# Network Load and Packet Loss Optimization During Handoff Using Multi-Scan Approach

Anwar Saif and Mohamed Othman
Deptartment of Communication Technology and Network, Universiti Putra Malaysia, Malaysia

**Abstract:** *Handoff is a critical function that enables mobile nodes to stay connected to the wireless network by switching the data connection from one WLAN to another. During handoff the communication may be degraded or interrupted due to the high packets loss. To prevent packet loss during handoff, a handoff management scheme that employs a transport protocol has been proposed. It supports multiple connections for Voice Over IP communication and makes handoff decision based on the number of frame retransmission on the MAC layer. Moreover, the handoff scheme uses the multi-scan technique that enables mobile nodes to use two WLAN interfaces for channel scanning and multi-path transmission rather than single WLAN interface. This technique introduces extra network overhead during multi-path transmission. This work optimizes the network overhead and packet loss and keeps VoIP communication at an acceptable level.*

**Keywords:** *Handoff, network overhead, packet loss, multi-scan, VoIP, and WLAN.*

*Received October 5, 2008; accepted May 17, 2010*

## 1. Introduction

The handoff is defined as the processes required for transferring the physical layer connectivity of a Mobile Node (MN) from one access point AP to another. In addition to physical connectivity it may also require transfer of some state information with respect to this MN. The IEEE 802.11 Wireless LANs (WLANs) standards call this physical connectivity as the association of an MN with the AP [2].

When an MN operating in infrastructure mode has already associated with a WLAN AP in a distribution system and starts moving away from the parent AP (Old-AP), the wireless link quality between the MN and the old-AP starts to depreciate and at some point falls below threshold, which in turn initiates the handoff process. At this stage the MN starts to search for other APs to attach to by undergoing a scanning process. Once the MN finishes scanning, it sorts out the scan results, selects an appropriate AP to attach to, and then MN authenticates and re-associates with the selected AP.

One of the critical issues for mobile Internet applications is the WLAN handoff that involves a number of link-layer and/or network-layer procedures which introduce packet delay and loss. Existing research on handoff can be classified into studies of layers 2 and 3 handoffs. Layer 2 handoff refers to the handoff that occurs when MN moves in the same type of networks, such as a Cellular Network or a WLAN consisting of one IP subnet. On the other hand, layer 3 handoff refers to handoff that occurs when MN moves within different networks/sub-networks with different IPs.

Handoff in WLANs has been addressed by many researchers, the main goal was to have seamless handoff by keeping delay, packet loss and jitter at acceptable levels to suit time sensitive applications such as VoIP. Layer 2 handoff schemes try to minimize the packet loss and delay on the MAC. Layer 3 handoff schemes try to come up with end-to-end handoff management schemes by changing the network infrastructure.

The handoff phenomenon has been addressed throughout two main directions. One of them manages the aspects that are related to minimizing the packet loss and packet delay in both types of handoff, layer 2 and layer 3 handoffs, whereas the second addresses the handoff criteria and the time when the handoff process should be triggered. Upper layer handoff managements rely on the end-to-end management schemes that introduce new hardware for managing the MN connectivity. Whereas, lower layer approaches have different philosophy, they are trying to minimize the amount of time needed to perform the handoff. Both approaches require changing in the WLAN architecture either in the hardware, firmware, or in the software.

The handoff management scheme [5] came up with a promising approach that uses the cross layer [12], multi-scan [1] along with the frame retransmission as a handoff trigging criterion. This approach eliminates the communication interruption, reduces packet loss, and keeps VoIP communication requirements at acceptable levels, as shown in Table 1. However it introduces an extra network overhead during handoff due to the transmission of the same packet via both interfaces (multi-path transmission).

Table 1. Required communication quality for VoIP [11].

| Quality | Good | Average | Poor |
|---|---|---|---|
| Delay (ms) | <150 | 150 -400 | >400 |
| Jitter (ms) | <20 | 20-50 | >50 |
| Packet loss % | <1 | 1-3 | >3 |

Although, employing the number of frame retransmission as a handoff criterion gives an early indicator about the handoff, some indicators may be faulty indicators that might be caused by changing in the wireless condition due to the barriers and other interferences and not from the handoff process. This faulty indicator leads to switching to multi-path transmission causing extra network load and packet loss.

In this work we are trying to answer the following question, is it possible to optimize the network overhead and packet loss during handoff by control the handoff triggers and perform the multi-path transmission based on a real handoff indicators?

For achieving our goal we have controlled the switching from single path transmission to multi-path transmission by introducing an instability threshold that ensures switching to multi-path when it is really needed.

## 2. Related Works

Handoff management scheme has been classified into two approaches: layers 2 and 3 handoff management approaches. These two approaches try to address the problem from different views. Layer 2 tries to solve the problem by examining the MAC layer behaviour without introducing new components, whereas the other approach tries to solve the problem by introducing new hardware that manages the handoff process at the transport level.

### 2.1. Layer 3 Handoff Management

Perkins C., Ed [9], and Johnson D. *et al.* [4] have proposed MIP handoff management schemes for IPv4 and IPv6 respectively. Handoff management using MIP is achieved by adding additional network facilities such as Home Agent (HA) or Foreign Agent (FA) to the network in order to support location management of the MNs. The handoff process using MIP is executed according to the following steps:

- Channel scan to search for a new AP.
- Association with the new AP.
- Acquisition of an IP in the new WLAN.
- Binding update to the HA and the CN.

However, in an MIP network an MN detects its movement by means of Router Advertisement (RA) packets. RA packet broadcasting infrequency increases the handoff decision delay period, thus causing communication quality to be degraded. Enhanced MIP protocols schemes such as Fast Mobile IP (FMIP) [6] and Hierarchical Mobile IP (HMIP) [14], have been proposed to improve the communication performance during handoff, but both of them did not examine the criteria for handoff. Moreover, these approaches are difficult to be deployed in WLANs that are administered by different organizations.

Handoff management should be achieved only on mobile nodes whenever possible, without setting up new facilities in networks, because WLANs have already spread and to avoid additional network cost.

An extension of the Stream Control Transmission Protocol (SCTP) called the mobile Stream Control Transmission Protocol (mSCTP) [10], has been proposed for achieving handoff only by end-to-end control. The mSCTP can handle more than one wireless interfaces which can be used to acquire a new IP from the new subnet then informs the Corresponding Node (CN) about the new IP. This post detection of new IP address enables the communication to continue without any network facilities.

### 2.2. Layer 2 Handoff Management

Mishra *et al.* [8] have investigated the delay of a WLAN handoff in a layer 2 and indicated that channel probe contributes a significant portion of the handoff delay (about 50-400ms). They suggested an MN to remember the visited APs and to construct a neighbor relationship graph of these APs. Hence, an MN knows the information of the neighbouring channels, unnecessary scans during a handoff can be avoided.

Brik *et al.* [1] proposed a new mechanism called Multi-scan in which an MN installs two radio interfaces. Thus, the MN can perform WLAN scan by using the secondary radio interface without influencing the communications with the current AP which is already connected to the first interface. This approach can eliminate the scan delay but it does not address the handoff between different IP subnets.

DualMAC [13], uses time division duplex concept to scan for a new AP using only one interface with two MAC addresses. This approach reduces the packet loss but increases the packet delay and does not address the handoff between different IP subnets.

Although a handoff decision criterion plays an important role in avoiding the performance degradation of applications during the handoff, yet it remains unanswered.

Wireless signal strength is one of the fundamental criteria that give an indication about the communication quality, unfortunately signal strength may fluctuate due to distance and barriers that are located between MN and AP, furthermore Receiving Signal Strength Indicator (RSSI) is varying form one vendor to another. K. Medepalli [7] proposed Jitter, and RTT as handoff criteria, but jitter and RTT are changing dynamically due to various factors such as congestion in wired network so they do not give an appropriate decision when the handoff should occur.

In our work, we employed the management scheme proposed by shagiru [5], that employs Multi-scan and Cross-layer approaches, and uses the number of frame retransmission in the MAC layer as a measure for the quality of the communication and though as a handoff criterion decision. If the retransmission of a frame in the MAC layer exceeded certain threshold, the HM transmits the frames via both interfaces. The multi-path transmission continues until one of the channels becoming more stable then it switch to single path transmission using the most stable interface. This approach supports end-to-end mobility and gives a good early indictor of handoff occurrence. We have also introduced the instability threshold that examines the handoff criterion during single path transmission and triggers the handoff processes based on a real handoff indicators.

## 3. The Handoff Manager Architecture

The soul of the design is to use the frame retransmission of the MAC layer as a measure for the wireless link quality, based on that HM can predict the handoff before it really happens.

Other two techniques are employed, Multi-Scan and Cross layer. Using the Multi-Scan approach, MN will be able to connect to two APs simultaneously using two interface cards. In addition, cross-layer approach enables the transport layer HM to obtain information about frame retransmission form the MAC layer, Figure 1. Based on the MAC information about the number of frame retransmission, the handoff manager will decide either to send the packets via the single path transmission using single interface or the multi-path transmission using the two interfaces.

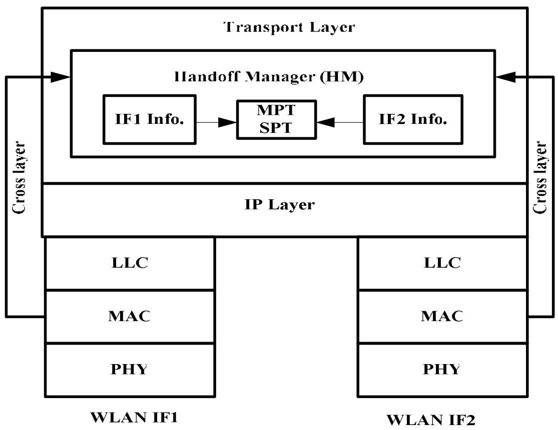


Figure 1. The handoff manager architecture [11].

## 4. The Framework

The work has been classified into two parts, the first part deals with the investigation of the network conditions during the single path transmission, whereas the other investigates the wireless conditions during the multi-path transmission Figure 2.

During the single path transmission the HM keeps monitoring the link state by examining the number of frame retransmission in the MAC layer and compares it with a pre-defined Multi-Path Threshold (MPT). The more closely the two values indicate a bad link condition and switching to multi-path has to occur. Instability threshold also introduced to control the faulty handoff indicators due to barriers and other wireless network interferences.

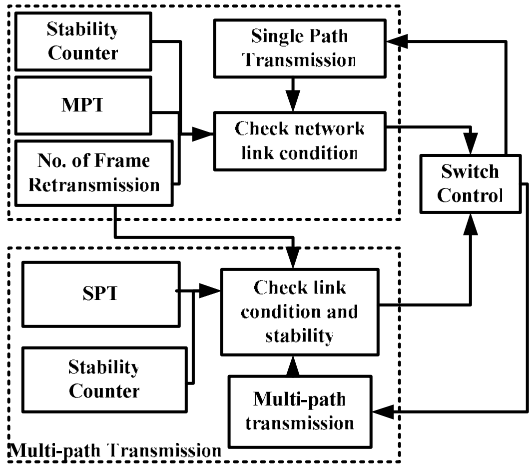


Figure 2. The HM framework.

During the multi-path transmission we followed the same algorithm proposed by [5] where both links are investigated based on the number of frame retransmissions. Single Path Threshold (SPT), and stability counter are used as a control parameters. In this case the link with the good condition will be used for next single path transmission phase.

## 5. The Handoff Manager Algorithms

As we have discussed, the handoff manager employs two parts single path transmission and multi-path transmission. Each of them has its own algorithm.

### 5.1. Single Path Algorithm

During the single-path transmission the MN communicates with the Corresponding Node (CN) through InterFace one (IF1). While communicating, the MN investigates the wireless link condition by examining the number of frame retransmission on the MAC layer of IF1 (Ret_IF1). If Ret_IF1 exceeds Multi-Path Threshold (MPT), the threshold for switching to multi-path transmission, which means HM detects deterioration in the wireless link condition of IF1. Therefore, InterFace two (IF2) has to be used to prevent packet loss and to investigate the condition of the alternative WLAN (Multi-path) [5].

The InStability Counter (ISC) operates only in the single path transmission mode. When the number of data frame retransmissions from the MAC layer on the interface meets the threshold, it means that the sender can send the packet from the frist attempt. The HM increases ISC by one, otherwise the HM resets ISC to zero because it concludes that the wireless link is still in a good condition and the sudden change might be caused by external source. When ISC exceeds the instability threshold (INS_THR), the HM judges that the WLAN connected to this interface is not stable and the handoff process has to start. Switching to multi-path transmission becomes necessary in order to prevent more packet loss, Figure 3.

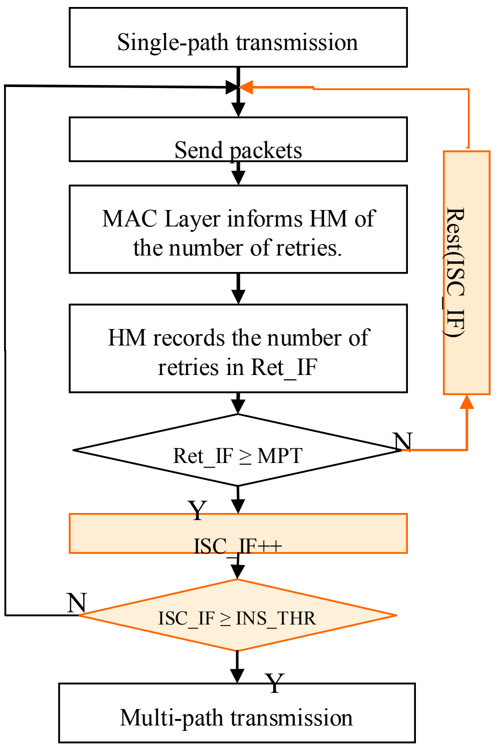


Figure 3. Single-path to multi-path transmissions.

## 5.2. Multi-Path Algorithm

During multi-path the MN sends the same data packets to the CN through both WLANs, so the network load doubles. Therefore, an operation is needed through which to return to single-path transmission as quickly as possible. Figure 4 shows the switching algorithm from the multi-path to the single-path transmission.

The number of data frame retransmissions that a packet experiences is used as a criterion for switching between single-path and multi-path modes. However, the wireless link condition usually fluctuates, so that a packet can experience retransmissions even when handoff is not needed yet. The wireless condition should be estimated by more than one packet.

To measure the stability of the wireless link condition, HM introduces a Stability Counter (SC) for each WLAN interface (SC_IF1, SC_IF2) and with the Single-Path Threshold (SPT), a threshold for returning to the single-path transmission. The SC operates only in the multi-path transmission mode. When the number of data frame retransmissions from the MAC layer on IF2 is zero which means that the sender receives an ACK frame for the sent data frame without any retransmission, the HM increases SC_IF2 by one; otherwise the HM resets SC_IF2 to zero because it concludes that the wireless link condition is not stable. When SC_IF2 exceeds the SPT, the HM judges that the WLAN connected with IF2 is stable and returns to the single-path transmission through IF2. The HM thus searches for a WLAN having good condition, and prevents packet losses while properly switching between single-path and multi-path transmission during handoff.

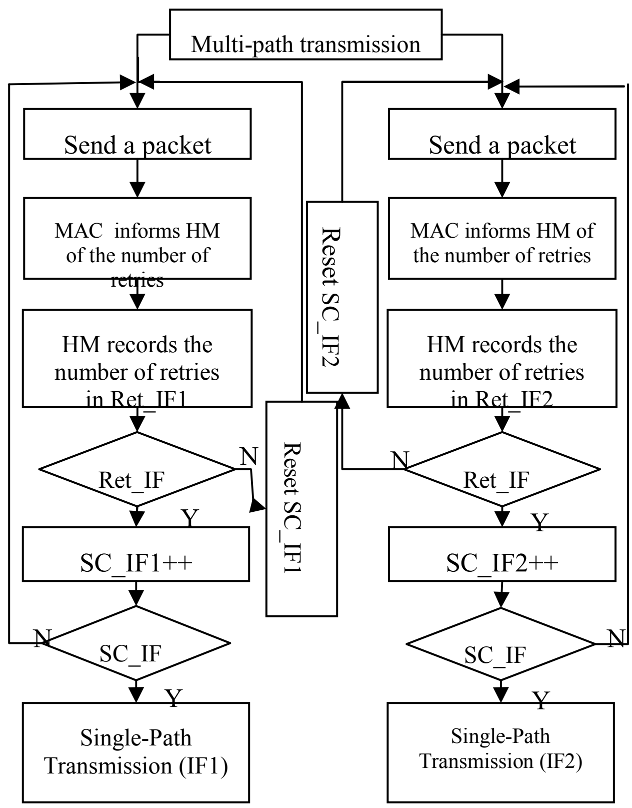


Figure 4. Multi-paths to single path transmission [5].

## 6. Simulation Experiments

During this experiment we have tried to demonstrate the effectiveness of our algorithm in optimizing the packet loss and network over head due to multi-path transmission. The experiment is carried out using NS2 Simulator version 2.27 [15]. We have examined the affect of the MPT, and ISC on the packet loss and network overhead. Two experiments have been carried out one to show network load and packet loss during the handoff using the original algorithm, and the second one to optimize the results by introducing the instability counter.

## 6.1. Simulation Model

Figure 5 shows the simulation model for our experiment, the model consists of two APs forming a two overlapped IEEE 802.11b wireless LANs, WLAN(A) and WLAN(B). The two APs and Corresponding Nodes (CN) are connected through routers R0, R1 and R2. Ten Mobile Nodes (MN) in the WLAN(A) are performing VoIP communication with their CNs with a packet size of 200 bytes encoded using G.711 voice codec and a packet interval of 20ms. The retry limit of 7 is used since the packet size is smaller than the RTS threshold (2347). The one way delay to the CN from WLAN(A) is set to 35 ms while that for WLAN(B) is set to 10 ms. The distance between the two APs is set to 30m. One of these MNs, MN(1) is equipped with two interfaces IF1 and IF2. This node will start moving from WLAN(A) to WLAN(B) at a speed of 4km/h while performing VoIP communication with it's corresponding node. The simulation will run for 90 second. The experiment uses SPT=2 which is the best value in which the original approach gets its best results.

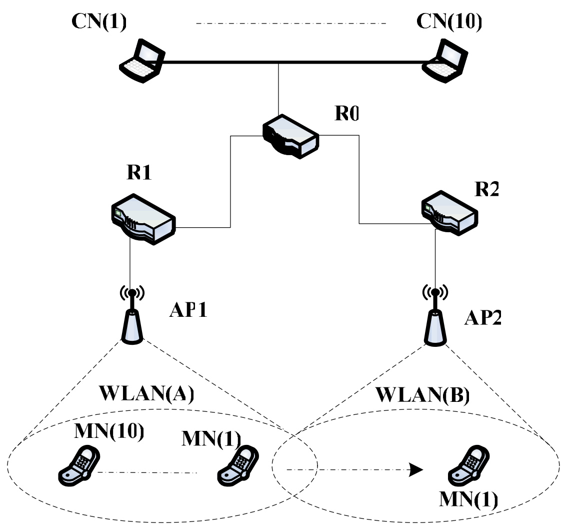


Figure 5. HM simulation model.

## 6.2. Simulation Results

The key player of our design is the tuning of MPT, and INS_THR. Adjusting these thresholds to appropriate values ensure good results that reduce packet loss and keep the network load overhead at a small value.

Based on the simulation model Figure 5 we have conducted our experiments by changing the values of MPT and INS_THR. MTP values are from 1 to 7 and INS_THR from 0 to 10. The value of INS_THR is equal to zero. The experiment is repeated 10 times for every pair of MPT and INS_THR values and the average of the results is plotted Figures 6 and 7.

### 6.2.1. Packet Loss

Figure 6 shows the average packet loss rate during handoff. To maintain the required communication quality for VoIP the packet loss rate should be maintained at or below 3%. When the MPT is three or four, the overall packet loss rate is 1.41% which is less than 3%. On the other hand the packet loss rate is higher for other MPT values and sometimes exceeds 3%. It is apparent that packet loss can be minimized at certain MPT values.

When the MPT is equal to a small value(<3), the original HM sensitively switches to multi-path transmission which may cause the packets sent from WLAN (B) through IF2 to arrive at the CN before packets sent from WLAN (A) through IF1. This happens because of the variation of delay between the two paths in addition to the delay that may occur due to contention in WLAN(A). Therefore, a packet sent from WLAN(A) arriving at the destination after the packets sent from WLAN(B) is regarded as a lost packet.

Figure 6 shows the packet loss in the original handoff scheme and the optimized packet loss when the instability threshold is employed during the single path transmission. With the optimized scheme, the packet loss is about 1.39% which is less than 3% that is required for VoIP communication.

In normal HM, when the MPT is small switching from single path to multi-path occurs more frequently due to the faulty wireless condition indicator that may occur due to the sudden interruptions in wireless link quality (interference with other wireless signals or objects in the path of the mobile node) , which leads to more packet loss.

In the optimized HM, we have controlled the frequent switching to multi-path transmission by introducing the instability indicator, this indicator ensures switching to multi-path only when there is a real degradation of the wireless link and a real handoff process has to occur.

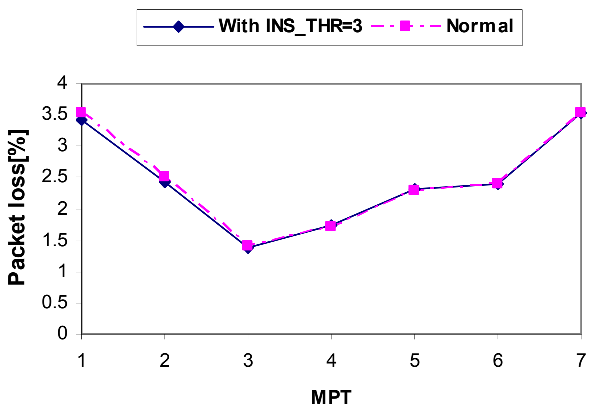


Figure 6. The packet loss during handoff when instability threshold is employed.

### 6.2.2. Network Load

In the proposed scheme, the HM selects the appropriate single-path or multi-path transmission according to the wireless link condition in order to reduce packet loss during handoff. The extra network load due to multi-path transmission, i.e., redundant traffic due to sending the same packets, should consequently be minimized.

By examining the network load during handoff for different values of MPT INS_THR, we found that the network load for the best case (SPT=2) can be optimized by controlling the INS_THR. The MPT is ranging from 1 to 7, and the instability threshold from 1 to 10.

The network load increases sharply when the MPT is small, because it is easy to switch to multi-path transmission when the MPT is small. As a result, the number of packets sent by multi-path transmission is increased. In this case, the switching to multi-path transmission can be minimized by avoiding switching due to faulty indicators.

Figure 7 shows that the network load can be optimized by applying the instability threshold during the single path transmission specifically for MPT equal to three or less. This reduction comes from controlling the switching to multi-path transmission. Switching to multi-path will only occur when there is a real handoff indicator any faulty triggers will have small impact on the switching process.

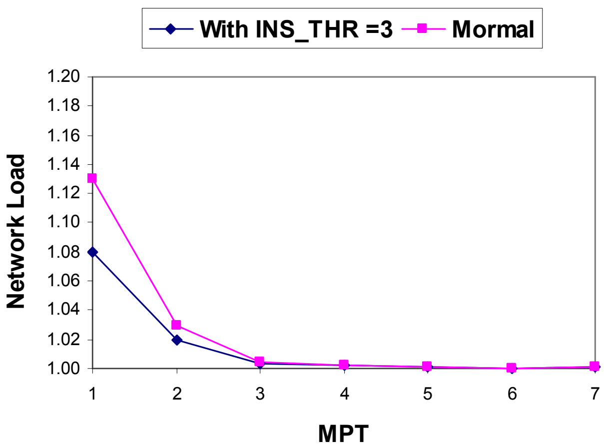


Figure 7. Optimized network load during handoff.

For the traffic without multi-path transmission the network load is about 80kb/s (200byte*8bits/20ms). As we have discussed earlier MPT of three and an SPT of two are recommended. By applying the instability threshold control, the optimized network load during handoff is reduced to 1.0035 times that of the load without multi-path transmission (80 kb/ s * 1.0035 = 80.28 kb/s) whereas that for the normal approach is 80.32 kb/s.

## 7. Conclusions and Future Work

A handoff management scheme that uses multi-scan eliminates the network interruption during handoff but introduces network overhead, so the main goal of this work was to optimize the network load and keeps packet loss at the required levels for VoIP communication. Introducing the instability threshold shows that packet loss can be kept at an acceptable value of 1.39% which is less than the required value (3%) and network load is optimized to 80.28 kb/s.

Network load and packet loss can be reduced if the queuing systems of the two interfaces are merged into a single system and this is kept for future work.

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**Anwar Saif** received his MSc degree in networking and distributed computation in 2008 from UPM University, Malaysia. He is interested in improving performance for computer and telecommunication networks.

**Mohamed Othman** received his PhD from the national University of Malaysia with distinction (Best PhD Thesis in 2000 awarded by Sime Darby Malaysia and Malaysian Mathematical Science Society). Now, he is a professor in computer science and dean of Faculty of Computer Science and Information Technology, University Putra Malaysia (UPM). Prior to that, he was a director of Information Development and Communication Center (iDEC) where he was incharge for UMPNet network campus, uSport Wireless Communication project and UPM Data Center.