Advanced Path-Migration Mechanism for Enhancing Signaling Efficiency in IP Multimedia Subsystem

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Abstract

Since Internet Protocol (IP) is the most important protocol in Next Generation Networks (NGNs), 3rd Generation Partnership Project (3GPP) utilizes Session Initial Protocol (SIP) based on IP as the base protocol for negotiating sessions in IP Multimedia Subsystem (IMS). Different from traditional circuit-switched network, in IMS, the media traffic and signaling are delivered through IP transport. The media traffic may affect the signaling efficiency in core network, due to traffic collisions and best effort packets delivery. This paper proposes a novel path-migration mechanism for enhancing the traffic efficiency in integrated NGN-IMS. The simulation results show that the interference and traffic collision can be reduce by applying proposed path-migration mechanism and the signaling efficiency in core network can be improved with higher system capability and voice quality.

Keywords: Next generation networks, IP multimedia subsystem, session initial protocol, signaling traffic, path migration

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1. Introduction

The architecture of Universal Mobile Telecommunications System (UMTS) are divided into three parts: circuit-switched network (CS), packet-switched network (PS) and IP Multimedia Subsystem. The UMTS services can be roughly divided into voice service, data service and packet-based multimedia service. When UMTS is integrated with heterogeneous wireless network technologies such as 802.11 series wireless local area network (802.11 WLAN) and 802.16 series network (Worldwide Interoperability for Microwave Access, WiMAX), it forms an ubiquitous services for anytime and anywhere, which required to reach the goal of next generation communication networks.

The IMS is a network subsystem specified by 3GPP [1]. The architecture of IMS has already been evolved during the development of 3GPP standardization. 3GPP proposed Release 99 (R99) in 1999 that contains the system architecture and services of core network and standards such as Wideband Code Division Multiple Access (WCDMA) and Time Division-Code Division Multiple Access (TD-CDMA). The All-IP architecture planed promptly after R99 (the forerunner of IMS). Due to the architecture was too complex, the development work was divided into Release 4 (R4) and Release 5 (R5).

In 2000, R4 was expected to exclude IMS. This release focused on the specification of IP transport, and was issued in 2001. R5 was completed in 2002, and brought the IMS into the 3GPP standard officially. The further IMS related functions are stabilized toward stability Release 6 (R6) [2] that released in 2005. Then followed Release 7 (R7) that adopted the concept of fixed mobile convergence (FMC).

Different from traditional circuit-switched network, the media traffic and signaling are delivered through IP transport in IMS. The media traffic will affect signaling efficiency in the IP core network, due to the traffic collisions and packets delivery mechanism in best effort mode. Theferfore, we have to prevent service failures in IMS-based multimedia services [3]. In this paper, we propose a novel path-migration mechanism for IMS. With adopting our mechanism, the signaling efficiency could be enhanced even when the network loading is increasing. Moreover, the meachnism can guaranteed overall SIP signaling related service such as emergency signalling and its efficiency.

The contributions made in this paper are summarized as follows:

(1) We discover that in the most current published researches, SIP call setup does not considering background or ongoing media traffic. In addition, the researches do not consider their mechnicm in the IMS environment [4][5][6].

(2) We use a real platform and testing environment to evaluate the impact of background traffic to signaling efficiency in IMS, which also completed with simulation results using OPNET Modeler simulator. From the both results, we can proof the influence of background and media traffic to IMS signaling.

(3) We propose a novel path migration mechanism for IMS to enhance the SIP signaling efficiency in each path. We also evaluate the proposed path migration mechanism through the OPNET network modeler.

Rest of the paper is organized as follows: in Section 2, we review and discuss the related works and technological background. In Section 3, we propose our path migration mechanism for NGN-IMS environments. We also present our experimental and simulation results in Section 4. Finally, we present our conclusions and future works in the section 5.

2. Related Work

First of all we introduce the IMS which play an important role in NGN. Then, we brief summary some researches which focus on the influences to call setup time and point out the problems. Finally, we show the basic concept of possible solution to overcome this problem.

2.1 IP Multimedia Subsystem

The concept of IMS is based on All-IP transport to merge telecommunication technologies, wireless networks and wired networks to provide more secured, extensible, real-time and interactive multimedia services at 3G and even future 4G networks [7][8][9]. IMS can be regarded as the trend of the future wireless communication network, which serves not only fixed users but also mobile users [10]. IMS uses the modified IETF SIP[11] to establish the service session. The main function is to combine circuit-switched and packet-switched domains. The contents are not limited by the access medium but become more extensible to offer more value-added services to user.

The architecture of IMS is shown by **Fig. 1**. The architecture can divided into three tiers: the Media/Transport plane, Control/Signaling plane and Service/Application plane.

The Media/Transport plane is a referral to a wide range of different access technologies. Based on IP transport layer, users access the system through Wireless LAN (WLAN), General Packet Radio Service (GPRS) or UMTS to acquire connectivity. Once connected to IMS, users can access a variety of multimedia services.

Set of IMS core components in Control/Signaling plane – Call Session Control Functions (CSCFs) – are consisted of Proxy-CSCF (P-CSCF), Interrogating-CSCF (I-CSCF) and Serving-CSCF (S-CSCF). CSCF is the main component that responsible for the SIP based voice and multimedia session control, including the application layer registration and location information exchange with Home Subscriber Server (HSS). P-CSCF is the first contact point for User Equipment (UE). The UE can obtain the P-CSCF address after registering with the access network. S-CSCF is mainly responsible for Call Service and Session Control. I-CSCF is the first connecting point when requests enter the serving network. I-CSCF is responsible for inquiring with HSS about the user's information and relevant location. I-CSCF has implemented the Hiding Inter-work Gateway (THIG) function to improve security and privacy. The SIP signaling will be processed and routed to the destination through this plane.

In the Service/Application plane, there are various application servers. The application servers provide users a wide range of IMS service. Operators can use the standard IMS architecture to build up their application servers.

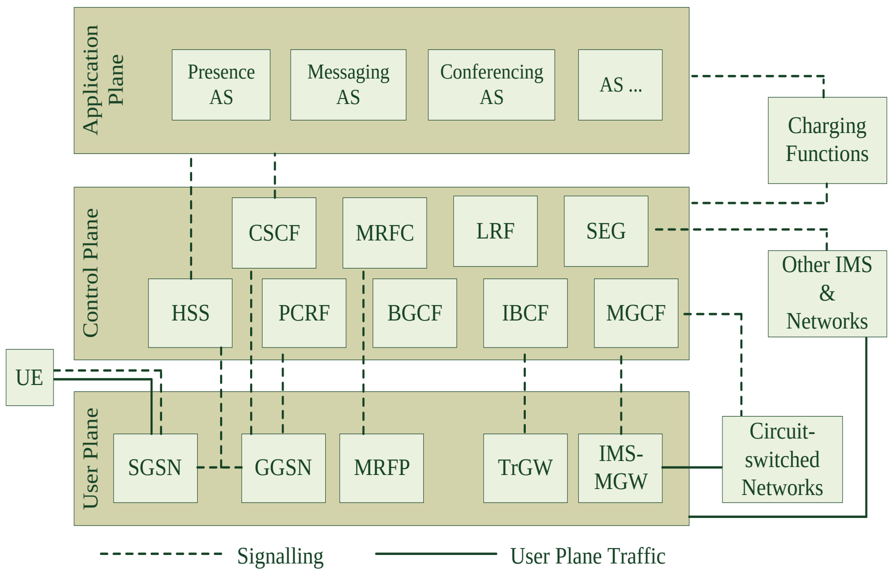

Fig. 1. Layered Architecture of IP Multimedia Subsystem

2.2 Traffic Analysis in IMS

As the **Fig. 2** shows, there are two major traffic types in IMS. The first one is signaling traffic consists of SIP method and response. The other is media traffic such as Real-time Transport Protocol (RTP) packets, which delivers multimedia traffics after session negotiation. The other signaling protocols in IMS are summaried in the **Table 1**.

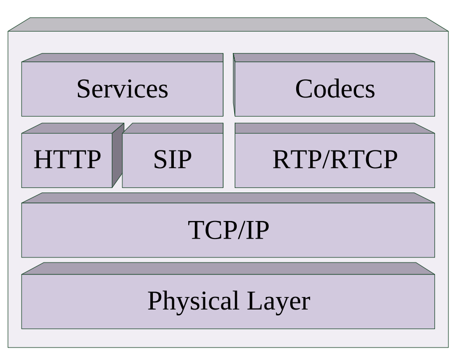

Fig. 2. Protocol Stack of IMS Services.

Table 1. Summary of Signaling Protocols in IMS

Protocol	Reference Point	Involved entities
SIP	Gm, Mw, ISC, Ma, Mm, Mg, Mi, Mj, Mk, Mr	UE, P-CSCF, I-CSCF, S-CSCF, AS, IBCF, MGCF, BGCF, MRFC
Dismeter	Cx, Dx, Sh, Dh, Gx, Rx, Ro, Rf	I-CSCF, S-CSCF, HSS, SLF, AS, SIP AS, OSA SCS, OSA SCF, IM-SSF, PCRF, MRCF, OCS, BCF, MGCF, IBCF, CDF
MAP (Mobile Application Part)	Si	IM-SSF, HSS
H.248	Mp, Mn	MRFC, MGCF, IMS-MGW
HTTP	Ut	UE, AS
Not specified	Ml, Mx, Ix, Iq	E-CSCF, LRF, BGCF, IBCF, TrGW, P-CSCF

Call setup delay is an important indicator for evaluating performance of IMS environment. There are some researches focused on the performance evaluation at different environments. Pack et al [4] analyzed the SIP message transfer delay over multi-rate wireless networks where different transmission modes based on adaptive modulation code are supported in their environment. They also found that different message size and channel condition affects the transfer delay time. Pack et al also derived the analytical expression for the average call setup delay. Then they observed the impact of the number of contending mobile nodes in a WLAN. From their simulation and analytical results, we can understand that the call setup latency was sensitive to the number of mobile nodes in a WLAN. Thus, an important Tinit value should be carefully chosen to avoid unnecessary end-to-end delay and retransmissions. Thus, the call setup latency cab be reduced **[5]**.

Curcio and Lundan [6] used a 3G network emulator to measure time delay parameters in their work. The parameters included post-dialing delay, answer-signal delay and call-release delay. They compared their results to local, national, international and overseas Intranet LAN calls to show the delay time in different region.

However, these literatures merely considered the impacts toword call setup time and no one considers the background traffics' effect on the call setup time and signaling efficiency for Voice over IP (VoIP) in IMS environments. In the real mobile communication network environments, the bandwidth is usually precious and limited. If we do not consider the effect of background traffic, ongoing media, or active calls to new sessions or signaling negotiation, it would cause a significant performance degradation on real system implementation.

2.3 Path Migration

Path migration is a concept which used for compromising or achieving Quality of Service (QoS) of network resource management. Xufeng and Ten-Hwang [12] proposed a path selection method for traffic migration to a better path in 802.6d based cluster environments, when the network efficiency is getting low. They proposed two migration mechanisms: forced migration and vulnerable migration. These two migration mechanisms can be triggered by network core or cluster side when the network's efficient degradation is occuring.

Wang et al [13] proposed Virtual ROuters On the Move (VROOM), an application based on path migration mechanism. They designed a virtual router manager in physical router in order to divide the routing task for lower network layer. One needs to manage the router or process large maintenance works, the online traffic could be migrated from original router to another virtual router without affecting ongoing data and traffic tranmissions.

These traditional path migration mechanisms are not suitable to be adopted directly in IMS environment. Therefore we propose a novel path-migration mechanism for IMS that will be discussed in the following section.

3. Path Migration Mechanism for NGN-IMS

Before introducing our path migration mechanism, we performed an evaluation in real IMS environment to give preliminary understanding about the relationship between background traffic (ongoing media session) and signaling efficiency. The background traffic can be various traffic flows on the internet such as other users' surfing the internet, download / uploading files, video streaming. The total bandwidth within a base station is limited. In our environment, we regard all the other traffic as backgound traffic.

3.1 Media Traffic Impact in IMS

Firstly, we use OpenIMS Core Project [14] as the core network platform to build our IMS testbed and we use IMS Bench SIP [15] to emulate the UE. We measure the call setup time with different background traffic over 100Base-T Ethernet Network.

The measurement result is shown as **Fig. 3** and **Table 2**. We can observe that when the bandwidth is occupied by different background traffic, the call set up delay is increasing. According to our measurement, the call setup delay increases significantly when background traffic rate is beyond 95Mbps.

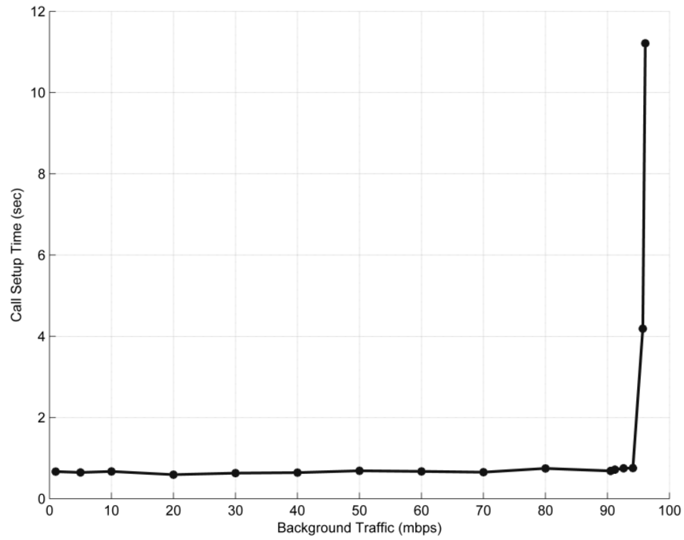

Fig. 3. Call Setup Delay with background traffic

Table 2. Measurement results of Call setup time with different background traffic

Background Traffic (mbps)	1	5	10	20	30	40	50	60
Call Setup Time (second)	0.668	0.646	0.671	0.592	0.63	0.642	0.687	0.672
Background Traffic (mbps)	70	80	90.5	91.2	92.6	94.1	95.7	96.1
Call Setup Time (second)	0.653	0.746	0.684	0.716	0.749	0.755	4.1873	11.213

3.2 Path Migration Mechanism for NGN-IMS

Our proposed path migration mechanism is based on IMS architecture. Access Point (AP) and Base Station (BS) are ruling as gateways, which located on access network domain and provides the connectivity for UE, forming the set as Traffic Manager Gateway (TMG). The main entry point for UE to connect to IMS is P-CSCF. By the consideration of SIP sginlling, P-CSCF is a node to route and process SIP message for UE.

Firstly, we define *B* as the total bandwidth of the physical link between routing node (P-CSCF) and the TMG of different access networks. *EC* is the Enhanced Channel with enough bandwidth resource for guarantee SIP signaling. *BT* is the background traffic, which generated by other sessions in the network. *R* is the residues bandwidth, which is still free and has not been used in the link. The relationship can be defined as

$$B = BT + EC + R \tag{1}$$

Thus, in our scenario, *B* is defined as the different bandwidth between Traffic Manager Gateway and P-CSCF. The network status can be divided into three situations such as traffic litght through the analysis result from last section:

- If background traffic (*BT*) is below 90% avaliable bandwidth (*B*), the network status is *NORMAL (Green)*.
- If background traffic (*BT*) is between 90% and 95% avaliable bandwidth (*B*), the network status is *CONGESTED (Yellow)*.
- If background traffic (*BT*) is higher than 95% avaliable bandwidth (*B*), the network status is *FULL (Red)*.

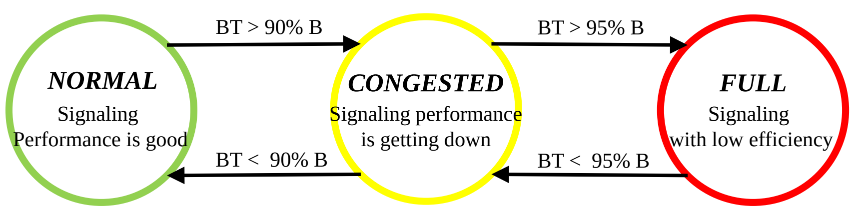

Fig. 4. Network status transition graph - Green is NORMAL, Yellow is CONGESTED, and Red is FULL

If we do not trigger the path migration mechanism or start well-arranged bandwidth control when *CONGESTED* occurs, the network situation will quickly jump to *FULL* states rapidly. Hence the network performance and IMS SIP signaling efficiency would fall down significantly. Thus, we can consider the relationship between *BT* and *B* to design our path migration mechanism. We have to avoid the network states is falling to *CONGESTED*, especially *FULL* state that will seriously affect the SIP signaling efficiency.

For overall bandwidth resource management function, we monitor the UE's states by operating the TMG. The default bandwidth allocated for Enhanced Channel (*EC*) is 15 percent of total bandwidth *(B)*. The *EC* is guaranteed to efficiently delivery SIP signaling messages in IMS. Different from regular QoS mechanism, any modification on the network equipment or protocol is unnecessary. The mechanism can be adapted on any existing network equipment. The process flow of proposed path migration mechanism is defined as algorithm in **Table 1**.

Table 3. Algorithm

Path Migration Mechanism for IMS
INPUT: *BT*, *B* Calculate *EC*;

Monitor the traffic between TMG and UE;
If If the used *BT* is more than 95 percent of *B*
    Channel status jumps into FULL;
    More session setup is prohibited.
Else If the used *BT* is more than 90 percent of *B*
    Channel status jumps into CONGESTED;
Else if the used *BT* is more than 80 percent of *B*;
    Setting the configuration of *EC* and UE over TMG*;*
    Migrate the SIP signaling message from *BT* to *EC;*
    Terminate SIP message transmission in *BT;*
Else
    Channel status jumps into NORMAL;
OUTPUT: *Channel status*

The step of path migration algorithm is described as follows: In the beginning, the overall bandwidth and measured background traffic is the input for calculating the bandwidth for enhanced channel. Then, we monitor traffic between TMG and UE. The different bandwidth usage is mapped to corresponding status. For instance, when the ongoing background traffic is more than 95% or 90% bandwidth, the channel status becomes FULL or CONGESTED. In our approach, we are devoted to avoid those situations. When the ongoing background traffic reaches 80% bandwidth, the path migration mechanism is triggered between TMG and P-CSCF.

We use IP-in-IP tunnel to build up the Enhanced Channel (EC) between P-CSCF and TMG in the migration process. This tunnel is used to accomplish the resource allocation and guarantee the bandwidth. Then, TMG and P-CSCF will classify the message type wether it is signaling message or not. SIP message is delivered through the Enhanced Channel. Thus, the SIP signaling message can be delivered correctly with guaranteed bandwidth.

Finally, if the background traffic is less than 80% bandwidth, we will release the Enhanced Channel. The channel status jumps to NORMAL.

4. Simulation Results and Analysis

In real environment, we observe, measure and analysis the impact of background traffic to signaling efficiency. Then we model the impact to simulator in order to accomplish more detailed analysis such as the amount of users who extaqblishing the calls.

In order to validate our path migration mechanism for IMS, we use the OPNET network modeler [16][17] to implement our path migration mechanism. The most important components for adopting path migration mechanism are the TMG and UE. The related parameters which used in this simulation are shown in the **Table 3**. The simulation scenario is shown in the **Fig. 5**. Then we compare the transmission efficiency with different background traffic.

There are two IMS realms / domains in our environment. We define there are a lot of UEs dispersed on the different domains and they are trying to establish voice calls. As the scenario, which is shown in **Fig. 5**. The users under the visit domain *ims.ntust.edu.tw* wants to establish the voice call with a user under *ims.niu.edu.tw* home domain. We deploy Traffic Manager Gateway according our path migration mechanism and algotithm specificated in **Table 3**.

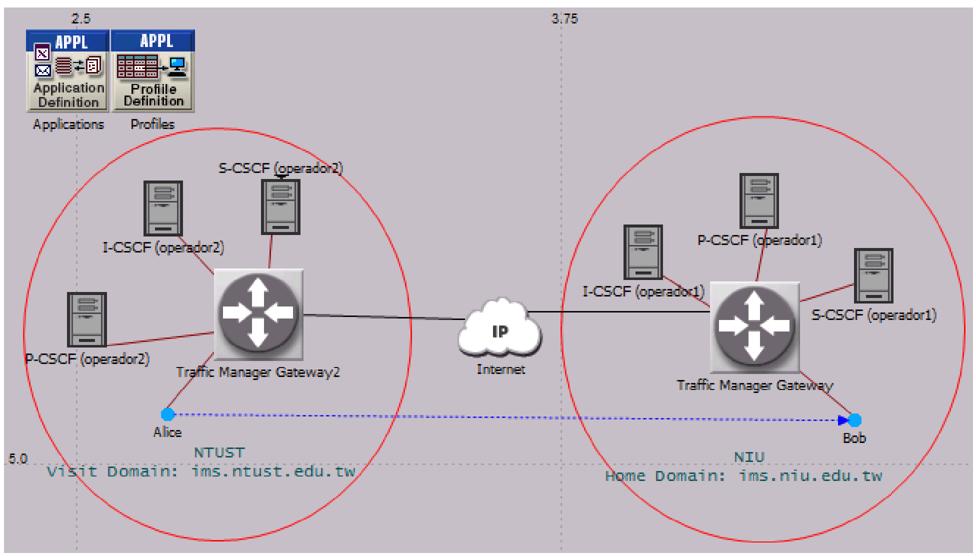

Fig. 5. Simulation Scenario

4.1 Model Delay in Real Environment

From the **Fig. 3** and **Table 2** in previous section, we formulate the relationship on IMS environments. The effect of background traffic ofr end-to-end delay can be modeled and reproduced in our OPNET network modeler. At 48th seconds of the **Fig. 6**, the packet end-to-end delay time incerases while the background traffic reach 95 percent bandwidth (B). That shows the overall path quality to deliver packets. It affects the call setup time and overall traffic.

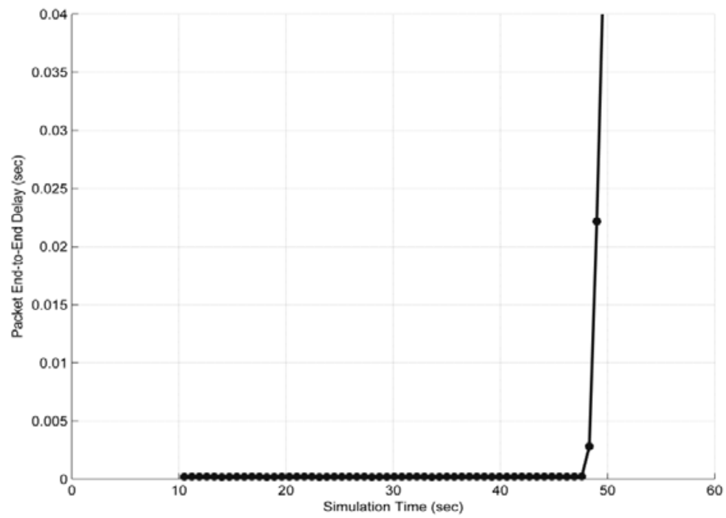

Fig. 6. Model real enviroment end to end delay in network simulator.

Then, we simulated this scenario according to the following description: Total simulation time duration is 1200 seconds. The clients uses IMS-SIP for negotiating calls, the codec for voice call is PCM quality (G.711). The packet discard ratio through internet cloud is 0.05 percent. The packet delivery latency is exponetially inclined by 50ms. In the beginning 150 seconds, we are waiting for network initialization, then those UEs start to establish voice call with other UEs in different domain every 10 seconds, which call length is 50 seconds. As the background traffic increases from 150th seconds, the network state will reach the threshold to hatch TMG trigger path migration close to 240th seconds. The network state will suddenly change to CONGSTED at the 300th seconds. From the results, we can obvious see call setup time, end-to-end delay, maximum active calls and MOS value with/without path migration.

Table 3. Parameters of Simulation

	Parameters
Duration	1200 seconds
Profile Start Offset	150 seconds
Profile Duration (Voice call)	50 seconds
Voice Codec	PCM quality (G.711)
Packet Discard Ratio	0.05%
Packet Latency	Exponetial 50ms
Call setup interval	10 seconds
BT rasing interval	50 seconds

4.2 Call Setup Delay

As mentioned previously, call setup delay is an important indicator for evaluating performance of IMS environment. From the **Fig. 7**, we can observe that the call setup time in path migration scenario is very stable until the network status jump to FULL at about 1020th seconds. However, in the scenario without path migration, the call setup time raise seriously when the network staus just jump into CONGESTED. After the calls conducted through IMS, the call setup time became longer since the 300th second. The turning point is seen at about 500th second. The reason of this phenomenon is the point of the original random back-off mechanism of Ethernet was triggered because the background traffic occupied all the bandwidth of TMG without our path mechanism. Thus, it causes the change because the waiting queue is clear and the task would be continued.

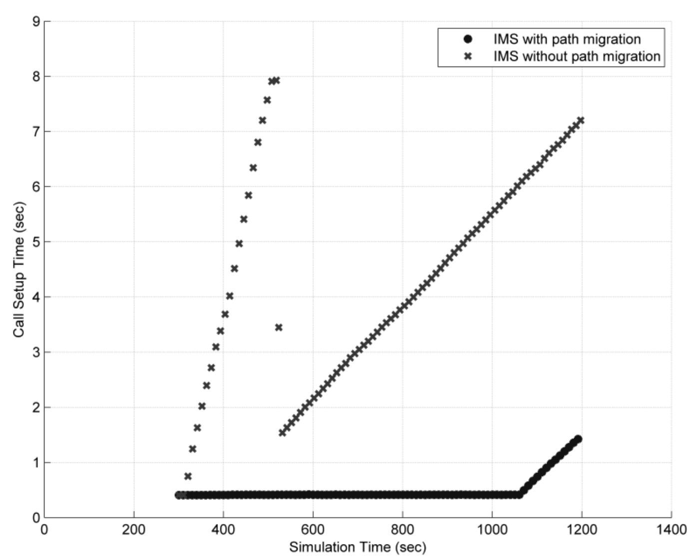

Fig. 7. Call Setup Time

4.3 Maximum Active Calls

As shwon in the **Fig. 8**, the system capability can be enhanced with our path mechanism. With well arrangement Enhanced Channel, we can see the active calls is in path migration scenario is more than the scenario without path migration. The maximum activive call in scenario without path migration is limited around 7 to 8 calls. In the path migration scenario, the session calls can continuously establish successful. Thus, the maximum system capability is higher if the IMS is deployed with path migration in Traffic Manager Gateway.

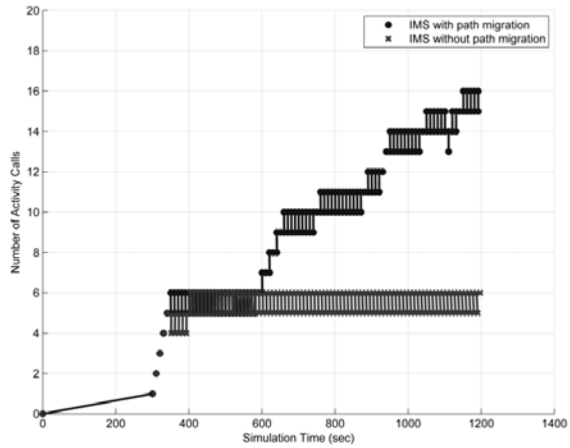

Fig. 8. Number of Active Calls

4.4 End to End Delay

In the **Fig. 9**, we can observe the end-to-end delay with different background traffic. The transmission latency in scenario without path migration is growing as the increment of background traffic. The message delivers delay is not acceptable when the channel is in CONGESTED state. For instance, the end-to-end delay is more than 0.5 second in normal channel. That means it takes at least 1 second for each round trip. If session negotiation needs more than 2 round trips, the total time cost could be pretty high. After triggering our path migration mechanism at 80 percent bandwidth utilization, the SIP message will be delivered through the enhanced channel. The end-to-end delay time is holded on 140 ms, instead of increasing cased by the background traffic.

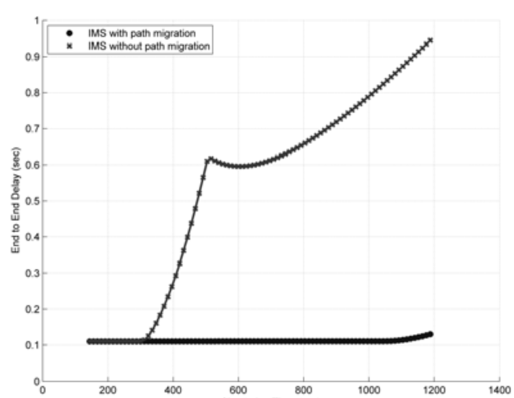

Fig. 9. End to End Delay

4.5 Packet Jitter

From the **Fig. 10**, we can observe that jitter in each scenario. The jitter stands for the delay variance in the transmission. We can see the connection stability in scenario with path migration is better than scenario without path migration. From the end-to-end delay and jitter results, the enhanced channel provide not only better transmit performance but also stable quality for connection in NGN-IMS. We can see there is a turning point at about 500th second in , the reason for the point is the original random back-off mechanism of Ethernet was triggered.

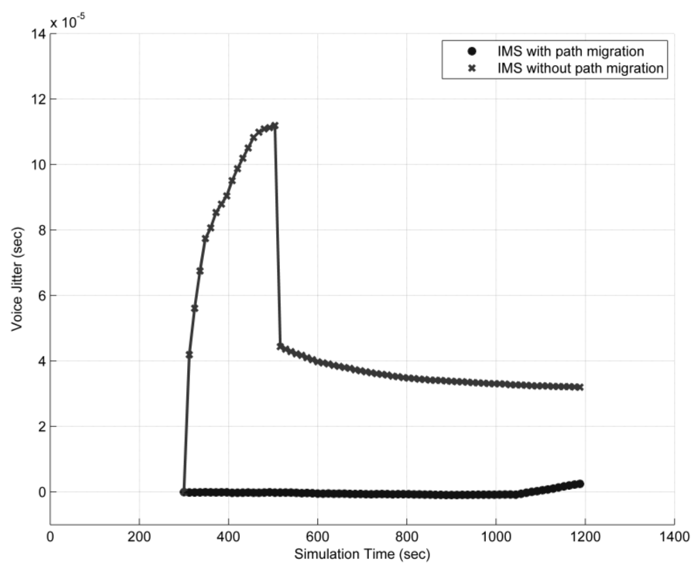

Fig. 10. Voice Jitter

4.6 Mean Opinion Score

The MOS (Mean Opinion Score) value is a measurement method for the voice quality. The different level of MOS is shown in **Table 4**. The MOS is measured through this simulation, as shown in **Fig. 11**, the score of path migration scenario is keep on 3.4, which is acceptable for a communication quality. The voice quality is quite low and almost impossible to communicate when the network status jump to CONGESTED state without path migration. At around 500th second, the MOS raises for a while because the random back-off was trigger to clear the queue. However, it could not improve the voice quality for a long time because the more and more packet is coming into the system.

Table 4. Mean Opinion Score Values

Score	Level	Description
5	Perfect	Equal to face-to-face conversation or radio reception.
4	Fair	Some distortions are , but the voice quality is generally clear. Equal to voice quality range for cellular phones.
3	Annoying	Acceptable, but with little noise.
2	Very Annoying	Nearly impossible to communicate.
1	Low	Impossible to communicate

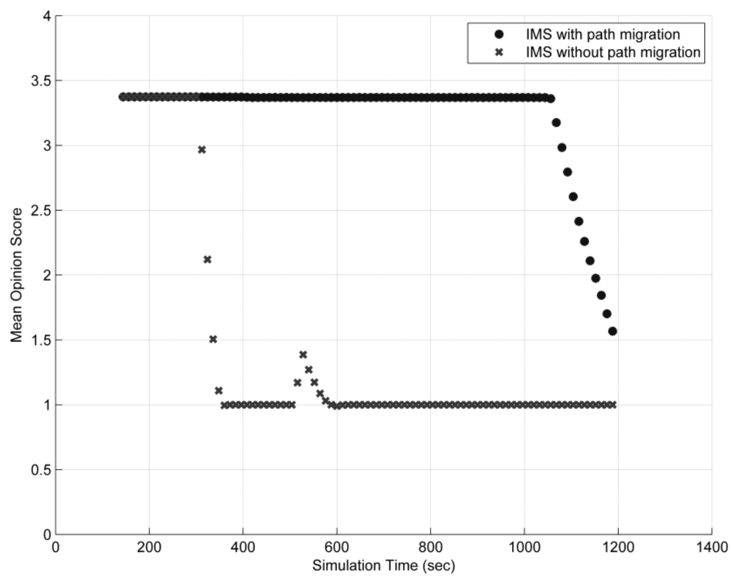

Fig. 11. VoIP MOS Value

5. Conclusion

The most important problem of IMS traffic efficiency is induced by best effort packet transmission in traditional IP network. In this paper, we enhance the signaling and traffic efficiency by adopting a path migration mechanism for NGN-IMS. Our experiments clearly show that the proposed path migration mechanism can greatly improve the SIP signaling efficiency when the overall network loading is high. The message delivery delay is acceptable for negotiating a normal service such as instant message or important signaling. We evaluate the perfomance of path migration from call setup delay, maximum active calls, end to end delay, packet jitter and Mean Opinion Score. The most important future work is an investigation of the path-migration mechanism using different access technologies such as bandwidth management in cellular network [18], Wi-Fi and other media/transport planes.

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