A Probabilistic Approach of Coverage prediction in Mobile Ad hoc Networks

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***Abstract* — A fundamental issue arising in mobile ad-hoc networks (MANETs) is the selection of the optimal path between any two nodes. It's very difficult to select of optimal path due to different factors affects the stability of the path. Such as mobility, coverage area, path loss, fading, energy level of the nodes and etc. In this paper we mainly focus the probabilistic approach of coverage area of the mobile nodes using gamma distribution function, and derive the simple approximate expression for coverage area. Based on the results we study the coverage area of the nodes. And we propose the new routing protocol coverage prediction Ad hoc On Demand multipath Distance vector Routing protocol (CP-AOMDV). To evaluate their performance, we are using network simulator (NS2). CP-AOMDV outperforms present protocol AOMDV. The result demonstrates that integrating coverage prediction mechanism with AOMDV is a promising way to improve performance in mobile ad hoc networks**

Keywords- AOMDV, Manets, coverage area, stability estimation, Route discover, Route maintenance

I. INTRODUCTION

A mobile ad hoc network (MANET) is a collection of mobile nodes that form a wireless network without the use of a fixed infrastructure i.e., base stations or access points or any centralized administration. The selection and maintenance of a multihop path, however, is a fundamental problem in MANETs. Node mobility, signal interference and power outages make the network topology frequently change; as a consequence, the links along a path may fail and an alternate path must be found. To avoid the degradation of the system performance, several solutions have been proposed in the literature.

We focus on the stability of a routing path, which is subject to coverage prediction caused by mobility of nodes. We define the coverage prediction of each node when the route is established until one of the links along the route becomes unavailable, while we say that a path is available at a given time instant t when all links along the path are active at time t. Then, our objective is to derive the probability of coverage till time t.

The probabilities of path duration and path availability strongly depend on the mobility pattern of the network nodes. In this paper we focus the Random Direction mobility model [1] to analyze the coverage of the nodes which was first introduced in [2, 3].

A. Our approach as Follows

We propose a simple, approximate expression for the probability of coverage under the RD model. Our findings suggest that, as the maximum coverage of the nodes. We discuss the coverage prediction based adaptive protocol CP-AOMDV, which is widely used, and compare it against existing protocol AOMDV [4].

We show how our analysis can be exploited to improve the efficiency of traffic routing in MANETs. In particular, we show how to select the optimal route in terms of coverage of the nodes in MANETs.

Finally we compare our results with the existing multipath routing protocol AOMDV and our results shows our approach outperforms in routing.

II. MOTIVATION AND RELEATED WORK

In this section we discuss why the analysis of coverage prediction in MANETs is useful and how our contribution is differ from other existing work. The problem of link and route stability has been widely addressed in the literature. Routing protocols accounting for route stability while selecting the source-destination path can be found in [5–7], just to name a few. In particular, the work in [7] considers nodes moving along nonrandom patterns and exploits some knowledge of the nodes motion to predict the path duration. Studies on link and path availability and duration are presented in [8-12]. In [8], a partially deterministic and a Brownian motion, where nodes start moving from the same location, are considered. Note that our analysis for the RD mobility is instead carried out under general initial conditions. In [9-11] nodes move with random direction and at random velocity, but both direction and velocity are kept constant over time so that the link [9, 10] and the path [11, 12] duration can be analyzed using geometric observations. Link and path availability under random mobility models that consist of a sequence of mobility epochs, each of them corresponding to a new value of node speed and direction, are studied in [13]. The work shown in [14] under the RD model, the time evolution of the node position can be described through a system of partial differential equations and that under mild conditions a (weak) solution of the these equations over a rectangular area can be found.

In general, the authors suggest the approximation to a standard distribution function without any mathematical support. In our paper we study the stability by using the coverage prediction of the nodes. After our detailed literature survey on stability estimation based on coverage prediction we found that there are inadequate papers available. In this paper, *Coverage prediction Ad-hoc On-demand Multipath Distance Vector* (CP-AOMDV) routing protocol is proposed to reactively discover and maintain stable routes adapted to radio channels in MANETs. In the proposed protocol, the link/route stability in the networks is estimated using coverage. The rest of the paper is organized as follows. In Section 3 we describe stability estimation based on the coverage prediction. In section 4 we discussed with proposed algorithm CP-AOMDV. The algorithm is implemented on NS2 and the simulation result is shown in Section 5. Section 6 gives an overview of related work and future work.

III. STABILITY ESTMATION BASED ON COVERAGE.

- Critical tasks are completed for the proposed CP-AOMDV routing protocol including:
- Proposing an approximate coverage prediction using gamma distribution function.
- The link should be selected based on the knowledge of the coverage of the nodes.
- Developing a new algorithm to discover the stable routes from source to destination based on the probabilistic approach.
- Estimate the route stability under the coverage prediction, based on the stability of the route we choose optimum path.

B. Proposed Coverage Prediction.

Assumptions and Definitions

- Since calculating the coverage area of the nodes because of the node mobility and some of the areas below the threshold signal level. In our approach we consider the circular area having the radius R. Let be desired received signal threshold level Γ. we are interested to calculate approximate probabilistic coverage area U (Γ) by using the gamma distribution function.
- Nodes move independently of each other.
- A free space propagation model is considered, i.e., the received signal only depends on its distance from the nodes.

In our problem we compute the approximate coverage area by using probability density of gamma distribution and by the power series expansion

$$\Gamma\alpha \int_0^\infty x^{\alpha-1} . e^{-x} dx \qquad (1)$$

The approximate coverage calculated by U (Γ) the following equation [15]

$$\Gamma . \frac{1}{\pi R^2} \int_0^{2\pi} \int_0^R P(RD > \gamma) . r . dr . d\theta \qquad (2)$$

$$\frac{1}{\pi R^2}\int_0^{2\pi}\int_0^{R} P(RD > x).r.dr.d\theta \qquad (3)$$

$$P(RD > \gamma)\ .\tilde{}_1\int_0^{\gamma} e^{-x}\, x^{\alpha-1} \qquad (4)$$

Since the exponential functions converge rapidly, we truncate at the fourth term.

$$.\tilde{}_1\int_0^{\gamma}[1 - \frac{x\ x^2 x^3}{1!\ 2!\ 3!}\ .\ x^{\alpha-1} \qquad (5)$$

$$.\tilde{}_1\int_0^{\gamma}[x^{\alpha-1} - x\ x^{\alpha-1} + \frac{x^2 x^{\alpha-1}}{2}\tilde{}\frac{x^3 x^{\alpha-1}}{6} \qquad (6)$$

$$P(RD > \gamma) = 1 - [\frac{\gamma^{\alpha+1}}{\alpha} - \frac{\gamma^{\alpha+1}}{\alpha+1} + \frac{\gamma^{\alpha+2}}{3(\alpha+3)} - \frac{\gamma^{\alpha+3}}{6(\alpha+3)}]$$

$$U(T) = \frac{1}{\pi R^2}1 - [\frac{\gamma^{\alpha+1}}{\alpha} - \frac{\gamma^{\alpha+1}}{\alpha+1} + \frac{\gamma^{\alpha+2}}{3(\alpha+3)} - \frac{\gamma^{\alpha+3}}{6(\alpha+3)}]\int_0^{2\pi}\int_0^{R} r.dr.d\theta$$

$$= 1 - \frac{\gamma^{\alpha+1}}{\alpha} + \frac{\gamma^{\alpha+1}}{\alpha+1} - \frac{\gamma^{\alpha+2}}{3(\alpha+3)} + \frac{\gamma^{\alpha+3}}{6(\alpha+3)} \qquad (6)$$

equation 6 represents the coverage prediction of nodes in of N hop path when nodes follow the random direction point model.

C. Estimation of Link and Route Stability

In the proposed CP-AOMDV routing protocol, the link stability LS_i for a radio link *i* is equal to the probability of the coverage prediction $PL(U(T1))$ which is less than a threshold value γ. The probability of the ink stability of the radio link is equal to LS_i given by

$$LSi = Q\left(\frac{\gamma - PL(U(T1))}{\sigma}\right) \qquad (7)$$

Where σ represents the variance of the propagation area. As to the stability of a given route, although the least stable link within a route would be the bottleneck for that route, the coverage area of the of multi-hop routes decrease with the increasing of route length [16]. To avoid selecting overlong routes, maximum hop count of routes could be restricted when selecting stable routes.

IV. THE COVERAGE PREDICTION AD HOC ON DEMAND MULTIPATH DISTANCE VECTOR ROUTING (CP-AOMDV)

The CP-AOMDV, the proposed protocol, combines the prediction of coverage and stability estimation methods, which can enhance data throughput and route lifetime for MANETs. The CP-AOMDV routing protocol, which is composed of three major processes

- *Coverage prediction & stability estimation*
- *Route Discovery*
- *Route Maintenance.*

The formats of control messages and routing table in these processes are mainly modified from the existing AOMDV routing protocol.

D. Coverage prediction & stability estimation

Our proposed approach we mainly focusing the coverage prediction and stability estimation process of all the available paths. In order to keep track of the coverage area and link stabilities between a given node and its neighbors, each node periodically broadcasts *Hello message* (HELLO) including the location of the broadcasting node toward its neighbor hoods. The time interval between two neighboring HELLOs needs to carefully choose based on the time difference we obtain the following steps.

- *Estimating the distance between the nodes:* In our approach we estimate the distance between the nodes by using time interval between the HELLO messages.
- *Calculating the probabilistic coverage area and stability estimation:* Based on the time interval the receiving node evaluates the approximate coverage area by using the simple expression 6. And the stability of the each route calculates by using the expression 7.
- Storing the values: Our proposed approach we modify the routing the routing table and record the estimations.

E. Route discovery

The route discovery process executes the proposed routing protocol to discover the stable routes with the maximum coverage and largest stability of the different available paths. The source node initiates this process to find all available routes through RREQs, and the destination node selects a stable route from these available routes. In our proposed algorithm route discovery process explained by the following steps.

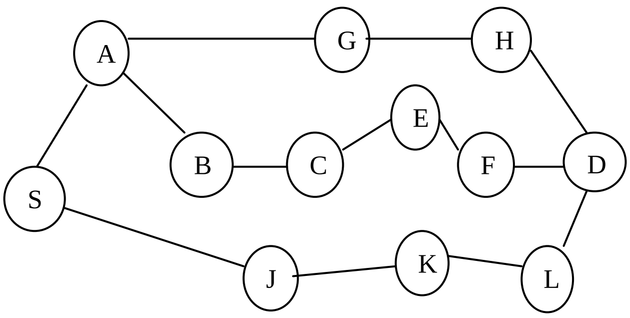

Figure1. Multiple routes from source to destination.

- Source node S starts to find stable routes by broadcasting route request messages (RREQs). The source node S creating RREQ message and broadcast to all its neighboring nodes. Figure () shows the RREQ format of our existing protocol but with an additional coverage prediction and stability estimation field included.

<table>
<tr><td>Type</td><td>Reserved</td><td>Hop Count</td><td>$P_L(U(T_i))$</td><td>LS_i</td></tr>
<tr><td colspan="5">Broadcast ID</td></tr>
<tr><td colspan="5">Destination IP address</td></tr>
<tr><td colspan="5">Destination Sequence Number</td></tr>
<tr><td colspan="5">Source IP address</td></tr>
<tr><td colspan="5">Source Sequence Number</td></tr>
<tr><td colspan="5">Request Time</td></tr>
</table>

Figure 2. CP-AOMDV RREQ message format

- After an intermediate node receives an RREQ from its neighbor, it rebroadcasts the RREQ if necessary. During a route discovery process, intermediate nodes might receive multiple RREQs. However, it does not rebroadcast all received RREQs but only the RREQ attached with higher coverage area and larger route stability comparing to prior received RREQs in order to reduce control overhead.
- Intermediate nodes compare the coverage area of the each node and calculate the stability of available routes from the source to the intermediate node by eqn 6 & 7. When the intermediate node decides to rebroadcast a specified RREQ, it replaces the values of the $PL(U(\Gamma i))$ and LSi in field of RREQ.
- Destination node D selects the multiple routes such as S-A-G-H-D, S-A-B-C-E-F-D, S-J-K-L-D with the maximum coverage and stability with multiple RREQs continually arriving. Then, it creates a Route Reply (RREP) message for responding RREQ. In our proposed routing protocol destination node selects multiple paths, in these multiple paths ordered based on the maximum coverage and higher stability.
- The stable route with maximum route stability is discovered by the specified RREP and the forward entries of route tables from source node through intermediate nodes to the destination are set up by replying RREP. The node accepts the selected route and start to sends data.

F. Route Maintenance:

The Mobile Ad hoc networks have time varying topology so the coverage prediction and the stability of routes would change with time. In order to react the change of topology a *Route Maintenance* process is proposed. Regarding to its frequent changing topology we evaluate the stable routes continuously. If any of the route is unstable due to it poor coverage, the source will automatically select another route from available paths. The route maintenance in our proposed algorithm involves the following steps.

- Source node S periodically sends the coverage prediction message to the destination node D. In figure. (1) the of available paths are S-A-G-H-D, S-A-B-C-E-F-D, S-J-K-L-D The coverage prediction message forward all the available paths in network.
- When the intermediate node receives the coverage prediction message it recalculate the estimations based on the coverage it may choose next hop.
- The destination node D determines whether the connecting route is still stable or not based on its coverage prediction. In the destination node, periodically update the coverage probability through the coverage prediction message.

When the destination node D identifies of weak coverage area it informs to the source through the RREP, then the source selects another path.

V. SIMULATION RESULTS AND ANALYSIS

We have implemented CP-AOMDV using the Network Simulator Ns-2 [17] with the CMU Monarch wireless extensions [18]. We have compared the performance of AOMDV routing protocols.

A. Simulation Environment

We have built a simulation model to support real time data transmission which consists of 100 wireless nodes to form ad hoc network within the 1000m by 1000m area. The nodes were equipped with Omni-directional antennas. The simulation time was set to 100 seconds, with a CBR connection established among the nodes. To test the performance of our proposed routing protocol with other protocol in MMANETs environment we used the packet size is 500 bytes and the raw channel bandwidth is 2 Mbps.

B. Performance Metrics

We have chosen the following metrics to evaluate the performance of routing protocols.

Packet delivery Ratio: The ratio between the number of packets received by the UDP sink at the final destination and the number of packets originated by the sources. It is a measure of efficiency of the protocol.

Packet loss (%): The percentage of data packets dropped in the network from source to destination. it's a important measure of efficiency of protocol.

Average End-to-End Delay of data packets: this includes all possible delays. It is very important for any application where data is processed online.

Normalized routing overhead: Normalized routing control overhead is the ratio of number of routing control packets to delivered data packets, A desirable routing protocol should offer a high packet delivery ratio, small end-to-end delay, small routing overhead and low power consumption.

C. Varying connections

Now we vary the number of CBR connections while fixing the mean speed at 5 m/s and the offered load at 2 Mbps. Figure.(3-6) shows various performance metrics as a function of the number of connections. Based on our results the performance of our proposed approach CP-AOMDV compared with the existing protocol AOMDV, both protocols degrades their performance with increasing number of connections. In smaller number of connections, the difference between CP-AOMDV and AOMDV is not very noticeable. However, with increase in the number of connections, CP-AOMDV perform much 40% better relatively

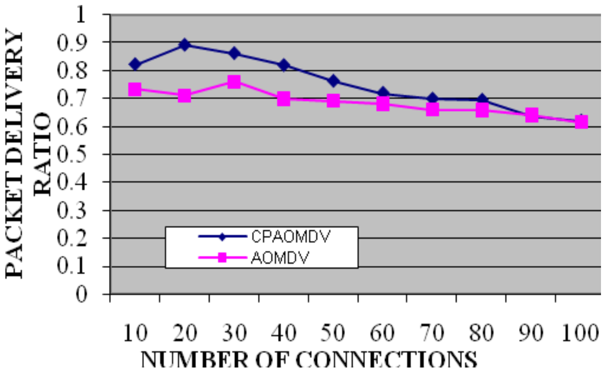

Figure3. Packet delivery ratio comparison between CP-AOMDV and AOMDV with varying number of connections

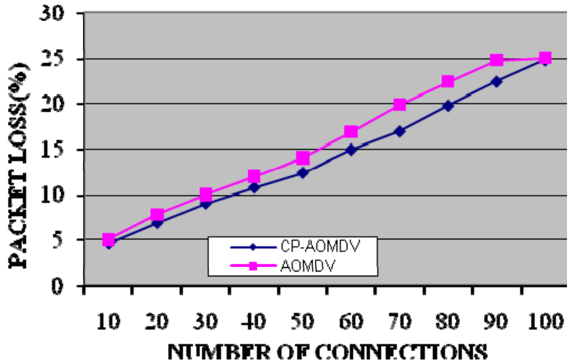

Figure 4. Packet loss percentage comparison between CP-AOMDV and AOMDV with varying number of connections

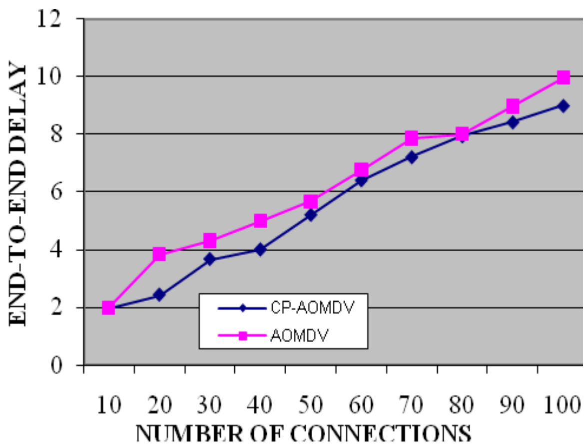

Figure 5. Packet loss percentage comparison between CP-AOMDV and AOMDV with varying number of connections

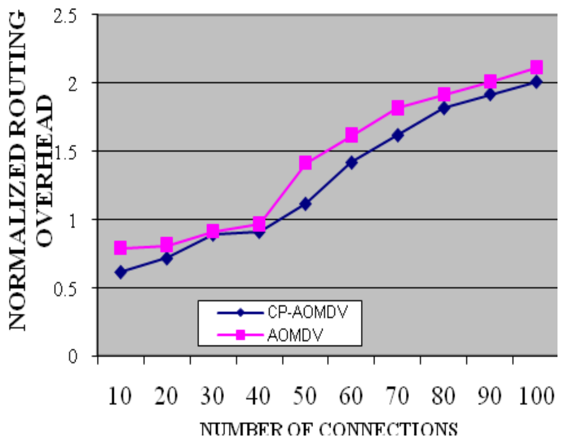

Figure 6. Normalize routing control overhead comparison between CP-AOMDV and AOMDV with varying number of connections

D. Varying Traffic Load

To evaluate network traffic load performance we fixed maximum speed at 1 m/s, varying source packet rate from 5 to 40 packets/s. All other parameters were as in the previous section. Figure. (6&7) shows variation of packet delivery ratio (PDR) with increasing packet rate and variation of average end-to-end delay with increasing packet rate.

Both protocols have decreased PDR with increasing packet rate. For low traffic loads, increased packet rate and the average end-to-end delay. The decrease of average end-to-end delay occurs because, at higher packet rate, more packets are dropped due to congestion. For both PDR and average end-to-end delay, CP-AOMDV outperforms AOMDV.

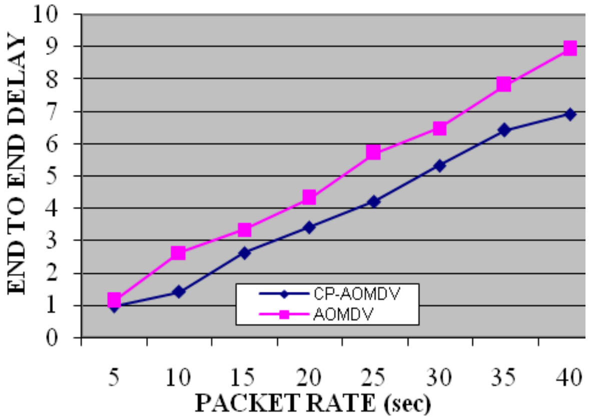

Figure 7. End-to-End delay comparison between CP- AOMDV and AOMDV with varying traffic loads

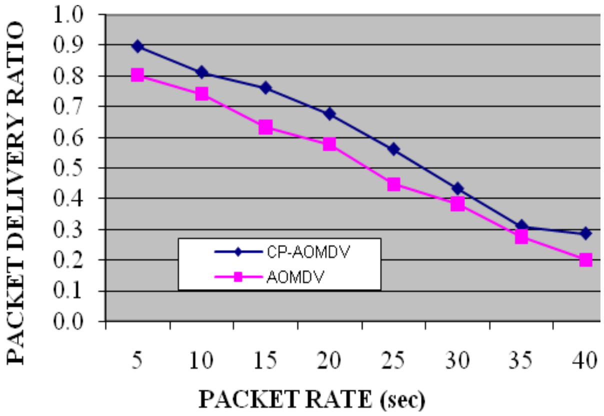

Figure 8. Packet delivery ratio comparison between CP-AOMDV and AOMDV with varying traffic loads.

E. Varying Node Mobility

We now compare AOMDV and CP-AOMDV with respect to node mobility. The simulated network area is 2200 m × 600 m, 2 Mb/s channel bandwidth, 100s running time, 100 uniformly distributed nodes moving at maximum speed in random directions with 20 connections. Maximum node speed was increased from 1 m/s to 10 m/s. The 512 byte CBR sources were fixed at 5 pack/sec.

- Throughput

Simulation results for network throughput are shown in Figure.(8).Throughput decreases with increased node mobility, with CP-AOMDV outperforming AOMDV, particularly in the mid-range mobilities, with significant performance increases realized.

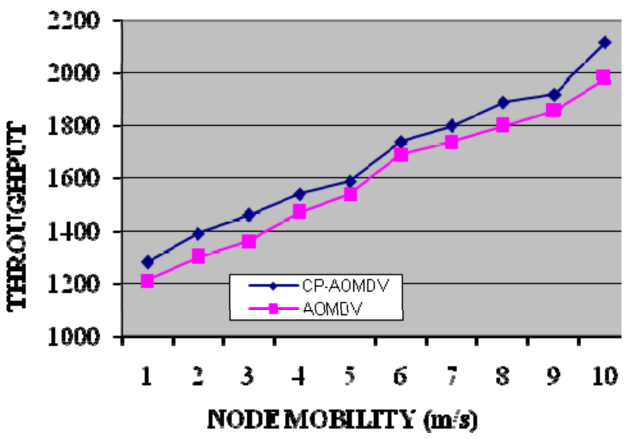

Figure 9. Throughput comparison between CP-AOMDV and AOMDV with varying mobility loads.

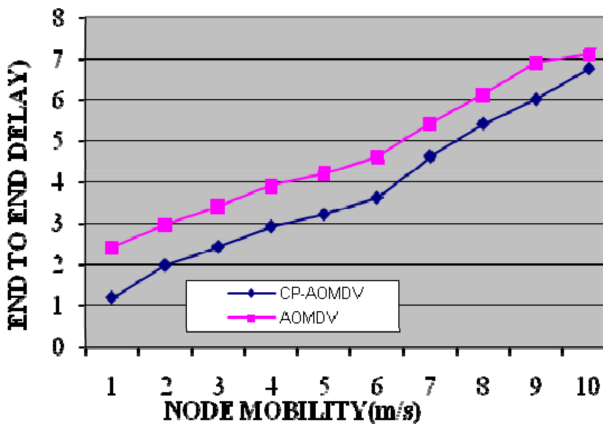

Figure 10.End-to-End delay comparison between CP-AOMDV and AOMDV with varying mobility loads

At extreme mobilities the throughput performances vary less and the advantages of CP-AOMDV 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 CP-AOMDV are less. At high mobilities channel and path characteristics change rapidly, again mitigating handoff scheme advantages, and increasing signal strength prediction efficacy.

- End - to – End delay

Figure 9. Shows average packet transmission delay results. CP-AOMDV outperforms AOMDV, with 24% and 28% improvements at a velocity of 4 m/s, for the smaller and larger networks, respectively. At extreme mobilities the performances converge

VI. CONCLUSION

We have proposed CP-AOMDV, Coverage prediction Adaptive Routing in multipath on Demand Mobile Ad Hoc Networks. This is because CP-AOMDV tries to prevent link failures by estimating the routes using prediction of the coverage area. The key factor in CP-AOMDV design is to calculate the probabilistic coverage area at each node. The mechanism is taking care of stability of the available paths. Every node is always aware of present available requirements. If poor coverage occurs at any point of time due to lack of resources, the intermediate node, inform about its status to previous node to take appropriate action. In CP-AOMDV the routing overhead was reduced compared with AOMDV routing protocol. In CP-AOMDV, all the intermediate nodes always update the coverage information through the coverage prediction message. Our ns-2-based simulation has confirmed the advantages of CP-AOMDV and demonstrated a significant routing overhead and power consumption improvement over AOMDV.

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