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Full Length Research Paper

The seamless vertical handover between (universal mobile telecommunications system) UMTS and (wireless local area network) WLAN by using hybrid scheme of Bi-mSCTP in Mobile IP

Bashar J. Hamza*, Chee Kyun Ng, N. K. Noordin, M. F. A. Rasid, and A. Ismail

Department of Computer and Communication Systems Engineering, Faculty of Engineering, Universiti Putra Malaysia, UPM, 43400 Serdang,Selangor Darul Ehsan, Malaysia.

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Nowadays many different types of networks communicate among themselves to form heterogeneous wireless networks (HWN). Seamless vertical handover (VHO) between a Universal Mobile Telecommunications System (UMTS) and a Wireless Local Area Network (WLAN) is necessary to provide continuous internet access for mobile node (MN) as roaming across these networks is to be without interruption. To support the seamless VHO and smooth mobility in the HWN, a network layer protocol mobile IP (MIP) is exploited. MIP has several attendant issues such as hybrid routing, registration delay, data session disruption during VHO, and packet overhead. These issues occur when the data packets of the MIP are sent from a foreign agent (FA) to a home agent (HA) via a tunnel when a MN moves to a new network which will cause a triangle routing. In this paper, we propose a hybrid scheme of mobile stream control transmission protocol (mSCTP) with a bicasting mechanism or so-called Bi-mSCTP under the MIP to overcome the abovementioned triangle routing. When an MN is in the area of VHO, the proposed scheme relies on the generated mSCTP signals to allocate a new care-of-address (CoA) to the corresponding node (CN) dynamically before the link layer handover. At the same time, it inserts a bicasting flag inside the address configuration (ASCONF) data chunk to inform the CN to start the transmission over both WLAN and UMTS links. The system performances were analyzed by using the NS-2 simulation tool. The results showed that the hybrid scheme introduces approximately 1.02 and 2.64 seconds reduction in delay performance over both mSCTP and MIP schemes respectively. It also reduces the packet loss rate by more than 21.7 and 45% compared to mSCTP and MIP respectively.

Key words: Seamless VHO, mSCTP, bicasting, mobile IP.

INTRODUCTION

The IEEE 802.11 Wireless Local Area Network (WLAN) has been widely deployed in offices, homes, campuses, airports and hotels. It provides low communication cost, high data rate (11 Mbits/s) and ease of proliferation. However, there are some disadvantages in WLAN such as small coverage area (up to 300 m) and low mobility.

The Universal Mobile Telecommunications System (UMTS) is a third generation (3G) cellular system which is expected to deliver low-cost, high-capacity mobile communications and offering data rates of up to 390 Kbps. The wireless radio access network for UMTS contains user equipment (UE) and UMTS terrestrial radio access network (UTRAN), which includes the node-B and radio network controller (RNC). The packet domain core network is comprised of the serving GPRS support node (SGSN) and the gateway GPRS support node (GGSN) (Hamza et al., 2010).

The next generation heterogonous wireless network

*Corresponding author. Email: mrym_bashar@yahoo.com.

(HWN) consists of various wireless technologies including UMTS and WLAN. Smooth mobility is expected to be the most significant feature for future HWNs. To achieve smooth mobility, especially for a seamless vertical handover (VHO) in wireless communication, it is necessary to install an association to a mobile node (MN) and keep the association while the MN is roaming (Kim et al., 2006). The management of VHO deals with a group of essential functions to vary the MN's point of attachment (POA) to the IP network, while keeping the connection with the corresponding node (CN) (Budzisz et al., 2008).

The location server for VHO is used to register the current IP address of an MN. Then, the location information of the MN is saved inside this server. The CN which is associating with the MN acquires the location information of the MN through the location server. The tracking of the current IP address of an MN is achieved by the location management. This IP address provides the gateway for any entity requiring to link with the CN (Liu et al., 2008). The MN can keep its present link without disconnection during new data session. However, the VHO faces several drawbacks such as high packet loss due to the disparity in bandwidth, a high handover delay from the high packet overhead and large congestion windows which will reduce the throughput of the network system. Currently, the seamless VHO problems are solved by different protocols in various ways such as Stream Control Transmission Protocol (SCTP), Mobile IP (MIP) and Session Initiation Protocol (SIP) to achieve a seamless VHO (Spatscheck et al., 2000; Berezdivin et al., 2002; Kozlovszky et al., 2006).

SCTP is an order of data packet delivery between two endpoints (Kozlovszky et al., 2006). It has a highly reliable transport layer protocol which provides stability similar to TCP, and also preserves the boundaries of data messages similar to UDP. Nevertheless, unlike TCP and UDP, SCTP offers advantages such as capabilities of multihoming and multistreaming which enhance reliability and availability. A multihoming host uses more than one network layer address to communicate. Hence for an MN, it can use multiple network interfaces simultaneously. If the primary path fails, the protocol will send traffic over the alternate path. Multistreaming can be used to deliver multiple objects (webpage, audio, video and text) that belong to the same association independently. Each stream is given a stream number that is encoded inside SCTP packets flowing through the association (Leu, 2009).

The SCTP with dynamic association reconfiguration (DAR) allows IP addresses to be added and removed from an SCTP association. The data packets can then be transmitted to the new destination. This enables an MN to move to a new network and implement a VHO at the transport layer. For prior forwarding of data packets from one node to the other, the data packet handshake between the two endpoints among the peer SCTP users must be established. On the other hand, being a network layer protocol, MIP ensures the smooth management of VHO during mobility. However, the MIP needs particular routers, such as a Foreign Agent (FA) and a Home Agent (HA). These routers are capable of intercepting and encoding/decoding data packets for the MN in the whole network (Stevens et al., 2010). Triangular routing of all arriving data packets to the MN via the home network can cause data session disruption in the MN during VHO which leads to further delays in receiving packets.

Session Initiation Protocol (SIP) is an application layer protocol responsible for establishing, modifying and terminating multimedia sessions (Schulzrinne and Wedlund, 2000). Some logical entities such as proxy servers, redirect servers, user agents and registrars can be extended to support personal mobility (Banerjee et al., 2003). Personal mobility enables an MN to switch between IP subnets while still being connectable to incoming requests and saving data sessions across subnet changes. Although SIP based protocols can facilitate VHO over HWN networks, it increases system complexity and does not allow seamless data packet sessions due to the long latency time (Pangalos et al., 2001).

In this paper, we propose a novel scheme to eliminate router overheads in the MN due to buffering, registration period and data session disruptions in the MIP during VHO. This new scheme is known as a hybrid scheme of mSCTP with bicasting or so-called Bi-mSCTP which uses an HA to continuously track the location of the MN during the course of bicasting in the MIP. It instructs the MN to transmit its own data packets to the CN by using either IP1 of the cellular UMTS or IP2 of the WLAN. In this way, the CN can send the same data packet to the MN over both UMTS IP1 and WLAN IP2 networks. The simulation results showed that the hybrid scheme has a VHO delay of about 0.302 seconds when the MN moves from a WLAN to a UMTS, while the VHO delays for both mSCTP and MIP schemes are 1.124 and 2.538 seconds respectively. Similarly, the proposed hybrid scheme has registered about 36.4 and 48.1% improvement in packet loss reduction compared to the mSCTP and MIP respectively.

RELATED WORK

Many researchers have proposed different mechanisms of VHO to enable global roaming of HWN between different access networks such as UMTS and WLAN networks. Sattari et al. (2004) presents network architecture for a seamless VHO over WLAN and UMTS based on two existing mobility protocols, SIP and MIP.

The authors perceived the VHO entity as a set of functions placed within the UMTS network which is responsible for VHO management. They proposed three solutions: MIP, SIP and hybrid based solutions. Although they analyzed the working principles of each solution, they did not provide any simulation results.

Varma et al. (2003) proposed solutions for the integrated GPRS and WLAN using MIP or SIP for mobility management. The study addressed only the location management aspect in place of a seamless VHO using the loose coupling integration approach. Ma et al. (2004) presented an mSCTP scheme for UMTS/WLAN VHO via two types of SCTP configurations; single-homing and dual-homing. In the single-homing configuration, the fixed server (FS) has one IP address which communicates with a multihomed MN. In the dual-homing configuration, both the FS and the MN have more than one IP address each to support the VHO. The authors changed the VHO operations to reduce the VHO delay in the dual-home configuration.

Kwon et al. (2008) proposed a multipath approach to reduce the packet loss during soft handoff. After the new IP address is added into the association, both old and new addresses are considered as the primary address of the association. Data from the corresponding host is duplicated and sent to both addresses. This avoids a long latency due to retransmission. Koh and Hyun, (2008) presented an extension of SIP to support a soft handover named mobile SIP (mSIP). The mSIP handover is designed to support the 'bicasting' of media streams from CN to MN during handover. In this way, an mSIP handover with bicasting can reduce the handover loss and latency compared to the baseline SIP scheme.

Fu et al. (2005) presented a handover scheme called Seamless IP diversity based Generalized Mobility Architecture (SIGMA). SIGMA used mSCTP to implement IP diversity by keeping the old path alive during the process of setting up the new path for seamless handover. In this way, the model improved some of the drawbacks associated with Mobile IP. However, in real life with the development of society and modern vehicles, people's rhythms of life unceasingly speed up. As such, in scenarios where the mobile host has faster travelling speed, it may move out of the overlapping region of the two adjacent access networks before finishing the steps of obtaining a new IP address and adding IP address into association with CN, thereby seriously reducing the handover performance of SIGMA. In an attempt to address this problem, Tao et al., (2010) proposed a Smooth Handover Scheme based-on mSCTP (SHSBM). This scheme adopts the advantages of SIGMA, and utilizes buffer and tunnel to better serve fast-moving users, with ensuring communication in ubiquitous environments as its main objective. The authors proved by simulation that the proposed SHSBM depict lower packet losses rate as well as higher throughput compared to SIGMA and MIPv6 in fast-moving scenarios.

OVERVIEW ON BI-MSCTP MECHANISM FOR VHO

The standard mSCTP management scheme for VHO between UMTS and WLAN networks is illustrated in Figure 1. In the cellular UMTS-IP1 region, the MN connects to the CN by using an IP configuration such as the IP1 address. When the MN moves to a new network such as the WLAN-IP2, the data packets of the cellular UMTS-IP1 address are discarded. The MN then begins movement detection and address configuration (Ma et al., 2007).

The MN will receive the IP2 address of the new location via the new access router of the WLAN by transmitting a change ASCONF data chunk. The MN then receives the ASCONF-ACK reply data chunk from the CN. It is vital to note that during the VHO session, the MN cannot receive data packets from the CN since this may lead to a high VHO delay. Once the MN moves away from the coverage of the WLAN network, the old IP address is deleted by transmitting an ASCONF data chunk. The MN then receives the replying ASCONF-ACK data chunk from the CN (Lee et al., 2006) (Figure 1).

The procedure of the Bi-mSCTP for VHO (Koh and Hyun, 2008; Kwon et al., 2008) is depicted in Figure 2. Initially, the MN in the cellular UMTS is tagged with an IP1 address. When it moves from cellular UMTS towards WLAN network, the access router of the WLAN is detected, thus provoking the MN to perform an IP address configuration such as in DHCP. Once the IP address configuration is completed, the MN directly communicates with the CN using the new address by transmitting an ASCONF data chunk which contains the VHO flag. This flag informs the CN to start bicasting to the MN. Thus, the CN can send a replica of the data packets to the MN via both UMTS-IP1 and WLAN-IP2 in the VHO region (Koh and Hyun, 2008) as specified in Figure 2.

In response to the ASCONF, the CN sends an ASCONF-ACK data chunk to the MN to add the new IP address in the association between the MN and the CN, which ensures that the MN's IP in the new network is set as the primary address of the MN. The CN then starts bicasting, and the MN sends its individual data packets to the CN through either UMTS-IP1 or WLAN-IP2. Conversely, as the MN leaves the WLAN-IP2 region, it senses the link down event for the UMTS-IP1 to disconnect the WLAN network by transmitting an ASCONF data chunk which deletes the old IP address. Upon receiving the ASCONF-ACK data chunk reply from the CN, bicasting is stopped. Henceforth, MN and CN use only the IP1 address for all future communications.

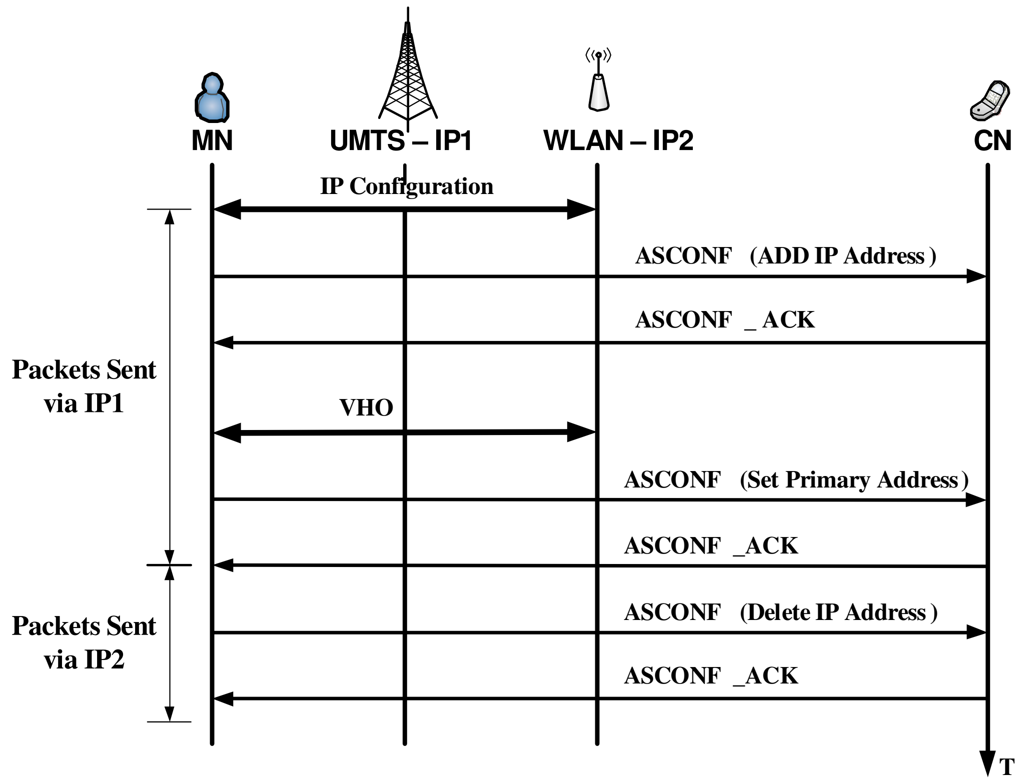


Figure 1. Standard mSCTP vertical handover.

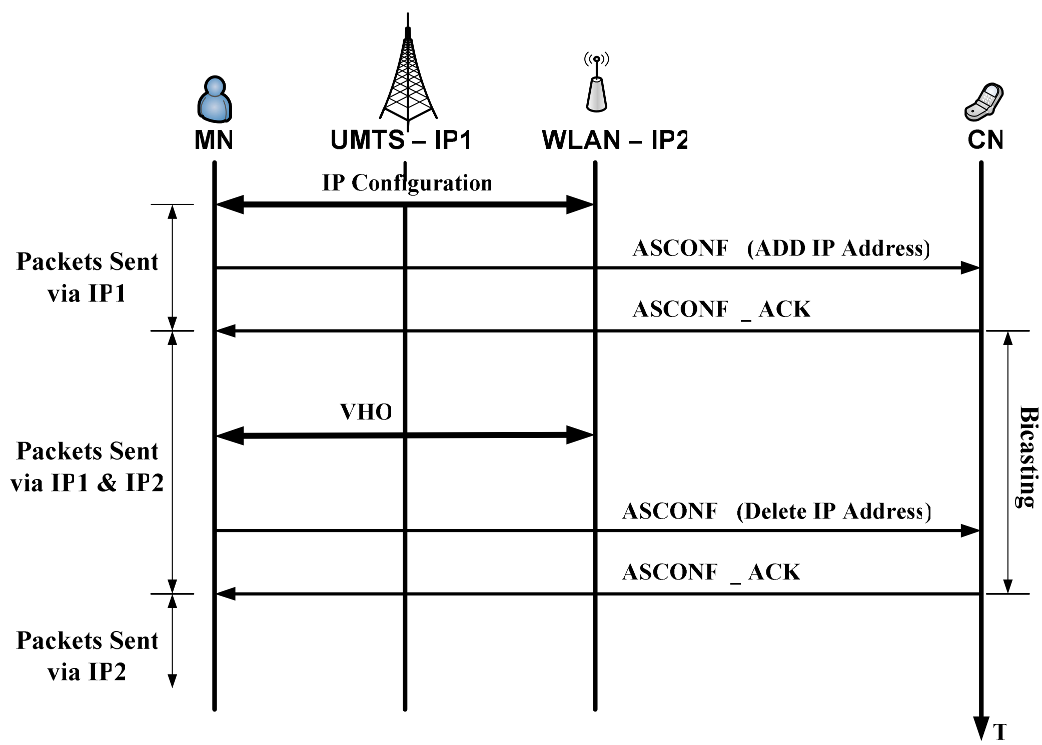


Figure 2. Procedure of Bi-mSCTP for VHO.

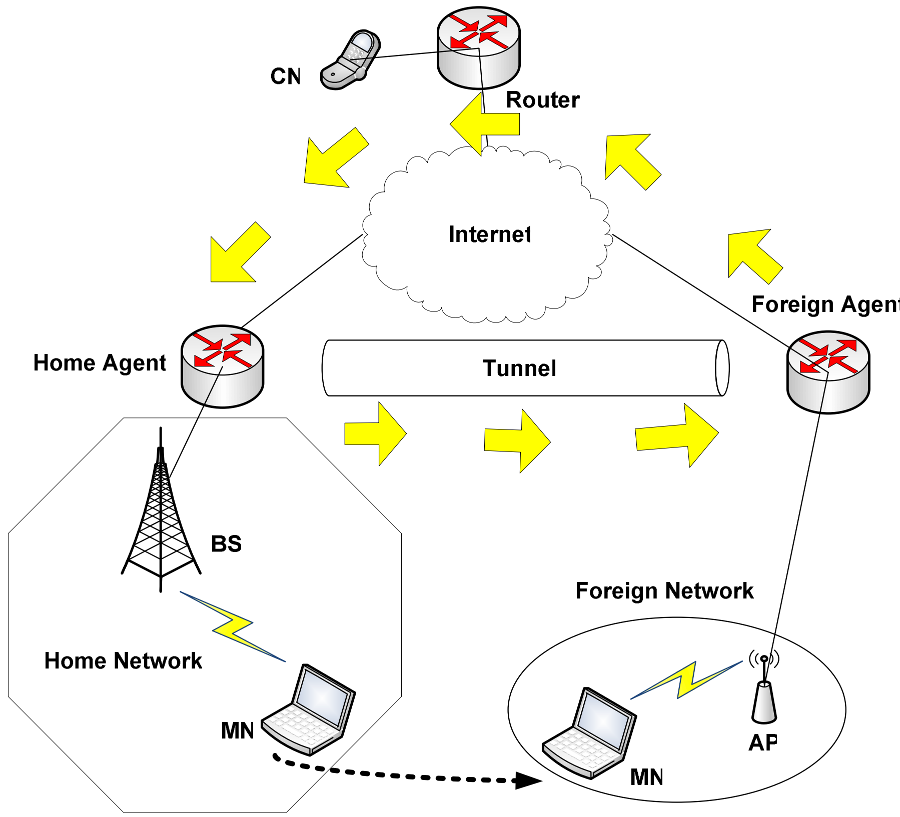


Figure 3. Components of MIP.

THE LIMITATION OF MOBILE IP (MIP)

Mobile IP (MIP) is virtually accepted as the internet standard for MNs although, it is yet to be widely deployed. MIP seeks to solve mobility issues at the IP network layer. The main components of MIP are the foreign agent (FA) and the home agent (HA) (Perkins, 1998) as shown in Figure 3.

The HA is located in the home network as a router capable of intercepting and encoding (encapsulating) transmitted data packets for the MN. The FA on the other hand, is a router of an MN located in a foreign network providing routing services to the MN upon successful registration. The FA decodes (decapsulates) and sends data packets tunnelled by the HA to the MN as shown in Figure 4 (Perkins, 1998; Ding et al., 2009).

When an MN moves into a new network such as a foreign network, it must get a new IP address compatible with the new network. In MIP, an MN can have two ADD IP addresses; a permanent home address (a fixed IP address allocated by its home network) as well as a care of address (CoA). A CoA is a temporal address assigned to the MN when it operates in a foreign network. When the MN is in the HA, it employs its home address to transmit or receive data packets. Moreover, when the MN travels away from its home network and enters a foreign network, it is allocated a CoA by the FA through the exchange of agent solicitation and advertisement massages also known as CoA discovery.

As soon as the MN discovers its CoA in the foreign agent, it transmits a registration request to its HA via its new network to inform the HA of the MN's new CoA (Ding et al., 2009). When the HA receives this request, it adds the necessary information to its routing table and sends a registration reply message back to the MN to approve the request (Sharma et al., 2004). This is referred to as the CoA registration. Once the registration process is successful, the HA intercepts any data packets transmitted with the MN's home address and tunnels them using its current CoA. The original packet can be decoded at the termination of the tunnel and forwarded to the MN. The whole procedure is shown in Figure 5.

There are a number of drawbacks in MIP. Every packet in the standard MIP incurs additional routing and packet overheads. This problem is especially an evident in applications used for transmitting relatively small and delay sensitive packets. A second issue in MIP is handover performance that is, the duration of the process. An unacceptable increase in the duration of the registration time can lead to more and more packets

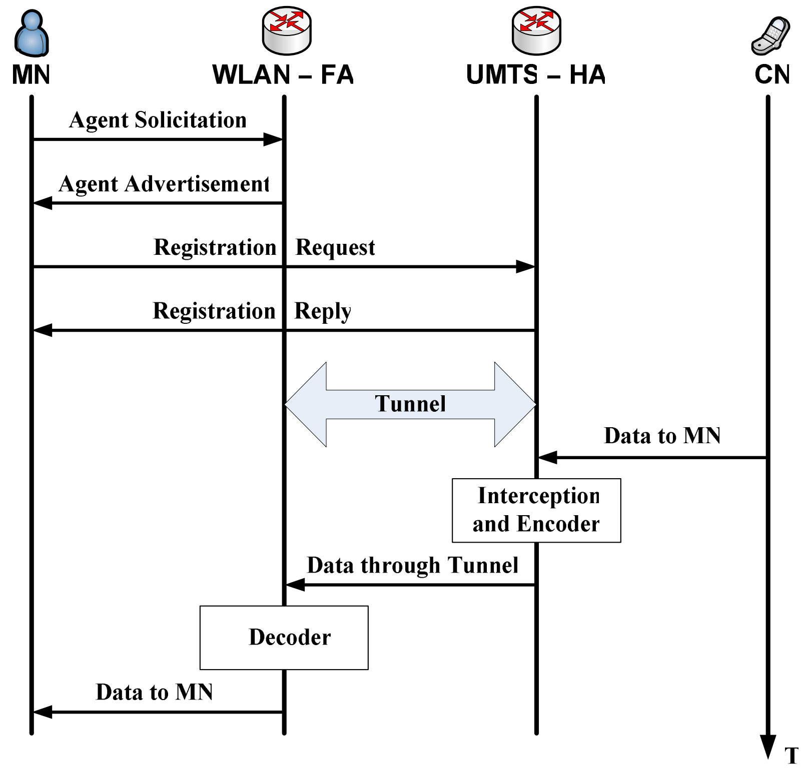


Figure 4. Mobility management using MIP.

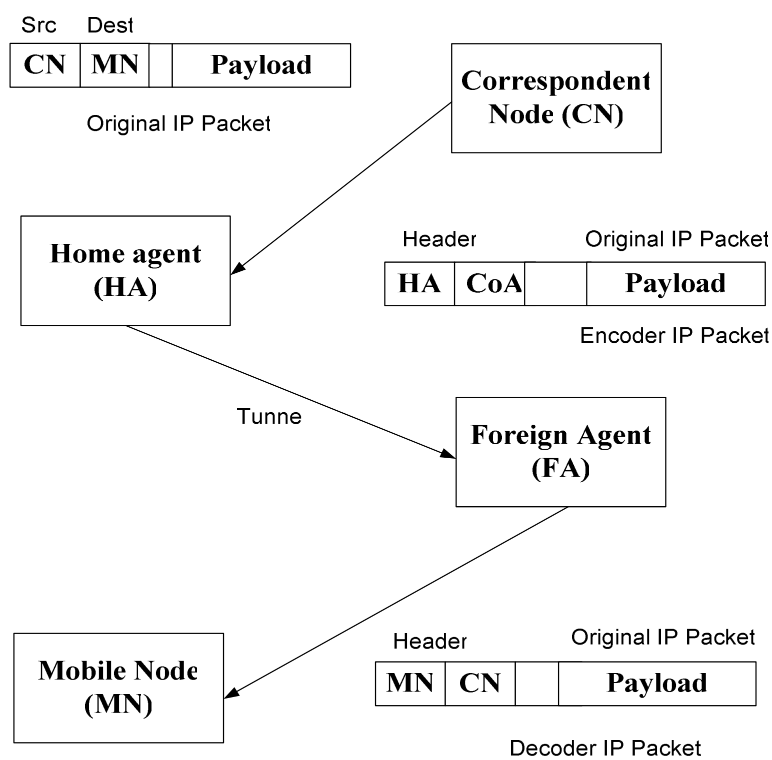


Figure 5. Procedure of data exchange between CN and MN via HA and FA.

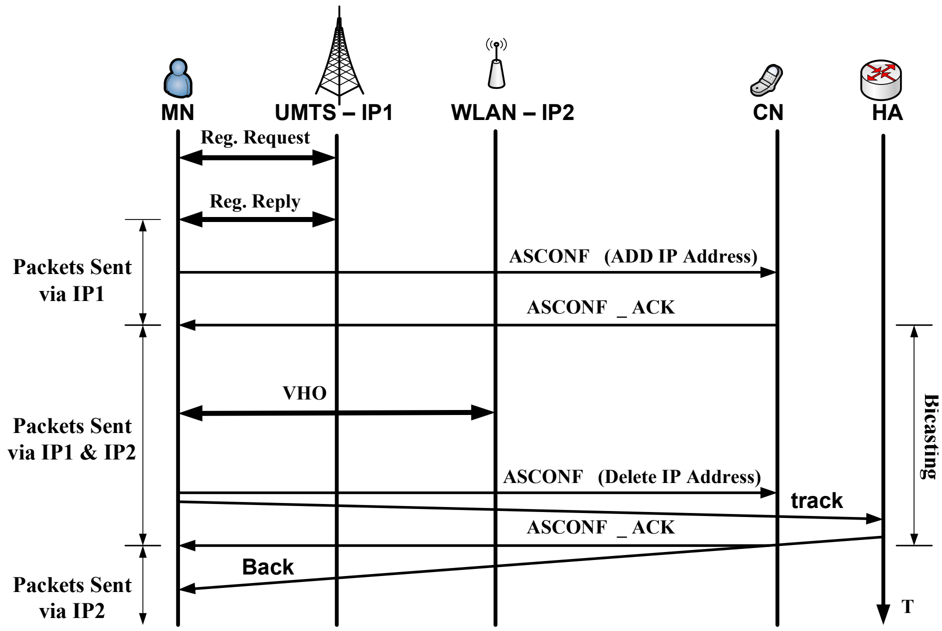


Figure 6. VHO procedure for the hybrid scheme.

being lost or reordered. On the other hand, the MIP approach provides some level of VHO support between UMTS and WLAN networks. Experiments have shown that it is difficult to keep the seamless continuity of data sessions over VHO due to the long latency. The aforementioned problems lead to data session disruption or degradation in the user experience during VHOs if MIP is used (Perkins, 1998; Sharma et al., 2004).

SEAMLESS VHO WITH THE HYBRID SCHEME OF BI-MSCTP FOR MIP

In this work, an integrated scheme employing mSCTP with bicasting or so-called Bi-mSCTP mechanism for MIP is proposed. It is proposed to overcome several MIP issues such as additional routing, time of registration, data session disruption and data packet overheads in the MN during VHO. The Bi-mSCTP mechanism relies on the generated signals to allocate a new CoA dynamically to the CN before the link layer handover. When the MN is in the region of VHO, it inserts a bicasting flag inside the ASCONF data chunk to inform the CN to start the transmission over both the WLAN and UMTS links.

Similarly, when the MN of the cellular UMTS moves to a new network such as a WLAN, it senses the signal strength of the new link and transmits a registration request to the access router of the old cellular UMTS network as shown in Figure 6. The old network then sends a registration reply message from its access router to the MN. Once this message is correctly received, the new CoA, which is allocated to the MN from the old access router will be employed in the new network. Thereafter, the MN will transmit an ASCONF data chunk to the CN. The CN then knows the new allocated CoA and adds a new IP by using the ASCONF transmitted from the MN. At this juncture, the CN commences the bicasting of data packets via both UMTS-IP1 and WLAN-IP2.

Henceforth, the MN transmits its individual data packets to the CN through either UMTS-IP1 or WLAN-IP2 depending on the quality of their links. In this way, the VHO delay is significantly minimized. The MN, upon receiving the ASCONF_ACK data chunk from the CN, adds a new CoA in the current association and sets it as the primary-IP address. The CN and MN then exchange data packets by using the new CoA since the registered primary-IP address is currently associated with the new network. This situation continues to persist until the MN completely leaves the WLAN-IP2 region.

When the MN senses the link down event for the UMTS-IP1, it seeks to move away from the coverage of the WLAN network. Thus, it transmits an ASCONF data chunk to the CN requesting to delete the old IP address in order to delete the old address of the WLAN. It then receives an ASCONF-ACK data chunk reply message from the CN to stop the bicasting procedure and delete the old CoA at the association address (that is, transmission over IP address of UMTS). Upon reception of this reply message, the CN and MN may only use the IP1 address for all future communication.

Moreover, the hybrid scheme uses the HA to

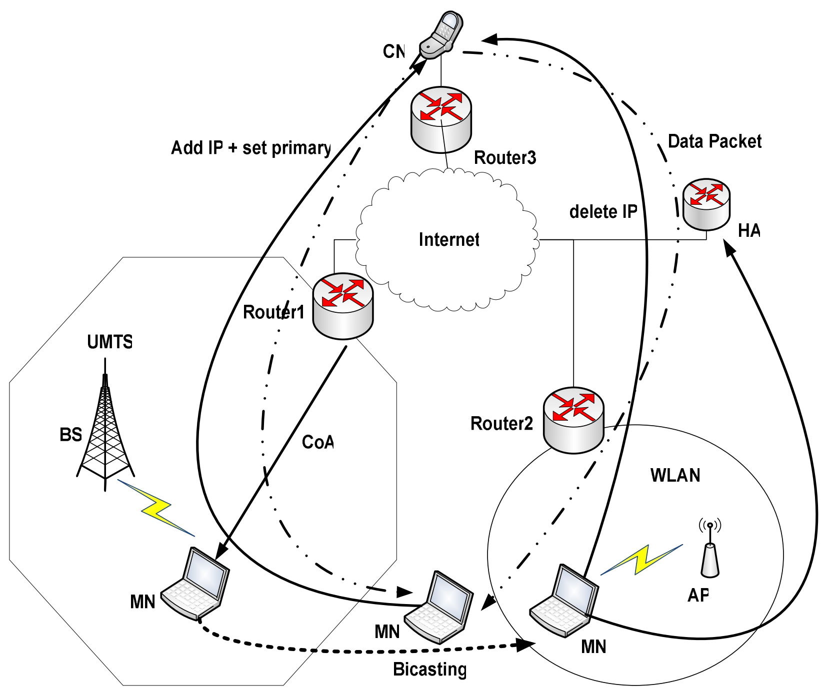


Figure 7. Schematic diagram of hybrid scheme of Bi-mSCTP scheme.

continuously track the location of the MN during the course of the bicasting under the MIP. Figure 7 shows a schematic diagram of how the MN is registered with the CN via its new CoA using DAR signals. In this way, the proposed scheme succeeds in discarding the use of a tunnel between the cellular UMTS and WLAN access routers. As a result, the delay due to the message exchanges in the tunnel is minimized. Similarly, it eliminates the routing-overheads due to buffering (Figure 7).

When a MN moves from the UMTS coverage area into the WLAN network as depicted in Figure 8, the VHO procedure occurs. Specifically, the MN of the UMTS network first scans to ensure that a WLAN network access within the vicinity is available. The cellular UMTS/BS periodically transmits a CoA advertisement for the outgoing MNs to WLAN networks to track the availability of the UMTS network.

When the MN detects the advertisement, it begins examining the received signal strength (RSS) to make the VHO decision. The MN first estimates the RSS from the WLAN access router and compares it with the UMTS network. If the RSS of the WLAN is found to be greater than the UMTS, then the VHO procedure is initiated. Otherwise, the MN maintains its connectivity with the UMTS network. The RSS of the UMTS will continue to get weaker as the MN moves away from the UMTS/BS towards the WLAN/AP. As the MN approaches the overlapping area of two networks, it informs the CN to start the bicasting of data packets via both UMTS-IP1 and WLAN-IP2 (Figure 8).

As the movement towards the WLAN network intensifies, the MN senses the high RSS of the new link and transmits a registration request to the access router of the cellular UMTS. It then assigns a new CoA from the old access router to the new WLAN-IP2 network. The WLAN HA then begins to track the location of the MN during the course of the Bi-mSCTP in MIP. Similarly, when the MN moves into the coverage area of the cellular UMTS, it begins a reverse VHO procedure. Figure 9 illustrates the whole VHO delay of the MNs when it roams between UMTS and the WLAN.

The whole VHO delay consists of three factors: delay of movement detection (T_{MD}), delay of IP address configuration (T_{AC}) and delay of exchanging all signals (T_{EX}) during VHO. The whole VHO delay ($T_{VHO\ Delay}$) (Koh and Hyun, 2008) can be computed as

$$T_{VHO\ Delay} = T_{MD} + T_{AC} + T_{EX} \quad (1)$$

In other words, T_{MD} is the delay that occurs between the start of the movement and the detection of the WLAN network by the MN. T_{AC} is the delay between the occurrence of the link layer signal and the configuration

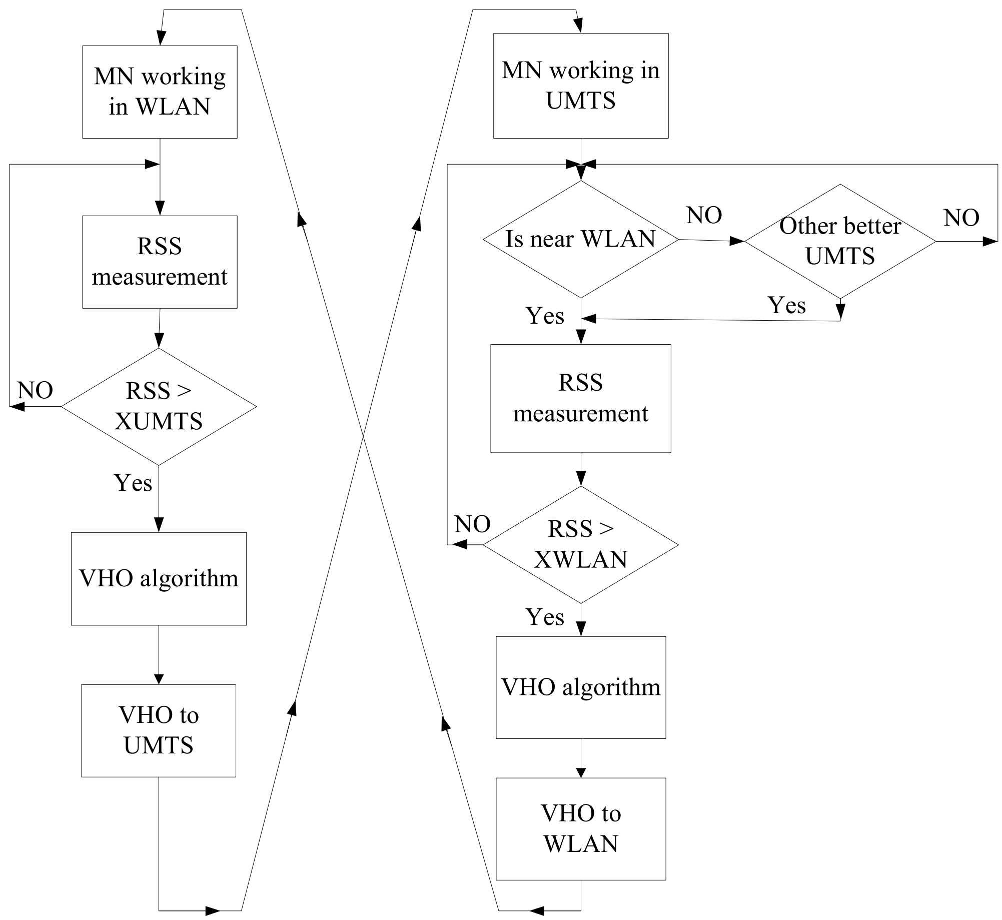


Figure 8. VHO mechanism between UMTS and WLAN.

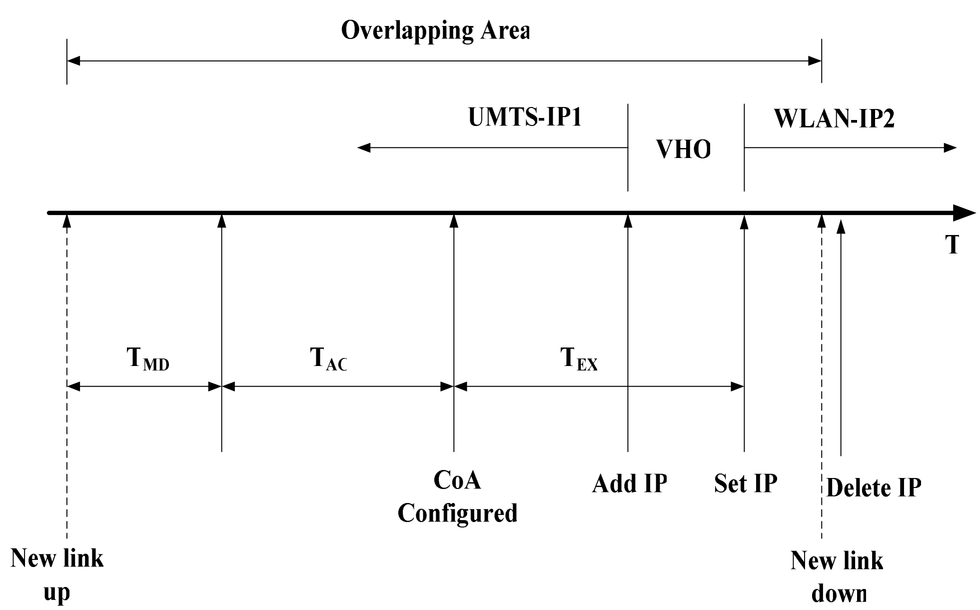


Figure 9. The VHO delay for Bi-mSCTP scheme in MIP.

of a new IP address for the MN. The T_{EX} represents the sum of two occurrence delays; the delay between the MN with HA registering the new CoA and the delay for the MN with CN to complete exchanging the ASCONF and ASCONF _ ACK data chunks during VHO. Since the hybrid scheme and the mSCTP uses the same DAR procedure, the VHO delay of the hybrid scheme is equal to that of the mSCTP as

$$T_{EX} = T_{mSCTP} \tag{2}$$

When the MN of the cellular UMTS moves to a new network such as a WLAN, it senses the RSS of the new link and transmits a registration request to the access router of the old cellular UMTS network as shown in Figure 6. The old network then sends a registration reply from its access router to the MN. This procedure can be represented by the following parameters; the period for router discovery, T_{rd} which comprises of the time for the router registration request, T_{rreq} , the time for the router registration reply, T_{rrep} during the moment of discovering the CoA from the old network, and the handling time to get a new IP address , $T_{new\text{-}IP}$ as

$$T_{rd} = T_{rreq} + T_{rrep} + T_{new\text{-}IP} \tag{3}$$

Once the MN acquires its new CoA, it transmits an ASCONF data chunk for add-IP to the CN. This informs the CN about the allocation of a new CoA to the MN through the DAR period, T_{DAR} where

$$T_{mSCTP} = T_{DAR} + T_{rd} \tag{4}$$

The DAR period, T_{DAR} can be given as

$$T_{DAR} = T_{add\text{-}IP} + T_{set\text{-}primary\text{-}IP} \tag{5}$$

where $T_{add\text{-}IP}$ and $T_{set\text{-}primary\text{-}IP}$ is known as the mSCTP add-IP time and the mSCTP set primary IP time respectively. Both $T_{add\text{-}IP}$ and $T_{set\text{-}primary\text{-}IP}$ have the same value which can be obtained from

$$T_{add\text{-}IP} = T_{set\text{-}primary\text{-}IP} = T_{ASCONF} + T_{ASCONF\text{-}ACK} \tag{6}$$

where T_{ASCONF} and $T_{ASCONF\text{-}ACK}$ denote the transmit delay of the mSCTP ASCONF chunk and the transmit delay of the mSCTP ASCONF-ACK chunk respectively. In other words, the $T_{add\text{-}IP}$ and $T_{set\text{-}primary\text{-}IP}$ represent the time it takes for the CN to return an ASCONF-ACK chunk after the MN informs it to add a new IP address.

Corresponding to Equations 2 and 4, the VHO delay, T_{EX} of the hybrid scheme can be expressed as

$$\begin{aligned} T_{EX} &= (T_{rreq} + T_{rrep} + T_{new\text{-}IP}) + (T_{add\text{-}IP} + T_{set\text{-}primary\text{-}IP}) \\ &= (T_{rreq} + T_{rrep} + T_{new\text{-}IP}) + 2 * (T_{ASCONF} + T_{ASCONF\text{-}ACK}) \end{aligned} \tag{7}$$

For the VHO that occurs when the MN moves from the cellular UMTS network to a new WLAN network, the VHO delay comprises of two parts; the time period for router discovery, T_{rd} and the round transmission time (RTT) of the ASCONF chunk between the MN and the CN, T_{DAR} . Theoretically, the router discovery time can be ignored because of the multihome feature of mSCTP and bicasting mechanism. Thus, the VHO delay, T_{EX} seriously depends on the ASCONF chunks between MN and CN as given by

$$T_{EX} \approx (T_{ASCONF} + T_{ASCONF\text{-}ACK}) \approx \left[\frac{\text{ASCONF Data Chunk Size}}{BW + \frac{d}{s}} \right] \tag{8}$$

where

$$(T_{rreq} + T_{rrep} + T_{new\text{-}IP}) << 2 * (T_{ASCONF} + T_{ASCONF\text{-}ACK}) \tag{9}$$

The (d/s) represent the propagation delay where d is the distance between MN and CN, and s is the wave propagation speed.

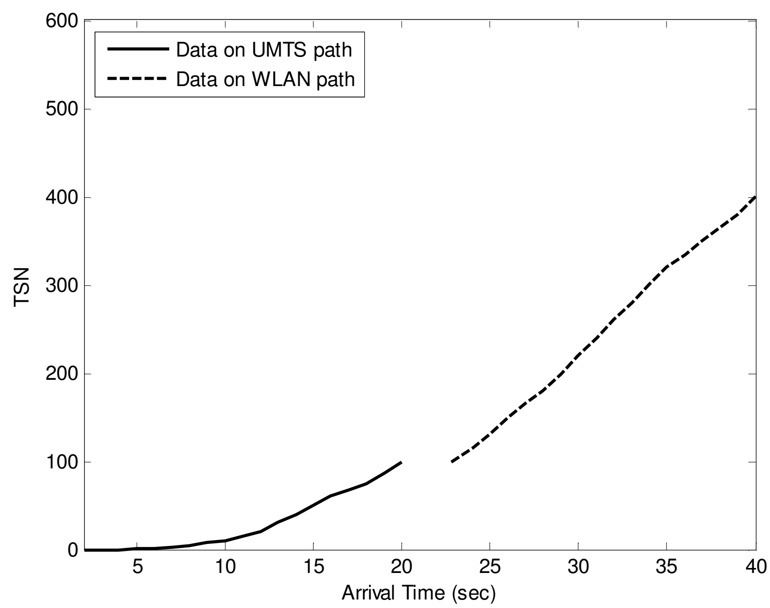
PERFORMANCE OF HYBRID SCHEME OVER VHO IN MIP

This presents the performance analysis of the hybrid of Bi-mSCTP scheme. The performance is simulated using an ns-2 network simulator version 2.29 (Heidemann, 2000). The SCTP module for our simulation is taken from the University of Delaware (Armando, 2002). In addition, the following parameters listed in Table 1 are configured in the proposed scheme for VHO in MIP.

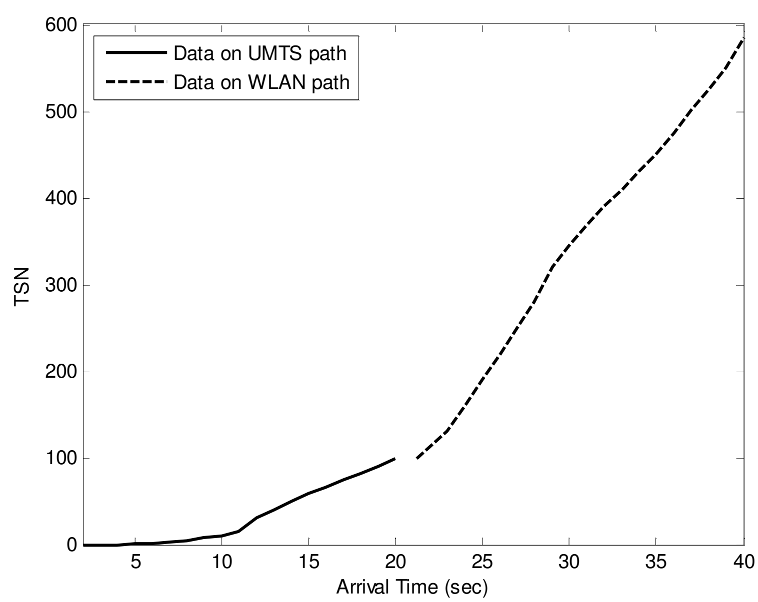
An important assumption is that the MN is multihomed while the CN uses bicasting mechanism. The MN, initially

Table 1. Network parameters.

Network parameter	UMTS	WLAN
Bandwidth	384 Kbps	10 Mbps
Transmission delay	25 ms	15 ms
Speed of MN	20 m/s	20 m/s
Wireless network coverage	radius 2000 m	radius 100 m
Fixed links between CN	10 Mbps	10 Mbps
RRS	-50 dBm	-70 dBm



(a)



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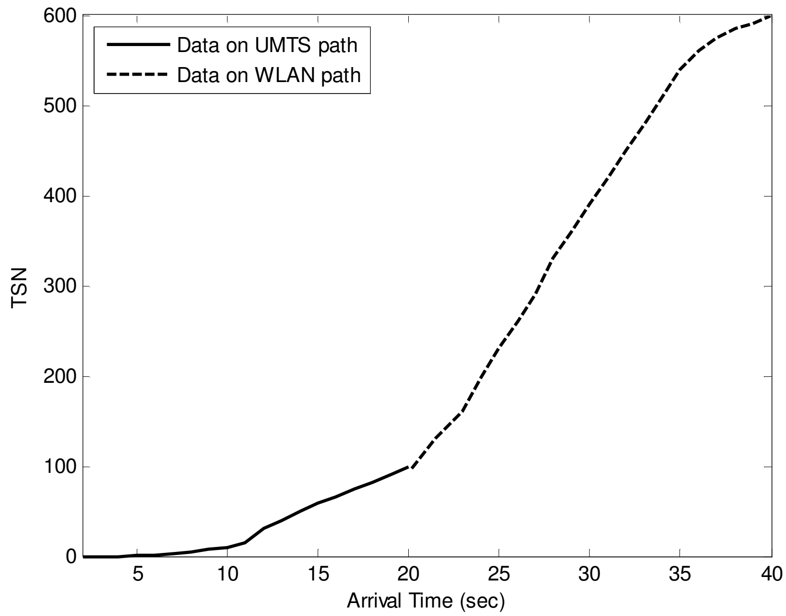


(c)

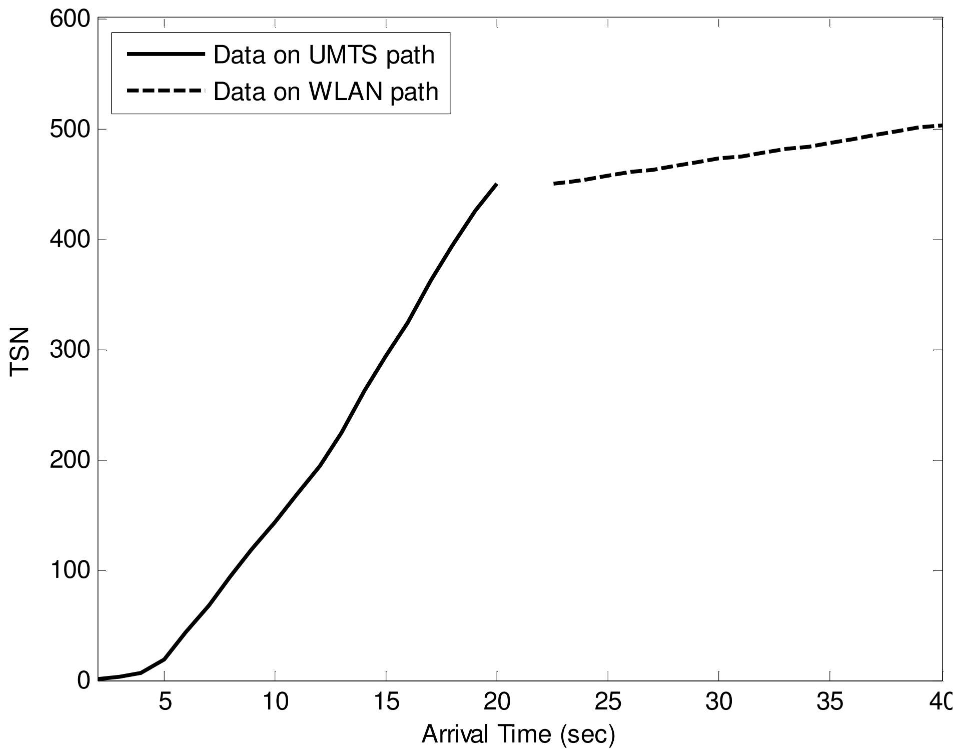
Figure 10. Delay performance when a MN moves away from the UMTS network under (a) MIP, (b) mSCTP and (c) proposed schemes.

located in the centre of a cellular UMTS network, starts moving towards the WLAN network at a speed of 20 m/s when t = 15 s. There exists a region where both the cellular UMTS and the WLAN networks overlap. The MN enters the WLAN network at t = 18 s, and leaves the cellular UMTS network at t = 21 s. Data transfer begins at t = 5 s, and the MN starts the VHO procedure at t = 20 s, when it reaches the mid-point between the BS of cellular UMTS network and the access router of WLAN network. The MN ensures an mSCTP connection by means of an FTP application, where the data packets are sent from the FTP server (CN) to the MN. The agent advertisement messages are broadcasted every 1 s, and the reset time of the monitoring link and connection timers is 0.5 s.

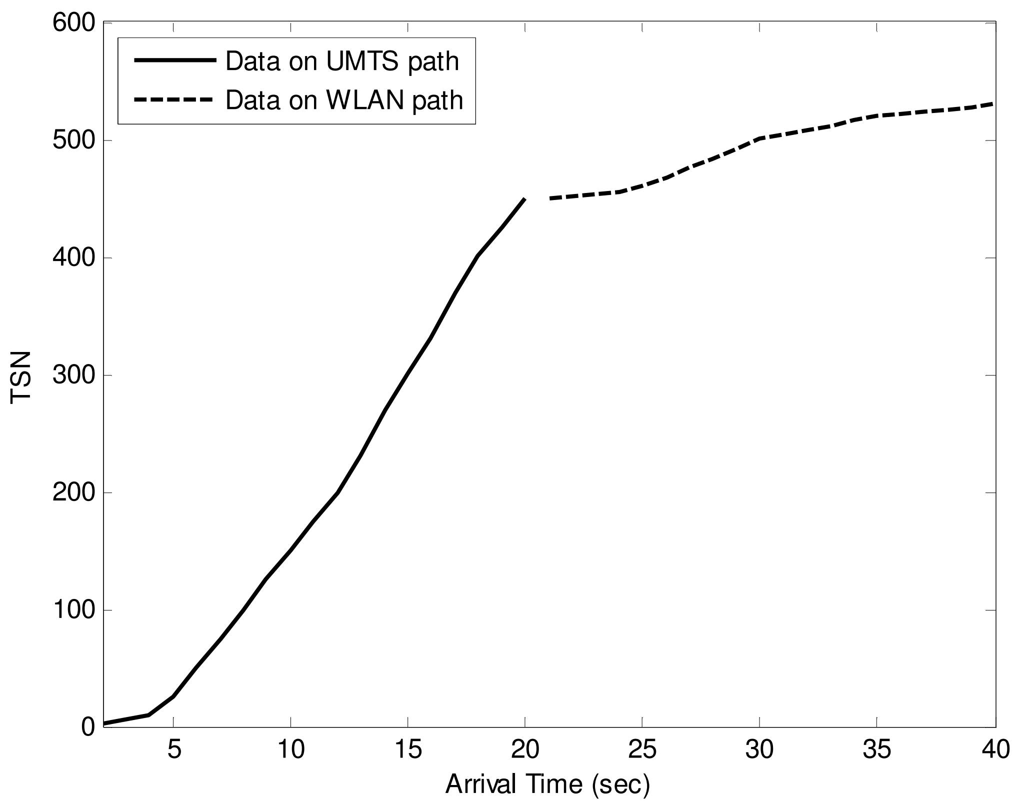
Figure 10 illustrates the VHO delay when an MN moves from cellular UMTS to WLAN under both MIP and mSCTP compared with the proposed scheme. The x-axis represents the arrival time of data chunks in seconds while the y-axis represents the transmission sequence number (TSN) of data chunks. The delay in the VHO is the time interval between the reception of the first packet of data chunk via the new path of WLAN by MN and the reception of the last packet of data chunk via the old path of cellular UMTS. In other words, the VHO delay, when MN moves away from cellular UMTS, is the period between the moment when MN receives the last packet using cellular UMTS and the moment when it receives the first packet using WLAN.

As shown in Figure 10, the MN initially receives data chunks from the CN via the old path of cellular UMTS. When the MN moves away from the cellular UMTS network coverage area into the WLAN network, the VHO occurs at 20 s. The VHO delay of the MIP as shown in Figure 10(a) is very high about 2.79 s due to the router-overheads and registration time. Referring to Figures 10(b) and (a), the VHO delay of mSCTP is lower than that of MIP because the mSCTP does not need any additional routing and registration time. In comparison with MIP, the mSCTP improves the VHO delay by 2.34-fold. From Figure 10(c), the MN receives the last packet using the old path before VHO at time 20 s, while at 20.15 s, it receives the first packet using the new path after VHO. Therefore, the VHO delay is just 20.15 - 20 = 0.15 s in this case. This is because the proposed scheme succeeded in discarding the use of a tunnel between cellular UMTS access router and that of WLAN. Moreover, from Figure 10(c), the MN maintains its connection as active while migrating from the coverage of cellular UMTS to WLAN network, since the CN can simultaneously send the same data packets to MN over both UMTS-IP1 and WLAN-IP2 networks during the process of handover. In this way, the proposed scheme reduces the excessive VHO delay suffered by both mSCTP and MIP schemes.

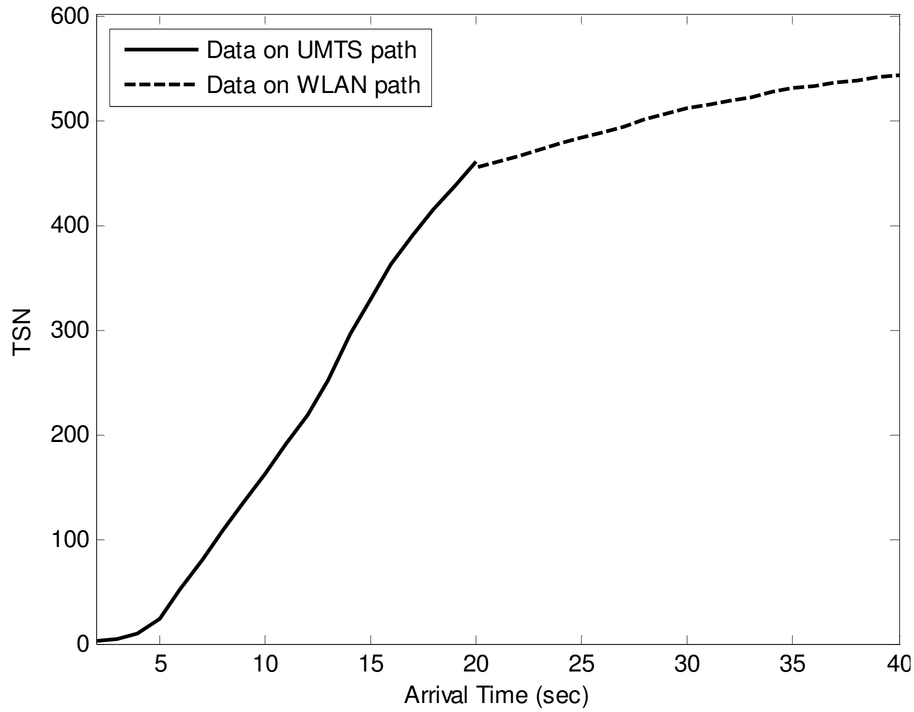
The sequence of the data packets received by MN


Data on UMTS path
Data on WLAN path
TSN
Arrival Time (sec)
0
100
200
300
400
500
600
5
10
15
20
25
30
35
40

(a)


Data on UMTS path
Data on WLAN path
TSN
Arrival Time (sec)
0
100
200
300
400
500
600
5
10
15
20
25
30
35
40

(b)



(c)

Figure 11. Delay performance when an MN moves away from a WLAN network in (a) MIP, (b) mSCTP and (c) proposed schemes.

when it migrates from the coverage of WLAN to cellular UMTS network in the proposed scheme, in both mSCTP and MIP are shown in Figure 11. From Figures 11(a) and (b), the VHO delay for both MIP and mSCTP schemes are 2.538 and 1.124 s respectively; while the proposed scheme avoided the VHO delay in both mSCTP and MIP schemes as shown in Figure 11(c). This is because the message exchanges were carried out without the use of a tunnel.

The throughput versus packet loss rate performance of the proposed scheme was compared with both mSCTP and MIP as shown in Figures 12 and 13 respectively. The abscissa denotes the packet loss rate while the ordinate denotes throughput. The total number of the lost packets during VHO period, which is also known as packet loss rate, depends on the VHO delay.

Figure 12 explains throughput versus the packet loss rate of the proposed scheme compared to both mSCTP and MIP at 100 ms delay. From the Figure, the proposed scheme realizes a clear enhancement in throughput at very low packet loss rate during VHO. This enhancement can be attributed to the fact that the proposed scheme has the ability to instruct MN to transmit the data packets to the CN using either IP1 of cellular UMTS or IP2 of WLAN during the period of the overlap, while the CN can send data packets to MN over both UMTS-IP1 and WLAN-IP2.

Figure 13 demonstrates the performance of the proposed scheme compared to both mSCTP and MIP at 200 ms delay. It can be seen that the proposed scheme achieved a higher throughput with a reduction in packet loss compared to both mSCTP and MIP schemes. Similarly, it provides a greater enhancement than MIP as the delay is increased as shown in Figures 12 and 13.

From Figure 12, the proposed scheme gains about 36.4 and 48.1% improvement in the packet loss rate compared to both mSCTP and MIP respectively. Similarly, at 200 ms delay, it reduced the packet loss rate by more than 21.7 and 45% compared to both mSCTP and MIP respectively as shown in Figure 13. Moreover, having successfully omitted the use of a tunnel in the proposed scheme, the existing router overheads in the MIP during VHO have been nullified.

CONCLUSION

To overcome the problem of the high VHO delay in the MIP, a hybrid scheme of a Bi-mSCTP mechanism under an MIP has been proposed in this paper. The proposed

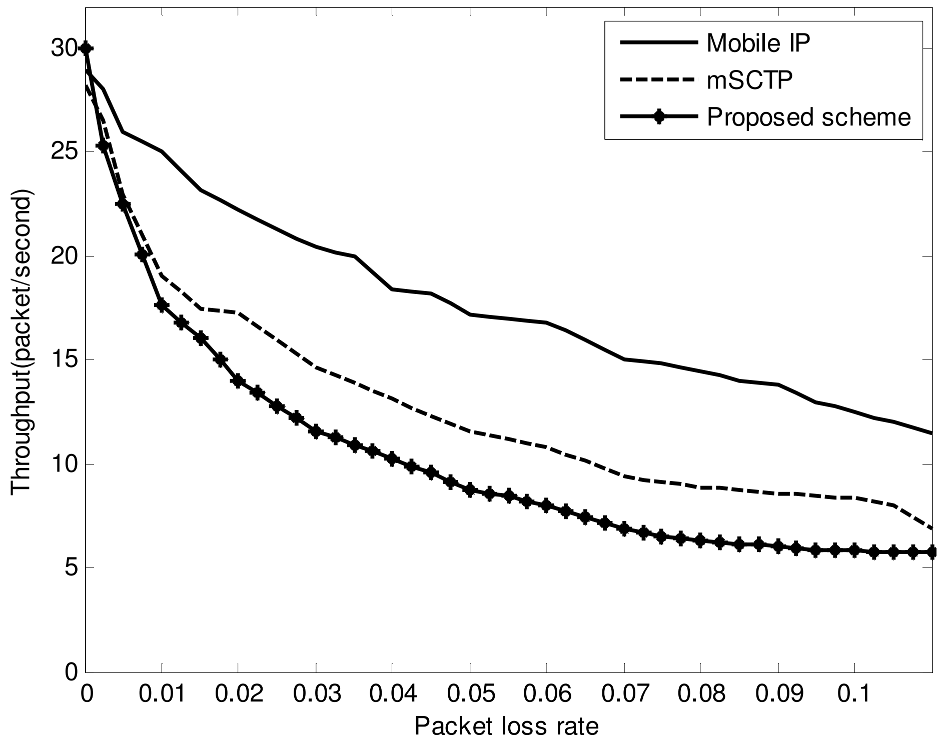


Figure 12. Comparison of throughput vs. packet loss rate of the proposed scheme, mSCTP and MIP at delay = 100 ms.

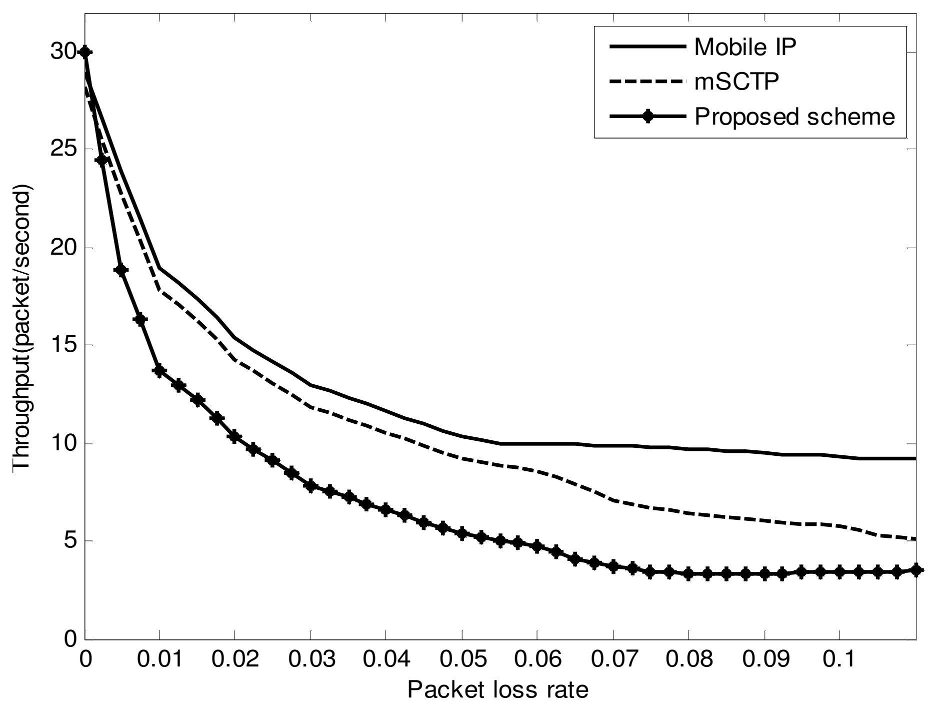


Figure 13. Comparison of throughput vs. packet loss rate of the proposed scheme, mSCTP, and MIP at delay = 200 ms.

scheme can be used to reduce the possible VHO delay and packet losses suffered by mSCTP and MIP, occurring during the period when the MN approaches the region of overlap of the WLAN and cellular UMTS networks during handover. The proposed scheme does not require any additional forwarding like FA, tunnal or buffering operation which incur additional overheads. In particular, it can be employed more successfully for MNs with a random movement in the overlapping region. The proposed scheme was also compared with both mSCTP and MIP in terms of throughput vs. packet loss rate for different delay scenarios. Consequently, the proposed scheme was found to optimize throughput with a very low packet loss rate when a VHO between cellular UMTS and WLAN networks occurs. Finally, the simulations results proved that the proposed scheme introduces approximately 1.04 and 2.64 s reduction in the delay performance over both mSCTP and MIP schemes respectively. In addition, it gains about 36.4 and 48.1% improvement in packet loss rate compared to both mSCTP and MIP respectively.

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