Power-Saving Mechanisms to Achieve Reduced Energy Consumption While Maintaining Effective Communication by Using the Appropriate Transmission Power in Mobile Ad-Hoc Networks

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Abstract

Communication in ad hoc networks necessarily drains the batteries of the participating nodes, and eventually results in the failure of nodes due to lack of energy. Since the goal of an ad hoc network is to support some desired communication, energy conservation techniques must consider the impact of specific node failures on effective communication in the network. One of the promising mechanisms proposed to reduce the energy consumption in Mobile Ad Hoc Networks (MANET's) is the transmission power control. In this research, our aim is to reduce energy consumption during both active communication and idle periods in communication. Mathematical analysis supported by simulations is used to validate the scalability of the proposed technique. The routing algorithm can use remaining battery energy to balance the routing or forwarding of packets among nodes by choosing appropriate nodes as packet forwarders. Using these metrics and this technique, we derive from DSR a new power aware and energy efficient protocol.

Keywords

MANET's, Power Saving, Energy Efficient, Transmission Power, Reluctance, Battery Life

I. Introduction

Ad-Hoc networks are dynamically formed, infrastructure less, wireless multi-hop networks. The nodes configure themselves into a network and co-operatively maintain network connectivity. Communication in ad hoc networks necessarily drains the batteries of the participating nodes, and eventually results in the failure of nodes due to lack of energy. Since the goal of an ad hoc network is to support some desired communication, energy conservation techniques must consider the impact of specific node failures on effective communication in the network .The challenge in ad hoc networks is that even if a host does not communicate on its own, it still frequently forwards data and routing packets for others, which drains its battery [1]. Switching off a non-communicating node may not be always a good idea, as it may disconnect the network. As time goes on, the battery energy gets depleted and the nodes move, so each node in the network must update its reluctance value, for the link over which it is communicating, in the table according to its remaining battery energy, assuming nodes move relative to each other and transmit power stays the same. A node sends a packet to other nodes in the network with this information so they can update their routing tables accordingly [2]. Reluctance updates should be generated at randomly chosen times, within a certain time limit, so that the nodes do not overwhelm the network with update packets. Our scheme makes use of the dynamic transmission power employed in current wireless network cards, along with battery status, especially the remaining energy, provided by smart batteries powering hand-held and mobile devices. In general there are three components to energy consumption in ad hoc networks. [3-5] First, energy is consumed during the transmission of individual packets. Second, energy is consumed while forwarding those packets through the network. Our goal is to reduce the power consumed to transmit the packet to the destination. Reluctance is the node's unwillingness to route packets for other nodes, possibly due to low battery level. Using a least-cost algorithm, we can find a route with the minimum cumulative reluctance value, which means a route using nodes that provide relatively high available energy and low required transmit power.

II. Related Work

The power control issue has implications in several network layers, since it influences the range of communication; it determines interferences and it affects routes (because of connectivity). The survey by Jones et al. about energy efficient techniques [7] explains some possible alternatives at all the network layer of the OSI model. In [10], the proposed energy efficient protocol slows down data transmission when the channel conditions become degraded.[2] Adaptive Error Control with ARQ/FEC (Automatic Repeat Request/Forward Error Correction). A dynamic power control and coding protocol for optimizing throughput, channel quality and battery life is studied in [12]. [13] by choosing properly the right algorithm for a problem and applying the energy saving techniques, the improvement in energy savings can be higher than 60%.However, some of those metrics may not lead to power savings, but, on the contrary, to the overuse of energy resources of a small set of mobiles, so that lifetime of the mobiles and network decreases. Therefore, this study utterly justifies the use of more energy efficient routing schemes for wireless ad hoc networks.

III. Power Saving Mechanism Features

- Each node keeps track of the remaining energy of its battery and assigns a battery level to itself. The battery level is updated on a timely basis. Additional study is needed to determine appropriate intervals for updates.
- A routing table is built based on "cost" values instead of minimum hop values. In our scheme we use "reluctance" as our cost for routing a packet through a node. Each node stores a static table of all possible reluctance values. An assignment of a reluctance value is derived from the node's remaining energy and transmission power levels [19].
- The larger the reluctance value of a node, the less likely it is that the node will route or forward packets for other nodes. If two nodes have equivalent remaining battery energy, a lower reluctance value is assigned to the node that can reach the destination node with lower transmit power. Also, a lower reluctance value is assigned to a node with higher remaining battery energy if the two nodes can reach the destination with equivalent transmit power.

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IV. Evaluation Methodologies

A. Cost Function and Metrics

A node sets the reluctance value for a link, depending on the quantized values for the remaining battery energy and transmits power the node needs to send a packet on the link. To incorporate such a scheme, we introduce three variables in the cost function.

- Px: power level of transmitting node along link lx
- Bi: battery energy level of node i
- rix: reluctance of node i along link lx

Reluctance values are assigned to ordered pairs of (transmit power level, remaining battery level), or, using the variables defined above, (Px, Bi). These values are stored in a static table that encompasses all the different combinations of power and remaining battery levels. During the neighbor discovery procedure, neighbors send their reluctance values back to the route discovery initiator based on their value of Bi and the transmit power associated with the route request, Ptx. Neighboring nodes assign their own reluctance to a specific link based on (Px, Bi) and send it back to the route request initiator in the route reply message so that the initiator can calculate all links reluctance values and find the route with least total reluctance. We measure reluctance by assigning a node with high battery level and low transmit power level a low reluctance value and a node with low battery and high transmit power a high

reluctance value. For instance, we might specify that (6, 4) has a higher reluctance value than (5, 4) since the power is higher in the first pair. The same is true for (3, 4) and (3, 5) since the battery level is lower in the first pair. The research looked at discovering routes by gradually increasing the transmit power starting from a low power state.

Table 1 shows the reluctance values and their division according to battery level and transmission power. From Table 1 the following corresponds to transmission power.

- Px1 corresponds to transmission power (Px< 10 dBm)
- Px2 corresponds to transmission power (10 dBm ≤ Px < 13 dBm)
- Px3 corresponds to transmission power (13 dBm ≤ Px < 17 dBm)
- Px4 corresponds to transmission power (17 dBm ≤ Px < 21 dBm)
- Px5 corresponds to transmission power (21 dBm ≤ Px < 23 dBm)
- Px6 corresponds to transmission power (Px> 23)

Table 1: Reluctance Values Division According to Battery Level

	P_x1	P_x2	P_x3	P_x4	P_x5	P_x6
Low Battery Level	61	62	63	64	65	66
$(0 \leq B_i < 4)$	51	52	53	54	55	56
Medium Battery Level	41	42	43	44	45	46
$(4 \leq B_i < 7)$	31	32	33	34	35	36
High Battery Level	21	22	23	24	25	26
$(7 \leq B_i \leq 9)$	11	12	13	14	15	16

In the routing procedure, the reluctance values are partitioned into three levels. A range of integer values is assigned for high battery level (7-9), a second range is assigned for medium battery level (4-6), and a third range is assigned for low battery levels (0-3). Therefore, the routing cost function can be computed and used as follows:

IF battery level is "high" (7 ≤ Bi ≤ 9)
IF a direct link from S to D exists THEN
Set reluctance value to lowest value from the range of high-level values
send packet directly to D
ELSE
Set reluctance value according to (Px,Bi)
Send the packet through lowest cost route (min W(k))
IF battery level is "medium" (4 ≤ Bi < 7)
IF a direct link from S to D exists AND (Bi ≥ 6) THEN
Set reluctance value to lowest from the range of the medium-level values
Send packet directly to D
ELSE
Set reluctance value according to (Px,Bi)
Send the packet through lowest cost route (min W(k))
IF battery level is "low" (0 ≤ Bi < 4)
IF a direct path from S to D exists AND Px is low THEN
Set reluctance value to lowest value from the range of the low-level values
ELSE
set reluctance value according to (Px,Bi)
send the packet through lowest cost route (min W(k))

B. The Power Model Used

A more advanced power model takes into account the cost of transmitting, receiving, and discarding both data and control packets. A simple power consumption equation that models the power consumed mainly a function of packet size and the cost of transmission is given by equation

$$Cost_{brdcst} = (l_{tr} \times C_{tr}) + C_{ca(tr)} + \sum_{n \in S} (l_{recv} \times C_{recv} + C_{ca(recv)}) \quad (1)$$

Here, ltr and lrecv are the length of the transmitted and received packets, respectively. Normally, ltr is equal to lrecv Ctr is the cost to transmit. Cca (recv) and Cca (tr) are the cost to access the channel in receive and transmit modes, respectively. S is the set of receiving nodes n. For point-to-point traffic, the cost is divided into transmitter and receiver costs. The cost at the transmitter is given by Equation

$$Cost_{p-to-p(tr)} = C_{tr(RTS)} + C_{recv(CTS)} + (l_{tr} \times C_{tr}) + C_{ca(tr)} + C_{recv(Ack)} \quad (2)$$

Where Ctr(RTS) is the cost of transmitting a request-to-send message, Crecv(CTS) is the cost of receiving a clear-to-send, and Crecv(Ack) is the cost of receiving an acknowledgment from the receiver. The cost at the receiver is given by Equation

$$Cost_{p-to-p(recv)} = C_{recv(RTS)} + C_{tr(CTS)} + (l_{recv} \times C_{recv}) + C_{ca(recv)} + C_{tr(Ack)} \quad (3)$$

Where Crecv(RTS) is the cost of receiving a request to send message, Ctr(CTS) is the cost of transmitting a clear to send message, and Ctr(Ack) is the cost of transmitting an acknowledgment to the sender. Nodes within wireless range of the transmitter and nodes within wireless range of the receiver that are not the destination must discard received packets. Therefore, the cost of discarding traffic is as follows in Equation

$$\text{Cost}_{discard} = \sum_{n\in S} C_{discd(RTS)} + \sum_{n\in D} C_{discd(CTS)} + \sum_{n\in S}([l_{discd} \times C_{discd}] + C_{ca(recv)}) + \sum_{n\in D}([l_{discddiscd}] + C_{ca(recv)}) + \sum_{n\in D} C_{discd(Ack)} + \sum_{n} C_{discd(Ack)} \quad (4)$$

Here, S is the set of nodes that are within the wireless range of the source node and D is the set of nodes that are within the wireless range of the destination node. Cdiscd(RTS) is the cost of discarding a request to send message received by nodes within wireless range of the transmitter. Cdiscd(CTS) is the cost of discarding a clear to send message received by nodes within wireless range of the destination node. Cdiscd(Ack) is the cost of discarding acknowledgment messages heard by nodes within wireless range of the destination node. Cdiscd is the cost of discarding data messages overheard by nodes within wireless range of the sender.

V. Simulations and Result

We used NS-2 as a platform for our simulations. NS-2 provides a linear battery model, where a fixed "cost" is subtracted from the battery every time a packet is sent or received. Therefore, nodes expend the same amount of energy from the battery whether they are sending to nearby nodes or too far away nodes [24] . In the normal battery model in NS-2, energy consumption does not depend on the location of the sending node with respect to the receiving node. We introduce a slight modification to the way energy is consumed from the energy source to allow for dynamic energy consumption based on the output power of the transmitter. This modification assumes a major part of the energy consumed is used by the transmitter and that 70% of this energy consumed is consumed by the receiver. The receive power is set to 70% to indicate that the receiver also consumes a considerable amount of energy, contrary to early studies that tend to marginalize the receiver energy consumption in MANETs [5, 14]. Processing power by the mobile node is ignored for both sending and receiving nodes. To evaluate the performance of our proposed power-aware DSR (PADSR) algorithm, we conducted a simulation study to investigate performance under the different factors mentioned above. Since our aim is to conserve energy and extend network life, one of the performance metrics we study is the relative network life using unmodified DSR (U-DSR) compared to using our new ODPADSR routing scheme under various network mobility and packet size factors

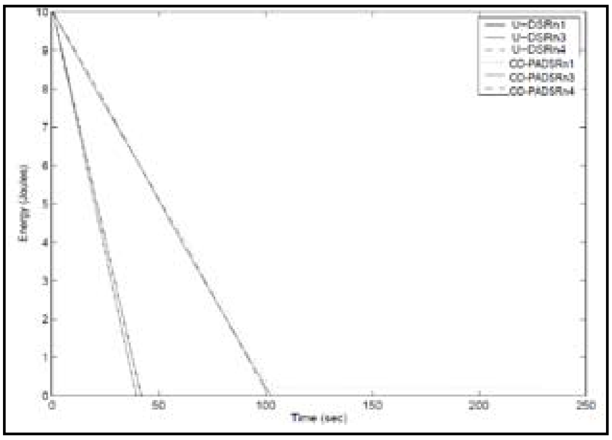

Fig. 1: Node Energy Variation With Time for the Dense Network

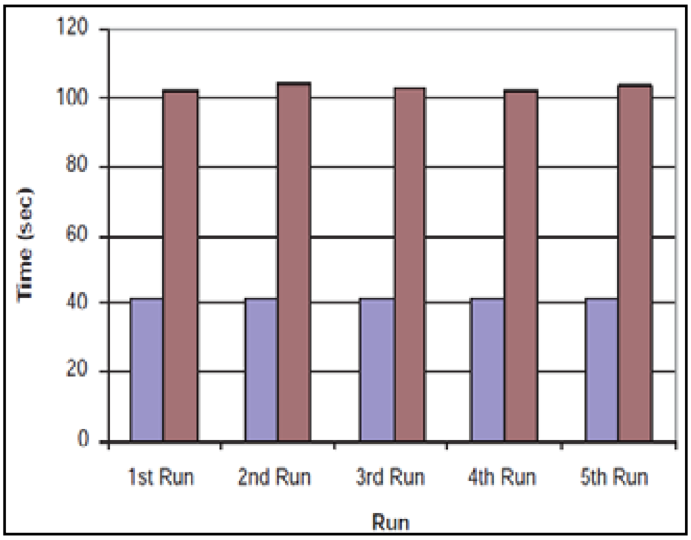

Fig. 2: Comparison of Network Life for the Dense Network Scenario

Table 2: Summary of Results for Single Flow Dense Network

	U-DSR	PADSR
Average Lifetime(s)	41.68	103.22
95% confidence Interval(s)	(41.66, 41.7)	(102.32, 104.13)
Average number of packets delivered	2056	5068.6
Average percentage of packets delivered	99.81	97.48
Average end to end delay(s)	0.05	0.50

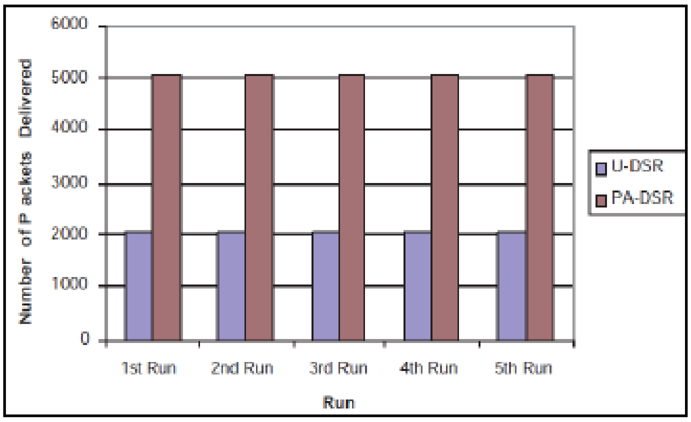

Fig. 3: Number of Packets Delivered in the Dense Network Scenario

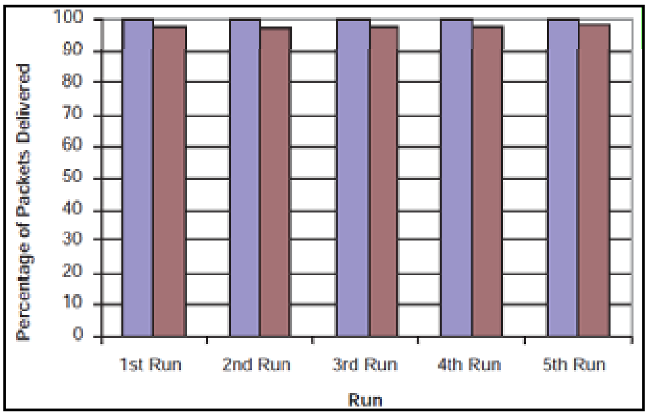

Fig. 4: Percentage of Packets Delivered in the Dense Network Scenario

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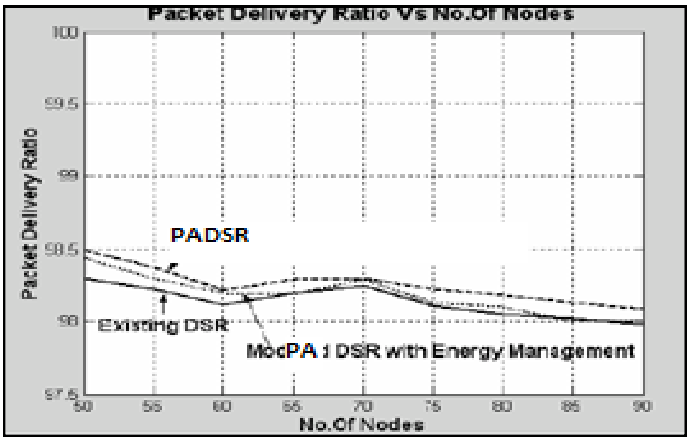

Fig. 5: Packet Delivery Ratio for Energy Efficient DSR Compared to DSR

Table 3: Summary of Ending Energies For DSR Scenarios

Protocol	Average Ending Energy(J)	Standard Deviation	Average Number of Dead Nodes
U-DSR -HC	42.365	23.636	8
PADSR-HC	23.190	6.064	10
U-DSR-LC	62.902	4.499	11
PADSR-LC	14.504	3.651	12
U-DSR-LS	84.968	13.902	8
PA-DSR-LS	58.3718	14.148	8
U-DSR-HS	116.284	30.79	7
PA-DSR-HS	112.04	23.9428	7

VII. Findings

Average change in energy over time showed that the average change in energy increase as time advances for the unmodified protocols, while it shows an increase in the beginning of time, it levels for some time before it starts to decrease. Average final node energies showed an uneven distribution of final average energies in the unmodified protocols, while it showed a more balanced distribution of final average node energies in the power-aware protocols. The end-to-end delay is the time taken by a data packet to reach destination from the source. As the number of nodes increases, the complexity of the network increases and hence the end-to-end delay increases. As the pause time decreases, the mobility increases, which increases the probability of link failures and hence the end-to-end delay increases. In -PADSR, the header of the data packet is reduced and the route cache is limited to contain the addresses of only the previous node, source and destination nodes which improve the processing capacity of the nodes. This reduces the processing time of the nodes which in turn reduces the end-to-end delay when PADSR is compared to existing DSR. The change in the percentage energy saving in accordance with the distance between the adjacent nodes for the modified DSR .It is observed that more energy is saved when the distance of separation is less and hence, an effective energy management is obtained in the modified DSR while in the existing DSR there is no energy management since the transmitting energy is constant regardless of the distance between the adjacent nodes.

VIII. Conclusion and Future Work

In multiple-hop networks, exploiting transmission power or battery energy reserve as the sole means to save energy hastens the "death" of relay nodes that forward packets between a sender and a receiver. Such schemes also lead to uneven variation in the energy resources at different nodes. Therefore, it is important to minimize the variation in energy expended to be fair to intermediate nodes in terms of distributing utilization of network energy resources, reduce network failure by not shrinking the network due to node failure, e.g. when an intermediate node serves two different destination nodes, and extend the life of the network by distributing the energy load among different intermediate nodes over time. The proposed scheme combines these two approaches by assigning a reluctance value to a link from the sending or forwarding node to the node in the next hop. Route updates are initiated over time to account for energy depletion and node movements. This result in updating the reluctance values assigned to the links used. Currently, the power-aware protocol takes its transmitting power value from a static table. It would be desirable to let the protocol select its transmit power table from a set of tables based on the environment in which it is deployed. For example, the power-aware scheme uses transmit power table in a static environment that is different from a table used in a mobile environment. Further, a transmit power table in a sparse network different than a table in a dense network.

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