A New Power Conservative Routing for Wireless Mobile Ad hoc Networks using Cross Layer Design

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Summary
Nowadays, the cross-layer design approach is the most relevant concept in wireless mobile ad hoc networks which is adopted to solve several open issues. It aims to overcome ad hoc networks performance problems by allowing protocols belonging to different layers to cooperate and share network status information while still maintaining separated layers. A cross layer design is particularly important for any network using wireless technologies, since the state of the physical medium can significantly vary over time. Perhaps information exchange between different layers can even optimize the network throughput.

In this paper, we proposed a simple cross-layer design among Physical, Medium Access Control and Network layers for power conservation based on transmission power control. In this method, we provided power control ability to the Dynamic Source Routing protocol. In this Power DSR (PDSR), the RREP control signals are used to piggyback the necessary information to enable the transmitting nodes to discover the required minimum amount of transmission power. We have implemented this protocol using Global Mobile Simulator (Glomosim) and studied its performance using on-demand routing protocol, DSR. We obtained around 15% power conservation with Power DSR. We also made an experiment with Power DSR at routing layer and Power Controlled MACA protocol at mac layer.

Keywords:
Mobile Ad Hoc Networks, power conservation, cross layer design, DSR routing protocol, Power DSR.

1. Introduction

A Mobile Ad hoc Network (MANET) [1] 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. In such a network, each mobile node operates not only as a host but also as a router.

The main building blocks of a wireless network design are routing, rate control, medium access (scheduling) and power control. These building blocks are divided into layers. Typically, routing is considered in a routing layer and medium access in a MAC layer, whereas power control and rate control are sometimes considered in a PHY and sometimes in a MAC layer. Several protocols have been designed independently without considering the interactions between these layers. Therefore, there is a need to provide joint solution for all these problems with protocol interactions which can led to increased network efficiency and Quality of Service(QoS) support. For this, a new concept called "Cross layer design" [2],[3] has been introduced. A cross layer design is particularly important for any network using wireless technologies, since the state of the physical medium can significantly vary over time. Perhaps information exchange between different layers can even optimize the network throughput.

It is well known that power is a precious resource in wireless networks due to limited battery life. This is further aggravated in ad hoc networks since all nodes are mobile terminals of limited weight and size. In addition, power control is of paramount importance to limit multiuser interference and hence maximize the spatial re-use of resources [4]. So, power conservation is a key objective in the design of ad hoc networks. Power control has been studied extensively in the context of channelized cellular systems [5], [6] and in a general framework [7].

In this paper, the main focus is to develop and test a distributed algorithm for joint power control, scheduling, and routing in wireless mobile ad-hoc networks. For this, a new power controlled DSR protocol (PDSR) is proposed which mainly concentrates on the reduction of the transmission power used and it is simulated in GloMoSim. Also the performance is measured by comparing with the protocols in layered architecture where there is no interactions between the layers. In this paper, we also made an experiment with two different power controlled protocols at two different layers of the cross-layered architecture.

2. Background

Wireless ad-hoc networks which are extensively studied in [8], [9] needs strong coupling among the traditional layers of the architecture and these interactions cannot be ignored. For instance adapting transmission rate based on link state information passed from physical to MAC layer, can improve the performance of the IEEE 802.11 protocol [10]. Another interaction, which increases network performance further, is coupling between network layer (routing) and MAC layer [11].

Future wireless networks are expected to accommodate a wide variety of nodes with different power constraints, bandwidth capabilities and vastly different QoS requirements. Many research efforts have been devoted to introducing new protocols in the specific layer of ISO-OSI protocol stack, which is a major shortcoming. Moreover these protocols have been designed independently without considering their interactions or impact on the design choices at other layers of the stack. Also, there is no distributed algorithm for joint power control, scheduling, and routing in wireless ad- hoc networks [12], [13], since these are considering infrastructured networks.

In order to develop a distributed algorithm jointly for these problems, we have to consider the routing and MAC protocols along with power control. If power control is not considered in any of these protocols, the problem of multi-user interference increases and gives rise to reduction in the throughput of the network. Also, using the fixed transmission power levels for the data packets reduces the life period of the battery. There fore there is a need to introduce a power controlled multiple access algorithm]. We proposed and developed a new power controlled multiple access (PCMA) protocol providing the interactions between physical and mac layers in [14]. The Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) mechanism of IEEE 802.11 Wireless Local Area Network (WLAN) is integrated with this power control algorithm. The exchange of control signals, Request Power To Send(RPTS) and Accepted Power To Send(APTS) ,is used to piggyback the necessary information to enable the transmitting nodes to discover the required minimum amount of power that is needed to transmit data packets. In [14], the power control technique is applied at MAC layer so that only data packets can be transmitted with minimum reduced power.

In this paper, we introduced this power control technique in routing layer to reduce the energy consumption for both data packets and control packets. Also we made an experiment with this power control technique applying at both MAC layer and routing layer.

3. Dynamic Source Routing Protocol

The Dynamic Source Routing protocol [15], is an on-demand routing protocol that is based on the concept of source routing. The protocol maintains a route cache in each node which is updated as new routes are learned. When a node has a packet to send to some destination, it looks in the cache to determine if it already has a route to the destination. If there are multiple routes to the destination in the cache, the routing logic selects the minimum hop route. The node then inserts this route in the routing header of the data-packet and sends it to the MAC layer for transmission over the medium. In case the source node has no route to the destination in its cache, it initiates a route discovery process: it broadcasts a *Route Request* (RREQ) packet containing the destination node address, the source node address and a unique *Request ID*. Each node that receives the route request checks its cache for a route to the destination in case the 'reply from cache' option is enabled in the routing agent logic. If this option is disabled or if no route is found in the cache, the node adds its own address to the address chain in the route request packet and rebroadcasts the packet. However, in case the node has already heard a route request with the same request ID earlier, the node does not rebroadcast the packet. This continues till the packet reaches the destination node or, if the 'reply from cache' option is enabled, till it reaches a node that knows a route to the destination. Here again, in case there are multiple routes, the minimum hop route is selected. This node makes up a *Route Reply* (RREP) packet and inserts the full source route to the destination in the route reply packet and uses the reverse route from itself to the source node to route this reply packet to the source node.

Route maintenance is carried out in case the links in the routes being used break due to channel fluctuations and node mobility causing the received power to fall below the receiver sensitivity threshold. *Route Error* (RERR) packets are generated at a node in case the link layer reports a broken link during a data-packet transmission. This route error packet is routed to the source node of the data-packet through the intermediate nodes in the route so that they can update the caches by removing the hop in error and truncating all other routes that contain that hop till that point.

4. Proposed Power DSR

We designed a new Power controlled DSR (PDSR) by modifying the existing DSR protocol [15]. The changes are needed in the route discovery phase of DSR algorithm. The RREP packet is send to the particular source with the transmission power in its header along with the route. Upon receiving the RREP packet, the source node measures the received power of the RREP packet and collects the transmitted power of the RREP packet that is piggybacked in the same packet. Then the source node calculates the pathloss of the RREP packet and calculates its required minimum transmission power using the receiver threshold (minimum power required for the receiver to detect the signal). The receiver threshold along with the path loss gives the optimum power required for transmission at MAC layer.

Controlling the transmitter power at a given node increases not only the operating life of the battery but also the overall system capacity of successful admitting new links between a source and a destination. The advantage of implementing a power controlled protocol in an ad-hoc network is that the source-destination pairs can be more tightly packed into the network allowing a greater number of simultaneous transmissions (spectral reuse).

4.1 PDSR Algorithm

(1) The RREP packet is sent to a particular source with the transmission power in its header along with the route.
(2) Upon receiving the RREP packet –

(a) if the node is intended source

1. Received power of the RREP packet is measured.
2. The transmitted power of the RREP packet that is piggybacked in the same packet is collected.
3. Then the node calculates the pathloss of the packet using: Pathloss = Tx power – Rx power.
4. Then the node calculates its required minimum transmission power using the receiver threshold. The receiver threshold along with the path loss gives the optimum power required for transmission at MAC layer.
   Required Min Tx Power = Path loss + Receiver Threshold
5. This Min Tx Power calculated at routing layer is directly passed to MAC layer where the node can transmit control packets (RPTS/APTS) and data packets to the destination with this reduced Tx Power.

(b) if the node is intermediate node

1. Performs all the calculations same as the source node and relays this RREP packet to the intended source through some intermediate nodes.
2. As the RREP is routed back along the reverse path, the nodes along the path will only setup forward route entries in their route table but also forced to enter the required power for transmission in the route table.

4.2 Cross-Layer Design for Power Control and Routing

Cross layering is generally intended as a way to let protocols interact beyond what allowed by standard interfaces. In the present DSR protocol [15], there is no information regarding the power parameters. To include this in our PDSR, it needs a cross layering between network and physical or MAC layer. The information shared among these layers are: Location of the nodes, Power levels, Distance between the nodes and Noise levels. Sharing these parameters based on the constraints among the layers finishes the job of the cross layer frame work. Here, the received power of the RREP packet is measured and is collected at the physical layer. Also other parameters such as transmission power, distance, antenna gains are present at the physical layer. To perform power control and routing these parameters are to be shared among physical, MAC and network layers. The following figure shows this information.

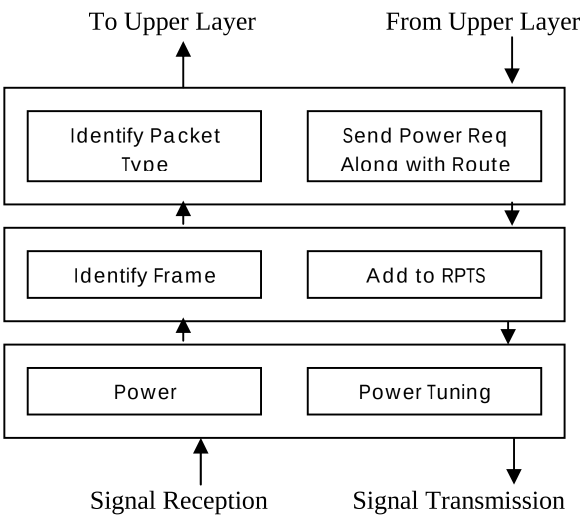

Fig. 1 CLD for Power control & Routing

5. Simulation and Results

We have used GloMoSim simulation tool to carry out our simulation. The GloMoSim [16] is the simulation software that has been developed for the purpose of scalable wireless network simulations. Like most of the network systems, GloMoSim is also built based on OSI seven-layered approach. It is designed using the parallel discrete–event simulation capability provided by PARSEC. Standard APIs are used between the different simulation layers. This allows the rapid integration of models developed at different layers by different people and builds a library of paralliezed models that can be used for the evaluation of a variety of wireless protocols. The protocol stack includes models for the channel, radio, MAC, network, transport and higher layers. The simulation parameters will be given in “Config.in “and “app.config” files in the “bin” directory of Glomosim. The following are the some of important parameters given in table 1.

Table 1:. Simulation Parameters

Simulation Parameters	**Value**
Simulation time	15M
Seed	1,2,3,4
Terrain range	1000x1000
No. of nodes	10,20,30,40,50,60,70,80
Node placement	Random
Propagation path-loss model	Free space
Radio type	Radio accumulated noise
Transmission power	30 dBm
Receiver threshold	-81 dBm
Mobility model	Random way point
Pause time	600sec
Minimum speed	0 m/sec
Maximum speed	35 m/sec
Packet size	512 Bytes
MAC protocol	MACA
Network protocol	IP
Routing protocol	DSR, Power DSR
Transport protocol	TCP
Application traffic	CBR

To analyze the performance of our transmit power control algorithm (Power DSR) at the network layer, experiments are done by choosing DSR and modified DSR (PDSR) protocols. DSR is chosen because it is the standard on demand routing protocol. It is known that the transmission power consumption is constant for original DSR with out power control [15]. But DSR with power control algorithm (PDSR) saves total power consumption by reducing the transmission power there by increasing the lifetime of nodes in the network. From the figure 2 it is understood that as the mobility of nodes increases the total transmission power consumption is moderately reduced in PDSR compared to DSR without power control. From figures 3 and 4, as the number of nodes increases gradually in the network and as the number of data packets to be transmitted are increased, it is observed that the transmission power consumption is minimum when PDSR is used instead of DSR.

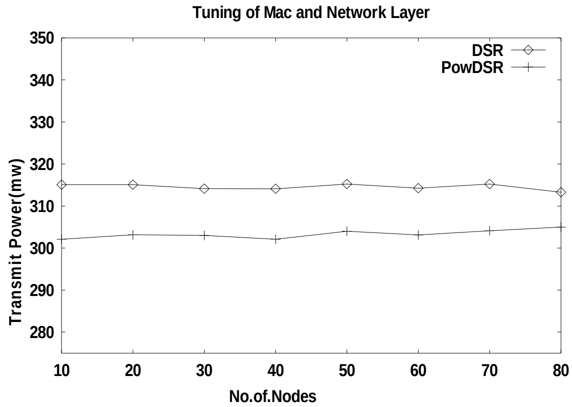

Fig. 2 Transmission power consumption of DSR vs PDSR for a network of 1000m by 1000m area with different number of nodes.

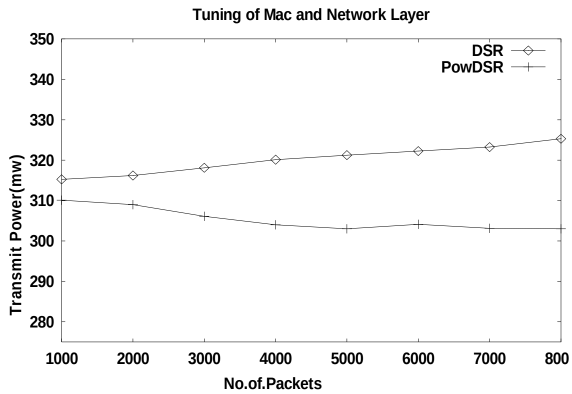

Fig. 3 Transmission power consumption of DSR vs PDSR for a network of 1000m by 1000m area with different number of packets.

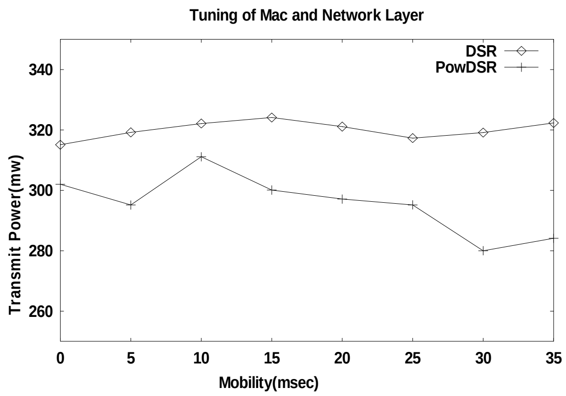

Fig. 4 Transmission Power Consumption of DSR vs PDSR for a network of 1000m by 1000m area with different mobility.

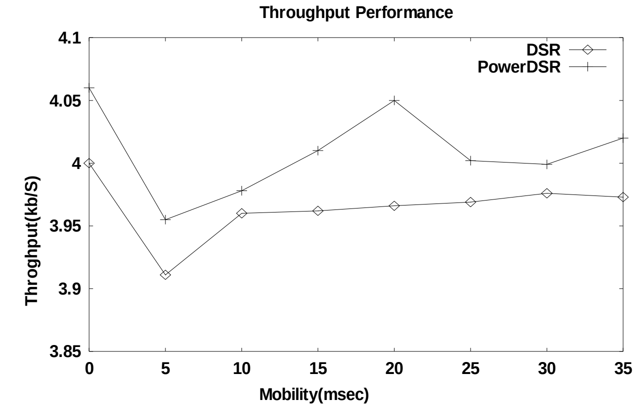

Fig. 5 Throughput of DSR vs PDSR for a network of 1000m by 1000m area with different mobility.

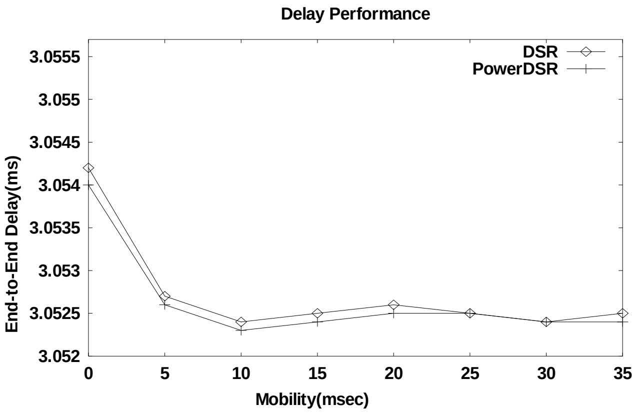

Fig. 6 Delay of DSR vs PDSR for a network of 1000m by 1000m area with different mobility.

The graph in figure 2 shows that when DSR routing protocol is used in the network, the total transmission power consumption is almost a constant value. But when PDSR is used as the routing protocol, a better reduction in the power consumption can be seen from this graph.

In figure 3, the simulation is run to analyze the transmission power consumption with respect to number of packets. So the simulation is repeated by changing the number of packets in the network. It can be observed from the figure 3, the DSR protocol when used in the network and as the number of data packets are increased gradually, the power consumption is increased rapidly. The PDSR protocol used minimum power for the same configuration as it has power control feature.

From the figure 4, it is observed that even the mobility of nodes increases gradually, the power consumption in the network with PDSR algorithm is better than DSR. From figures 5 and 6, it is shown that there is an increase in network throughput with PDSR and end-to-end delay is almost same as DSR.

6. Experiment

Besides PDSR protocol, we also made an experiment in which we used two different power controlled protocols at two different layers to reduce the transmission power. The simulation parameters used in the experiment are specified in table 2.

Table 2: Simulation Parameters

Simulation Parameters	Value
Simulation time	15M
Seed	1,2,3,4
Terrain range	1000x1000
No. of nodes	10,20,30,40,50,60,70,80
Node placement	Random
Propagation path-loss model	Free space
Radio type	Radio accumulated noise
Transmission power	30 dBm
Receiver threshold	-81 dBm
Mobility model	Random way point
Pause time	600sec
Minimum speed	0 m/sec
Maximum speed	35 m/sec
Packet size	512 Bytes
MAC protocol	MACA,PCMA
Network protocol	IP
Routing protocol	DSR, Power DSR
Transport protocol	TCP
Application traffic	CBR

The power controlled MACA protocol (PCMA) proposed in [14] is used at MAC layer and our new PDSR is applied at Network layer.

With this experiment results, figures 7,8,9,10 and 11, it is observed that the total transmission power consumption of the network is further reduced than in PDSR. In the experiment we observed mainly the total transmission power consumption in the network under different scenarios. Also a little bit increase in network throughput is found but average end-to-end delay has been increased slightly in our experiment. Because the power calculations are done in two layers, mac and network.

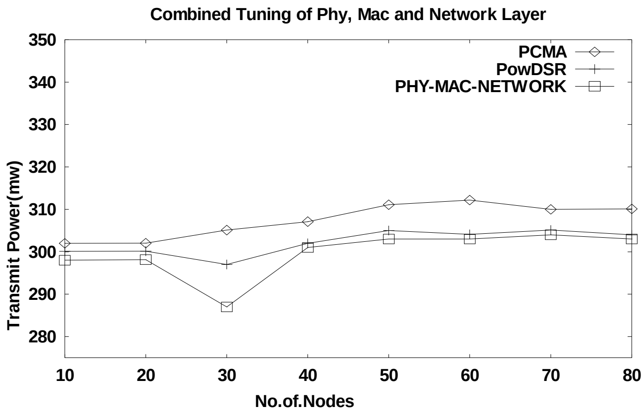

Fig. 7 Transmission power consumption of DSR vs PDSR for a network of 1000m by 1000m area with different number of nodes.

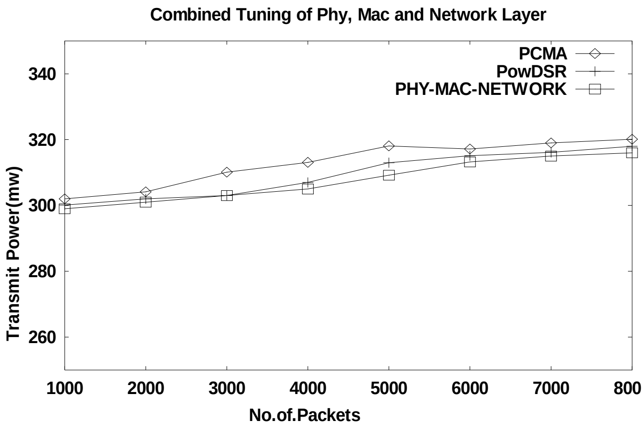

Fig. 8 Transmission power consumption of PCMA, PDSR vs Experiment for a network of 1000m by 1000m area with different number of packets.

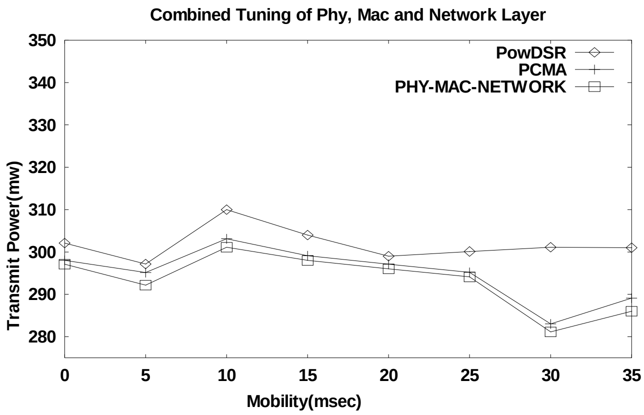

Fig. 9 Transmission power consumption of PCMA, PDSR vs Experiment for a network of 1000m by 1000m area with different mobility.

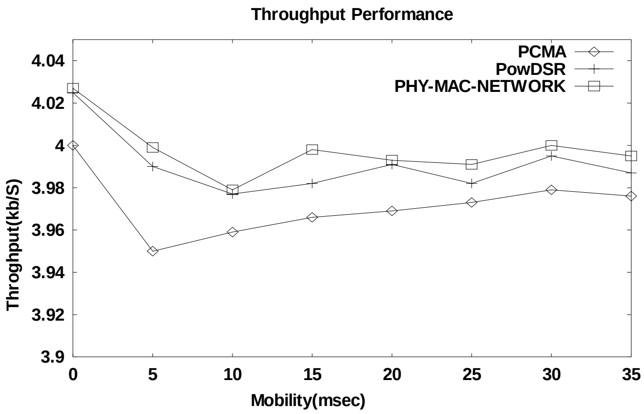

Fig. 10 Throughput of DSR , PDSR vs Experiment for a network of 1000m by 1000m area with different mobility.

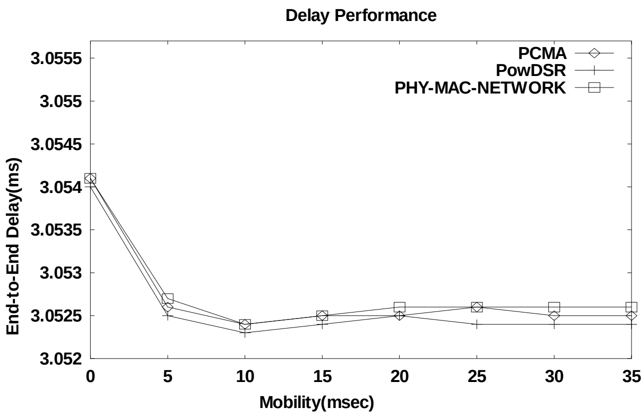

Fig. 11 Delay of DSR , PDSR vs Experiment for a network of 1000m by 1000m area with different mobility.

7. Conclusion

In this paper, we proposed an algorithm for joint power control and routing, PDSR, along with cross layer interactions in wireless ad-hoc networks. The performance analysis shows that there is a better improvement with this algorithm compared to existing DSR algorithm. The network capacity improvement using transmission power control have been done for low density network, the same can be extended for any high density network, with certain modifications in the algorithms. Our experiment reveals the fact that the transmission power tuning can be applied at two different layers for better performance but it increases the cost of the network design.

The present work succeeded in enhancing throughput and energy savings. However it is suggested if proper cross layer interactions are provided between TCP and below layers, additional benefits of power control can be achieved.

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