Energy Consumption Rate-Based Routing for Mobile Ad Hoc Networks

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***Abstract*— This paper describes an adaptive routing mechanism based on the energy consumption rate of nodes for on-demand routing protocols in mobile ad-hoc networks. Our algorithm allows a fairly energy consumption during route establishment by building routes that are lower congested than the others. To do this, the congestion information is obtained from a computed cost that depends mainly on the energy consumption rate. The main features of our mechanism are that it is simple, efficient and it can be applied for any on-demand routing protocol. We evaluate through simulations the performance of the AODV routing protocol including our scheme, which we called AODV-energ, and we compare it with the basic AODV routing protocol. Results show that our new concept outperforms the basic AODV. Indeed, our scheme reduces to 20**

***Index Terms*— mobile ad-hoc network, on-demand routing protocols, network lifetime, energy conservation, adaptive unicast routing.**

I. Introduction

A Mobile Ad-hoc NETwork (MANET) is a set of wireless mobile nodes dynamically forming a temporary network. The goal of this architecture is to provide communication facilities between end-users without any centralized infrastructure. Note that, in an infrastructure network, if a node looses connection with the coordinator, then it cannot transmit any packets. However, with a distributed protocol, if a node looses connection with some nodes, it may still be able to maintain some connectivity. In a such network, each mobile node operates not only as a host but also as a router. It is also possible to have an access to some hosts in a fixed infrastructure depending on the kind of mobile ad hoc network available. Some scenarios where an ad hoc network could be used are business associates sharing information during a meeting, military personnel relaying tactical and other types of information in a battlefield, and emergency disaster relief personnel coordinating efforts after a natural disaster such as a hurricane, earthquake or flooding. In fact, in such scenarios, maximizing the network lifetime is a very important deft since recharging battery is very difficult (hard) to do in such conditions. To this end, there are several works that have been presented [9] in order to extend network connectivity based on energy conservation mechanisms. The network connectivity notion is strictly related to the possibility of routing between all nodes in the network. Indeed, the goal behind is to minimize the energy consumption while maintaining the existing of routes between nodes. The works that have been presented in the literature dealing with the energy exhaustion problem, propose different strategies to enhance performance based on power saving. Indeed, these strategies address the incorporation of energy conservation at all layers of the protocol stack for wireless networks [9].

In this paper, we discuss some works related to three main classes of power saving. The first one focus on power aware routing. Research works belonging to this class have proposed different routing algorithms based on energy conserving mechanisms for routing in mobile ad hoc networks [14, 15, 16, 17]. Routing based on expected node lifetime (i.e. rate-based) is a very frequently used idea and there are many papers about this [2, 8, 16, 22]. There is a well-known problem with these so called max-min (maximize the minimum residual energy/lifetime) schemes. Avoiding nodes with low residual energy (or lifetime) increases the average path length. These routes consume more energy per-packet and reduce the effective network lifetime – the max-min strategy does not help if many nodes are running out of energy and when a large network is considered. In this work, we use the mean cost rather than minimize maximum cost to select the "best" path. The second class proposes some modifications in 802.11 MAC layer [18, 19, 20] to allow nodes to transmit packet at a low power level. Moreover, nodes can be in two modes: active mode or sleep mode to enable energy conservation depending on communication behavior. The different mechanisms that have been presented in this area use some strategies to decide when a node should transit into a specific mode [7, 21]. The third class concerns the adjustment of

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the transmit power level for every packet in a wireless mobile ad hoc networks [10, 11, 12,13].

We first introduce a simple energy consumption rate-based algorithm for on-demand routing protocols. We are interested in the on-demand routing protocols since this kind of routing concept is efficient and it has the advantage to save energy consumption that is affected by the huge routing overhead comparing to data packets. There are two steps that are considered, route request and route reply broadcasting which are generated by the sources and destinations or by intermediate nodes if the required routing information are available in that nodes, respectively.

In the on-demand routing process, a minimum hops algorithm is always applied to establish routes between sources and destinations. Our work consider another metric in the route establishment process. This parameter includes in route cost computation the rate of energy consumption. We believe that by this way the algorithm avoids nodes that participate in communications more than other and it selects nodes that participate less than the other in the communications.

We integrated our scheme in the AODV (Ad hoc On-Demand Distance Vector) routing protocol introduced in the Draft [4]. This routing protocol consumes less energy than other on-demand routing protocols such as DSDV and TORA as shown in [7]. We investigated the characteristics of route establishment algorithm in AODV protocol. The performance evaluation studied with different useful metrics and different scenarios, show the great benefits of this approach in terms of energy consumption, end-to-end delay, and route establishment delay.

At the end of the paper the most important works that have been done in this area are discussed and different classes of approaches other that presented above are covered.

The remainder of this paper is organized as follows: in Section II, we give the most important characteristics of AODV routing protocol and its main limitations. In Section III, we describe our algorithm in detail. Simulation methodology and performance evaluation of our proposal are investigated in Section IV. We provide a global view of some works related to power conservation in mobile ad-hoc networks in Section V. Section VI concludes the paper by summarizing results and outlining future works.

II. Basic AODV routing protocol

A. Overview

The Ad hoc On Demand Distance Vector (AODV) is a reactive routing protocol. In fact, it is self-starting, enables multi-hop routing between participating mobile nodes wishing to establish and maintain an ad hoc network. This protocol builds routes between nodes only as desired by source nodes. It discovers routes quickly for new destinations, and does not require nodes to maintain routes to non-active destinations. AODV ensures link breakages and breakdowns are handled efficiently. The AODV protocol establish routes using a Route REQuest (RREQ) / Route REPly (RREP) query cycle. So, when a node requires path to destination, it broadcasts RREQ message to its neighbors which includes latest known sequence number for that destination. This message is flooded until information required is complete by any means. Each node receiving the message creates a reverse route to the source. The destination sends back RREP message which includes number of hops traversed and the most recent sequence number for the destination of which the source node is aware. Note that if an intermediate node has a fresh route to the destination it doesn't forward the RREQ and it generates a RREP toward the source. Each node receiving the RREP message creates a forward route to the destination. Thus, each node remembers only the next hop required to reach any destinations, not the whole route.

Each node receives a duplicate of the same RREQ, it drops the packet. Moreover, AODV uses sequence numbers to ensure the freshness of routes. In fact, the routes to any destination are updated only if the new path toward that destination has greater sequence number than the old one or it has the same sequence number but with less number of hosts. So, AODV protocol builds routes between nodes regarding the shortest path parameter.

B. AODV Limitations

Routes in AODV protocol are established based on minimum hop count. This consideration might have a bad effect when the number of communications increases and so it is more likely to include other parameters that have a significant effect on network connectivity and lifetime. Furthermore, power is a very important constraint in wireless network. If a node, that participate in a route establishment, has very low energy, this later will break very soon. Moreover, this can has also a bad effect on the network lifetime: there are some nodes that will dead very faster than another ones. So, this can affect network connectivity if key nodes dead very soon. Note that, key nodes are the nodes that routes cannot be established if they dead when their energy returns to zero. To deal with these problems, the power should be taken into account in the route establishment algorithm. To this end, we propose an energy-aware routing establishment mechanism and we apply it to the AODV routing protocol. The result showed in [22] that the first node in Shortest Path routing metric died sooner than all the battery -cost-aware routing presented in that paper, but most of the other nodes had longer expiration time. The main feature of our work compared to the related works in this area (that will be discussed in Section V) is that is simple and efficient according to the obtained performance enhancement comparing to the results obtained with the basic protocol.

III. Our proposed mechanism

A. Motivation

Having in mind the different problems and constraints described above, that are in general related to routing based on minimum hop count, we propose a simple energy consumption rate-based mechanism that aims to maximize the network lifetime and enhance the performance obtained by the basic AODV routing algorithm. So, the goal is routing or re-routing around nodes that we expect that they have more residual lifetime than other.

The idea of routing based on residual lifetime is used frequently in the literature [2, 8,16,22]. In [16], the authors propose max-min algorithm that use $zPmin$ parameter. This parameter represents the minimum power consumption in the network. The described method require accurate power level information for all the nodes in the network. For large scale sensor networks this is not a feasible assumption. In [8], routes are built based on a computed cost. This cost just take into account the current energy level. Some of the ideas of this paper could be considered as an extension of [8] proposal. However, we use a different way to compute the residual lifetime for each node. We aim to address a very simple design that does not require any addition overhead or packet control to apply the energy aware routing. Moreover, the cost metric that we use in route built is updated periodically according to real power consumption behavior. The feature of our algorithm is that it can be applied to any kind of routing protocol. Furthermore, since reactive routing protocol have benefits for ad hoc networks, our scheme is suitable for on-demand concept and it helps to improve user performance metrics while achieving good energy conservation.

B. Computation of the expected residual lifetime

In our algorithm, we do not only consider the current energy level value of a node as the case of several mechanisms that have been proposed in this area. However, we take into account also the rate of energy consumption at each constant period. In fact, we believe that considering energy rate consumption allows us to get information about the energy exhausted in packet transmission and reception without doing complex computation of these above values. Then, using the estimated rate consumption and residual energy, we compute the expected residual lifetime assuming that the node continues to consume energy with that rate. By this way, we give more real information about the battery lifetime behavior in each node. Moreover, we try to differentiate between nodes that participate in communications more than other nodes even they have the same energy level. At each period of time number j called "update period"[1] and for each node, we follow the following formula to compute energy rate consumption:

$$Rate\_consumpt^{j} = \frac{Remain\_energy^{j} - Remain\_energy^{j-1}}{Update\_period_{j}}$$

where $Remain\_energy^{j}$ is the estimated residual energy computed at update period number j and it is computed as follows:

$$Remain\_energy = Current\_energy - (Nb\_buff\_packet * Trans\_energy)$$

where $Current\_energy$ is the current energy value of the node. For more accurate estimation of this residual energy, we reduce the value of the power that will be consumed to transmit the remaining packets in the buffer noted by Nb_buff_packet. The parameter $Trans\_energy$ quantifies the needed energy for transmitting one packet.

To minimize the bias against transient consumption rate, we use an estimator of Exponentially Weighted Moving Average (EWMA) to smoothen the estimated energy consumption rate values. Let $Rate\_consumpt^{j}_{avg}$ be the average energy consumption rate at step j (for each update period) computed according to the following iterative relationship:

$$Rate\_consumpt^{j}_{avg} = (1-\alpha) * Rate\_consumpt^{j}_{curr} + \alpha * Rate\_consumpt^{j-1}_{avg} \quad (1)$$

where $\alpha \in [0, 1]$[2].

Then, we can estimate the expected residual lifetime in each node considering $Remain\_energy$ and $Rate\_consumpt_{avg}$ values that will be defined at each update period j using the following equation:

$$Residual\_lifetime^{j} = \frac{Remain\_energy^{j}}{Rate\_consumpt^{j}_{avg}} \quad (2)$$

[1]The optimal value of this time period is out of the scope of this paper.

[2]The value of α used in simulation is 0.25.

C. Computation of route establishment cost

Using the residual lifetime value computed using equation 2, each node computes a cost at each route request demand. This cost is defined as following:

$$cost_{res\_life} = Residual\_lifetime^{j} * weight_{k} \qquad (3)$$

where $weight_k$ is a multiplicative factor in the interval [0,1] defined for each energy interval k. Hence, k goes from 1 to 4 referring to four energy intervals: the first one is from 50% to 100% of initial energy value. The nodes that have energy level in this interval are more favorite to participate in the route establishment. So they are assigned with the greatest weight which is equal to 1. The second interval is from 30% to 50%. The nodes in this interval are less favorite to participate in route establishment than the nodes in the first interval. They are assigned with a weight equal to 0.75. The third interval is from 10% to 30%. The nodes in this interval have a low energy level. The protocol should avoid the use of these node if there are other possibilities. The weight related to this interval is equal to 0.5. The last interval goes from 0% to 10%. In the route establishment scheme that we consider, these nodes are strongly avoided. Indeed, they are assigned with the lowest weight which is equal to 0.25. We aim by this way to extend the lifetime of these nodes as possible as if there are some other cost-effective alternative. This yielding small value weight for small interval and a great one for the largest interval.

Now we will explain the benefits and the reasons behind the using of the weight in the cost computation. The computed lifetime is an estimated value based on the mean energy consumption rate in the lasted periods. This generated residual lifetime of nodes varies over time depending on energy consumption rate. So there are some cases where nodes have less energy but generate a long lifetime because they did not participate a lot in communications in the last periods. Hence, we should take about their energy level as a second criteria to generate their cost for route establishment. We give the following example to explain these cases. In Figure 1, the node S would communicate with D. It sends a RREQ to A and B. Nodes A and B have the following values for residual lifetime 65s and 62s, respectively and their energy levels are equal to 20W and 50W, respectively (assume for this example that the initial energy level is equal to 100W). Each node receiving the RREQ packet computes its own cost and includes it in the RREQ packet before forwarding it to S. If we do not use the weight in the cost computation and we only consider the residual lifetime value, the communication between nodes S and D will be through A. However, even A has a longer lifetime than B (which can be explained by the fact that A did not participated a lot in communications in the last periods), it has an energy level less than that of B. Hence, it is more fair to let B participating in route establishment than A.

Node	Next hop	Seq #	Hop count	**Mean cost**	**Min lifetime**	...

TABLE I
NEW FIELDS OF THE AODV TABLE ENTRY

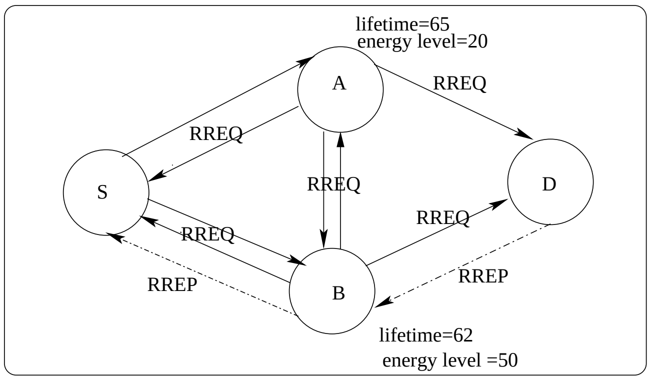

Fig. 1. An example to show the benefits of introducing the weights when computing route cost

D. Integration of our scheme in the basic AODV protocol

As described in Section II, the basic AODV routing protocol uses minimum hop parameter to establish routes between sources and destinations. However, considering the new energy-constraint metric, we follow a new route discovery scheme. Indeed, routes are established based on residual lifetime cost value ($cost_{res\_life}$) defined in Eq.3. Each RREQ packet includes the sum of costs of the traversed nodes in the used path. Then each node maintains for each reverse route the mean cost in the routing table entry and routes are built based on the maximum mean cost defined as follow:

$$cost_{mean} = \frac{\sum cost_{res\_life}}{number_{hops}} \qquad (4)$$

where, $number_{hops}$ is the number of traversed hops. Hence, each routing entry in the routing table is extended with the fiels shown in bold style in Table I.

Furthermore, this new design requires that nodes act at all duplicate RREQ packets to select the maximum cost that can be founded. However, the cost of considering routes without min hops as used in the basic algorithm, could add latency and possibly more routing packet overhead. Therefore, our algorithm should design the energy conserving concept to find a trade-off between maximum lifetime route and data-delivery quality. To this end, routes are updated regarding the extra number of hops in the new route comparing to the old hops count in the previous route. This means that the route is changed when a new one has a high cost and the extra number of hop count in the path could not be more than 3 hops. We claim this condition to deal with the following case that is more likely to happen: For example, given two routes, each with one very high cost node and the rest has a low cost, the metric will prefer the longer one without taking into account the difference between hop count, which is clearly wrong. Indeed, including many nodes to built a route because they have a longer expected lifetime (higher mean cost), has a bad effect on the total network energy that will decrease very fast.

Moreover, nodes that receive the RREP packet includes the minimum residual lifetime value in the reversed path. This allows the source node to avoid as feasible as route failure and so it observe during data communication a timer that is compared with the minimum residual lifetime in the route as figured in Table I. The source sends a RREQ packet before this minimum residual lifetime of the route expires. Furthermore, when we have two routes toward the same destination with the same cost, we consider the route with maximum minimum residual lifetime. By this way, we ensure that the connectivity in a network is maintained for as long as possible.

IV. Performance evaluation

We have implemented our mechanism in the ns-2 simulator. We have extended the AODV protocol to support our energy consumption rate-based algorithm. The latest version of AODV protocol is used. We report in this section the large set of simulations we have done by various network topologies and scenarios. We also provide an analysis of performance obtained.

The energy model used bears similarities to earlier studies [3]. It is assumed that the radio interface, when powered on, consumes 1.15W when listening to the channel for any incoming packet, 1.2W while actually receiving a packet and 1.6W while transmitting a packet.

A. Simulation scenarios

The 50 nodes used in our simulations move in an area of 1500x300 according to a random waypoint mobility model as described in [1]. The radio model is very similar to the first generation WaveLAN radios with nominal radio range of 250m. The nominal bit rate is 2 Mbps. In this mobility model each node moves toward a random destination and pauses for certain time after reaching the destination before moving again. In our simulations, the nodes move at an average rate of 15m/sec. The pause times are varied to simulate different degrees of mobility. The traffic sources start at random times toward the beginning of the simulation and stay active throughout. The sources are CBR (constant bit rate) and generates UDP packets at 4 packets/sec, each packet being 512 bytes. Each simulation is run for 900 seconds simulated time. Each point in the plotted results represents an average of ten simulation runs with different random mobility scenarios. In table II, we summarize the deferent parameters used in our simulations.

Number of nodes	50
Area where nodes move	1500*300
Radio model	WaveLAN radio
Radio Range	250 m
Bit rate	2Mbps
Maximum speed	30 m/s
Sources are CBR	UDP: 4packets/s
Packet size	512 bytes
Time of one simulation	900

TABLE II
PARAMETERS FOR SIMULATION SCENARIOS

B. Simulation metrics

We analyze several QoS metrics to evaluate the performance of our approach and we compare results with the basic AODV protocol. The following metrics are defined:

- **Gain on delivery fraction:** This metric measures the gain (in %) on the delivery fraction at the end of simulations of our new mechanism (aodv_energ), compared with the basic AODV protocol. Note that, the delivery fraction is measured as the ratio of the number of data packets delivered to the destination and the number of data packets sent by the source**.**
- **Route bytes:** It is the **routing overhead** which is measured as the total number of Bytes of transmitted routing packets.
- **Mean delay:** It is the average delay of all the flows that have the same priority in the different stations. The average delay is used to evaluate how well the schemes can accommodate real-time flows.

In order to show the gain on energy and the effect on the connectivity of the network and thus the useful lifetime, we evaluate the following metrics:

- **Gain on remaining energy:** This metric stands for the gain (in %) on the total remain energy at the end of simulations of our new mechanism (aodv_energ), compared with the basic AODV protocol.
- **Behavior of the number of death nodes during simulation**: This metric allows to have an idea on how soon nodes are dying out of power and how many nodes are dead (i.e., have zero energy) during simulation.

C. Simulations results and analysis

We present in this subsection the performance of the basic AODV and our energy consumption rate-based routing algorithm applied to AODV (aodv-energ) for the various metrics presented above. We vary the number of traffic sources and pause times to reflect various loads and mobility[3].

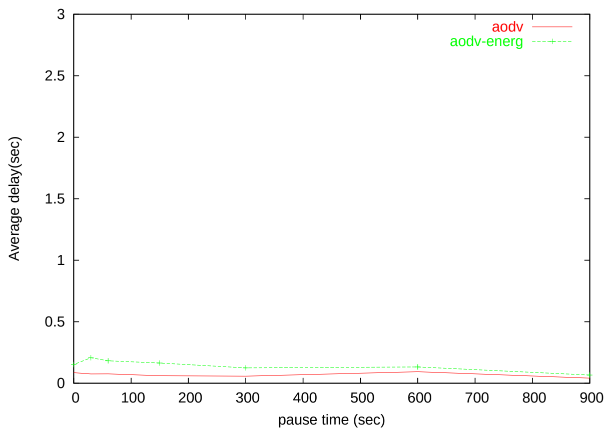

Fig. 2. Average delay for 10 sources

In Figures 2, 3, and 4, we plot the mean delay of our new mechanism and the basic AODV routing protocol. This metric is improved with 20 and 30 sources which demonstrates the efficiency of re-routing based on energy consumption rate. More specifically, low energy consumption rate informs that the node does not participate a lot in communications that include sending, receiving, and forwarding packets. This lets packets follow routes that generate a high cost and so are less congested which yielding to lower delay comparing to the obtained delay with routing based on minimum hops count that does not take into account energy behavior through the time and so ignore the busy nodes. Moreover, we remark that

[3]Note that pause time = 0 means constant movement and pause time = 900 sec means stationary network.

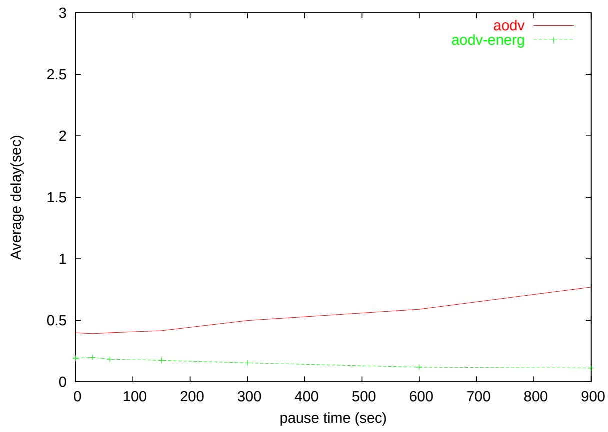

Fig. 3. Average delay for 20 sources

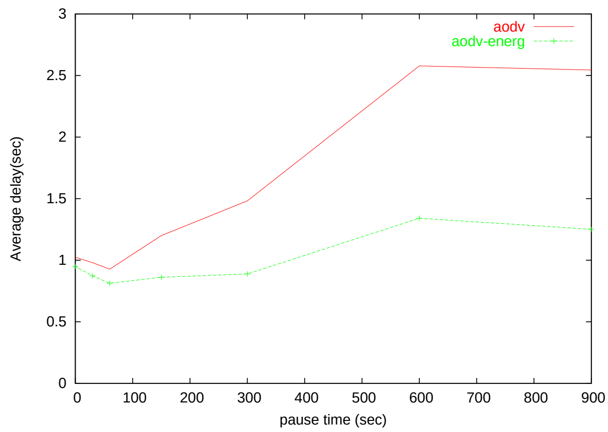

Fig. 4. Average delay for 30 sources

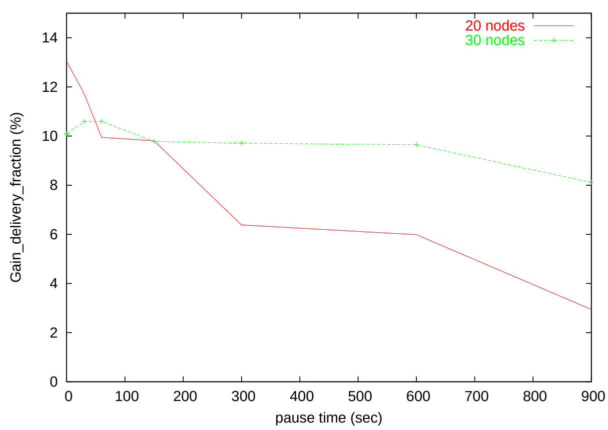

Fig. 5. Gain on delivery fraction for 20 and 30 sources

the improvement on delay increases with low network mobility as the basic AODV does not change routes frequently in the stationary network case. However, in such scenarios, our algorithm allows re-routing and refresh routes including new nodes that have better quality than in the old routes which improves the end to end delay. Note that we mean by a good quality node, the node that is less busy and have more energy than other nodes in the some other alternative route possibilities. Furthermore, we follow the RREQ broadcasting mechanism by source nodes since the minimum residual lifetime in the route will turn to zero soon. By this way, route failures are more avoided than in the basic AODV protocol. There are no improvement in the obtained average delay with low loads (10 sources). Indeed, the obtained results with our mechanism are a little greater than those of the basic AODV which could be explained by the fact that we use routing packet broadcasting in the research of other alternative routes more than in the basic AODV which might be high comparing to the low total load. The plot shown in Figure 6 enforces this claim given that the obtained route bytes of our mechanism is larger than in the original protocol. Moreover, this affects the packet delivery fraction which presents the same little difference between our algorithm and the basic one for the same reasons presented above. However, we obtain a good performance enhancement using 20 and 30 sources as shown in Figure 5[4]. The improvement attempts more than 10 % for 30 sources and 13 % for 20 sources. These results are proved by the fact that routing overhead is low with our new mechanism as shown in Figures 7 and 8.

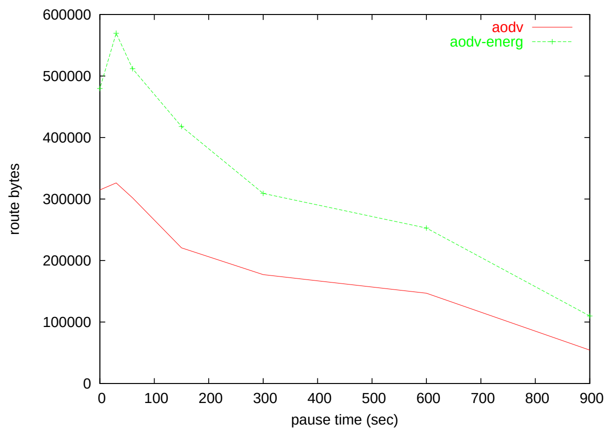

Fig. 6. route bytes for 10 sources

To demonstrate the efficiency of our scheme regarding to the energy consumption, we plot in Figure 9 the gain in the total remaining energy that is obtained at the end

[4]We did not show the results for 10 sources because it has no gain value.

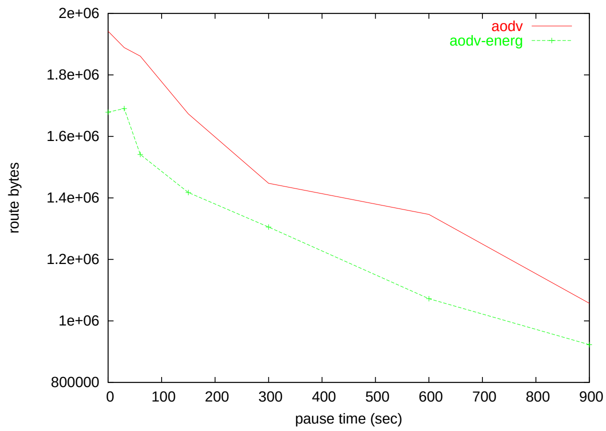

Fig. 7. Route bytes for 20 sources

of simulation. Our algorithm presents an improvement for more than 26 % for 30 sources, more than 17 % for 20 sources, and for more than 10 % for 10 sources. We observe that the gain on energy increases with high load. This show that our addressed mechanism give more benefits when communications increase. Moreover, this metric demonstrate how network longevity can be extended.

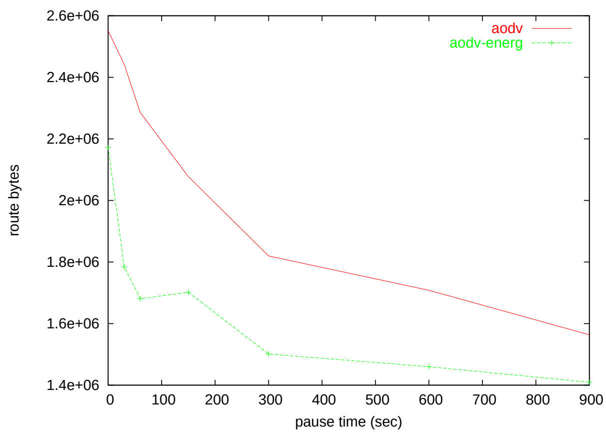

Fig. 8. Route bytes for 30 sources

In Figure 10, we investigate the behavior of the number of dead nodes during simulation. The plot presents how many nodes are dying as a function of simulation time for 20 sources and pause time equal to zero. Indeed, this number has a great importance since it informs about network connectivity. On one hand, the more the large number of survived nodes is, the more routes could be established. On the other hand, when this number is small, communications between some nodes might be impossible. This is due to the fact that the nodes that could participate in the route built between these nodes (sources and destinations) are dead and so there no possibility that they communicate between each other

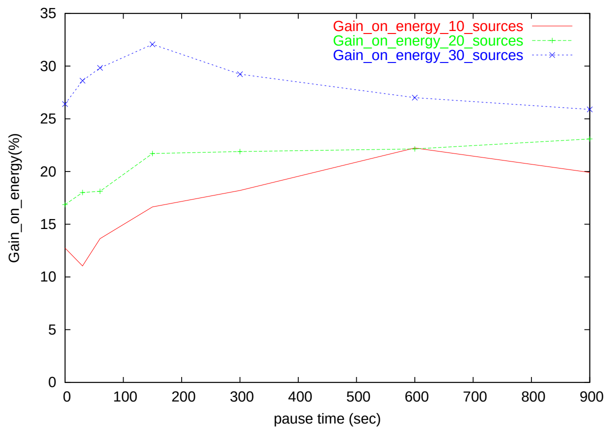

Fig. 9. Gain on total remaining energy

even their battery allow a long lifetime. The experiment that we have done shows that our mechanism is able to keep more survived nodes than the basic AODV protocol. Indeed, there is about 100 second difference between the first died node in the two mechanisms. Moreover, we can see that our algorithm always outperforms the basic protocol during all simulation time. Indeed, the number of survived nodes in our mechanism is usually greater than in the basic protocol. For example, at 500 second, there are only five nodes that are dead for our mechanism, however the basic AODV protocol leads to more than 15 dead nodes. This result shows the efficiency of our scheme that aims to have as smaller as possible a number of congested nodes participating in communications and which allows load balancing in the network. This is the effect of including energy consumption rate in routing process.

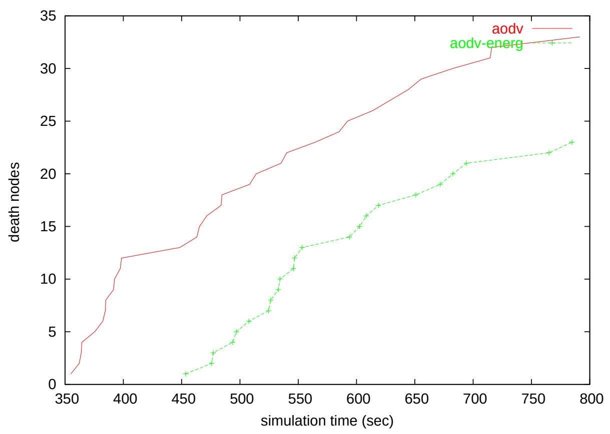

Fig. 10. Number of death nodes for 20 sources (pause time = 0)

V. Related work

Energy coming to be constraining factor for many mobile systems. There are several works that have been addressed to deal with battery usage conservation problem. As mentioned in the Section I, the works that have been presented in this area can be divided into three main class approaches.

The first class of approaches, in which our work can be classified, focus on power aware routing. There are many routing algorithms based on energy conserving mechanisms, that have been described for ad hoc networks. Routing based on expected node lifetime (i.e. "rate based") is a very frequently used idea and there are many papers about this [2, 8, 16, 22]. In [16], the authors propose a max-min algorithm and present some theoretical properties to show how to choose routes while running minimum energy. Despite of the great benefits of that mechanism, it requires periodically an exchange of the energy consumption value information of all the nodes in the network. In one hand, this adds more overhead to obtain this accurate information and consume more energy. In the other hand, this design will be hard to address in a large network with high number of nodes. However, our algorithm is designed for on demand and doesn't require to have a global view of the network. In [14], different metrics as energy consumed per-packet, time to network partition, variance in battery life of nodes, are presented to introduce power-aware routing. Maximizing network lifetime based on the knowledge of the message rate has been also investigated in [2]. The mechanism describes an hierarchical routing methods. The authors propose an algorithmic approach that aims to reduce the battery consumption. This approach defines a class of flow augmentation algorithms coupled with flow redirection. Unlike the conventional approach of minimizing the cost of the route from a source to a given destination, the strategy here was geared toward balancing the battery usage among the nodes in the network in proportion to their energy reserves. The presented algorithms are only centralized and there is no solution for distributed network. In [8], an energy-aware routing algorithm that follows a new route discovery scheme, is described. This scheme is based on the remaining energy value, number of neighbors and mainly a sleep-active node model. Using current energy level in the route establishment algorithm, it is not sufficient to achieve a maximum route lifetime since the behavior of energy consumption is very important to a better estimation of the residual lifetime of nodes. This sleep-active node model, switches off the radio interfaces when nodes are idle. Our algorithm does not apply this model. That is, switching off radio interface can interfer with routing, as routes cannot be formed via sleeping nodes. This also can result in longer routes or in failure of route discovery. The latter may result in longer delays or lost packets due to buffer overflows at the source. To find a good trade off between energy conservation and good performance, it requires more energy consumption in order to compute the requested paths. Moreover, improvement performance remains restricted to some limited scenarios. The algorithm described in [22], considers the remaining battery capacity of each node as metric. It chooses the route with minimal total transmission power if all nodes in the route have remaining battery capacities higher than a threshold; otherwise routes including nodes with the lowest remaining battery capacities are avoided. This require that the lowest energy node information should be provided. No previous knowledge of the information generation rate is required. However, it is necessary to evaluate alternative routes for each destination and to know the minimum value of the battery capacities, dynamically changing, of the hosts belonging to each route. This design is deferent to our work. That is we consider in the cost computation, the expected residual lifetime of each node, according to the communication experiences of a node in the lasted period. Indeed, a giving two nodes that have the some energy level, might not have the same residual lifetime if they do not participate in communication at the same rate. Moreover, that paper include refer to battery operating devices, with adjustable transmission energy that we don't consider in our work.

The proposal in [5], called span, presents a conserving energy scheme based on sleep-active model. A local election is used to elect coordinators. The elected coordinators are connected by paths in such communication can be possible between large number of nodes. Each node has at least one coordinator neighbor. The coordinators remain awake at all times and therefore form a low latency routing backbone for the network. The Span coordinator election algorithm is intended to approximate a minimal capacity-preserving set of coordinators.

The second class of energy conservation that we introduced above, proposes some modifications in 802.11 MAC layer to achieve power saving. In [17], the authors propose the Power Controlled Multiple Access (PCMA) mechanism, in order to enhance medium utilization by reducing the transmit power of nodes as well as possible. Moreover, the described mechanisms in [12, 21] suggest some strategies to power off nodes during idle time in order to save power. Several parameters are used to decide when a node should transit into a specific mode as location information [12], or number of neighboring around the node obtained by the feedback of broadcasting [4]. In [21], nodes can be in two modes: active mode or sleep mode to enable energy conservation depending on communication behavior. A mobile should power itself off in two cases: the first one is when it has no packets to transmit and a neighbor begins transmitting a packet not destined for it. The second case is when it does have packets to transmit but at least one neighbor-pair is communicating. Each mobile determines the length of time that it should be powered off through the use of a probe protocol, the details of which are available in [21]. However, the difficulties of considering the sleep-active mode is what is the best way to transit between the two modes (sleep active) without affecting the performance, as explained above. Furthermore, Combining power optimization and efficient power aware routing is very interesting.

The third class deal with the issues related to power control. They address some techniques of tuning the transmit level of every packets according to many giving parameters as neighbor number, end-to-end network throughput, topology information, and other techniques based on routing concepts. In [11], the protocol proposes that a node can adjust its transmit power based on a limit number of its neighbors that it should has. In [12], the authors suggest some methods based on power control that aim to optimize the global throughput neighbor a long the path by observing the degree of each node participating in route establishment. Comparing to our work, we did not consider optimizing power while sending messages. The goal of power control mechanisms addressed in MAC layer is to minimize as possible as, the amount of contentions between nodes and so the interference. While these schemes have some benefits that concern the enhancement of medium utilization, reducing collision, and improving the total throughput, they have also some disadvantages. Indeed, making the control power at MAC layer to control the number of neighbors in order to reduce the interference, can affect the role of routing protocol. Hence, routing protocols couldn't have the possibility to establish routes with the optimal nodes since every time the next hop is depending on MAC layer transmit power. To solve this problem, power control is coupled with routing to provide the control of topology [23]. The authors propose three algorithms based on power control, routing and clustering in Ad hoc network. That is, a solution for implementing power control at network layer is described. The results of that work provide a good energy conservation. However, some problems are addressed for future works as how to achieve a trade-off between power saving and QoS issues.

There are other parameters in the other layers that we can take into account, to adjust the transmit power, conserve energy, and provide QoS guaranties specially for real time applications. This will let the power saving a cross-layer design that aims to enhance the performance and let the energy consumption close to the minimum. The challenge here is to achieve a compromise between complexity and QoS enhancement. Indeed, the complexity should to be reduced because it consumes power as well as communications, some times much more.

VI. Conclusion and future works

On-demand routing protocols are useful for mobile ad hoc network environment for their low routing overheads. However, they require to consider the reasons for link failure to improve its performance. Link failure stems from node mobility and lack of network resources. Therefore, it is essential to capture the aforesaid characteristics to identify the quality of links. Furthermore, the routing protocols that support QoS must be adaptive to cope with the time-varying topology and time-varying network resources. For instance, it is possible that a route that was earlier found to meet certain QoS requirements no longer does so, due to the dynamic nature of the topology. In such a case, it is important that the network intelligently adapts the session to its new and changed conditions. Indeed, it is not enough to find a shortest path but also with available resources as battery. If battery energy is not taken into consideration in their design, it may lead to premature depletion of some nodes' battery leading to early network partitioning. Since computing complexity consumes power as well as communications, we proposed in this paper a simple and efficient energy consumption rate based algorithm to establish routes between sources and destinations.

Performance evaluation using ns-2 simulator shows that the longevity of the network can be extended by a significant amount. Overall, we conclude that our mechanism demonstrates significant benefits at high traffic and high mobility scenarios. We expect that these scenarios will be common in ad hoc networking applications. Even though we implemented the algorithm on AODV, the technique used is very generic and can be used with any on-demand protocol.

Indeed, a large literature presents several works that have been done to optimize power consumption in Ad hoc network. That considerable research has been devoted to low-power design of the entire network protocol stack of wireless networks in an effort to enhance energy efficiency. Therefore, the key to energy conservation in wireless communications should be based on a coordination between all levels of the wireless protocol stack. Moreover, how to address an efficient cross layer QoS model based on energy conservation and other key metrics for real time applications. In other words, How to map between service differentiation and power management. Hence, this issue remains a very crucial research area in the future.

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