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OPTIMIZING THE POWER AWARE ALGORTHIM FOR PREDICTING ROUTE LIFETIME IN LARGE SCALE MANET

[1]Gokulapriya.R, [2]Tamilselvi.R, [3]Arulmurugan.V.S
[1]PG Scholar, Department of Electronics and Communication Engineering Shree Venkateshwara Hi-tech Engineering College, Gobi
[2]PG Scholar, Department of Electronics and Communication Engineering Shree Venkateshwara Hi-tech Engineering College, Gobi
[3]HOD, Department of Electrical and Electronics Engineering, Shree Venkateshwara Hi-tech Engineering College, Gobi
[1]prijaylavan@gmail.com, [2]tamil20r@gmail.com, [3]arulpvp@gmail.com

Abstract: One of the important and challenging problems in the design of ad hoc networks is the development of an efficient routing protocol that can provide high-quality communications among mobile hosts .for that proposing new protocol to evaluate the node lifetime and the link lifetime utilizing the dynamic nature, such as the energy drain rate and the relative mobility estimation rate of nodes. Integrating these two performance metrics by using the proposed a power aware routing technique for wireless ad hoc networks where all nodes are located within the maximum transmission range of each other. a packet forwarding technique where immediate nodes can elect to be redirectors on behalf of source- destination pairs with the goal of reducing the overall transmission power needed to deliver packets in the network, thus, increasing the operational lifetime of networked devices and protocol environment based on Adhoc on demand distance vector routing (AODV).

1. INTRODUCTION

A critical design issue for future wireless ad hoc networks is the development of suitable communication architectures, protocols and services that efficiently reduce power consumption thereby increasing the operational lifetime of network enabled wireless devices. Transmission power control used for communications impacts the operational lifetime of devices in different ways. For devices where the transmission power accounts only for a small percentage of the overall power consumed (e.g., a wireless LAN radio attached to a notebook computer) reducing the transmission power may not significantly impact the device's operational lifetime. In contrast, for small computing/communication devices with built-in or attached radios (e.g., cellular phones, PDAs, sensors, etc.) reducing the transmission power may significantly extend the operational lifetime of a device, thus, enhancing the overall user experience.

The design of routing protocols for wireless ad hoc networks is challenging. Bandwidth and power resources available in wireless networks represent scarce resources. The signaling overhead of routing protocols may consume a significant percentage of the available resources reducing the end user's bandwidth and power availability. This is compounded by the fact that topology changes in wireless and mobile networks occur at a much faster time scale in comparison to wired networks. Thus, routing protocols should be capable of rapidly responding to these changes using minimum signaling and taking into account the power reserves distributed in wireless networks.

Building such ad hoc networks poses a signi_cant technical challenge because of the many constraints imposed by the environment. Thus, the devices used in the eld must be lightweight. Furthermore, since they are battery operated, they need to be energy conserving so that battery life is maximized. Several technologies are being developed to achieve these goals by targeting speci_c components of the computer and optimizing their energy consumption. For instance, low-power displays (see [13]), algorithms to reduce power consumption of disk drives (see [9, 19, 34]), low-power I/O devices such as cameras (see [5]), etc. all contribute to overall energy savings. Other related work includes the development of low-power CPUs (such as those used in lap- tops) and high-capacity batteries.

Our focus, in the past year, has been on developing strategies for reducing the energy consumption of the communication subsystem and increasing the life of the nodes. Recent studies have stressed the need for designing protocols to ensure longer battery life. Thus, [21] observes that the average life of batteries in an idle cellular phone is one day. [32] studies power consumption of several commercial radios (WaveLAN,Metricom and IR) and observes that even in Sleep mode the power consumption ranged between 150170 mW while in Idle state the power consumption went up by one order of magnitude. In transmit mode the power consumption typically doubled. The DEC Roamabout radio [1] consumes approximately 5.76 watts during transmission, 2.88 watts during reception and 0.35 watts when idle.

If we examine the existing MAC protocols and routing protocols in this context we see a clear need for improvement: in all of the current protocols, nodes are powered on most of the time even when they are doing no useful work. At the MAC layer, nodes expend scarce energy when they overhead transmissions. In Figure 1, node A's transmission to node B is overheard by node C because C is a neighbor of A. Node C thus expends energy in receiving a packet that was not sent to it. In this case, clearly, node C needs to be powered o_ for the duration of the transmission in order to conserve its energy. Our MAC layer protocol (summarized in section 4) does precisely this and saves large amounts of energy. Routing protocols designed for ad hoc networks are also guilty of expending energy needlessly. In most of these protocols the paths are computed based on minimizing hop count or delay. Thus, some nodes, become responsible for routing packets from many source{destination pairs. Over time, the energy reserves of these nodes will get depleted resulting in node failure. A better choice of routes is one where packets get routed through paths that may be longer but that pass through nodes that have plenty of energy reserves.

The design of a power-efficient routing protocol should consider both data transmission and route discovery. In terms of power transmission, these protocols should be capable of efficiently discovering routes involving multiple hops, thus minimizing the transmission power in comparison to standard flooding based ad hoc routing designs. PARO departs from broadcast-based designs and supports a node-to-node based routing approach that is more suited to the efficient discovery of power-aware routes. PARO is not only applicable as a local area routing technology where all nodes are within direct transmission range of each other (e.g., personal area networks, home networks, sensor networks, WLANs) but it can also perform power optimization as a layer 2.5 routing technology operating below wide-area MANET routing protocols. In this case, PARO provides wide-area routing protocols with local energy-conserving routes and wide-area routing is used to forward packets when the source and destination nodes are outside the maximum transmission range of each other.

2. PARO MODEL

2.1 Link Assumptions

PARO requires that radios are capable of dynamically adjusting the transmission power used to communicate with other nodes. Commercial radios that support IEEE 802.11 and Bluetooth include a provision for power control. PARO assumes that the transmission power required to transmit a packet between nodes A and B is somewhat similar to the transmission power between nodes B and A. This assumption may be reasonable only if the interference/fading conditions in both directions are similar in space and time, which is not always the case. Because of this constraint PARO requires an interference-free Media Access Control (MAC) found in frequency band radios such as Channel Sense Multiple Access (CSMA). In addition, PARO requires that every data packet successfully received is acknowledged at the link layer and that node in the network are capable of overhearing any transmissions by other nodes as long as the received signal to noise ratio (SNR) is above a certain minimum value. Any node should be capable of measuring the received SNR of overheard packets. This includes listening to any broadcast, unicast and control (e.g.acknowledgment) packets.

2.2 Cost Function

The goal of PARO is to minimize the transmission power consumed in the network. A node keeps its transmitter “on” to transmit one data packet to another node for seconds where Ä is the size of the transmitted frame in bits (e.g.,data plus layer 2 headers) and is the raw speed of the wireless channel in bits/second. Similarly, the receiver node keeps its transmitter on to acknowledge a successful data seconds where Ð transmission for a combined period of Ð is the size of the acknowledgement frame including layer 2 headers. a network composed of several static nodes. Let's assume there are several alternative routes between a given source-destination pair in the network and that each route involves a different set and number of forwarding nodes the minimum transmission power at node such that the receiver node along route is still able to receive the packet correctly while Æ is the number of times a data packet is forwarded along route including the source node. Transmission power only thus, it neglects the cost of processing overheard packetsand the cost of keeping the radio in a listening mode. PARO is suitable for devices for which adjusting the transmission power benefits the overall power consumption. The power consumption during the transmission mode of such devices is higher than the power consumption during reception and listening modes, as is the case with a number of commercial radios.

PARO mainly uses data packets for route discovery in some cases the protocol uses explicit signaling to discover routes in the network The goal of any power-efficient routing protocol should be to reduce the signaling overhead to a minimum in order to save power. PARO tries to find the route for which the transmission power, È , is minimized, and furthermore, it tries to do discover this route using as little transmission power as possible. Let Ê be the transmission power consumed by the routing protocol to discover the route for which È is a minimum, then the cost fuction.

3. PROTOCOL OPERATIONS

Prior to transmitting a packet, a node updates its packet header to indicate the power required to transmit the packet. A node overhearing another node's transmission can then use this information plus, a localized measure of the received power, to compute (using a propagation model) the minimum transmission power necessary to reach the overheard node. In this simple manner, nodes can learn the minimum transmission power toward neighboring nodes. PARO does not, however, maintain routes to other nodes in the network in advance but discover routes on a per-node ondemand basis. This approach has the benefit that signaling packets, if any, are transmitted only when an unknown route to another node is required prior to data transmission, thus reducing the overall power consumption in the network.

At first the operation of PARO may seem counterintuitive because in the first iteration of PARO the source node communicates with the destination node directly without involving any packet forwarding by intermediate nodes (i.e., redirectors). Any node capable of overhearing both source and destination nodes can compute whether packet forwarding can reduce the transmission power in comparison to the original direct exchange between source and destination nodes. When this is the case an intermediate node may elect to become a redirector and send a route-redirect message to the source and destination nodes to inform them about the existence of a more power efficient route to communicate with each other. This optimization can also be applied to any pair of communicating nodes; thus, more redirectors can be added to a route after each iteration of PARO with the result of further reducing the end-to-end transmission power. PARO requires several iterations to converge toward a final route that achieves the minimum transmission power, as defined in Equation 1.

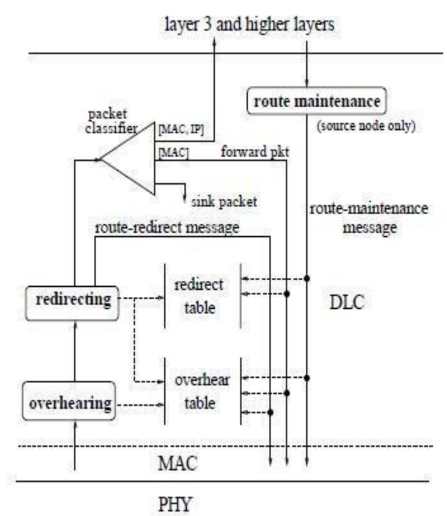

Figure 1: PARO Model

The PARO model comprises three core algorithms that support overhearing, redirecting and route-maintenance, as shown in Figure 1. The overhearing algorithm receives packets overheard by the MAC and creates information about the current range of neighboring nodes. Overheard packets are then passed to the redirecting algorithm, which computes whether route optimization through the intermediate node would result in power savings. If this is the case, the node elects to become a potential redirector, transmits route-redirect messages to the communicating nodes involved and creates appropriate entries in its redirect table. The overheard packet is then processed by the packet classifier module with the result that one of the following actions is taken: (i) the packet is passed to the higher layers if both MAC and IP addresses match; (ii) the packet is dropped if neither MAC nor IP addresses match; or (iii) the packet is forwarded to another node when only the MAC address matches. In the latter case, PARO searches the redirect table to find the next node en route and the searches the overhear table to adjust the transmission power to reach that node.

When PARO receives a data packet from the higher lay the destination node exists. If this is not the case, PARO searches the overhear table to see if transmission power information regarding the destination node is available. If this is not the case, PARO transmits the packet using the maximum transmission power anticipating that the receiving node is located somewhere in the neighborhood. Once the destination node replies with a packet of its own then PARO's route optimization follows as described previously. PARO relies on data packets as the main source of routing information in the network. When nodes are mobile and no data packets are available for transmission, a source node may be required to transmit explicit signaling packets to maintain a route. The role of the route maintenance algorithm is to make sure that a minimum flow of packets is transmitted in order to maintain the route when there are no data packets available to send at the transmitter.

4. PROTOCOL DESIGN

The overhearing algorithm processes packets that are successfully received by the MAC, and creates a cache en-try in the overhear table or refreshes an entry in the case that information about the overheard node already exists. Where the Á is a unique identifier of the overheard node the minimum transmission power necessary to communicate with the overheard node. Definition: Let the minimum signal sensitivity level at node at which a packet can still be received properly. If Ê is the measured received signal power at node from a packet transmitted by node at power then the minimum transmission power for node to communicate with node The two-ray propagation model is appropriate for outdoor environments where a strong line of sight signal exits between the transmitter and receiver nodes and when the antennas are Omni directional.

The two-ray propagation model assumes there are two main signal components. The first component is the signal traveling on the line of sight and the second component is a reflection wave from a flat ground surface Redirecting The redirecting algorithm is responsible for performing the route optimization operation that may lead to the discovery of new routes that require less transmission power. The redirecting algorithm performs two basic operations: compute-redirect, which computes whether a route optimization between two nodes is feasible; and transmit redirect, which determines when to transmit route-redirect Messages.

5. ROUTE CONVERGENCE

The case where only one intermediate redirector node was added to a route between a source-destination pair. a source-destination route comprised of five segments with four redirectors requiring four iterations for route convergence. the route taken by data packets after each iteration and the intermediate nodes selected as redirectors after transmitting successful route-redirect requests

6. MOBILITY SUPPORT

In static networks there is no need for route maintenance once the initial route between source-destination pairs has been found, other than when nodes are turned off and on. Adding support for mobile nodes to the core algorithms is challenging because of the uncertainty concerning the current range of neighboring nodes as they move in the network

7. OVERHEARING

Any node transmitting a packet to the next hop redirector in the route has to determine the next hop's current range, which may be different from its last recorded position. Clearly, the preferable transmission estimate is the one that transmits a packet using the minimum transmission range. If a node transmits a packet assuming that the next hop's current range is the same as the last recorded range then three scenarios may occurs: (i) The current position of the next redirector is within the current transmission range. In this case, the transmitting node finds the next redirector but some power is wasted because more power is used than necessary for this operation. (ii) The current position of the next redirector is at the same transmission range thus the transmission is optimum. (iii) The current position of the next redirector is outside the current transmission range. In his case, the transmitting node fails to find the next redirector and has to attempt a new transmission using more power than the current level.

7.1 Performance Evaluation

In this section, we present an evaluation of PARO and discuss a number of performance issues associated with power optimization and route maintenance. We used the ns network simulator with the CMU wireless extension [1] to evaluate PARO. The simulator supports physical, link and routing layers for single/multi hop ad-hoc networks. The propagation model is based on a two-ray model discussed in Section 3.1. After receiving a packet each node invokes a propagation model to determine the power at which the packet was received. If the node determines that the packet was successfully received (e.g., the received power was above a certain threshold) it passes the packet to the MAC layer. If the MAC layer receives an error-free packet it passes the packet to the link layer and so on. The simulation uses the standard ns/CMU mobility model.

We use the IEEE 802.11 MAC protocol which uses Channel Sense Multiple Access with Collision Avoidance (CSMA/CA) also referred to in IEEE 802.11 as the Distributed Coordination Function (DCF). In IEEE 802.11 a packet is successfully captured by a node's network interface if the sensed SNR of the received packet is above a certain minimum value1 otherwise the packet cannot be distinguished from background noise/interference. Communication between two nodes in IEEE 802.11 uses RTS-CTS signaling before the actual data transmission takes place. Due to the potential problem of nodes not being able to listen to RTS-CTS packets in the case of a system with dynamic transmission power control, we always transmit RTS-CTS packets at maximum transmission power.

7.2 Power Optimization

As discussed in Section 3.3, the more densely populated the network the higher the average number of potential redirector nodes, and the lower the average transmission power between source-destination pairs. The simulation topology consists of a 100x100 network with 10, 30 and 100 randomly positioned static nodes for each experiment. The simulation trace lasts for a duration of 100 seconds with ten UDP/CBR flows transmitting 512 bytes packet every three seconds. The simulation uses a value for _ = 1 which configures PARO to find the best power-efficient route. Figure 5 shows that the aggregate power necessary to transmit all data packets versus the number of nodes in the network. Figure 5 also indicates (between parenthesis) the average number of times a packet is forwarded before reaching its destination node (i.e., average number of redirectors en route). This number is dependent on the number of nodes and node density, as mentioned previously. The higher the number of nodes in the network the higher the probability of having more redirectors between communicating nodes. We observe that the aggregate transmission power decreases as the number of redirector nodes increases. At first the aggregate transmission power decreases rapidly when there are between an average of 0.5 and 2.9 redirectors present. The aggregate transmission power then decreases slowly up to an average of 5.4 intermediate redirector nodes, as shown in the simulation plot. Figure 5 shows that in terms of transmission power alone, it does not pay to have more than three redirectors per source- estination pair. Having more than three redirectors may increase end-to-end delay and likelihood of network partitions. Figure 5 also indicates the transmission power needed if no redirectors were added between source- destination pairs. Comparing the two scenarios (i.e., with and without redirectors) in Figure 5, we clearly observe the benefit (i.e., power savings) of adding intermediate redirector nodes. However, even if no intermediate nodes are found between source-destination pairs, by default PARO will use the minimum transmission power information (if available) to communicate with a destination node. This operation is in contrast with traditional wireless LAN systems, which always use the maximum transmission power to communicate with a destination node even if the destination node is in very close proximity to the transmitter.

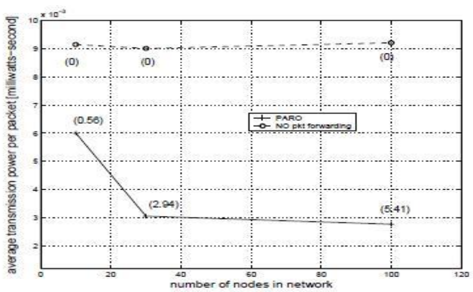

Figure 5. Transmission Power versus Average Number of Redirectors

8. CONCLUSION

In MANETs, a link is formed by two adjacent mobile nodes, which have limited battery energy and can roam freely, and the link is said to be broken if any of the nodes dies because they run out of energy or they move out of each other's communication range. PARO consumed less power in order to find power-efficient routes compared to MLSR due to its point-to-point on-demand design. An early implementation of the PARO system using a commercial IEEE 802.11 radio showed a basic proof of concept even though some inef ficiencies and anomalies were identified. Currently, we are studying the performance of Internet applications and transport protocols operating over PARO. We are particularly in terested in studying quality of service issues such as delay, "goodput" and packet error rates under such a regime. Furthermore, we are investigating complementary techniques that help save reception and idle power in PARO-based wireless ad hoc network.

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