request INVITE from P2P client 1008...

=>Incoming Timestamp: 53.418612

==>Processing ...

==>Forwarding to IMS network ...

=>Completing Timestamp: 53.4295621
________________________________________________________
Request 200 OK from IMS PTT Server...

=>Incoming Timestamp: 55.657532

==>Processing ...

==>Forwarding to P2P Overlay ...

=>Completing Timestamp: 55.872535
________________________________________________________
Request ACK from P2P client 1008...

=>Incoming Timestamp: 56.224684

==>Processing
```

Fig. 12. The PTT-IMS Gateway with message flows of interworking scenario

In our test-bed, we sequentially increased the number of IMS users from one to five users joining the P2P PTT service. The PTT service is demonstrated by launching peers and clients and have them join sequentially to the ongoing session. The experience shows that every additional IMS user taking part in the P2P PTT service via the IP-GW increases the packet load through the gateway until the moment at which the P2P PTT peer reaches its threshold. The P2P PTT peer then temporarily accepts the last IMS user. Then, call transfer methods are executed to transfer all IMS sessions that are controlled by the P2P PTT peer in the P2P overlay network to the PoC server in the IMS network as shown in **Fig. 13**.



```
==>Processing ...

==>Forwarding to P2P network ...

=>Completing Timestamp: 71.942369
________________________________________________________
Request INVITE from IMS client 1011...

=>Incoming Timestamp: 76.654138

==>Processing ...

Number of IMS clients exceeds the limitation. Call Transferring is performaned ...

Call Transfering is successfully finished...

==>Forwarding to P2P network ...

=>Completing Timestamp: 76.676523
________________________________________________________
Request INVITE from P2P client 1012...

=>Incoming Timestamp: 81.259543
```

Fig. 13. The PTT-IMS Gateway with message flows of interworking scenario

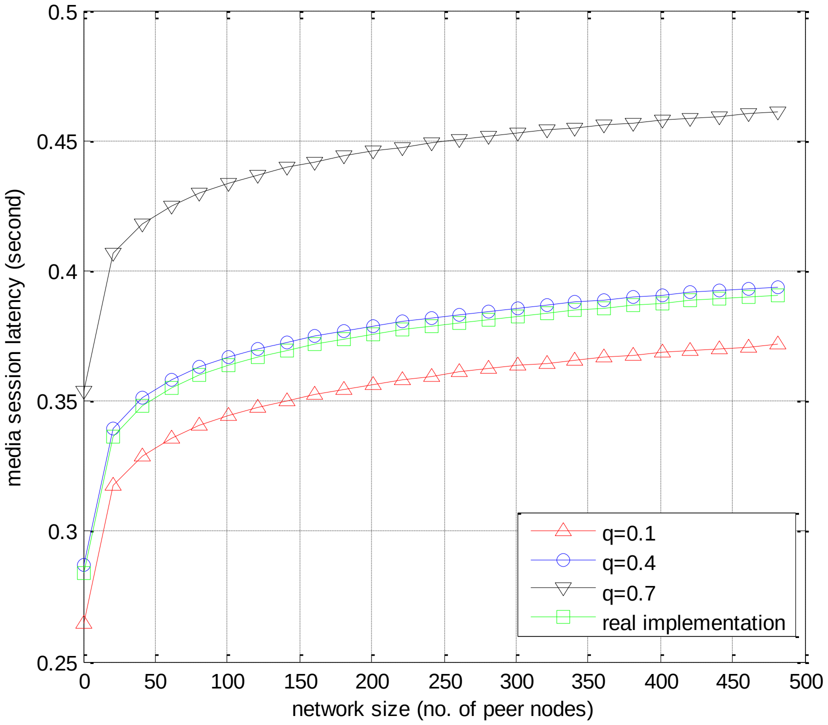


Fig. 14. Latency as network size of service scenario I

The **Fig. 14** shows the performance for the service scenario I including the measured result from the testbed. The delay time for a peer in P2P system to establish a media session with PoC in IMS system is about 0.25s ~ 0.4s which can be acceptable in a delay-sensitive application.

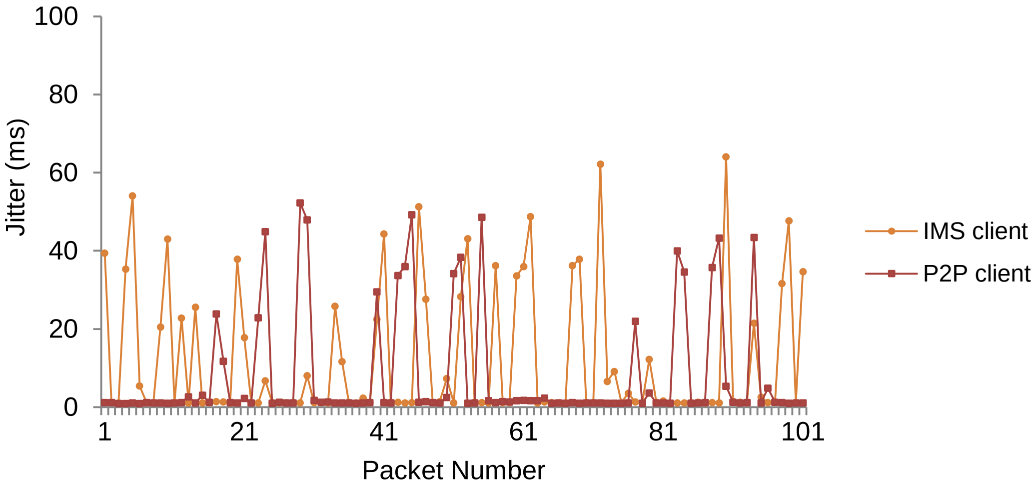


Fig. 15. Jitter between packets in scenario I

The **Fig. 15** illustrates the jitters for transfering media streams in scenario I. Jitters are almost below 40 ms for both the IMS client and the P2P client meaning that the media streams are smooth and users will have good experiences during the conference regardless of whether or not the client receives media streams via the gateway.

5. Conclusions

In this paper, we have proposed a system model for enabling the PTT service interworking in P2P overlay networks with IMS networks. We have introduced three interworking PTT service scenarios and described detailed functions of each component in the architecture. We performed analyses to confirm the session setup latency taken between two hosts in three interworking PTT service scenarios. We also conducted the experiment measurements, in terms of packets through the IP-GW, in the test-bed to demonstrate the realization of interworking PTT service between P2P overlay and IMS networks. Our system achieved a good performance to support interworking PTT services .The results promise to support better services and contribute to expanding potential applications for communication in IMS and P2P networks.

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