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CDMA Ad Hoc Networks Using Beam Forming on Demand Routing Protocol for Longer Transmission Range Improvement in the Energy Efficiency Technology

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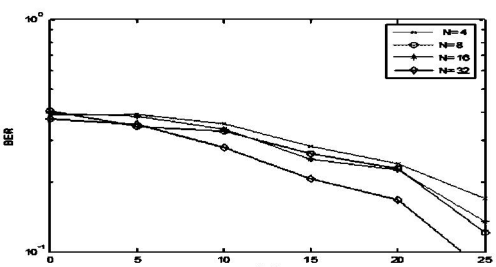
ABSTRACT : In this paper, we propose an energy improve on demand longer transmission range for CDMA mobile ad hoc networks, for which improvements in the energy consumption are realized by both introducing an energy based routing measure and by enhancing the physical layer performance using beam forming. Exploiting the cross-layer interactions between the network and the physical layer leads to a significant improvement in the energy efficiency compared with the traditional AODV protocol and ensures a faster response to system changes, and reduced overhead. for Indian Army.

Keywords: AODV protocol, system model, CDMA.

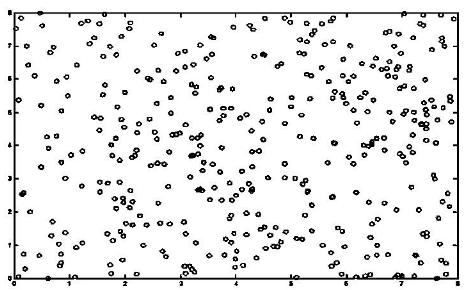
I. INTRODUCTION

In ad hoc networks, every node must participate not only as a host, but also as a router forwarding packets to their destinations. When network topology changes unpredictably due to node movements, the hosts need to determine the routes to other nodes frequently. Ad-hoc On-Demand Distance Vector routing protocol (AODV) proposed in [1] is one of the developed protocols that enable routing with continuously changing topologies. AODV establishes routes when they are first needed and does not maintain routes to destinations that are not in active communication. There have been several studies on the performance of AODV protocol and other on demand ad-hoc routing protocols ([2], [3]). However, these earlier studies did not focus explicitly on the energy efficiency of the protocols. With the tight energy constraints in the ad hoc network, the energy consumed for data transmission, route establishment and maintenance should be kept as low as possible. The energy consumed for the correct transmission of a packet is an important Q o S measure for the ad hoc networks [5]. There has been significant effort in proposing energy efficient routing protocols (*e.g.* [6], [8]), with a more recent focus on cross-layer design solutions (*e.g.* [5], [13]). However, previously proposed solutions do not consider on-demand routing for mobile ad hoc networks. In recent years, beam forming technology has been recognized as a breakthrough with its potential to unshackle the capacity limitations of ad hoc networks. The benefits provided bybeamforming, such as longer transmission range and reduced interference have been studied in [9]. Moreover, a vast research literature focuses on analyzing the performance of medium access control (MAC) protocols using beam forming (*e.g.* [10] [11]). However, the performance advantages and the tradeoffs associated with the interactions between beam forming and routing, are less understood. In this paper, we propose an energy aware AODV (EAAODV) protocol. The improvements in the energy consumption are obtained by both introducing an energy based routing measure and by enhancing the physical layer performance using directional antennas. Moreover, compared with the traditional AODV protocol, exploiting the cross-layer interactions between the network and the physical layer leads to a significant improvement in bandwidth and energy efficiency, and ensures a faster response to system changes with reduced overhead transmissions. Our simulation results for a CDMA ad hoc network show that an optimal signal-to-interference (SIR) target can be determined by combining the requirements for the considered performance metrics, such as energy, end-to-end latency and overhead energy for maintenance of the routing table.



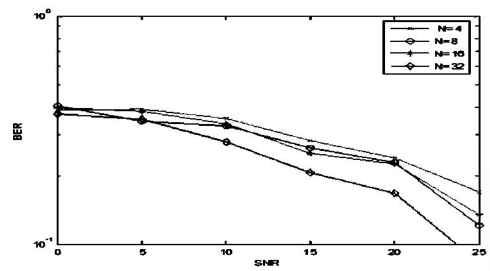
II. SYSTEM MODEL

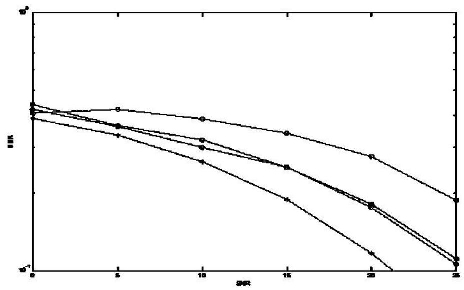
We consider an ad hoc network consisting of N mobile nodes. For simulation purposes, the nodes are assumed to have a uniform distribution over a square area, of dimension $D^* \times D^*$. It is assumed that each node generates traffic to be transmitted towards a randomly chosen destination node. The traffic can be relayed through intermediate nodes. Consequently, a node can also act as a router forwarding packets to the destinations. To accomplish this, the node must determine the route of an outgoing packet according to a pre-set routing metric. For the multi-access scheme, we employ synchronous direct-sequence CDMA. All nodes use independent, randomly generated and normalized spreading sequences of length *G*. The transmitted bits are detected using a matched filter receiver. A link is considered to be available if the ratio of sign alto-interference (SIR) at the receiver is above a pre-defined threshold. By setting the SIR threshold properly, the mobile hosts are protected from draining their energy by transmitting over a poor link. On the other hand, the SIR threshold level can affect the network connectivity: for a high SIR threshold, fewer links will be available for transmission. For mobile users, frequent changes in topology are triggered by the nodes' mobility, and a higher SIR threshold will result in an increased effort to find new routes, and thus higher overhead.

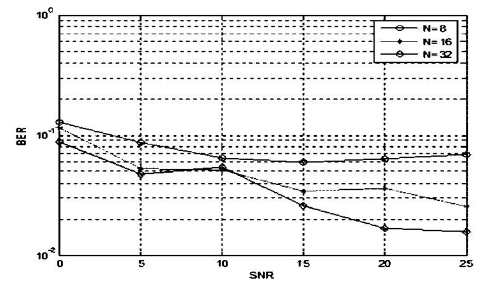


III. ENERGY AWARE ROUTING METRIC

Ad Hoc on-demanded Distance Vector routing (AODV) is used for ad hoc networks to create routes as they are needed. Given the same sequence number, traditional AODV protocol selects the route with a fewer number of hops to the destination, without specifically accounting for the links' quality. To improve the energy efficiency for the AODV protocol, we consider as a routing metric the energy required for the correct transmission of a packet from mobile node *i* to node*j*, *Eij* [4]: $Eij = MPjRPc(\gamma ij)$, (1) where *M* denotes the length of the packet, P_j is the transmission power, *R* represents the data transmission rate and $Pc(\gamma_{ij})$ is the probability of correct reception of a packet, with γ_{ij} equal to the SIR of link (*i*, *j*). The function in (1) depends on the details of the data transmission, such as modulation, coding, radio propagation and receiver structure. We choosethe same data transmission model as the one in [4], whichgives $Pc(\gamma_{ij}) = (1 - 2BERij)M$, (2) where *BERij* is the bit error rate for link (*i*, *j*). For no coherent frequency shift keying (FSK), $BERij = 0.5\ \exp(\gamma_{ij}2)$(3). The energy requirement for correct transmission of a packet on a specific route (from a source node to its corresponding destination) can be determined to be [5]: *Er* = link (*i*, *j*) *rEij*, (4) where *r* is a route. Obviously, selecting the paths with a minimum energy requirement improves the energy efficiency of the network. Based on this observation, the energy per packet on a route can be used as the routing criterion to improve the energy efficiency of the network.







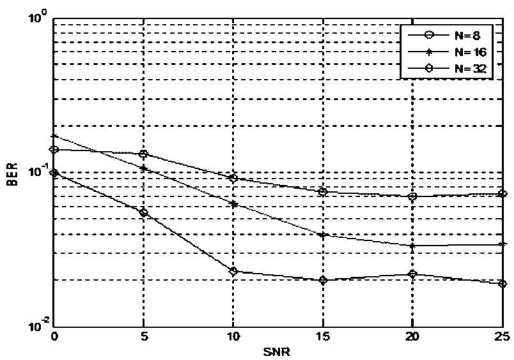
IV. ENERGY AWARE AODV

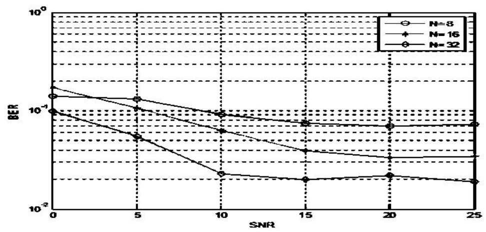
In our proposed Energy Aware AODV (EA-AODV) protocol, the energy per packet on a route is employed as the routing metric. The basic routing mechanism is described in the following. When a node *S* needs a route to some destination *D*, it will broadcast a Route Request to its neighbors. The latest sequence number of its destination is broadcasted as well. Each intermediate node forwarding the Route Request records a reverse route back to node *S* (according to our proposed energy efficient metric). Then, node *S* can transmit data packet along this energy efficient path. As the nodes move around randomly, the link quality between nodes may change unpredictably. The link quality depends on the achieved signal-to-interference ratio (SIR). When the SIR between node i and node *j*, say γij drops below the system SIR threshold γTh, link (*i*, *j*) is considered to be broken. When a link goes down, any node that has recently forwarded packets to a destination using this link is notified by an Unsolicited Route Reply message, and the route to the destination that contain this broken link is disabled. A new Route Discovery process as described above is initiated to find a new route to the destination. In order to maintain routes, the routing protocol needs an effective way to detect the link breakages. AODV usually requires that each node periodically transmit a HELLO message with a default rate of once per second. However, HELLO messages create extra control overhead and increase bandwidth consumption. Furthermore, once a link breaks, changes in the links' quality due to mobility are no acknowledged at the network level until some pre-defined number of Hello messages have been lost. Thus, until an action occurs, the energy of the mobile host is wasted for transmitting over a route that actually has a broken link. In the AODV specification document [1], it is suggested that an alternative method may be used when physical layer or link layer information is employed to help the nodes detect link breakages. In our proposed energy aware AODV, cross-layer interactions between the physical and the network layer are exploited to improve the network performance. The link state information detected by the physical layer helps the routing scheme maintain the local connectivity at the network layer and yields an improvement in bandwidth savings and overhead energy efficiency, by eliminating the HELLO message used in the traditional AODV protocol. In EA-AODV, once the links connecting to the active neighbors become unavailable, the physical layer can detect this based on the received SIR for that particular link. Ain dictation message can inform the network layer immediately to trigger a routing table update. Since EA-AODV establishes routes on demand, only the case of an active link's SIR falling below the threshold will trigger an information message for the network layer. Moreover, the next-hop information for a traffic flow obtained from the routing scheme at the network layer determines the activated direction of the switched beams at the physical layer, thus further reducing the implementation complexity.

V. DIRECTIONAL ANTENNAS IN EA-AODV

Using directional antennas has the effect of improving the communication range, as well as reducing the interference, by focusing the radiation only in the desired direction and adjusting to changing traffic conditions or signal environments. Generally, smart antenna systems use sophisticated adaptivebeamforming to achieve a better interference rejection performance. However, simple switched beam systems have the advantage of reduced cost and reduced implementation complexity. Switched beam systems provide a significant range extension and a considerable interference rejection capability, when the desired user is at the center of the beam. In this work, we propose a joint routing and beam forming algorithm, based on energy aware AODV protocol. Each mobile node is assumed to be equipped with a switched beam system consisting of Directional beams. Each of the beams has a conical radiation pattern *Pg*, spanning an angle of $2\gamma/K$ radians with equal space [12]. The beams are assumed not to be overlapping. Starting from the 3 o'clock position, the beams are numbered from 1 to *K* clockwise. It is also assumed that the orientation is maintained by the nodes even when they move around. We employ directional antennas at the transmitter and omni directional antennas at the receiver. In directional mode, the radio transmitter uses only the antennas that are active. For data packets transmission, only the beam pointing to the direction of the next hop will be activated. For relaying nodes transmitting multiple flows using the same beam, the transmissions are time-multiplexed. The broadcast control packets are transmitted using all beams simultaneously. In our study, we assume that the nodes in the network are able to determine the relative direction of a neighbor node. Then, when node *i* wants to transmit a packet to node *j*, node *i* determines the direction of node *j*, γij, relative to itself. Let γn denote the direction of the n^{th} beam for node *i*, where *n* is the index number of the beams as mentioned above. The index number of the beam that should be selected is the *n* which gives min $|\gamma ij \; \gamma \; \gamma n|$, $n = 1...K$. Suppose node *i* has a data packet to transmit. The next hop along the path is determined according to the routing table. At the physical layer, node *i* determines the relative direction of that next-hop node and the index number of the desired beam. Then, as described above, the control logic unit of switched beam activates the beam pointing to that particular direction. For different traffic flows relayed by node *i* the traffic can be time multiplexed, if the destination nodes are located on the direction of the same beam, or simultaneously transmitted, if the destination nodes are located such that different beams can simultaneously be activated for transmission. For broadcasting messages, for example a Route Request, all the beams are activated and the Request message is broadcasted to all directions in order to find a route to the destination. While it has been shown in [7], that wireless bandwidth savings can be achieved by limiting the spread of the route discovery queries to specific regions, for simplicity, we use all directions broadcasting in this work. Using directional antennas, and considering a simple free space propagation model, with propagation exponent $n = 2$, the Signal-to-Interference Ratio over link (i, j), γij, can be determined to be:

$\gamma ij = GpiGij(\gamma ij)/d2ij\_Nk = 1, k\_= i[pkGkj(\gamma kj)]/d2\ (kj)$, (5) where *G* is the spreading gain, *N* is the number of nodes in the network, pi is the transmission power of node *i*, and *dij* is the distance between node *i* and node *j*. $Gij(\gamma ij)$ represents the antenna gain from *i* to *j*, and depends on γij, the relative direction of *j* to *i*. For directional transmitters and omni directional receivers, if γij is within one of the current active beams in the switched beam system, the antenna gain *Gij* is set to be equal to the main lobe gain according to the radiation pattern *Pg*; otherwise, the antenna gain *Gij* is considered to be the side lobe gain. At the receiver, omni directional antennas are employed with a gain equal to 1.





VI. PROPOSED SIMULATION RESULT

To simulate the performance of our proposed routing algorithm, we have built a simulation environment based on an AODV simulator [14] developed for OMNET++ [15]. We have simulated four different scenarios: Traditional AODV with minimum hop routing for CDMA ad hoc mobile networks using omni directional antennas; Proposed AODV with energy as routing metric for CDMA ad hoc mobile networks using omni directional antennas; Traditional AODV with minimum hop routing for CDMA ad hoc mobile networks using directional antennas; Proposed AODV with energy as routing metric for CDMA ad hoc mobile networks using directional antennas.The performance metrics that we have considered are the average energy per path consumption, the overhead energy consumption rate (the percentage of energy spent for transmitting control messages) and the end to end latency. For the numerical results, we have selected N = 25 nodes, uniformly distributed over a square area. The nodes move around in a restricted random walk mobility model with aaverage speed of 5 meters/sec. The source-destination pairs of nodes are randomly chosen and the traffic burst arrival is modeled as a Poisson process with parameter ? = 1. The burst length is 64 packets and message packet length is 64 bytes. All users transmit with the same fixed power level, and for the numerical results, we have selected a path loss propagation model with propagation exponent 2. The spreading gain is selected to be G = 128. Fig. 1 illustrates the variation of average energy consumptions for a correct transmission of a data packet from its source to the destination. Various network densities are achieved by varying the deployment area. Given a fixed network density (25 nodes distributed in a 400 × 400 m^2 area), the average energy consumption with different SIR threshold values. From both Fig. 1 and 2, we can see that using an energy related routing metric significantly reduces the energy consumption. The performance can be further improved by enhancing the underlying physical layer using beam forming. The results show that even for the traditional AODV protocol, the benefits of directional antennas are significant. Figure 1 illustrates the increase in the energy consumption with the enhanced interference level caused by a higher density network. Fig. 2 shows an energy gain with the increase in the SIR threshold. This is due to a better links' quality, which yields reduced retransmissions. On the other hand, higher SIR thresholds imply fewer available links, with a negative impact on the network connectivity, and resulting in an increased overhead for route maintenance.

100 200 300 400 500 600 70010?910?810?710?6

10?510?410?310?210?1

Energy per Packet vs Network Density

Energy per Packet

Size of Network Field (Meter)

CDMA with Hops Metric

CDMA with Energy Metric

CDMA with Hops Metric using Directional Antenna

CDMA with Energy Metric using Directional Antenna

2 3 4 5 6 7 8 9 10 11 12

10?810?710?610?5

10?410?310?210?1

Energy per Packet vs SIR

Energy per Packet SIR

CDMA with Hops Metric

CDMA with Energy Metricm CDMA with Hops Metric using Directional Antenna CDMA with Energy Metric using Directional Antenna Fig. 2. Energy per Packet vs. SIR Threshold, Width of Network Area is400m Figure 3 illustrates this phenomenon, and shows an optimal SIR target that reduces the energy overhead for various scenarios. We defined the overhead energy ratio as the ratio of energy consumption for control messages to the total energy consumption for both control and data messages. Fig. 3 also shows a substantial performance improvement for the scenarios using beam forming, especially for the high SIR threshold region, for which directional antennas significantly increases the network connectivity. Figure 4 shows a tradeoff between the energy savings and the latency. The energy improvement is achieved at the cost of increasing the number of hops, thus resulting in as light increase in latency. For the first two cases with out beam forming, the energy metric routing gives a longer average

2 3 4 5 6 7 8 9 10 11 12

00.10.20.30.40.50.60.70.80.91

Overhead Energy Rate vs SIR

Overhead Energy Rate SIR

CDMA with Hops Metric

CDMA with Energy Metric

CDMA with Hops Metric using Directional Antenna

CDMA with Energy Metric using Directional Antenna

2 3 4 5 6 7 8 9 10 11 12

050100150200250300

Latency vs SIR Latency SIR

CDMA with Hops Metric

CDMA with Energy Metric

CDMA with Hops Metric using Directional Antenna CDMA with Energy Metric using Directional Antenna Fig. 4. End-to-End Latency vs. SIR Threshold, Width of Network Area is 400 m path length, which explains the higher latency obtained over the entire SIR threshold range. The beam forming antennas again overcome the main disadvantage of operating at high SIR thresholds, namely low connectivity for the network. The longer transmission range of the directional antennas yields a lower average hop count for the routes, and thus a lower latency. This becomes apparent for the high SIR threshold region (above 8). On the other hand, as the SIR threshold decreases, the performance is dominated by the retransmissions caused by the lower link quality, resulting into an increased end-to-end delay. This becomes noticeable when the SIR threshold drops below 6, when the routing favors the low energy routes, at the expense of a higher hop count per route, and higher delays. According to our simulation results, if the metric considered is the energy consumed for a correct transmission of a packet, the high SIR threshold region is the best choice for all considered scenarios. If we consider the other performance metrics, such as latency and overhead energy, the high SIR region remains a best choice for the beam forming scenarios, while the low SIR region gives better performance for omni directional antennas. If all performance metrics are considered, our results show that a good choice for the SIR threshold is in the range [6, 8].

VII. CONCLUSION

In this work, we have proposed an energy aware on-demand routing protocol for CDMA mobile ad hoc networks. The traditionalAODV protocol was improved by both introducing an energy based routing measure, and by enhancing the physical layer performance using directional antennas. Furthermore, we have exploited the cross-layer interactions between the network and the physical layer to reduce the implementation complexity and the transmission overhead. We have studied the performance of the proposed protocol, considering metrics such as the average energy per path consumption, the overhead energy consumption rate (the percentage of energy spent for transmitting control messages)and the end to end latency. Taking into account the above metrics, our simulation results show that an optimal SIR threshold can be selected to improve the network performance.

VIII. ACKNOWLEDGEMENT

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