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Evaluation of Power Control Mechanism on OLSR Routing Protocol

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***Abstract* —The mobility that characterizes the wireless networks, is leading to the use of ad hoc networks for wireless communications. Due to the constant motion of wireless devices, infrastructure wireless networks cannot provide connectivity at all times, in comparison with ad hoc networks, which are more easy to use and are based on abstract and continuously altering topologies. The use of specialized routing protocols is improving the performance of these networks, concluding to lower power consumption and faster communication. However, routing is not enough to preserve the battery power of the mobile devices. By using a power control mechanism on top of the routing protocols, further power savings can be achieved. In this paper, we present a power control mechanism which relies on the routing protocol in order to make decisions about power management and the behavior and the performance of the network. The mechanism is based on using SNR (Signal-to-Noise Ratio) as a metric for adjusting the transmission power accordingly and eventually saving a respectable amount of energy to prolong life time of mobile devices and benefit the performance ad hoc networks.**

Keywords—ad hoc, power control, routing

I. INTRODUCTION

Ad hoc networks are decentralized wireless networks, since they don't depend on any infrastructure to function. Each node communicates with its peers, as long as they can hear each other. Additionally, due to the expansibility of the network, the nodes can even communicate with peers outside their range, by utilizing various routing protocols. Messages can be forwarded by the intermediate nodes that exist in the between a sender and a remote receiver, making communication possible.

The versatility of ad hoc networks in combination with the advances in routing techniques, have changed the role of the former. Ad hoc networks nowadays are found not only in military network communications, but in commercial and civilian wireless communications as well. Corporate buildings use ad hoc networks for the communication between the employees. This advancement comes with a lot of benefits, such as the access to network resources while being away from the workstations, using mobile wireless devices.

However, mobile devices depend heavily on a limited amount of power, stored in batteries. The most important challenge that mobile devices have to deal with is to consume the least amount of power possible in order to operate and execute their tasks. One of these tasks is wireless communications of course. The use of routing protocols in ad hoc networks, affects power consumption to a great extent. In order to utilize the benefits of these protocols, the exchange of various control messages is required. HELLO, topology or other control messages are transmitted very often, so that the routing tables are not outdated and provide valid information. As a result, additional power is consumed for this task.

Reducing the amount of power that is consumed for the functions of the protocols is not efficient. Power reduction results to range reduction, which in the case of the protocols would have a serious impact on routing and reaching remote destinations. On the other hand, using the routing protocols, it is possible to extract information that will help in reducing the transmission power of the nodes for the actual communication, in specific, packets that contain the information that need to be sent.

Routing protocols, however, do not only manage to find a route along the network for sending the packets, but many of them aim at energy saving by selecting routes with the least number of hops possible. The path that each packet will follow will be shortest, minimizing that way the retransmissions that are needed to send the packet. This is beneficial not only for the overall power consumption of the network, but it minimizes delay as well.

The energy saved from the above techniques might not be enough though. While an important amount of power is saved, the most important source of power saving which is the transmission power of each node separately, is not taken into account. When a node transmits a packet, it does so using the highest transmission power available. Since the MAC protocol uses the RTS (Request-To-Send) / CTS (Clear-To-Send) mechanism and due to the hidden node problem, if the sender transmits the packet using the maximum available energy, many nodes will cease transmitting. As a result, the throughput of the network is reduced. To sum up, a way to efficiently reduce transmission power has to be proposed, so that energy is saved not only during the routing phase of the transmission, but in the transmission itself, while the performance of the network benefits by means of throughput.

In this paper, we propose a mechanism that is based on SNR in order to adjust the transmission power of the nodes and save energy. We define a set of SNR threshold values, which can be used in the proposed extension for power management. The mechanism depends on feedback messages which, in order to avoid unnecessary overhead in the network, are implemented

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inside the message headers of OLSR protocol. The mechanism works in such a way that the routing protocol is not affected by the adjustments made by the newly introduced mechanism, ensuring connectivity of the nodes and maximizing power consumption and throughput. We perform modifications in the routing tables that are produced, to keep information that is related to the neighbors of each node, such as received and transmission signal levels.

II. Related Work

There has been a lot of research in the area of routing protocols with target on power consumption. Most of the proposals have focused on modifications on the routing scheme of the protocols, so that the above is achieved. However, there are other proposals that take advantage of the routing protocol in order to perform other actions that are related to power consumption.

A first approach has been presented in [1] where transmission power is modified in order to increase battery duration and improve throughput due to reduced interference. Algorithms such as [2] are implemented at data link layer, and can thus be combined with any ad hoc routing protocol. Also, in [3], the authors introduce a practical mechanism that modifies the adapter's transmission power by taking advantage of the data that Linux drivers such as Minstrel and Atheros provide.

An alternative approach is to modify the routing protocol, such as in [4] and [5] where AODV is modified for improved energy consumption and evaluating using NS-2 and [6]. Another similar cross-layer approach is [7] with the MAODV-PC protocol and more recently the one by [8]. Proactive routing protocols have also been combined with power awareness features such as in [9].

The rest of the paper is organized as follows. In section III we define and analyze the mechanism that we propose. In section IV we discuss the experiments and the results of the mechanism, in order to confirm its efficiency. Finally, in section V we summarize our work and mention possible future ideas.

III. Mechanism for Power Consumption

The mechanism that we propose in this paper, aims at reducing power used in wireless transmissions, by using the minimum amount of power needed to transmit a packet to a certain neighboring node. The adjustment of the power to lower levels than then maximum one, leads to reduction of the consumed energy for network transmissions.

A. Power control mechanism

The power control algorithm we use is based on the measurement of the SNR of a node, which defines the quality of the reception. [10] showed that the acceptable SNR value is different for each data rate. Fig. 1 shows the relation between frame success ratio and SNR for each rate. Using the data provided by this figure, we can assume that for different transmission rates, different amount of power is needed for successful transmission, provided that there is no source of interference in the network and the nodes are moving relatively slowly, such as devices used by pedestrians.

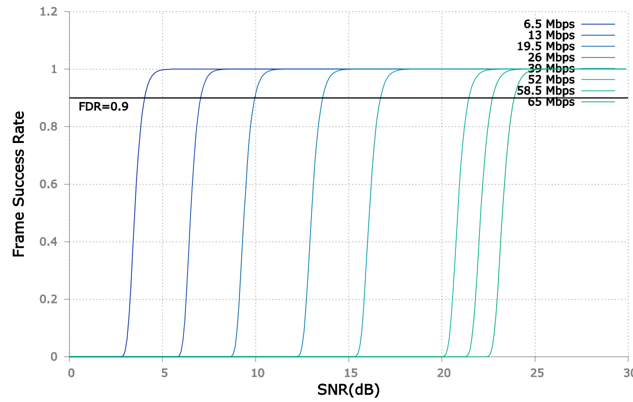

Fig. 1. Frame success ratio vs SNR for different rates suported by 802.11n

Assuming that the channel is clear, when a node transmits to another node with a rate R, the received power is calculated in dB as:

$$P_{Rx} = P_{Tx} + PathLoss + G_T + G_R \quad (1)$$

where P_{Rx} the received power, P_{Tx} the transmitted, and G_T and G_R the gains for each antenna. For a successful reception, SNR at the receiver when receiving at rate R is SNR_R, which is calculated as:

$$SNR_R = P_{Rx_R} - N \quad (2)$$

where N is the power of the background noise and P_{Rx_R} is the received power when receiving at rate R.

Eventually, to find the power the sender needs to send the packet successfully without wasting energy is:

$$P_{Tx_R} = SNR_R + N - PathLoss - G_T - G_R \quad (3)$$

It is obvious that the calculation of the transmission power cannot be done without any feedback from the receiver. The usual case is to send control messages to the neighbors to get the necessary parameters. However, some of the nodes might not be stationary, but moving, which results to calculations based on outdated data. By increasing the frequency that these messages are sent could solve the problem, but it would add significant overhead in the network and extend power consumption even more. As a result, the goodput of the network might be reduced, in order to ensure connectivity. The solution to the problem can be given by taking advantage of the control messages sent by the routing protocol that is used in the ad hoc network.

B. Routing protocol extension

As mentioned above, feedback messages sent to serve the purpose of a power control mechanism might cause traffic congestion and reduce the payload, since there are other control messages by other mechanisms, such as the routing protocols, exchanged in the network. Additionally, the information that is required by the above mechanism is small in size. Given that the frequency of the protocol control messages is high, we can take advantage of this fact and add our new information in the headers of the routing messages. This will save a respectable amount of capacity and minimize the busy time of the network.

Here we propose an extension for the power control mechanism that takes advantage of the OLSR protocol header control messages to exchange the necessary information.

1) OLSR protocol

OLSR protocol is a proactive protocol for ad-hoc networks that is widely used. In this protocol, routing is accomplished by sending routing messages in short intervals. One of the available message types that are sent are the HELLO messages, which are used for neighbor discovery. Consider two neighboring nodes that are not aware of the presence of each other. Either of them will broadcast first a HELLO message. The message will be received by the other node, which will afterwards assume there is an asymmetric link towards the first node. When the second node transmits a HELLO message, the first node will be in the recipients list, and when it gets the message, it will discover the symmetric link between them.

It is obvious that method that is used in OLSR to perform neighbor discovery, is not based on explicit two-way communication. This fact means that it is not possible to send any information back to the sender of the message in order to inform it about the signal quality. However, when a node A has already discovered the presence of a node B due to a previous reception of a HELLO message from B, the HELLO message that is to be sent by A contains a neighbor entry for B. The HELLO message is defined as in Fig. 2:

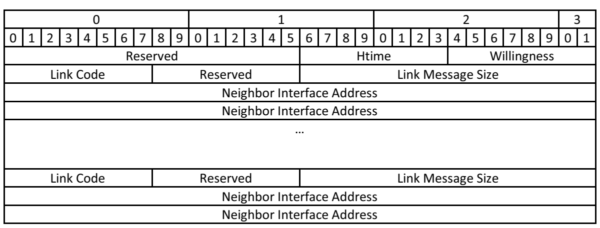

Fig. 2. Structure of a HELLO message of OLSR protocol.

In case the sender node of the HELLO message has received previously any incoming HELLO messages, it lists inside the content of the message the IP addresses of the nodes with the corresponding information that are related to the OLSR protocol.

2) Extension of OLSR

In our mechanism, we extended the structure of HELLO messages that lie in OLSR by adding information related to the power control mechanism. It obvious that in our mechanism the sender node needs to know the value of the received power at the other end, in order to calculate path loss, which is required to adjust the transmission power for the future packets towards the receiver node. To do so, we alter the HELLO neighbor entry in such a way that it contains the reception power of a HELLO message sent by that neighbor. We added another 4 bytes in each link message of the HELLO packet, to include the necessary information. Extending the link message header offers many advantages. The messages remain compatible and can be processed by nodes that have not implemented our extension, and the message size remains constant and no additional power consumption takes place, since there is not any additional traffic from mechanism packets in the network.

The power control mechanism works as follows: Consider two nodes A and B that are not aware of the presence of each other. At some time, A broadcasts a HELLO message that is heard by B. While B listens the message, it measures R_x of the packet. From the definition of OLSR protocol, B will contain an entry for node A when it broadcasts a HELLO message. In this entry, B adds the R_x value that measured earlier, in order to inform A about signal quality. When A listens the message, it will extract this value from the message, and use it in its calculations to adjust its transmission power towards B.

However, the extension as described above, has some issues that need to be addressed. First of all, routing messages are exchanged periodically, which means that the required information will be lost. So, the feedback information has to be stored somewhere, in order to be used later. To do so, we altered the routing table that is maintained by OLSR protocol, by adding two fields in the routing table that contain the reception power of the node when it receives a packet from a certain node and the reception power at the other end. The first value is stored in the routing table in order to be included in the HELLO message, while the second is the value that is read from a received HELLO message and is needed for the power control calculations.

Power management using the proposed scheme concludes with the following algorithm. Suppose node A wants to send a data packet to node B. Before sending the packet, it checks the routing table to find the IP address of the next hop. Then, it modifies its transmission power based on the proposed power management mechanism, using the information about the reception power of the node, which is stored in the corresponding entry. In this way, the mechanism can switch to different energy levels, based on the destination of the packet. The pseudocode for the proposed overall mechanism is the following:

```
hello_received(packet){
    source_ip = GetSourceIp(packet);
    rx_power = MeasureRxPower();
    rx_power_of_source_node =
ExtractRxFieldFromOLSRHeader(packet);
    UpdateRoutingTableEntry(source_ip, rx_power,
rx_power_of_source_node);
}

send_hello_message(hello_message, routing_table){
    foreach entry in hello_message do{
          rx_power_from_entry = GetRxPowerFromNode(entry,
routing_table);
          AddRxPowerToEntry(entry, rx_power_from_entry);
    }
    send_message();
}

send_packet(packet, data_rate){
    destination_ip = GetDestinationIp(packet);
    rx_power = GetRxPowerOfNode(destination_ip);
    snr_threshold = GetSnrThresholdForRate(data_rate);
    //Calculate Path Loss
     //P_tx for HELLO is always 20
    path_loss = hello_tx_power - rx_power;
    noise = GetNoise();
    tx_gain = GetTxGain();
    tx_power = snr_threshold + noise - path_loss - tx_gain -
rx_gain;
    //Set limititations to Tx Power
    if( tx_power < 5 )
          tx_power = 5;
    else if (tx_power > 20)
          tx_power = 20;
```

```
    SetTxPower(tx_power);
}
```

One more limitation that we add to the extension, is that the HELLO messages, even though they are broadcasted and do not have a specific recipient, must be sent using the maximum transmission power possible, as in the default case. The neighborhood discovery is based mostly on the HELLO messages defined by OLSR, which means that if they are broadcasted with less than the maximum power, the neighbor discovery range will be reduced. This could have some effects on the network discovery and the construction of the routing table, with possible exclusion of remote nodes, because a possible neighbor that can create a route to that destination cannot be found. Also, knowing that these messages are sent with maximum power, path loss calculation is easier to calculate, as shown in the pseudocode above.

IV. Experiments and Results

To prove the validity of our mechanism, we conducted experiments using Network Simulator 3 (NS-3). The setup of the experiments consist of an ad hoc network that applies the OLSR protocol for routing. We made the necessary modifications on the code that implements the protocol, in order to simulate our case. Moreover, we modified the PHY layer of the nodes, in order to extract the necessary information such as transmission and reception power that are accessible from there.

The setup of our experiments consists of a set of nodes uniformly distributed in a 400x200 square area that move randomly with a constant speed of 1m/s, simulating pedestrians. To inspect the efficiency of the mechanism, we run experiments with 10, 20, 40, 60, 80 and 100 nodes, for each different data rate that 802.11n provides. The parameters of the experiments are summarized in TABLE I.

TABLE I. Experiment Parameters

Parameter	Value
Area	400x200 m
OLSR HELLO Interval	4 seconds
Moving speed	1 m/s
Packet size	1000 bytes
Application data rate	200 kbps

The results of our experiments are summarized in figures 3-7. In Fig. 3, the average power consumption of the network for different number of nodes and for different data rates is displayed. In Fig. 4 we display throughput of the network in each case, and finally, in Fig. 6 packet loss is displayed. All these results are compared to the corresponding results when not using the power control mechanism in figures Fig. 5 and Fig. 7.

In Fig. 3, we can see that the transmission rate is an important factor in transmission power selection. The power control mechanism tends to raise the lower bound of power transmission as the rate is higher. While the density of the network increases, the average power is not reduced further throughout the experiments. This happens because the routing protocol creates paths with the minimum hops each time, and overlook more fragmented paths. As a result, the average power consumption shows only a small variation, and is independent of the density of the network. Using the power control mechanism, we have achieved to lower the average power consumption of the nodes up to 85% of the maximum for the lower data rate available. While rate is increasing, power saving does not go below 34%.

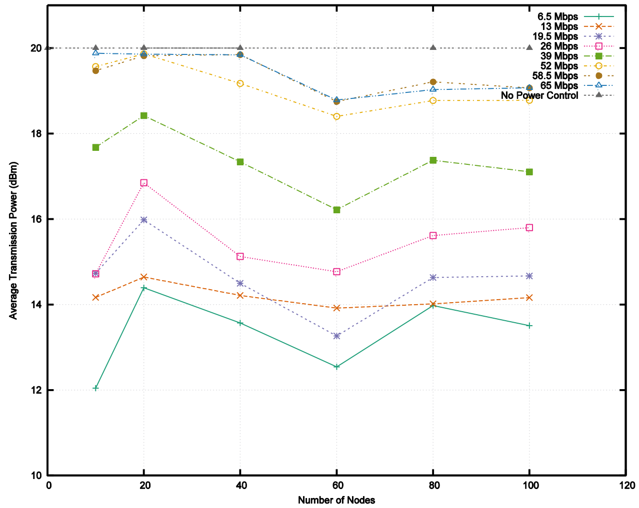

Fig. 3. Average power consumption vs number of nodes in the network.

In Fig. 4, we display the results regarding the network throughput, while the number of the nodes is increasing.

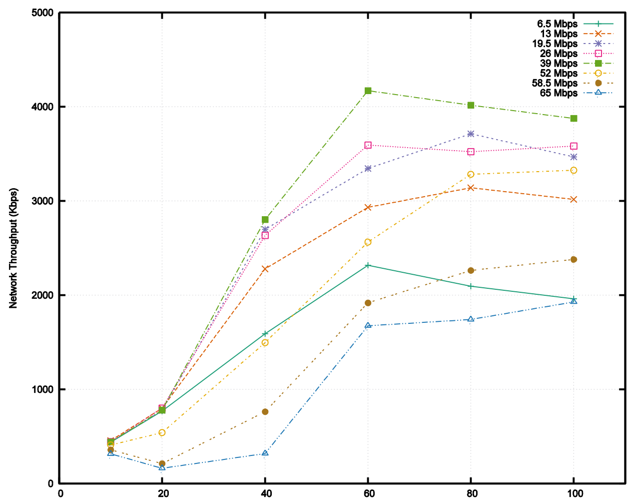

Fig. 4. Throughput vs number of nodes in the network using the proposed mechanism.

The results in Fig. 4 and Fig. 5 show that while using the mechanism, throughput is slightly lower than the corresponding one without the mechanism. This happens because power control guarantees lower power consumption, but there is a small chance that some packets will be lost, resulting in lower throughput in the network.

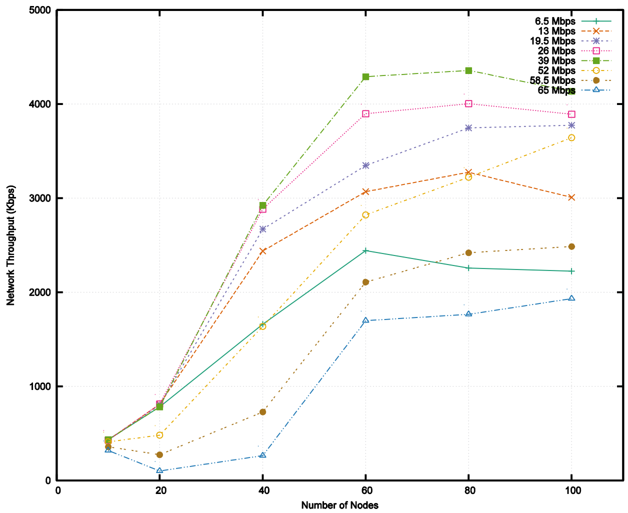

Fig. 5. Throughput vs number of nodes in the network without the proposed mechanism.

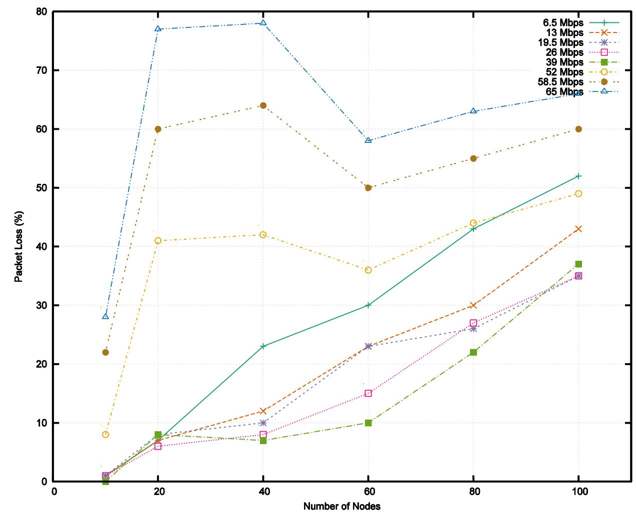

Fig. 7. Packet loss vs number of nodes without the proposed mechanism.

In Fig. 6 and Fig. 7 the results regarding packet loss are displayed. While using the mechanism, packet loss is slightly higher. This happens because transmission power decreases more than necessary, in order to save energy based on the proposed method. Main cause of this effect are the long intervals of HELLO broadcasts, which transfer data that are not close to the current status of the node who sent the HELLO packet. When the HELLO interval of the routing protocol is large, the mechanism tends to be less reliable, because it is based on outdated data. On the other hand, when such messages are sent more frequently, power setting and routing could be more accurate, but network overhead is higher as well.

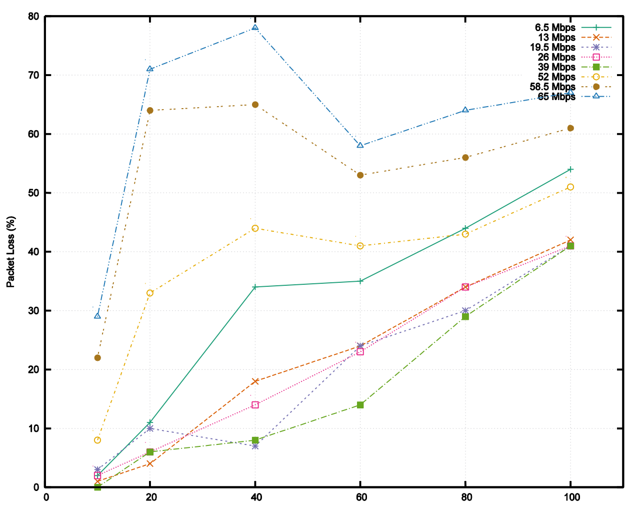

Fig. 6. Packet loss vs number of nodes using the proposed mechanism.

The results show that wireless networks are capable of saving up to 85% energy when using the mechanism. Moreover, the integration of the mechanism in the network does not have any important negative effects on its throughput. However, the mobility of the nodes requires that the routing protocol sends messages more frequently, in order to provide more recent data to the nodes, and make the transmission power calculation more precise. Another addition that could improve the performance of the mechanism is the reduction of RTS/CTS transmission power, limiting the range inside which nodes are not allowed to transmit.

V. Conclusions and Future Work

In this paper, we presented a power control mechanism that is able to be integrated in existing proactive routing protocols for ad-hoc networks, in order to save energy that is of high importance for mobile devices. The mechanism is applied through the routing protocol's functions, thus it effects towards the network are negligible. Power saving is applied using a formula that is based on fundamental metrics that are measured during packet reception and are distributed to the necessary nodes using the routing protocol features. The results showed that depending on the data rate, the nodes spend from 34 - 85% less energy to send the packets, thus prolonging their uptime for the saved amount of energy. It is noticed that throughput and packet loss do not vary much in comparison with the normal case which does not use the mechanism.

The theoretical approach that was presented in this paper is efficient, but can be improved furthermore, with the addition of monitoring and dynamic data processing mechanisms, making possible the detection of nodes' behavior inside the environment. The use and processing of live data from the network can lead to a more accurate calculation of the needed transmission power to save energy and send the packet successfully to the receiver. Finally, the proposed mechanism has not been designed for reactive routing protocols, such as AODV and DSR, so another proposition for future work is the study of proactive routing protocols and integration of the proposed mechanism in them.

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