Adaptive Receiver Power Routing Protocol for Mobile Ad Hoc Wireless Network

Lawal Bello, Panos Bakalis, Predrag Rapajic, Kwashie A. Anang and Titus I. Eneh
Mobile and Wireless Communications Research Centre, University of Greenwich, Chatham, UK
Email: {L.Bello, P.Bakalis, P.Rapajic, K.Anang, T.Eneh}@greenwich.ac.uk

***Abstract*— In this paper, an Adaptive Receiver Power Routing (ARPR) protocol technique for Mobile Ad Hoc wireless network is proposed. The adaptive receiver power routing (ARPR) protocol evaluates the effect of environment, and signal path loss on a mobile ad hoc wireless network quality of service (QoS) and throughput performance. The proposed technique is incorporated into Dynamic Source Routing (DSR) protocol. Mathematical analysis supported by computer simulations is used to validate the scalability of the proposed technique. The simulation results showed that when ARPR is incorporated into DSR the throughput performance increased by 62.5 %, compared to the conventional DSR protocol model, without ARPR. The simulation result also showed that the average received power for individual nodes was 1.0×10^{-10} watt for the proposed ARPR model and 5.0×10^{-2} watt for conventional model.**

***Index Terms*— adaptive receiver, DSR routing protocol, mobile ad hoc networks, power-routing**

I. INTRODUCTION

Power is consumed in mobile ad hoc wireless network due to excessive utilization during network routing operations. Thus, a node may cease to function as a result of power depletion. This problem consequently leads to mobile nodes behaving selfishly and thus affecting the entire performance of the network [1]. In [2], [3], selfish nodes were described as nodes that lack network resources such as transmit power and bandwidth to carry out their network operation. Selfish nodes are nodes participating in routing operations but may not be willing to use their computing and energy resources to forward packets that are not directly beneficial to them. They may be dropping packets instead of forwarding packets to their respective destinations.

MANET are used in areas where infrastructured network are not possible without having any centralized administration, such as disaster areas, battlefield, emergency and rescue places. These areas are severely affected by different environmental conditions such as hill shade, which consequently affect the received signal power strength, network routing operation and the entire performance of the network [4]. Different routing protocols have been proposed, these protocols can be classified either as reactive or proactive protocols [5]. The reactive routing protocols sends out route request for routes-to-destination if the source node have data packets to send. The proactive routing protocols uses routing tables which are maintained via periodic updates from all other nodes in the network, irrespective of the fact that the network may not be active in terms of data traffic. Yuvaraju et. al in [1], reported that proactive routing protocols consumes more power as compare to reactive routing protocols, which is due to continuous periodic update of the proactive routing protocols. Routing protocols ensures the proper routing of packets from source to destination via intermediate nodes. The total power consumption and the received signal power strength depends on the distance between mobile nodes, signal path loss, network environmental conditions and the type of application running. Currently, most research work carried out in the area of routing protocols uses free space path loss model to represent the network environment [4], [3], [2], [6]. However, free space path loss model does not include the effects of other environmental conditions; such as hill shade, when evaluating the received signal power.

II. RELATED WORK

Anderegg and Eidenbenz in [7], proposed an energy-efficient routing protocol (Ad Hoc-VCG protocol) for detecting selfish nodes, to ensure that a packet from a source node-to-destination gets routed along the most energy-efficient path via intermediate nodes. The Ad Hoc-VCG protocol works efficiently for networks where communications session between mobile nodes does not change frequently during a session. However, considering the nature of MANETs, where mobile nodes are free to move randomly and network topology changes rapidly and unpredictably. Thus, this routing protocol is not suitable for practical applications in MANET. There are two general techniques in detecting selfish nodes within a network; these are Watchdog and Pathrater [8]. These techniques are combined with the standard reactive routing protocol in MANET and the selfish nodes are recognized by listening to the next nodes to observe if the packets are forwarded, and if not the node is marked as selfish node after some time. However, watchdog and pathrater techniques are detective rather than preventive techniques; they might not detect selfish nodes in the presence of limited transmission power, network congestions and partial dropping of packets due to link or routing failure. Nie and Zhou in [9] proposed a model

Manuscript received January 31, 2011; revised; June 10, 2011; accepted June 14, 2011.

© 2011 ACADEMY PUBLISHER
doi:10.4304/jcm.6.7.571-580

which detects selfish nodes and forced them to cooperate. However, forcing a node with limited network resources to cooperate can affect other cooperative mobile nodes in the network. Researches carried out by Yuvaraju et. al in [1] and Ramachandran et. al in [6], showed that as network capacity increases, the total power consumption increases concurrently, thus requiring more routes to reach the destination, consequently increasing the end-to-end delay. Routing are distributed overall the participating nodes and this can be critical under resource consumptions especially when the network size increases [10]. Our research focused on designing an adaptive receiver power routing protocol, which will improve the quality of service and the throughput performance of MANET routing protocols.

The rest of the paper is organized as follows. Section II present a summary of related works. Section III gives an overview of Dynamic Source Routing protocol. Section IV describes the proposed ARPR power model for Dynamic Source Routing protocol. Section V presents the simulation; model and environment. Section VI presents results and disussion. Finally VII presents conclusions.

III. OVERVIEW OF DYNAMIC SOURCE ROUTING PROTOCOL (DSR)

Dynamic Source Routing is a simple, efficient and an On-demand routing protocol designed specifically for use in multi-hop wireless ad hoc networks of mobile nodes that uses source routing rather than hop-by-hop routing approach [12]. Each packet to be routed carries in its header, a complete ordered list of nodes through which the packet passes. The advantage of this protocol is that, intermediate nodes do not need to maintain up-to-date routing information in order to route the packets they forward. Due to the on-demand characteristics of DSR, periodic route updates and neighbor detection are eliminated to minimize bandwidth consumption [5], [13]. DSR has two basic mechanisms of operations, Route Discovery process by flooding the network with a route request (RREQ) packets to all its neighboring nodes containing the IP address of both sender and receiver in the packet header as shown in Fig. 1(a), whilst Route reply returns the route reply messages (RREP). The route reply contains the list of the best routes from the source initiator to the target destination as shown in Fig. 1(b).

Performance evaluation conducted on both proactive and reactive protocols in [12], [14], [15], [16], [17], showed that DSR performs better than Ad Hoc On demand Distance Vector (AODV) and other proactive protocols in terms of throughput, end-to-end delay, and packets drop. The DSR performance is attributed to its characteristics of having multiple routes to other destination. In case of link failure, it does not require a new route discovery processes. Because of this, end-to-end delay is reduced, less packet dropping and less energy consumption. Reference [18], [19], [20] showed that, the DSR has less energy consumption in the entire network as compared to its counterpart AODV, which losses energy due to broadcasting hello messages to update its routes. Hence, the DSR protocol was chosen as genial candidate for carrying out this research.

A. Conventional DSR Packet Format

To improve the communication performances and reliability; traffic data sent between mobile nodes are subdivided into packets headers. The DSR protocol uses specific headers to carry information. The header must be a multiple of 4 bytes in case other headers follow the DSR Options header. The DSR header format is shown in Table I.

TABLE I.
CONVENTIONAL DSR HEADERS

Next Header	Reserved	Payload	Options	Data
8 bits	8 bits	16 bits	0 bits	0 bits

The packets formats are defined as follows:

- **Next Header:** The size of the Next Header field is 8 bits. The Next Header field shows either the type of the first extension (if any extension header is available) or the protocol in the upper layer such as TCP, UDP.
- **Payload Length:** Specifies the length of the payload, in bytes, that the packet is encapsulating. The value of the Payload Length field defines the total length of all options carried in the DSR Options header such as route request option, route reply option.

B. Convention DSR Protocol

Routing protocol is responsible of routing packets from the IP datagram between mobile nodes, and also verifies if the packet is coming from the upper layer or lower layer of the network protocol stack and makes a decision of where to forward the packet protocol (appendix A) [21]. Figure 2, shows the network protocol stack and the process model for the conventional DSR routing protocol. DSR protocol is implemented at the network layer; IP dispatch is the root process for network layer, and has as a child process; manet manager. Manet manager acts as manager process for DSR and provides an interface to DSR routing protocols.

C. Modification Cost of DSR Protocol

Sheetalkumar et. al in [3], gave the modification cost for existing dynamic source routing protocol as shown in Table II. The authors in [3], considered the minimum route maintenance energy, which involved the modification of routing software and 802.11; without considering the proper modification of DSR routing algorithm and transmits power control. Also to the best of our knowledge this modification have not being applied to existing version of the DSR protocol to achieve an optimized quality of service. The routing algorithm modification cost involves the cost of changes made to existing routing algorithm. In our work we considered modification of the routing software and power control.

© 2011 ACADEMY PUBLISHER

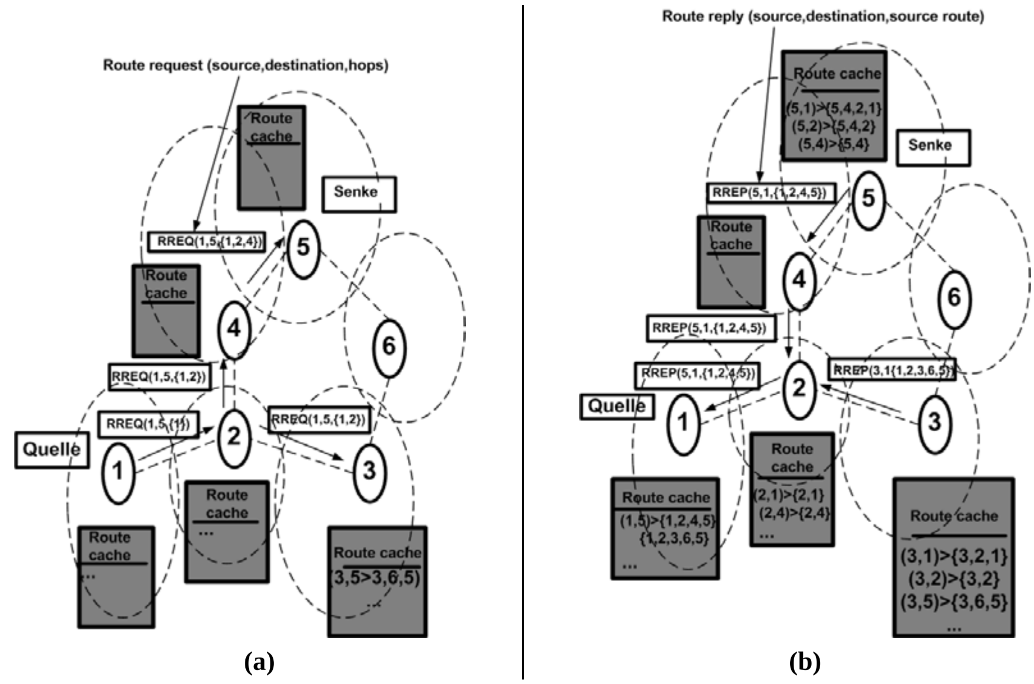

Figure 1. Overview of DSR protocol: (a) Route request process. (b) Route reply process [11].

TABLE II.
MODIFICATION COST

Routing features of power routing protocol	Routing software modification	IEEE 802.11 modification	Radio hardware modification
Link energy cost	Yes	No	No
Tx power control	Yes	Yes	Yes
Route discovery min. energy route	Yes	No	No
Route maintenance min. energy	Yes	No	No
Link cache	Yes	No	No

IV. PROPOSED ADAPTIVE RECEIVER POWER CONTROL PROTOCOL

Considering current MANET applications, it is important for existing routing algorithm for MANET to be modified to specifically accommodate power model for better routing in the network. However the free space path loss model only takes into account distance between mobile nodes and the frequency of transmission. The free space model is limited in its ability to accurately predict signal path loss in most network environments. Our technique takes into account the modification of existing routing algorithm for dynamic source routing protocol (DSR), modification of power control and the inclusion of mathematical model to represent other environmental conditions.

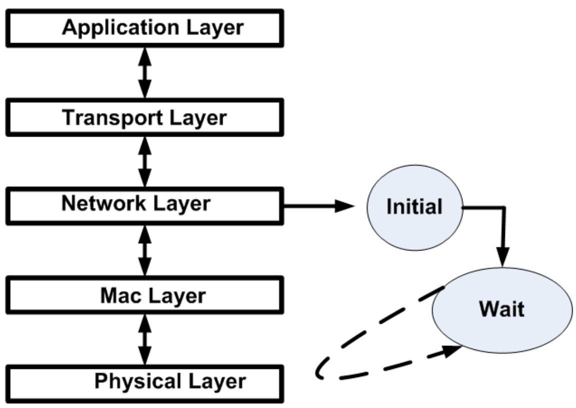

Figure 2. Conventional DSR Protocol

A. DSR Packet Format with Power Values

In this section, we describe changes made to the conventional DSR packet format. We added four power values to the conventional DSR packet format; which included, transmit power level, received power level, minimum transmit power level and minimum receive power level as shown in Table III.

For successful transmission and reception of data packets the minimum transmit and minimum received power levels are required. These power values are made available to the DSR protocol of the protocol stack.

B. DSR Protocol with Power Model

DSR protocol is implemented at the network layer, with addition of power model process (appendix B). The Physical layer, wireless mac layer, sends the measured values of transmit power, minimum transmit power, received signal

© 2011 ACADEMY PUBLISHER

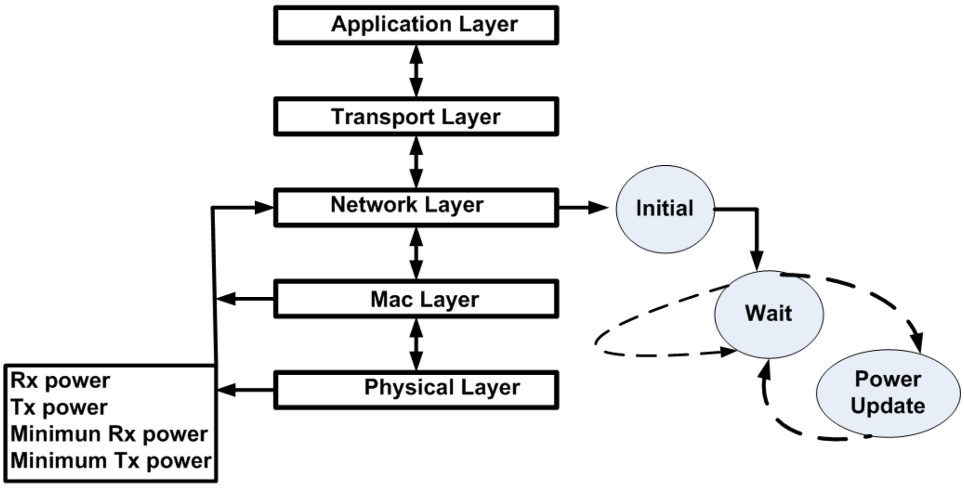

Figure 3. Modified DSR Protocol with Power Model

TABLE III.
MODIFIED DSR PACKET FORMAT

Header	Reserved	Payload	Options	Data
(8 bits)	(8 bits)	(16 bits)	(0 bits)	(0 bits)
Rx Power (W) 0 bit	Tx Power (W) 0 bit	Min Tx Power (W) 0 bit	Min Rx Power (W) 0 bit	

power and the minimum received signal power to network routing layer (refer to figure 3) along the DSR packets, where it is stored and used for routing decision making process. Manet manager is responsible for spawning the DSR child process when a node is configured for DSR with power model

C. Power Management in DSR Protocol

The setbacks to power management in ad hoc mobile communications is choosing transmit power. The transmit power level determines the quality of the received signal. Most of the transmit power is consumed during the network routing processes. The idea behind power routing is to avoid unnecessary waste of packets as well as network resources that can make nodes to behave selfishly. At the network layer, the routing algorithms must select the best route that satisfies the probabilistic power condition as describe below.

```
If ((P_Tx >= Min_tx)&&(P_Rx >= MinRx))
{
Route Request send = True
}
Else
{
New routing search
}
```

D. Adaptive Receiver Power Model

We present the adaptive power model used for our analysis. This model assist us to analyze the effect of signal path loss, and other environmental conditions on the received signal power and the general performance of the network. The environmental conditions can be in different forms depending on the network operating environment. In urban areas, the environmental conditions may include cars engine noise, horns, trains, construction machines, and aircrafts noise etc. While in rural areas, it may include sounds from farm animals, and wildlife.

For a given environmental condition, the environmental constant Env_{const}, is the sum of the ambient noise level and boltzmann constant, which is given as:

$$Env_{const} = A_{noiselevel} + k_B \quad (1)$$

where $\text{A}_{noiselevel}$ is the ambient noise level, which is the sound pressure level at a given location and k_B is the Boltzmann constant, which is the physical constant value relating energy to individual particle level with temperature. Env_{const} includes noises from transport, industries, and recreation activities.

Assuming no obstructions between a transmitting mobile node and a receiving mobile node; signals will be transmitted through free space to a receiver located at a distance D [m]. The free space path loss model used in our analysis is given by [22], as:

$$P_L = \frac{\lambda^2}{(4\pi D)^2} \quad (2)$$

where P_L is the free space path loss, D is the distance between any two mobile nodes and λ is the carrier wave length.

The general loss (G_L) over the transmission channel is the sum of the free space path loss propagation model and the environmental constant value and can be written as

$$G_L = P_L + Env_{const} \quad (3)$$

From [23], the received signal power P_{Rx}, can be written as

$$P_{Rx} = P_{tx} + Env_{const} - 10P_L \times 10log10(D) + T \quad (4)$$

where P_{tx}, is the transmitted signal power and *T* is the terrain. However, due to frequent topology changes

© 2011 ACADEMY PUBLISHER

associated with movements of mobile nodes in the network, the transmit power level for each mobile node is not the same. The minimum transmit and receive power, Min_{tx}, Min_{Rx} for successful transmission and reception of data/control packets requires to meet the probabilistic power condition given in (5) and (6)

$$Min_{tx} \geq \beta_0 \times \eta_0 \times g(u, v) \tag{5}$$

$$Min_{Rx} \geq \beta_0 \times \eta_0 \tag{6}$$

where β_0 is the signal to noise ratio, η_0 is ambient noise level strength and *g(u,v)* is the transmitter and receiver antenna gain.

V. SIMULATION MODEL

OPNET Modeller (version 16.0), developed by OPNET Technologies is used for all our simulations [21]. Details about the simulation model and environment are presented in the rest of this section.
OPNET Technologies, Inc. is a leading provider of solutions for IT service assurance. OPNET's best-in-class solutions address: application performance management, network performance management, and Network Research and Development. OPNET Solution delivers broad visibility and monitoring across infrastructure, infrastructureless domains as well as deep data collection and analysis to enable powerful root cause diagnosis. OPNET's solutions have been operationally proven in thousands of customer environments worldwide, including corporate and government enterprise, defense agencies, network service providers, and network equipment manufacturers [21].

A. Simulation Parameters

The adaptive receiver power model was computed and incorporated into DSR protocol. We simulated a network with 80 mobile nodes, using file transfer protocol (ftp) applications with medium load, which are randomly selected (sources and destinations) within a topology area of 700 × 500 meters. Constant Bit Rate (CBR) agents, with packets sizes of 4096 bits were used for traffic generation in the network. The simulation time was 3600 seconds real time, each simulation scenario was repeated 10 times, which enabled the simulation to converge for accurate result. The basic parameters used for the simulations are summarized in Table IV.

B. Performance Metrics

We use the following metrics to compare the performance of DSR protocol with proposed adaptive receiver power control protocol to conventional DSR protocol without adaptive receiver power control protocol.

- **Throughput:** represents the total number of successful packets in (bits/sec) received from all WLAN nodes of the network.
- **Bit Error Rate:** is the number of bit errors divided by the total number of transferred bits during a simulated time.

TABLE IV.
SIMULATION PARAMETERS

Parameters	Values
Simulation time	3600 seconds
Topology area	700 × 500 m
Number of nodes	80 nodes
Simulator	OPNET 16.0 wireless suite version
Node Mobility Model	Random Way point
Data rate (bits)	5.5 Mbps
Physical Characteristics	802.11g
Data rate (bits)	5.5 Mbps
Transmit power	0.100 W
Packet size (bits)	4096 bits
Packet inter-arrival time	0.5 seconds
Routing protocol	DSR
Boltzmann constant	1.379e-23 J/K
number of trials	10
Ambient Noise Level	1.0e-26

- **Bandwidth Utilization:** this metric measures the total bandwidth consumption, a value of 100.0 % indicates full usage of bandwidth.
- **Delay:** represents the end-to-end delay of all the packets received by the wireless LAN of the mobile nodes in the network.
- **Received Power (W):** this measures the power that is received by the individual nodes in the network.

VI. SIMULATION RESULTS AND DISCUSSION

Simulation results are presented in this section. Figure 4, shows the performance throughput with and without ARPR power model. The initial rise in throughput is due to route discovery processes initiated by the routing protocol. This shows that more control information in the form of route request (RREQ) and route reply (RREP) were forwarded by all nodes in the network, which lead to a higher throughput. As the network stabilized and more network routes are discovered, the DSR throughput performance with ARPR protocol was approximately 800000 bit/sec as compared to 480000 bits/sec for DSR without ARPR power model, and both remained constant throughout the simulation period.

The BER is an important performance metric, which determines the success of packets transfer over a wireless channel. Bit errors causes packets to be corrupted, resulting in data segments or acknowledgments lost. When acknowledgements do not arrive at the sender (source mobile node) within a given time, the sender retransmits the data segment, and exponentially backs off its retransmit timer for the next retransmission. Repeated errors result in a small congestion window at the sender and causes low throughput as experienced by conventional DSR protocol without ARPR power model as shown in Figure 4.
Figure 5, shows the BER curves for DSR protocol with- and without ARPR power model. For the DSR protocol with ARPR power model, the BER is approximately 0.009 as compared to 0.019 for the conventional DSR protocol without ARPR. This shows the noise level in the wireless channel affects the throughput performance of the entire network. Transmission of packets over the

© 2011 ACADEMY PUBLISHER

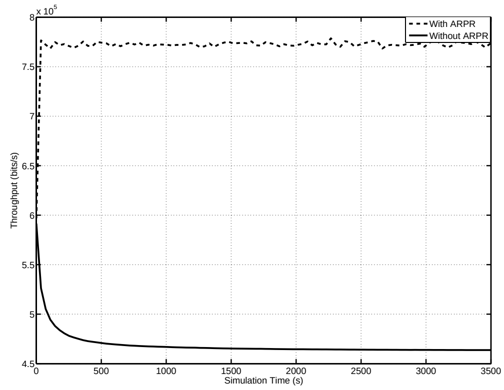

Figure 4. The throughput (b/s); a comparison of DSR protocol with and without ARPR

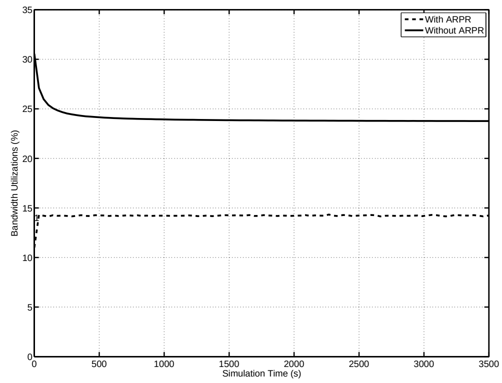

Figure 6. The bandwidth utilization; a comparison of DSR protocol with and without ARPR

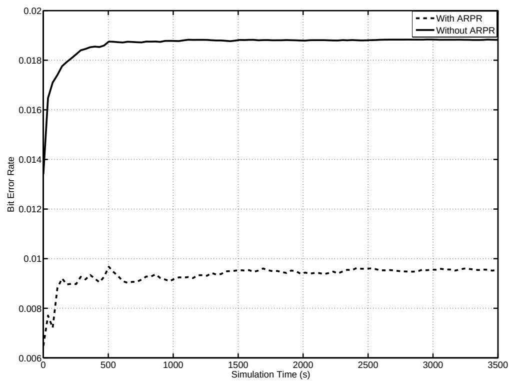

Figure 5. The bit error rate; a comparison of DSR protocol with and without ARPR

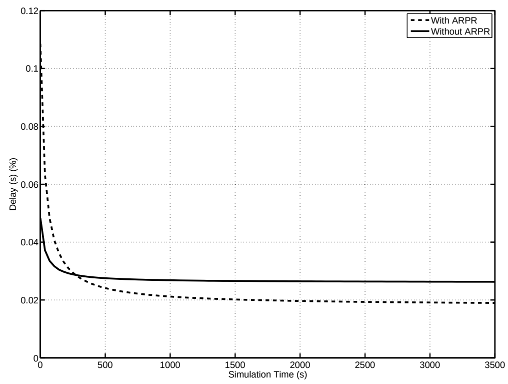

Figure 7. The delay; a comparison of DSR protocol with and without ARPR

wireless channel has been scheduled in accordance to probabilistic power condition and mobility models (refer to table I), and these helps to reduces interference noise in the wireless link channel.

The ARPR power model assist in controlling the data traffic delivery and avoids traffic redundancy, which can lead to channel bandwidth consumption. Figure 6 shows that DSR protocol with ARPR power model has 14 % bandwidth utilization rate as compared to 24 % for the conventional DSR protocol without power model. A value of 100 % indicates full usage of the channel. The higher rate of bandwidth consumption by DSR protocol without ARPR model is due to packet drop by the mobile nodes, which do not have enough power to participate in network routing operation. Hence DSR have to retransmit data/control packets.

Figure 7 shows the delay curves for DSR protocol with-and without ARPR power model. The curves, shows that the packet delay increases initially, which is due to the DSR protocol trying to find the valid routes to destinations. When the network stabilized, the DSR protocol with ARPR model delay reduced and remained constant at 0.02 seconds compared to 0.03 seconds for the conventional DSR protocol without ARPR power model.

Figure 8 shows the power consumed at each node after 3600 seconds real time of simulation. Each node has an initial transmit power of 0.1 watts and the figure shows that with ARPR power model, the received power consumption for the individual nodes was 1.0×10^{-10} watt as compared to 5.0×10^{-2} watt for DSR protocol without ARPR power model.

From the simulation results we conclude that using probabilistic ARPR power model to find the routes save mobile nodes to die away as a result of power depletion during the network routing operation which consequently leads to mobile nodes behaving selfishly and thus affecting the quality of service and performance throughput of the entire network. Our protocol performs better in terms of power saving, bandwidth consumption, delay reduction, low bit error rate as compared to work in [2], [6], [24], despite the fact that they have used different mobility parameters as well as routing protocols. However, [24] agreed that their approach was extremely expensive in terms of power consumption and this warrant investigation into more approach that can save more power of the mobile nodes.

© 2011 ACADEMY PUBLISHER

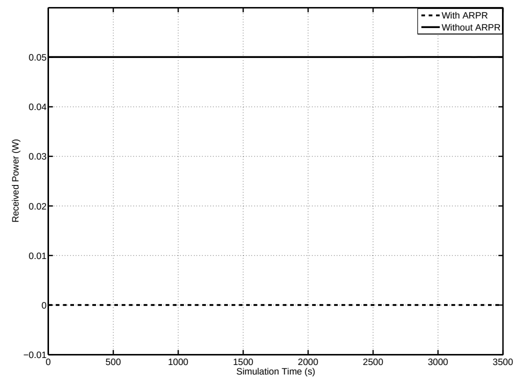

Figure 8. The received signal power; a comparison of DSR protocol with and without ARPR

VII. CONCLUSION

In this paper, we have proposed an adaptive receiver power routing (ARPR) protocol technique, which is incorporated into Dynamic Source Routing Protocol (DSR) for better throughput performance. OPNET wireless suite simulator was used to evaluate the effect of environmental conditions, signal path loss on quality of service and throughput performance of Mobile Ad hoc Wireless Network. With the proposed ARPR power model, there is a significant power saving. For example, for a practical power model, our simulations show that the network life time with the proposed ARPR model is twice better than the conventional model.

Simulation results shows that the longevity of the network was achieved in terms of throughput of 800000 bits/sec with proposed ARPR power model as compared to 480000 bits/sec of conventional DSR protocol without ARPR power model. However, the power received by individual nodes for the proposed ARPR power model was 1.0×10^{-10} watt as compared to 5.0×10^{-2} watt without ARPR power model.

APPENDIX A

```
/∗ Create the DSR packet∗/

dsr_pkptr =
dsr _pkt_support_pkt_create(IpC_Protocol_Unspec);
/∗Set the route request option in DSR packet header∗/
dsr_pkptr =
dsr_pkt_support_option_add(dsr_pkptr,dsr_tlv_ptr);0.1in
/∗Set the DSR packet in a newly created IP datagram ∗/
/∗The source address of the IP datagram is the ∗/
/∗node's own IP address and the destination address∗/
/∗of the IP datagram is the limited broadcast address ∗/
/∗(255.255.255.255) for IPv4 or the all node link ∗/
/∗layer multicast address for IPv6∗/
if(inet_address_family_get(&dest_address)

==InetC_Addr_Family_v4)
{
ip_pkptr =
dsr_rte_ip_datagram_create (dsr_pkptr,
InetI_Broadcast_v4_Addr,
InetI_Broadcast_v4_Addr, OPC_NIL);
}
else
{
ip_pkptr =
dsr_rte_ip_datagram_create (dsr_pkptr,
InetI_Ipv6_All_Nodes_LL_Mcast_Addr,
InetI_Ipv6_All_Nodes_LL_Mcast_Addr, OPC_NIL);
op_ici_install (ip_iciptr);
}
if (LTRACE_ACTIVE)
{
inet_address_print (dest_hop_addr_str, dest_address);
inet_address_to_hname (dest_address, dest_node_name);
sprintf (temp_str, "destined to node %s (%s) with ID
(%d)",
dest_hop_addr_str, dest_node_name,
route_request_identifier);
op_prg_odb_print_major
("Broadcasting a route request option in packet",
temp_str, OPC_NIL);
}
/∗Increment the route request identifier/∗
route_request_identifier++;
/∗ Access the IP datagram fields/∗
op_pk_nfd_access(ip_pkptr, "fields", &ip_dgram_fd_ptr);

/∗ If the non-propagating route request feature/∗
/∗ has been enabled, set the TTL field in the /∗
/∗ route request packet to one/∗
if (non_prop_route_request)
{
/∗ Set the TTL to one /∗
ip_dgram_fd_ptr− >ttl = 1;
}
else
{
/∗ Set the TTL to the default /∗
ip_dgram_fd_ptr− >ttl = IPC_DEFAULT_TTL;
}

/∗Insert the originating route request information in
/∗
/∗ the originating route request table/∗
dsr_route_request_originating_table_entry_insert
(route_request_table_ptr, dest_address,,
ip_dgram_fd_ptr− > ttl);

/∗Update the statistic for the total traffic sent /∗
dsr_support_total_traffic_sent_stats_update
(stat_handle_ptr, global_stathandle_ptr, ip_pkptr);

/∗ Update the statistics for the routing traffic sent /∗
dsr_support_routing_traffic_sent_stats_update
(stat_handle_ptr, global_stathandleptr, ip_pkptr);
/∗ Update the statistic for the total number of route
```

© 2011 ACADEMY PUBLISHER

requests sent/∗
dsr_support_route_request_sent_stats_update
(stat_handle_ptr, global_stathandle_ptr,non_
prop_route_request);

/∗ Send the packet to the CPU which will broadcast it/∗
/∗ after processing the packet/∗
manet_rte_to_cpu_pkt_send_schedule_with_jitter
(module_data_ptr, parent_prohandle, parent_pro_id, ip_pkptr);

Appendix B

/∗ Create the DSR packet/∗
dsr_pkptr =
dsr_pkt_support_pkt_create(IpC_Protocol_Unspec);
//Get the power levels from DSR packet
rec_pow = op_pk_nfd_get_dbl (dsr_pkptr, ”rx_power”, &rx_power);
tx_pow = op_pk_nfd_get_dbl (dsr_pkptr, ”tx_power”, &tx_power);
mini_tx = op_pk_nfd_get_dbl (dsr_pkptr, ”min_tx”, &min_tx);
mini_rx = op_pk_nfd_get_dbl (dsr_pkptr, ”min_rx”, &min_rx);

/∗ Set the route request option in the DSR packet header /∗
dsr_pkt_support_option_add (dsr_pkptr, dsr_tlv_ptr);

/∗ Set the DSR packet in a newly created IP datagram /∗
/∗The source address of the IP datagram is the node’s /∗
/∗ own IP address and the destination address of the /∗
/∗IP datagram is the limited broadcast address/∗
/∗ (255.255.255.255) for IPv4 or the all node link/∗
/∗ layer multicast address for IPv6/∗
if (inet_address_family_get (&dest_address)==
InetC_Addr_Family_v4)
{
ip_pkptr = dsr_rte_ip_datagram_create (dsr_pkptr,
InetI_Broadcast_v4_Addr,
InetI_Broadcast_v4_Addr, OPC_NIL);
}
else
{
ip_pkptr = dsr_rte_ip_datagram_create (dsr_pkptr,
InetI_Ipv6_All_Nodes_LL_Mcast_Addr,
InetI_Ipv6_All_Nodes_LL_Mcast_Addr, OPC_NIL);

/∗ Install the ICI for IPv6 case /∗
ip_iciptr = op_ici_create (”ip_rte_req_v4”);
op_ici_attr_set (ip_iciptr, ”multicast_major_port”,
mcast_major_port);
op_ici_install (ip_iciptr);
}

if (LTRACE_ACTIVE)
{
inet_address_print (dest_hop_addr_str, dest_address);
inet_address_to_hname (dest_address, dest_node_name);
sprintf (temp_str, ”destined to node %s (%s) with ID (%d)”, dest_hop_addr_str, dest_node_name,
route_request_identifier);
op_prg_odb_print_major (”Broadcasting a route request option in packet”, temp_str, OPC_NIL);
}

/∗ Increment the route request identifier /∗
route_request_identifier++;

/∗ Access the IP datagram fields /∗
op_pk_nfd_access (ip_pkptr, ”fields”, &ip_dgram_fd_ptr);

/∗ If the non-propagating route request feature /∗
/∗ has been enabled, set the TTL field in the /∗
/∗ route request packet to one/∗
if (non_prop_route_request)
{
/∗ Set the TTL to one /∗
ip_dgram_fd_ptr_ ttl = 1;
}
else
{
/∗ Set the TTL to the default /∗
ip_dgram_fd_ptr ttl = IPC_DEFAULT_TTL;
}

/∗ Insert the originating route request information in/∗
/∗ the originating route request table/∗
dsr_route_request_originating_table_entry_insert
(route_request_table_ptr, dest_address, rec_pow,tx_pow,
mini_tx, ip_dgram_fd_ptr ttl);

/∗ Update the statistic for the total traffic sent/∗
dsr_support_total_traffic_sent_stats_update (stat_handle_ptr, global_stathandle_ptr, ip_pkptr);

/∗ Update the statistics for the routing traffic sent /∗
dsr_support_routing_traffic_sent_stats_update
(stat_handle_ptr, global_stathandle_ptr, ip_pkptr);

/∗ Update the statistic for the total number of route requests sent /∗
dsr_support_route_request_sent_stats_update
(stat_handle_ptr, global_stathandle_ptr,
non_prop_route_request);

/∗ Send the packet to the CPU which will broadcast it/∗
/∗ after processing the packet/∗

if ((tx_pow = mini_tx) && (rec_pow = mini_rx))

© 2011 ACADEMY PUBLISHER

manet_rte_to_cpu_pkt_send_schedule_with_jitter (module_data_ptr, parent_prohandle, parent_pro_id, ip_pkptr);

ACKNOWLEDGMENT

The authors would like to thank the OPNET Technology Group for providing the software used for the simulations (OPNET Modeler Simulator).

REFERENCES

[1] B. N. Yuvaraju, T. Mohit, and N. C. Niranjan, "Enhancing the Performance of MANETs by Monitoring the Energy Consumption and Use of Mobile Relays," in *Proceedings of the IEEE International Association of Computer Science and Information Technology - Spring Conference*, Singapore, Apr. 2009, pp. 85 – 89.

[2] S. Singh, M. Woo, and C. S. Raghavendra, "Power-Aware Routing in Mobile ad Hoc Networks," in *Proceedings of the 4th annual ACM/IEEE international conference on Mobile computing and networking Dallas*, 1998, pp. 181 – 190.

[3] S. Doshi, S. Bhandare, and X. Timothy, "An On-demand Minimum Energy Routing Protocol for a wireless ad Hoc Network," in *ACM SIGMOBILE Mobile Computing and Communications Review.*, vol. 6, no. 3, jun 2002, pp. 50 – 66.

[4] X. Y. Li, Y. Wang, H. Chen, X. Chu, Y. Wu, and Y. Qi, "Reliable and energy-efficient routing for static wireless ad hoc networks with unreliable links," *IEEE Transactions on Parallel and Distributed Systems*, vol. 10, no. 20, pp. 1408 – 1421, Aug. 2009.

[5] D. B. Johnson, D. A. Maltz, and J. Broch, "The Dynamic Source Routing Protocol for Multi-HopWireless Ad hoc Networks," in *Networks.Computer Science Department Carnegie Mellon*, University, Pittsburgh, PA 15213-3891.

[6] B. Ramachandran and S. Shanmugavel, "Received Signal Strength-based Cross-layer Designs for Mobile Ad Hoc Networks," *IETE Technical Review*, vol. 25, no. 4, 2008.

[7] L. Anderegg and S. Eidenbenz, "Ad hoc-vcg: A truthful and cost-efficient routing protocol for mobile ad hoc networks with selfish agents," in *Proceedings of the 9th annual international conference on Mobile computing and networking (MobiCom '03)*, San Diego, California, USA, Sept. 2003, pp. 245 – 259.

[8] S. Marti, T. J. Giuli, and M. Baker, "Mitigating routing misbehaviour in mobile ad hoc networks," in *Proceedings of the 6th annual international conference on Mobile computing and networking (MobiCom '00)*, Boston, MA, USA, Aug. 2000, pp. 255 – 265.

[9] J. Nie and Z. Zhou, "An energy based power-aware routing protocol in ad hoc networks," in *Proceedings of the International Symposium on Communications and Information Technologies (ISCIT '04)*, vol. 1, Sapporo, Japan, Oct. 2004, pp. 280 – 285.

[10] M. Conti, E. Gregori, and G. Maselli, "Cooperation issues in mobile ad hoc networks," in *Proceedings of the 24 International Conference on Distributed Computing Systems Workshops (ICDCSW '09)*, vol. 7, 2009, pp. 803 – 808.

[11] "Interoperability laboratory for security in ad-hoc networks," http://www.uni.lu/secan-lab/.

[12] SreeRangaRaju and J. Mungara, "Performance Evaluation of ZRP over AODV and DSR in Mobile Adhoc Networks using Qualnet," *European Journal of Scientific Research*, vol. 45, pp. 658–674, 2010.

[13] S. Basagni, M. conti, S. Giordano, and I. Stojmenovic, *Mobile Ad Hoc Networking*. IEEE Press, 2004.

[14] N. Qasim, fatin Said, and H. Aghvami, "Mobile Ad hoc Networking Protocols Evaluation through Simulation for Quality of service," *IAENG International Journal of Computer Science*, vol. 36, no. 1, 2009.

[15] B. R. A. Kumar, L. C. Reddy, and P. S. Hiremath, "Performance Comparison of Wireless Mobile Ad Hoc Network Routing Protocols," *IJCSNS International Journal of Computer Science and Network Security*, vol. 8, no. 1, 2008.

[16] J. Broch, D. A. Maltz, D. B.Johnson, Y.-C. Hu, and J. Jetcheva, "A Performance Comparison of Multi-Hop Wireless Ad Hoc Network Routing Protocols," in *Networks.Computer Science Department Carnegie Mellon*, University, Pittsburgh, PA 15213-3891, 1998.

[17] M. A. Rahman, M. S. Islam, and A. Talevski, "Performance Measurement of Various Routing Protocols in Ad Hoc Network," in *Proceedings of the International MultiConference of Engineers and Computer Scientist*, vol. I IMECS, Hong Kong, 2009.

[18] S. Z. Yang, B. Qi, and J. He, "Simulation comparison of four wireless Ad hoc routing protocols," *Information Technology Journal*, vol. 3, no. 3, pp. 219 – 226, 2004.

[19] A. Boukerche, *Algorithm and Protocls for Wireless and Mobile Ad Hoc Networks*. Wiley Seris on Parallel and Distributed Computing.

[20] L. Quakil, S. Senouci, and G. Pujolle, "Performance Comparison of Ad Hoc Routing Protocols Based on Energy Consumption," in *Ambience Workshop*, Torino, Italy, 2002.

[21] "Opnet simulator," http://www.opnet.com/.

[22] A. Goldsmith, *Wireless communication*. New York, NY: Cambridge University, 2005, pp. 31–35.

[23] G. Zanca, F. Zorzi, A. Zanella, and M. Zorzi, "Experimental comparison of rssi-based localization algorithms for indoor wireless sensor networks," in *Workshop on Real-World Wireless Sensor Networks (RealWSN'08)*, Glasgow, UK, Apr. 2008.

[24] B. Chen, K. Jamieson, and H. Balakrishnan, "Span: An energy-efficient coordination algorithm for topology maintenance in ad hoc wireless networks," in *Proceedings of the 7th ACM MOBICOM*, Rome, Italy, Jul. 2001.

Lawal Bello received his BSc degree in Computer Science in 2004 from Usmanu Danfodiyo University Sokoto, Nigeria and MSc degree in Computer Networking engineering from University of Greenwich, UK. He is currently a PhD student with the mobile and wireless research centre at the school of Engineering, University of Greenwich, United Kingdom. His research interest includes design and performance evaluation of routing protocols in mobile ad hoc wireless networks.

© 2011 ACADEMY PUBLISHER

Dr Panos S Bakalis received his BSc in Electrical Engineering, Athens, 1975, and his PG Diploma in Electronics and Control in 1980, at CLP London. He received his MSc in Systems Engineering 1982, and his PhD in Control Engineering both at City University London. From 1986 - 92 he was Senior Lecturer at Thames Polytechnic, London and from 1992 - 96 became Senior Lecturer in the School of Computing at the University of Greenwich. Since then, he moved to the Department of Computer and Communications at the Medway School of Engineering, University of Greenwich where he has worked as a Senior Lecturer in Computer Networking. His research interests are in computer process control and optimization of large-scale systems. He has published papers in international Control Conferences and Journals. From 2008 he has widened his research interests to include the field of Ad Hoc Wireless Computer Networks Protocols (MANET) using OPNET Modeler. He has published several papers in International Communications Conferences and Journals. As MSc Programme Leader in Computer Networking he is supervising students for MSc projects and PhD thesis, in the capacity of MANET field.

Prof. Predrag Rapajic received his BE in 1982, University of Banjaluka, Bosnia and Herzegovina, ME in 1988, University of Belgrade and his PhD in 1994 from the University of Sydney, Australia. Before and after his PhD, he held several full time industrial positions, the latest one in 1996 with Motorola, Sydney. He held academic positions at the University of Sydney 1990-1995, the Australian National University, Canberra, Australia 1996-2000 and the University of New South Wales, Sydney, Australia 2000-2005. He is currently holding chair as Professor of Communication Systems and he is director of research program in Computer and Communications Engineering, University of Greenwich, UK. Prof. Rapajic's research interests include adaptive multi-user detection, equalization, error control coding, mobile communication systems, multi-user information theory, information capacity and modelling of time variable communication channels. Prof Rapajic has published more than 180 highly influential research papers in IEEE Transactions, books, peer-refereed international journals and conferences in the area of mobile communications

Kwashie A Anang received his Diploma in Electrical and Electronic Engineering from the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana in 1997 and his BEng degree in Electrical and Electronic Engineering and MSc degree in Wireless Communication from University of Greenwich in 2005 and 2007. He is currently doing his PhD with the University of Greenwich. His research interest includes next generation cellular wireless systems, mobile ad hoc wireless networks routing protocols and antenna design.

Titus Ikechukwu ENEH received his Bsc in Electrical and Electronic Engineering in 1999 from Enugu State University of Science and Technology (ESUT) Enugu, Nigeria. Msc in Electrical and Electronic Engineering from University of Greenwich Uk in 2005. Currently doing his PhD with the University of Greenwich. His research interest includes adaptive Multi-user detection, Information capacity and MIMO OFDM.

© 2011 ACADEMY PUBLISHER