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Channel Aware Routing Protocol for MANET

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Abstract

Wireless mobile ad hoc networks (MANETS) are self configuring, dynamic networks in which nodes are free to move. In mobile ad hoc networks, the major performance constraint comes from path loss and channel fading. This project implements a channel adaptive routing protocol which extends the Ad hoc On-Demand multipath Distance vector (AOMDV) Routing protocol to accommodate channel fading. This channel aware routing protocol uses the channel average non fading duration as a routing metric to select stable links for path discovery and senses the channel to avoid channel fading by applying a preemptive handoff strategy before a fade occurs. This channel aware routing protocol maintains reliable connections by exploiting channel state information. Using the same information about the channel, paths can be reused when they are available rather than discarding them completely. This Channel aware routing protocol will be implemented in heterogeneous network.

Keywords— channel adaptive routing, wireless networks, mobile ad hoc networks, fading, protocol.

1. INTRODUCTION

An ad-hoc network is a local area network (LAN) that is built spontaneously as devices connect. Instead of relying on a base station to coordinate the flow of messages to each node in the network, the individual network nodes forward packets to and from each other. Ad-hoc network does not contain any access point, instead each node acts as access points. Wireless communication enables information transfer among a network of disconnected, and often mobile, users. Popular wireless networks such as mobile phone networks and wireless LANs are traditionally infrastructure-based, i.e. base stations, access points and servers are deployed before the network can be used. In contrast, ad hoc networks are dynamically formed amongst a group of wireless users and require no existing infrastructure or pre-configuration.ad hoc networks makes them particular useful in situations where rapid network deployments are required or it is prohibitively costly to deploy and manage network infrastructure. Some example applications include, Attendees in a conference room sharing documents and other information via their laptops and handheld computer; Armed forces creating a tactical network in unfamiliar territory for communications and distribution of situational awareness information; Small sensor devices located in animals and other strategic locations that collectively, monitor habitats and environmental conditions; Emergency services communicating in a disaster area and sharing video updates of specific locations among workers in the field, and back to headquarters.

Unfortunately, the ad hoc nature that makes these networks attractive also introduces many complex communication problems. Although some of the first ad hoc networks were deployed in the early 1970's, significant research problems remain unanswered.

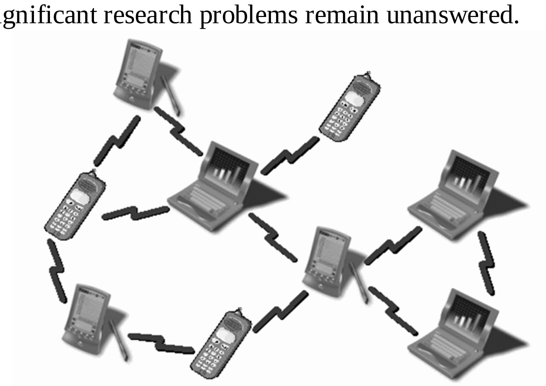

Figure 1 Ad hoc Network

A mobile ad-hoc network (MANET) is a self-configuring network of mobile routers (and associated hosts) connected by wireless links the union of which form an arbitrary topology. The routers are free to move randomly and organize themselves arbitrarily; thus, the network's wireless topology may change rapidly and unpredictably. Such a network may operate in a standalone fashion, or may be connected to the larger Internet. Minimal configuration and quick deployment make ad hoc networks suitable for emergency situations like natural or human-induced disasters, military conflicts, emergency medical situations etc. The earliest MANETs were called "packet radio" networks, and were sponsored by DARPA in the early 1970s. BBN Technologies and SRI International designed, built, and experimented with these earliest systems. Experimenters included Jerry Burchfiel, Robert Kahn, and Ray Tomlinson of later TENEX, Internet and email fame. It is interesting to note that these early packet radio systems predated the Internet, and indeed were part of the motivation of the original Internet Protocol suite. Later DARPA experiments included the Survivable Radio Network (SURAN) project, which took place in the 1980s. Another third wave of academic activity started in the mid 1990s with the advent of inexpensive 802.11 radio cards for personal computers. Current MANETs are designed primarily for military utility; examples include JTRS and NTDR.A mobile ad-hoc network (MANET) consists of mobile hosts equipped with wireless communication devices. The transmission of a mobile host is received by all hosts within its transmission range due to the broadcast nature of wireless communication and Omni-directional antennae. If two wireless hosts are out of their transmission ranges in the ad hoc networks, other mobile hosts located between them can forward their messages, which effectively build connected networks among the mobile hosts in the deployed area. Due to the mobility of wireless hosts, each host needs to be equipped with the capability of an autonomous system, or a routing function without any statically established infrastructure or centralized administration. The mobility and autonomy introduces a dynamic topology of the networks not only because end-hosts are transient but also because intermediate hosts on a communication path are transient. A typical MANET network is shown in the figure

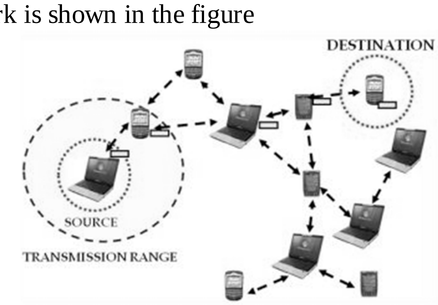

Figure. 2 Mobile Ad-Hoc Networks

In the figure 2, mobile nodes are connected via wireless links. It has no infrastructure and dynamic i.e. free to move.

The Characteristics of MANETs are Operating without a central coordinator,Multi-hop radio relaying,Frequent link breakage due to mobile nodes,Constraint resources (bandwidth, computing power, battery lifetime, etc.),Instant deployment.

Wireless mobile ad hoc networks (MANETs) are self configuring, dynamic networks in which nodes are free to move. A major performance constraint comes from path loss and multipath fading. Many MANET routing protocols exploit multihop paths to route packets. The probability of successful packet transmission on a path is dependent on the reliability of the wireless channel on each hop. Rapid node movements also affect link stability, introducing a large Doppler spread, resulting in rapid channel variations.

In a MANET, wireless devices could self-configure and form network with an arbitrary topology. Multicast is a fundamental service for supporting information exchanges and collaborative task execution among a group of users and enabling cluster-based computer system design in a distributed environment. Although it is important to support multicast in a MANET, which is often required by military and emergency applications, there is a big challenge to design a reliable and scalable multicast routing protocol in the presence of frequent topology changes and channel dynamics. Many efforts have been made to develop multicast protocols for MANETs. These include conventional tree-based protocols and mesh-based protocols. The tree-based protocols (e.g., MZRP) construct a tree structure for more efficient multicast packet delivery, and the tree structure is known for its efficiency in utilizing network resources. However, it is very difficult to maintain the tree structure in mobile ad hoc networks, and the tree connection is easy to break and the transmission is not reliable.

The mesh-based protocols (e.g., Core-Assisted Mesh protocol) are proposed to enhance the robustness with the use of redundant paths between the source and the set of multicast group members, which incurs a higher forwarding overhead. There is a big challenge to support reliable and scalable multicast in a MANET with these topology-based schemes, as it is difficult to manage group membership, find and maintain multicast paths with constant network topology changes. In order to support more reliable and scalable communications, it is critical to reduce the states to be maintained by the network, and make the routing not significantly impacted by topology changes. Recently, several location-based multicast protocols have been proposed, for MANET.

These protocols assume that mobile nodes are aware of their own positions through certain positioning system (e.g., GPS), and make use of geographic routing to transmit packets along the multicast trees. In these protocols, a multicast packet carries the information of the entire tree or all the destinations into the packet headers. Thus, there is no need to distribute the routing states in the network. Although these protocols are more robust than the conventional topology-based multicast schemes, the header overhead increases significantly as the group size increases; this prevents the scaling of these protocols and constrains these protocols to be used only for small multicast groups.

Additionally, there is a need to efficiently manage the membership of a potentially large group, obtain the positions of the members, and transmit packets to member nodes that may be located in a large network domain and in the presence of node movements. The existing small-group-based geographic multicast protocols normally address only part of these problems.

2. RELATED WORK

In this section, we first summarize the basic procedures assumed in conventional multicast protocols, and then discuss a few channel adaptive algorithms proposed in the literature.

As introduced in Section 1, Routing protocols for MANETs can make use of prediction of channel state information (CSI) based on a priori knowledge of channel characteristics, to monitor instantaneous link conditions. With knowledge of channel behavior, the best links can be chosen to build a new path, or switch from a failing connection to one with more favorable channel conditions.

Some routing protocols available for MANETs are Dynamic Source Routing protocol, AODV- Ad Hoc Distance Vector Routing protocol, AOMDV- Ad Hoc On demand Distance Vector Routing protocol. In this project a novel channel adaptive routing protocol which extends the Ad hoc On-Demand Multipath Distance Vector (AOMDV) routing protocol to accommodate channel fading will be implemented in heterogeneous network. The protocol is “Channel Aware Routing Protocol for MANETS” Which is the extension of CA-AOMDV: Channel Aware - Ad Hoc On demand Distance Vector Routing protocol. This CA-AOMDV is the extension of AOMDV

An ad-hoc network is the cooperative engagement of a collection of mobile nodes without the required intervention of any centralized access point or existing infrastructure. In this paper Ad-hoc On Demand Distance Vector Routing (AODV), a novel algorithm for the operation of such ad-hoc networks is presented. Each Mobile Host operates as a specialized router, and routes are obtained as needed (i.e., on-demand) with little or no reliance on periodic advertisements. This new routing algorithm is quite suitable for a dynamic self starting network, as required by users wishing to utilize ad-hoc networks. AODV provides loop-free routes even while repairing broken links. Because the protocol does not require global periodic routing advertisements, the demand on the overall bandwidth available to the mobile nodes is substantially less than in those protocols that do necessitate such advertisements. Nevertheless we can still maintain most of the advantages of basic distance-vector routing mechanisms. This show that AODV algorithm scales to large populations of mobile nodes wishing to form ad-hoc networks.

AOMDV is an extension of single path routing protocol AODV. It is a multi path routing protocol. It finds multiple routes between source and destination. It uses alternate routes on a route failure. New route discovery is needed when all routes are failed. The main goal of AOMDV is to perform faster and efficient recovery from route failures in dynamic network. To achieve this goal AOMDV computes multiple loop free and link disjoint paths. The notion of an advertised hop count is used to maintain multiple loop free paths. The property of flooding is used to ensure link- disjointness of the multiple paths computed within a single route discovery. AOMDV combines the use of destination sequence numbers in DSDV with the on demand route discovery technique in DSR to formulate a loop free, on demand, distance vector protocol.

A key factor deciding the performance of a routing protocol in mobile ad hoc networks is the manner in which it adapts to route changes caused by mobility. Exploiting the intuition that a less dynamic route lasts longer, a new metric, the Route Fragility Coefficient (RFC), to compare routes is proposed. RFC estimates the rate at which a given route expands or contracts. Expansion refers to adjacent nodes moving apart, while contraction refers to their moving closer. RFC combines the individual link contraction or expansion behavior to present a unified picture of the route dynamics. It is shown that lower the value of RFC, more static (less fragile) the route. Then this metric is used as a basis for route selection so that route discovery yields routes that last longer and hence increase throughput while reducing control overhead. A simple distributed mechanism to compute RFC is provided, so that a Route-Request (RREQ) packet contains the metric for the path it traversed, when it reaches the destination.

The Mobile-Mobile communication channel is used to characterize the channel between any two nodes. Finding the relative speed between nodes is very tedious so this M-M channel uses individual node speeds. It incorporates large scale path lose and small scale fading. This develops a statistical model for a narrowband mobile-to-mobile channel taking into consideration Rician scattering near receiving and transmitting antennas both individually and concomitantly. From the proposed channel model we obtain the probability density function of the received signal envelope, the time correlation function and RF spectrum of the received signal, and level crossing rates and average fade durations. The impact of these parameters is discussed on communication networks supporting an Intelligent Vehicle Highway System.

In a mobile channel, energy arrives at the receiver by scattering and diffraction over and/or around the surrounding environment. A short range mobile-to-mobile channel in a highway environment will also contain a much stronger direct line-of-sight component, possibly also with a strong ground reflected wave. These components combine vectorially at the receiver and give rise to a resultant signal that varies greatly depending on the distribution of the phases of the various components. These short-term variations in the received signal are called multipath fading. Long term variations in the signal, such as shadowing or path loss, are also present. The relative motion of the vehicles will give rise to a Doppler shift in the signal. Thus, the mobile radio signal varies rapidly over short distances (fading), with a local mean power that is constant over a small area, but varies slowly as the receiver moves.

Mobile ad hoc networks are characterized by multi-hop wireless links, absence of any cellular infrastructure, and frequent host mobility. Design of efficient routing protocols in such networks is a challenging issue. A class of routing protocols called on-demand protocols has recently found attention because of their low routing overhead. The on-demand protocols depend on query floods to discover routes whenever a new route is needed. Such floods take up a substantial portion of network bandwidth. Here a particular on-demand protocol, called Dynamic Source Routing is focused, and shows how intelligent use of multipath techniques can reduce the frequency of query floods. An analytic modeling framework is developed to determine the relative frequency of query floods for various techniques. Results show that while multipath routing is significantly better than single path routing, the performance advantage is small beyond a few paths and for long path lengths. It also shows that providing all intermediate nodes in the primary (shortest) route with alternative paths has a significantly better performance than providing only the source with alternate paths.

3. CHANNEL-AWARE AOMDV PROTOCOL

One of the main shortcomings of AOMDV is that the only characteristic considered when choosing a path is the number of hops. Path stability is completely ignored. Thus, selected paths tend to have a small number of long hops meaning that nodes are already close to the maximum possible communication distance apart, potentially resulting in frequent link disconnections. Further, channel conditions are idealized with the path-loss/transmission range model, ignoring fading characteristics inherent in all practical wireless communication environments. In CA-AOMDV, we address this deficiency in two ways. In the route discovery phase, we utilize the ANFD, of each link as a measure of its stability. In the route maintenance phase, instead of waiting for the active path to fail, we preempt a failure by using channel prediction on path links, allowing a handover to one of the remaining selected paths. This results in saved packets and consequently smaller delays.

This CA-AOMDV (Channel Aware - Ad Hoc On demand Distance Vector Routing protocol) is the channel-aware version of the AOMDV routing protocol. The key aspect of this enhancement, which is not addressed in other work, is that the use of specific, timely, channel quality information allowing us to work with the ebb-and-flow of path availability. This approach allows reuse of paths which become unavailable for a time, rather than simply regarding them as useless, upon failure, and discarding them. The channel average nonfading duration (ANFD) is utilized as a measure of link stability, combined with the traditional hop-count measure for path selection. The protocol then uses the same information to predict signal fading and incorporates path handover to avoid unnecessary overhead from a new path discovery process. The average fading duration (AFD) is utilized to determine when to bring a path back into play, allowing for the varying nature of path usability instead of discarding at initial failure. This protocol provides a dual attack for avoiding unnecessary route discoveries, predicting path failure leading to handoff and then bringing paths back into play when they are again available, rather than simply discarding them at the first sign of a fade. Further, the same information is required to determine ANFD, AFD and predict path failure, enhancing efficiency. The overall effect is a protocol with improved routing decisions leading to a more robust network.

There are two phases in CA-AOMDV; they are Route discovery phase, Route maintenance phase.

Route discovery in AOMDV results in selection of multiple loop-free, link-disjoint paths between source (n_s) and destination (n_d), with alternative paths only utilized if the active path becomes unserviceable. One of the main shortcomings of AOMDV is that the only characteristic considered when choosing a path is the number of hops. Path stability is completely ignored. Thus, selected paths tend to have a small number of long hops meaning that nodes are already close to the maximum possible communication distance apart, potentially resulting in frequent link disconnections.

A. Route Discovery

Route discovery in CA-AOMDV is an enhanced version of route discovery in AOMDV, incorporating channel properties for choosing more reliable paths. CA-AOMDV uses the ANFD as a measure of link lifetime. The duration, D, of a path is defined as the minimum ANFD over all of its links

$$= \Delta \min \qquad h, \qquad (1)$$

where h is link number, and H is number of links/hops in the path. Before forwarding a RREQ(Route Request) to its neighbors, a node inserts its current speed into the RREQ header so that its neighbors can calculate the link ANFD using the formula. The path duration, D, is also recorded in the RREQ, updated, as necessary, at each intermediate node. Thus, all information required for calculating the ANFD is available via the RREQs, minimizing added complexity. Similarly, to the way the longest hop path is advertized for each node in AOMDV to allow for the worst case at each node, in CA-AOMDV the minimum D over all paths between a given node, n_i, and n_d, is used as part of the cost function in path selection. That is,

$$\mathcal{D}^{i,d}_{\min} \triangleq \min_{\zeta \in \text{path\_list}^d_i} \mathcal{D}_\zeta, \quad (2)$$

where path $list^d_i$ is the list of all saved paths between nodes n_i and n_d. The route discovery update algorithm in CA-AOMDV is a slight modification of that of AOMDV. If a RREQ or RREP for n_d at n_i, from a neighbor node, n_j, has a higher destination sequence number or shorter hop-count than the existing route for n_d at n_i, the route update criterion in CA-AOMDV is the same as that in AOMDV. However, if the RREQ or RREP has a destination sequence number and hop-count equal to the existing route at n_i but with a greater $D^{i,d}_{min}$, the list of paths to n_d in n_i's routing table is updated. So, in CA-AOMDV, path selection is based on $D^{i,d}_{min}$, as well as destination sequence number and advertized hop-count.

The routing table structures for each path entry in AOMDV and CA-AOMDV are shown in Table 1. The handoff dormant time field in the routing table for CA-AOMDV is the amount of time for which the path should be made dormant due to channel fading. In the table1 below the routing table entries of AOMDV and CA-AOMDV are compared. All entries in AOMDV and CA-AOMDV are same except CA-AOMDV contains D_{min} and handoff dormant time.

B. Route Maintenance

Route maintenance in CA-AOMDV takes advantage of a handoff strategy using signal strength prediction, to counter channel fading. When the predicted link signal strength level falls below a network specific threshold, the algorithm swaps to a good-quality link. The fading threshold is chosen so as to provide robustness to prediction errors. The presence of multiple users experiencing independent channel fading means that MANETs can take advantage of channel diversity, unlike data rate adaptation mechanisms such as Sample Rate.

All nodes maintain a table of past signal strengths, recording for each received packet, previous hop, signal power, and arrival time. However, this will depend on the packet receipt times compared with the specified discrete time interval, Δt. If packets are received at time intervals greater than Δt, sample signal strengths for the missed time intervals can be approximated by the signal strength of the packet closest in time to the one missed. If packets are received at intervals of shorter duration than Δt, some may be skipped. An example of handoff in CA-AOMDV is shown in Fig. 2. The handoff process is implemented via a handoff request (HREQ) packet. The CA-AOMDV handoff scheme is described below.

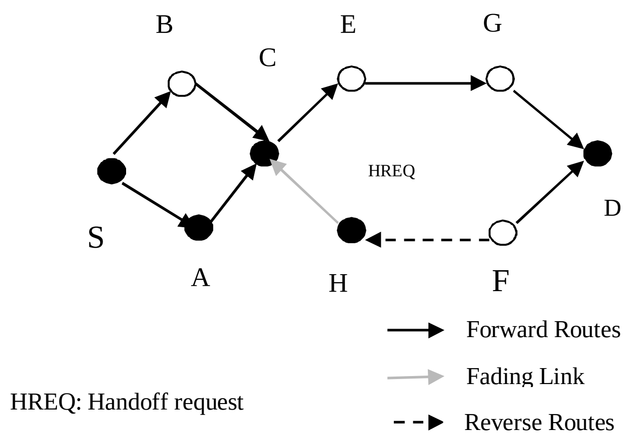

Figure. 3 Handoff in CA-AOMDV.

In the figure3 node F has predicted a forthcoming fade for its link with node D and has generated a HREQ. Having no alternative paths to choose from, node D forwards the HREQ to node C which may then be able to handoff to the path with node E as the next node.

C. Prediction Length

In CAAOMDV, a given node may have multiple paths to the destination, each with a different next hop node. If an intermediate node has multiple paths to the destination, upon receiving an HREQ it can immediately switch from the active path to a good alternative one, without further propagating the HREQ. Therefore, the time needed to implement a handoff in CA-AOMDV is the duration, in terms of the discrete time interval Δt, for the HREQ to be propagated to the fading link uplink node. For example, if n_i and n_j are neighbors in a given path and n_j predicts a fade on link $l_{i,j}$, it will generate a HREQ and forward it to n_i. Thus, a suitable prediction length ψ corresponds to the number of discrete time intervals, Δt, for transmission of a HREQ between n_j and n_i, which can be approximated by using the data propagation time T^i_j from n_j to n_i, with ψ=round($T^i_j/\Delta t$) where "round" is the integer rounding function. In addition to choosing a threshold with a suitable error margin, as described above, to enhance the robustness of the prediction process to errors in CA-AOMDV, the signal strength is predicted at $t_0+\psi$ and $t_0+2\psi$.

D. Handoff Trigger

Route handoff is triggered when a link downstream node predicts a fade and transmits a HREQ to the uplink node. Let T_R be the transmission range, assumed to be the same for all nodes, let R(t) be predicted signal strength at time t and recall R_{th} as the fade prediction threshold. If the prediction at $t_0+\psi$ is above R_{th} while that at $t_0+2\psi$ is below, the maximum transmitter velocity v^{max}_T ensuring signal strength above R_{th} at $t_0+\psi$ is determined. If a fade is predicted at either time, the receiver checks whether the link is at breaking point with respect to distance. The HREQ registers the following fields: source IP address, destination IP address, source sequence number, fade interval index, long term fading indicator, AFD, and v^{max}_T.

E. Handoff Table

In addition to the routing table each node maintains a local handoff table. Each entry includes: source IP address, source sequence number, destination IP address, and expiration timeout. expiration timeout indicates when a path is expected to be available again (out of the fade) and is set to the maximum AFD of all currently faded links with paths through that node to a particular n_s. Note that this is similar to the way advertized hop-count is set to the maximum number of hops for any path going through a node for a particular n_s in AOMDV. Whenever a node receives a HREQ targeting a particular n_s, it checks its handoff table for an entry relating to that n. The handoff table is updated if no entry exists for that n, if the new HREQ has a longer AFD or if the existing entry is stale due to the expiration timeout having expired. If any unexpired entry is found for that n with the same or higher source sequence number, the HREQ is dropped.

F. Forwarding the HREQ

Any node receiving a nonduplicate HREQ checks for alternative paths to n_d. If not, as for the case of node D in Fig.1.3, it propagates the HREQ. Otherwise, if it has one or more "good" alternative paths to the n_d, it marks the fading path indicated in the HREQ as dormant, setting the handoff dormant time in its routing table entry for that path to the AFD recorded in the HREQ. The HREQ is then dropped. If a fade is predicted on the active path, a nondormant alternative path to n_d is then adopted prior to the onset of link failure. For example, if node C in Fig.1.3 receives a HREQ from node D, it marks the path with next hop = D as dormant, and adopts the path with next hop = E. The dormant path is retained for use when the fade is over, reducing path discovery overhead.

4 . PERFORMANCE EVALUATION

A. Simulation Results

We now compare AOMDV and CA-AOMDV with respect to node mobility. The simulated network areas were 2,200 m 600mand 2,800m_600 m, 2 Mb/s channel bandwidth, 100 s running time, 100 uniformly distributed nodes moving at maximum speed in random directions with 20 connections. Maximum node speed was increased from 1 to 10 m/s. The 512-byte CBR sources were fixed at 5 packets/s.

B. Throughput

Simulation results for network throughput decreases with increased node mobility, with CA-AOMDV outperforming AOMDV, particularly, in the mid-range mobilities, with significant performance increases realized. At 4 m/s, CA-AOMDV provides 25.5 and 12.2 percent improvements for the smaller and larger networks, respectively. At extreme mobilities, the throughput performances vary less and the advantages of CAAOMDV are greater with smaller network area (shorter path lengths) as previously noted. At low mobilities, path characteristics vary less quickly and the advantages of handoff in CA-AOMDV are less. At high mobilities, channel and path characteristics change rapidly, again mitigating handoff scheme advantages, and increasing signal strength prediction efficacy.

C. End-to-End Delay

CAAOMDV outperforms AOMDV, with 24 and 28 percent improvements at a velocity of 4 m/s, for the smaller and larger networks, respectively. At extreme mobilities, the performances converge.

D. Normalized Routing Control Overhead

Normalized routing control overhead is the ratio of number of routing control packets to delivered data packets. Overhead for both protocols increases with increasing node mobility because the more quickly changing network topology increases routing update frequency. Except for extreme mobilities, CA-AOMDV maintains a lower routing overhead compared with AOMDV, with 14 and 16 percent improvements at 4 m/s for the smaller and larger networks, respectively.

A simulation result was gained by averaging over six runs with different seeds. The following metrics were studied:

1) *Packet delivery ratio*: The ratio of the number of packets received and the number of packets expected to be received. So the ratio is the total number of received packets over the multiplication of the group size and the number of originated packets.

2) ***Normalized control overhead*****:** The total number of control message transmissions divided by the total number of received data packets.

3) ***Average path length*****:** The average number of hops traversed by each delivered data packet.

4) ***Joining delay*****:** The average time interval between a member joining a group and its first receiving of the data packet from that group. To obtain the joining delay, the simulations were rerun with the same settings except that all the members joined the group after the source began sending data packets.

5. CONCLUSION

A channel-based routing metric is proposed which utilizes the average nonfading duration, combined with hop-count, to select stable links. A channel-adaptive routing protocol, CA-AOMDV, extending AOMDV, based on the proposed routing metric, is introduced. During path maintenance, predicted signal strength and channel average fading duration are combined with handoff to combat channel fading and improve channel utilization. A new theoretical expression for the lifetime of the multiple reusable path system used in CA-AOMDV is derived. Theoretical expressions for routing control overhead and packet delivery ratio also provide detailed insights into the differences between the two protocols. Theoretical analysis and simulation results show that CA-AOMDV outperforms AOMDV in practical transmission environments.

REFERENCES

[1] O. Tickoo, S. Raghunath, and S. Kalyanaraman, “Route Fragility: A Novel Metric for Route Selection in Mobile Ad Hoc Networks,”
Proc. IEEE Int’l Conf. Networks (ICON), pp. 537-542, Sept. 2003.

[2] M. Park, J. Andrews, and S. Nettles, “Wireless Channel-Aware Ad Hoc Cross-Layer Protocol with Multiroute Path Selection Diversity,” Proc. IEEE Vehicular Technology Conf. (VTC)-Fall, vol. 4, pp. 2197-2201, Oct. 2003.

[3] M.K. Marina and S.R. Das, “On-Demand Multipath Distance Vector Routing in Ad Hoc On-Demand Network Systems (WONS), pp. 251-269, March 2004. Networks,” Proc. Ninth Int’l Conf. Network Protocols (ICNP), pp. 14-23, Nov. 2001.

[4] C.E. Perkins and E.M. Royer, “Ad-Hoc On-Demand Distance Vector Routing,” Proc. IEEE Workshop Mobile Computing Systems and Applications (WMCSA), pp. 90-100, Feb. 1999.

[5] A. Nasipuri and S.R. Das, “On-Demand Multipath Routing for Mobile Ad Hoc Networks,” Proc. Int’l Conf. Computer Comm. And Networks (CCCN), pp. 64-70, Oct. 1999.

[6] A.S. Akki and F. Haber, “A Statistical Model of Mobile-to-Mobile Land Communication Channel,” IEEE Trans. Vehicular Technology,vol. 35, no. 2, pp. 2-10, Feb. 1986. The Network Simulator - ns-2, http://www.isi.edu/nsnam/ns, 2008.

[7] C.S. Patel, G.L. Stuber, and T.G. Pratt, “Simulation of Rayleigh Faded Mobile-to-Mobile Communication Channels,” IEEE Trans. Comm., vol. 53, no. 11, pp. 1876-1884, Nov. 2005.

[8] R.J. Punnoose, P.V. Nikitin, and D.D. Stancil, “Efficient Simulation of Ricean Fading within a Packet Simulator,” Proc. IEEE Vehicular Technology Conf. (VTC), vol. 2, pp. 764-767, Sept. 2000.

[9] J. Broch et al., “A Performance Comparison of Multi-Hop Wireless Adhoc Network Routing Protocols,” Proc. ACM MobiCom, pp. 85-97, Oct. 1998.

[10] D. Niculescu and B. Nath, “Ad Hoc Positioning System (APS) Using AoA,” Proc. IEEE INFOCOM, pp. 1734-1743, Apr. 2003.

[11] M. Park, J. Andrews, and S. Nettles, “Wireless Channel-Aware Ad Hoc Cross-Layer Protocol with Multiroute Path Selection Diversity,” Proc. IEEE Vehicular Technology Conf. (VTC)-Fall, vol. 4, pp. 2197-2201, Oct. 2003.

[11] X. Lin, Y.K. Kwok, and V.K.N. Lau, “RICA: A Receiver-Initiated Approach for Channel-Adaptive On-demand Routing in Ad Hoc Mobile Computing Networks,” Proc. Int’l Conf. Distributed Computing Systems (ICDCS), pp. 84-91, July 2002.

[12] B. Awerbuch, D. Holer, and H. Rubens, “High Throughput Route Selection in Multi-Rate Ad Hoc Wireless Networks,” Proc. Conf. Wireless