Evaluating Energy-aware Behavior of Proactive and Reactive Routing Protocols for Mobile Ad Hoc Networks

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Keywords: MANET, Routing, Proactive, Reactive, Energy-aware, Power-saving

Abstract

Ad hoc routing technology has been developed primarily for networks of mobile nodes. In many cases the operational life of a node will be limited by its power source, so power consumption can be a critical issue. All the layers of communication are coupled in power consumption. Ad hoc routing protocols may consume different amounts of power and their routing decisions may be conditioned. Power consumption must be distributed on the nodes of the network and the overall transmission power for each connection must be minimized. We have therefore modelled two contrasting protocols for the MANETs (Mobile Ad Hoc NETworks), namely the reactive protocol DSR (Dynamic Source Routing) and the proactive protocol OLSR (Optimized Link State Routing). DSR and OLSR have been simulated by *ns-2* Network Simulator. We will analyze these two protocols with particular attention to their energy performance.

1. INTRODUCTION

In the last few years, thanks to the proliferation of wireless devices, the use of mobile networks is growing very fast. In particular, a very large number of recent studies focused on Mobile Ad-hoc Networks (MANETs) [1]. A MANET is a network without fixed infrastructure, in which every node can act as a router; this is required when the two end-points interchanging data are not directly within their radio range. This kind of network, self-organizing and self-reconfiguring, is very useful when it is not economically practical or physically possible to provide a wired networking infrastructure (battlefield scenarios, natural disasters, etc.). The performance of a mobile ad hoc network depends on the routing scheme employed, and the traditional routing protocols do not work efficiently in a MANET. This kind of network, in fact, has a dynamic topology (every node can move randomly and the radio propagation conditions change rapidly over the time) and a limited bandwidth (so that the control traffic overhead must be reduced to the minimum) [2]. Developing routing protocols for MANETs has been an extensive research area in recent years, and many proactive and reactive protocols have been proposed from a variety of perspectives ([3]-[7]). These protocols try to satisfy various properties, like: distributed implementation, efficient utilization of bandwidth and battery capacity, optimization of metrics (like throughput and end-to-end delay), fast route convergence and freedom from loops.

In this work, we will try to analyze the performance of a MANET from the energetic point of view. Since mobile hosts today are powered by battery, efficient utilization of battery energy is important. Battery life, therefore, can also affect the overall network communication performance: when a node exhausts its available energy, it ceases to function and the lack of mobile hosts can result in partitioning of the network. Therefore, reducing power consumption is an important issue in ad hoc wireless networks. But the majority of the routing proposals to date have not focused on the power constraints of unethered nodes: traditional routing protocols tend to use shortest path algorithms (minimum hop count) without any consideration of energy consumption, often resulting in rapid energy exhaustion for the small subset of nodes in the network that experience heavy traffic loads. In recent years a number of power-aware metrics have been proposed (like [8]-[14], [18]-[21]). Since the majority of these metrics have been applied to DSR routing protocol, we decided to perform an energetic evaluation of this protocol, to verify its power consumption features and to compare them with a different type of protocol, i.e. the proactive protocol OLSR. This way, we can test the energetic behavior of two different routing protocols, focusing on their weak and strenght points, in order to address new directions towards the definition of new energy-aware metrics. We pursue a double objective. Firstly, we want to evaluate how different approaches affect the energy usage of mobile devices when using two of the most promising routing protocols currently considered under IETF's MANET working group [1]. In fact, among the great variety of different proposals, DSR and OLSR have arrived to the RFC status. Secondly, we want to check whether or not, under the IEEE 802.11 technology, some of the power aware routing proposals in the literature could be efficiently utilized to extend the lifetime of nodes and connections. In fact, we believe that, because of the overhearing and idle activity of a network interface card based on the current IEEE 802.11 technology, a majority of the proposed schemes not only are quite tricky to be implemented, but also could not achieve their assumed benefits. The simulation results presented in this paper were obtained using the *ns-2* simulator [22], which is a discrete event, object oriented, simulator developed by the VINT project research group at the University of California at Berkeley.

In this work, we will simulate a mobile ad hoc network evaluating the energy impact of different protocols on the network lifetime. The DSR and OLSR routing protocols are introduced in section 2.. Section 3. is an overview of the scenario and model used for the power consumption modelling. The simulation results are then presented. Protocol enhancements are suggested in section 4., and finally some conclusions are drawn.

2. ROUTING APPROACHES FOR MANETS

Routing protocols for mobile ad hoc networks have different features. About the way to exchange routing information, the main difference is between reactive and proactive routing protocols. A reactive (or on-demand) routing protocol determines routes only when there is any data to send. If a route is unknown the source node initiates a search to find one and it is primarily interested in finding any route to a destination, not necessarily the optimal route. A proactive routing protocol, instead, attempts to maintain routes to all destination at all time, regardless of whether they are needed. To support this, the routing protocol propagates information updates about network's topology or connectivity through the network. From the nodes organization point of view, we can have a hierarchical routing system (some routers form a sort of backbone) or a flat address space (where the routers are peers of all others).

2.1. A reactive protocol: DSR

The Dynamic Source Routing protocol (DSR) is a reactive protocol ([16]). This generates less overhead and provide more reliable routing than proactive routing, but at the cost of finding the optimal route. Mobile hosts do not utilize periodic messages, with a consequently energetic advantage in battery consumption. DSR updates automatically only when it needs to react to changes in the routes currently in use. This protocol is simple and efficient. The protocol is composed of the two main mechanisms of "Route Discovery" and "Route Maintenance", which work together to allow nodes to discover and maintain routes to arbitrary destinations in the ad hoc network. Other advantages of the DSR protocol include easily guaranteed loop-free routing and very rapid recovery when routes in the network change. The DSR protocol is designed mainly for mobile ad hoc networks of up to about two hundred nodes, and is designed to work well with even very high rates of mobility.

2.2. A proactive protocol: OLSR

The Optimized Link State Routing (OLSR) protocol is an optimization of the classical link state algorithm, tailored to the requirements of a MANET ([17]). Because of their quick convergence, link state algorithms are somewhat less prone to routing loops than distance vector algorithms, but they require more CPU power and memory. They can be more expensive to implement and support and are generally more scalable. OLSR operate in a hierarchical way (minimizing the organization and supporting high traffic rates). The key concept used in OLSR is that of multipoint relays (MPRs). MPRs are selected nodes which forward broadcast messages during the flooding process. This technique substantially reduce the message overhead as compared to a classical flooding mechanism (where every node retransmits each message received). This way a mobile host can reduce battery consumption. OLSR provides optimal routes (in terms of number of hops). The protocol is particularly suitable for large and dense networks as the technique of MPRs works well in this context.

3. SIMULATIONS

3.1. Energy Consumption Model

A generic expression to calculate the energy required to transmit a packet p is: $E(p) = i * v * t_p$ Joules, where: i is the current consumption, v is the voltage used, and t_p the time required to transmit the packet. We suppose that all mobile devices are equipped with IEEE 802.11g network interface cards (NICs). The energy consumption values were obtained by comparing commercial products with the experimental data reported in [14].

The values used for the voltage and the packet transmission time were: $v = 5$V and $t_p = (\frac{p_h}{6*10^6} + \frac{p_d}{54*10^6})$ s, where p_h and p_d are the packet header and payload size in bits, respectively. We calculated the energy required to transmit and receive a packet p by using: $E_{tx}(p) = 280mA * v * t_p$ and $E_{rx}(p) = 240mA * v * t_p$, respectively. Since receiving a packet and just being idle, i.e., when simply powered on, are energetically similar [14], we assumed $E_{idle}(t) = 240mA * v * t$, where t is the NIC idle time.

Moreover, we account for energy spent by nodes overhearing packets. As shown in [14], we assume the energy consumption caused by overhearing data transmission is the same as that consumed by actually receiving the packet.

For the purpose of evaluating the effect of overhearing, we modified the energy model to account not only for the energy expenditure due to transmission and reception, but also for overhearing packet exchanges. Thus, the total amount of energy, $E(n_i)$, consumed at a node n_i is determined as:

$$E(n_i) \quad = \quad E_{tx}(n_i) + E_{rx}(n_i) + E_o(n_i), \qquad (1)$$

where E_{tx}, E_{rx}, and E_o denote the amount of energy expenditure by transmission, reception, and overhearing of a packet, respectively. Notice that, as the average number of neighboring nodes affected by a transmission increases, the network is more dense, and so Eq. 1 implies that the packet overhearing causes much more energy consumption.

3.2. Metodology and Simulation parameters

The simulation results presented in this paper were obtained using the *ns-2* simulator. *ns-2* is a discrete event, object oriented simulator developed by the VINT project research group at the University of California at Berkeley. The simulator has been extended to include: node mobility, a realistic physical layer that includes a radio propagation model, radio network interfaces and the IEEE 802.11 MAC protocol using the Distributed Coordination Function (DCF). The radio propagation model includes collisions, propagation delay and signal attenuation. In our experiments we have set a 54Mbps data rate, and a radio range of 250 meters.

To compare the DSR and the OLSR protocols, we simulated a dense wireless network, with 50 nodes moving in a 870×870 m area (with a density of about 66 nodes/km^2). Each node moves in this area according to the random waypoint mobility model, with a speed of 5 m/s and no pause time. In terms of traffic we studied two different situations: in a first case, we considered a fixed connection pattern, with 12 CBR/UDP sources generating 20 packets/s (packet size is set to 512 bytes), in a second case, we simulated a variable connection pattern, where a single, 10 seconds lasting, connection between two random nodes of the network is created every 10 seconds of simulation. The duration of each simulation is 450 seconds, with a startup period during the first 100 seconds (where no traffic is generated).

Due to the random nature of the mobility model we used, the results of each simulation were considered as IID random variables (X1, X2, $\ldots$, Xn) with finite mean. We repeated the simulations, i.e., we varied to the value of n, to obtain an estimation with a 95 percent confidence interval, by using the following definition:

$$\overline{X}(n) \pm t_{n-1,0.95}\sqrt{\frac{S^2(n)}{n}} \qquad (2)$$

where $t_{n-1,0.95}$ is the upper 0.95 critical point for Student's t distribution with n-1 degrees of freedom, $X(n)$ is the sample mean and $S^2(n)$ is the sample variance.

We mainly analyzed the time when each node dies due to lack of remaining battery (i.e., expiration time of nodes) as well as the lifetime of connections, which captures the effects of disconnections due to lack of possible routes (i.e., expiration time of connections). We also measured the average end-to-end delay per packet, as well as the throughput. For the purpose of investigating the effect of overhearing, and according to the energy model described earlier, we modified the *ns-2* energy model to allow measuring the battery energy consumed when overhearing packet exchanges, as well as the energy due to the idle operation mode.

3.3. Simulation results

3.3.1. Idle Power and Overhearing influence

Our first task is to evaluate the influence of Idle Power and Overhearing over energy consumption in a MANET. These effects reduce the network lifetime, consuming rapidly the nodes' batteries with very low differences between reactive and proactive protocols. As we can notice from Fig. 1, even with a low idle state energy consumption, all the nodes in the network tend to exhaust their battery at the same time (i.e. when idle power consumes all the device energy), no matter if we are evaluating DSR or OLSR protocol.

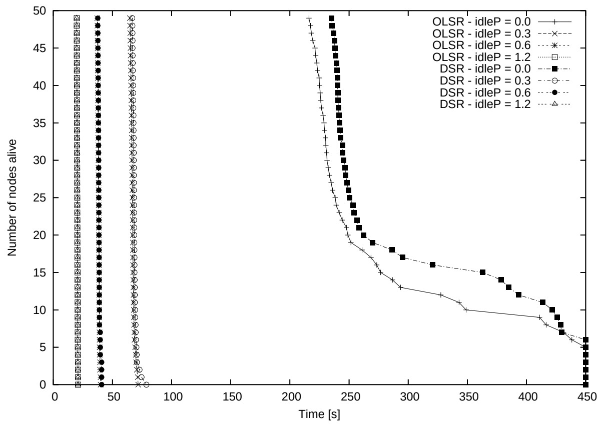

Figure 1. Number of Nodes Alive vs Time, varying Idle Power.

To evaluate the influence of Overhearing effect, we modified *ns-2* code to choose if decrease or not the energy of a node when it overhears packets. Then, we simulated the DSR and OLSR protocols with and without this effect (setting the initial energy to a lower value, because we excluded the energy consumption in idle state). The results, from energetic point of view, can be seen in Fig. 2.

The same results are mumerically shown in table I. As we can see, the amount of energy spent in overhearing is larger than 90% in both protocols, because it depends primarily on nodes density and transmission range in the network.

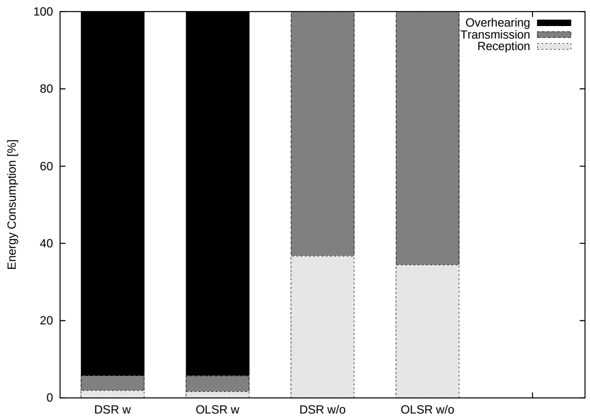

Figure 2. Energy percentage consumption by type, with (w) and without (w/o) Overhearing effect.

Table 1. Energy percentage consumption by type: Transmission (Tx), Reception (Rx) and Overhearing (Ov).

	DSR w/o	OLSR w/o	DSR w	OLSR w
Tx	63.32	65.60	3.84	4.10
Rx	36.68	34.40	1.90	1.59
Ov	0.00	0.00	94.27	94.31

Because Idle Power and Overhearing effects dominate the energy consumption in the simulation of a dense, high-trafficated network, to evaluate the actual differences between reactive and proactive protocols in a MANET from energetic point of view, we will ignore both of these effects in the rest of this work. In the implementation of DSR protocol, this last consideration leads to an important remark. When we neglect the energy consumption in overhearing packets, we must turn off the promiscuous mode of the protocol. This means that DSR can not rescue routing information from packets directed to another node. Therefore, in the following of this paper, we will consider the DSR protocol without the promiscuous mode operation.

3.3.2. Fixed Connection Pattern

We simulated the DSR and OLSR protocols using the minimum hop count routing policy. This is the same of using MTPR policy (Minimum Total Transmission Power Routing, [15]), because every packet transmission costs the same energy (therefore the protocols will search the minimum hop route, to save energy). In this first case, the network experiments an high, static traffic load, with 12 CBR/UDP traffic sources sending a constant amount of data between 100 and 400 simulation seconds. Fig. 3 shows the number of remaining nodes in the network over time, plotting the halt-time of mobile nodes.

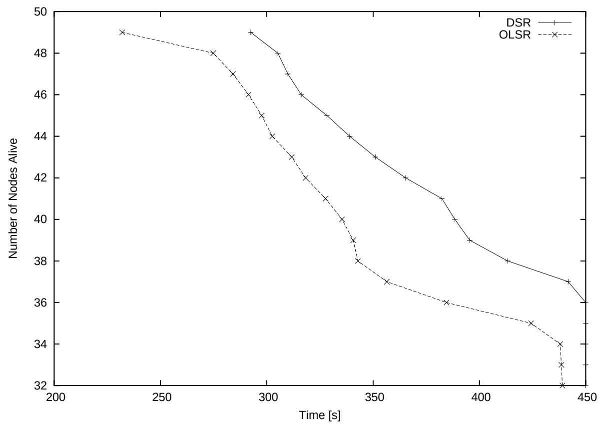

Figure 3. Nodes Alive vs Time, with Fixed Connection Pattern.

The more the line is on the top right of the plot, the more the protocol prolongs the nodes lifetime (thus prolonging the lifetime of the entire network). We can see how DSR takes advantage from its reactive nature: in the first 100 seconds of simulation, while OLSR spends energy to update the network topology, DSR does not generate packets (because there is no data transmission in the network). However, the gap is between 30 and 80 seconds, demonstrating the good performances of OLSR with high traffic rates. To have a better vision of the behaviour of the routing protocols with respect to the traffic, we can plot the lifetime of the connections of our simulated MANET. The Fig. 4 shows how the response of OLSR and DSR is very similar (but, obviously, shifted: the proactive protocol starts its periodic exchange of message at the beginning of the simulation).

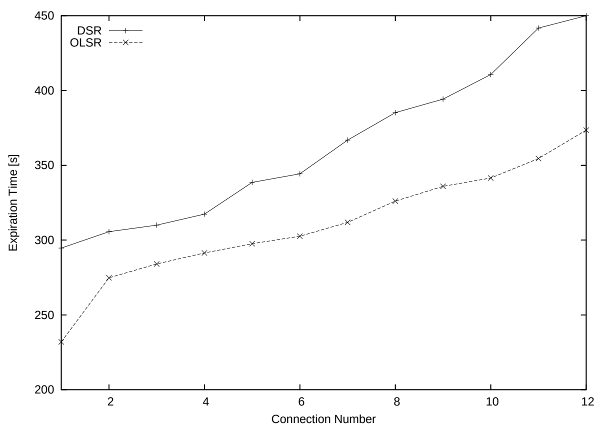

Figure 4. Connection Expirations, with a Fixed Connection Pattern.

To evaluate the performance of the protocols, we can extract from simulation some classical network metrics, like the data packet delivery ratio (the percentage of data packets delivered to the destination), the end-to-end delay (the time interval between the moments the packet is sent and received by the source and destination nodes) or the routing overhead (the amount of control informations sent over the data traffic). These parameters are shown in table II.

Table 2. DSR - OLSR performance evaluation, with Fixed Connection Pattern.

	DSR	OLSR
Packet ratio (%)	92.68	71.15
E2E delay (ms)	12.23	13.54
Overhead (%bytes)	0.86	14.77

We can see how the overhead of OLSR is considerably higher than the one of DSR. The data packet delivery ratio is very different between the two protocols. To know the reason, we plotted the throughput of the dynamic scenario over simulation time in Fig. 5.

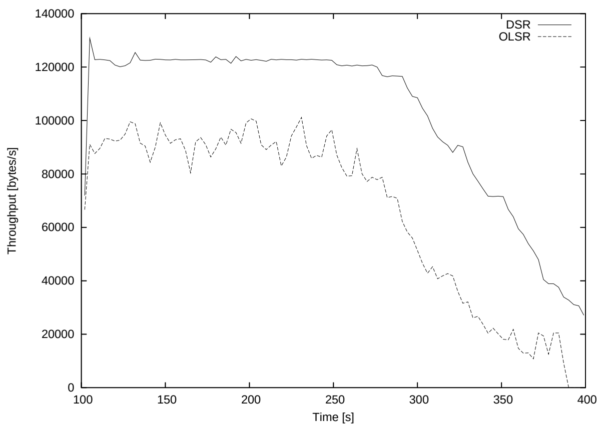

Figure 5. Throughput vs Time, with a Fixed Connection Pattern.

Before of the expiration of connections, DSR has a stable throughput, while the one of OLSR varies a lot. This is why DSR, being reactive, rapidly reacts to path changes, while these changes lead to packet losses in OLSR. This could be repaired updating the routing tables of OLSR more frequently, but this could lead to very high values of routing overhead. These issues are better analyzed in section 3.3.4..

3.3.3. Variable Connection Pattern

In a second time, we simulated the same, dynamic network topology to have a variable connection pattern: in this case, a random connection (512 bytes packets, sent at a rate of 20 packets/s) is generated every 10 simulation seconds. Every simulation lasts exactly 10 seconds: this way, we can expect a constant throughput of 10240 bytes/s for all traffic time (between 100 and 400 seconds). In this scenario, the reactive protocol will have to work a little more, to continuously find new routes to the destinations added by the connection pattern. Fig. 6 shows nodes lifetime, for the simulated network.

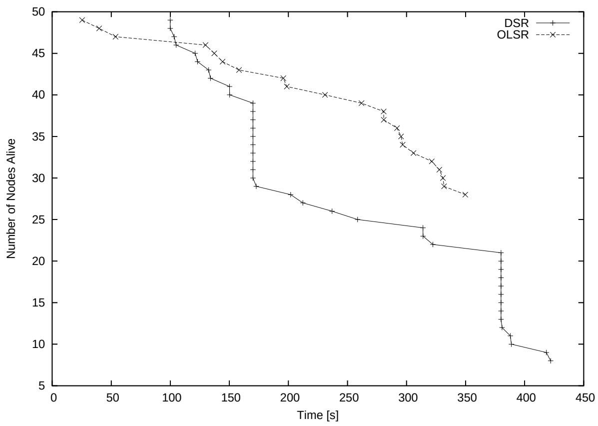

Figure 6. Nodes Alive vs Time, with Variable Connection Pattern.

The results are different from the previous connection pattern: while DSR experiments no energy consumption in the first 100 seconds of simulation, with OLSR protocol most nodes can prolong their lifetime over the simulation. Moreover, DSR activity causes many simultaneous lacks of energy, corresponding to RREQ broadcast storms. The behavior of OLSR, then, leads to a better distribution of energy consumption over the network in this case. To see the protocol performance in terms of connections lifetime, we repeated the simulation providing the nodes with enough energy to survive all simulation time. So, we can expect a linear plot of connections expirations over time, according to equation 3. This equation models expected expiration time (ET_{exp}) for every connection i.

$$ET_{exp}(i) = 100 + 10 \cdot i \tag{3}$$

Then, we can plot the Connection Expiration Delay ($ED(i)$) as the difference between the expected value and the measured one, as shown in 4, where $ET_{sim}(i)$ is the expiration time of connection i, taken from the simulations.

$$ED(i) = ET_{sim}(i) - ET_{exp}(i) \tag{4}$$

Fig. 7 plots the values of $ED(i)$ for DSR and OLSR protocols, in the simulated scenario: a positive value corresponds to a delay in the delivery of the last connection packets, while a negative value represents an early expiration (due to an unrecovered path loss).

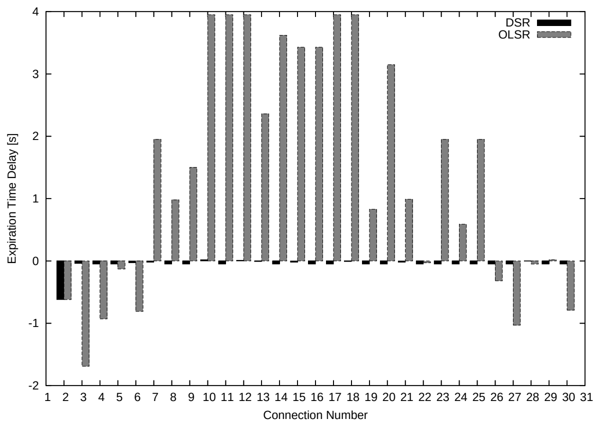

Figure 7. Connection Expirations Delays, with a Variable Connection Pattern.

As we can see, DSR performs well in terms of connection delay, delivering almost all packets without delay (even if the reactive path construction introduces some delay for every route request). On the other hand, OLSR shows high delays (up to 4 seconds), because it experiences problems with the simulated mobility rate (as stated in the previous paragraph).

To compare clearly the performance of the protocols, table III shows the values of considered metrics.

Table 3. DSR - OLSR performance evaluation, with Variable Connection Pattern.

	DSR	OLSR
Packet ratio (%)	98.32	72.69
E2E delay (ms)	9.82	35.98
Overhead (%bytes)	1.98	222.42

As expected, OLSR has an high average end-to-end delay value (influenced by the delay values previously seen), while the average end-to-end delay of DSR has to cope with the path construction delay. With respect to the previous simulation, the higher value of overhearing percentage is mostly due to the lower amount of data sent (remember that the normalized control protocol overhead is given by the ratio between routing packets sent and data packets received). To better justify the low value of OLSR data packets delivery ratio, we plotted the throughput over time for this simulation in Fig. 8.

As in the previous case (fixed connection pattern), the DSR throughput over time shows an almost stable behavior, while OLSR value changes frequently over the time. In the following section, we will analyze the relationship between protocols performance in terms of throughput and nodes mobility.

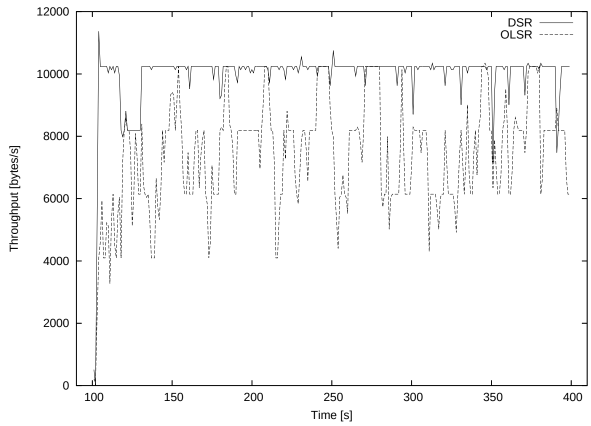

Figure 8. Throughput vs Time, with a Variable Connection Pattern.

3.3.4. Influence of mobility over performance

The throughput of OLSR is very low, and it is due to an improper setting of protocol parameters: the refresh period of the paths must depend on the mobility degree of hosts (5 m/s in our case) to maintain paths updated and avoid losses. To verify this hypothesis, we repeated the fixed connection pattern simulation with different degrees of nodes mobility, maintaining the same refresh time parameter for OLSR protocol (namely, 1 HELLO message per second). In Fig. 9, we can observe that, indeed, the packet delivery ratio decreases very fast with an increasing mobility for the OLSR protocol. To avoid this effect, we must adjust the OLSR's parameters to appropriate values.

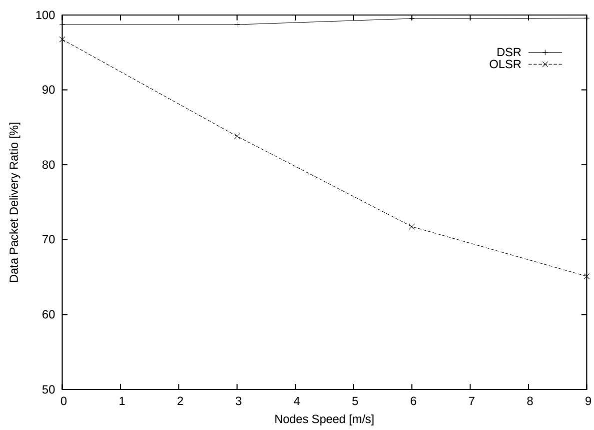

Figure 9. Packet Delivery Ratio variation with speed.

To better see the slow reaction of OLSR to path changes in the network, we plotted the throughput over time with different nodes speed, in figures 10, 11 and 12.

From the figures, it is clear how DSR rapidly reacts to topology changes, while OLSR can't reach the same perfor-

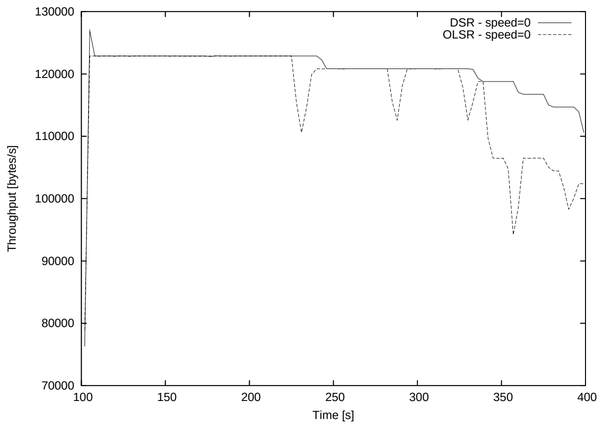

Figure 10. Throughput vs Time, with speed = 0 m/s.

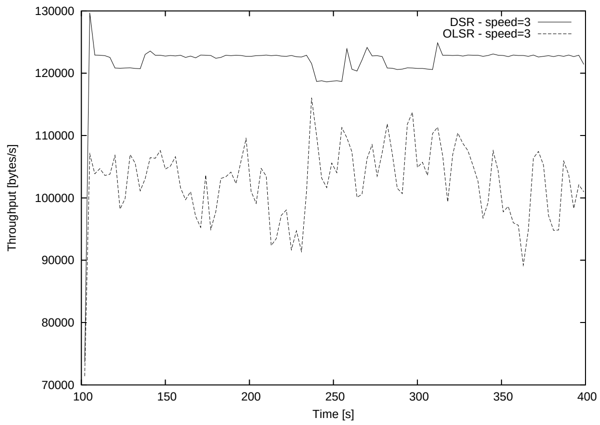

Figure 11. Throughput vs Time, with speed = 3 m/s.

mance values.

4. ENERGY ISSUES

Our simulations demonstrate how, with a static connection pattern, DSR protocol outperforms OLSR from energetic point of view, taking advantage from its reactive nature. When network traffic becomes more variable, instead, the higher load requested to the reactive protocol to dinamically find paths to the destinations makes OLSR more suitable to this kind of networks (dense and high trafficated). We can also notice how DSR is more adaptive to dynamic networks, rapidly recoverying path losses: this leads to better performance in terms of average throughput. Only with a low nodes mobility OLSR can achieve good results in terms of end-to-end delay and load balancing (because of its global topology knowledge), but this advantage is lost when nodes mobility increases. To take profit by these features, OLSR needs a better tuning of topology updates, in order to improve its performance. In this case, new power-aware metrics could be suc-

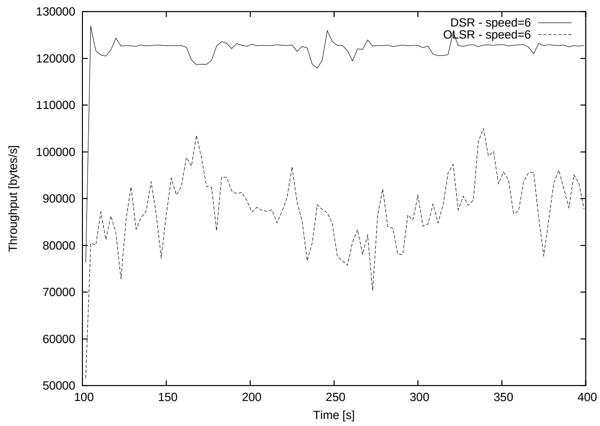

Figure 12. Throughput vs Time, with speed = 6 m/s.

cessfully applied to both protocols to improve their energetic behavior. Future works could focus on this issue.

5. CONCLUSIONS

In this paper we analyzed some routing protocols from the energetic point of view. Our simulations show that a reactive protocol takes advantage from its routing policy, but a proactive routing protocol can perform well with high traffic load and a variable traffic pattern. If the mobile network is very dense, the problem of overhearing seriously affects the lifetime of nodes, independently of the routing protocol. This problem must be investigated at different network layers, i.e. introducing a good sleep mode policy for the devices. At the routing layer, we notice that we require new power-aware metrics for protocols, especially to OLSR, to improve its performance in MANETs. Future works will focus on new energy saving policies for OLSR and DSR and on comparing the effectiveness of these new policies.

REFERENCES

[1] Internet Engineering Task Force, "Manet working group charter", http://www.ietf.org/html.charters/manet-charter.html.

[2] C.-K. Toh "Maximum Battery Life Routing to Support Ubiquitous Mobile Computing in Wireless Ad Hoc Networks", in IEEE Communication Magazine, June 2001

[3] E.Royer and C.-K. Toh, "A Review of Current Routing Protocols for Ad Hoc Mobile Wireless Networks", IEEE Personal Communications Magazine, Vol. 6, No. 2, April 1999.

[4] C-K. Toh, "Associativity Based Routing For Ad Hoc Mobile Networks", Wireless Personal Comm. Journal,

Special Issue on Mobile Networking and Computing Systems, Vol. 4, No. 2, Mar. 1997.

[5] Z.J. Haas, "A New Routing Protocol for the Reconfigurable Wireless Networks", Proceedings of the ICUPC'97, San Diego, CA, Oct. 1997.

[6] V.D. Park, M.S. Corson, "A Highly Adaptive Distributed Routing Algorithm for Mobile Wireless Networks", IEEE lNFOCOM'97, Kobe, Japan, 1997.

[7] C.E. Perkins, E.M. Royer, "Ad-hoc On-Demand Distance Vector Routing", Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications, Feb. 1999.

[8] S. Lindsey, K. Sivalingam, C. S. Raghavendra, "Power Optimization in Routing Protocols for Wireless and Mobile Networks," Handbook of Wireless Networks and Mobile Computing, I. Stojmenovic, Ed., Wiley, 2001.

[9] S. Singh, M. Woo, C. S. Raghavendra. "Power Aware Routing in Mobile Ad Hoc Networks," Proc. 4th Annual Int'l. Conf. Mobile Comp. and Net., Oct. 1998, pp. 181-90.

[10] C. E. Jones et al., "A Survey of Energy Efficient Network Protocols for Wireless Networks," Wireless Net. J., vol.7, no. 4, Aug. 2001, pp. 343-58.

[11] S-L. Wu, Y-C Tseng and J-P Sheu, "Intelligent Medium Access for Mobile Ad Hoc Networks with Busy Tones and Power Control," IEEE Journal On Selected Areas In Communications, Vol. 18, No. 9, September 2000.

[12] S. Singh and C. S. Raghavendra, "PAMAS - Power Aware Multi-Access protocol with Signalling for Ad Hoc Networks," ACM SIGCOMM, Computer Communication Review, July 1998.

[13] Peng-Jun Wan, Gruia Calinescu, Xiangyang Li, Ophir Frieder, "Minimum-Energy Broadcast Routing in Static Ad Hoc Wireless Networks", IEEE INFOCOM, Anchorage, AK, 2001.

[14] Laura Feeney, M. Nilsson, "Investigating the Energy Consumption of a Wireless Network Interface in an Ad Hoc Networking Environment," IEEE INFOCOM, Anchorage, AK, 2001.

[15] Dongkyun Kim, J.J Garcia Luna Aceves, K. Obraczka, J.-C. Cano, P.Manzoni, "Power aware routing based on the energy drain rate for mobile ad hoc networks", Wireless Communications, 2005

[16] David B. Johnson, David A.Maltz, Yih-Chun Hu, and Jorjeta G. Jetcheva, "The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks DSR", Internet Draft, February 2002.

[17] P.Jacquet, P.Muhlethaler, T.Clausen, A.Laouiti, A.Qayyum, L.Viennot, "Optimized Link State Routing Protocol for Ad Hoc Networks"

[18] J.-E. Garcia, A. Kallel, K. Kyamakya, K. Jobmann, J.-C. Cano, P. Manzoni; "A Novel DSR-based Energy-efficient Routing Algorithm for Mobile Ad-hoc Networks" IEEE INFOCOM, 2003.

[19] C. Taddia, A. Giovanardi, G. Mazzini, M. Zorzi; "Energy efficient unicast routing protocols over 802.11b" IEEE GLOBECOM 2005.

[20] Andrew McCabe, Mikael Fredin, Alan Cullen, Leif Axelsson; "A power consumption study of dsr and olsr" IEEE GLOBECOM 2005.

[21] Nguon Taing, Sakchai Thipchaksurat, Ruttikorn Varakulsiripunth, Hiroshi Ishii; "Performance Improvement of Dynamic Source Routing Protocol for Multimedia Services in Mobile Ad Hoc Network" IEEE INFOCOM, 2005.

[22] K. Fall and K. Varadhan, (Eds.) "ns Notes and Documents", The VINT Project. UC Berkeley, LBL, USC/ISI, and Xerox PARC, February 25, 2000. Available from http://www.isi.edu/ salehi/ns_doc/.