A Load Aware Routing Protocol for Mobile Ad hoc Networks

Yasser A. Dahab, Hesham N. Elmahdy and Imane A. Saroit

Abstract---The Ad hoc On-Demand Distance Vector (AODV) routing protocol is an efficient Mobile Ad hoc NETworks (MANETs) routing protocol. It uses hop count as a metric for the path selection. AODV does not support Quality of Service (QoS) and neither any load-balancing mechanism. The performance of the network can be improved by using a load balancing mechanism. Such a mechanism transfers jobs from overloaded nodes to under loaded nodes. In this paper, we propose a new protocol called "Load-Aware AODV" (LA-AODV), to provide QoS and load-balancing features. LA-AODV is based on AODV, where protocol messages extensions are used to accomplish QoS and load-balancing features. LA-AODV is a cross-layer solution that works in conjunction with a QoS-based MAC layer. It uses only local information and does not require any additional communication or co-operation between nodes.

The path selection in LA-AODV is based on the current MAC load of the nodes. The proposed protocol selects the path with the minimum MAC load based on a metric called "MAC load indicator". We show through simulations that LA-AODV outperforms AODV in terms of received packets, delay, and routing overhead.

Keywords---Ad hoc Networks, MANET, AODV, LA-AODV, Load balance, QoS, DCF, EDCA, DAA-EDCA, Cross Layer.

I. Introduction

A Mobile Ad hoc NETwork (MANET) is a wireless network, which consists of a collection of mobile nodes. Nodes communicate with each other without the need of centralized access points or base stations. A MANET is self-organizing, and adaptive network. Due to the limited transmission range of the nodes, multiple hops may be needed in exchanging data between two nodes. Each node in a MANET acts both as a router and as a host.

MANETS find place when using of wired networks either impractical or expensive.

Conferencing, Home Networking, Emergency Services, Sensor Fields, and Military Battle Site Networks are examples of applications, where mobile ad hoc networks can be deployed.

Manuscript received on February 16, 2011, review completed on March 01, 2011 and revised on March 04, 2011.

Yasser A. Dahab is with the Information Technology Department, Faculty of computers and information, Cairo University, Cairo, Egypt. E-Mail: ydahab@aswanonline.com

Hesham N. Elmahdy is with the Information Technology Department, Faculty of computers and information, Cairo University, Cairo, Egypt. E-Mail: ehesham@mailer.eun.eg

Imane A. Saroit is with the Information Technology Department, Faculty of computers and information, Cairo University, Cairo, Egypt. E-Mail: isaroit@fci-cu.edu.eg

Digital Object Identifier No: WC032011017.

MANETs exhibit unique characteristics such as free node mobility, unpredictable link properties, dynamic topology, limited bandwidth, and limited energy resources.

Nowadays, real time applications using wireless links is getting more attention. Such applications demand specific characteristics on QoS, such as throughput, delay, jitter, and error rate.

The characteristics of MANETs make the provision of QoS for real time applications very challenging.IEEE 802.11 is the most deployed wireless MAC protocol, but it gives only the best effort support for the applications. This means that IEEE 802.11 deals equally with all applications. IEEE 802.11e and DAA-EDCA were introduced as an extension of IEEE 802.11 to give support to applications, which have demands on QoS.

Many routing protocols were designed specifically for ad hoc networks. Ad hoc routing protocols can be broadly classified into three types, *proactive*, *reactive*, and hybrid [1].Proactive routing protocols are similar to the routing protocols used in wired networks.

They maintain entries in their routing tables for all possible destinations in the network. This approach works well at low mobility, and allows packet transmission to occur as soon as a data packet is generated by the application. Topology changes can be frequent in MANETs that leads proactive protocols to generate lots of control traffic for maintaining routing tables.

Reactive or on-demand protocols try to reduce the amount of control traffic required, by determining routes *on-demand*. This means that nodes acquire a route to a certain destination only when a need arises. This approach reduces the amount of control traffic required. On the other hand, it can have an extra delay due to route discovery, if no route is currently assigned.

Hybrid protocols combine both the active and reactive aspects. They perform proactive route maintenance in a local region, but use a reactive route discovery process to find routes to destinations.

AODV is an on demand routing protocol, which was designed for MANETs. AODV provides a basic routing functionality that is sufficient for best effort applications such as file transfer or e-mail download. In order to support real time applications, it is not sufficient to provide a basic routing functionality alone. Nowadays, the cross-layer design approach is adopted to solve several open issues in MANETs. It allows protocols belonging to different layers to cooperate and share network information states.

Our objective is to extend AODV with a load balancing mechanism by which the performance of the network can meet the demands of real-time applications. The proposed protocol can work in conjunction with several QoS IEEE 802.11 based MAC protocols in a cross-layer fashion. We explain briefly in the following subsections the basic protocols used in this paper.

A. IEEE 802.11

The Distributed Coordination Function (DCF) and the Point Coordination Function (PCF) are defined as medium access mechanisms by the IEEE 802.11 standard. DCF is based on the Carrier Sense Multiple Access with Collision Avoidance (CSMA-CA) mechanism, to transmit data. The access mechanism of the PCF is contention free central polling, where the Access Point (AP) controls all transmissions.

According to DCF, a station senses the medium before a transmission of a packet. Sending of the packet occurs, after sensing the medium Idle for the duration of DIFS (Distributed Inter frame Space). Otherwise, the transmission is deferred and a backoff process begins. A backoff timer is set to the value of a variable called CW (Contention Window). The timer is initialized with the value of minimum contention window (CWmin).

During the backoff period, the backoff timer is decremented by one for each time slot of the idle medium. The packet is sent out, when the backoff timer reaches zero. The packet is to be retransmitted, when a collision occurs. A collision happens, when two or more stations begin to transmit at the same time.

The CW is incremented exponentially with each attempt to retransmit the packet. CW is reset to CWmin after the successful transmission of the packet. [2] DCF has not any mechanism to differentiate different flow types.

B. IEEE 802.11e

IEEE 802.11e was introduced as an enhancement to IEEE 802.11 to provide QoS support. It introduces a new coordination function called Hybrid Coordination Function (HCF). HCF combines the aspects of DCF and PCF with enhanced QoS mechanisms. The Enhanced Distributed Channel Access (EDCA) is the contention based channel access mechanism of HCF. The contention free channel access mechanism of HCF is called Hcf Controlled Channel Access (HCCA).

The transmission opportunity (TXOP) was introduced by IEEE 802.11e. It is defined as the time period during which a station has the right to transmit. Four Access Categories (ACs) were introduced by EDCA for different types of data traffic. Service differentiation is achieved through assigning different parameters to each AC. The parameters are AIFS, maximum/minimum contention window, and TXOP. These parameters are referred as EDCA parameters. Frames are mapped into different ACs according to the QoS of their applications.

Each station has four transmission queues, one for each AC, and four Enhanced Distributed Channel Access Functions (EDCAFs). Each AC contends for the channel as the standard DCF. Each access category has its own backoff, and accordingly a different channel access probability. EDCA parameters are not adjusted according to the network conditions. Detailed description of IEEE 802.11e can be found in [3].

C. The Dynamic Adaptive Approach for Enhancement of EDCA (DAA-EDCA)

DAA-EDCA is a MAC protocol, which adapts the contention window size dynamically according to the network load. It is an extension of the standard IEEE 802.11e. DAA-EDCA utilizes frames loss rate, to change the contention window size. This parameter is defined as the ratio between the lost frames of an access category to the number of the total sent frames of this access category, during a given observation interval.

The protocol compares the frames loss rate of each access category with a corresponding threshold α (AC), which is the maximum tolerated loss rate of this access category. When the network is under loaded, reduces DAA-EDCA the contention window size from CW to CW / 4. In case of medium network load, the contention window size is reduced from CW to CW / 2. The contention window size is increased with high network load conditions.

The contention window size is limited by the minimum and the maximum contention windows. Increasing the contention window means doubling its value. The protocol deals differently with best effort access category, it reduces the CW to CW / 2 when the instantaneous network load is less than 0.75, otherwise is increased to 2 * CW [5].

D. The Ad hoc On-Demand Distance Vector (AODV) Routing Protocol

AODV is a destination-based reactive protocol, which avoids routing loops by using of sequence numbers. Each sequence number is generated by the destination node. The protocol makes use of different routing messages to accomplish the routes discovery and the maintaining of links. The protocol routing messages are Route REQuest (RREQ), Route REPly (RREP), Route ERRor (RERR), and HELLO.

RREQ is used, when a new route discovery is needed. AODV uses RREP as a reply message for a route request. Using of periodic HELLO messages enables AODV to check the presence of active neighbors. AODV utilizes RERR to record a link breakage. A routing table is used by AODV to maintain the necessary information states about different routes [9]. AODV has not any mechanism either for load balancing or QoS.

The rest of the paper is organized as follows: Section II includes a brief review of some approaches to enhance the performance of AODV. Section III describes our proposed protocol LA-AODV. Experimental results are illustrated in Section IV. Finally, conclusions are discussed in Section V.

II. Related Works

A lot of works has been done to support load aware routing. Intermediate nodes do not reply to the request message, when load exceeds a maximum threshold as in [13] to balance the load in the network. The Contention and Queue- aware Routing (CQR) was introduced in [10], which utilizes contention and interface queue length for the load balancing of the network. The congestion status was used by the Congestion adaptive Routing Protocol (CRP) to have an adaptive routing process [15].

Load balance routing is achieved through utilizing the packet success rate as in [14]. A load balancing protocol was proposed in [12], which was based on a gossiping mechanism. The forwarding probability of the routing messages is adjusted adaptively according to node distribution and load status. The Dynamic Load-Aware Routing (DLAR) protocol defines the network load as the number of on going traffic in the interface queue. The routing decisions are made based on the node queuing length.

The Load-Balanced Ad hoc Routing (LBAR) protocol makes routing decisions by utilizing the total number of routes passing through the node and its neighbors. All these protocols make use of the metric directly, but LA-AODV deals with metric indicators. This enables the protocol to give more investigations of the path and the nodes.

III. Methodology

Simulation is used as a technique for performance evaluation of the proposed protocol. LA-AODV was simulated using the Network Simulation (NS) version 2.28 on Linux [17]. The proposed protocol is implemented as an extension of AODV-UU, which is an AODV implementation for NS.This section starts by giving an overview of the proposed protocol followed by a description of our simulation setup and parameters.

A. The Load Aware Ad hoc On Demand Distance Vector (LA-AODV) Routing Protocol

LA-AODV is based on AODV, where protocol messages extensions are used to accomplish QoS and load-balancing features. The current average MAC load is computed in the MAC layer and is made available to the network layer through the cross layer approach. The current average MAC load of a node is defined as the ratio of time in which the channel observed busy to a specific observation time.

LA-AODV maps the value of the current average MAC load into one of three values:

- 0 indicates a low average MAC load.
- 1 refers to a medium average MAC load.
- 10 is an indication of high average MAC load.

The new mapped value is called average MAC load indicator. Both RREQ and RREP messages were extended with a field called PI (Path Indicator). PI contains the accumulated values of the average MAC load indicators of each node in the path. The routing table is also extended with a field called ACC_PI (ACCumulated Path Indicator), which contains the accumulated indicator values of the path. Both values of PI and ACC_PI can be used to abstract information about the nodes conditions of the path by using simple mathematical operations as following:

- Nr. of High load nodes = (PI or ACC_PI) div 10
- Nr. of medium load nodes = (PI or ACC_PI) mod 10
- Nr. of low load nodes = hop count - ((PI or ACC_PI) div 10) - (PI value mod 10)

LA-AODV follows the basic steps as the original AODV; however it utilizes the accumulated path load indicator as routing metric instead of the hop count used by AODV. LA-AODV starts the route discovery phase when a node needs to transmit a packet to a destination. The node begins to transmit when the route to the destination is known.

The node floods RREQ packets in case of unknown route to the destination to the neighbor nodes. These packets contain the PI extension with the value of 0. When intermediate node receives a RREQ packet, it checks firstly if it is the first time to have this RREQ packet. In first time case, the node adds a new routing entry in its own routing table and its current average MAC load to the value of PI of the RREQ packet and then propagates the RREQ packet.

If not, the node compares the PI value of the RREQ packet with the value of RTPI in its own routing table. The RREQ packet is dropped, when the value of PI is greater. The value of RTPI is changed to the value of PI. Then adds the node its current average MAC load to the value of PI filed of the RREQ packet and propagates the RREQ packet.

When the destination node receives the RREQ packet, it sends a RREP packet to the reverse route created by the intermediate nodes. Each node in the reverse route adds its current average MAC load to the PI of the RREP packet. LA-AODV drops the RREP packet in the node receiving the packet, when the current average MAC load of the node is greater than a maximum threshold. The source node starts to transmit its packets, when it receives the RREP packet LA-AODV deals with route maintenance as the original AODV.

LA-AODV Algorithm Pseudo-Code

RREQ:	Route Request Packet
RREP:	Route Reply Packet
RERR:	Route Error Packet
HELLO:	HELLO Packet
CURR_MAC_LOAD:	Average MAC load of a node
PI:	Value of nodes indicators in the RREQ packet
RTPI:	Routing Table Path indicator
LOAD_MAX_THRESHOLD:	Max. Accepted average load

BEGIN
(*When a node receives a routing message*)
IF (message type = RREQ)
{
IF (*the node is the source of RREQ*)
THEN {(*drop RREQ*)
END
}
ELSE IF (*RREQ has been heard before*)
// Original AODV would drop the RREQ message
THEN IF (RTPI > PI)
THEN (RTPI = PI)

```
        ELSE {Drop RREQ
      END
          }
        ELSE {Adding of new routing entry
      RTPI = PI
      }
(Reverse Route Creation in Routing Table)
IF (I am the destination)
Then (Sending Of RREP Packet)
ELSE {PI = PI + CURR_MAC_LOAD
 Forward RREQ
  }
END
}

IF (message type = RREP)
{
  IF (RREP has been heard before)
THEN IF (RTPI > PI)
        THEN (RTPI = PI)
         ELSE {Drop RREP
      END
          }
     ELSE {Adding of new routing entry
      RTPI = PI
      }

IF (I am the destination)
Then (send packet)
ELSE {
// Original AODV would forward RREP
 IF (CURR_MAC_LOAD < LOAD_MAX_THRESHOLD)
PI = PI + CURR_MAC_LOAD
THEN (Forward RREP)
 ELSE (drop RREP)
    }
END

IF (message type = RERR)
(Do as in original AODV)
END

IF (message type = HELLO)
(Do as in original AODV)
END

END
}
```

B. Simulation Setup and Parameters

AODV and LA-AODV were simulated using the Network Simulator (NS) version 2.28, with the patch [7] for EDCA. AODV-UU version 0.9.5 for NS was used [18]. AODV-UU is an AODV implementation for AODV, which was introduced by Uppsala University. A DAA-EDCA Implementation for NS was used as in [5]. The simulation setup involves ten nodes randomly placed in a grid. All traffics are periodic of Constant Bit Rate (CBR) type, with a constant packet size of 512 Bytes. The physical, MAC, routing layer parameters were set as in table 1.

TABLE I

Value	**Parameter**
802.11e, DAA-EDCA	MAC
AODV, LA-AODV	Routing
802.11g	Physical Layer
0.000009	SlotTime
0.000010	SIFS
16	PreambleLength
54M	PLCPDataRate
54M	dataRate
54M	basicRate
7	ShortRetryLimit
4	LongRetryLimit
4us	CCAtime

The standard IEEE 802.11e and DAA-EDCA were used in these simulations as MAC protocols. Random way point was selected as a mobility pattern.

The simulations were conducted in two scenarios, to compare the performance of LA-AODV with AODV. Twelve Flows are generated in the first scenario, with different network load conditions. This is achieved through changing the data rate of each source. Data rates were of 9, 10, 11, and 12 Mbps. Studying the impact of mobility was achieved through the use of five mobility rates. Eighteen flows were generated in the second scenario, with the same simulation parameters as in the first scenario.

We study the impact of mobility and network load on the performance of the two protocols. Different mobility rates and load conditions were used to accomplish this task. Varying load conditions were achieved through changing the source data rates and the number of data flows.

We focus on three performance metrics in our simulations, which are received packets, average end to end delay, and Normalized Routing Overhead (NRO). Received packets are the packets, which were received of each flow. The average end to end delay is defined as the average time needed to transfer a packet from a source to a destination. NRO is the number of routing packets transmitted per data packet.

IV. EXPERIMENTAL RESULTS

We studied initially the impact of two MAC protocols on the performance of AODV and LA-AODV. It can be seen from the below figures that both protocols perform better with DAA-EDCA as a MAC protocol. In the first six figures, each flow uses data rate of 10 Mb/s.

Figures 1 and 2 depict the impact of mobility on the received packets of 12 and 18 flows respectively. The proposed protocol outperforms the original AODV in the received packets as illustrated in the two figures.

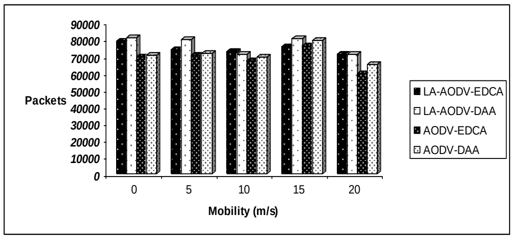

Fig. 1: Received Packets of 12 Flows (Data Rate = 10 Mb/s)

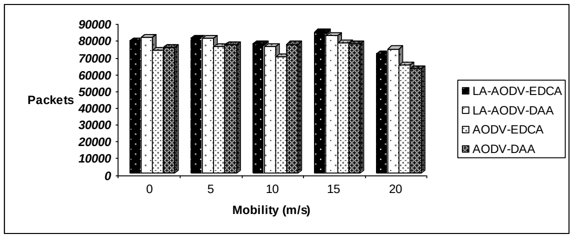

Fig. 2: Received Packets of 18 Flows (Data Rate =10 Mb/s)

The average end to end delay of both protocols is to be seen in figures 3, and 4.

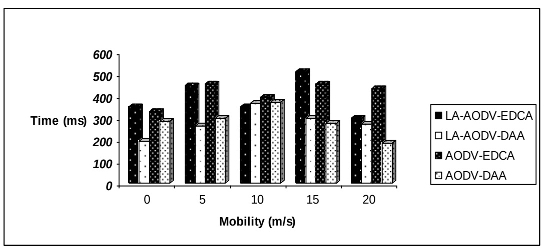

Fig. 3: Average Delay of 12 Flows (Data Rate = 10 Mb/s)

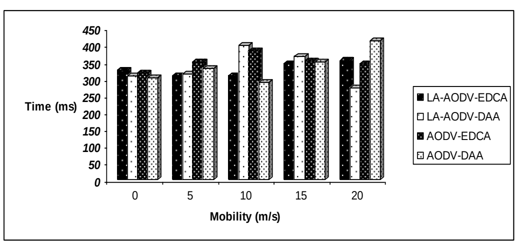

Fig. 4: Average Delay of 18 Flows (Data Rate = 10 Mb/s)

We have average delay in these figures as a function of different mobility rates.

Both figures show that AODV needs more delay to transmit a packet than LA-AODV. A better performance of both routing protocols is achieved through using DAA_EDCA as a MAC protocol.

We can see in figures 5 and 6 that LA-AODV makes use of less routing control packets than the original AODV to accomplish the routing protocol.

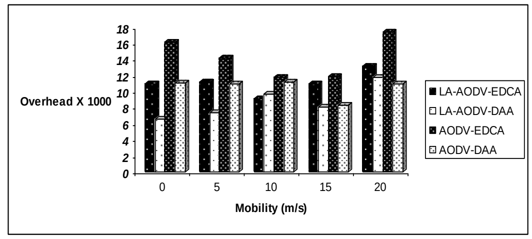

Fig. 5: Protocols Overhead for 12 Flows (Data Rate = 10 Mb/s)

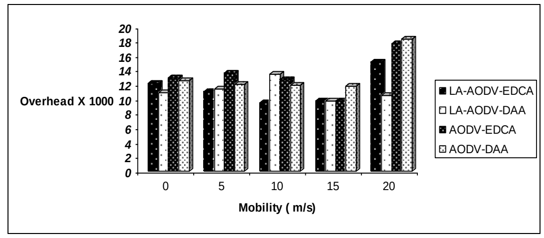

Fig. 6: Protocols Overhead for 18 Flows (Data Rate = 10 Mb/s)

The following six figures show the impact of different network loads on the performance of LA-AODV and AODV. Data rates of 9, 10, 11, and 12 Mb/s are used with mobility rate of 5m/s.

Both of figure 7, and 8 shows that, varying the network load does not affect the performance of LA-AODV. The proposed protocol outperforms AODV in received packets.

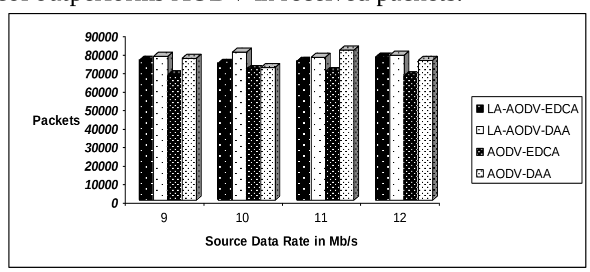

Fig. 7: Received Packets of 12 Flows (Mobility = 5 m/s)

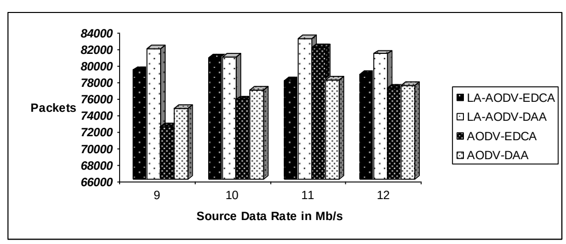

Fig. 8: Received Packets of 18 Flows (Mobility = 5 m/s)

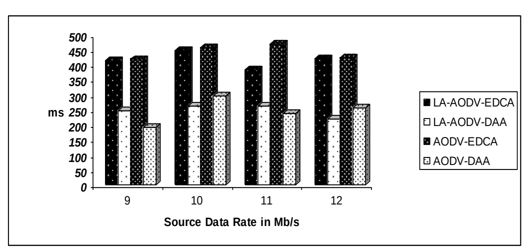

Fig. 9: Average Delay of 12 Flows (Mobility = 5 m/s)

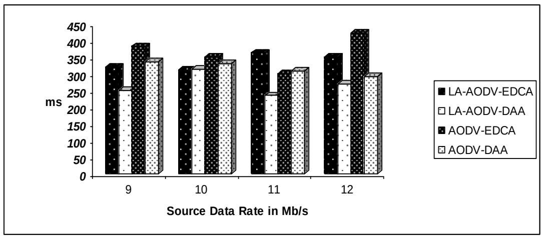

Fig. 10: Average Delay of 18 Flows (Mobility = 5 m/s)

DAA-EDCA has more effect on the average end to end delay performance for AODV and LA-AODV. LA-AODV shows best average delay results with DAA-EDCA as shown in figure 9 and figure 10.

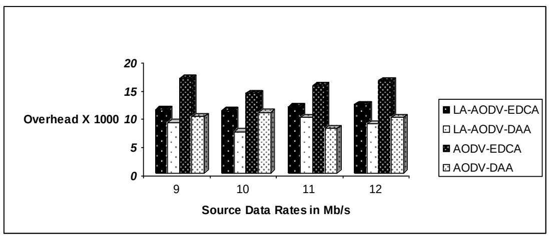

Fig. 11: Routing Overhead for 12 Flows (Mobility = 5 m/s)

LA-AODV shows a better routing overhead than AODV as in figure 11 and figure 12.

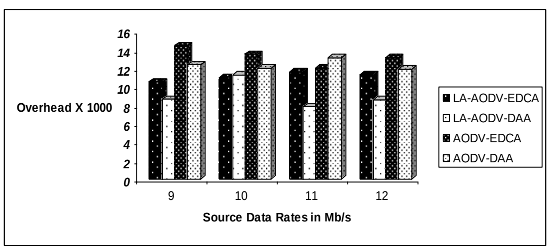

Fig. 12: Routing Overhead for 18 Flows (Mobility = 5 m/s)

Figures 1-12 show that the behavior of LA-AODV does not change with the increasing of the network load or the mobility rate.

V. Conclusions

In this paper, we have proposed a new routing protocol LA_AODV using a cross layer approach. LA-AODV utilizes the accumulated path indicator as a routing metric. A lot of information about nodes conditions of the path can be extracted from this metric. The proposed protocol makes use of metric indicators instead of the metric itself. This gives the opportunity to give more investigations of the path and the nodes.

Simulation results showed that the proposed protocol outperforms AODV in throughput, end to end delay, and routing overhead. LA-AODV can be seen as a general extension of AODV. It can be used with any other cross layer metric with simple modifications. Simulation results showed that LA-AODV gives best results in conjunction with DAA-EDCA as MAC protocol. Further work will deal with deeper analysis of the information encoded in the accumulated path indicator metric.

References

[1] C. Siva Ram Murthy and B.S. Manoj, “Ad hoc wireless Networks, Architectures and protocols”, “Prentice Hall Communications Engineering and Emerging Techno”, NY. 2004.

[2] Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Amendment 8: Medium Access Method MAC) Quality of Service Enhancements, IEEE-SA Standards Board Std. 802.11e, Nov 2005.

[3] G. Bianchi, I. Tinnirello, and L. Scalia, “Understanding 802.11e Contention-Based Prioritization Mechanisms and Their Coexistence with Legacy 802.11 Stations,” IEEE Network, vol. 19, no. 4, pp. 28-34, 2005.

[4] R.Moraes, P. Portugal, F. Vasques, “Simulation Analysis of the IEEE 802.11e EDCA Protocol for an Industrially-Relevant Real-Time Communication Scenario”, IEEE ETFA’06, Prague, Czech Republic, Sept. 20-22, 2006.

[5] Yasser A. Dahab, Hesham N. Elmahdy and Imane A. Saroit, “Improving the Performance of IEEE 802.11e using A Dynamic Adaptation Approach”, CiiT International Journal of Wireless Communication, Vol 2, No 9, pp. 276-280, September 2010.

[6] S. Wiethoelter and C. Hoene. Design and Verification of an IEEE 802.11e EDCF Simulation Model in ns-2.26 Technical Report TKN-03-019, Telecommunication Networks Group, Technische Universitaet Berlin, November 2003.

[7] S.Wiethoelter and C. Hoene, An IEEE 802.11e EDCF and CFB Simulation Model for ns-2, http://www.tkn.tuberlinde/research/802.11e_ns2/, last visit on Feb. 13th, 2011.

[8] Frank Roijers, Hans van den Berg and Michel Mandjes “Performance analysis of differentiated resource-sharing in a wireless ad-hoc networks”, Performance Evaluation, Volume 67, Issue 7, pp. 528-547, July 2010.

[9] C. E. Perkins, E. Belding-Royer, S. Das, “Ad hoc On-demand Distance Vector (AODV) Routing”, IETF RFC 3561, 2003.

[10] X. Gao, X. Zhang, D. Shi, F. Zou and W. Zhu, “Contention and Queue-Aware Routing Protocol for Mobile Ad Hoc Networks”, WiCOM, September 2007.

[11] Toh Chai Keong, Le Anh-Ngoc and Cho You-Ze, “Load Balanced Routing Protocols for Ad Hoc Mobile Wireless Networks”, IEEE Communications Magazine, Institute of Electrical and Electronics Engineers Inc., Vol. 47, No. 8, pp. 78-84, 2009.

[12] Zhu Bin, Zeng Xiao-ping, Xiong Xian-sheng, Chen Qian, Fan Wen-yan, Wei Geng, “A Novel Adaptive Load Balancing Routing Algorithm in Ad hoc Networks”, Journal of Convergence Information Technology, Volume 5, Number 5, July 2010

[13] Y. J. Lee and G. F Riley, “A Workload-Based Adaptive Load-Balancing Technique for Mobile Ad Hoc Networks” ,WCNC, March 2005.

[14] F. Zou, X. Zhang, X. Gao, D. Shi, E. Wang, “Load Balance Routing Using Packet Success Rate for Mobile Ad hoc Networks”, WiCOM, September 2007.

[15] D.A. Tran and H. Raghavendra, “Congestion Adaptive Routing in Mobile Ad Hoc Networks”, IEEE Transactions on Parallel Distributed Systems, Vol. 17, no. 11, pp. 1294-1305, November 2006.

[16] X. Zhang, X. Gao, D. Shi and D.K. Sung, “Lifetime-aware Leisure Degree Adaptive Routing Protocol for Mobile Ad hoc Networks” , ICWMC, March 2007

[17] Network Simulator, ns-2, http://www.isi.edu/nsnam/ns, last visit on Feb. 13th, 2011.

[18] AODV-UU implementation for ns-2, http://sourceforge.net/projects/aodvuu, last visit on Feb. 13th, 2011.

Yasser A. Dahab received his B.Sc. in Industrial Electronics from the Faculty of Electronic Engineering, Menofia University, Menofia, Egypt in 1986. He received his M. Sc. in Computer Science from Friedrich-Alexander University, Erlangen, Germany in 1996. He is working toward his Ph. D degree. His researches are focused on computer networks, specially wireless and mobile Ad hoc networks. E-mail: ydahab@aswanonline.com

Dr. Eng. Hesham N. Elmahdy is an associate professor at the Information Technology Department in Faculty of Computers and Information, Cairo University. He received his B.Sc. in Automobile Engineering with honor degree in the Military Technical Collage, Cairo in 1981. He received his first M. Sc. in Computer Science in the Institute of Statistical Studies & Research, Cairo University, Cairo in 1992. He received his second M.Sc. in Computer Science in the University of Mississippi in August 1996. He received his Ph D in Computer Science in the University of Mississippi in December 1997. His current research interests are Networks, Distance Learning, and Multimedia. E-mail: ehesham@mailer.eun.eg

Imane A. Saroit received her B. Sc. In 1985, M. Sc. in 1990, and the Ph. D in 1994 all from Faculty of engineering, Communication department, Cairo University. She worked in Cairo university since 1989, She is now a professor in Information Technology department and Vice dean for Education and Student Affairs, Faculty of Computers and Information, Cairo University. Her researches are focused on computer networks, specially wireless and mobile networks E-mail: isaroit@fci-cu.edu.eg