A Dynamic and Reliable Mesh Routing Protocol for Wireless Mesh Networks (DRMRP)

Dr. Ahmed H. Omari † and Ala'a H. Khrisat ††,

Applied Science University, Amman, Jordan
DRMS, Computer Center Amman, Jordan

Summary
A new routing algorithm has been introduced for Wireless Mesh Networks based on metrics associated with each route, the protocol is distinguished by being new technique that would use multi routing metric criteria and satisfies high packet delivery ratio, low delay, low overhead, and multiple gateway support. None of the known routing protocols for the mobile Ad Hoc Networks (MANET) and wired networks fulfill all of the five mentioned criteria. Mesh routing protocols usually forward all of the packets destined for a node to a gateway, then the gateway will route the packets to the destination. Mesh routing protocol also supports multiple gateways and routing based on metrics associated with each route. This reduces control overhead as well as the delay for a node to join the network. Control packets, called the registration and re-registration packets, are sent along the route to the gateway to ensure the validity of the route and to discern any link failure. The protocol also supports routing based on metrics associated with each route which allows a node to choose a gateway, as well as a route, based on a metric.

Key words:
MRP, wireless mesh networks, GATEWAY, MANET, PDR, and CBR.

1. Introduction

Routing is a very important part of a network as it creates a communication path between a source and destination, and forwards packets on that route. Without routing, the nodes will not be able to communicate with each other.
Wireless systems used in the industry today are mostly cellular radio links, using point-to-point or point-to-multipoint transmission. These traditional wireless systems have limitations and liabilities, such as, rigid structure, careful planning, and dropped signals [1]. Wireless Mesh Networks are more suitable for real life applications needed today. Wireless Mesh networks are multihop ad hoc wireless networks that also support wired devices and have gateways for providing connectivity to the Internet. An ad hoc wireless network is a temporary network consists of two or more devices (nodes), which has networking and wireless communications capabilities [2]. A node can communicate with another node that is within its radio range. To communicate with nodes outside the radio range, an intermediate node(s) is used to forward messages to the destination node. The most important feature of a Wireless Mesh network is that it provides Internet connectivity to nodes in the network. The traffic between two nodes in the Wireless Mesh network is only a small fraction of the total traffic, which travels to and from the Internet. A gateway is a special node that may have a wireless and a wired interface(s). The wired interface connects to the Internet while the wireless interface is towards the Ad Hoc Network. Gateways provide Internet connectivity to the Ad Hoc Network by forwarding packets from the Internet to the Ad Hoc Network and vice versa. The devices help each other relay and transmit packets through the network. A node can receive and send messages, and it also functions as a router that can relay messages for other nodes. Through the relaying process, a wireless data packet is delivered to the destination while passing through intermediate nodes. These Ad Hoc Networks can be deployed with minimal preparation, and they provide a reliable, flexible system that can be extended to hundreds of devices. The technology is self-configuring, self-healing and scalable. It offers redundant communication paths, such that in an event of a link or node failure, the nodes can find another route to the destination. Nodes can join or leave the network at anytime. The network itself discovers the new nodes and incorporates them into the existing network. However, there is one drawback, that is, node density has to be sufficient to ensure network connectivity.

2. Related Work

Significant research has been done for routing in Ad Hoc Networks focusing on different ideas; some of them compared two or more protocols to determine which one is the best. Other research papers studied protocols with different nodes or ways to evaluate the protocol performance; Lee, S., Su "A Performance Comparison Study of Ad Hoc Wireless Multicast Protocols" [3], investigated the performance of multicast routing protocols in wireless mobile Ad Hoc Networks MANET.

Manuscript received April 5, 2009
Manuscript revised April 20, 2009

In the research they simulated a set of wireless Ad Hoc multicast protocols and evaluated them in various network scenarios. The relative strengths, weaknesses, and applicability of each multicast protocol to diverse situations are studied and discussed. The final conclusion is that, in a mobile scenario, mesh based protocols outperformed tree-based protocols. The availability of alternate routes provided robustness to mobility. Also the research shows that, the route maintenance in Reactive Routing Protocols in Ad Hoc Multicast (AM) Route performs well under no mobility, but it suffers from loops and inefficient trees even for low mobility. Ad Hoc Multicast Routing protocol utilizing Increasing id-numberS (AMRIS) was effective in a light traffic environment with no mobility, but its performance was susceptible to traffic load and mobility. Core-Assisted Mesh Protocol (CAMP) showed better performance when compared to tree protocols, but with mobility, excessive control overhead caused congestion and collisions that resulted in performance degradation. On-Demand Multicast Routing Protocol (ODMRP) was very effective and efficient in most simulation scenarios. However, the protocol showed a trend of rapidly increasing overhead as the number of senders increased.
Davids Jones[4], in his study “A performance comparison of Multi-Hop Wireless Ad Hoc Network Routing Protocols” presents the results of a detailed packet-level simulation comparison four Multi-hop Wireless Ad Hoc network routing protocols that cover a range of design choices as: Destination-Sequenced Distance-Vector (DSDV), Temporally-Ordered Routing Algorithm (TORA), Dynamic Source Routing protocol (DSR) and Ad hoc On-Demand Distance Vector (ADOV). It extended the Network Simulator NS-2 network simulator to accurately model the MAC and Physical-layer behavior of the IEEE 802.11 wireless LAN standard, including a realistic wireless transmission channel Model, and presents the results of simulations of networks of 50 mobile nodes [4].

Carla Dewali [5], in her study “Simulation of Large Ad Hoc Networks” this paper presents the simulation of routing protocol in Ad Hoc Network used the original NS-2 simulator and Ad Hoc wireless networks. And alleviate the scaling of routing protocol, it base the computation of the interactions on the truncation algorithm for the protocol simulated, this exploits the real-life properties of signal propagation consequence NS-2 performs much more effectively (up to 30 times faster) [5].

3. The DRMRP Protocol

3.1 Protocol Fundamentals

An ideal Wireless Mesh Routing Protocol would support routing based on metrics associated with each route and also satisfy the following criteria: *High packet delivery ratio, low delay, low overhead*, and *multiple gateway support*. Multiple gateway support means that when more than one gateway is available in the network, the routing protocol should maintain routes to all of them. This offers two advantages [6]:

- *Traffic Migration*: If one gateway stops functioning, data traffic can be routed to another gateway.
- *Load balancing*: Data traffic can be distributed among the gateways depending on the metrics associated with routes to these gateways.

None of the routing protocols known so far, whether for the Ad Hoc networks or for the wired networks, have all of the criteria listed above. A new routing algorithm is needed, which would satisfy all of these requirements. We claim that our routing protocol supports dynamicity and scalability for mesh wireless networks.

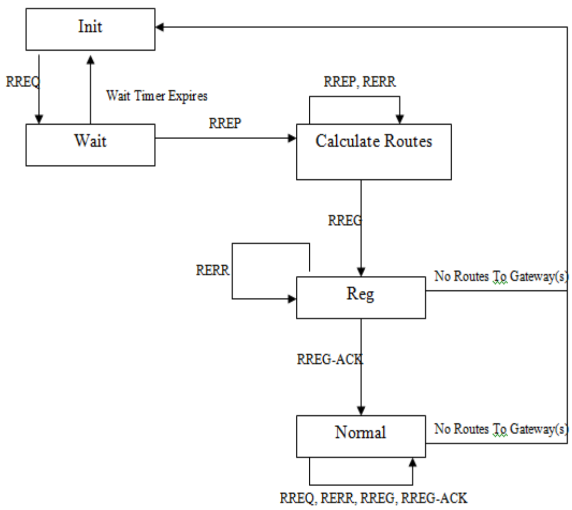


Figure-1- the State diagram at the node

Mesh Routing Protocol is suitable for Ad Hoc Wireless Mesh Networks, where the network consists of a gateway and some other nodes (i.e. mobile and/or static nodes). All nodes of the network are proactively maintaining routes towards the gateway. If a node has to communicate with another node, either in the same network or in the Internet, the node has to go through the designated gateway.
This assumption based on the fact that the traffic between any two nodes in the Wireless Mesh Network represents a

small fraction of the total incoming and outgoing network traffic.

The major highpoint of our protocol is supporting of multiple metrics associated with each route, where different packets from the same source can be categorized according to packet type and delivered to different routes of the gateway (i.e. *telnet* traffic/packets can be sent over the lowest delay path while, *ftp* traffic/packets can be sent over the route that having higher bandwidth and better network availability and stability). Before getting the protocol into operational mode, all of the required configuration parameters and the number of needed routes should be set and maintained.

The figures shown briefly describe the protocol and the node state diagram. Figure -1- shows the Mesh Routing Protocol (MRP) node state diagram and Figure -2- shows the MRP gateway flow diagram.

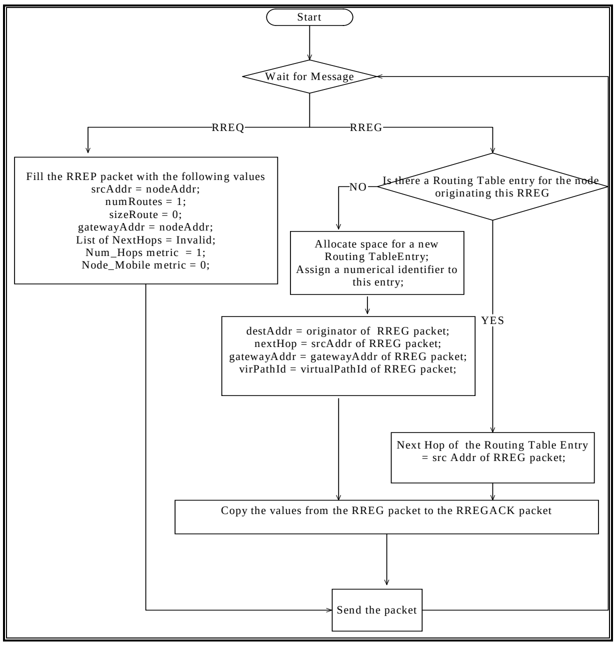


Figure-2- MPR flow diagram at the Gateway

3.2 Protocol Components

The Mesh Routing Protocol is composed of 3 basic mechanisms:

- Route Acquisition: Is the mechanism by which a node acquires routes toward the gateway.
- Route Registration and Re-Registration: Is the mechanism by which a node registers with the gateway such that the gateway becomes aware of the node. The Re-Registration mechanism ensures the freshness of the routes.
- Route Failure detection and propagation: Mesh Routing Protocol relies on the link layer to inform it about a link breakage. Upon receiving this information, MRP propagates the route error information to downstream nodes and initiates the search for new routes. The nodes receiving the route error invalidate routes toward the gateway utilizing the broken link and initiate search for new routes.

4. Methodology used and Simulation

4.1 Methodology used

Mesh Routing Protocol (MRP) was simulated using Glomosim. Glomosim is a well known discrete-even network simulator [7]; it is scalable and can be used to simulate large networks [8]. In this work MRP has been simulated in different scenarios and compared with AODV, Wireless Routing Protocol (WRP), Bellman-Ford, and Fisheye State Routing (FSR). AODV is an on-demand protocol while WRP, Bellman-Ford and FSR are proactive protocols. This allows us to compare the Mesh routing protocol with both on-demand and proactive protocols in d5fferent scenar56s. In scenario-1, we vary the number of Constant Bit Ratio (CBR) sources, while in scenario-2 the speed of the mobile node was varied. The metrics used for studying the simulation results are Packet Delivery Ratio (PDR), Average End-to-End Delay and Control Overhead.

4.2 Analysis and results

Intensive experiments and comparisons were performed to prove our claims; the simulation results shown in the following diagrams represent the different scenarios and parameters being used. The experiments results are shown on the figures below where our observations were stated in order to give clear explanations of the results.

Figure-3- clearly shows that MRP has the maximum Packet Delivery Ratio PDR. This is because MRP is a proactive protocol, and nodes maintain routes to the gateways all of the times. Another important note is that, the MRP is having the highest throughput; this is because the MRP sends Registration messages at regular intervals and expects their acknowledgement accordingly. And the MRP scheme being used would discover link breakages faster.

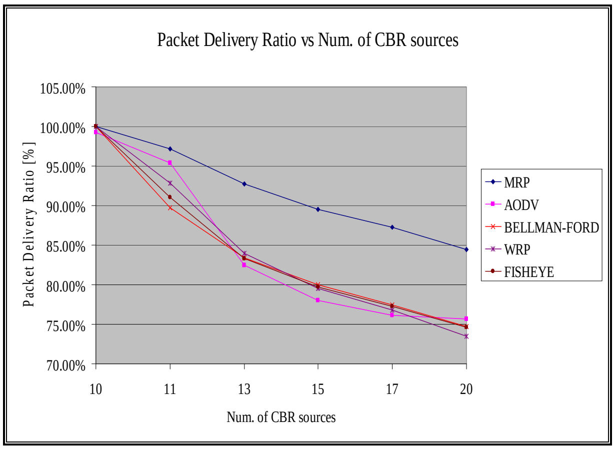


Figure 3: packet delivery ratio vs. number of CBR

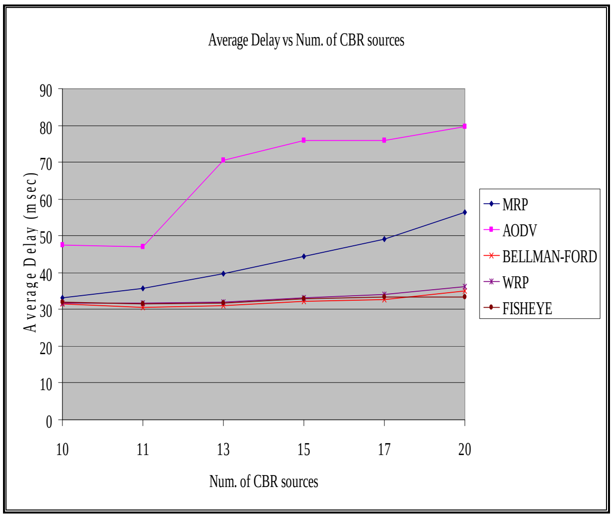


Figure 4: Average Delay vs. Num. of CBR Sources

Figure-4- shows that AODV has the highest delay while proactive protocols have the lowest delay. MRP's delay is between AODV and the other proactive protocols. Although MRP is proactive, the route acquisition process is similar to on-demand protocols. We found that MRP reacts to a lost packet and searches for new routes same as on-demand protocols. This process adds more delay to the MRP, where it is not the case with proactive protocols. Proactive protocols do not react when a packet is lost; they keep on forwarding packets on the same route. This technique results in packets loss with no delay increase.

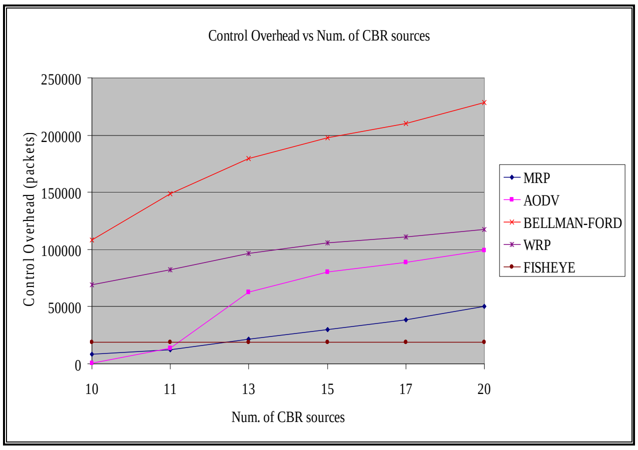


Figure-5-:-control Overhead vs. Num of CBR

Figure-5- comparing the different algorithm we found that FSR has a constant control overhead with minimum control overhead. The reason for this behavior is that the FSR is a Link-State protocol, having a small scope and radius of 2. The control overhead is bound to be low since updates are minimal (not too many), where updates need to be broadcast throughout the network. The updates are limited to 2 hops only, which is not the case with Bellman-Ford and WRP whose control overhead is considerably higher. Bellman-Ford has the highest overhead because the current implementation of this protocol in the simulator does not include all of the RIP optimization features. We also observe that MRP's overhead is lower than that of AODV, because, in MRP, the Route Request RREQ and Route Reply RREP travel a single hop; while in AODV, they travel all the way from the source to the destination and back. Besides, the RREQ is broadcast by all the nodes receiving the RREQ. This adds more to the total control overhead of AODV. As expected, the control overhead and the delay increase with the number of CBR sources.

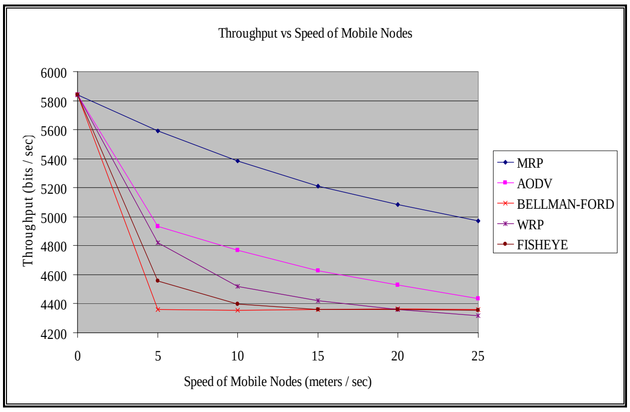


Figure-6-: Throughput vs. Speed of Mobile Nodes

In Figure-6- it is clear that MRP delivers the highest number of packets in all speeds. This is because the mobile nodes are in constant motion and the route breaks quite often, the proactive MRP algorithm is faster in fixing route breakage than the non-proactive AODV where RREQ and RREP travel single hop; Route discovery (in AODV) does not happen if there is no data to be transferred on the path, since nodes are not sending state most of the times and then the intermediate nodes are not able to satisfy the route request. This is not the case with MRP, where all nodes proactively maintain the route toward the gateway. This proactive approach helps in fixing route errors fast, hence transferring more packets. MRP also sends Registration messages at regular intervals and expects their acknowledgement back. Due to this scheme, link breakages are discovered early and faster. We observe that the throughput drops dramatically when increasing the mobile node speed; this observation is expected because the mobile node loses its connectivity with the next hop more often as speed increase. The phenomenon leads to more route breaks that would result on more route repairs and data loss. Therefore, the throughput degrades when increasing the mobile node speed.

Figure-7- show that AODV delivers the highest number of packets. MRP delivers a slightly less number of packets; but if we add the throughput in both directions (from and to the gateway), MRP delivers the highest number of packets. Bellman-Ford, FSR, and WRP deliver fewer packets than AODV or MRP.

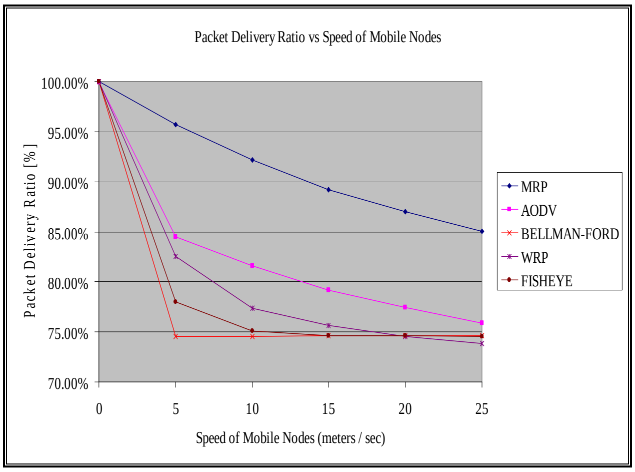


Figure 7: Packet Delivery Ratio vs. Speed of Mobile Nodes

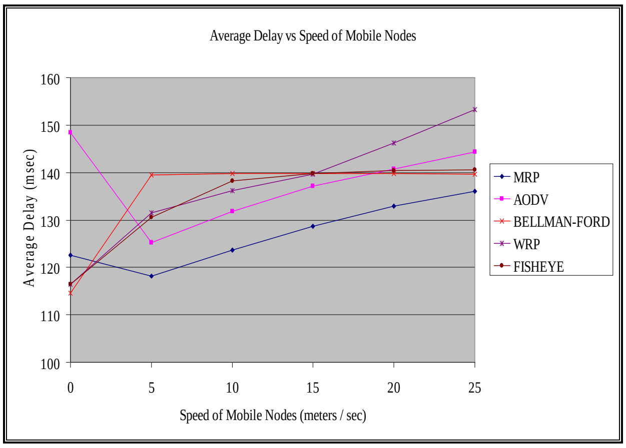


Figure-8-:Average Delay vs.speed of mobile nodes

In Figure-8-MRP has the least delay. The control overhead is almost the same as result in the first scenario-1

5. Summary and Future Work

MRP, AODV, Bellman-Ford, FSR, and WRP have been simulated in GlomoSim, and the performance has been compared. The performance metrics are *Packet Delivery Ratio (PDR)*, *Average End-to-End Delay*, and *Control Overhead*. Two different scenarios have been used to compare the protocols. In the first scenario, we increase the number of CBR sources, while, in the second scenario, we increase the speed of the mobile nodes. The performance of the protocols in upstream and downstream directions has been compared separately. AODV delivers the highest number of data packets in the downstream direction. MRP delivers fewer packets than AODV, while the proactive protocols deliver the least number of packets. In the reverse direction, MRP delivers the highest number of packets. AODV delivers fewer packets than MRP, while the proactive protocols deliver the least number of packets. It was observed that MRP delivers the highest number of packets if the results for both the directions are combined. This is true for both the scenarios.
Proactive protocols have the least delay, while AODV has the highest delay. The delay of MRP is greater than proactive protocols but less than AODV. It has been observed that the delay of MRP is closer to the proactive protocols rather than AODV. This is due to the proactive nature of MRP. The routing overhead of Bellman-Ford is maximum. FSR has the least overhead. MRP has a lower overhead than AODV. It has been observed that only FSR has a lower overhead than MRP. MRP also supports routing based on metrics associated with each route and multiple gateways. This is evident from experiments performed in Scenario-2. A high throughput, low delay,

low routing overhead, routing based on metrics and multiple gateway support make MRP the best choice for Wireless Mesh Networks.

The design, implementation and evaluation of MRP are still lacking in the coming a few areas. These areas are listed below and will be addressed in the future.

- *Extending the RREG Packet:* The RREG packet should be extended to include resource reservation requests.
- *Security:* The routing protocol packets should be properly authenticated and encrypted.
- *Evaluation of routing based on route metrics*: MRP should be simulated in an environment that offers a large number of metrics associated with each route. This will allow extensive evaluation of MRP's support of routing based on route metrics.

Acknowledgments

This work is supported by the Applied Science University, Amman, Jordan.

References

[1] B. Schrick and M. Riezenman (June 2002). "Wireless Broadband in a Box," *IEEE Spectrum*, pages 38-43.

[2] C.-K. Toh (2001). "Ad Hoc Mobile Wireless Networks: Protocols and Systems"

[3] Sung-Ju Lee, William Su, Julian Hsu, Mario Gerla, and Rajive BagrodiaWireless (2006) "A Performance Comparison Study of Ad Hoc Wireless Multicast Protocols" Adaptive Mobility Laboratory Computer Science Department University California Los Angeles, CA 90095-1596

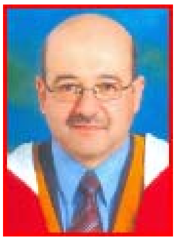
[4] Davids Jones (March 2008) "A Performance Comparison Of Multi-Hop Wireless Ad Hoc Network Routing protocols "IEEE

[5] Carla dewali (Aug.2007)"simulation of large ad hoc Networks"IEEE

[6] S.R. Das, R. Castaneda, J. Yan, and R. Sengupta, .Comparative Performance Evaluation of Routing Protocols for Mobile, Ad hoc Networks, In *Proceedings of IEEE IC3N'98*,Lafayette, LA, Oct. 1998, pp. 153-161

[7] X. Zeng, R. Bagrodia, and M. Gerla (May 2004). "GlomoSim: a Library for Parallel Simulation of Large-scale Wireless Networks," *In Proceedings of the 12th Workshop on Parallel and Distributed Simulations*, Banff, Alberta, Canada.

[8] R. Bagrodia, R. Meyer, M. Takai, Y. Chen, X. Zeng, J. Martin, B. Park, and H. Song (October 2003). "Parsec: A Parallel Simulation Environment for Complex Systems," *Computer*, Vol. 31(10), pages 77-85.



Dr. Ahmed H. Omari (1963)
Received the B.S. degree in Computer Science from Yarmouk University, Jordan in 1985, the MSc in Computer Science from the University of Jordan, 2000, and PhD in Computer Information Systems in Message Authentication, 2004. During 1985-1989, he worked as software developer, during 1989-1995, he worked as systems analyst and systems engineer, during 1995-2000, he assigned as DBA and project manager, during 2000-2003, he worked as e-Government project manager and Vice President of the Communication and Computer Department in the Public Security Directorate, Jordan. Since 2004 he became Assistant Professor at the Applied Science University, Amman Jordan, during that time, he was adjunct professor in DePaul University, Jordan University and AABFS. Since 2005 he is the Assistant Dean and the Head of Computer Networks System of the faculty of Information Technology. His research interests are: Wireless Networks (MANET), e-Government and Network Security.

Eng. Ala'a khrisat (1982)
Received her B.S. degree in Computer Engineering from Al-Balqa Applied university, Jordan in 2006, she received her MSc in Computer Science from Al-Balqa Applied University, in 2009, she is currently working for the DRMS, Amman Jordan as network engineer.