Efficient Stochastic Dijkstra Protocol For Mobile Ad-Hoc Network With Quality of Service

D. K. Kothari and Prof. Dilip Patel

***Abstract*—Mobile Ad Hoc Networks (MANET) consists of a group of mobile nodes, which autonomously establish connectivity via multi - hop wireless communications. This Paper present a new protocol model, a stochastic Dijkstra Routing (SDR), for MANET. To effectively route the traffic for ever changing nodes in MANET with a constrains of less overhead and best quality end to end packet delivery ratio, a novel approach SDR will be presented which involves the technique of evenly or equally distribution of traffic through random variable for a link metrics to provide sort of load balancing. In MANET, SDR protocol shows good agreement for above mention constrains compares to AODV (Ad hoc On demand Distance Vector) routing protocols.**

Simulation study compared SDR with AODV and the result show that SDR is able to achieve better or comparable results at lower load and better results at higher traffic loads as compared to AODV. In addition, SDR achieves this performance with better delay and improved traffic characteristics along with significantly lower consumption of MAC layer resources and remain consistence in the confidence interval. So, the proposed SDR scheme in this paper promises for QoS (Quality of service) in MANET.

***Index Terms*—MANET, Load Balancing, SDR and AODV**

I. Introduction

AD -hoc networking is not a new concept. As a technology for dynamic wireless networks, it has been deployed in military since 1970s. Commercial interest in such network has recently grown due to the advances in wireless communication. A new working group for MANET has been formed within the Internet Engineering Task Force [2], aiming to investigate and developed candidate standard Internet routing support for mobile, wireless IP autonomous segments and develops a framework for running IP based protocols in Ad hoc networks. In MANET, all nodes are mobile, and they communicate with each other via wireless connections. There is no fixed infrastructure. All nodes are equal and there is no centralized control or overview. There are no designated routers: all nodes can serves as routers for each other and data packet are forwarded from node to node in a multi fashion.

Routing is the task of directing data flow from source to destination maximizing network performance. This is particularly difficult in MANET. Due to the mobility of the nodes, the topology of the network changes constantly, those paths which were initially efficient later on they become infeasible. This means routing information should be updated more regularly than in wired networks, so that in principal more routing control packets are needed. However, this is a problem in MANET, since the bandwidth of the wireless medium is very limited, and the medium is shared: nodes can only send or receive data if no other node is sending in their neighborhood. The access controlled by the protocols at the medium access control layer, such as ANSI/IEEE 802.11

DCF [7] (Mostly use in MANET), which in their turn create extra burden of overhead.

Numerous Protocols have been proposed and implemented for MANET routing. A details performance comparison is given in [1]. For routing overhead and packet delivery ratio AODV performance better than other protocols. Also, it seems easier to compare the SDR parameters with on demand routing protocol AODV in terms of network performance. So, in this paper only AODV is chosen for comparison with SDR.

This paper present, a novel approach for efficient routing in MANET, which is SDR algorithm, in which link metrics are treated as random variables. Given a realization of these metrics a shortest path algorithm such as Dijkstra algorithm provides a tree of shortest paths from a source to all other nodes in the networks. This tree depends on the values of the link metrics. Early experiments showed that the distribution of the link metrics strongly influenced the frequency distribution of these shortest paths. This paper clearly makes this idea to reality by successfully modeling this frequency distribution and this work comes under generic heading of ”StochasticDijkstra” routing concept.

The remainder of this paper is organized as follow- In the next section II, AODV protocol working in details. The section III describe in details the components of SDR Protocol follow it with brief a specifics of implementation model in section IV -A and the simulation results and comparison with AODV Protocol in section IV -B. I conclude in section V with a brief overview of my future research plan.

II. AD HOC ON DEMAND DISTANCE VECTOR (AODV)

AODV routing protocols is meant for use by ever changing nodes to route the traffic in a proper manner

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in MANET. It provides low processing time and storage overhead, less utilization of network resources, multi hop routing mechanism between source to destination in an ever demanding loop free fashion with a dynamic self-starting capacity. One distinguishing feature of AODV is its use of a destination sequence number to determine freshness of routing information and to prevent routing loops. Destination sequence number and loop freedom features of AODV solve the classical problem of "counting to infinity" in distance vector protocols and reduce the complexity of implementation which results in easy to program.

Route Request (RREQs) and Route Replies (RREPs) are the two message types defined by AODV. Theses message type are handed by UDP with IP headed processing application. Whenever end-to-end route is present, AODV protocol does not play any role for route discovery. When a route to a new destination is needed. AODV's node uses a broadcast RREQ to satisfy the particular destination. Once the fresh route determined through destination itself or intermediate node, the same fresh route made available by unicasting a RREP back to the source of the RREQ. Also HELLO message indicates that the node is remaining in activation without any change in MANET. Since AODV is as routing protocols it deals with route table management. AODV have the number of fields exist in each route table entry and they are Destination IP address, destination sequence number, Hop count, Next Hop Lifetime.[2]

A. Keeping Route Updates

An important feature of AODV is the maintenance of timer-based state in each node regarding utilization of individual routing table entries. A routing table entry is expired if not used recently. A set of predecessor nodes is maintained for each routing table entry, indicating the set of neighboring nodes, which use the entry to route the packets. These nodes are notified with RERR packets when the next-hop link fails. Each predecessor nodes, in turn, forwards the RERR to its own set of predecessors, thus effectively erasing all routes using the broken link. In contrasts to DSR (), RERR packets in AODV are intended to inform all sources using a link when a failure occurs.

When a node receives a broadcast RREQ, it first checks to see whether it has received a RREQ with the same source IP address field within the last BCAST_ID_SAVE milliseconds. If such a RREQ has been received, the nodes silently discard the newly received RREQ.

If, on the other hand, the node has a route for the destination, it compares the destination sequence number for that route with the destination sequence number field of the incoming RREQ [2].

B. Mechanism of Route Replies

Once a node receive a route request for particular destination and have a fresh route to fulfill that request, the source node generate a RREP message and put it back to same IP address field of the received RREQ. Also source node copy its destination sequence number from the entry in its routing table.

In RREP generating process, the nodes creates or updates an entry in its routing table for the source IP address. The expiration time for the route table entry is set to the current time plus ACTIVE_ROUTE_TIMEOUT seconds.

C. Hello Message and Failure

All nodes generates a "hello" message once every HELLO_INTERVAL milliseconds. The whole process of "initiating triggered route replies "can be access by [2].

Three consecutive failures to receive a hello message from a neighbor indicate that the link is down or broken. Alternatively, the node can use any physical layer or link layer methods to detect link failure with nodes it has considered as neighbor. In both the cases, the node should assume that the active connection with neighbor has been broken and need replacement [5].

III. STOCHASTICDIJKSTRA ROUTING PROTOCOL (SDR)

The SDR protocol provides a scalable effective load balancing for traffic distribution over a MANET and reduced overhead to improved network performance in worst case scenario. The novel feature of SDR is that the choice of a shortest path from origin to destination clearly depends on the value of the link metrics, which controlled by random variable's distribution through stochastic process. This paper shows that, the choice of link metrics distribution strongly influences the probability of a given path being selected as the shortest path.

A. The MANET Environment

A fixed routing strategy does not work in a MANET because the nodes frequently move. Signals sent from one node to another are subject to varying amounts of interference, due to the presence of buildings or other obstructions between the nodes. Also, signal strength depends on the distance between the source node S and the receiving node A. In turn node A may relay the message to another node B and so on. Eventually the message arrives at the destination node D.

The distance between mobile nodes is used in models of attenuation of radio signals between antennae close to ground level. Typically, the signal strength E satisfies a relationship of the form

$$E \propto \begin{cases} 1/r^2 & for \quad r < r_c \\ 1/r^4 & for \quad r \geq r_c \end{cases} \tag{1}$$

The crossover point r_c is the reference distance. Details for these models are available in [3]. Typical values of r_c are 100 meters for outdoor scenarios and one meter for indoor scenarios when the microwave frequencies are in the 1-2 GHz band [1],[3]. The signal to noise ratio (interference) may also be modeled in a similar fashion.

In this context the SDR is performing the task of modeling the distribution of the separation between mobile nodes. If the distance apart were less than a certain limit, a link would exist between those two the two nodes. It is possible to derive a probability distribution for the distribution between two points in a planar region but this does not seem to be useful. Instead SDR protocol will specify certain limits as follows.

Consider two mobile nodes A and B, which are separated by a distance of $r = r(t_0)$ meters at time t_0 . The SDR scheme specifies a threshold distance r_{thr} to signal when a change of path may be imminent. In general, requirement is that $0 < r < r_{thr}$. Suppose that . Considering that a timer operates at intervals of size δt . At time t_0 let the speed of B relative to A be $\nu = \nu(t_0)$ in a direction directly away from or towards A. Only this component of velocity is relevant. We can write,

$$\nu(t_0 + \delta t) \approx r(t_0) + \nu(t_0)\delta t \quad (2)$$

Clearly, Protocols must have $\nu(t_0 + \delta t) \leq r_c$ if, $r(t_0) \leq r_{thr}$ then routing mechanism need $\nu(t_0)\delta t \leq r_c - r_{thr}$

$$\delta t \leq \frac{r_c - r_{thr}}{\nu(t_0)}$$

The faster the nodes move around, the more frequent the routing updates have to be. This increases the routing overheads as the simulations in [1] show. "The frequency of updates and hence the routing overheads will be inversely proportional to the speed of the moving nodes."

B. SDR Routing Strategy

Let $n = n(t_0)$ be the current number of nodes in the MANET at time t_0. I write n in this fashion since nodes may join and leave a MANET during its lifetime. Similarly, let $m = m(t_0)$ be the number of links currently in use.

$$m \leq \frac{n(n-1)}{2}$$

These links will exist if certain minimal conditions on signal strength and/or interference are satisfied. Also SDR wish to minimise the overheads when updating the routes. Hence, this paper prefer to avoid running the Dijkstra or Bellman-Ford algorithms regularly as few shortest paths are likely to change after one or two updates. Indeed the running time of Dijkstra's algorithm $O(n^2)$ is while the Bellman-Ford algorithm requires O(mn) steps. At worse this uses $O(n^3)$ steps. These algorithms would also use a significant amount of battery power.

SDR maintain efficiently kind of caching mechanism or a routing table, just like other MANET proposed routing protocols. In the following discussion, let S be a source node and let D be a destination node. Route discovery is used to obtain a source route to some desired destination D. To do this SDR protocol broadcasts a Route Request packet that is flooded throughout the network in a controlled manner. The SDR implementation insures a supply of routes that is large enough to allow multiple routes from S to D. In addition, SDR take care that this supply of potential routes should not be too large because it results in undesirable excessive overheads in route selection.

This paper take the advantage of the directional nature of a MANET topology by implementing a version of selective flooding, in which node only send packets in directions within 45^o, say, of the approximate direction from S to D. This idea is in [4]. A counter inserted in the header of each flooding packet and decremented by 1 at each hop. When the counter in the flooding packet reaches zero, it is discarded. This hop counter can be initialized to the known or estimated diameter of the relevant part of the MANET. To keep the flooding within (safe) limits, The SDR protocol strategy insists that the number of potential routes found from S to D be no more than a preset constant k. Potential routes from S to D in excess of the cutoff k can be discarded.

At the initial phase of a MANET, there will be few or no known paths so the task of route discovery would be largely carried out with a flooding procedure. Subsequently, the caches would be used as the primary source of information for new routes. During the lifetime of the MANET, some old routes from S to D will cease to work because a pair of adjacent nodes on that route has moved so far apart that the link is deemed to be broken, due to signal attenuation or interference. In that case, that route is now useless and should be discarded. Of course, it may be recreated by a future Route Request. Also new Route Requests should be sent only if a cache becomes empty or has only very few entries.

C. SDR Implementation Model

The novel idea of SDR is to use of a stochastic nature to achieve a form of load balancing in which a number of alternative routes are set up. These ideas were originally developed in the context of a stable topology where the long-term distribution of routing metrics is available in principle. In the MANET context, all metrics may be assumed to be in a permanent state of flux so these distributions are of no use. Instead, the SDR prefer a simple method of routing packets from S to D that does not rely on detailed knowledge of probability distributions for link metrics.

Let us assume that there are r paths $P_1, ..., P_r$ from S to D currently in the cache. Let us assign probabilities $p_1, ..., p_r$, respectively to these r paths. Clearly we have $P_1 + ... + P_r = 1$. Define $Q_1 = p_1$ and $Q_j = Q_{j-1} + p_j$ for $2 \leq j \leq r$. The simplest approach is to assign equal probabilities to these paths. This would not distinguish between paths on the basis of hop count so that longer paths are just as likely to be chosen as shorter paths However, it may be argued that longer paths are less likely to be maintained because of the motion of the nodes. Perhaps a better alternative would be to make the probability p_i of selecting P_i inversely proportional to its hop count.

The SDR mechanism applies the following rule to incoming packets. For every arrival we generate a random number from a uniform distribution on [0, 1], say u. Because of the short life expectancy of a particular route, the SDR scheme does not need to insist on a long period for our random number generator. A standard congruential random number generator may be sufficient for our needs. Thus we assign this incoming packet to path j chosen has a slightly smaller metric than the other. If where $Q_{j-1} < u \leq Q_j$. Hence the route chosen for the packet is determined by the random number chosen.

The effect of this the SDR strategy is to distribute the traffic load over a number of alternate routes. At the same it keeps up to date with the currently available routes. This paper is tested these ideas via MANET traffic simulations and result shows achievement of effective load balancing improves exclusively, the network performance compare to AODV or other traffic engineering ideas. See the section entitled Simulation and Results for details comparison. In implementation model, the TCP/IP Performance has been assumed to properly modified* for MANET traffic.

D. Some Computing Aspects

It remains to consider certain computing aspects of a possible implementation of the Proposed SDR algorithm. For reasons of efficiency, the SDR scheme prefers to avoid floating point arithmetic. Firstly, the algorithms for generating uniform random numbers are quite fast. It is a simple step to scale up the random numbers and the cut-off points Q_j by a factor of 2^k for some integer k > 0 via bit shifting. If k is close to 10, say, the error in truncating the fractional part of $s^j Q_j$ can be safely neglected. Thus better to assign a random number l according to the value of $2^k u$ for the uniform random number u as it will satisfy $2^k Q_j \leq 2^k < 2^k Q_{j-1}$ for some positive integer j. The values of the Q_j need only be calculated at the initialisation stage.

E. Load Balance & Link Failure Treatment

The major rationale for stochasticDijkstra routing (SDR) is the aim of load balancing. It is easy to give examples where all the traffic takes just one of two possible routes for the reason that the path actually chosen has a slightly smaller metric than the other. If a smaller metric, then all traffic would go the other way. This plane led to the problem of load flap. To avoid this, the SDR split the traffic so that the balance is as even as possible. Consider the example of delay, which is an example of an additive metric. In this scenario, it possible to use mean delay as metrics.
However, delay is a random variable as it is influenced by traffic loading, itself another random variable. Queueing theory shows that in the M/M/1 case the queueing delay W satisfies $W \propto \frac{1}{1-\rho}$ where ρ is the link utilisation. Of course, $0 \leq \rho < 1$.

For a traffic demand where there are r alternative paths $P_1, P_2, ..., P_r$ with utilisations $\rho_1, \rho_2, ..., \rho_r$ For a traffic demand where there are r alternative paths with utilisations respectively, the idea is to balance the loads so that the delays are approximately the same for each path Then need to split the flows so that the desired load balance is obtained. I wish to assign every packet to one of these paths in a pseudorandom fashion with the required probabilities. Better still, I would prefer that every packet in a given microflow went the same way. respectively, the idea is to balance the loads so that the delays are approximately the same for each path Then need to split the flows so that the desired load balance is obtained. I wish to assign every packet to one of these paths in a pseudorandom fashion with the required probabilities. Better still, I would prefer that every packet in a given microflow went the same way.

SDR approach could be easily understood by the example-1 in which Path 1 with utilisation 205% gets 70% of the traffic, while Path 2 with utilisation 305% gets the remaining 30% of the traffic. This is exactly the type of load balancing that required. If the utilisation changes significantly, it would preferable to change the splitting ratios accordingly.

MANET traffic has to rely on other protocols such as a suitably modified version of TCP/IP to ensure that packets arrive in the correct order. Some discussion is available in [6]. Indeed, the constant movement of nodes in a MANET will ensure that routes are changing and so packets are likely to get out of order. Existing MANET protocols are already subject to this problem so a protocol such as TCP/IP is needed to order the packets in their correct sequence.

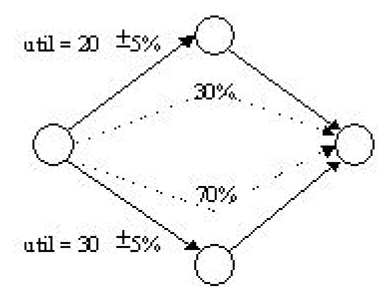

Fig. 1. Illustration of Load Balancing in MANET

The question can be raised, what happens if a link fails. Suppose that we have four paths P_1, P_2, P_3, P_4 with traffic proportions 40%, 30%, 20% and 10% respectively. Suppose that P_2 fails (see fig. 2). How are we to reroute the 30% of traffic that was supposed to take route P_2? If we simply distribute this load pro rata, we would get the proportion 57.14%: 28.57%: 14.29%. This might significantly increase the delay on P_1. An alternative approach that SDR scheme uses is to distribute this 30% of traffic evenly. This would lead to the proportion 50%: 30%: 20%, this spreads the traffic more evenly. Other ideas for recovering from link failures are worth investigating. They should be fairly simple, as the routers should not have to incur substantial overheads in trying to reroute traffic that would otherwise have used the failed link.

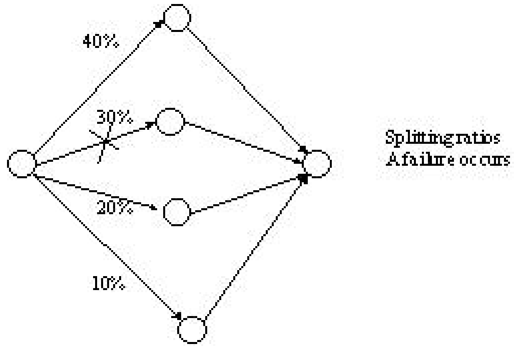

Fig. 2. Illustration of link failure scenario in MANET

IV. SIMULATION RESULTS

The Proposed SDR protocol simulated in QualNet (Version 4.0), and the performance of SDR was compared with a Popular routing protocol AODV, for the same network and load characteristics and the same version of QualNet. AODV has been chosen to compare with SDR because its shown performs well in a vast majority of MANET scenario.

A. Simulation & Network Model

The experiment has been carried out, in which study has been made for the performance of SDR and AODV with increasing traffic. In experiment , variation has been introduce for source-destination pairs. In experiment, 45 nodes were uniformaly dustrubuted initially in a terrain of 600m*600m and moved as per the random (waypoint) model with a inimum speed of 0.001 m/s ,maximum speed of 20m/s, with a pausetime of 12seconds. The link bandwidth was 1.5 to 2 Mbps.The simulation used a two- ray pathloss model and no propagation fading model wsa assumed. The application used was CBR(Costant Bit Rate) ,and both source and destination were pairwise distinct and chosen randomly. The start time for all source is 45s and end time of all correspoing destination 270s. The Study has been made for following end -to-end and network-wide characteristics:

1) End-to-end Packets delivery capacity: It measured as ratio of the total number of packets which were sent from the sources to the total number of packets that were received at the destinations, and averaged over the number of source-destination pairs.
2) End-to-end delay: Measured as the average delay in sending packets from source to destination and averaged over

B. Results Comparison

The comparison has been made for AODV and SDR* to verify the MANET performance. From Fig. 3 it can be seen that SDR is performing slightly better than AODV in very low loads (The points for 10, 11, and 12 source-destination pairs) and SDR performs better than AODV in higher loads. This indicates that the degradation in performance of AODV is rapid and drastic, while for SDR, it is more gradual and stable. In addition, from fig. 4, it can be clearly understood that SDR delivers these packets at lower delay for a low loads along with an increasingly lower delay at higher loads compare to AODV.

V. CONCLUSION AND FUTURE WORK

This paper describes the design, implementation and performance of a new routing protocol, SDR, for MANET. Simulation has been performed and the result shows that SDR performs better than AODV for end-to-end packets delivery capacity and end-to-end delay. Regardless, a result clearly indicates that, variance of the observed values (width of confidence interval) is always lower in SDR. It has been observed that the load balancing mechanism of SDR enables.

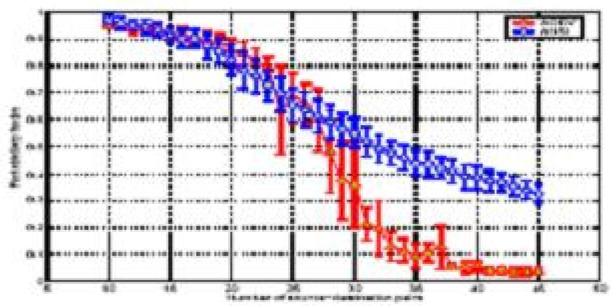

Fig. 3. Simulated output of Average Packets Delivery Capacity Experiment Represents Packet Delivery Fraction on Vertical axis and Number of Source to destination Pairs on horizontal axis.

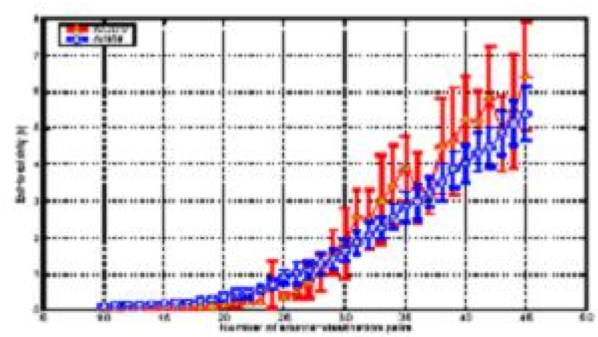

Fig. 4. Simulated output of Average End-to-end delay Experiment Represents End to End Delay on Vertical axis and Number of Source to destination Pairs on horizontal axis.

effective control over the activity of almost all the nodes in MANET, and thus more responsive to topological fluctuations as compared to AODV. Hence SDR drastically reduces the network resource utilization by generating lower number of RERRs. So, the quality of services constraints in MANET for providing value added service could be easily satisfied by SDR algorithm. The SDR approach could be applied for traffic with QoS (Quality of services) requirements to match the higher order SLA (service level agreement) in MANET. Probably, this could be achieved by application of Best Effort (BE) traffic to have proper load balance in MANET. I am currently analyzing 'simulation work' for this proposed scheme to see whether these idea work well in practice. In it, i have planned to assign separate random number for the more commonly selected paths and use only a few of the rarely chosen paths for routing in mobile ad hoc networks.

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