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ENERGY CONSUMPTION ON MAC LAYER IN ADHOC NETWORKS

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Abstract: A wireless ad-hoc network is a collection of mobile nodes that makes a multi hop autonomous system without any fixed infrastructure. The nodes use service of other nodes in the network to transmit packet to the destination nodes. Mobile device are battery operated and this is the limited resource. So the energy conservation is the critical issue in the network. There are many approach suggested for energy conservation. We have suggested two energy efficient techniques to reduce energy consumption at protocol level. In first techniques energy conservation done by reducing number of route request message while in the second techniques energy conservation done by power control techniques.
Keywords: component; MANET; power control; energy-aware protocol; power management;

I. INTRODUCTION

Wireless ad-hoc networks are formed by devices that are able to connect with each other using a wireless physical channel without having to option to a pre-existing system infrastructure. These system, also known as mobile ad-hoc systems, can form stand-alone collection of wireless stations, but some of these stations could also be linked to a mobile system or to a permenant system. Compared to mobile systems ad-hoc systems are more flexible to changing traffic requirements and physical requirements[1]. Also since the attenuation appearances of wireless channels are nonlinear, energy efficiency will be higher. These characteristics will make ad-hoc networks attractive for pervasive communications. A mobile ad-hoc network (MANET) group has been formed within IETF. The primary focus of this working group is to develop and evolve MANET specifications and introduce them to the Internet standard track. The goal is to support mobile ad-hoc networks with hundreds of routers and solve challenges in this kind of network. Mobile ad-hoc networks could enhance the service area of access networks and provide wireless connectivity into areas with poor or previously no coverage Connectivity to wired infrastructure The multihop property of an ad-hoc network needs to be bridged by a 2 gateway to the wired backbone. The gateway can has a system interface on both types of systems and be a part of both the global direction finding and the local ad-hoc direction finding. Users whould benefit from ubiquitous systems in several types. Host mobility enables the users' devices to transfer all around the systems and maintain connectivity and reachability. Wireless systems can be described in two types: First, infrastructure systems which consists of a system with fixed and wired gateways When it goes out of the area of one base positions, it connects with a new fixed base positions and starts communicating through it. Second, infrastructure less (ad-hoc) systems fig. 1.1: In ad-hoc networks all nodes are mobile and may be connected dynamically in an arbitrary manner. All nodes of these systems behave as routers and take part in discovery and maintenance of routes to other nodes in the system.

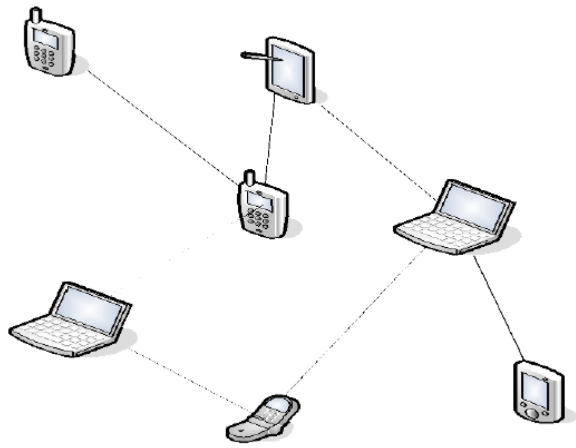


Fig. 1 Infrastructure less Wireless Network

II. RELATED WORK

Ad-hoc networks enable users to spontaneously form a dynamic communication system. However, to offer high-quality and low-cost facilities to Ad-hoc system vertex, multiple technical experiments still require to be addressed. First, wireless systems are plagued by scarcity of transmission bandwidth; therefore, a key issue is to satisfy user requests with minimum service interruption. Second, because system nodes have restricted energy resources, the energy used for transferring information across the network has to be minimized. Ad-hoc wireless networks are constrained by limited battery power, which makes energy management an important issue. Energy-efficient design in mobile ad-hoc networks (MANETs) is more important and challenging than with other wireless networks. Therefore, traffic loads in MANETs are heavier than in other wireless networks with fixed access points or base stations, and thus MANETs have more energy consumption. It is possible that some key nodes will over serve the network and have their energy drained quickly, causing the network to be partitioned. Thus simple solutions that only consider power constraints may cause severe performance degradation.

Third, no centralized control implies that energy-efficient management in MANETs must be done in a distributed and cooperative manner, which is difficult to achieve.

A. CAUSES FOR ENERGY AWARE

1. Limited energy reserve: The ad-hoc networks have limited energy reserve. The enhancement in battery skills is very slow as related to the expansions in the field of mobile computing and communication.

2. Difficulties in replacing the batteries: In situations like battlefields, natural disasters such as earthquakes, and so forth, it is very difficult to replace and recharge the batteries. Thus, in such situations, the conservation of energy is very important.

3. Lack of central coordination: Because an ad-hoc network is a distributed network and there is no central coordinator, some of the nodes in the multihop routing should act as a relay node. If there is heavy relay traffic, this leads to more power consumption at the respective relay node.

4. Constraints on the battery source: The weight of the nodes may increase with the weight of the battery at that node. If the weight of the battery is decreased, that in turn will lead to less power of the battery and thus decrease the life span of the battery. Thus, energy management techniques must deal with this issue; in addition to reducing the size of the battery, they must utilize the energy resources in the best possible way.20

5. Selection of optimal transmission power: The increase in the transmission power increases the consumption of the battery charge.

B. ANALYSIS OF ENERGY CONSUMPTION

The wireless channel is characterized by signal strength attenuating with distance from the transmitter. Nodes can correctly receive a packet if the signal strength of the packet at the node is above a certain threshold called Receive Threshold. There is a lower threshold called Carrier Sense Threshold, up to which the received signal strength is enough for the receiver to detect the packet sent, but the receiver it correctly. All received signals that falls between these thresholds cause the channel to be sensed busy and contribute to the interference at the receiver. Another important parameter in wireless network is the Signal to Interference Ratio.

1. Measurement of Energy Consumption

Since energy is a scarce and non-renewable resource in wireless ad-hoc networks, energy efficient protocol design is a key concern. Four possible energy consumption states are identified. Transmit, receive, idle and sleep. The first two states are when the node is transmitting and receiving packets respectively. Idle state is when node is waiting for any packet and is continuously sensing the medium and the sleep state is a very low power state where the node can neither transmit or receive. The cost associated with each packet at a 21 node is represented as the total of incremental cost *m* proportional to the packet *size* and a fixed cost *b* associated with channel acquisition.

$$Cost = m \times size + b \tag{1}$$

$$Cost_{broadcast} = m_{send} \times size + b_{send} + \sum_{n \in S} (m_{recv} \times size + b_{recv}) \tag{2}$$

Where

S = set of nodes within transmission range of transmitter node

m_{send}, b_{send} = incremental and fixed cost for sending the broadcast packet,

m_{recv}, b_{recv} = incremental and fixed cost for receiving the broadcast packet.

2. Calculation Of Energy Required For Transmission And Reception Of a Single Packet

• For Data Packets

Packet length = 1500bytes,
Bit rate = 250kbps (48ms/packet or 20.8 packets/se)
Total packet size = size of (preamble + PLCP header + MAC header + IP header + Data)
= (144 + 48 + 28 × 8+20 × 8 + 1500 × 8) bits (default values, as used in NS-2).
Thus, we have 144+48bits sent at 1Mbps, with a transmission time for single packet 0.19ms.

With 8 × 1548 bits sent at 11Mbps, the transmission time for a single packet is 1.128ms. Hence the total transmission time for a single packet is 1.128+0.19 = 1.318ms.

• For Ack packets

Packet length = 14bytes,
Bit rate = 250kbps,
Total packet size = size of (preamble + PLCP header + ACK)
= (144 + 48 + 14 × 8) bits
So, transmission time for a single packet is 0.304ms

• Calculation Of Energy Spent

The transmission and reception cost for a packet can be calculated like this for a particular packet. For an example if the transmission and reception power are taken 1.3mW and 0.9mW respectively then various energy components are

$$E\ Tpck = 1.3 \times 1.318 \times 10{-}3 = 1.713mW$$
$$E\ Rpck = 0.9 \times 1.318 \times 10{-}3 = 1.186mW$$
$$E\ Tack = 1.3 \times 304 \times 10{-}6 = 0.395mW$$
$$E\ Rack = 0.9 \times 304 \times 10{-}6 = 0.274mW$$

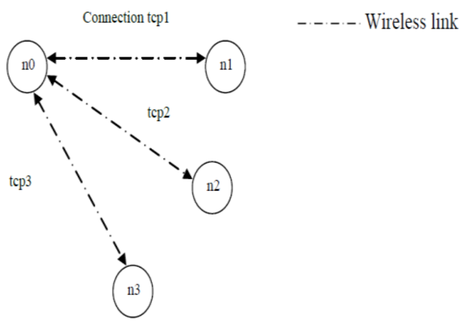
Thus energy calculation can be done using the equations.
Energy consumption is not an issue of a single layer. Different layer protocols affect energy in various ways. The effect of different layers is described further.

III. EVALUATION OF ENERGY CONSUMPTION

Energy conservation in an ad-hoc network is the procedure of determining the transmit power of each communication terminal. It is calculated at each and every node in wireless network which is either transmitting or receiving any packet. Energy consumption at mac layer is also considerable.

A. SIMULATION SCENARIO

Simple topology with 4 nodes is used. Each node is connected to other by wireless link. A simple MANET example script available in ns-2.30/tcl/ex is used as a base script. The node movement patterns are generated by giving commands as given in script. A node is situated at random position at the start of simulation and moves toward random destination in the script with random velocity as specified in command. The traffic is generated manually using commands in script. We have used ftp as TCP traffic.



We have established three TCP connections, tcp1, tcp2, and tcp3. We have configured Energy Model which is implemented in ns, is a node attribute.

ftp1 – 1s to 38 s ftp2 – 1s to 38 s ftp3 – 1 s to 38 s

Each and every node consumes energy in transmitting DATA packets, CONTROL packets and ACK packets.

1. Analysis Based On Proactive Routing Protocol-DSDV

Destination Sequence Distance Vector was one of the earliest protocols developed for ad-hoc networks. Primarily design goal of DSDV was to develop a protocol that preserves the simplicity of RIP, while guaranteeing loop freedom. It is well known that Distributed Bellman-Ford (DBF)[10] the basic distance vector protocol, suffers from both short-term and long-term routing loops and thus exhibits poor convergence in the presence of link failures. DSDV also uses triggered incremental routing updates between periodic full updates to quickly propagate information about route changes. Therefore, always propagating distance information immediately upon change can trigger many updates that will ripple through the network, resulting in a huge overhead. So, DSDV estimates route settling time (time it takes to get the route with the shortest distance after getting the route with a higher distance) based on past history and uses it to avoid propagating every improvement in distance information. Among the proactive protocols we have discussed, DSDV seems to suffer from poor responsiveness to topology changes and slow convergence to optimal paths. This is mainly because of the transitive nature of topology updates in distance vector protocols. In order to understand basic Energy Consumption, simulation model ns – 2.30 [10] is used for evaluation. In recent, the CMU Monarch research group developed a model for wireless simulations complete with physical, data link, and medium access control (MAC) layer in ns – 2.30. Initial energy which is given to each and every node is 100 Joules. Transmit Power, Receive Power and Idle Power is also configured. Node 0 is sender which sends tcp traffic to all the nodes. While other nodes which receive TCP packets they give ACK to the sender node so they also consume some amount of energy. Node 0 which is sender node for tcp traffic consumes energy and after the end of simulation some amount of its energy is drained. Energy draining of the receiver nodes is less compared to sender node because they have to send only ACKs of the tcp packets. Energy is also consumed when there is transmission and reception of RTS and CTS packets. In present depicted scenario energy at sender node at the end of simulation is 77.73 joules. While energy of receivers node 1, node 2 and node 3 at the end of simulation is 85.13 joules, 85.46 joules, 85.26 joules respectively. As the time exceeds transmission power gradually increases. It is depicted from the output trace file that if the transmission power is less than the receiver power or vice versa then both the reception and transmitter node adjust its power in order to compensate the required power for transmitting and receiving packets. In short the power is finally balanced for duplex transmission.

2. Analysis Based On Reactive Routing Protocol-DSR

Examples of reactive routing protocols are the dynamic source Routing (DSR), ad-hoc on-demand distance vector routing (AODV) and temporally ordered routing algorithm (TORA). DSR makes aggressive use of source routing and route caching. With source routing, complete path information is available and routing loops can be easily detected and eliminated without requiring any special mechanism. Because route requests and replies are both source routed, the source and destination, in addition to learning routes to each other, can also learn and cache routes to all intermediate nodes. DSR employs several optimizations including promiscuous listening which allows nodes that are not participating in forwarding to overhear on-going data transmissions nearby to learn different routes free of cost [2]. Basic DSR protocol lacks effective mechanisms to purge stale routes. Use of stale routes not only wastes precious network bandwidth for packets that are eventually dropped, but also causes cache pollution at other nodes when they forward/overhear stale routes. Taking DSR as a routing protocol Energy Consumption can be studied. For the same scenario as taken for DSDV protocol Energy Consumption is analyzed from output trace file. In present depicted scenario energy at sender node at the end of simulation is 77.72 joules. While energy of receivers node 1, node 2 and node 3 at the end of simulation is 85.43 joules, 85.64 joules, 85.00 joules respectively. This is also highlighted from results and graph.

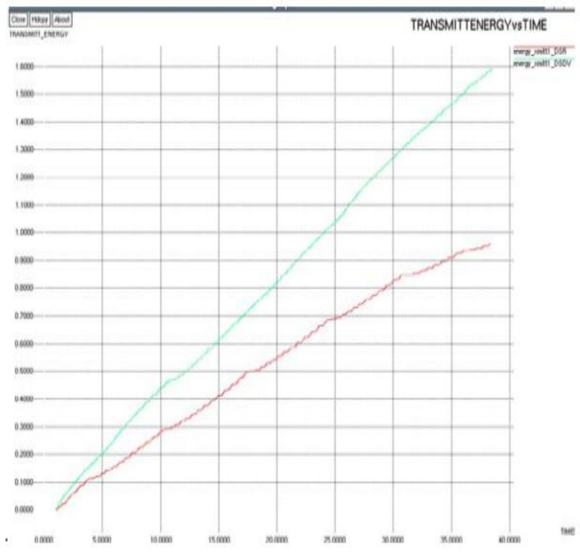


Fig 2 comparison of transmit energy for node 1 using DSR and DSDV as a routing protocol

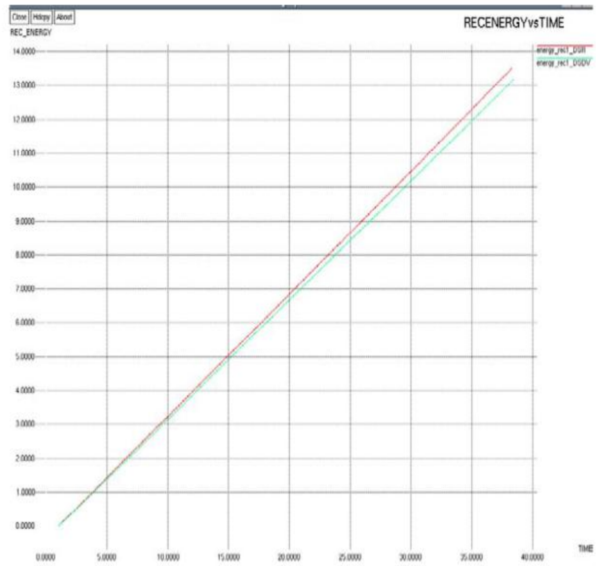


Fig 3 comparison of receive energy for node 1 using DSR and DSDV as a routing protocol

After analysis of Energy Consumption based on routing protocols DSR and DSDV it can be analyzed that there is no considerable change in energy consumption for transmission and reception of packets. There are many causes of this. The routing overhead was found to stay stable regardless of mobility rate. Levels of transmission power and reception power using DSDV and DSR protocols given in the table which is shown below.

Table 1Energy Level For Routing Protocols

Receiver Node	Proactive Routing - DSDV		Reactive Routing - DSR	
	Transmit Power	Receive Power	Transmit Power	Receive Power
Node 1	1.591	13.177	0.961	13.510
Node 2	0.816	13.622	1.061	13.538
Node 3	1.401	13.249	1.800	13.101

The delay is low in the case of low traffic even though mobility is high. When mobility increases DSDV suffers from low throughput. When traffic load starts to increase the delay also increases. With increased mobility delays starts to grow and throughput decrease. The bottle neck of DSDV seems to be vastly decreasing packet delivery ratio when mobility gets high. So, with normal traffic and less mobility performance of DSR and DSDV are quiet equal. DSR performs better in dense network.

IV. PROPOSED SIMULATION

The limited energy capacity of mobile computing devices has brought energy conservation to the forefront of concerns for enabling mobile communications. Such expectations demand the conservation of energy in all components of the mobile device to support improvements in device lifetime. Application-level techniques can be used to reduce the amount of data to send, and so the amount of energy consumed. However, once the application decides to send some data, it is up to the network to try to deliver it in an energy-efficient manner. To support energy-efficient communication in ad hoc networks, it is necessary to consider energy consumption at multiple layers in the network protocol stack [2]. At the network layer, intelligent routing protocols can minimize overhead and ensure the use of minimum energy routes. Communication in ad hoc networks necessarily drains the batteries of the participating nodes, and eventually results in the failure of nodes due to lack of energy. Since the goal of an ad hoc network is to support some desired communication, energy conservation techniques must consider the impact of specific node failures on effective communication in the network.

A. ENERGY SAVING AT ROUTING LAYER

Routing protocols for ad hoc networks generally use hop count as the routing metric, which does not necessarily minimize the energy to route a packet. Energy-aware routing addresses this problem by finding energy-efficient routes for communication. At the network layer, routing algorithms should select routes that minimize the total power needed to forward packets through the network, so-called minimum energy routing. However, minimum energy routing may not be optimal from the point of view of network lifetime and long-term connectivity, leading to energy depletion of nodes along frequently used routes and causing network partitions. Therefore, routing algorithms should evenly distribute forwarding duties among nodes to prevent any one node from being overused. Hybrid protocols explore the combination of minimum energy routing and capacity-aware routing to achieve energy efficient communication while maintaining network lifetime.

B. MAC LAYER SOLUTION

When not transmitting, a wireless communication device is continuously listening for incoming transmissions. This listening cost can be quite high since a node must try to receive a packet to see if there is actually a packet being transmitted to it or any other node. If there are currently no transmissions destined for a given node, this listening wastes significant amounts of energy. In wireless communication devices, the cost of listening is only slightly lower than the actual cost of receiving, since listening requires minimal processing overhead compared to receiving. The low-power state turns off the receiver inside the device, essentially placing the device in a suspended state from which it can be resumed relatively quickly. In a completely off state, the device consumes no energy. However, the time it takes to resume a device from a completely turned off state can be prohibitively long and may even consume extra energy to re-initialize the node. This is called communication device suspension. At MAC layer each and every node continuously senses the medium that if any packet is arriving towards it or not. So it remains in idle state during that time. In idle state the node also consumes energy which is nearly same as the receive mode. One solution is that the radio interface of that node can be OFF at that time.

C. MODIFICATION

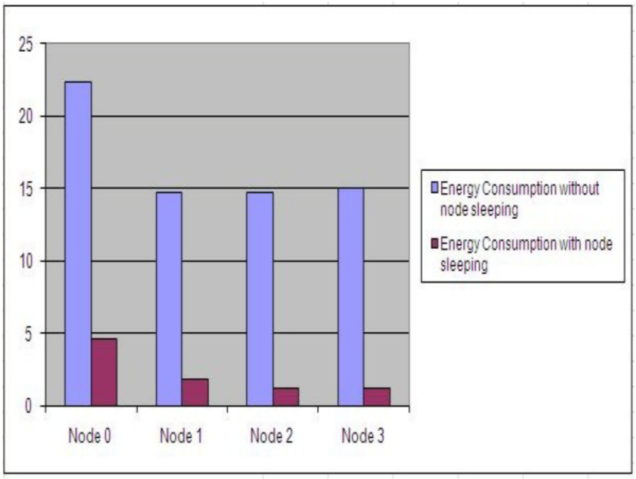
The radio interface of the node can be off at the time when there is not any packet arrival as well as between successive transmission and reception of packets. The MAC standard continuously checks the value of timer of transmit packet as well as receive. The transmit packet and the received packet contains time of its transmission and reception. So when the packet transmission completes, the state of radio is checked and it is made off until the next packet arrives. So energy consumption is reduced during that interval. The same procedure is carried out at the receiver side. So, the energy consumption is considerably reduced. According to the status of radio interface of the node, consumption of energy of various states like idle and sleep can be calculated which are available in energymodel. In mac-tdma which is the 802.11b standard for wireless network but it has a capability for radio shutdown. Radio shutdown depends upon the timer of packet transmission and reception. The packet contains the information of the transmission time of that particular packet in its header. According to it the packet transmission timer sets and resets. So at the expiration of the timer the radio interface of the node becomes off. So energy consumption is reduced between two successive transmissions. In energymodel there are various classes which calculates the energy consumed in various states of node like idle, sleep etc. but there is no any direct link from mac-tdma to energy model and it doesn't make any node idle or sleep. Value of transmit power, receive power, can be binded from tcl script. According to that initialized value the energy consumption of node in various states is also calculated. When node switches from one state to another state it requires some amount of time as well as consumes some amount of energy also.

Node	Energy Consumption without node sleeping	Energy Consumption with node sleeping
Node 0	22.285 joule	4.64 joule
Node 1	14.75 joule	1.81 joule
Node 2	14.7 joule	1.19 joule
Node 3	15 joule	1.19 joule

Table 2 Comparison of energy consumption with and without node sleeping

From above table it is concluded that by making node sleep when there is no necessity to put it idle the unnecessary energy consumption can be avoided so the lifetime of network becomes long. Comparison of energy consumption with and without node sleeping is also shown in figure.

Fig. 4.1 Comparison of Energy Consumption



V. CONCLUSIONS

Energy consumption plays significant role in network lifetime. So It is important to study how to reduce the power consumption while at the same time fully-utilize the bandwidth resource. By making the physical interface aware of the mac activity power consumption can be reduced. The radio interface of node is made ON and OFF on the event of packet transmission and reception. So energy consumption is improved with network resources.

VI. FUTURE WORK

However MAC layer is not the only layer for power conservation. There is other option of future work. The other option is enhancement in energy consumption like routing based protocol. Routing can be made energy efficient which includes information of minimal energy for routing over particular path. On the other way, consideration should also be rewarded on higher levels of the protocol stack.

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