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OFDM Based Channel Adaptive Multipath Routing in Wireless Mobile Ad-hoc Networks

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Abstract: A Wireless Mobile Ad-hoc Network can be used for wide range of application as it has the capability to establish network anywhere, any time without any infrastructure. In MANETs packet transmission is affected by radio link fluctuations. Hop count is a simple routing metric that calculate the distance between a source and destination on the number of routers in the path. Routing protocols for ad hoc networks have less channel fading. The minimum hop count is not enough for a routing protocol to achieve a good performance. So in this paper, channel adaptive protocol using OFDM technique, extensions to a multipath routing protocol to accommodate channel fading is introduced. The resulting protocol is referred to as Channel Adaptive Multipath routing protocol (CAMR). Using channel state information (CSI), a pre-emptive handoff strategy is applied to maintain reliable and stable connections. Paths are reusable, rather than simply regarding them as useless. In this paper we provide theoretical analysis of multiple path system, as well as comparison between CAMR and AOMDV. We also show that there is a close match between the theoretical and the simulation results which confirms the improved network performance of CAMR over AOMDV

Keywords**:** channel adaptive routing, route handoff, routing protocols, channel fading

I. Introduction

A Wireless Mobile Ad hoc Network is a collection of mobile nodes or terminals that communicate with each other by forming a multi-hop radio network and has decentralized organization. The packet transmission in MANETs is done using radio link and infrared. Routing is a critical issue in mobile ad hoc networks (MANET) because of their dynamic network topology. In MANETs, routing is done by using many numbers of protocols. Although routing design is greatly impacted by the fading mechanisms in the wireless channel, existing routing protocols for MANET consider typically only the path-loss effect as far as propagation impairment is concerned while ignoring the deleterious effects of channel fading and shadowing. Link breakages in wireless networks can severely deteriorate network throughput and routing performance. Another significant drawback of existing routing protocols for wireless ad hoc networks is that the considerable differences in the communication channels between nodes are rarely considered, which can directly impact the network lifetime.

Many MANET routing protocol exploit multihop paths to route packets, and the successful packet transmission on the paths depends on reliability of the wireless channel on each hop. Highly dynamic nature of nodes affect link stability, introducing large Doppler spread, resulting large channel variations [1]. Route outage probability metric, if used to select optimal route paths, is perhaps more appropriate MANETs than the conventional minimum hop-count metric because it is much more for desirable for a packet to reach its destination with a high success probability even if it involves a few additional hops than it be lost while transferring a route with fewer hop counts. To monitor instantaneous link conditions routing protocol can make use of prediction of channel state information (CSI) based on prior knowledge of channel characteristics. With the knowledge of channel behaviour best link can be chosen to establish a new path, or hand over from failing connection to the one with more favourable channel conditions.

In this paper, we introduce an extended channel adaptive version of the AOMDV routing protocol, which uses average non fading duration as a routing metric along with hop count. The main parameter in the enhancement is that, we use channel quality information to work with ebb-and-flow of path availability. In this methodology, we can reuse the path which becomes unavailable for a time, rather than discarding

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them or regarding as useless .Here, we uses channel average non fading duration (anfd) as a measure of link stability. This protocol uses the same information to predict signal fading and perform necessary handoff, so it can reduce unnecessary overhead on the path discovery phase. Orthogonal Frequency Division Multiplexing (OFDM) is used here to calculate ANFD and AFD. Using this the handoff scheme will perform between the available narrow bands.

The average fading duration (afd) is utilized to determine when to bring a path back into active state, allowing for varying nature of path usability instead of discarding at initial failure. This protocol provide a method for avoiding unnecessary route discoveries predicting path failure leading to handoff and then reuse the path when they are available again. Also, the same information is necessary to determine anfd, afd, and predict path failure, and enhancing efficiency. Transmissions via unreliable wireless connection can result in large packet losses. So, it is important to consider a routing protocol which adapts to channel variations. We call this protocol Channel Adaptive Multipath Routing Protocol (CAMR).

The rest of the paper organized as follows. In section II we review channel adaptive schemes, AODV and AOMDV. Proposed methodology is detailed in section III. CAMR handoff scheme and OFDM Techniques are described on Section IV. Simulation and discussion are presented in section V and section VI is the conclusion.

II. LITERATURE REVIEW

A. Channel adaptive schemes

In the literature several channel adaptive scheme that is developed for MANETs to maintain stable connection. Shweta Jain and Samir R. Das[1] proposed an anycast mechanism at the link layer to exploit path diversity in the link layer by choosing the best next hop to forward packets when multiple next hop choices are available again.P.Pham et.al[2] implemented the channel adaptive scheme in medium access control (MAC) protocols and proposed a Markov model for Rayleigh channels and an innovative Markov model for IEEE 802.11 distributed coordination function.[3] considers link stability largely in terms of longevity of a given link, termed “associativity”; a similar idea, with respect to node mobility, is considered.[5] utilizes node-to-node routing, based on the “best” node which received a given transmission. While throughput improvements of 35 percent over traditional routing techniques are achieved, it is not clear how much delay or overhead is expended through node negotiation with each transmission. Signal strength as a path selection criterion, is used in [8]; [14] introduces outage probability into both the routing and MAC protocols; [9], [10] utilize the bit transmission rate in the network layer; and [17] employs SNR to support channel adaptive routing.

B. AODV

AODV is a single-path, on-demand routing protocol. When a source node, Ns, generates a packet for a particular destination node, Nd, it broadcasts a route request (RREQ) packet.

Here the source and destination IP addresses remain constant for the lifetime of the network, source sequence number is a monotonically increasing indicator of packet “freshness,” destination sequence number is the last known sequence number for nd at ns and hop-count is initialized to zero and incremented at each intermediate node which processes the RREQ. A RREQ is identified by the source sequence number and broadcast ID. An intermediate node processes a RREQ if it has not received previously. If an intermediate node has a route to destination node with destination sequence number at least that in the RREQ, it returns a route reply (RREP) packet, updated with the information that it has. If not, it records :source IP address, source sequence number, broadcast ID, destination IP address and expiration time for reverse path route entry, and forwards the RREQ to its neighbours.

The route expiration time is the time after which the route is considered to have expired and a new route discovery process must be undertaken. Ns send packets via the first path it hears about. If it receives a later RREP which has either new information or a shorter hop-count, it discards the original route information. When a route becomes inactive, a route error (RERR) packet, with sequence number incremented from the corresponding RREP and hop-count of 1, is sent by the upstream node of the broken link to source node. While receiving a RERR, Ns initiates a new route discovery process if it still has packets to send to Nd. Nodes also periodically send “hello” messages to neighbouring nodes to maintain knowledge of local connectivity.

TABLE1. RREQ PACKET FIELDS

Destinati on IP address	Destinati on sequence number	Advertis ed hop count	Ro ut list	Entry expirati on time

TABLE2. RREP PACKET FIELDS

Destination IP address	Destinati on sequenc e number	Adverti sed hop count	Rou t list	Entry expirati on time

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C. AOMDV

AOMDV extends AODV to provide multiple paths. In AOMDV each RREQ and RREP defines an alternative path to the source or destination. The routing entries contain a list of next-hops along with corresponding hop counts for each destination. To ensure loop-free paths AOMDV introduces the advertised hop count value at node i for destination d. This value represents the maximum hop-count for destination d available at node i. Consequently, alternate paths at node i for destination d are accepted only with lower hop count than the advertised hop count value. By suppressing duplicate RREQ at intermediate nodes node-disjointness can be achieved. In both AODV and AOMDV, RREQ initiates a node route table entry in preparation for receipt of a returning RREP.
The time after which the entry is discarded, if a corresponding RREP has not been received, is called as Entry expiration time. In AOMDV, the routing table entry is slightly modified to allow for maintenance of multiple entries and multiple loop-free paths. First, hop-count is replaced by advertised hop-count and it is the maximum over all paths from the current node to Nd, so only one value is advertised from that node for a given destination sequence number. Second, next-hop IP address is replaced by a list of all next-hop nodes and corresponding hop-counts of the saved paths to nd from that node, as follows:

TABLE3. AOMDV ROUTING TABLE

Source IP address	Source sequence number	broadcast ID	destination IP address	destination sequence number	Hop-count

D. Problem statement

Route discovery in AOMDV results in selection of link-disjoint, multiple loop-free paths between Ns and Nd , with alternative paths only utilized if the active path becomes unserviceable. One of the main drawback of AOMDV is that the path is selected only using the number of hops. Path stability is not taken into account. Thus, selected paths tend to have a small number of long hops .That means nodes are already close to the maximum possible communication distance apart, which will result in frequent link disconnections. Further, channel conditions are idealized with the path-loss or transmission range model, ignoring fading characteristics in all practical wireless communication systems.

III. CHANNEL- ADAPTIVE MULTIPATH ROUTING PROTOCOL (CAMR)

CAMR considers channel fading to overcome the deficiency of AOMDV. The result of route discovery in AOMDV finds the selection of multiple loop- free, link-disjoint paths between source and destination node. In the route discovery phase, stability is measured using anfd. These channel state information is determined by OFDM technique. The available frequency band information is always available at transceiver of each node. From this received signal OFDM can measure the average fading duration and average non fading duration of a particular channel. the In the route maintenance phase, instead of waiting for the active path to fail, a channel prediction is used to determine the failure, and a handover is made to one of the remaining selected paths. Thus number of dropped packets and delay can be reduced.

A. Orthogonal Frequency-Division Multiplexing Technique (OFDM)

OFDM is a multicarrier system, and it divides the available bandwidth into many narrow bands. The main advantage of this system is that its ability to cope with channel fading ,without complex equalization filters. In the proposed channel adaptive Multipath routing, OFDM technique utilizes the Channel State Information (CSI) , and determine the available narrow bands in the system ,when channel fading occurs. The handoff algorithm works based on the available non faded narrow band selected by OFDM. Here OFDM uses Fast Fourier Transform. OFDM is simple in concept, even though its implementation is complex. Mathematically, it can be implemented by using an Inverse Fast Fourier Transform (IFFT) in the transmitter and conversely an FFT in the receiver.

B. Channel State Information (CSI)

- **Average non fading duration**

The mobile Rayleigh or Rician radio channel is characterized by rapidly changing channel characteristics. As the amplitude of a signal received over such a channel also fluctuates, the receiver will experience periods during which the signal cannot be recovered reliably.
If a certain minimum (threshold) signal level is needed for acceptable communication performance, the received signal will experience periods of

- sufficient signal strength or "non-fade intervals", during which the receiver can work reliably and at low bit error rate
- Insufficient signal strength or "fades", during which the bit error rate is close to one half (randomly guessing ones and zeros) and the receiver may even fall out of lock.

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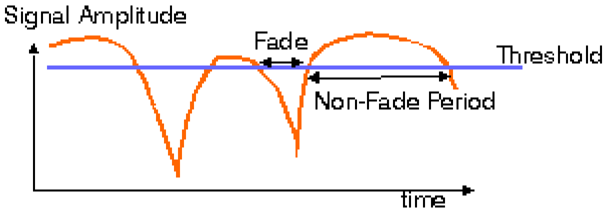

Figure1. The two-state simplification of the wireless channel behaviour - Gilbert-Elliot model

The average nonfading duration is affected by two parameters such as the physical propagation environment and the node velocities. The anfd ($\tilde{V}$) , is the average length of time that the signal envelope spends above a network-specific threshold, Rth , and is given by $V=c(Go)^{1/2}/(Rthd^{\alpha/2}f0[2\pi(V_t^2+V_r^2))]^{1/2}$ (1)

- **Average Fading Duration**

The average fading duration ($\tilde{V}$), is the average length of time that the signal envelope spends below Rth . For mobile-to-mobile channel the average fading duration is given by,

$v = (e^{\rho 2} -1) / [\rho f_T (2\pi (1+m^2)^{1/2}]$ (2)

- **Route discovery**

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

$D = \mathrm{Min}_{(1 \leq h \leq H)}\ \mathrm{anfd}(h)$ (3)

Where h is link number, and H is number of links/hops in the path. Before forwarding a RREQ to its neighbours, a node inserts its current speed into the RREQ header so that its neighbours can calculate the link ANFD using (1). 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 advertised for each node in AOMDV to allow for the worst case at each node, in CAMR the minimum D over all paths between a given node, ni, and nd, is used as part of the cost function in path selection. That is,

$D\ min^{i,d} = \mathrm{Min}(_{\iota \in path\text{-}list^{d}_{i}})\ D_{\iota}$ (4)

Where path list di is the list of all saved paths between nodes ni and nd. The route discovery update algorithm in CAMR is a slight modification of that of AOMDV.

C. Route maintenance

In Mobile environments it is necessary to find efficient ways of addressing path failure. Using prediction and handoff to preempt fading on a link on the active path, disconnections can be minimized, reducing transmission latency and packet drop rate. Route maintenance in CAMR takes advantage of a handoff strategy using signal strength prediction, to counter channel fading. When a source node broadcasts an RREQ for a multicast group, it often receives more than one reply. The source node keeps the received route with the greatest sequence number and shortest hop count to the nearest member of the multicast tree for a specified period of time, and disregards other routes. At the end of this period, it enables the selected next hop in its multicast route table, and unicasts an activation message to this selected next hop. On receiving this message the next hop enables the entry for the source node in its multicast routing table. If this node is a member of the multicast tree, it does not propagate the message any further. And if it is not a member of the multicast tree, it would have received one or more RREPs from its neighbours. It keeps the best next hop for its route to the multicast group, unicasts MACT to that next hop and the corresponding entry in its multicast route table is enabled. This process continues until the node that originated the chosen RREP (member of tree) is reached. The activation message ensures that the multicast tree does not have multiple paths to any tree node.

IV. CAMR HANDOFF SCHEME

Here, whenever the channel is getting faded, depending up on the average non fading duration, each node can switch from the fading channel to the better available channel in the network. This Handoff mechanism improves the connectivity in the network. An example of handoff in CAMR is shown in Fig. The handoff process is implemented via a handoff request (HREQ) packet. For each received packet all the nodes maintain a table, which contain past signal strength, previous hop, and time of arrival. Typically, the required number of samples in the packet depends on the packet receipt times, compared with specified discrete time interval.

A. Handoff Trigger

Whenever the downstream node identify the probability of fade and send a HREQ to the uplink node ,in this case route handoff triggered. The HREQ registers the following fields: source IP address, destination IP address, source sequence number, fade interval index, long term fading indicator, AFD, and vT max. in the Handoff Table to Avoid Duplicate. At the same time if the probability of fading occurs, the receiver checks whether the link is at breaking point with respect to distance

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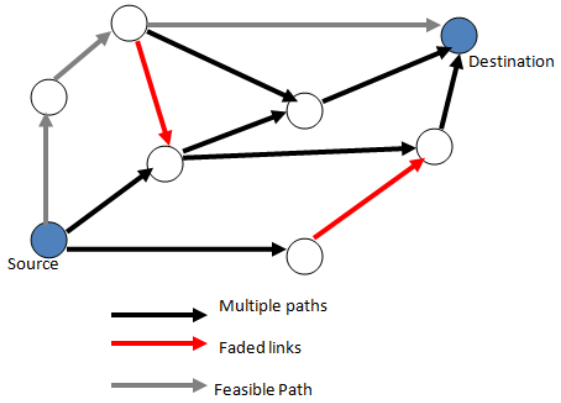

Figure 2. Handoff mechanism

B. *Handoff Table*

In order to avoid duplicate HREQ ,each node maintains a local handoff table. The field in the handoff table are source IP address, source sequence number, destination IP address, and expiration timeout. Expiration time out denote when the channel recover from fading and will be available again .It is calculated using the maximum average fading duration (afd) of all currently faded links. If any unexpired entry is found for that Ns with the same or higher source sequence number, the HREQ is dropped

C. *Forwarding the HREQ*

Any node receiving a non duplicate HREQ checks for alternative paths to *Nd*. If not, as for the case of node D, it propagates the HREQ. Otherwise, if it has one or more "good" alternative paths to the *Nd*, 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 non dormant alternative path to *Nd* is then adopted prior to the onset of link failure.

D. *Mathematical Model*

00: Channel mode (CM) = {Non fading (NF), Fading (F)}
01: NF ϵ CM
02: if Rth > ῡ , CM → NF
03: else
CM→F
04: Take Rth = .7
05: $\bar{\upsilon} = \dfrac{c\sqrt{G_0}}{Rth\ d^{\alpha/2}\ f_0\ \sqrt{2\pi(V_T{}^2+V_R{}^2\ )}}$
06: if CM = F do handoff ( )
07: else continue
08: handoff ( )
{Available free channels}
New channel ϵ {free channels}
Actual channel → new active channel

E. *CAMR Algorithm*

The simplified CAMR algorithm is given below

1. Broadcast RREQ to all the nodes
2. RREP from all the nodes with hop count, Signal strength and destination address
3. Determine the ANFD and AFD from the received signal strength
4. If AFD < Threshold,then remain in the same channel .
5. Else, search the available other channel using OFDM.
6. Update the routing table with newly available channel and broadcast this to all nodes,
7. If nearby channel is available ,then perform handoff
8. If Acknowledgement received from the destination that data reached successfully
9. Else, request retransmission

V. SIMULATION AND RESULTS

Simulations are done using Network simulator version 2.34.We used mobile-to mobile channel with Doppler frequency. This model has considered an area of 1000X 1000m^2 with a set of mobile nodes placed randomly and broadcast range is 200m.The simulation was carried out for different number of nodes using Network simulator (NS2). Simulation results are given below

A. *Average End-to End Delay*

Figure 4 shows the average end to end delay simulation results. Channel adaptive multipath routing has lower end to end delay as it performs route hand off mechanism. Simulation results has close match with theoretical concepts

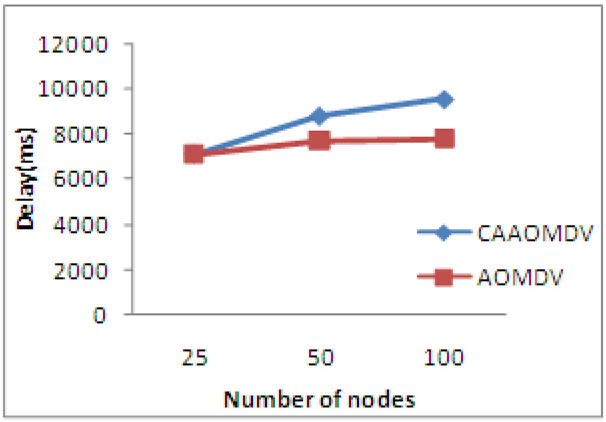

Fig.3 Average end to end delay Vs number of nodes

B. *Network Throughput*

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Simulation result for network throughput shown in figure 3. Network throughput decreases as mobility of node increases. Channel adaptive routing provide 25% improvement in throughput compared with AOMDV

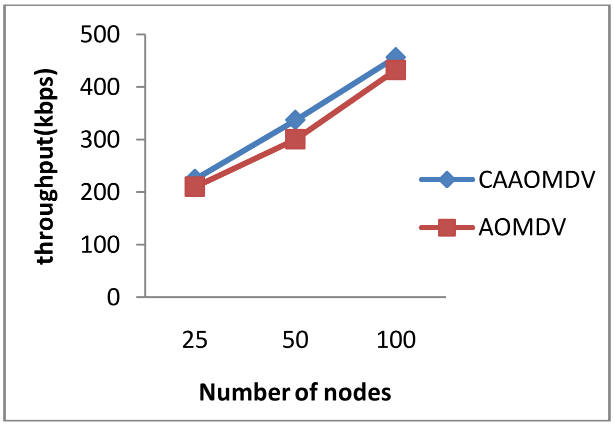

Figure 4. Throughput Vs number of nodes

VI. CONCLUSIONS

A channel adaptive multipath routing protocol that considers average non fading duration as a routing metric along with no. of hops has been proposed in this paper. By predicting the channel fading a route hand off mechanism introduced. Performance evaluation of the channel adaptive multipath protocol with popular MANET routing protocols AOMDV and AODV have done. Simulation results showed improvement in Routing control overhead, throughput and end to end delay, compared with AODV and AOMDV. Channel adaptive multipath routing does not provide security when there is a handoff between neighbour nodes, we can't make sure that there are no intruders on hackers else any other damage to the information bring transferred. So, in future this work can be extended to make a security mechanism with secure route handoff.

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