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Energy Consumption Model For Internet Connectivity In Mobile Ad-Hoc Networks

Seelam Srinivasa Rao
Associate professor, ECE Department
Nalla Narasimha Reddy Educational Society's Group of Institutions

Dr. K.Chenna Keshava Reddy
Professor, ECE Department
Jothishmati College of engineering and Technology
Tukapally, shameerpet, Hyderabad

Abstract- **Multi-hop wireless ad hoc wireless networks have no fixed network infrastructure. Such a network consists of multiple nodes that maintain network connectivity through wireless links. Additionally, these nodes may be mobile and thus the topology of the network may change with time. It will be useful if the nodes in this network could communicate with the Internet; this can be done via gateways which in turn inter-connect to the Internet. This functionality requires that the nodes in the ad hoc network to discover the gateway, using a gateway discovery protocol. However, a limiting factor (particularly for mobile nodes) is suing their limited energy supply provided by batteries. In order to understand the potential effect this paper considers two key areas: internetworking between a multi-hop mobile wireless ad hoc network and the Internet and the energy utilization as a function of number of gateways and the mobility pattern of nodes. Using simulation on various mobility patterns and networks density scenarios, we show that increase the number of gateways in ad hoc network significantly improves the power efficiency of mobile node and therefore prevent network partition due to death nodes.**

Keywords- Energy consumption, Gateway, MANET, AODV, Transmission range.

1.Introduction

There have been great advances since the first invention of the wireless networks. Nowadays, many people expect to be connected at anytime, anywhere, and in anyplace. Such networks are very useful in both daily life and in emergency situations. The price of the equipment and its installation are decreasing allow wireless networks become even more popular. Although the advantages and convenience of wireless network, people always desire more than that. Most of the mobile equipments that form the wireless networks (mobile node) are rely on the limited battery power that make limit in the usage time. Longer battery life is desirable, but not always practical, affordable, or achievable. [1][3]

Lowering energy consumption is a key goal in many multi-hop wireless ad hoc networking environments, especially when the individual nodes of the network are battery powered. These requirements have become increasingly important for new generations of mobile computing devices (such as Personal Digital Assistant (PDAs), laptops, and cellular phones) because the energy density achievable in batteries has grown only at a linear rate, while processing power and storage capacity have both grown exponentially. As a consequence of these technological trends, many wireless-enabled devices are now primarily energy-constrained; while they possess the ability to run many sophisticated multimedia networked applications, their operational lifetime between recharges is often short. In addition, the energy consumed in communication by the radio interfaces is often higher than, or at least comparable to, the computational energy consumed by the processor.[6]

The effective total transmission energy, which includes the energy spent in potential retransmissions consumed per packet, is the proper metric for reliable, energy-efficient communications. The maximum and minimum of energy of candidate nodes is dependent on the number of gateway and mobility pattern of mobile nodes, since they directly affect the energy utilized in changing their immediate hop path to get to the desired external destination. Analysis of the interplay between the numbers of gateway and mobility patterns of mobile node reveals several key results.

2. Internet connectivity for Mobile Ad-Hoc Networks

In spite of the fact that, a MANET is useful in many situations such as emergency, battle field, disasters, or in remote area, the ability to connect to the Internet is generally highly desirable. This internetworking is achieved by using gateways, which act as bridges between a MANET and the Internet. In order to communicate with a host located on the Internet a mobile node in the MANET needs to find a route to a gateway. This requires gateway discovery. [9][11]

The ad hoc routing protocols were designed for communication within a MANET. Therefore, the routing protocol needs to be modified in order to provide bridging capability between a mobile device in a MANET and a fixed device in a wired network. To achieve this network interconnection, gateways that understand the protocols of both the MANET protocol stack and the TCP/IP suite are needed. All communication between the two networks must then pass through the gateway. Gateways expand the communication beyond an ad hoc network, but require some last hop mobility management.

Two classes of approaches have been proposed to support connectivity between ad hoc networks and the Internet.

- Proactive schemes flood advertisements from nodes through the whole ad hoc network to find the gateway. Such approaches provide good connectivity, but impose a high overhead, especially when not all the nodes in the ad hoc network require external connectivity.

- Reactive schemes allow the mobile nodes to broadcast solicitations to find nodes and gateways as they are needed. Such approaches keep the overhead of maintaining connectivity to external networks low, but negatively impact on the mechanisms necessary for gateway discovery and movement detection.

- Hybrid scheme that combines proactive and reactive techniques to provide connectivity with reduced overhead. In our approach, gateway discovery advertisements are flooded within a limited number of hops. Nodes that are outside this hop limit use reactive techniques to solicit foreign agents when needed. A hybrid approach combines the advantages of both proactive and reactive approaches and provides good connectivity while keeping overhead costs low.

Choosing an addressing scheme is also an important issue when designing gateway discovery protocol for MANET. Two popular approaches are: Mobile IP and IPv6. Mobile IP using the traditional IPv4 addressing scheme and TCP/IP protocol stack is easy to deploy. However, mobile IP requires additional mechanism to handle problems of triangle routing, keep session alive when roaming… IPv6 solves the scalability problem and provide a unified architecture, but nodes in both wired and wireless domain need to change addressing architecture in order to communicate with each other. Here we will use the IPv6 solution which provide a better scalability and a complete solution [7][20].

2.1 Proactive gateway discovery

The proactive gateway discovery is started by the gateway itself. The gateway periodically broadcasts the Gateway Advertisement messages which are transmitted after expiration of the gateway's timer (ADVERTISMENT_INTERVAL). The time between two consecutive advertisements must be chosen with care so that the network is not flooded unnecessary often. All mobile nodes residing in the gateway's transmission range will receive the advertisement.

When the advertisement is received, the mobile nodes that do not have a route to the gateway create a route entry for it in their routing table. Mobile nodes that already have, update the entry for it. Next the advertisement is forwarded by the mobile nodes to other mobile nodes residing within their transmission range. To assure that all mobile nodes within the mobile ad hoc network receive the advertisement, the number of transmissions is determined by NET_DIAMETER defined by the protocol. However, this will lead to unnecessary duplicated advertisements and this is a disadvantage of this mechanism. However, we can solve this problem by comparing the RREQ ID with the original IP address.

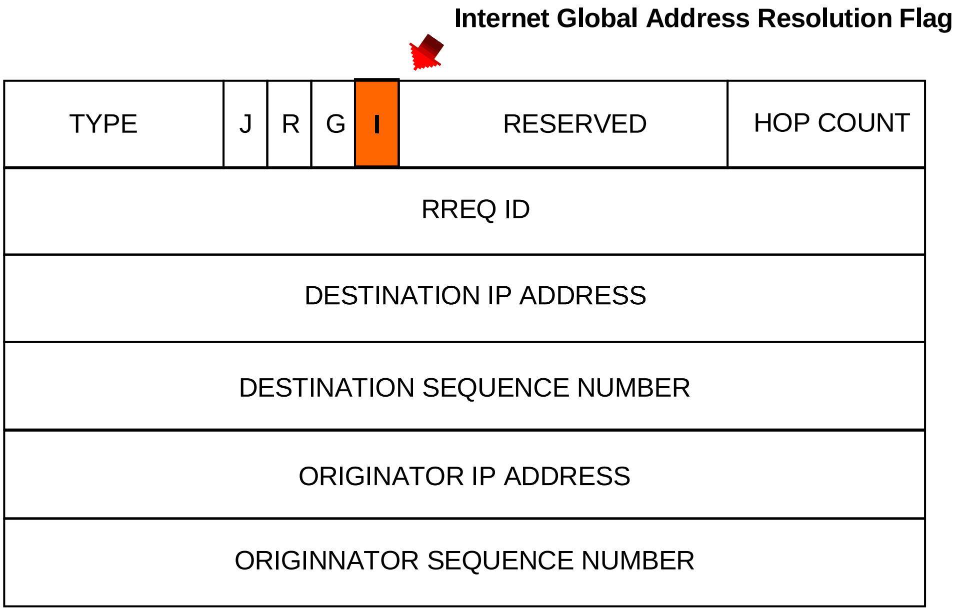

Figure 1: RREQ_I message format

An advertisement is approximately a RREP_I message and since this message does not contain any field similar to the RREQ ID field in RREQ messages, a new AODV message has been introduced: Gateway Advertisement (GWADV). This message is basically a RREP message extended with one field from the RREQ message, namely the RREQ ID field. When a mobile node receive a GWADV, it first checks to determine whether a GWADV with the same originator IP address and RREQ ID already has been received during the last BCAST_ID_SAVE seconds. If such a GWADV message has not been received, the message is rebroadcasted (after decrementing the life time). Otherwise, the newly received GWADV will be discarded. Hence, duplicate GWADVs are not forwarded and the advertisement is flooded through the whole network without causing too much congestion. However, the disadvantage of this solution is the fact that a new AODV message is introduced which requires AODV to be modified.

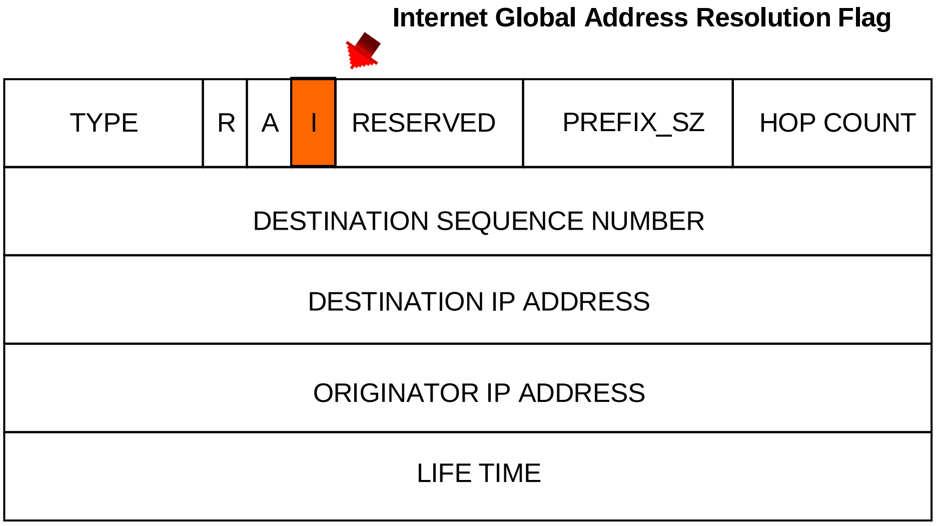

Figure 2: RREP_I message format

2.2 Reactive gateway discovery

Unlike the previous mechanism, reactive gateway discovery is initiated by a mobile node that wants to find or update information about a gateway. The mobile node broadcasts a RREQ_I (I stands for Internet Global Address Resolution flag, this is an extension to the standard RREQ message) to all members of its multicast group. Thus, only the gateways are addressed by this message and only they will process it. Intermediate nodes that receive the message simply forward it by broadcasting it again after decrementing the time to live. When received a RREQ_I, a gateway unicasts back a RREP_I containing the IP address of the gateway [30][28].

The advantage of this approach is that RREQ_I is only sent when mobile node needs information about the reachable gateways. Hence, periodic flooding of the complete mobile node ad hoc network, which has obvious disadvantages, is eliminated. The disadvantage of reactive gateway discovery is that the load on forwarding mobile nodes, especially on those close to a gateway, is increased.

2.2 Hybrid gateway discovery

To minimize the disadvantages of proactive and reactive gateway discovery, the two approaches can be combined. This results in a hybrid method for gateway discovery. For mobile nodes within a certain range around a gateway, proactive gateway discovery is used. Mobile nodes residing outside this range use reactive gateway discovery to obtain information about the gateway. The gateway periodically broadcasts a RREP_I message which is transmitted after expiration of the gateway's timer (ADVERTISEMENT_INTERVAL). All mobile nodes residing in the gateway's transmission range receive the RREP_I. Upon receipt of the message, the mobile nodes that do not have a route to the gateway create a route entry for it in their routing tables. Mobile nodes that already have a route to the gateway update their entry for it. Next, the RREP_I is forwarded by these mobile nodes to other mobile nodes residing in their transmission range. The maximal number of hops a RREP_I can move through the ad hoc network is the ADVERTISEMENT_ZONE.

When a mobile node residing outside this range needs gateway information, it broadcasts a RREQ_I to the ALL_MANET_GW_MULTICAST address. Mobile nodes receiving the RREQ_I simply rebroadcast it. Upon receipt of this RREQ_I, the gateway unicasts back a RREP_I.

3. Energy consumption model for Internet connectivity in MANET

The more closely a simulation reflects specific hardware, the more accurate its estimate of the energy consumed. The energy consumption model and simulation environment were chosen to balance these goals: a precise estimate of energy consumption and high-level insight into protocol behavior. The CMU Monarch Project's mobility-enhanced ns-2 simulation environment models the IEEE 802.11 MAC layer, logging control and data messages. The energy consumption model was therefore built based-on the IEEE 802.11 protocol, rather than electronic properties such as mode switching and signal response. Experimental results reflecting the observed energy consumption of an IEEE 802.11 wireless interface were incorporated into the model, providing a quantitative example of energy consumption [23].

The network interface has four possible energy consumption states: transmit and receive are for transmitting and receiving data. In the idle mode, the interface can transmit or receive. This is the default mode for a node in an ad hoc environment. The sleep mode has extremely low power consumption. The interface can neither transmit nor receive until it is woken up. A base station moderates communication among mobile nodes, scheduling and buffering traffic so that the mobiles can spend most of their time in the sleep state.

In an ad hoc environment, there are no base stations and therefore nodes cannot predict when they will receive traffic. The default state of a node in ad hoc networks is idle. The model assumes that the same link-layer operation always has the same costs: an assumption that may not be true if, for example, signal strength affects the energy required to receive the data.

Inconveniently, wireless network interface card (NIC) specifications do not provide information about power consumption in these different modes. Due to the existing indirect nature of the measurements, these values have considerable uncertainty (as much as 5– 10%). Nevertheless, they provide a good indication of relative costs, which is most important for high level analysis. In [23], the study about a detailed of an energy consumption model also gives some keys property which were used in the model used in this paper:

- The cost of receiving is significant because if a broadcast message is received by more than about four neighbors, the total cost of receiving the packet is greater than the cost of sending it. The relative costof receiving is likely to increase, reflecting a trend toward greater sensitivity and signal processing capabilities at the receiver.

- The fixed cost of sending or receiving a packet is relatively large compared to the incremental cost. For small packets (130 bytes broadcast or 230 bytes point-to-point), the fixed cost is greater than the incremental cost of sending or receiving a byte. This implies, for example, that small ROUTE_REQUEST or "HELLO" messages are a relatively expensive mechanism. It also suggests

- that source routing headers are relatively inexpensive in terms of energy consumption.

- Discarding a packet is generally much less expensive than receiving it. With large messages, non-destination nodes can reduce their energy consumption while data is being transmitted and therefore significant reduce energy consumed to receive and process the packet if they can quickly determine that the packet is not relevant to them and then enter sleep mode for the duration of the packet..

4. Simulation Environment

We are using Ns-2, a highly modular discrete event simulator, developed for simulating the behavior of network and transport layer protocols in a complex network topology. Transmit and receive characteristics were based on specifications for the LucentWaveLAN 2.4 GHz DSSS IEEE 802.11 PC card, which has a nominal data transmission range of 250 m. Compared to these older WaveLAN cards, newer cards have greater receive sensitivity and nominal transmit range.

• 48 mobile nodes moved around a 1000m × 1000m area for 300 s of simulated time. When there are few nodes innetwork and mobile nodes want to connect to nodes outside ad hoc network, it needs to send gateway discovery message to almost every nodes in ad hoc network. As the result other node have to stay awake to response to the require nodes or forward intermediate traffic. Early studies on simulation scenarios using 12 and 24 nodes show that the energy consumption of nodes is not much different.

• 12 randomly chosen source-destination pairs provided traffic load. Each source sent a constant bit rate stream consisting of four 64-byte IP packets/s to its destination. In highly dynamic and heavy traffic, nodes in MANET have to always stay awake to carry traffic and therefore energy variation is low.

5. Analysis and Discussion

5.1 Effect of changing the number of gateways

Changing the number of gateways in ad hoc networks not only has a big impact on the performance of the system, but also can make a significant difference in energy consumption of the mobile node. In this simulation, different numbers of gateways are placed in a square area (1000m x 1000m) in order to maximize the network coverage. In practice, the question of where/how to place these gateways is result of a site survey. When deploy wireless network, a site survey provides guidance for the deployment process which includes find out dead-end and maximizing network coverage... In these simulations the placement of the gateways to the Internet were chosen to be uniformly distribute over the square simulated area.

By placing different number of gateways in the simulation area, the results show that the energy consumption of mobile nodes is different under all mobility patterns. By increasing the number of gateways, the residual energy of the nodes is increased significantly. Viewed another way, the total energy consumption decreases because the mobile node can chose an alternative way to reach to the gateway. Increasing the number of gateways makes the routes shorter and therefore decreases the number of route hops required by the packet to reach its destination. The energy consumed when changing the number of gateway from 1 to 2, and from 2 to 3 is quite substantial. The energy utilization ratio is between 15 – 25% of total energy consumed (Figure 3). If there are only few gateways, in order to reach the nodes outside ad hoc network, the number of hops to reach the gateway point is greater than when there are many numbers of gateways. Although nodes can choose different paths, there is only one default gateway. Furthermore, the number of hops to reach the destination is still high and changing the default gateway requires activating the gateway discovery protocol which will consume a lot of power.

However the energy decrease is not simply counter proportionally to the number of gateways. Once the coverage of gateways reaches a threshold, increasing the number of the gateway does not further reduce the energy used. Sometimes, it will slightly increase the energy consumption level, because it will make the gateway discovery protocol more complicated (about a 5% increase in our simulation).

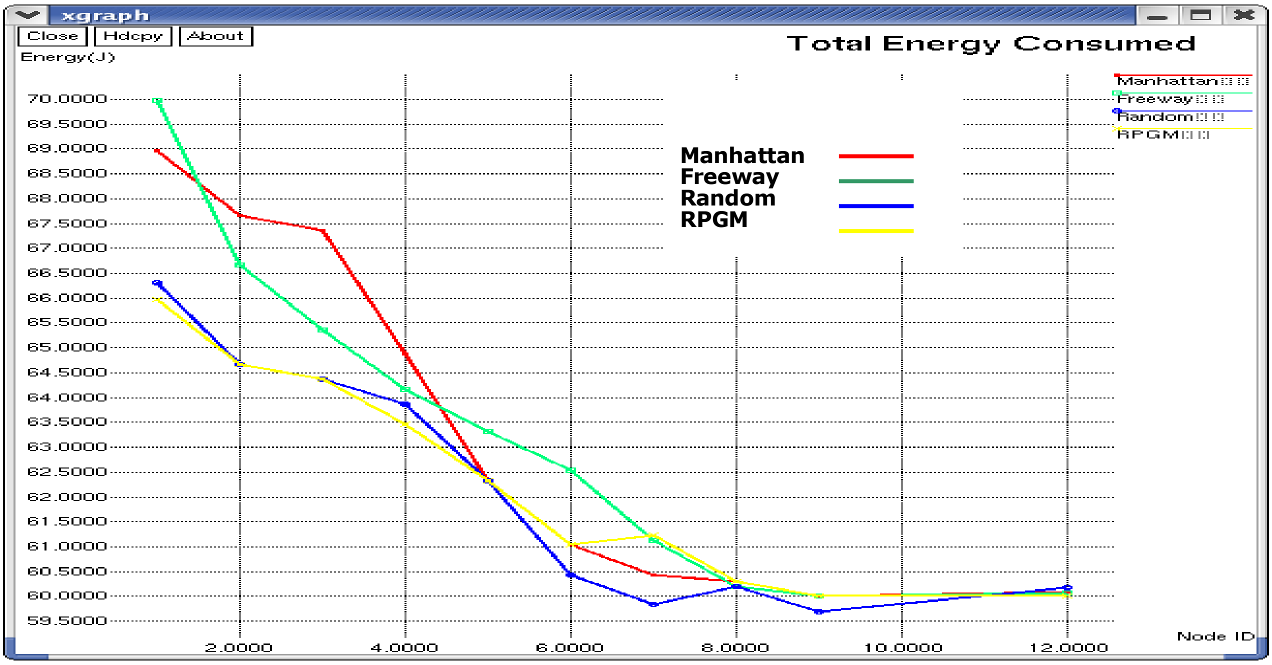

Figure 3: Energy as a function of number of gateways

In a small number of gateways scenarios, the Freeway and Manhattan mobility model consumes more energy than other scenario. The reason is that, in such scenarios, the packet needs to be forwarded through a large number of intermediate nodes before reach the gateways. This increase in the number of forwarding node requires more energy. Our simulation results show that, about 10-15% of extra energy was spent for this forwarding along strings of nodes.

Moreover, in practice, the shortest path sometimes does not mean the optimal path regarding energy consumption. When we added a multi-state error model, the results show that optimal routes also depend on the link state and quality. Packets transmitted on high error rate and high latency links are usually dropped due to the queue being full or due to a timeout; both increase the node’s energy consumption significantly (Figure 4) due to retransmission.

In the low mobility scenario and in the cases where there are only a few nodes in the network, the result shows that the energy consumption of mobile node is very similar. In these scenarios, most of the nodes have to be awake all the time to carry forward traffic for other nodes; as there are a few options for nodes to choose to reach to the destination. In the forwarding state, the mobile node’s consumption energy is as great as in receive or transmits state; hence for the total energy consumption is high. Another reason is that, the network may be partitioned because a node that is far from the other nodes may not find the way to reach the gateway and therefore is unable to send traffic to its desired destination.Under high

could lead to the situation where the queue at the gateway is full, hence packets will be dropped and therefore they will

load, total consumed energy consumed in the simulation is also high. The reason is that gateways have to carry traffic from multiple nodes to the Internet; hence they quickly become network bottleneck. This

need to be retransmitted if the source traffic is TCP. Each of these re-transmission cost additional energy

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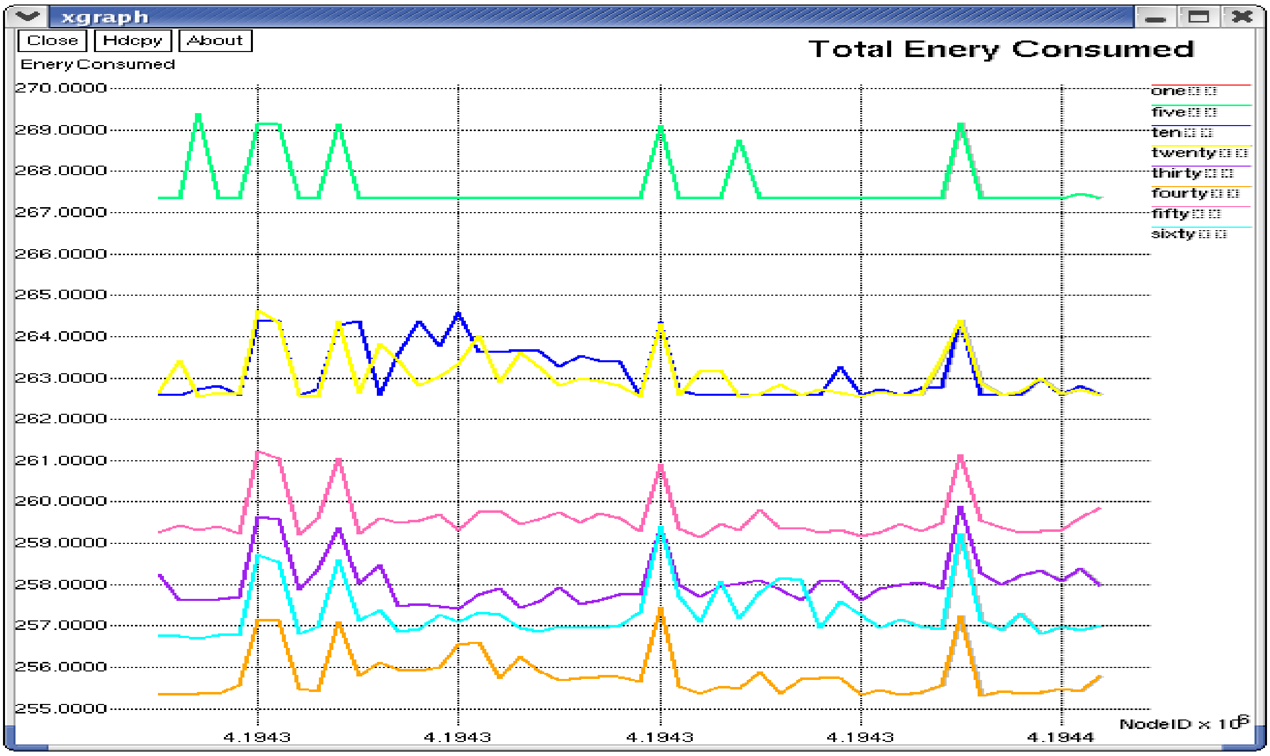

Figure 4: Energy consumed using multi-state error model

Placing gateways in different positions in the network also shows a difference in energy consumption rates. If packets are forward a large number of hops, then extra energy will need to forward these packets.

Conclusion

We have made an in-depth study concerning Internet connectivity for a mobile ad hoc network. We have evaluated a number of different scenarios and have chosen and recommend using reactive gateway discovery protocols using an IPv6 addressing scheme. This solution provides greater flexibility and scalability while providing the necessary functionality and high performance for a ad hoc network.

To capture the interesting mobility features including spatial, temporary dependence and geographic restriction, the paper has investigated and evaluated an ad hoc network while the internetworking with the internet under several mobility patterns (Random Waypoint, Freeway, Reference Point Group Mobility, Manhattan). The analysis and discussion of each mobility pattern with regard to energy offer some useful insight for the development and deployment of real-world scenarios.

The simulation results show that increasing the number of gateways could significantly improve the energy saving of a mobile node in most of mobility scenarios. Although the energy efficiency is not proportional to the number of gateways, as the number of gateways change from 1-2 and from 2-3 in the tested scenario, the energy saving could change by as much as 20%.

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