Handoff Management Architecture for 4G Networks over MIPv6

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Summary
The future 4G networks will satisfy the user's need of mobility, eternal information access and independence. Many organizations are now working towards realizing 4G Networks. 4G networks are known for their seamless connectivity between existing networks which include GSM, wireless LAN, Bluetooth etc. Such next generation 4G networks are represented by heterogeneous environment with different access network technologies that vary in bandwidth, latency and cost. Seamless Connectivity in such networks entirely depends on efficient handoff mechanisms. In this paper we present a Handoff Management Unit (HMU) based on Mobile IPv6 (MIPv6). The research discussed here, reflects seamless handoff across different types of networks over the MIPv6 core network.

Key words:
4G Networks, handoff mechanism, MIPv6, Handoff Management Unit, Fast Binding Acknowledgement Algorithm

1. Introduction

The need for advanced mobile communication systems have mainly increased as the user requirements have accelerated exponentially. Many organizations such as IEEE, Electronics and Telecommunications Research Institutes, Korea University etc have been working towards 4G networks to provide Seamless Connectivity anywhere anytime. The 4G networks would be heterogeneous in nature where there would be multiple service providers, equipped with varied technologies offering varied services for the benefit of the users. A simple 4G network is shown in Fig. 1.

It is very clear from Fig. 1 that a user could utilize multiple services offered by multiple providers enabling seamless connectivity. In 4G networks a mobile node in network could access services and bandwidth offered by other service providers without pre registration or pre subscription. To enable such diverse mobility options there is a need for an interface management technology which not only provides convergence of the varied services offered but also provides service provider coordination based on MIPv6 core architecture. It may so happen that some additional components may be necessary to monitor the spectrum or shared spectrum. Security becomes a major concern when multiple interfaces are involved in communication. The interfaces have varied transmission rates, varied technologies, varied services and varied spectrum allocation. Thus, it is very necessary for the user to have compatible devices to enjoy such connectivity [1].The mobile node should also be capable of auto configurability without the user intervention. A very critical aspect is to design a Business Model that combines the offerings of service providers, efficient sharing of resources and allocation of services. Resourceful Mobility Management would be a key area for 4G networks. Handoff Management is an integral element of Mobility Management [2].

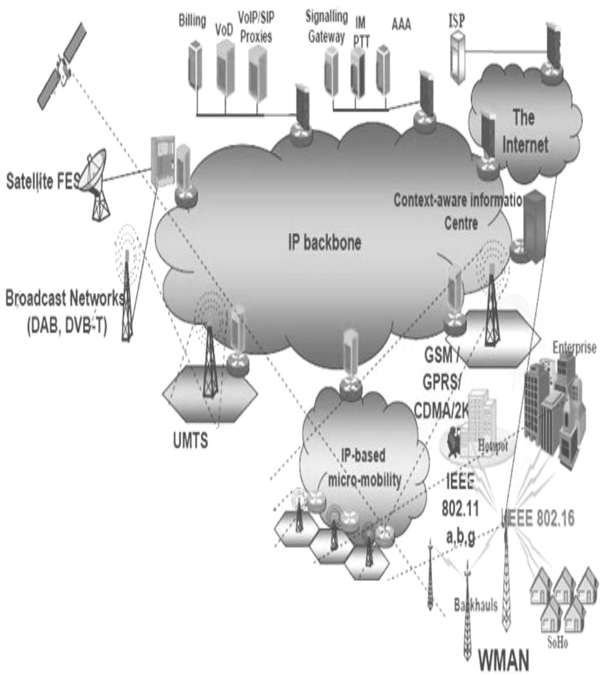

Fig. 1: A sample 4G Network

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In this paper, network interface switching, decision making within services offered and connectivity management are studied. A new handoff management mechanism based on the fast binding acknowledgement (FBA) scheme is proposed over MIPv6. The FBA will facilitate the Horizontal and Vertical Handoff. The performance of the FBA is analyzed and demonstrated through the Experimental Study given in this paper.

2. Related Work

4G network architecture designs have been extensively studied. The Open Wireless Architecture and Open Access Spectrum [3] architecture propose that multiple service providers would have to converge and offer services. Many issues still remain with respect to the implementation of such networks [4].4G networks consist of multiple access technologies whose convergence could be established over an IP core network efficiently. Based on our study, it is very clear that the IP Core would be a very eminent part of the 4G network. We envision an IP Core network offering varied services over varied interfaces in our architecture put forth in this paper. As studied from the research conducted by NGMC forum, Korea and CJK collaboration [5] [6] on 4G implementation, it is very evident that the 4G architecture would incorporate an IP core network for communication. We consider a 4G network converged over the MIPv6 core. MIPv6 is a layer 3 protocol, well defined by RFC3775 [2]. The usage of MIPv6 is advantageous as it provides better mobility support and better addressing schemes [8].A basic 4G network which has a IP Core is as shown in Fig. 2.

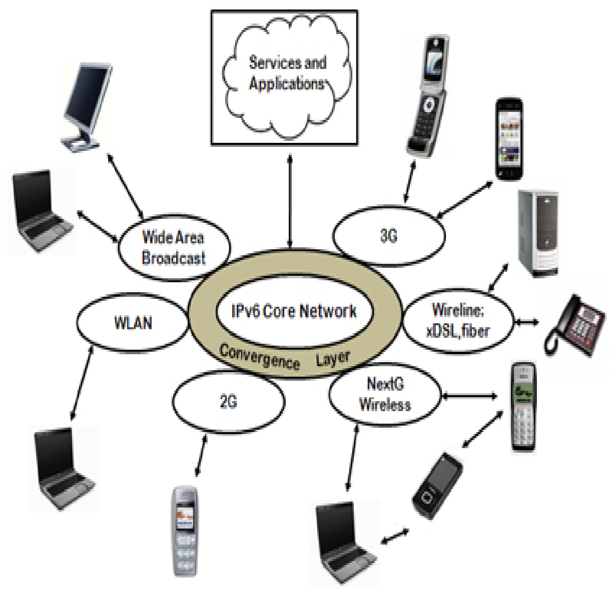

Fig. 2:4G network integrated over a IP core

To provide seamless connectivity handoff management is a very important criterion to be considered in 4G Network architecture design. [9]. Handoffs are differentiated into various categories [10]. In our research presented through this paper we consider handoffs across diverse networks that are available for data transactions. Handoff is a process in which an ongoing data transaction or an ongoing call is transferred from one interface to another interface without neglecting the fact that the terminal is mobile. The interfaces are interconnected through the core IP network. There are many terms associated with handoff management like Hand off latency, interface association time and connection reestablishment time [9]. Handoff latency is the time between the last data transmission and the next data transmission after the interfaces over which the data transmissions were taking place have been changed. Handoff latency could be represented as shown in Eq. (1)

$$\text{Handoff Latency} = \text{Interface Association Time} + \text{Connection Reestablishment Time} \quad (1)$$

Handoff occurs across interfaces. The time taken to get association with the new interface is known as the Interface Association Time. Once the interface is established, the time taken to restore the previous data transmission is known as connection reestablishment time. Handoffs based on the networks involved can be of two kinds: Horizontal handoffs and vertical handoffs. Horizontal handoffs occur between identical network technologies whilst Vertical handoff occurs between different network topologies.

A good deal of research is being done towards the implementation of Handoff mechanisms. Handoff management involves several challenges like Quality of Service (QoS), communication cost, Received Signal Strength (RSS), service type, end user preference etc. Many approaches exist to provide efficient handoff techniques which consider a few parameters or a combination of these parameters for decision making. WLAN to CDMA2000 and vice versa handoff management schemes based on RSS and end user preference have been realized using IP/MIP connectivity[11]. Soft Handoff using MIP [9] has been considered as a robust mechanism across data communication involving multiple interfaces. Multiple Interface handoff pose a major security threat [12][13]. A key based handoff mechanism [13] could be considered as a secure option. This scheme introduces additional packet transactions to provide security. SIP based handoff management techniques are easy to implement and efficient but suffer long handoff delays which could be negated by using node tracking techniques [14]. The node tracking technologies could be considered as an additional network management cost.

Terminals of the next generation networks are envisioned to demand high bandwidth with superior QoS. RSS measure has been considered as a parameter for superior QoS provision. Many algorithms have been developed to handle handoff based on the RSS measure which assure superior QoS [15][11]

IP based Protocols have been developed to manage handoff. An IP based protocol which incorporates buffering scheme [17] was found effective. Not only did this protocol effectively reduced data loss but also exhibited reduced delays in handoffs. Another Fast Handoff Mechanism over MIPv6 was effective due to the Candidate Access Router Discovery [16] mechanism incorporated into the network to manage handoffs. It is very apparent that IP based solutions prove effective for handoff management.

Handoff Management Architectures implemented through Handoff Servers have been also proposed by many researchers [18]. These Handoff Servers maintain connectivity with the nodes over IP Tunnels [19]. We have used one such server based approach in our research.

There is still lot of issues to be addressed while considering realization of 4G networks [4] [5]. Many organizations are working towards the realization of seamless connectivity. In this paper we propose a MIPv6 based architecture, capable of handling handoffs across various interfaces providing varied services.

3. Proposed System

User Mobility providing any where any service access demands could be addressed by a MIPv6 based core network architecture. Multiple services offered over multiple interfaces have to be effectively managed in 4G networks. We put forward a Handoff Management Unit (HMU) for mobility management in 4G Networks. A conceptual architecture of the HMU proposed is as shown in Fig. 3.

Operator or Service provider coordination is a key for deployment of 4G networks which is well understood in our proposed architecture. IP convergence over MIPv6 is considered for realization of our architecture [8]. The HMU integrates the varied services offered to the nodes. The services offered by the providers are integrated over the MIPv6 core. The services offered are monitored and maintained by the HMU. The HMU is also responsible for handoff management across the interfaces offered and is capable of managing both horizontal and vertical handoffs shown by our experimental study discussed later. The HMU proposed also incorporates proactive handoff support [10]. In proactive handoff the user decides the service and the interface medium for the handoff.

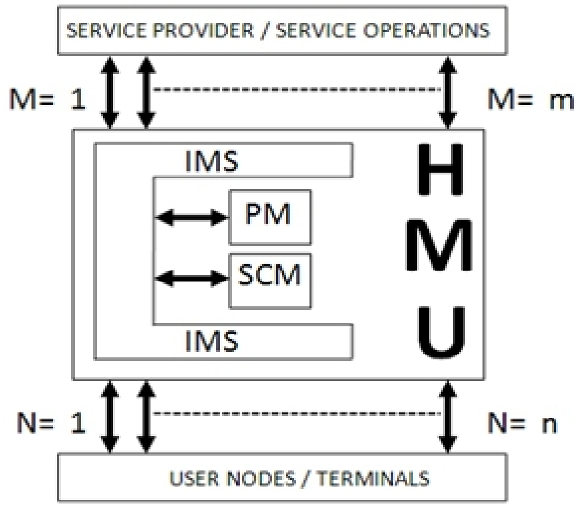

Fig 3. HMU Architecture

The HMU integrates services offered by the Service Providers M = 1, 2, 3 ……*m* to user nodes N= 1, 2, 3…….*n*. The Service Providers are connected to the HMU over the MIPv6 core, through various interfaces J=1, 2, 3…….*m* represented by MJ*m*. The nodes receive the services offered over MIPv6 from the HMU. The Nodes transact data from the HMU through interfaces I=1, 2, 3…… *n* represented by Ni*n*.

The HMU embodies the Seamless Connectivity Manager (SCM), the Interface Management System (IMS) and the Policy Manager (PM). The SCM, IMS and PM coordinate with each other to provide valuable network management architecture. The SCM is the monitoring unit of the HMU which interacts with the IMS and PM for efficient network management. The SCM monitors the ongoing communications and also facilitates new service requests from the nodes. The HMU has multiple interfaces for interaction with the service providers and also with the nodes. Interface management is handled by the IMS.

In 4G networks, various service providers offer services. 4G networks are defined to provide services to users without prior subscription. Priority resolution is a major factor taken into consideration in the design of the HMU. Priority resolution of the service provider to be selected for service offering is done by the PM. The PM uses a Fast Binding Algorithm (FBA) for priority resolution in our approach.

3.1 FBA Algorithm

With multiple service providers, integrating and offering services through the HMU, priority resolution is a very important factor taken for the design of the HMU. The priority resolution is carried out by the PM using the FBA when the user node has no specific handoff decision taken. When the user node requests for a service NS*n* over interface Ni*n* to the HMU without any user priority, the

HMU relies on the FBA for decision making. The FBA algorithm is based on the quickness in response from service providers M. The response time from the service providers M could be represented as Trp*m* where r = 1,2,3…*m* . The internal timer of the PM could be represented as Tp*m*. The working of the FBA could be explained by the algorithm given below.

(i) FBA Algorithm:

1. Receive request to provide service NS*n* to node N
2. Start PM Timer Tp*m*
3. Send service provision requests to service providers M through the IMS where MS*m* = NS*n*.
4. Obtain service availability confirmation time Trp*m*
5. Calculate $\Delta Tr = Trpm - Tpm$ (r = 1,2,3…..*m*)
6. Find Minimum ΔTr
7. Priority set to Service provider M = *r* offering services to HMU over interface MJ*m*

The FBA algorithm offers quick response times reducing handoff overheads. The FBA algorithm is a fair and unbiased approach to resolve multiple issues related to various providers integrating over a MIPv6 based core network. The FBA algorithm could also be seen as an energy efficient model of handoff implementation. The performance of the FBA is evaluated and presented in the subsequent sections.

3.2 Operation of the HMU

The HMU could be considered as a monitored bridge between the service providers and the user nodes integrated over the MIPv6 core. The HMU integrates the varied services offered by different service providers to the user nodes. The HMU is unconditionally the most important integrating unit of the proposed architecture.

Consider a node N = n (n= 1,2,3….*n*) which requests for a service NS*n* over the interface Ni*n* to the HMU. The user node could specify a preferred service provider M=*m(pref)* providing service MS*m(pref)* or else the HMU decides on the service provider. The HMU receives the request through the IMS and sends the request to the SCM. If the SCM receives a MS*m(pref)* service request, then it would ask the PM to send a service request to service provider *m (pref)* over the interface MJ*m(pref)* through the IMS. The IMS interacts with service provider *m(pref)* over interface MJ*m(pref)*. The SCM on getting a confirmation from the service provider M=*m(pref)* initiates a connection to provide a service NS*n* = MS*m(pref)* over interface NI*n*. This kind of a handoff is also referred to as a proactive handoff [10].

If the user node provides no service provider preference and requests for a service NS*n* over interface NI*n*, the HMU is responsible for the service provider selection. The request received by the SCM is sent to the PM for service provider decision making. The PM uses the FBA algorithm for provider decision making. Based on the FBA the PM responds that service provider M=*m*, offering MS*m* over interface MJ*m* would be best suited. The SCM sends a service request to service provider *m* and initiates the service delivery to node N=*n* over interface NI*n*. The SCM monitors the service connections provided and is also responsible for handoff management in case of a link failure or service failure.

It could be stated that the HMU is capable of handling both horizontal and vertical handoff operations. Network connectivity between the HMU, the nodes and service providers is maintained over the MIPv6 known for its mobility management and multi addressing capabilities.

4. Performance Evaluation

For investigating the performance of the proposed architecture, we constructed a MIPv6 based test. We have built our test beds over MIPv6 [20]. As discussed the HMU is capable of handling both horizontal handoff and vertical handoff. We have organized our experiments to investigate the HMU performance for horizontal handoff, vertical handoff and multi interface handoff.

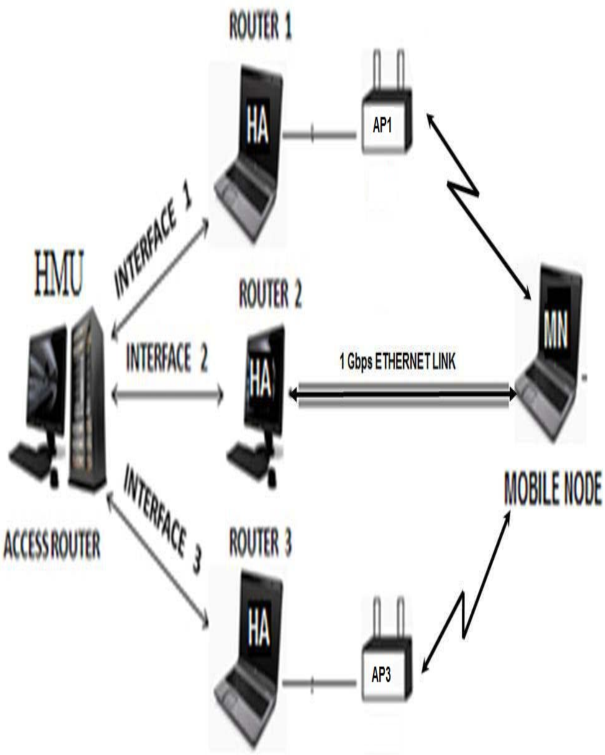

Fig. 4: MIPv6 Test Bed

A test bed constructed for evaluation is as shown in Fig. 4. The HMU or Access Router developed was deployed on a Quad Core Server with 4GB RAM running on Windows 2003 Server SP1. The Home Agent's (HA) shown as ROUTER 1, ROUTER 2 and ROUTER 3 in Fig. 4 was realized on Windows XP SP2 systems. Host Agents HA1 and HA3 were connected to Linksys WRT54G routers represented as AP1 and AP3 respectively. AP1 and AP3 provide 802.11b connectivity over MIPv6. Interface 2 provides high speed LAN access over MIPv6 through ROUTER 2. The mobile node (MN) was run on Sony Vaio Laptop running on Windows XP SP2 having WLAN and a LAN interface. For the purpose of handoff evaluation we have considered a FTP application developed on the Access Router which also houses the HMU.

To evaluate the performance during handoff operations, we have developed a bandwidth monitoring utility capable of monitoring the bandwidth across all the interfaces of communications. The bandwidth utility consists of a packet capture utility whose responses have been considered for graphical representation in this section. The bandwidth utilized is directly proportional to the packets transacted over a particular interface. We have organized this section to evaluate the performance of the HMU to handle Horizontal Handoff, Vertical Handoff and Multi-Interface handoff. All the evaluations carried out are based on the test bed shown in Fig. 4.The handoff latency is calculated based on Eq. (1).

4.1 Horizontal Handoff Evaluation

Horizontal Handoff is a handoff between interfaces of similar network technologies. From our test bed it is clear that a handoff across AP1 to AP3 and vice versa could be considered as a horizontal handoff. The handoff is initiated every 30 seconds by movement of the MN from AP1 to AP3 and vice versa. The bandwidth is monitored on the MN using the Bandwidth Monitor utility developed. The results obtained are tabulated in Table 1 and the bandwidth graph considering the packet capture utility results are shown in Fig 5.

SL. NO	Handoff Interfaces Involved	Interface Association Time(s)	Connection Reestablishment Time(s)	Handoff Latency(s)
1	WLAN AP1 - WLAN AP3	1.001832005	0.011280959	1.013112964
2	WLAN AP3 - WLAN AP1	1.008099015	0.009289195	1.01738821

Table 1: Horizontal Handoff Simulation Results

The average Handoff Latency obtained is about 1.015245 Sec for horizontal handoff.

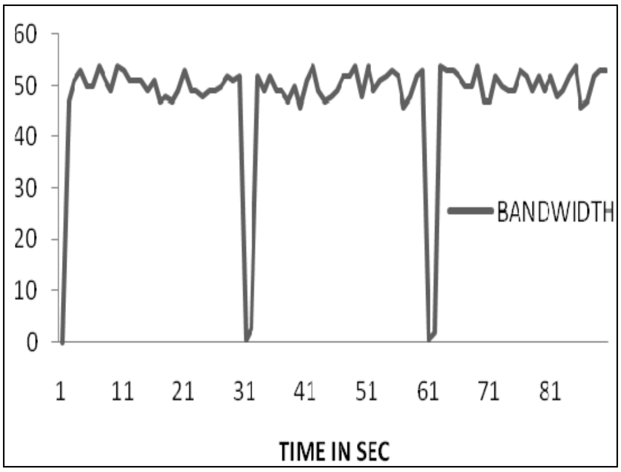

Fig. 5: Horizontal Handoff Evaluation

4.2 Vertical Handoff Evaluation

In this section we investigate the performance of the HMU across interfaces of different technologies. Vertical Handoff could be described as a handoff across the high speed LAN to AP1 and vice versa. Considering our test bed we could also evaluate vertical handoff across high speed LAN to AP3 and vice versa .For evaluation the MN is positioned within the AP1 range or AP3 range maintaining LAN connectivity initially. To induce handoff, we unplug the LAN interface and re plug the LAN interface to reinitialize LAN connectivity.

The results obtained for vertical handoff across the LAN interface to AP1 and vice versa are given in Table 2. The bandwidth monitored on the MN during the handoff is as shown in Fig. 6.

SL. NO	Handoff Interfaces Involved	Interface Association Time	Connection Re-Establishment Time	Handoff Latency
1	LAN - WLAN AP1	1.0016446	0.012349488	1.013994089
2	WLAN AP1 - LAN	1.008090653	0.009954815	1.018045468

Table 2: Vertical Handoff Simulation Results between LAN and AP1

We also evaluated the vertical handoff capability of the HMU across LAN to AP3 and vice versa. The handoff latency values obtained in seconds are shown in Table 3.

SL. NO	Handoff Interfaces Involved	Interface Association Time(s)	Connection Re-Establishment Time(s)	Handoff Latency(s)
1	LAN - WLAN AP3	1.009009653	0.0106963	1.019705953
2	WLAN AP3 - LAN	1.002173368	0.01129682	1.013470188

Table 3: Vertical Handoff Simulation Results between LAN and AP3

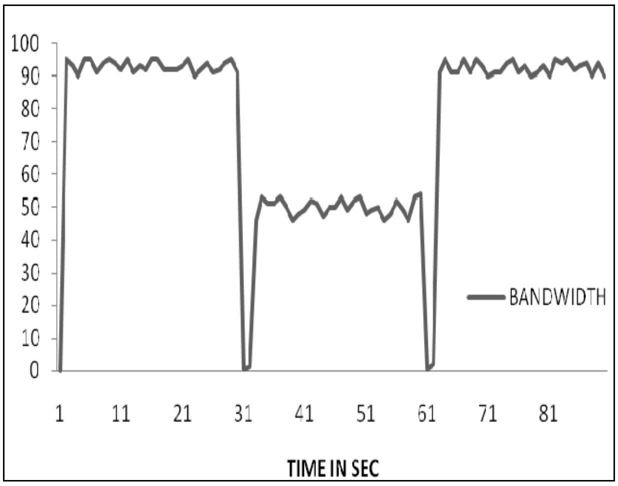

Fig. 6: Vertical Handoff Evaluation between LAN and AP1

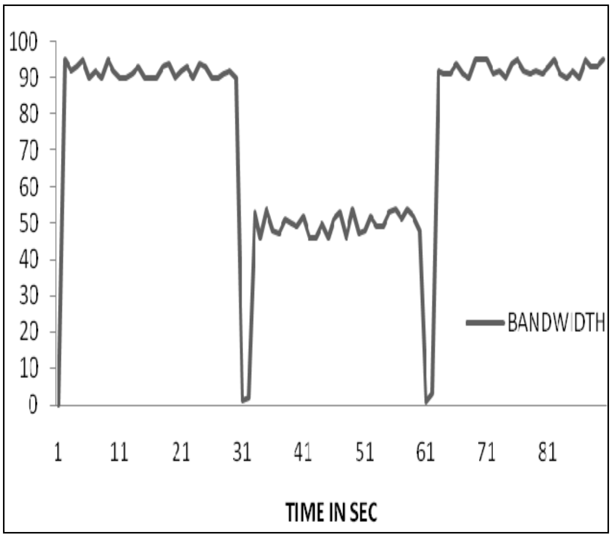

Fig. 7: Vertical Handoff Evaluation between LAN and AP3

Fig 7 shows the bandwidth monitored on the MN during a handoff across the LAN to AP3 interface initiated after 30 seconds and vice versa initiated after 60 seconds.

From the results obtained in Table 3 and Table 4, it could be concluded that the HMU effectively manages vertical handoff having a low average handoff latency delay of about 1.0163 seconds.

4.3 Multi Interface Handoff Evaluations

In this section we would evaluate the performance of the HMU to handle multi interface handoffs. The HMU in this test would maintain the handoffs of the MN across AP1 to LAN to AP3 to AP1. The handoff latency timings obtained are tabulated in Table 4.

SL. NO	Handoff Interfaces Involved	Interface Association Time(s)	Connection Re-Establishment Time(s)	Handoff Latency(s)
1	WLAN AP1 - LAN	1.000980158	0.01996507	1.020945228
2	LAN - WLAN AP3	1.000899158	0.010643338	1.011542496
3	WLAN AP3 - WLAN AP 1	1.008105303	0.008475396	1.0165807

Table 4: Multi interface Handoff Simulation Results

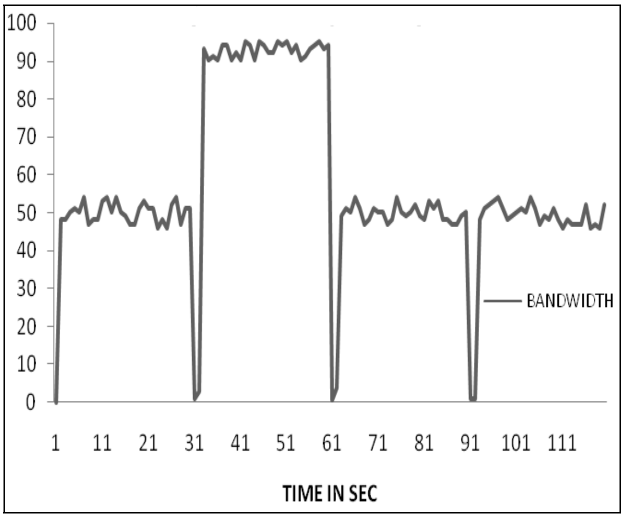

Fig. 8: Multi Interface Handoff Evaluation

The handoffs were initiated at intervals of 30 seconds across various interfaces. The bandwidth monitored through the utility on the MN during the various handoff provided data which is graphically represented in Fig. 8.

Our experimental evaluation represented through the results obtained makes it very evident that the HMU effectively handles various handoff operations with minimal handoff latency delays.

4. Conclusion

Through this paper we have proposed the HMU for effective handoff management in 4G networks. The 4G network integrates various service providers offering varied services over the MIPv6 core. The HMU adopts the FBA algorithm for priority resolution. The FBA algorithm developed is unbiased and uses a fair approach to resolve the priority issue. The HMU effectively handles horizontal, vertical and multiple interface handoffs as shown through our experimental evaluation.

4G networks would revolutionize the future networks providing better QoS, superior integrated services and mobility to the users. A lot of research is ongoing to realize 4G networks [4][5]. We are currently working on an intelligent billing system which would be integrated with the HMU.

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