ISSN 2320 – 2602
Volume 3, No.12, December 2014
International Journal of Advances in Computer Science and Technology
Available Online at http://warse.org/pdfs/2014/ijacst013122014.pdf

Survey on Minimizing Energy Consumption in Mobile adhoc Networks

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ABSTRACT

A mobile ad hoc network consists of nodes that move arbitrarily. It leads to dynamic topologies. Power failure of a mobile node not only affects the node itself but also its ability to forward packet on behalf of others and the overall network life time. For this reason many research efforts have been devoted to reduce energy consumption. The goal of this paper is to facilitate research efforts in combining existing solutions in order to offer a more energy efficient approach. Towards this goal we have given a review of mobile ad hoc networks and discussed various power saving techniques. We also discuss the energy saving methods that can be used to reduce energy. They are such at device level, at transmission level and by using energy efficient routing protocols. We had also given a comparative analysis of these techniques.

Keywords: Mobile Ad-hoc Networks, Routing Protocols, Energy efficiency, networking

1. INTRODUCTION

A mobile ad hoc network [1] is a collection of mobile nodes that are dynamically and arbitrarily located in such a manner that the interconnections between nodes are capable of changing on a continual basis. Military, law enforcement, and disaster relief operations are often carried out in situations with no preexisting network infrastructure (e.g., base stations). Because batteries carried by each mobile node have limited power supply, processing power is limited, which in turn limits services and applications that can be supported by each node. This becomes a considerable issue in mobile ad hoc networks because, as each node is acting as both an end system and a router at the same time, extra energy is required to forward packets from other nodes. Mobile devices consume power even in their sleep modes. For example, in mobile phones, even if they are not in use, there is a constant power drain because the trans-receiver is constantly hearing for signals.

To solve these problems researchers tried to optimize power consumption in every aspect of mobile devices. Energy consumption [2] can be reduced at device level, at transmission level or may be by using optimized power aware routing protocol. Power utilization can be optimized by employing routing algorithms that avoid nodes with less battery power remaining while trying to minimize the total power consumed in transmitting a packet. In this paper we have given a brief description of basic aspects of mobile ad hoc network and studied various power saving techniques in mobile ad hoc networks and given a comparative analysis of these techniques.

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 wastes energy in receiving a packet that was not sent to it. Clearly, node C should be powered off for the duration of the transmission in order to conserve its energy. For example, all the packets from 0-3, 1-4, 2-5, in Figure 2. will be routed through the central node. This will lead to a relatively early death of the central node. We need to reduce energy consumption and increase the life time of the network.

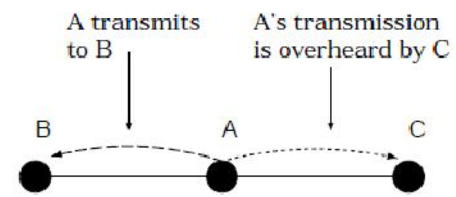

Figure 1. Overhearing

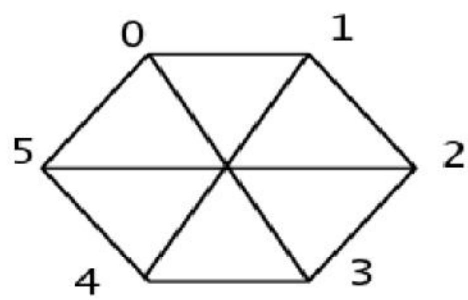

Figure 2. Early death of nodes in Manet.

The remainder of this paper is organized as follows. Section 2 describes the various power saving techniques employed by mobile operating systems and devices. Section 3 and 4 describes metrics for power optimization and power aware techniques. Section 5 describes various power aware routing algorithms. Section 6 presents the conclusion and future work.

2. ENERGY-EFFICIENCY IN MANETS

Unlike cellular networks, the lifetime of mobile hosts will deeply impact the performance of the ad hoc mobile network. In a cellular network, a reduction in the number of active mobile users will reduce the amount of signal interference and channel contentions. However, since ad hoc mobile hosts need to relay their messages through other hosts toward their intended destinations, a decrease in the number of mobile users can also degrade network performance. As the number of available hosts decreases, the network may also be partitioned into smaller networks. To prolong the lifetime of each node, ad hoc routing protocols should consider power consumption. For example, routing protocols should be able to accommodate sleep periods without causing any adverse consequences; that is, hosts can stop transmitting and/or receiving for arbitrary periods of time when it is idle. Moreover, transmission power can be used as a routing metric. Since most mobile hosts of an ad hoc network today operate using batteries, it is important to minimize the power consumption of the entire network. The power required by each mobile host can be classified into two categories, such as communication related and non communication related. The former can be further divided into two parts, namely: Processing power, transceiver power.

Each mobile host consumes some processing power to function network algorithms and run applications. Transceiver power specify to the power used by the radio transceiver to communicate with the other mobile hosts. In mobile power consumption, each protocol layer is closely coupled. For example, if a routing protocol need frequent updates of routing information, it is difficult to implement sleep mode at the data link layer. We therefore briefly summarize the power conservation schemes for each layer below. In mobile Ad hoc network there can be three aspects to reduce the power consumption

- Power saving at mobile device level
- Power saving by controlling transmission level of packet
- Power saving by using optimized power routing protocol

2.1 Power saving at mobile device level

Mobile devices consume energy[3] even in their sleep mode for example, in mobile phones, even if they are not in use, there is a constant power drain because the trans-receiver is constantly hearing for signals to itself. A lot of efforts are currently going on to reduce the power consumed in each and every aspect of a mobile device. Now we give a brief report of some of these methods.

The operating system [3] of a machine is responsible for using hardware efficiently, for the disk drives, this means having a fast access time and disk bandwidth. Access time has two major components seek time and Rotational latency. Seek time is the time for the disk arc to move the heads to the cylinder containing the desired sector. Rotational latency is the additional time waiting for the disk to rotate the desired sector to the disk head. Disk bandwidth is the total number of bytes transferred, divided by the total time between the first request for service and the completion of the last transfer. One method of energy conservation in mobile devices is to spin down a disk in its idle time. The spin down delay is the amount of time the disk is idle before it spins down. The maximum power savings were obtained by using a spin down delay of two seconds as opposed to the 3-5 minutes recommended by most manufacturers. To justify this claim, the authors presented two points: frequency of sleep and length of sleep. They claim that, with shorter delays, the disk gets to sleep for a longer time and hence save more power.

The drawback of spinning down a disk after such short delays is the time and energy needed to spin up the disk, which results in user delay. Traces used by the authors show that the spin down occurs 8-15 times an hour. This translates to 16-30 seconds of user delay per hour, which is reasonable compared to the power savings incurred.

CPU scheduling is the basis of multiprogrammed operating systems. By switching the CPU among processes, the operating system can make the machine more productive. The power consumed by a processor is directly proportional to the supply voltage, the switching capacitance of the various devices and the frequency of the clock. Gates in CMOS CPU‘s switch state at every clock cycle, which lead to a short circuit between the power supply and ground. As a result more power is wasted with higher frequency.

The power required by the CPU is given by CV^2F, where C is the total capacitance of the wires, V is the supply voltage and F is the operating frequency. There are various algorithms proposed for adjusting the clock frequency in idle time. The main idea behind it is to balance the CPU usage between bursts of high utilization and idle times. Task or process scheduling can be an effective way of accomplishing this. Almost all processes have a deadline by which they need to be executed. It has been observed in that even when the processor is operating at the worst case, in scheduling the tasks, there is some idle time. This idle time is called the slack time. This slack time can be used to conserve energy by slowing down the processor and reducing the voltage. These techniques are known as, static slowdown and voltage scaling. We can reduce or eliminate the idle time by reducing the voltage to operate the processor such that, the process takes longer to finish but is completed before its deadline.

Memory is the most significant resource of mobile device .In mobile devices, memory instructions are among the uppermost consumers of power. Since lots of small devices do not have a secondary storage, the power consumed by the memory is very crucial and needs to be optimized. Some of the memory devices like Direct Rambus DRAM (RDRAM), have come out with a DRAM that allows the individual devices to be in different power states. These devices are in decreasing order of power states and increasing order of access times: Active, Standby, Nap and Power down.

Memory Placement policies for code and data can also assist to diminish the power consumption. If active pages with temporal locality are grouped together and placed on the same memory chip before moving to the next, the remaining chips can be powered down. This technique helps in reducing the power consumed in reading data from memory. The simulation results given in [3] show power saving of about 6% - 50% using the static, dynamic and temporal locality placement policies.

2.2 Power Saving by Controlling Transmit Power Level

The power control problem[4] in wireless ad hoc networks is that of choosing the transmit power for each packet in a distributed fashion at each node. The problem is complex since the choice of the power level fundamentally affects many aspects of the operation of the network .One is , the transmit power level determines the quality of the signal received at the receiver which affects the physical layer.s Second , it determines the range of a transmission which affects routing in terms affects network layer.It determines the magnitude of the interference it creates for the other receivers which affects the transport layer due to congestion.

Transmit power control is therefore a prototypical cross layer design problem affecting all layers of the protocol stack from physical to transport, and affecting several key performance measures, including the trinity of throughput, delay and energy consumption. Cross-layer design, in general, should be approached holistically with some caution, keeping in mind longer term architectural issues. Thus arises the question of where in the network architecture should power control be located, the resolution of which requires an appreciation of the issues involved at each layer.

Power control is important in wireless ad hoc networks for at least two reasons: It can impact on battery life, and it can impact on the traffic carrying capacity of the network. Following are the design principles for power control.

1. To increase network capacity it is optimal to reduce the transmit power level. 2. Reducing the transmit power level reduces the average contention at the MAC layer. 3. The impact of power control on total energy consumption depends on the energy consumption pattern of the hardware. 4. When the traffic load in the network is high, a lower power level gives lower end-to-end delay, while under low load a higher power gives lower delay. 5. Power control can be regarded as a network layer problem. So based on above design guidelines Kawadia & Kumar in[6] propose some protocols which attempt to achieve several design objectives and perform several optimizations simultaneously.

The COMPOW protocol attempts to increase network capacity, while meeting the needs of several other layers by choosing a common power level throughput the network.

The CLUSTERPOW protocol relaxes this constraint and provides a joint solution to the power control, clustering and routing problem, again with the goal of maximizing network capacity.

The MINPOW protocol achieves a globally optimal energy consumption solution for awake nodes, but may or may not increase network capacity depending on the wireless hardware.

2.3 Power Saving by Optimized Power Aware Routing Protocol

Routing is the process in which a route from a source to a destination node is identified and is achieved either by computing all routes before and pre-sorting them or computing them when needed.

A routing protocol is a protocol that specifies how routers communicate with each other to disseminate information that allows them to select routes between any two nodes on a network. Typically, each router has a priori knowledge only of its immediate neighbors. A routing protocol shares this information so that routers have knowledge of the network topology at large. In wireless ad hoc networks, every host acts both as a router and a packet sender, so the classical routing protocols used by wire linked networks are not applicable at all to ad hoc mobile networks. The routing protocols for ad hoc may be classified on the basis of following three criteria: Based on the logical organization, based on how to obtain routing information and based on how the routing path is created.

3. ENERGY AWARE ROUTING METRICS

End-to-end throughput and delay are widely used performance metrics in wired and wireless networks. However, since the network topology is dynamically changing, the bandwidth and battery power are important factors in wireless ad hoc networks. Hence, we should also consider other metrics as well. Such metrics can influence the design of routing protocols, and there exist trade-offs in using different metrics. For example, although on-demand routing algorithms can reduce control overhead (i.e., optimizing the bandwidth), it requires some route acquisition time (i.e., the time required to discover and establish a route when desired), thus increasing end-to-end delay. Therefore, in routing protocol design one should optimize some reasonable metrics in addition to others. The following is a list of metrics worthy of consideration: Maximum end-to-end throughput, Minimum end-to-end delay, Shortest path/minimum hop, Minimum total power (battery capacity), Load balancing (least congested path), Minimum overhead (bandwidth).

Energy constraints in the routing protocol significantly change the problem. First of all, the exchange of routing information between nodes entails an energy cost: this cost must be traded against the energy savings that result from using this information to make routes more efficient. In addition, even with perfect information about the links and network topology, the route computation must change to take energy constraints into account. Specifically, a route utilizing a small number of hops (low delay) may use significantly more energy (per node and/or total energy) than a route consisting of a larger number of hops. Moreover, if one node is often used for forwarding packets the battery of that node will die out quickly, making that node unavailable for transmitting its own data or forwarding packets for others.

Thus, the routing protocol under energy constraints must somehow balance delay constraints, battery lifetime, and routing efficiency. There has been much recent work on evaluating routing protocols under energy constraints.

Reactive routing is more energy efficient. This is not surprising since proactive routing must maintain routing tables via continuous exchange of routing information, which entails a significant energy cost.

Recent studies have stressed the need for designing protocols to ensure longer battery life. We see a clear need for improve in the MAC protocol, following are some such possibilities:

- In all of the current protocols, nodes are powered on most of the time even when they are doing no useful work.
- Much useful energy of the nodes is wasted in overhearing other transmissions.

Routing protocols are designed in such a way that the paths are computed based on minimizing hop count or delay. Thus, some nodes become involved in routing packets for many source-destination pairs. Over time, the battery of these nodes will get depleted and this will cause node failure.

Some intuitive suggestions for improving the situation can be:

- A better choice of routes is one where packets get routed through paths that may be longer but that pass through nodes that have enough battery life remaining.
- Routing packets through lightly-loaded nodes is also energy-conserving because the contention will be less so less collisions and this will minimize the energy required.

3.1 Currently used Metrics

The problem of routing in mobile ad hoc networks becomes difficult because of node mobility. Thus, we have to optimize two conflicting constraints on the one hand, in order to optimize routes, frequent topology updates are required, but on the other hand, frequent topology updates result in higher message overhead, and hence causes more power consumption.

Different routing protocols use one or more metrics to determine optimal paths. The most common metric used are:

- Shortest-hop routing: This metric is used in DSR (Dynamic Source Routing), DSDV (Destination Sequenced Distance Vector), TORA (Temporally-Ordered Routing Algorithm), WRP (Wireless Routing Protocol) and the DARPA packet radio protocol.
- Shortest delay: This can also be used as a metric in some of the above protocols, in place of hop-count.
- Link quality: This metric is used by SSA (Signal Stability based Adaptive Routing) and by the DARPA protocol. Here, link quality information is used to select the path. Here the shortest path may be discarded due to poor link quality.
- Location stability: SSA, along with link quality, also uses this metric. This metric favour choosing paths through stable nodes. This will avoid frequent rerouting and hence will save the power.

4. ENERGY AWARE TECHNIQUES

Now we list some power aware routing metrics, which do result in energy-efficient routes. Minimize Energy consumed/packet: This is one of the most obvious metrics that reacts our intuition about conserving energy. Assume that some packet j traverses nodes $n_1 ... n_k$.Where n_1 is the source and n_k the destination. Let T (a; b) denote the energy consumed in transmitting (and receiving) one packet over one hop from a to b. Then the energy consumed for packet j is,

$$E_c=\sum_{i=1}^{k} T(N_i, N_{i+1})$$

Thus the goal og this metric is to minimie e_j, $\forall$ packets j.

Maximize Time to Network Partition: This metric is very important in mission critical applications such as battle site networks. Unfortunately, optimizing this metric is very difficult if we need to simultaneously maintain low delay and high throughput.

Minimize Variance in node power levels: The intuition behind this metric is that all nodes in the network are equally important and no one node must be penalized more than any of the others. This metric ensures that all the nodes in the network remain up and running together for as long as possible.

Minimize Cost/Packet: If our goal is to maximize the life of all nodes in the network, then metrics other than energy consumed/packet need to be used. The paths selected when using these metrics should be such that nodes with depleted energy reserves do not lie on many paths. Let fi(xi) be a function that denotes the node cost or weight of node i. xi represents the total energy expended by node i thus far. The total cost of sending a packet along some path as the sum of the node weights of all nodes that lie along that path. The cost of sending a packet j is

$$c_j = \sum_{i=1}^{k-1} f_i(x_i)$$

The goal of this metric is to minimize c_j, $\forall$ packets j.

4.1 Lifetime Prediction Routing

Lifetime Prediction Routing (LPR) [13]is an on demand source routing protocol that uses battery lifetime prediction. The objective of this routing protocol is to extend the service life of MANET with dynamic topology. This protocol favors the path whose lifetime is maximum. We represent our objective function as follow:

Lifetime Prediction: Each node tries to estimate its battery lifetime based on its past activity. This is achieved using a Simple Moving Average (SMA) predictor by keeping track of the last N values of residual energy and the corresponding time instances for the last N packets received/relayed by each mobile node. This information is recorded and stored in each node. We have carefully compared the predicted lifetimes based on the SMA approach to the actual lifetimes for different values of N and found N=10 to be a good value.

This approach is a dynamic distributed load balancing approach that avoids power-congested nodes and chooses paths that are lightly loaded. This helps LPR achieve minimum variance in energy levels of different nodes in the network.

5. ENERGY EFFICIENT ROUTING PROTOCOLS

A lot of effort and research is currently on going to reduce the power consumed in each and every aspect of a mobile device. We give a brief description of some of the methods in the following sections. Conventional routing protocols [15-17] for ad hoc networks select the routes under the metric of the minimum hop count. Such min-hop routing protocols can use energy unevenly among the nodes

5.1 Transmission Power Control based MANET Routing

Flow Augmentation Routing (FAR), Online Max-Min Routing (OMM) and Power aware Localized Routing (PLR) protocols fall into this category. Table 1 shows these protocols.

FAR protocol: The FAR protocol assumes a static network and finds the optimal routing path for a given source–destination pair that minimizes the sum of link costs along the path.OMM protocol: FAR maximizes the network lifetime when data-generation rate is known. The OMM protocol achieves the same goal without knowing the data-generation rate in advance. It optimizes two different metrics of the nodes in the network: Minimizing power consumption and maximizing the minimal residual power. PLR protocol: The PLR protocol is a localized, fully distributed energy-aware routing algorithm but it assumes that a source node has the location information of its neighbors and the destination. It is equivalent to knowing the link costs from itself to its neighbors and to the destination. Based on this information, the source cannot find the optimal path but selects the next hop through which the overall transmission power to the destination is minimized.

5.2 Load Balanced Routing Protocols for Ad Hoc Mobile Wireless Networks

These routing protocols [5][13-14] can generally be categorized into three types based on their load balancing techniques. Table 2 shows these protocols.

Delay-based: Where load balancing is achieved by attempting to avoid nodes with high link delay. An example protocol using this approach is Load-Aware On-Demand Routing (LAOR).

Traffic-based: Where load balancing is achieved by evenly distributing traffic load among network nodes. Examples of traffic based load balanced routing protocols are Associativity Based Routing (ABR), Load Balanced Ad Hoc Routing (LBAR), and Traffic-Size Aware (TSA) scheme.

Hybrid-based: Where load balancing is achieved by combining the features of traffic- and delay-based techniques.

5.3 RECENT ENERGY EFFICIENT PROTOCLS

Efficient power aware routing (EPAR)[14], a new power aware routing protocol that enhance the network lifetime of MANET. In contrast to conventional power aware algorithms, EPAR identifies the ability of a node not just by its residual battery power, but also by the estimated energy spent in reliably forwarding data packets over a specific link. Using a mini-max formulation, EPAR selects the path that has the largest packet capacity at the least residual packet transmission capacity. This protocol able to handle high mobility of the nodes that often cause changes in the network topology.

5.4 Current Handling of the Problem and issues

The energy conservation issue is currently handled at the MAC layer and also the network layer. At the network layer, this problem is handled by energy aware and efficient routing protocols. One way to achieve this is by finding multiple paths between source and destinations, and assigning each path a probability of being chosen, depending on the energy metric. To send a packet, one of the paths is randomly chosen depending on the probabilities. Hence none of the paths is used all the time, preventing energy depletion.

5.5 Problems with Current Routing Protocols Related to Energy Efficient Routing.

The existing work not being concentrating on many directions. The existing work related to energy efficient depend on only to save the energy of network but at the same it has to optimize the other parameters like through put, delay, reliable and jitter. It should also increase network lifetime.

Table 1. Taxonomy of Energy Efficient Routing Protocols

Approach		**Protocols**	**Goal**
Minimize Active Communication Energy	Transmission Power Control	Flow Augmentation Routing(FAR) Online Max-Min(OMM) Power Aware Localized Routing(PLR) Minimum Energy Routing(MER)	Minimize the total transmission energy but avoid low energy nodes
		Retransmission-energy Aware Routing (RAR) Smallest Common Power(COMPOW)	Minimize the total transmission energy while considering retransmission overhead
Minimize Inactive Energy	Load Distribution	Localized Energy Aware Routing (LEAR) Conditional Max-Min Battery Capacity Routing (CMMBCR)	Distribute load to energy rich nodes
	Sleep/Power Down Mode	SPAN Geographic Adaptive Fidelity(GAF) Prototype Embedded Network(PEN)	Minimize energy consumption during inactivity

Table 2. Categorization of Load Balanced Routing Protocols

Load balanced routing protocols	Delay-based	LAOR
	Traffic-based	• ABR • LBAR • TSA
		•
	Hybrid-based	• CSLAR • LARA

6 CONCLUSION AND FUTURE WORK

In this paper, we have given an overview of mobile ad hoc networks its features and investigated the problem of power saving in mobile ad hoc networks. We have studied current power saving techniques used at different levels. Power saving at routing protocols level is much easier as compared to, power saving at device level or transmission level. Each of these techniques saves some energy of mobile device and if we use these different techniques in a combined in a manner it saves lot of energy and increase the lifetime of network. We have studied the important issue of power management in mobile wireless communication. Most protocols have concentrated on how to quickly re organize the ad hoc network in case of mobility and to find out the shortest route to destination without incurring much routing overheads. Since mobile hosts have limited battery lifes, mobile networks should consume battery power more efficiently to maximize the network life.

Though end to end throughput and delay are also important metrics, one cannot design a well tailored ad hoc routing protocol with only these metrics. Battery power capacity, transmission power consumption, stability of routes etc, should also be considered. It should also focus on selecting the stable nodes into path using the node information like node mobility, remaining energy of node, neighboring node, total traffic, and battery status. We can find new methods to increase life time of the network to reduce energy consumption. Removing redundancy is also another focus so that energy is not wasted in redundant data forwarding. Another tradeoff to consider for energy efficiency is whether the routing policy would be proactive (table driven) or reactive (on demand). As evident, a proactive routing policy would consume much more energy because of frequent updates as compared to a reactive one.

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