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Improving Vertical Handover over Heterogenous Technologies Using A Cross Layer Framework

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Abstract— **With the evolution of the Mobile Users number and the Application constraints, no single Network Technology can satisfy the Mobile User requirements overall situation. To achieve anywhere and anytime connectivity, interworking different network technologies is an important issue to consider. If we consider a Multi Interface Mobile User supporting WLAN and Cellular networks which is under the coverage of a WLAN and a cellular network in the same time. The main objective of a Mobile User is to benefit from the high Quality of Service (QoS) with the minimum cost.**
If the WLAN can satisfy the Mobile User requirements in terms of QoS, no network switching is required. Otherwise, switching to the cellular network is required. Seamless switching between different wireless technologies referred as Vertical Handover is becoming a requirement nowadays. In our paper, we address the Mobility Management between the LTE and the Mobile Ad hoc Networks (MANETs).

Keywords—LTE; MANETs; Mobility Management; Cross Layer Framework; MIH; mSCTP.

I. INTRODUCTION

Nowadays, we note not only how fast the number of mobile users is growing but also the evolution and the diversity of applications such as interactive games, video Streaming and social Network services. These two facts have led to the increase of mobile application demand.

Achieving anywhere, any time and under any network coverage communications is becoming an emerged issue. In order to investigate this aspect, multi-interfaces devices are conceived in order to support different network technologies. Also, Switching processes from one interface to another are defined. These processes are conceived to allow Vertical Handover between heterogeneous networks.

Applications Requirements in terms of latency, throughput and delivery ratio are making the Vertical Handover process hard to achieve. For this reason, the User application is an important criterion to take into account while switching from one network technology to another. In this paper, we investigate upon the Vertical Handover while taking into account the Application Requirements and the Network performance.

To enhance the Vertical Handover process between two different technologies which are the IEEE and the 3GPP, a Cross Layer Framework is considered. Interactions between the Application, the Transport, the Routing and the MAC layers are exploited to get accurate information about the current network performance, the alternative network performance and the Application requirements.

To define our Quality Aware Vertical Handover process, we consider a system model where a Mobile User (MU) is under the coverage of the LTE network and the IEEE 802.11 Mobile Ad Hoc Network. As a consequence, the MU can choose to be connected through the best one.

Mobile Ad Hoc Network (MANET) is a dynamic network that relies on wireless medium. It offers a direct connectivity between the wireless nodes. Due to nodes mobility, the topology of the network may change dynamically without prediction.

LTE (*Long Term Evolution*) network [1,2] is a well-designed technology that offers high data rate that could reach 176 Mb/s and reduced latency that could reach 10 ms. LTE is defined as the RAN (*Radio Access Network*) of the 3GPP Release 8. An all-IP flat network supporting QoS is designed as the network core of the 3GPP Release 8. This core network is referred as SAE (*System Architecture Evolution*).

In this paper, we address the Mobility Management between two Heterogeneous Networks which are MANETs and LTE. To switch from one network to another in seamless way is an important issue to study in order to provide the requested services to the mobile user everywhere. In this paper, we focus on the cross layer interactions in order to manage the mobility through heterogeneous networks.

II. MOBILITY MANAGEMENT: SURVEY

Mobility Management schemes are defined within the same network in order to provide Horizontal Handover. Also, they are defined across Heterogeneous Networks in order to achieve Vertical Handover. To perform Handover, several Mobility Management protocols working at different layers of the OSI Model are defined. Mobility Management mechanisms can be executed by the Layer 2 to carry out Hard or Soft Handover in several cellular networks such as WiMAX. Also, they can be implemented in the Network layer such as MIP (*Mobile Internet Protocol* version 4 or

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version 6) protocol and its several extensions such as FMIP (*Fast MIP*), PMIP (*Proxy MIP*) and CMIP (*Client MIP*). Also they can be provided by the Transport layer with the mSCTP [3] (*mobile Stream Control Protocol*) protocol. Finally, Handover can be executed by the Application layer using the MSIP (*Mobile Session Initiation Protocol*) protocol.

To make these mentioned Handover executor protocols work well, the IEEE 802.21 is defined. The IEEE 802.21 standard [4] referred also as MIH (*Media Independent Handover*) aims to help mobile devices to detect and select networks effectively through defined Triggers and events. Also, it defines a way to transport L2 information to the Handover executor protocols.

In our paper, we use the mSCTP as a Handover executor protocol combined to the MIH standard. We considered mSCTP as the Mobility Management protocol for its ability to provide efficient Vertical Handover as compared to other protocols such as Mobile IP and SIP [5].

A. *mSCTP Overview*

mSCTP [3] (*mobile SCTP*) is an end-to-end connection transport protocol. It is derived from SCTP (*Stream Control Transmission Protocol*) to provide seamless handover. SCTP [6] is a transport protocol for IP network and it is considered as the third Transport protocol after TCP and UDP. SCTP provides reliable data transmission service between two endpoints. It supports multi-homed IP endpoints. When a link failure occurs, SCTP uses a secondary link. In fact, the SCTP endpoint uses multiple IP addresses to setup an association with a SCTP endpoint. From this IP addresses list, only one IP address is considered as the primary while the other ones are used for backup. mSCTP is based on the multi homing concept of SCTP and the Dynamic Address Reconfiguration (DAR) extension. The Multi-homing manages numerous IP addresses assigned to a specific node. These IP addresses are considered as logical paths between the sender and the receiver. During the connection setup, the end hosts exchange their IP addresses lists. One IP address will be chosen as a primary address and it will be used to exchange the traffic. DAR extension offers to the nodes the opportunity to add, delete or reconfigure the IP address status during the mSCTP session without connection perturbation or interruption unlike SCTP, in which the session must be interrupted when changing from one IP address to another. Using the multi-homing concept, a mSCTP terminal can use multiple IP addresses for a specific association with another mSCTP terminal.

Several studies and researches focus on the mSCTP protocol. For example, the authors of [7, 8] studied the mSCTP performance in a crossover mobility pattern case where the Mobile Node (MN) is moving forward and backward between the old and the new regions. They note that the mSCTP performance can be degraded as the crossover movements occur more frequently. In fact, the MN may suffer from performance degradation due to the problems of packet recording, transmission timeout and packet loss during handover. In mSCTP handover, each time the primary path is switched, the congestion control parameters of the new primary path will be initialized and the congestion control window begins in the slow start. In order to overcome this issue, the authors adopt MIP location management function to record the location of MN and related parameters like control window's size and slow start threshold in the Correspondent Node (CN). When the MN moves in the overlapping region again, mSCTP does not need to restart the window's parameters as it uses the saved parameters.

According to the authors of [9], mSCTP was designed for communication between a mobile endpoint and a corresponding stationary endpoint. This situation does not match the real case in mobile networks where both endpoints can be mobile and accordingly a simultaneous mobility problem can be faced. Simultaneous mobility happens when the communication endpoints are mobile and they move at the same time [9]. In that case, the endpoint devices update the IP address simultaneously and the probability of broken association may become high. To overcome this problem, the authors in [9] suggest a new solution for mSCTP combining Address Handling Function (AHF) and Simultaneous Mobility Detection Function (SMDF) as well as Name Server (NS).

B. *MIH Overview*

MIH defines a logical entity, Media Independent Handover Function (*MIHF*), located on layer 2.5 between MAC and Network layers of the OSI model. It provides a framework that allows interaction between higher layers and lower layers. The MIHF supports three types of services: Media Independent Event Service (*MIES*), Media Independent Command Service (*MICS*), and Media Independent Information Service (*MIIS*). The MIES aims to provide and to predict link changes such as LINK_DETECTED, LINK_UP, LINK_DOWN, LINK_GOING_DOWN, etc. These events are propagated from lower layers to upper layers through the MIH layer. MIES is divided into two categories, link events and MIH events. Link events are generated from the lower layer and transmitted to MIH layer. The MIH events are the events forwarded from MIH to upper layers. MICS refers to the commands, such as initiate handover and complete handover, sent from higher layers to lower layers. It allows enabling handover mechanism. MICS includes MIH command and Link command. MIH Commands originate from the upper layers down to the MIHF. Link Commands are specific to the lower layers. MIIS provides a framework by which MIHF can discover homogenous and heterogeneous network information existing within a geographical area to facilitate seamless handover when roaming across these networks. The MIIS provides a bidirectional way for the two layers to share information such as current QoS, performance information and service availability.

To manage the Mobility between different network technologies, a system model which includes Heterogeneous Networks must be defined.

III. System Model

4G networks are based on the coexistence of Heterogeneous Networks. To allow connectivity across different technologies, Multimode devices have been designed. The mobile device is able to support different wireless access technologies and to select the appropriate network based on the information gathered from the network and the application requirements.

To consider the Vertical Handover issue, we define a System Model based on Heterogeneous Environment. Our System Model involves two different kinds of Network Technologies: MANET based IEEE 802.11b and LTE.

The proposed architecture assumes that the MANET is under the coverage of the LTE network as shown in Fig.1. Mobile Users, referred as MNs (Mobile Nodes), equipped by devices supporting two radio interfaces: the LTE interface and the IEEE802.11b based ad hoc mode interface. In our work, we assume that the Mobile user prefers to communicate through MANET if it offers the required performance to his requested applications due to its free cost.

Our goal is to achieve an efficient Seamless Handover between LTE and MANETs by avoiding the ping pong effect and considering the required QoS. We aim to make the Handover decision more reliable by executing the Vertical Handover only if it is necessary. In our paper, the Vertical Handover is executed based on the performance offered by the current network and the requirements of the application.

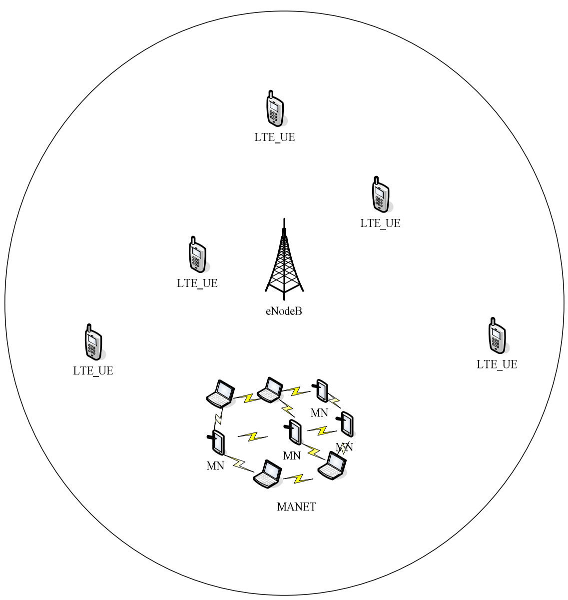

Fig 1. System Model.

IV. PROPOSED SCHEME

A. Overview

To define a Cross Layer Approach used to manage the QoS and the mobility in MANET-LTE environment, we exploited the IEEE 802.21 specifications. The IEEE 802.21 specifications define an abstraction layer that allows higher layers to interact with different lower layers technologies. This abstraction layer can be exploited by any upper layer to improve Handover performance. In our work, this abstraction layer is exploited by our designed Cross Layer Framework, shown in Fig.2, to improve the Routing and the Handover performance.

In [10], we exploited the interactions between MAC layer, Routing layer and Application layer to perform a Quality Aware and a load balancing data routing based on the Application layer and the MAC layer information.

In this paper, interactions between Transport, Routing and MAC layers are also exploited in order to perform an efficient Vertical Handover. Vertical Handover is defined as a network switching process which happens when a Mobile Node is moving during a communication. In our proposal, Vertical Handover is necessary only if a new network is detected by the MAC layer and a Path Quality Decrease is detected by the Routing layer. In our framework, Vertical Handover from MANET to LTE is executed at the Transport layer by the mSCTP protocol. The interactions between the different OSI layers are used to make a reliable decision about the Vertical Handover execution.

Our contribution deploys three Cross Layer designs. The first design includes the MAC layer, the MIH Sub-Layer and the Routing Layer. Interaction between MAC layer and Routing Layer is exploited to provide more accurate information about the whole Path Quality from Source to Destination using prediction methods. MIH Sub layer reports an event to the Routing layer if a new network is detected.

The second design involves the Application and the Routing layers in order to take into account the Application requirements during the Routing process and the Vertical Handover Decision process. This design defines a software entity called XLME (Cross Layer Management Entity). This defined entity is used to classify the Traffic according to its QoS requirements and to manage the interaction between Routing and Upper layers. The Traffic classification is based on the Application Layer information.

The third design involves the Transport and the Routing Layer in order to execute the Vertical Handover. In fact, our routing protocol QA-AOMDV [10] (*Quality Aware-AOMDV Protocol*), which is an extension to the AOMDV (*Ad hoc On demand Multipath Distance Vector*) protocol is not only designed to select the most optimized paths during the routing process and to provide a fair allocation of traffic among the different available paths but also to decide when a Vertical Handover execution is required. If the current Path Quality is decreased during the communication process and a new network event is received from the Lower layer, QA-AOMDV sends a trigger to the Transport layer in order to perform a network switching or Vertical Handover to the new network.

According to our approach, the Path Quality is provided by the cross layer designed between the Routing layer and the MAC layer, while the new networks detection information is provided by the MIHF Layer. The Network Switching is executed by the Transport layer based on the information exchanged between the Routing, the MIHF and the Transport layers. Application Requirements are taken into account due to the cross layer designed between Application and Routing layers.

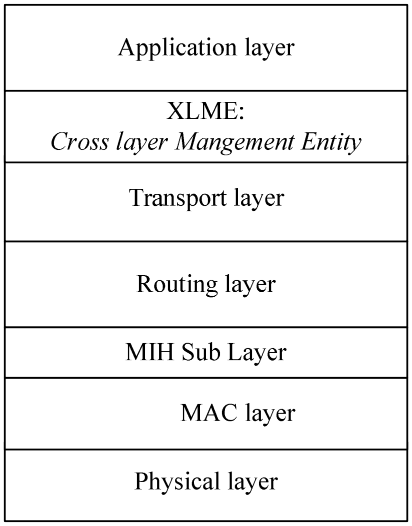

Fig 2. Proposed Cross Layer Framework for Mobility Management within Heterogeneous Networks.

B. *Gathering the whole Path Quality*

In wireless ad hoc network, the quality of a path depends on the quality of its composing links. To get information about the whole path quality, exploiting the MAC layer information by the Routing layer is a key alternative. In the conventional MAC layer, only information about the link quality can be provided. To get the whole path quality in terms of *Delay* and *Packet Losss Ratio*, we deployed prediction methods within the MAC layer to predict the Link quality in terms of *Delay* and *Loss*. These predicted values will be transmitted to the Routing Layer using the RREP (*Route Reply*) packet. In such way, the Routing protocol can get information about the whole path quality from source to destination. Based on the whole path quality information, our routing protocol performs a reliable routing process. This cross layer design and the used prediction method is further explained in our work [11].

C. *Gathering the Application Class*

To take into account the Application requirements in the Routing layer, the interactions between Application and Routing layer were exploited. To achieve this goal, we defined a Software entity called XLME (*Cross layer Management Entity*), shown in Fig.2, to classify the Traffic according to tis requirements in terms of QoS. To hold the Traffic differentiation in our routing and mobility management processes, we defined three Traffic classes according to the acceptable QoS thresholds defined by the ITU-G1010 standard [12]. This cross layer design is further explained in our work [11].

D. *Network detection*

To provide mobility management through different technologies, we use the IEEE 802.21 standard to detect the new networks or the network performance change. In our scheme, we consider multi interface devices that can communicate through different technologies. The MAC layer can check the connectivity with the current network through the RSSI measurement. Also, it can check or detect the existence of other networks through the RSSI measurement. To determine the current network switching criteria, we first calculate the difference between the RSSI (*Received Signal Strength Indicator*) for both networks. The Mobile device starts to measure the RSSI for both networks when an alternative network is detected at time T_{start}. The Mobile device terminates measuring when one of the networks is deactivated at time T_{end}. The absolute difference of RSSI between two networks at i^{th} measurement can be expressed as $G(i)$ as the following:

$$G(i) = RSSI_{<C>i} - RSSI_{<A>i} \quad 1<i\leq n \tag{1}$$

Where n is the number of measurement during the period ($T_{end} - T_{start}$). $RSSI_{<C>i}$ is the measured RSSI of the current network at the i^{th} measurement. $RSSI_{<A>i}$ is the measured RSSI of the alternative network at the i^{th} measurement.

According to IEEE 802.21 standard, A "LINK_DETECTED" Event is sent from the MAC layer to the upper layers through the MIHF if a new network is detected. In our framework, this event is sent only when the new detected network is better than the current one that is when

$$G(i) \leq 0 \tag{2}$$

We replace the MIH "LINK_DETECTED" event by "BETTER_LINK_DETECTED" event.

E. *Interactions between Routing and Transport layers for Vertical Handover execution*

According to our designed protocol QA-AOMDV [10], multiple paths are searched in parallel to find the most qualified ones. If the different paths offer similar quality, the number of stored paths in the routing table is reduced to only one which provides the best delay. QA-AOMDV aims to minimize the energy consumption, and to free the resources in order to enhance the link quality. If QA-AOMDV receives a Better Link Detected Event from the MIHF layer, it first checks its routing table. If no available route meets the QoS requirements of the application, the event is reported to the Transport layer in order to execute the vertical handover. Otherwise, the event will not be reported to the higher layer since the application can be satisfied without the need to execute a vertical handover. The algorithm of our idea is described in Fig.3.

As shown in Fig.3, the MIHF layer of the mobile user will sense the RSSI of the different existent networks in its coverage. When the MIHF layer detects a better network as defined in (2), it sends a "BETTER_LINK_DETECTED" event to the Routing Layer. Once the Routing layer receives this event, the routing protocol QA-AOMDV which operates in this layer checks the necessity to process to handover.

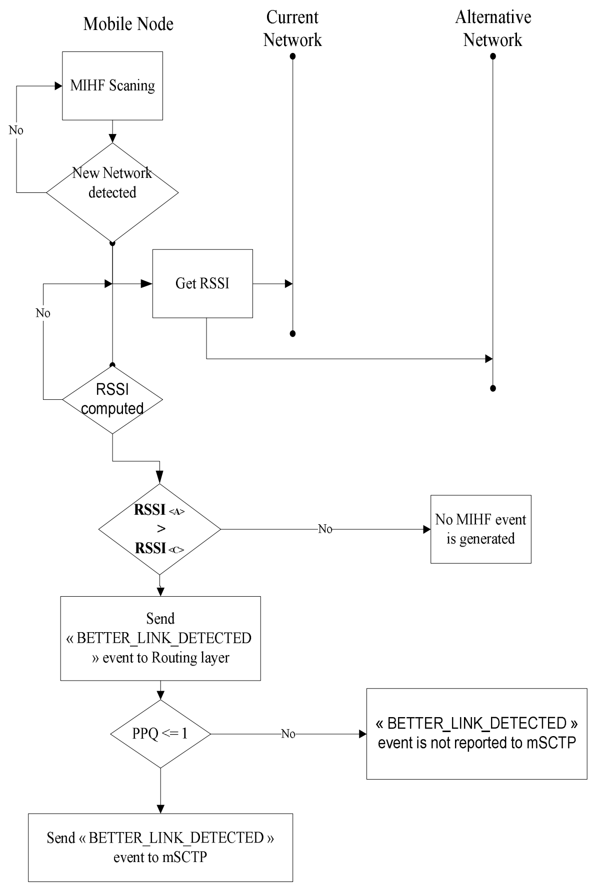

Fig 3. Flowchart illustrating the proposed mobility management algorithm.

It first checks its routing table for paths replying to the application requirements in terms of QoS.

If the routes stored in the routing table satisfy the application requirements, QA-AOMDV assumes that the handover is not necessary and no event is sent from Routing to Transport layer.

If the routes stored in the routing layer do not satisfy the application requirements, QA-AOMDV assumes that the handover is necessary and the "BETTER_LINK_DETECTED" event is sent from the Routing to the Transport layer. Once this event is received by the Transport layer, the mSCTP starts the handover execution in order to switch from the current network to the alternative one.

The Path quality of a path *i* is defined according to 3 [11]:

$$PPQ_i = w_d \times \frac{D_{th}}{D_i} + w_p \times \frac{P_{th}}{P_i} \quad (3)$$

P_i and D_i are respectively the measured packet loss ratio and the end to end delay of the path *i* from source to destination. P_{th} and D_{th} are the acceptable threshold values of packet loss and delay respectively defined for each class of service according to the ITU-G1010 recommendation [11]. $w_p$and w_d are the weights of packet loss and delay.

The weights' value depends on the traffic class. More the parameter is critical for the traffic, more its weight is higher. QA-AOMDV [10] defines three class of service:

- Class 1: Error tolerant and delay sensitive applications
- Class 2: Error and delay tolerant applications
- Class 3: Timely and non-error tolerant applications

For class 1, we assume that the delay is much more important than packet loss. For class 2, the weights of delay and packet loss are equal since the applications of this class are not critical in terms of delay and packet loss. For class3, we consider that the packet loss is much more important than the delay since no error is tolerated. To compute $w_p$and $w_d$of each class, we use the AHP (*Analytic Hierarchy Process*) method [13].

A route *i* does not satisfy the application requirement only if it offers a packet loss ratio and a delay equal or superior to the threshold values. Based on (3), a route *i* does not satisfy the application requirement if:

$$PPQ_i \leq 1 \quad (4)$$

V. PERFORMANCE INVESTIGATION

Through simulations, we compare our proposed scheme to MIH. Simulations are performed using the Network Simulator NS2. Simulation scenarios have been repeated ten times. Each data point in the curves is the average of ten simulation runs. To investigate the handover performance of our Proposed Contribution and MIH, we consider a simulation scenario where the Mobile Node (MN) is under the coverage of MANET and LTE networks as shown in Fig.1. We assume that the Mobile Node is first connected through MANET due to its free cost and it is making a VoIP communication. The MN is then moving according to the Random waypoint mobility model. For fair comparison, we consider that the mobility management protocol for MIH is also mSCTP. We investigate upon Class 1 Traffic. In our future work, further simulations will be handled for remaining traffic. Simulation parameters are summarized in Table I.

TABLE I. SIMULATION PARAMETERS.

MANET Parameters	
Network size	10 nodes
Transmission range	250m
PHY/MAC technology	802.11b
Propagation model	Shadowing model
LTE Parameters	
Number of LTE Users	20
Number of eNB	1
MN Parameters	
Mobility model	Random way Point
Average mobility speed	2 m/s
Number of interfaces	2
Class 1 Traffic (VoIP)	
Traffic model	CBR
Traffic rate	64 Kbit/s
{w_d, w_p}	{0.6, 0.4}

To show the benefits of our enhancement, we measured the End to End Delay and the number of executed Handover per Handover Tentative. We consider that a Handover Tentative is when the MIHF layer detects a new network. Further comparison parameters such as Handover Latency and packet loss ratio will be considered in future works.

Fig.4 shows the Handover Decision according to the Handover Tentative. We consider that the MN detects 50 times a new network. According to the MIH also referred as IEEE 802.21 standard, if a new network detected the MIHF layer send a LINK_DETECETED to the mobility management protocol in the upper layer which is mSCTP in our scenario. In order to avoid the ping pong effect, the handover is executed only if the detected network is more efficient than the current one in term of RSSI and the application requirements are not satisfied in terms of end to end delay and packet loss ratio. From Fig.4, we note that our proposed protocol avoids the unnecessary network switching or handover.

Table II summarizes the number of executed Handover when Handover Tentative varies from 10 to 500. Based on Table II, our proposed protocol reduces the number of unnecessary handover by 83% at least as compared to MIH. Table II shows also the performance of MIH and our proposed schema in a scalable environment when the number of Handover Tentative is equal to 500. Our proposal shows better results than MIH by avoiding the number of unnecessary executed handover. In contrast to our proposed cross layer approach, MIH generates and sends an event from MIHF layer to the upper layers when a new network is detected without checking the performance of the new network and the offered QoS of the current network.

Fig.5 reports the End to End delay variation according to the simulation time for the VoIP Traffic. From the Figure, we note that the End to End Delay increases when a Vertical Handover occurs (represented by a pic in the Figure).

In our simulation scenario, we assumed that our MN starts with MANET connectivity while it is under the coverage of LTE and MANET. While moving, it can switch from MANET to LTE and from LTE to MANET. From Fig.5, we note that our proposed contribution reduces the number of executed Vertical Handover with keeping an acceptable QoS.

From Fig.5, we note that our Proposed Contributon outperforms MIH. It offers stable measurements. In fact, our contribution deploys a Quality Awar routing process to select the best appropriate path to each Traffic class and also it implements a Quality Aware and a reliable Handover Algorithm to execute the Vertical Handover only if the current network does not satisfy the Application requirements and the Alternative network provides better performance in terms of RSSI.

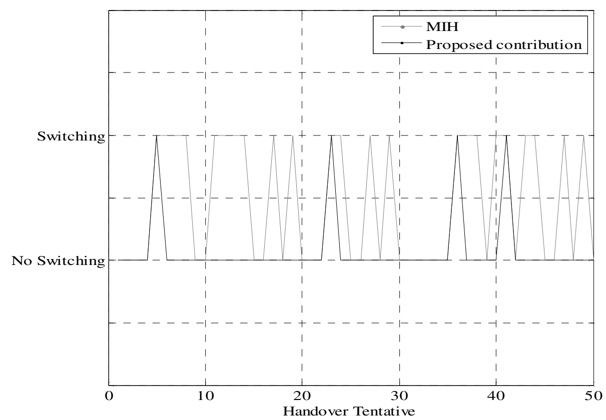

Fig 4. Handover Decision Vs. Handover Tentative.

VI. CONCLUSION

In this paper, we addressed the QoS issue in the Mobility Management process through Heterogonous Networks. We proposed a cross layered approach that involves the MIH standard, the mSCTP protocol and our designed routing protocol QA-AOMDV. This proposed cross layered Framework performs a Context Aware Routing and Mobility Management through MANET and LTE networks. A simulation study was conducted in this paper to investigate the ability of our scheme to reduce the ping pong effect. The decision making process of our scheme depends on RSSI parameter which is not well adopted to qualify the different kind of networks. Therefore, defining other parameters to qualify more accurately the networks will be our future work. Also, contribution complexity investigation is needed for handling the processing time and energy consumption.

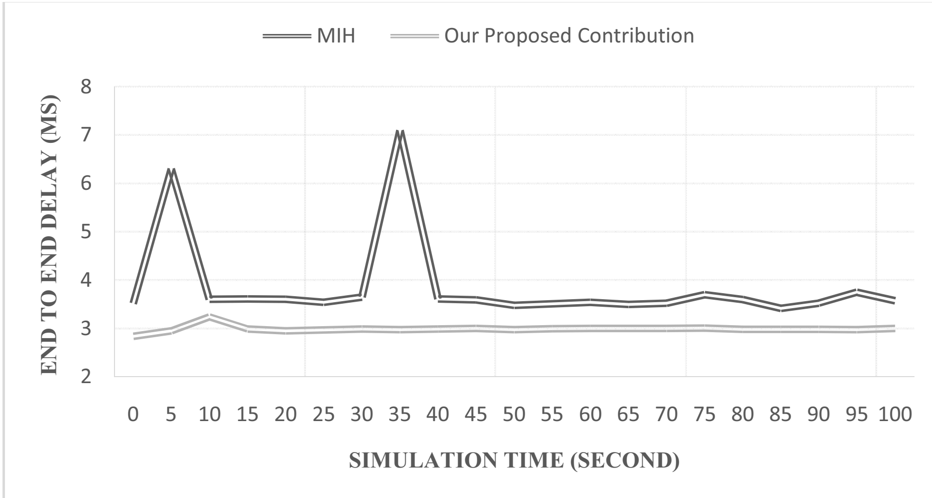

Fig 5. End to End Delay Vs Simulation Time.

TABLE II. NUMBER OF EXECUTED HANDOVER.

	Handover Tentative										
	10	**50**	**100**	**150**	**200**	**250**	**300**	**350**	**400**	**450**	**500**
MIH	5	23	55	63	115	121	153	164	193	230	259
Proposed Contribution	1	4	7	23	26	30	34	38	42	46	46

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