Riaz HUSSAIN[1], Shahzad A. MALIK[1], Raja A. RIAZ[1,2], Saeed AHMED[1], Ghufran SHAFIQ[1], Adeel IQBAL[1], Shafayat ABRAR[1] and Shahid A. KHAN[1]

Dept. Of Electrical Engineering, COMSATS Institute of Information Technology, Islamabad (1), School of ECS, University of Southampton (2)

A Host Based Autonomous Scheme for Seamless Vertical Handover

***Abstract**. In this paper we suggest a host based, end-to-end selfreliant scheme for handover in heterogeneous network environment. It directly involves the correspondent node in the handover process. The proposed scheme imitates the Network Address Translation. It maps a logical address to another logical address. It modifies the address information in the header of the packet while it is in transition. In principle the process is identical to the NAT box operation, but the goal is different. While NAT is primarily used in conjunction with masquerading to hide the private IP address space, HaMAT works in conjunction with MIH and serves to hide the IP address change of the mobile node encountered due to the vertical handover. HaMAT is a functional entity just like Media Independent Handover Function, and it resides inside the Mobile Node and Correspondent Node. By eliminating the need for rerouting, tunneling and route optimization as required in Mobile IP, HaMAT achieves high performance results in terms of handover delay, end to end packet latency, jitter and the overhead involved. The service disruption time for HaMAT is as low as 10 msec compared to reported handover delays of 260 msec and 1 sec for MIPv4 and MIPv6 respectively.*

***Streszczenie.** W artykule zaproponowano bazujący na hoście schemat przełączania typu handover w niejednorodnym środowisku sieciowym. Schemat imituje Network Address Translation i mapuje logiczny adres orasz modyfikuje nagłówek w pakiecie. (**Bazujący na hoście autonomiczny schemat przełączania typu handover**)*

Keywords: Heterogeneous Networks, Mobility, Mobile IP, Vertical Handover.
Słowa kluczowe: przełączwenie typu handover, sieci niejednorodne

Introduction

As user demand of ubiquitous networks cannot be met by a single technology, the diverse technologies will have to complement each other to provide ubiquity of service. This phenomenon has introduced multi-interface mobile devices —possibility to connect to different networks. All-IP future is likely to converge these diverse access technologies. The ultimate fruition from availability of wide ranging network connectivity options can be achieved if a mobile user may be allowed to switch a live session to a different network of his choice [2]. Migration of a live session from one layer-2 access technology to another and maintaining an agreeable QoS is called seamless vertical handover in heterogeneous environment.

Several solutions have been offered in last few years. SIP is one of the existing solutions for vertical handover. It is an application layer solution. It involves messaging between various SIP entities including user agent, registrar server, proxy server and redirect server. Handover delay reported in [5] is significantly high for moderate error ratio, not suitable for VoIP. SCTP, a transport layer solution, has intrinsic ability to provide mobility by virtue of multihoming and multistreaming. It does not demand any change in the core network infrastructure. Just by allowing dynamic addition and deletion of streams the mobility can be supported. However the biggest obstruction to its adoption is the fact that most of the internet traffic uses TCP and UDP at the transport layer [6]. A detailed survey of transport layer mobility management schemes is given in [7]. Host Identity Protocol (HIP) manages mobility by introducing a new layer in the TCP/IP stack to separate the location identifier and address identifier [8],[9]. MIP and its variants FMIP, HMIP, F-HMIP [10] are the most prominent network layer mobility solutions. Proxy MIP [11], Cellular IP [12] and HAWAII [13] are micro mobility management protocols. These protocols claim reduced handover delay by localizing the registration and signaling. However devices using these protocols will have to rely on some other protocol for global mobility. Nadjia Kara in [14] in addition to MIP and its variants also include the analysis of path extension and multicasting techniques for handover management in IP networks.

The distributed architecture solutions, such as SIP or MIP, not only raise deployment issues, but also introduce potential bottlenecks and single points of failure. Exchange of messages among different entities increases the handover delay. Using a transport layer protocol for handover management means fixing a protocol for data transportation. This would limit the inherent freedom, provided by TCP/IP model, of the network application to use the optimum data transportation mechanism. Introducing a new layer means changing the TCP/IP stack. Path extension techniques require additional signalling for path extension, which increases the handover delay. Also as the path extends the network resources consumed in delivering a packet are increased. Multicasting techniques waste a lot of bandwidth. The variants of MIP for optimization optimize the handover but trade-off one aspect for another; for example, i) HMIP minimizes binding updates, but sacrifices route optimization and introduces overhead due to per-packet encapsulation for tunnelling. ii) FMIP reduces packet loss by creating a tunnel between previous and new access routers, which has additional overhead and consumes bandwidth. iii) PMIP reduces the handover latency by reducing the mobility related signalling, however, as it is a network based mobility management scheme the network access authentication delay is high.

Except for transport layer solutions all mobility management schemes require support from the network; however, it is desirable to absolve the network of processing and the end points should do the maximum [15]. Since end-to-end signalling increases handover delay the end-to-end schemes for handover are considered very rarely. However, end-to-end schemes are not only free of potential bottlenecks or single point of failures; they also minimize deployment issues and are highly scalable. In [16], [17] an end-to-end handover scheme called Mobile-IP with Address Translation is introduced. However, it requires IP-address Mapping Server in the architecture and seeks support from the DNS, which denigrates its claim of no

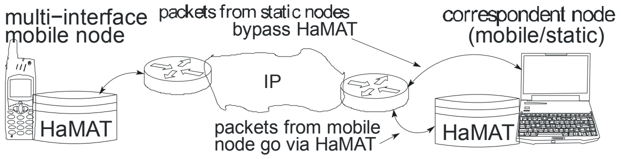

Fig.1. HaMAT Architecture

network infrastructure modification and also evokes single point of failure. This scheme suffers from large signalling delays among MN, IP Address Mapping Server and CN. Using DNS for mobility is also an open issue. In this works we propose a Host based autonomous Mobile Address Translation (HaMAT), which is an end-to-end self-reliant scheme. It does not require network modification, addition of any server or change in TCP/IP stack. The architecture absolves HaMAT of maintaining any server. This would not only eliminate the single point of failure but also allow the mapping information to move along with the mobile node. HaMAT achieves high performance results in terms of service disruption time, end to end packet latency, jitter and the overhead involved.

Our major contribution in this paper is introduction of HaMAT and conceptualization of its coaction with MIH to accomplish handover in heterogeneous environment. In addition we analyze i) Impact of delay between the Home Network (HN) and Foreign Network (FN) on handover delay and ii) Impact of delay between Mobile Node (MN) and Correspondent Node (CN). This analysis has already been done for MIP and its variants in [18].

Rest of the paper is organized as follows: In section 2 we present HaMAT, our network layer vertical handover solution, and talk over its architecture. In section 3 we analyze the handover delay. Section 4 provides the comparison of HaMAT with MIP. Section 5 highlights the major advantages, limitation and open issues with HaMAT.

Mobile address translation

1) Architecture:

The proposed HaMAT solution for handover in heterogeneous network environment, works on the same principle as the Network Address Translation (NAT). Though with different goal, just as NAT box maps a logical address to another logical address HaMAT translates Home Address (HoA), a logical address at the time of session initiation, to Foreign Address (FoA), another logical address obtained by MN on target network as shown in Figure 1. While NAT is primarily used in conjunction with masquerading to hide the private IP address space, HaMAT works in conjunction with Media Independent Handover (MIH) and serves to hide the IP address change of the mobile node encountered due to vertical handover.

Table 1. HaMAT Lookup Table

Home Address (HoA) = 32 or 128 bits IP Address)	Has Moved From Home Network (bool = y/n)	Foreign Address (FoA = 32 or 128 bits IP Address)
w.x.y.z	n	
$w_1.x_1.y_1.z_1$	y	$w_1'.x_1'.y_1'.z_1'$
$w_2.x_2.y_2.z_2$	y	$w_2'.x_2'.y_2'.z_2'$
a.b.c.d	n	
...	...	...
...	...	...

In the HaMAT architecture MN and CN are the communicating nodes, reachable through TCP/IP network; MN with multiple L2 interfaces and CN which may be mobile or static. HaMAT is a functional entity that resides inside the MN and CN. HaMAT translates the address using the HaMAT lookup table [Table 1]. The lookup table has the HoA, FoA and a boolean field to quickly check if translation is needed or not?

2) Operation:

In this subsection we elaborate the complete handover process [Figure 2] for connection oriented services where context of the connection cannot be changed and HaMAT provides transparency of socket pair. Assuming MN is connected to the Point of Attachment (PoA) and call/connection is established with the CN. To get the mobility support for handover from the CN, the MN registers with the HaMAT at CN as a mobile node. At this point an entry for the MN is created in the HaMAT table, registering MN’s HoA. The update at the CN is confirmed by the acknowledgement. The registration serves two purposes a) Confirmation of getting the mobility support from the CN and b) Ensures no processing delay or overhead for packets from nodes that do not require mobility; bypass the HaMAT at the CN. After registration any packets exchanged between MN and CN will go via HaMAT at both ends. When a MN realizes the need for handover, for reasons such as degradation in Relative Signal Strength (RSS) or availability of better access option in terms of cost, speed, or range etc., L2 at MN informs Local MIHF which passes this information to upper layer through MIH Event Service (MIH:ES). Local MIHF requests remote MIHF through MIH:ES to provide the list of Candidate Target Networks. Old Point of Attachment (oPoA) responds with the MIH “Command Service” (MIH: CS) Handover Initiate along with the list of Candidate Target Networks. MIHF in the MN requests, using MIH Information Service (MIH:IS), its various L-2 interfaces to acquire the channel parameters of the relevant network. Each interface reports back the requested information to the local MIHF. As there is no direct relationship among parameter values of incompatible access networks the MIHF in the MN decides on the basis of weighted values for the most suitable target network and informs it to the upper layer using MIH:ES. Network layer acquires the IP address on the target network after confirming the required QoS with the target network. This new acquired address is the Foreign Address (FoA), which is assigned to the target network interface. MN informs HaMAT (at the CN end) of change of IP using old network interface. Since this is the most vulnerable point in handover process as any fraudulent source can inject the change of IP address message pretending to be the MN. To avoid such masquerading following possible measures can be used. a) Challenge-response, b) Private key encryption, c) Use of Public-Private keys or d) Return Routability [21]. We do not evaluate these options in this paper and leave it for a later stage.

HaMAT (at CN) updates its lookup table and acknowledges MN of change of IP. From now on all messages from CN would be forwarded by the HaMAT (at CN) after address translation from HoA to FoA or vice versa. MN sends its Home Network interface to idle/sleep/off/powersave mode to conserve the battery power of a limited energy MN. In order to preserve context of the connection the MN assigns its HoA as an additional IP address to the target network interface. To ensure zero packets loss HaMAT (at MN) can store the packets or bicast them for a brief transition period.

It is important to note that the handover delay, the time when need for handover arose and when the first packet is received through target network, is quite long but the disruption time is only for duration when the home network interface is sent to idle/sleep/off/power-save mode and when the HoA is assigned to the target network interface.

Analysis of Handover Delay

Since HaMAT is an end-to-end scheme and it involves end-to-end signalling, in this section, we analyze the impact of end-to-end signalling on the VHO[1].

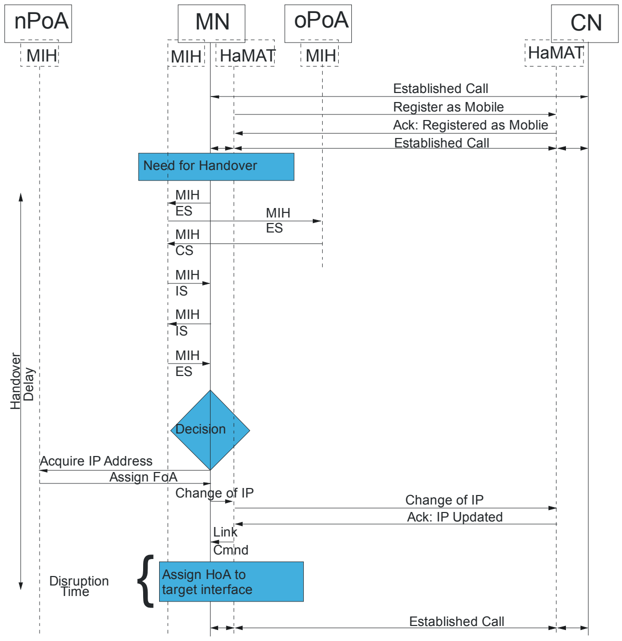

Fig.2. Handover Process using HaMAT

Let

Delay between the MN and the PoA = t_{mn-poa}
Time for scanning the available channels = t_{scan}
Authentication time at the DL layer = t_{dl_auth}
Association time at DL layer = t_{assoc}
Authorization at Network layer = t_{n_auth}
Acquiring new IP = t_{acq_ip}
Duplicate Address Detection (DAD) = t_{dad}
Distance between the MN and AR = t_{mn-ar}
Distance between the MN and CN (1/2 RTT) = t_{mn-cn}

1) MIP

This technique requires Home Agent (HA) and Foreign Agent (FA) entities in the network. When a MN enters a Foreign Network (FN) it discovers the FA through agent advertisement message, generated either periodically or solicited by MN. HA is also discovered in the same fashion. In the FN the MN acquires the CoA and registers through FA in FN with its HA in the HN. A tunnel (IP in IP) forwards the packet from HA to MN via FA. MN can send packets directly to the CN, provided CN has no ingress filtering enabled. To minimize the adversary of triangular routing, route optimization allows the direct routing of packet from CN to MNs current location.

In addition to parameters defined above for MIP we introduce following additional parameters.

Delay between the HN and the FN = t_{hn-fn}
Delay between MN and FA = t_{mn-fa}

In the deterministic model we find the impact of distances among signalling entities on the handover delay. Let the Handover Delay is denoted by D_{MIPv4}

(1)

$$D_{MIPv4} = t_{scan} + t_{mn-poa} + t_{dl\_auth} + t_{assoc} + t_{n\_auth} + t_{acq\_ip} + 4(t_{mn-fa}) + 2(t_{hn-fn})$$

In MIPv4 MN discovers the FA information by sending an Agent Solicitation message, the response is Agent Advertisement message; giving the doubling impact of the communication time between MN and FA. Once FA has been discovered the MN sends Registration Request message to the FA, which relays it to the HA in HN.

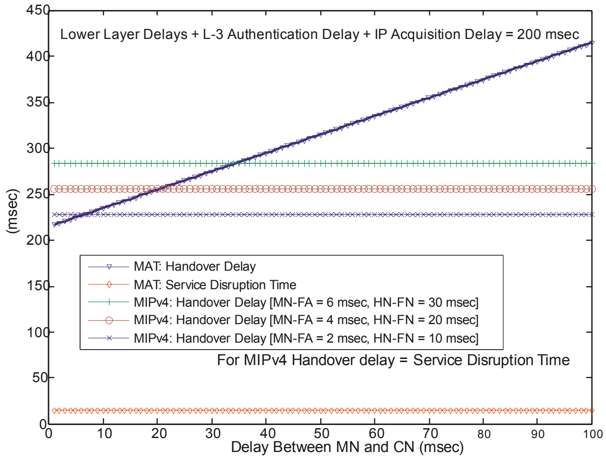

Fig.3. Impact of delay between MN and CN.

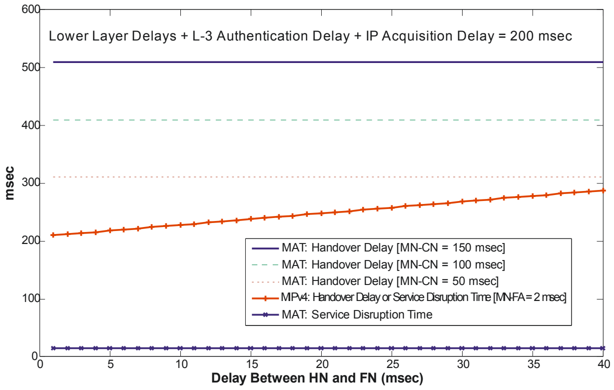

Fig.4. Impact of delay between HN and FN.

FA confirms the registration after getting the Registration Reply message from the HA. In MIP the Round Trip Time (RTT) between the MN and CN has zero impact on handover delay, since CN is completely oblivious of mobility of the MN. The first four terms in the above equation are entirely dependent on the underlying access technology and are beyond the control of MIP, but make respectable portion of the total handover time. The network layer authentication and new IP acquisition, if trimmed, can substantially reduce the handover delay.

In MIPv6 FA is not required due to stateless auto configuration and the Handover Delay D_{MIPv6}

(2)

$$D_{MIPv6} = t_{scan} + t_{mn-poa} + t_{dl\_auth} + t_{assoc} + t_{n\_auth} + t_{acq\_ip} + 2(t_{hn-fn})$$

Predominantly $t_{hn-fn} \gg t_{mn-fa}$ and $t_{mn-cn} \gg t_{hn-fn}$, so it is more attractive to focus on reducing the messaging between HN and FN and reducing the signalling between the MN and CN.

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[1] As analytical model is developed for analyzing the impact of end-to-end signaling on the VHO performance, so we exclude the delays incurred in identification of loss of signal, such as missing 3 beacons in WiFi, and we start from the point where MN has decided to shift from existing PoA

2) HaMAT

This technique does not demand any network modification, instead seeks mobility support from the CN. Handover process commences with the acquisition of FoA. This change is communicated to the CN by the HaMAT, which resides inside the MN. On receiving the acknowledgment of change of IP address from the CN the MN assigns the HoA as additional IP address to the target network interface.

For HaMAT handover delay analysis we define two more parameters

Delay in bringing down the network interface $=t_{dn}$

Delay in assigning HoA to a network interface $=t_{asn\_ip}$

Values for these parameters obtained are 3 msec and 7msec respectively on an Intel Core2Duo 2.0 GHz PC running Linux.

Let the handover delay is denoted by D_{HaMAT}

(3)

$$D_{HaMAT} = t_{scan} + t_{mn-poa} + t_{dl\_auth} + t_{assoc} + t_{n\_auth} + t_{acq\_ip} + 2(t_{mn-cn}) + t_{asn\_ip}$$

3) Results

The graph shown in Figure 3 depicts the impact of distance between MN and CN for the two network layer mobility management solutions. For MIP the handover delay remains unaffected by variation in the t_{mn-cn} while for HaMAT it shoots up. However, the disruption time for HaMAT remains constant and is very low as compared to MIP handover delay.

As depicted in Figure 4 the variation in the delay between the HN and the FN has no impact for HaMAT, whereas for MIP it gradually increases and remains lower than any of the HaMAT considered cases. However the disruption time remains constant and has a much lower value than that of MIP.

Comparison and Simulation Results: MIP Vs HaMAT:

1) End to End Packet Latency

Unlike MIP in HaMAT the packet starts its journey, from CN, directly towards the current location of the MN and vice versa. At the CN end HaMAT translates the IP address before sending it on course. Thus, eradicating the need for rerouting from HN to FN, reducing the number of hops a packet has to traverse; consequently cutting down the total propagation delay. End-to-End latency as simulated in NS2 yields the results as shown in Figure 5. For simulation 4000 packets with average packet size of 1000 bytes were sent by FTP application running on TCP variant Newreno. Latency gradually increases as the congestion grows and the waiting time in the buffers of intermediate routers goes up. Graph shows a clear gain in terms of latency with HaMAT.

In Figure 6 we calculated the mean end-to-end delay for packets. In the NS2 simulation the CN is 3 hops away from HN with a total of 140 msec link delay. We varied the link delay between HA and FA from 30 msec to 110 msec and observed the delays encountered by packets for 7 MBytes file transfer. As expected, the graph shows that the end-to-end delay increases with the increase in the delay between the HN and the FN for MIPv4. In this simulation we kept the distance equal between CN and MN, in terms of number of hops and link delays, before and after the handover. For HaMAT the end-to-end delay remains unchanged as packet latency is independent of the delay between the HN and the FN. Contrary to MIPv4, in HaMAT the packet latency can even be lower than it is before handover, if the MN gets closer to the CN. The horizontal line in the graph represents the mean delay between CN and HN of the MN. For HaMAT the gap between horizontal line and the top of the bar represents the delay between MN and its PoA and for MIPv4 the gap accounts for re-routing and delay between MN and its PoA.

2) Overhead

In MIP when a packet is received by the HA for a MN it is tunnelled, using IP in IP to reroute to the actual location of the MN. Not only that every packet has to be processed by the HA and FA, but every packet is burdened by 20 Bytes of overhead of an additional IP header. Since HaMAT solution has chucked out the need for rerouting the packet size remains constant from its inception to its delivery to the MN.

To evaluate overhead the traffic run was generated on NS2 for MIP and HaMAT with FTP application. Simulation results show difference in the overhead involved in the last leg of the routing i.e. from HA to FA with tunnelling and with HaMAT where there is no tunneling or rerouting. Gain is more prominent when the average packet size is reduced from 1000 Bytes to 550 Bytes. So in MIP for smaller size packets the penalty is huge. Four(4) Mbytes of data was transferred in NS2 simulation.

3) Jitter

The variation in the end-to-end transmission delay is improved by a leap jump as there is only one leg of transmission in HaMAT. Variation in the transmission delay accumulated on each leg of transmission in MIP shows greater fluctuation from mean value of packet latency. In Figure 5, the thickness of the curve and bigger spikes for MIP and a much smooth and tuned curve with little variations for HaMAT portray a noticeable reduction in the jitter.

4) Handover Delay

Time when a MN realizes the need for handover and initiates the handover process to the time when session is transferred to the target interface is greater in HaMAT as compared to MIP. The MIH messages exchanged would be same in both solutions, MIP and HaMAT, but in cases when MN is very far apart from CN the exchange of messages would be more time consuming than the communication in MIP between HA and FA. However by making the disruption time independent of the distances the impact of this deficiency would be very limited as increased handover delay would only mean to start the handover process well in advance so that messaging is complete before connection with the existing PoA is lost.

Conclusion

We conclude by summarizing the advantages, disadvantages, limitations and issues associated with our proposed handover scheme of HaMAT.

HaMAT offers following advantages by involving CN in the handover process. By eliminating the need of rerouting we save the bandwidth, save the processing and achieve reduced packet latency and jitter. Tunnelling which is required in MIP not only requires additional processing but also introduces overhead (20 bytes for every packet in IPv4). HaMAT dispose of need for tunneling by setting the direction of the packet right towards the current location of the MN when it enters the network. Although HaMAT requires signaling between MN and CN, causing larger handover delay, but this only translates to the requirement of early start of the handover process. The disruption time is made independent of delays among network entities. The disruption time is confined in the range between 10 to 20 msecs depending on how quickly theMN is capable of sending an interface to idle mode and assigning the IP address. Our proposed HaMAT scheme harvests the benefits that are achieved through pre-authentication schemes thus the power consumption on two network interfaces is not much worrisome. By virtue of miniscule disruption time and by enabling HaMAT to store packets the setup of HaMAT can ensure zero packet loss.

The down side of this approach is that MN has the responsibility of disseminating the information about its updated location. Also HaMAT puts onus on CN which may not be mobile. This feature may work against its adoption. Also when CN is very far (compared to distance between HA and FA in MIP) this results in increased handover delay. This aspect has extremely adverse effect particularly when the connection breaks before the IP is acquired in the target network. In break-before-make additional messaging would be required between MN and CN in order to build a trust relationship. Another issue that needs to be addressed is to find out the time when the HN would be able to reuse the MN's HoA, once MN has moved to another network? Also we have argued that using two network interfaces for the brief duration of handover delay is worth it since we have accomplished reduced disruption time, reduced packet latency, lower jitter and less overhead, however for a limited power MN this should be given its due consideration.

The proposed HaMAT solution provides a substantial gain when compared with MIPv4. MIPv6 uses route optimization to mitigate the inefficiencies due to rerouting and tunneling. However,MIPv6 achieves this only after deploying additional nodes in the network. Not only that route optimization process itself requires end-to-end signaling, but route is optimized after handover execution is completed. Until the route the optimized the pakcets have to be tunelled. HaMAT handover solution can work with both IPv4 and IPv6 without requiring any network modification. Also it provides fluent transition from IPv4 to IPv6 for mobile nodes demanding seamless handover in heterogeneous environment. Route optimization and pre-authorization schemes for optimization of MIP argue in favor of our proposed HaMAT solution when objection such as end-to-end signalling and battery consumption on two network interfaces are raised. We have achieved the goals without involving any server or router, without network modification, and without disturbing the TCP/IP stack, some daunting tasks for a widely deployed network such as internet.

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***Authors**: PhD. (candidate) Riaz Hussain, prof. Dr. Shahzad A. Malik, assoc. prof. Dr. Raja Ali Riaz, M. Sc. Saeed Ahmad, B.Sc. Ghufran Shafiq, M.Sc. Adeel Iqbal, assoc. Prof. Dr. Shafayat Abrar, prof. Dr. Shahid Ahmed Khan, COMSATS Institute of Information Technology, Department of Electrical Engineering, Park Road, Chak Shehzad Campus, 44000, Islamabad, Pakistan, email: rajaali@comsats.edu.pk, http://ciit-isb.edu.pk.*