OPTIMIZATION ALGORITHM FOR A HANDOFF DECISION IN WIRELESS HETEROGENEOUS NETWORKS

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Abstract

Future wireless networks will consist of multiple heterogeneous access technologies such as UMTS, WLAN and Wi-Max. The main challenge in these networks is to provide users with a wide range of services across different radio access technologies through a single mobile terminal. With regard to vertical hand off performance, there is a need for developing algorithms for connection management and optimal resource allocation for seamless mobility. The Media Independent Handover (MIH) architecture is used for the special case of handoff optimization between heterogeneous networks. The signaling messages are exchanged by triggers in 802.21 is obtained through Service Access Points (SAP). These messages must be delivered in a timely and reliable manner. In this paper, a novel solution to communicate MIH messages and to review their limitations are analyzed. An efficient solution using 3SE a Sender-Side Stream control, transport-layer protocol Extension, that modifies the Standard SCTP protocol is introduced. 3SE aims at exploiting SCTP's multi homing and multi streaming capabilities and is optimized by using MIH services. The performance is analyzed for various packet loss conditions and bandwidth capacity.

Keywords

Cross Layer Design, MIHF, Multihoming, Next Generation Networks, SCTP

1. INTRODUCTION

Future wireless networks aim is to provide universal ubiquitous coverage across different radio technologies, in which a multi-model mobile terminal(MT) will be able to connect to wireless access networks [1] (for example, Wireless Local Area Network (WLAN), Universal Mobile Telecommunication Systems(UMTS), CDMA2000 (Code Division Multiple Access) and Wireless Metropolitan Area Network (WMAN) simultaneously. Users expect service providers to offer permanent connections while roaming between networks. A large variety of applications utilizing these networks will demand features such as real time, high availability across different access technologies in a seamless way. However, the support to mobility raises new issues related not only to hand off management such as low disruption time [2], but also the Quality of Service (QoS). Handoff can be divided into two types: Horizontal and vertical. Horizontal handoff is experimented when the mobile node moves within the same technology networks, while vertical handoff occurs when the mobile node moves through different technology networks. Each technology provides its own enhancements to support minimum service disruption when switching from one access point to another, but inter technology roaming are not yet well supported. The increase requirement of the intelligence in such environment is behind our

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motivation to introduce autonomic networking. This is because future network is expected to embrace the heterogeneity arising from the different network control technologies such that it appears homogeneous to the potential users of network services. In order to address some of these challenges the IEEE 802.21 Media Independent Handover (MIH) service work group has introduced a standard for handovers without being tided into the features or specifies of particular wireless technologies [3]. The MIHF facilitates standards-based message exchanges between the various access networks or attachment points to share information about the current link layer conditions such as traffic load, network capacities, and commands to control the behavior of the lower layers. To perform seamless handovers, the delay and reliability of MIH messages are important elements. If the information is not given on time, the Mobile Terminal (MT) may lose its current connection prior to completing all the necessary signaling. The support of mobility raises new issues related not only to handoff management such as low disruption time but also to the quality of service and increased packet loss. A requirement for the transport protocol is to be able to maintain its performance under conditions of high packet loss and congestion. A new suite of protocols that handles multi homing is being worked upon by the IETF (Internet Engineering Task Force), featuring the Stream Control Transmission Protocol (SCTP). The IETF provides requirements and guidelines for the transport protocol used by MIH messages. SCTP can deal with multiple interfaces and it inherits from TCP its congestion control scheme; unfortunately it also inherits TCP limitations to deal with unreliable, highly variable radio channel conditions. To overcome these limitations and developing a multi homed and multi streaming transport layer protocol for wireless channels, a new transport layer protocol based on SCTP is proposed and it is called 3SE (Sender Side SCTP Extension). 3SE provides a new improved congestion control and multi homing feature to optimize the MIH messages while guaranteeing Service continuity.

2. RELATED WORK

Several mobility management techniques have been proposed for Next Generation Heterogeneous wireless networks. In [4], an adaptive transport layer (ATL) was proposed for integrated networks with the capabilities of adaptive congestion control, multimedia support and providing fairness of transmission. In [5], a network selection mechanism for 4G wireless networks was proposed. The article [6] introduced important performance criteria to evaluate seamless vertical mobility, eg. Network latency, congestion, service type etc. In [7], managing mobility and adaptation in IEEE 802.21 enabled devices was proposed. Cross Layer design techniques are being introduced to allow the traditional TCP/IP stack to cope in wireless environment [8]. In [9], the authors propose a generic signaling solution using the Next Steps In Signaling (NSIS) framework. While the solution allows for the MIH to communicate with a signal transport protocol, the General Internet Signaling Transport (GIST) layer runs over standard protocol such as UDP, TCP or SCTP. Hence, the performance of this solution is dependent on the actual underlying protocol used to carry the MIH messages. Locating IEEE 802.21 mobility servers using DNS was introduced in [10]. The performance analysis using UDP and TCP was proposed in [11]. The authors of [12] introduced a solution to efficiently carry MIH messages using the SCTP protocol. The scheme in [13] portrays how cross-layer design leverages the protocol stack in wireless access networks. Cross-layer signaling such as in [14] can enhance the reactivity of the protocol stack by quickly extracting relevant information from non-adjacent layers. These design principles are used in this paper to find responsive solutions to mobility management in unpredictable environments. 802.21 MIHS services are used for handover optimization in [16] in conjunction with SIP and in [15] through FHMIP. These two papers show that MIHS assisted handovers are a significant improvement over traditional vertical handoffs.

3. OVERVIEW OF IEEE 802.21

The Media Independent Handover (MIH) framework [3], developed by the IEEE802.21 work group, is an evolution for all networks, providing capabilities to detect and initiate handoff from one network to another. This is done by providing mechanisms to easily exchange information about the network. A cellular phone will be able to switch over to a less expensive Wi-Fi hotspot and back to the cellular network once the hotspot is no longer available. In this section, an overview of the MIH architecture, the services it provides and its protocol to deliver the message exchange are discussed.

3.1. Architecture

The standard designed a new function to control access to the lower layers (layer1 and layer2). This new function provides new Service Access Points (SAPs) and allows for information to be queried by the upper layers (layer3 and above). Both mobile devices and network hardware must implement the standard to work, but everything should remain backward compatible for non-MIH aware devices. As shown in figure 1. the MIHF can be seen as layer 2.5 in the mobility control plane.

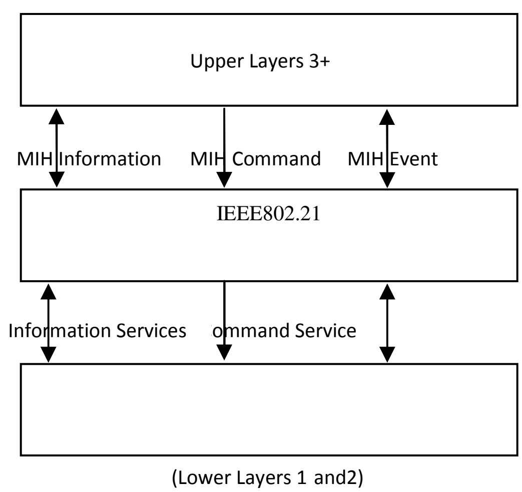


Figure 1. MIH Architecture

It is located between the MAC and PHY layers, and the upper layers, namely IP and above. It facilitates cross layer and cross-entity interactions. An MIH User can be any entity that needs across to cross-layer information, ranging from the IP layer to the application. In the network, the MIHF can be used to perform Network- initiated handoff and support the MTs handoff process.

The MIHF in the MT may communicate with other MIHFs located in other nodes, namely PoSs. These PoSs may be located anywhere in the network and provide different services.

3.2. MIH services

The MIHF which provides three principal services: Media Independent Event Services (MIES), Media Independent Command Services (MICS) and Media Independent Information Services (MIIS).

Media Independent Event Services

The MIES provides event classification, event filtering and event reporting corresponding to dynamic changes in link characteristics, link status and link quality. There are two types of events : Link event and MIH event. The MIHF registers Link Event notifications with the interfaces. Any upper layers entities in either a local or remote stack can register for an MIH Event notification, either in groups or with predetermined thresholds. The lower layers will generate a Link event and send it to the MIHF which will report to any entity that has registered either an MIH Event or a remote MIH Event. The information reported is meant to merely notify of an event occurrence. These events, both link and MIH, fall in to six categories: administrative, state change, link parameter, predictive, link synchronous, and link transmission. A state change event represents a change in the state of the interface such as Link Up or Link Down. A link parameters event indicates that the measurement has crossed a configurable threshold. The parameters can carry information such as signal strength, or Quality of Service (QoS) values. A predictive event indicates a possibility of losing the connection in the near future. A link transmission event is used to indicate success or failure of a packet transmission. Finally link synchronous indicates a change in the Point of Attachment (PoA).

Media Independent Command Services

The Media Independent Command Services (MICS) allows commands to be delivered to link layers by higher layer mobility protocols. The commands can either configure link behavior or poll the links for their status. Similar to MICS, there are two types of commands: Link commands issued by the MIHF to the lower layers, and MIH commands issued by users to the MIHF. It is noted that link commands are always local and destined to one interface while MIH commands may be for local or remote MIHF. MIH commands may contain actions regarding multiple links.

Media Independent Information Services

The Media Independent Information Services (MIIS) allows handoff related information to be relayed across networks. MIIS messages relate to quality of service, cost information, channel parameters, network discovery, security, power management issues, service and application classes and network vendors information. The MIIS provides a report mechanism to handoff decision engines in advanced mobility scenarios.

The communication between layers occurs through the well-defined Service Access points(SAPs), covered in the previous section. MIHFs use the protocol to perform discovery of other MIHFs along with their capabilities, and to register with remote entities. The only problem is they have to send the data over some physical link, therefore the MIH protocol takes care of encapsulating in MIH frames and sending over the physical link. The MIH message header contains the MIH services ID, action ID, and a unique transaction ID (TID). This TID is used to match request and response message and detect duplicate messages. A sender MIHF can set the ACK-Req bit in the MIH header requesting an acknowledgement message (MIH-ACK) to be sent. The sender may retransmit the message if no response is received. The MIH protocol also specifies a flow control mechanism to handle congestion. The acknowledgement mechanism is optional if the MIH protocol is run over a reliable and congestion aware transport protocol such as SCPT or 3SE.

4. A JOINT MIHF AND 3SE

In this section a new transport protocol named as Sender Side SCTP Extension (3SE) is introduced. It is the extension of SCTP. It aims at exploiting SCTP's multi homing and multi streaming capabilities by selecting in real time the best choice among available, alternate paths to the same destination. In Integrated cellular networks, routing plays a critical role in finding a route [18] to divert congested traffic from a congested primary path to another less crowded path. The provision of QoS guarantees and service continuity to the end user needs to support of new transport layer protocols that can jointly control the end-to-end performance supplied to applications and mask the use of different technologies at lower layers. It is well-known that loss-based end-to-end congestion control such as TCP does not work efficiently in lossy wireless networks. Also TCP can not handle multiple IP addresses in a single connection and it is not suited to deal with the highly unreliable, variable conditions of radio channels. 3SE provides several enhancements to TCP including security and robustness. It is a reliable message oriented protocol with multi homing and multi streaming capabilities. As shown in Figure 2, the protocol allows end points to communicate via multiple addresses, often due to the presence of multiple network interfaces. Original SCTP uses multi homing for failure recovery. The basic idea of 3SE is to combine a new improved congestion control and multi streaming and multi homing capabilities to optimize the delay reduction in exchanging MIH messages while guaranteeing service continuity. If messages are not provided on time, a current connection may be lost before obtaining all the necessary signaling. Furthermore, the connectivity requiring handoff is most likely suffering from increased packet loss. A key point that determines the transport protocol to use is the network conditions over which the messages are exchanged.

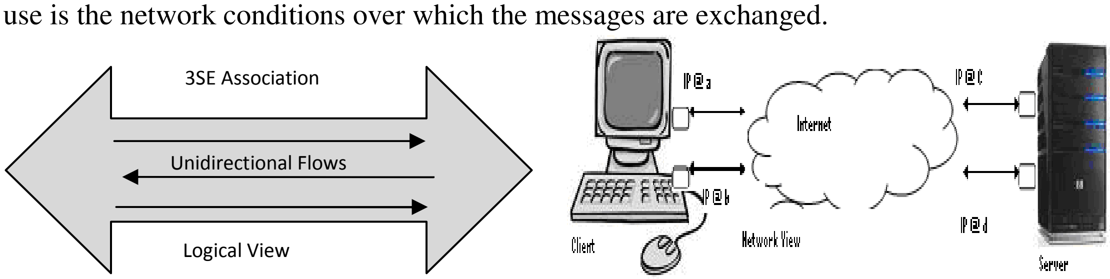


Figure 2. 3SE Architecture

In general, handoff management is executed by three steps: network selection, handoff decision and handoff signal processing. Both early handoff and late handoff are undesirable because an early handoff would lead to false handoff initiation and a late handoff would lead to handoff failure. Therefore, the events notifying a change (i.e. congestion) or predicting a connection loss (i.e. Link Going Down), along with the commands to execute handoff, will be exchanged over a congested connection and the packet loss might be high. Soon after a node attaches to a new network, other messages such as MIIS requests are likely to be exchanged.

The MIH mechanisms that may support reliability and flow controls namely message acknowledgement and rate control. The use of those capabilities depends on the transport protocol used by the MIHF. The MIPSHOP [19] (mobility for IP: Performance, Signaling and Handoff Optimization) working group at the Internet Engineering Task Force (IETF) provides requirements and guidelines for Transport protocol selection.

4.1. Congestion Control

If a loss event occurred in wireless environment the congestion window size will be dropped. This is one of the major problems of TCP and SCTP. When packets are lost due to mobility or worst radio channel conditions, the transmission rate reduction causes a significant throughput decrease. In order to overcome this problem, and identify losses due to congestion, 3SE estimates the exact bandwidth capacity in advance. If the router under estimates the bandwidth capacity, it will under utilize the link and waste the valuable bandwidth resource, and if the router overestimates the capacity, it will provide improper feedback to senders to increase their congestion windows and may cause queue growth and even buffer overflow. It is very difficult to decide a proper value of bandwidth capacity in advance for a wireless link. This is because a wireless channel is shared by competing neighbor nodes and the number of nodes sharing this channel may change all the time. And another reason is that the wireless link bandwidth is affected by many changing physical conditions such as signal strength, propagation distance and transmitter power.

Every time a loss event is reported, the output rate of the connection link on the primary path is compared to the most recent estimate of the path available bandwidth. If the output rate is computed as $C_{wnd/}$RTT, and it is larger than available bandwidth, the 3SE infers that a sender is causing congestion. Then the traditional congestion control mechanism is applied i.e., the congestion window size is reduced either to one packet in case of time out expiration or to the slow start threshold (SS_{thesh}), previously set to half of the last C_{wnd}, when the loss is notified by the reception of three duplicate SACKs (dupSACKs).

On the contrary; if the 3SE sender is not using all the available bandwidth, 3SE infers that there is no congestion; it then applies a smooth reduction of the congestion control parameters; setting, as in [20], the slow start threshold to

$$SS_{thresh} = \frac{B * RTT}{P} \quad (1)$$

where B is the bandwidth estimate, P is the maximum packet size and RTT_{min} is the minimum observed Round Trip Time in case of triple dupSACK, since 3SE performing the standard congestion window reduction, sets the C_{wnd} to the SS_{thresh} value.

Unlike SCTP, which uses the SS_{thresh} value reached in the previous transmission and which can be completely unrelated to the path condition, 3SE also tries to properly set the value of the slow start threshold on the idle path. i.e., the value of (1) is halved,

$$SS_{thresh} = \frac{B_{idle} \cdot RTTmin_{idle}}{2p}$$

where B_{idle} and $RTTmin_{idle}$ refers to idle path.

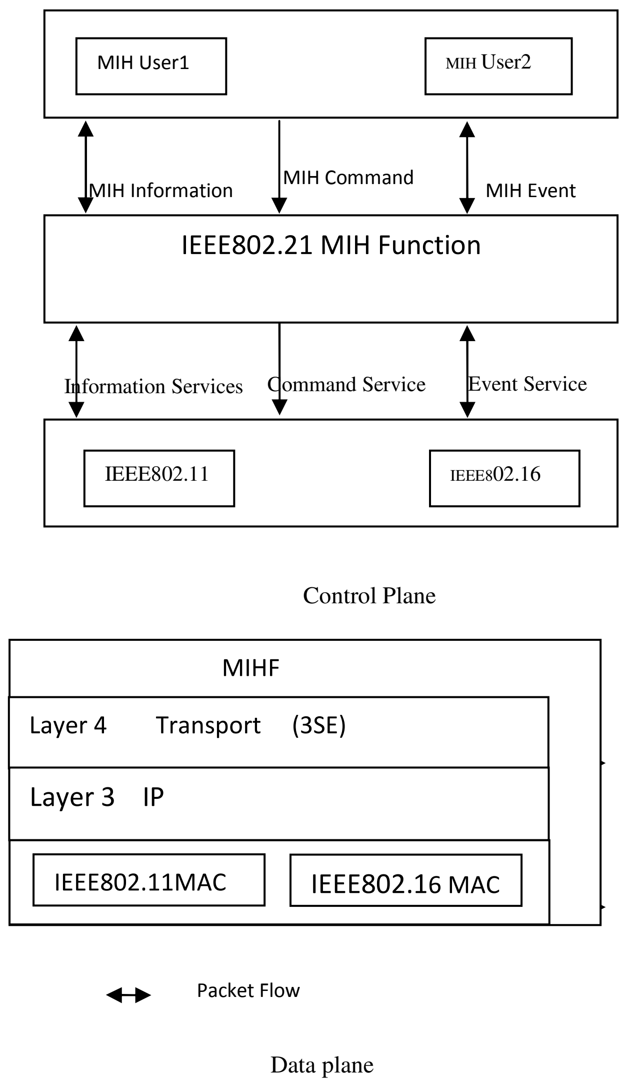


Figure 3. Architecture of MIHF in mobility management protocol

4.2. Interface Selection for Multihoming

The proposed design is based on a strong interaction between MIH and 3SE, in which each layer is enhanced by using the capabilities provided by the other one. In the control plane, 3SE is an MIHF User and is placed above the MIHF. 3SE uses MIH services (Information, Command, Event) to be aware of changes at the lower layers, getting to adapt its transmission parameters and select the best interface. Also MIHF transmits and receives MIH messages by using 3SE as a transport layer protocol. Therefore in the data plane, the MIHF is placed above 3SE in the TCP/IP. model. This architecture is shown in fig: 3. In this control plane, it is proposed that 3SE implements a path management that minimizes the delay to transmit the packets that use the MIH services. Every wireless station is connected to the internet via more than one Access Points (APs), thus exploiting multihoming. Therefore 3SE can decide which address to use to transmit messages. Links have different capacities. This address can be registered as primary path for the peer node. It can also use alternative address to retransmit messages. The advantages of using multiple wireless interfaces would be wasted without an efficient management of the available paths, based on relaxing the rigid "Primary-Secondary" path definition in SCTP. Upon each retransmission time out expiration, the available bandwidth on the primary path is compared to

those estimated on the secondary path. If the bandwidth on the secondary path is larger than the bandwidth on the path where the time out occurred then the path definition are swapped. The secondary path becomes the new primary path and vice versa. The aim of this change is to transmit new packets on the path that seems to be in better conditions, increasing the probability of a successful communication. In order to avoid frequent path swaps, a time hysteresis of 60s is introduced

Path Selection Algorithm:

```
    for each interface  x  do
        for each interface (y ≠ x) do
            estimate Bandwidth (x, y);
   if Bandwidth (x,y) ≤ α  Bandwidth(a, b)    then
                    a=x;
                    b=y;
              end
           end
      end
```

where, $\alpha \leq 1$, is a switching coefficient. This will reduce frequent updates, when multiple combinations of x and y returns similar values of Bandwidth (x, y).

Path selection algorithm is proposed to estimate the bandwidth to transmit a packet using one interface i and includes one retransmission on another interface j. Dependency on the availability of feed back information, bandwidth estimation is carried on the primary and on the secondary paths.

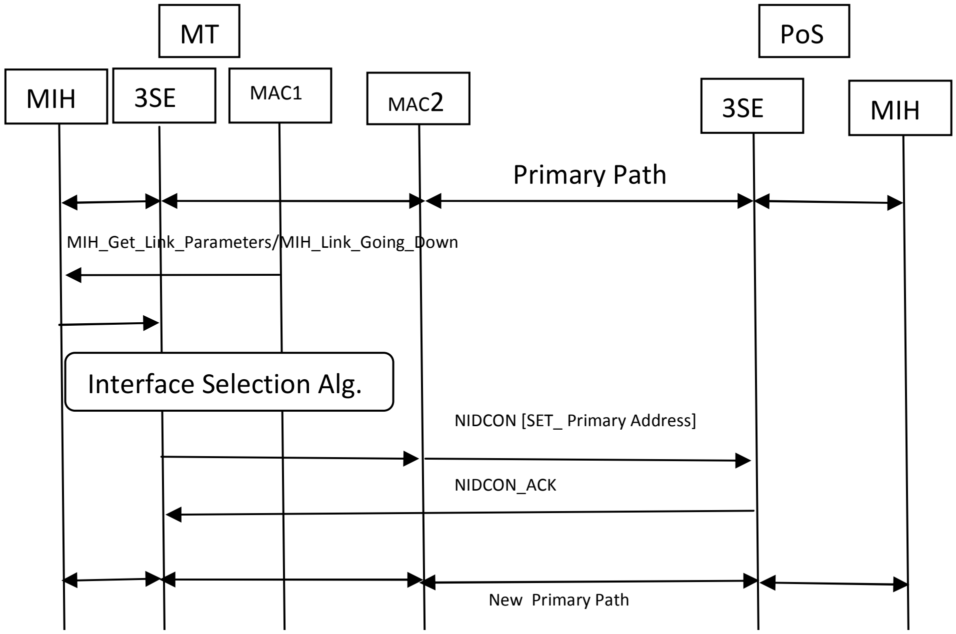


Figure 4. Path Selection

4.2.1 Bandwidth Estimation on Secondary Path

In this case, it is required to establish if the secondary path toward the unused interface is less congested than the primary path toward the destination address currently engaged; besides, the wireless link is often the bottleneck in the network path. Hence on the secondary path it is preferred to trade off estimation accuracy using an approach based on Packet Pair[23], that avoids sending massive amounts of data. If the two packets are queued next to each other at the bottleneck link[24] , then the resulting inter packet spacing after the bottleneck will be proportional to the bottleneck bandwidth. Under ideal conditions, if P is the packet size and Δt is the separation of the packets after the bottleneck and the bottleneck bandwidth is given by

$$B=P/\Delta t \qquad (2)$$

While implementing this approach raises problems such as probe packet dropping, downstream congestion, and the presence of multiple bottlenecks. A possible solution, proposed in[23], consists of sending packets of different sizes. 3SE replaces SCTP transmission of the two Heartbeat packets with the transmission of a six-packet train on the secondary path, like the SProbe Tool[21]. The small packets are 40 bytes long, like standard SCTP Heartbeats; the size of the large packets is set to the Maximum Transfer Unit (1200 bytes). The bottleneck bandwidth is calculated from the dispersion of the large packets that, taking more processing time at the routers, have higher probability of being queued. The measurement is valid only if there are no losses or out of order. If the measurement is valid, the value of the dispersion Δt is returned to the center by the Heartbeat ACK and it is used to compute the available bandwidth according to (2).

4.2.2 Bandwidth Estimation on the Primary Path

Since the transmission of the data packets is continuous, the flow of returning SACKs can be used to collect a bandwidth sample. A 3SE sender uses a value of the RTT and the amount of data confirmed by the received SACKs to estimate the available bandwidth. If, the generic k^{th} RTT, Δ_k, one or more SACKs notify that a total of d_k bytes have been received, the bandwidth sample, B_k, can be estimated as,

$$B_k = d_k / \Delta_k \qquad (3)$$

In order to average the sampled measurements and the filter out the high frequency components, 3SE employs a low pass filter. Hence the filtered bandwidth B_k can be written as

$$\hat{B}_K = \propto \hat{B}_{k-1} + (1-\propto)\hat{B}_k \qquad (4)$$

Where α is a constant set to 0.9.

4.3. Fast Movement Switching detection using MIH Services

Typically this framework is designed to provide generic link intelligence independent of different radio technologies. Nevertheless we choose to integrate two emergence wireless access technologies as a case study: Wireless Local Access Network (WLAN) and Wireless Metropolitan Access Networks (WMAN) based on IEEE 802.11e and IEEE 802.16e respectively.

Such internetworking between WLAN and WMAN is considered as a viable option towards attaining the 4G scenario. Introducing the additional entities to the initial framework will lead to the occurrence of handoff in a seamless and fast way. We first emphasize on fast because the delay resulted in handoff in both WLAN and WMAN is rather high. As normal handoff in WLAN is already hard, which means break-before-make and almost all part of the delay of interruption is due to the time required for channel scanning in the neighboring area. While WMAN supports three types of handoff: hard handoff, Fast Base Station Switching (FBSS) and Macro-Diversity handoff (MDHO) [3]. In this section it is defined that when 3SE executes the path selection algorithm, which is performed by estimating the bandwidth of the channel connection and determining the reachability of the peer node. In order to receive triggers from MIHF, 3SE should subscribe to receive certain event triggers. The communication by triggers in 802.21 is obtained through Service Access Points (SAP). As discussed in section 4.2.1 that a 3SE endpoint can advertise local change to switch primary path and 3SE replaces SCTP transmission of the two Heartbeat packets (usually every 15 seconds) with the transmission of a six-packet train on the secondary path (two small, two large and two small), like the SProbe Tool[21]. The small packets are 40-bytes long, like standard SCTP Heartbeats. The size of the large packets is set to the Maximum Transfer Unit (1500 bytes in this simulation). The proposed solution uses the algorithm presented in section 4.2 to determine the appropriate primary path. 3SE retrieves the current packet loss using the MIH_Get_Link_Parameters command from MICS. The polling is periodically done for every few seconds and upon receiving MIH_Link_Going_Down events. This meant that link conditions are degrading and connection loss is imminent. As shown in Figure 4, if the best interface is different after running the algorithm, 3SE sends a New Address Configuration (NIDCON) packet containing a SET_PRIMARY_ADDRESS option.

The MIH function has several defined SAPs for access to the handover features and the interfaces, which are used to enable communication between MIHF and other layers. In the present standard there is a none technology independent MIH_SAP which allows the communication between the MIHF and upper layers, namely, IP, transport and application. However the communication between low layers (Medium Access Control and Physical Layer) and the MIHF should be medium dependent. 3SE will use the MIH services to increase its response time by registering for MIH_Link_Down events (L2 connection is lost). As shown in Figure 5, while receiving the MIH_Link_Down, 3SE sends a NIDCON packet with a DELETE_IP option to the peer node if there is a new interface available. If the node has single interface, 3SE will wait until the connection is re-established to update the peer node. 3SE also interacts with the IP protocol to receive indication that a new address has been configured. When the new address is available, 3SE sends an NIDCON packet with the UPDATE_IP option to register the new address. It is noted that MIH_Link_UP event only indicates the node's Layer2 is ready to send upper messages. 3SE requires the IP layer to be configured before it can send any messages.

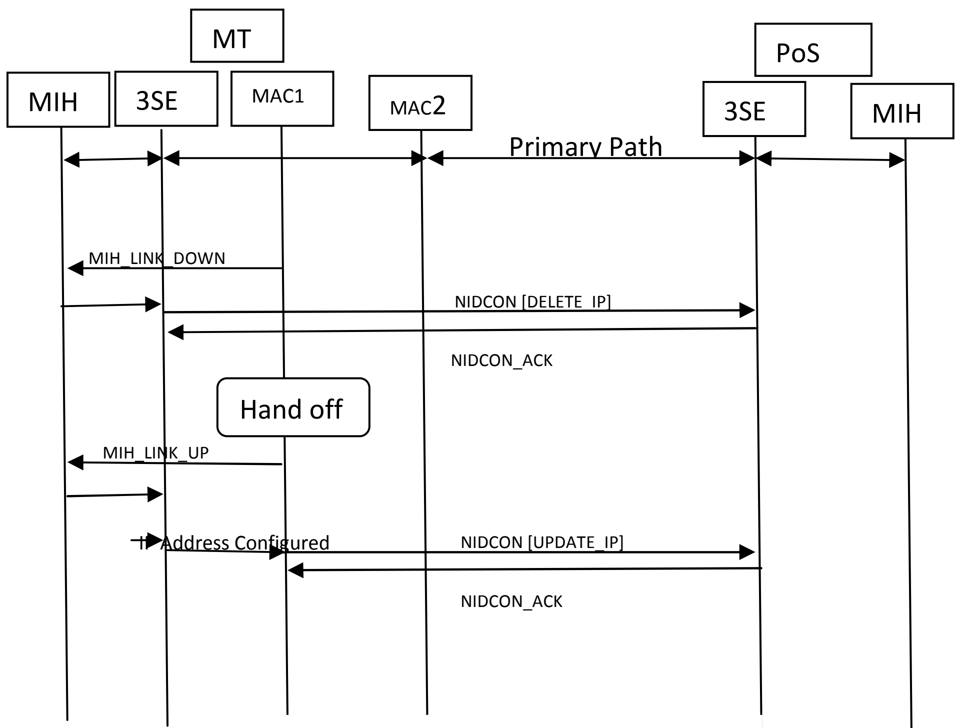


Figure 5(a). MN with two interfaces

4.4.MIHF Controls of 3SE

It is proposed that the MIHF makes use of the multistreaming capability of 3SE to prioritize messages in the data plane. A 3SE-aware application can configure the number of streams and the list of addresses to use. It can also note the lifetime and prioritizing of each packet. The proposed method exploits those capabilities. The MIHF standard merely assists in providing information to determine when to handoff and initiating the handoff through MIH services namely MIES, MICS, and MIIS. These services are independent of each other and have different constraints. As shown in Figure 6 the MIH services can be provided by distinct POSs. When an MIHF makes an association with a POS, it will only make streams for the supported services. It is proposed that the MIHF update and maintain information about the events sent to 3SE and indicate when they are no longer valid. The proposed algorithm will give a decision when the message from MIHF to 3SE is no longer valid.

Step1: When a new message is to be sent, lookup its priority

Step2: Suspend all messages from the same category.

Step3: If the multiplicity is 1, then suspend the message from the same category; else if there are already M messages in the sending list, cancel the oldest event in the list.

Using this method, MIHF removes low priority and invalid messages. Also 3SE may have successfully transmitted messages but the MIHF indicating the same as expired; here the 3SE will just ignore the command. To avoid handling multiple identifiers, the MIHF uses the Transaction ID in the MIH message header as a context identifier when sending a message and when telling 3SE to skip the message. There are four types of events: Link State events indicate a change in

the state of the interface. Link Prediction events indicate the link condition are degrading and connection loss is imminent. Link Parameters events indicate that the link parameters have crossed specified threshold and changes in network conditions. Finally, the Link Synchronous events indicate that L2 handover is imminent or completed handover.

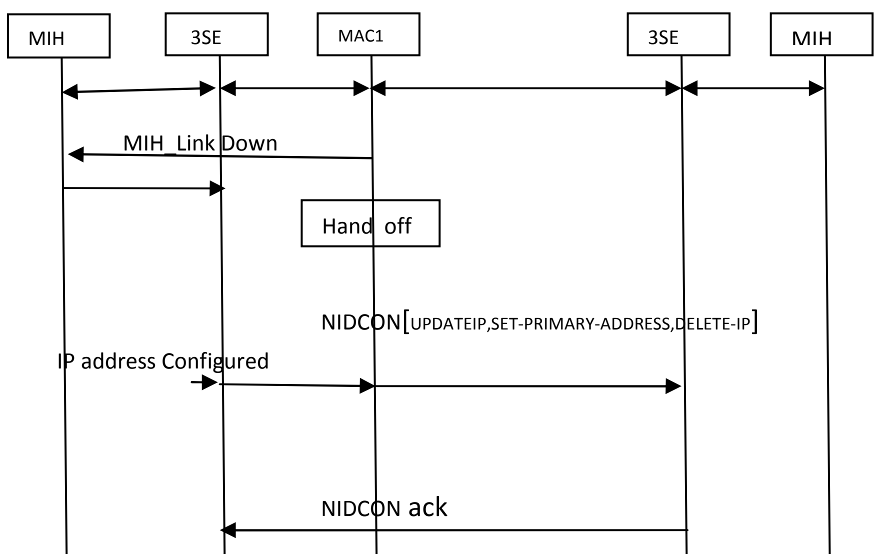


Figure 5(b) MT with only one interface

Figure 5(b). 3SE Signaling using MIH Services

5. PERFORMANCE EVALUATION

The performance of the proposed protocol is evaluated by ns-2 simulator. It is assumed that a fixed node is connected with one or more Access Points(APs) through the Internet, and the wireless portion is an 802.11b WLAN. Links have different capacities, unless otherwise specified, the one-way propagation delay is set to 40ms on the fixed part and is negligible on the wireless channel. The 3SE includes implementation of Dynamic Address Reconfiguration and Integration with the MIH framework. The simulation results evaluating the transport of MIH messages via 3SE and the impact of handover signaling delays.

The network configuration used to perform the evaluation is shown in Figure 7. We study the signaling delays to perform a handoff with an MT equipped with multiple interfaces. We perform the analysis of two representative cases differentiated by the availability of an alternative technology that can be used to support the signaling. In the first case, the MT does not have multihoming capability.

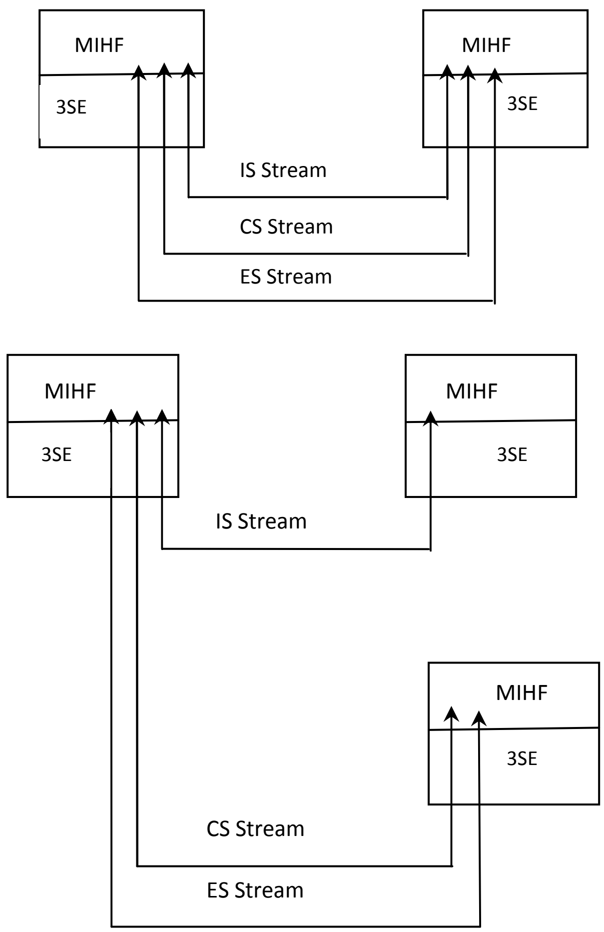


Figure 6. MIH Service Deployment

This will happen when the MT has single interface, when the other interfaces are turned off, or when there is no current coverage for the other interfaces. The MT can only connect to an IEEE 802.11 Access Point (AP), namely AP1 or AP2. In the second case, the MT has a second available interface of type IEEE 802.16, which allows it to connect to the 802.16 Base Station (BS), namely BS6. In all cases, the MT is first connected to AP1 and in moving away at constant speed. To represent the error process on the wireless channel, two models are employed. In the single scenarios, the traditional two-state Gilbert model is used; otherwise, a three-state discrete-time Markov chain [22] is adopted. The three-states correspond to (i) error-free conditions, (ii) short burst of consecutive errors, and (iii) long burst of errors corresponding route failures. In both models, the chain time slot is equal to the slot time parameter in 802.11b (namely, 20μs).

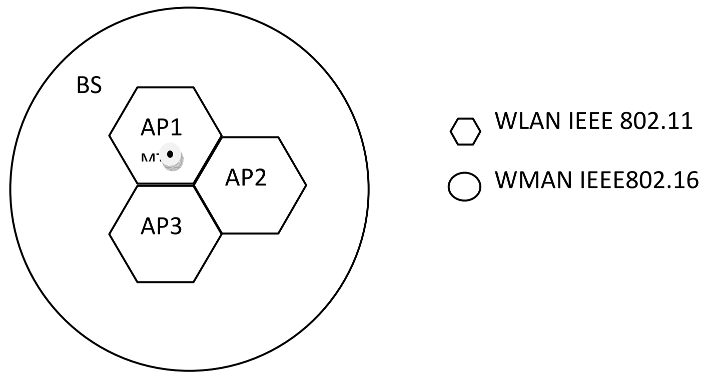
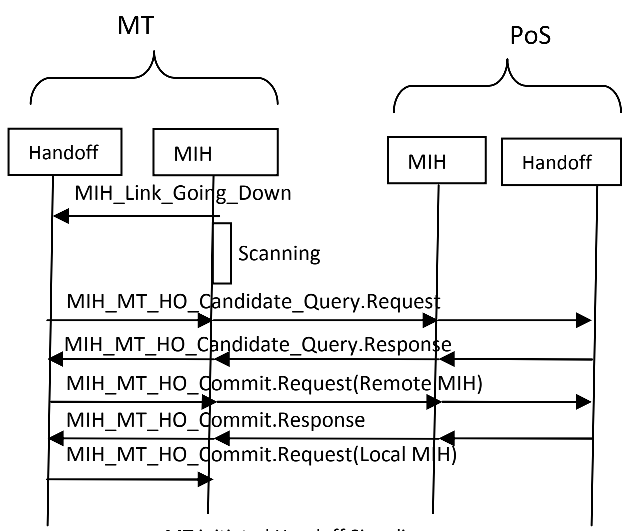


Figure 7. Service area of 4G wireless network



MT initiated Handoff Signaling

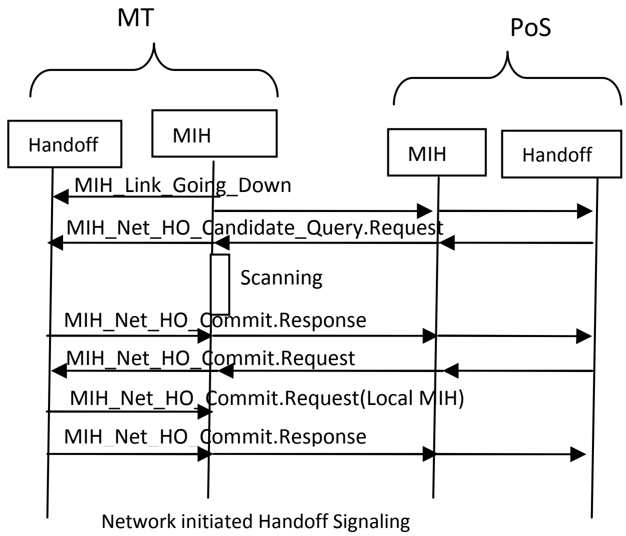


Figure 8. Handoff signaling according to the proposed architecture

The performance of the proposed solution is analyzed for MT-initiated and Network-initiated handovers. The handoff signaling message flows are shown in the Figure 8. For MT-initiated handoff, the reception of a local MIH_Link_Going_Down triggers scanning to find a target AP. Then the MT communicates with the PoS via MIH_MT_HO_Candidate_Query request/response messages to get information about potential target networks. Upon receiving the response, the MT decides which target AP to use and informs the PoS via a MIH_MT_HO_commit request. When the PoS acknowledge the request, the handoff is executed.

In the case of network initiated handoff, the MT first sends a remote MIH_Link_Going_Down message to the PoS. The PoS communicates the MT to determine the potential targets via the MIH_Net_Candidate_Query requests, triggering a scan. The results of the scan are communicated to the PoS, which performs the target selection. The decision is transmitted to the MT via an MIH_Net_HO_commit request. When receiving the request, the MT performs the handoff and sends a confirmation to the PoS.

5.1. Impact of the packet loss on the MIH handoff signaling delay

The results in Figure 9(a) and (b) show the average MIH handoff signaling delays for the MT and Network-initiated handoff respectively.

5.1.1 Effect of the multihoming capability

The highest delays occur when the MN has only one interface. With a packet loss of 40% delays is measured up to 3.2s for both MT and Network-initiated handoff. When the MT is multihomed the handoff signaling delays are decreased because 3SE makes use of the second interface for retransmission but does not change the primary path. It is observed that the delays up to 1.6s when the primary connection suffers from 35% of packet loss. On the other hand, if MIH services are used, the adequate path is computed according to the algorithm described in section 4.2. This leads to delay upto 1s in both MT and Network-initiated handoff.

5.1.2 Effect of using MIH services

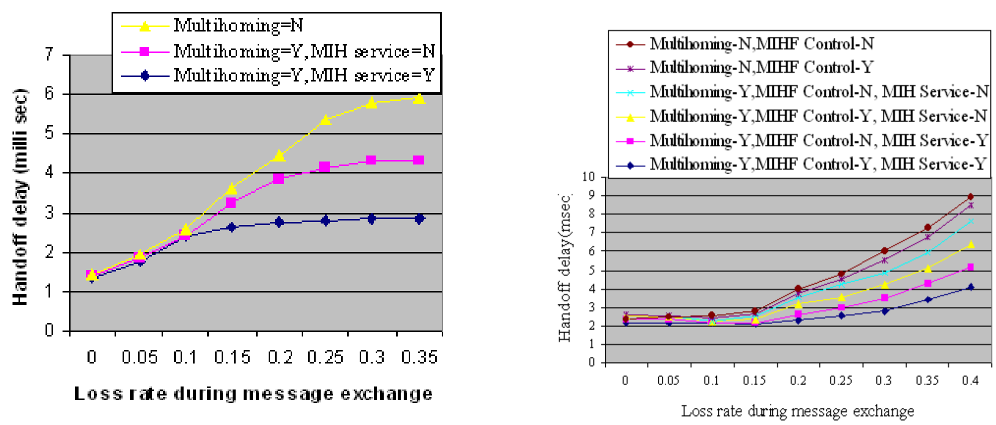
It is observed that the cross layer optimization does not provide better performance when the MT is not multihomed. Though the connection is weak, retransmission should happen on the same interface. Also it is absorbed that if the packet loss is less than 15%, all solutions perform the same wit hdelays between 0.6 and 1s. This is because using the 802.11 interface still provides better results than changing the primary path to the 802.16 interface. Beyond 15% packet loss rate, the interface selection algorithm estimates it is beneficial to change the path.

5.1.3 Effect of MIHF controlling 3SE

In the case of MT-initiated handoff there are only commands sent, no remote events. The results are identical whether the MIHF controls 3SE or not; thus the curves overlap. For Network-initiated handoff, it is noticed that if the MIHF indicates when events are outdated, the delays are reduced by upto 20%. This is especially true when the MT only has one interface. If the MT is multihomed, the impact is less due to the existing lower transmission delays.

5.2 Channel Contention and Radio Channel Errors

It is considered that several fixed stations operate in the wireless portion of the network. The transmission rate over the radio channels is set to 11Mbps and path #1 is the initial primary path of all SCTP and 3SE associations. The Figure 10 depicts the average delay experienced by a wireless station during the reception of data packets. Increasing the number of nodes from four to eight, some losses occur due to buffer overflow at the APs, reducing the average number of queried packets and consequently dropping the transfer delay. From that point on, the average delay increases proportionally to the number of wireless stations. Figure 11. reports the resequencing times of both 3SE and SCTP.



MT – Initiated Handoff Network Initiated Handoff

Figure 9 MIH Handoff signaling delays

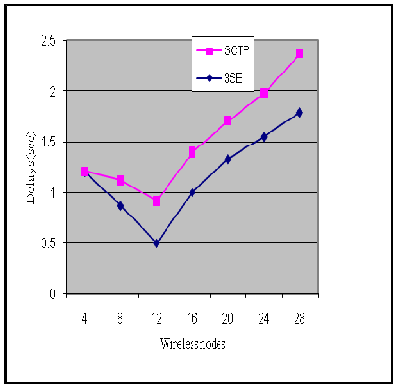


Figure 10 Average delay experienced by a wireless station during the reception of data packets

3SE resequencing times are higher than the ones of SCTP, particularly when the number of mobile stations increases. Figure 12 shows the packet loss probability at the transport layer as a function of the number of wireless stations and for two different values of the error probability over the wireless channels. When the channel error probability is small (Pe1=Pe2=0.001), all protocols experience a similar packet loss ratio even though 3SE associations incur slightly higher losses than SCTP as the number of wireless stations increases. This is due to the buffer overflow that occurs at the APs. For larger values of channel error probability (Pe_1=Pe_2=0.1), the benefits of the nodes partition between the APs, which is induced by 3SE, becomes evident also in terms of loss probability.

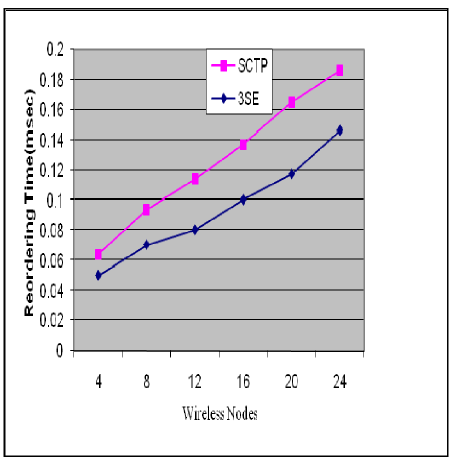


Figure 11. Resequencing times of both 3SE and SCTP

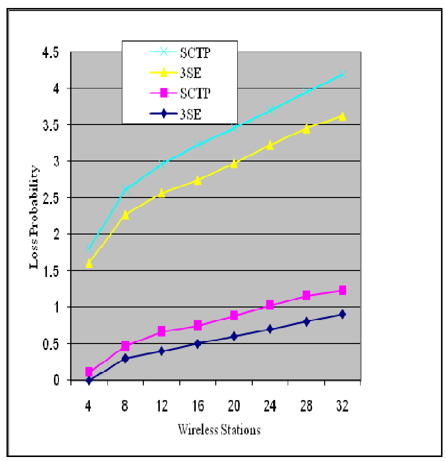


Figure 12. Packet loss probability

6. CONCLUSION

Vertical handoff is defined as a process which transfers a user connection from one technology to another. In the near future, vehicular and other mobile applications will expect seamless vertical handoff between heterogeneous access networks, via multiple interfaces. This is achieved by exchanging information across multiple layers of the same entity and by sharing information between nodes in the network. Therefore if a link event is not propagated quickly enough across the protocol stack service disruption could occur due to latent handovers. The proposed framework introduce 3SE and its capabilities namely multihoming, multistreaming, address reconfiguration and is able to distinguish among losses due to congestion and radio channel failures. Among the main novelties introduced by 3SE, there are the diversified bandwidth estimation and the efficient use of multihoming by the redefinition of primary and secondary path. In addition, they provide a complete solution to use 3SE as an efficient transport solution for MIH. The solution combines a path selection algorithm and the use of MIH services to optimize 3SEs behavior. Simulation results shows that the proposed solution reduces the impact of packet loss and the event generation rate on the transmission delays.

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