

A Comparison between MIPv6 and Cross Layer Movement Detection Mechanisms

M.A. Abdelatif, George K. Kalebaila, and H. Anthony Chan
Department of Electrical Engineering, University of Cape Town

Abstract— MIPv6 is the envisaged mobility management protocol for 4G networks. MIPv6 would allow the prevalent wireless devices to change their point of attachment across heterogeneous networks. However MIPv6 violates 4G service requirements since the protocol does not inherently feature seamless roaming capabilities. MIPv6's movement detection mechanism causes hard handover which leads to packet loss and handover delay. In contrast to MIPv6, cross layer mechanisms are more efficient in providing soft handover capabilities. Cross layer techniques break the boundaries between the layers in the protocol stack by facilitating inter-layer communication. As a result cross layer mechanisms are able to sense overall performance degradation in the protocol stack, allowing for faster movement detection and ultimately seamless roaming.

A comparison between the movement detection mechanisms of MIPv6 and a cross layer scheme is carried out. Verification through simulation proves that the cross layer's movement detection mechanism fairs better than MIPv6's Router Discovery protocol.

Index Terms— Cross layer design, MIPv6, Mobility Management, Next Generation Wireless Networks.

I. INTRODUCTION

TERMINAL mobility has proved to be an attractive feature for network users. This is evidenced by the widespread penetration of wireless mobile devices such as cell-phones, laptops and Personal Digital Assistants. Terminal mobility in 4G networks should allow users to move ubiquitously and seamlessly while maintaining network connectivity. The other types of mobility, namely, service and personal mobility ensure application continuity during network handover. However these are still intrinsically dependant on the calibre of terminal mobility management provided. Terminal mobility in Next Generation Wireless Networks is a challenge since the 4G service requirements of ubiquitous roaming and seamless mobility must be adhered to.

To ensure ubiquitous roaming, Next Generation Wireless Networks (NGWN) consolidate various radio-based access networks to provide wide-area coverage. These access networks are heterogeneous due to their differing radio access technologies. Examples of these access networks include the wireless IEEE 802 standards in addition to cellular PLMNs

such as UMTS and CDMA. Trade-offs between bandwidth and coverage practically constrains the creation of a 'perfect network'; this drives heterogeneity in network specifications. In addition the interworking of deployed networks—which are heterogeneous— becomes a feasible option for ubiquitous coverage.

On the other hand seamless mobility must be provided when terminals roam across these access networks. Minimal disruption to service delivery must be ensured when mobile users change their point-of-attachment. In essence this is a mobility management problem [1].

The mobility management scheme that is envisaged to handle terminal mobility in NGWN is MIPv6. The choice of MIPv6 is a result of the architecture of NGWN rather than it being the best option. In NGWN, access networks would provide a gateway to an all-IP core network. This IP core network could be seen as the well-established Internet. To ensure uniformity all connected networks would have to parse and transport IP packets natively. In addition, network layer convergence around the IP layer is assumed to hide lower-layer specifics from applications. However IP packets are not optimized for radio transmission. As a result Radio Access Routers will handle the translation of packets from the wired core to the wireless domain since they provide wired-to-air interfaces [2]. The wired IP protocols would be ported for use in the wireless domain. Mobile IP (MIP) the mobility management protocol conventionally used for handovers in wired mediums will be ported as the de facto mobility standard in wireless networks. And since IPv6 will replace IPv4, MIPv6 will handle mobility in NGWN. This sees the marriage of wired protocols in wireless environments.

Wired protocols do not scale well in wireless environments because they are based on the ISO OSI protocol stack. The OSI protocol stack works well in wired environments because it mitigates complexity by modularizing functionality into layers. However this has shortcomings in the lossy wireless environment. By confining protocols to specific layers, inter-layer interaction is jeopardized. Each protocol behaves autonomously to some degree. Critical variables, indicating the state of the environment, that bear relevance to other protocols are not shared. Higher layers, such as the application layer, assume lower layers provide a lossless platform. As a result the protocol stack cannot adapt holistically to rapid changes in an erratic environment. This induces research into cross layer feasibility for wireless networks.

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Coupling cross layer functionality with a mobility management scheme in NGWN that does not violate the 4G service requirements is needed. This paper aims to research the validity of using MIPv6, a single layer protocol, against that of using a cross layer mobility management scheme. Specifically, the movement detection mechanisms of both are comparatively analyzed.

Section II of the paper explains mobility management and its constituents with specific regard to movement detection. Section III analyzes MIPv6 and its movement detection mechanism, namely IPv6 Neighbor Discovery protocol, including Router Discovery and Neighbor Unreachability Detection. Section IV discusses a cross layer mobility management scheme with specific reference to its movement detection mechanism. Section V outlines the results of a simulation testing the MIPv6 and cross layer's movement detection mechanism. Section VI concludes the paper by comparing the results of the simulations to recommend a mobility management paradigm for use in NGWN.

II. MOBILITY MANAGEMENT

A. Construct

Mobility management enables terminals to maintain a service connection to the network during handover or after a terminal has changed its point-of-attachment. Mobility management consists of location management and handoff management. These are further divided into their subsequent constituent parts of call delivery and location update (including paging) in location management and network registration and movement detection in handoff management [1].

The primary focus of this paper is towards handoff management and specifically movement detection. It can be assumed that network registration takes a constant amount of delay in an assortment of handover scenarios. Thus movement detection critically determines the handover latency in handoff management.

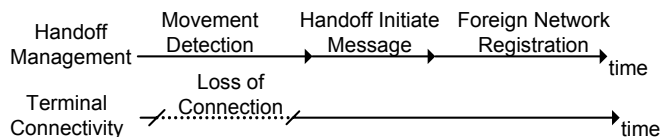
B. Movement Detection

Movement detection is the process of recognizing the need for handoff before or after loss of attachment to a serving network. Subsequent to movement detection, handoff initiate messages can be generated to commence registration with a new network. If the handoff initiate message is triggered before loss of network attachment then soft handover is possible. Conversely hard handover is the loss of attachment to a network with no concurrent foreign network registration. Theoretically soft handover can zero handover packet loss since the network senses no loss of connection. Thus movement detection principally determines the amount of packet loss incurred during handoff.

Both handoff scenarios can be seen in Fig. 1, where movement detection is shown to primarily affect terminal

connectivity during handover. Here terminal connectivity refers to the data-link layer association between a terminal and the access router. If this layer-2 traffic connection is broken we assume the terminal has lost its point-of-attachment. It can be seen that movement detection can minimize the handover latency incurred in handoff management. This is achieved through minimizing the time between detecting movement and launching the handoff initiate message. The time between sending a handoff initiate message and the regaining of network attachment is the network registration time, which is assumed constant. The handoff initiate message propagation time and the procedures taken for address redirection for the moving terminal cannot be controlled. As a result one would want the movement detection to happen early enough to induce a handoff trigger before loss of attachment. In the extreme case of hard handover the loss of connection is its movement detection mechanism, i.e. a mobile device surmises movement when no traffic can be sent or received. In this case of extreme hard handover a mobile device has to wait for data-link reconnection for subsequent network registration.

A) Hard Handover



B) Soft Handover

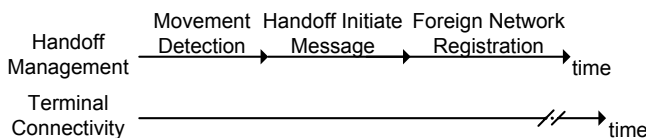


Fig. 1. The effect of handoff management on terminal connectivity on a time scale. A) Hard handover occurs due to the latent triggering of a handoff initiate message. B) Soft handover occurs due to early handoff initiation, thus network connectivity can be continuous.

Handover packet loss and latency depend on the movement detection mechanism that a mobility management scheme employs. This paper aims to compare two movement detection approaches employed by the mobility management schemes of a cross layer architecture and MIPv6.

III. MIPv6

Mobile IPv6 (MIPv6) is the extension of the IPv4 mobility protocol, Mobile IP. MIPv6 would be the key protocol in NGWN for mobility management because it resides in the convergence network layer. Additional augmentation to MIPv6 maybe likely due to the notable success of micro-mobility protocols such as HMIPv6. It is important to note however that even though these protocols reduce signaling

overhead by localizing mobility domains they do little to enhance movement detection. The handoff management scheme (including its movement detection mechanism) in MIPv6 would still remain IPv6 Neighbor Discovery protocol, including Router Discovery and Neighbor Unreachability Detection.

IPv6 Neighbor Discovery protocol is a merging of IPv4 ARP and the IPv4 ICMP Router Discovery Protocol [3]. The Neighbor Discovery protocol is used in home and foreign subnets to determine configuration and routes between neighbouring nodes. The protocol houses several processes in its definition including the mobility processes of Router Discovery, Neighbor Unreachability Detection, Address Autoconfiguration and Prefix Discovery. Router Discovery and Neighbor Unreachability Detection are the movement detection mechanisms whilst Address Autoconfiguration and Prefix Discovery form the network registration part in the IPv6 Neighbor Discovery protocol.

Address Autoconfiguration [4] allows for the stateless configuration of a nodes IP address on an interface as replacement for DHCP. This is used by a mobile node (MN) to form its CoA after Prefix Discovery. Prefix Discovery [4] allows nodes to discover network prefixes for local destinations.

Router Discovery [4] allows nodes to discover resident routers on a local subnet. The resident router advertises its presence by broadcasting Router Advertisements on its local subnet. A roaming MN can capture these advertisements and use it to register on the subnet by configuring its CoA to match the subnet prefix. A MN can also preempt Router Advertisements by requesting router feedback through Router Solicitation packets. Neighbor Unreachability Detection [4] allows nodes to discover which neighbouring nodes are no longer on a local subnet. This is done by adding neighbouring nodes' link-layer address to a neighbour cache. If a neighbour does not send neighbour advertisements or receive neighbour solicitation packets for a time period its corresponding entry in the cache is removed. MIPv6 uses IPv6 Neighbor Discovery extensively to return a subnet back to stability after MN movement. It forms part of MIPv6's movement detection mechanism because it allows for movement notification after a node moves.

Movement detection in MIPv6 is done through loss of IPv6 Router Discovery router advertisements. In the header of a router advertisement is an Advertise Interval field that indicates the time periods between consecutive router advertisements. If a MN does not receive a router advertisement packet from its default router within this time period it surmises that it has moved away from home. The time period that the MN finds out about movement is the movement detection period. Currently this period is too long for time-sensitive applications. It also violates the seamless requirement in NGWN due to heavy packet loss and handoff latency.

The movement detection time period in MIPv6 can be

reduced in two ways. The first is by reducing the advertise interval in the router advertisements. This however floods the network with unnecessary periodic packets which causes subnet congestion. The second is through assigning a weight to the advertise interval known as the mobility detection factor. If the mobility detection factor is small then loss of a few router advertisements indicates MN movement. However this is not necessarily the case in a wireless environment, where in this noisy environment the advertisement might be lost or corrupted. The MN will wrongly surmise that it has moved away from its home subnet which is a false positive. Movement detection false positives are very costly since there could be no better network to commence services with other than the one it recently surmised movement from.

Furthermore, MIPv6's movement detection mechanism breaks a network connection before establishing a new network association. In other words, MIPv6 forces hard handover when a MN changes networks. For NGN delay-sensitive applications this handover latency is not transparent to the higher-layers.

More so, MIPv6 does not select the best subnet to register with in line with its current application. It chooses the first foreign router in the router list maintained through receiving router advertisements. The router list is in order of the largest to smallest router timeouts. A router timeout is incremented each time a foreign router advertisement is received. If a router timeout has expired the MN removes the foreign router from its list. The first router on this list is assumed to be the closest and the safest to register with. However the selected subnet might not be the best suited network to support current applications. MIPv6 cannot, as a single-layer mobility management scheme, decide which subnet is most suitable to handover its application to. This is strictly not a movement detection feature however the handoff initiate message generated by the movement detection trigger should ideally recommend a best network to target. This is impossible for single layer schemes as they cannot obtain an application's QoS requirements. Cross layer designs can solve this problem through multilayer interaction.

IV. CROSS LAYER MOBILITY MANAGEMENT

The cross layer architecture proposed in [1] is given as a holistic mobility management scheme; however this paper focuses only on the movement detection advantages it offers.

The scheme in [1] facilitates multilayer interaction by providing a cross layer module which has access to various stack parameters. The cross layer module, identified as the Cross Layer Manager (XLM), houses 3 distinct functional blocks, namely, Link Information Manager (LIM), Decision Engine (DE) and Handoff Manager (HM). The stack parameters are obtained through stack embedded elements called Layer Agents (LA). The architecture of the cross layer design can be seen in Fig. 2.

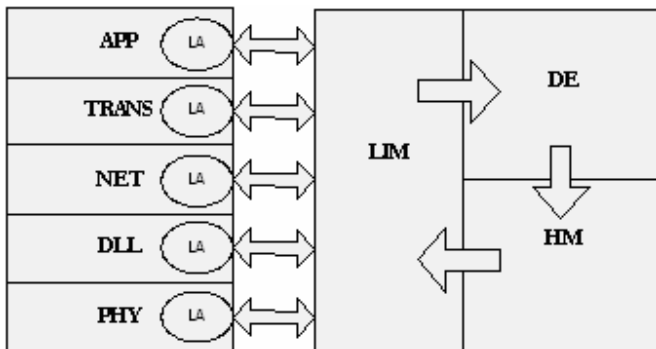


Fig. 2. The architecture of the cross layer mobility management scheme.

The Layer Agents pass predetermined stack parameters to the LIM. The parameters are only passed on a value change as to not induce a XLM wakeup on every arrival interrupt. For parameters that are likely to rapidly jitter around a value, such as SNR, thresholds are set so that only a significant value changes interrupt the XLM. The LIM maintains a state table of stack parameters which is updated on every parameter arrival interrupt. For every state table refresh a wakeup interrupt is triggered for the DE. The DE houses handoff algorithms which determine whether handoff should take place. A handoff initiate trigger is then sent on a positive handoff outcome for network registration by the HM. The HM could then return a CoA IP address to the LIM for state table identification.

The objective behind using cross layer functionality for mobility management is that advanced mobility scenarios can be supported. Advanced mobility scenarios are scenarios where heterogeneous access networks overlap, with each overlapping network offering various standards of service. Advanced mobility scenarios include the Always Best Connected and the Multimedia Aware paradigms. Here handoff decisions are more complex and application and session requirements have to be taken into account for optimum network targeting. Single layer schemes have no access to handoff critical information and thus cannot choose a network best suited for its application.

Movement detection in the cross layer scheme is done through sensing stack performance. This is achieved through tracking channel-sensitive parameters that deteriorate when a connection break is imminent. Channel-sensitive parameters, such as Signal-to-Noise Ratio, are a good indicator of movement because they are inversely proportional to BTS-to-terminal distance. If a terminal is at a distance away from the BTS where stable terminal-to-BTS communication is unachievable handoff is ripe. Other parameters mirror communication deterioration through packet loss. An example of such a parameter would be TCP segment retransmissions. When the value of these parameters drops or exceeds a certain threshold a terminal can surmise movement. The thresholds

that determine handoff imminency can be based on measurements taken during previous handovers. In addition one parameter is not sufficient to determine handoff. Packet loss could occur in wireless environments through corruption due to the high level of radio interference and distortion. Thus an overall stack performance evaluation is required to truly determine handoff imminency.

In addition overall stack performance evaluation is needed for optimal network targeting. The user's policy and preferences have to be cross checked with the nominal specifications a network offers. Additionally the run-time variables of the network in question have to conform to the application's throughput requirements and delay tolerances. All these stack parameters are weighted and aggregated to form a cost function. Each network features a cost function that describes it. All these cost functions are then compared to filter out the ideal target network to handoff to [5].

Because the cross layer movement detection mechanism senses handoff before it occurs, hard handover can be avoided. If the Decision Engine (DE) can initiate a handoff message before the terminal loses its current connection a new connection can be established. The thresholds that determine handoff can be optimally set to trigger movement detection before the data-link connection is broken. If network registration occurs quickly enough, a smooth point-of-attachment change can occur that is transparent to higher layers.

In addition the handoff initiate message that is generated can put requirements on the target network based on the application demands. This can be achieved through obtaining stack parameters that indicate the application requirements and session service types.

A simulated comparison between MIPv6 and the cross layer movement detection mechanisms can be seen in the following section.

V. SIMULATION AND RESULTS

A. Implementation and Simulation Scenario

Simulation was carried out on both movement detection mechanisms in order to compare the performance of each. OPNET Modeler 11.0 was used for construction and simulation. MIPv6 comes as a built-in model shipped in the protocol suite of OPNET however the cross layer architecture was built from process model level upwards. The cross layer functionality was augmented to the MIPv6-enabled WLAN workstation's (wlan_wkstn_adv) protocol stack.

An OPNET Mobile_IP scenario that was shipped in with the models library was used to simulate MIPv6 for roaming nodes. This scenario is depicted in Fig. 3, where 4 WLAN access routers, each with its own Basic Service Set domain, are connected to an IP cloud. Two roaming WLAN workstations migrate across the BSS domains while sending UDP video traffic to each other through the domain's resident access

router. The access routers act as the WLAN's access point to the Internet.

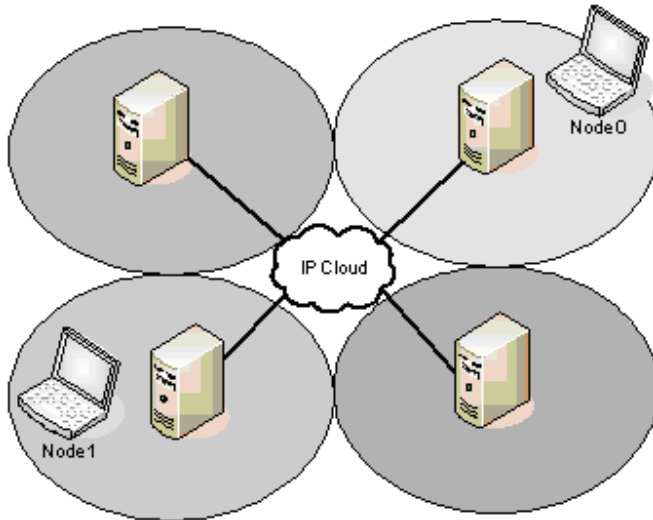


Fig. 3. A Mobile_IP scenario under the OPNET model library showing MIPv6 enabled nodes roaming across 4 different BSS domains. The nodes are sending UDP video traffic to each other via the domain's access router through an IP cloud.

This scenario was chosen because it mirrors intra-domain mobility in NGWN with delay sensitive traffic generated in some access networks. Both the cross layer and MIPv6's movement detection mechanisms were monitored.

B. Results

The results collected compare the handoff triggers between MIPv6's IPv6 Router Discovery and the cross layer movement detection mechanism. The handoff triggers indicate the start of handoff initiation message generation necessary to induce foreign network registration. These handoff triggers are a good indication of a mobility management protocol's movement detection efficiency.

Fig. 4 shows the cross layer handoff triggering against the UDP video traffic received by one of the mobile nodes.

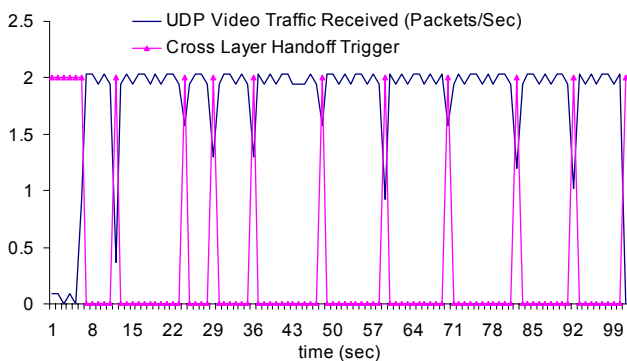


Fig. 4. A graph showing cross layer handoff triggering when UDP video traffic drops below a certain threshold.

The UDP traffic deteriorates when the mobile node reaches the boundaries of its access point coverage; at which the SNR between the router and the node is too low for throughput. At this point handoff to the new access point is ripe. Cross layer handoff is triggered when the UDP throughput deteriorates below a certain threshold. This threshold was hard-coded in the Decision Engine to be 1.75 packets/sec. The handoff trigger is shown to be a spike where the apex is the exact time at which movement detection was realized. The thickness of the spike should be infinitesimally small. However due to the time resolution the thickness is significant.

In Fig. 5, Router Solicitation packets generated by the mobile node are measured against the mobile node's resident WLAN access point connectivity. The WLAN access point connectivity is the layer-2 data-link that determines whether a mobile node can achieve throughput. It can be seen from the figure the amount of time the node spends in each domain characterized by the access point connectivity. When a mobile node moves from one domain to another there is a zero-dip in the connectivity. Once the mobile node handoffs, the WLAN connectivity moves back to the unity value. The number of seconds between subsequent zero dips is the amount of time a node spends in a BSS domain. MIPv6 movement detection is shown as the spikes when Router Solicitation messages are sent by the mobile node. In the last two cases in Fig. 5 movement detection is realized on a loss of connectivity.

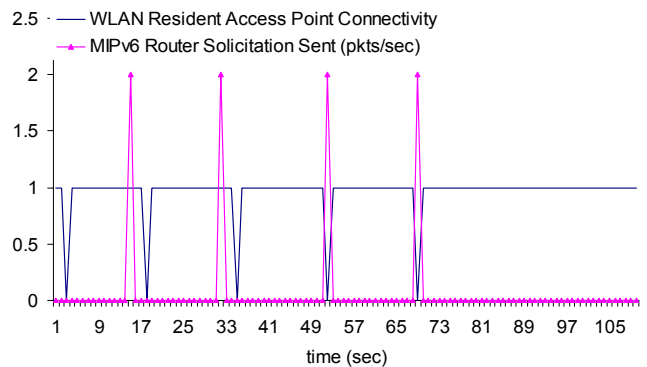


Fig. 5. A graph showing MIPv6 handoff triggering through Router Solicitation against WLAN access point connectivity.

In Fig. 6, the first couple of Router Solicitation messages occur before loss of layer-2 connectivity. However the second couple of Router Solicitations messages are only sent when the layer-2 connection is broken. Meanwhile, all cross layer handoff triggers occur before the loss of the data-link layer connection as seen in Fig. 6. In some cases there are false positives for movement detection. This is seen when the mobile node remains stationary in a domain. Even though there is no movement the cross layer movement detection mechanism triggers twice. This triggering could be due to other stack parameters changing yielding a movement detection false positive.

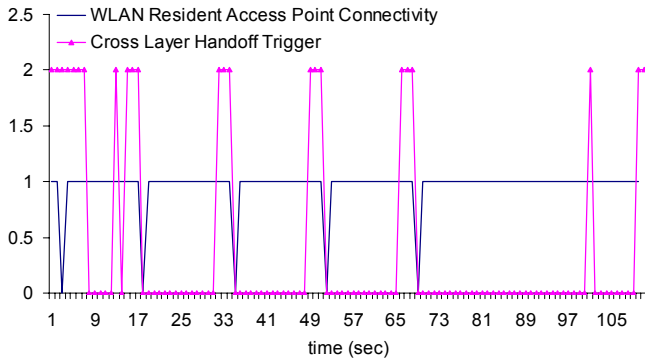


Fig. 6. A graph showing cross layer handoff triggers against WLAN access point connectivity.

Finally we compare the efficiency of both movement detection mechanisms against each other shown in Fig. 7. Both were shown on an identical timescale responding to the same conditions. We can see that in some cases both handoff triggers occur at the same time. However in most cases the cross layer movement detection triggers before the MIPv6 generates Router Solicitation messages. We then draw conclusions on these results.

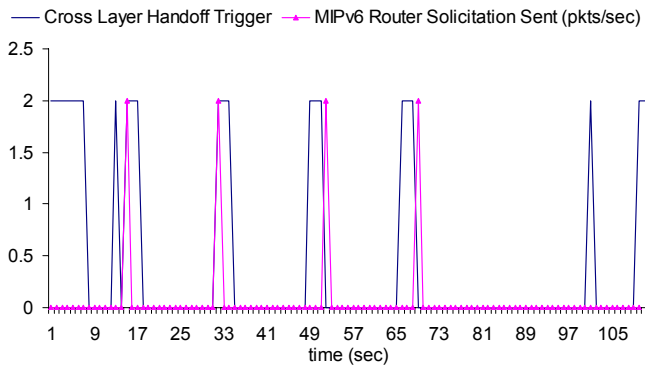


Fig. 7. A graph showing cross layer handoff triggering and MIPv6 handoff triggering.

VI. CONCLUSIONS

From the results section we can see that the cross layer architecture's movement detection mechanism is more effective than its MIPv6 counterpart. Cross layer handoff triggers occur on a timelier manner than MIPv6 in general. In the exceptions where the cross layer trigger does not precede MIPv6 Router Solicitations, both trigger at the same time. The superiority in performance by the cross layer architecture can be attributed to its better choice of trigger variables. Whilst MIPv6 relies on timeouts, the cross layer scheme tracks variables that mirror handoffs better. This is not possible in MIPv6 since it is a single layer scheme. Thus in NGWN there should be a shift in paradigm from single layer schemes to multilayer functionality.

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M.A. Abdelatif received his undergraduate degree with honors in Electrical and Computer Engineering at the University of Cape Town in 2005. He is currently enrolled as a Masters of Science candidate at the same university.