DLFR: Taming stochastic behavior of Global Networks.

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Summary

Mobile ad hoc networks (MANET) are difficult to support real time services efficiently because of their unpredictable and frequent topology changes. One of the important concerns is the reliability of routes. Although finding optimal path for MANET is incompletely defined problem and specific routing protocols trade off efficiency for the reliability. In particular, typical shortest path estimating routing protocols use redundant paths to achieve reliability. In this paper, we propose a new routing protocol for estimating the shortest path in such open networks by introducing a statistical metric for "the reliable routing path selection".

Keywords:

MANET (Mobile Ad Hoc Network), MD (Mobile Device), FT (Forwarding Time), CFT (Cumulative Forwarding Time), DLFR (Dynamic Link Forward Routing).

1. Introduction

A Mobile Ad-hoc Network (MANET) is aggregation of Mobile Devices (MDs) that are able to connect on a wireless medium forming a dynamic network, routing traffic through multi-hop-paths in order to ensure connectivity between any two devices in the network. The ability for the network topology to change over time as links in the network appear and disappear is embedded in the stochastic behavior of such networks. In order to enable communication between any two devices in such a MANET, a routing protocol is employed. The abstract task of the routing protocol is to discover the ever changing topology to ensure that each device is able to acquire a recent image of the ad hoc topology for constructing routes [2]. Mobility is indeed a serious factor *contributing* to the performance of MANET. Stochastic limits the capacity to maintain a connection, or to guaranty a quality of service between two communicating devices. Rest of the paper is as follows. Section 2 discusses impact of the stochastic in building challenges for MANET. Section 3 summarizes existing routing protocols for MANET. Section 4 gives the design of stochastic model for Dynamic Link Forward Routing (DLFR) protocol. We present implementation and performance evaluation of DLFR in Section 5 and finally article is concluded in Section 7.

2. Stochastic governing MANET challenges.

Already wireless medium is blamed of inefficient communication due to interference and poor signals and at the top of it the random mobility of open networks adds to the existing challenges of wireless communication. The unpredictability encircling such networks brings a spectrum of challenges along with [1].

Routing: Since the topology of the network is constantly changing, the issue of routing packets between any pair of MDs becomes a challenging task [3]. Reactive routing is more promising relative to proactive. Multicast routing is another challenge because the multicast tree is no longer static due to the stochastic movement of devices within the network. Routes between devices may potentially contain multiple hops, which is more complex than the single hop communication.

Security: MANET in their current incarnation is very fragile. The protocols that are central to MANET construction assume benign participants. Major research challenge is the *system itself that doesn't (or barely) works, how can it work with a security system that is blocking connections?*[4]. The MANET is naturally bandwidth-limited so Secure protocols used on the Internet (e.g., SSL) are of questionable use. Also MANET tends to use UDP instead of TCP and most Internet security protocols are TCP oriented. MANET environment is too dynamic for current security options.

Reliabilty: Wireless link characteristics introduce reliability problems, because of the limited wireless transmission range, the broadcast nature of the wireless medium (e.g. hidden terminal problem), mobility-induced packet losses, and data transmission errors.

Quality Of Service (QOS): Providing different quality of service levels in an environment ruled by nomadic nodes is the nastiest challenge. The inherent stochastic feature of communications quality in a MANET makes it difficult to offer fixed guarantees on the services offered to a device. An adaptive QoS is required over the traditional resource reservation to support the multimedia services.

Power Consumption: For most of the light-weight mobile terminals, the communication-related functions should be optimized for lean power consumption. Conservation of power and power-aware routing must be taken into consideration.

Internetworking: In addition to the communication within an ad hoc network, internetworking between MANET and fixed networks (mainly IP based) is often expected in many cases. The coexistence of routing protocols in such an environment is a challenge for the harmonious mobility management.

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3. Routing Background.

As described in the previous section, open networks have always been subject to unpredictable changes. Ad hoc networks also had to develop efficient routing protocols to instantly handle terminals mobility leading to changing topology. Globally, five different categories of routing protocols are designed:

Proactive Protocols– Similarly to static networks, these protocols build routing tables providing a path to any accessible destination on the network. Periodic beacon messages are triggered in order to adapt the backbone to topology changes at the cost of higher energy consumption and channel occupancy. The two flagships in proactive routing protocols are the *Wireless Open Shortest Path First (W-OSPF)* [6] and the *Optimized Link State Routing (OLSR)* [7]. Yet, the more the mobility increases, the harder it becomes to maintain the routing tables. Accordingly, these approaches have shown not to be very adapted to fast mobile networks. Recent results [5] also pointed out the relationship between performance and density, arguing that proactive routing could only be efficient on dense networks.

Reactive Protocols– In order to limit the waste of resources, reactive networks only open routes on demand. Hence, the mobility of nodes not involved in the opened route does not influence network management. However, the dynamic topology due to mobility of nodes belonging to the opened route reduces the performance of reactive networks. Local repairs are possible in the case of a route failure and, in order to reduce the latency of a broken path, reactive networks also use periodic beacon messages. In this category, the *Direct Source Routing (DSR)* [8] protocol and the *Ad hoc On Demand Distance Vector Routing (AODV)* [9] are two potential candidates, although that the IETF recently chose a modified and improved version of AODV called *Dynamic MANET On-demand (DYMO)* [10] as the only candidate to IETF standard track RFC for reactive routing in MANETs.

Geographic Routing– It is a stateless approach where no backbone or route is generated. Instead, geographic information of the destination and intermediate nodes are used in order to wisely choose the best candidate to forward a packet toward the intended destination. Those protocols are based on two functions: *the greedy forwarding* and the *recovery*. Indeed, each node receiving a packet will try to choose the best candidate among its neighbors with the maximum progress toward the destination node. This is the *greedy forwarding* phase and *Most Forward within Radius* [11] is the technique most widely used in order to find the best progress. But in some cases, the packet falls in some local maxima, where not any single node in the neighborhood may bring any potential progress toward the destination. Accordingly, a recovery phase is triggered, where the packet is sent back until an alternate candidate is found. This is the *recovery phase* to circumvent the local maxima. The first and still pioneer protocol in this field is the *Greedy Perimeter Stateless Routing (GPSR)* [12] protocol. Stochastic embedded in nodes mobility still alters the precision of geo localization information, potentially reducing the performance of the geographic forwarding approach. Yet, the stateless feature of geographic routing made them good candidates for routing in Vehicular Ad Hoc Networks, where GPS systems are commonly accepted.

Fish-Eye Routing– In order to deal with the lack of precision of geographic information, dynamic topology problem is handled in a different way whether the destination node is far or close from the intermediate or sender node. – *Locally*: Frequent position updates of all neighboring nodes are triggers as mobility has a significant local influence. – *Remote*: Only coarse mobility maintenance is triggered as the remote mobility does not have a significant influence on a local decision. The *Fisheye State Routing (FSR)* [13] protocol and the *Landmark Routing (LANMAR)* [13] are two proactive approaches in which node keeps up to date state information about all nodes in its inner circle, while the accuracy of such information decreases as the distance increases. Even if a node does not have accurate state information about distant nodes, packets will be routed correctly because the route information becomes more and more accurate as the packet gets closer to the destination. Another proactive protocol in this category is called *Distance Routing Effect Algorithm for Mobility (DREAM)*. It is based on *location information*, and adapts its location update to both mobility rate and distance. Finally, a reactive approach called *Location-Aided Routing (LAR)* [13], also based on *location information*, and has been developed, where each node maintains the location about nodes it is aware of with respect of the distance. The farer is the node; the larger is area and then, on demand, orients route requests toward the area where the destination node is.

Hybrid Routing– This is the last category of protocols which mixes the proactive approach for local routing and reactive even geographic approach for distance routing. Most of the protocols developed in this category either create local zones, clusters, or trees and uses a reactive routing strategy to route between them. The *Zone Routing Protocol* [14] and the Hybrid Ad Hoc Routing Protocol [15] are examples of this approach.

4. DLFR: Architecture.

DLFR facilitates statistical treatment of stochastic behavior of unpredictable links between two random MDs in MANET and then extends the concept to the entire open network. Time metric followed in DLFR is forwarding time (FT) between a typical pair of MDs in the multi-dimensional feature space and is a dissimilarity measure that takes into account correlation between FTs and normalizes each feature to zero mean and unit variance (Box-Muller Transformation). Similar property is reflected in Mahalanobis distance widely used in cluster analysis and other classification techniques. It is closely related to Hotelling's T-square distribution used for multivariate statistical testing.

Dynamic Link Forward routing protocol operation is illustrated in Figure 1. The service required by the MD 1 resides at MD 10. The MDs 2, 6 and 7 can act as immediate hop for the route to MD10. MD 1 broadcasts the *RouteSearch* control packet including its services information to immediate neighboring MDs. All immediate MDs receiving the broadcast update their service directories. We added a new field to the standard packet header. This field is called the ***Forward Time (FT) Field***, and it is initialized to zero by the source device before broadcasting a *RouteSearch* packet.

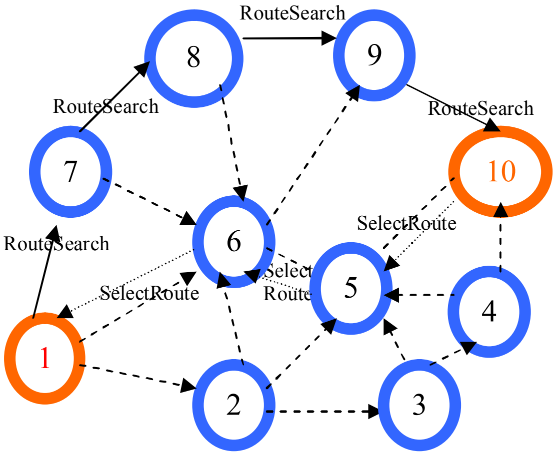

Figure 1: Dynamic Link Forward Routing.

Every intermediate device that receives the *RouteSearch* packet estimates its FT based on DLFR Algorithm. FT estimation is a unique prediction based mechanism with which each device finds the FT to all its neighboring devices. Along with the FT, *RouteSearch* packet contains the FT of the previous link of the so far discovered candidate route. When the destination device obtains more than one path, it simply selects the path with the minimum CFT (Cumulative Forward Time) metric associated with it. Hence the candidate route with minimum CFT is selected and the traversed path is backtracked to send a *SelectRoute* Packet to the sender device to initiate the data transfer. When the source device receives the Reply, it is in fact receiving the path to the intended destination and the FT metric associated with that path. When the DLFR algorithm follows the Box-Muller (1958) transformation for estimating FT for each link over the network, it allows transforming uniformly distributed random variables, to a new set of random variables following Normal distribution. DLFR start with a group of pairs of two independent random numbers (r_p, r_{p+1}) which come from a uniform distribution (in the range from 0 to 1). DLFR estimates the FT as a sample of t_i where i varies from 1 to N_s (N_s :Sample size > 50, as per the definition of Central Limit Theorem) between the two MDs for ***kth*** link. The FT between a typical link joining MD_1 and MD_2 is predicted as statistics of N_s samples defined as:

$$t_i = s_i * \sigma_k + \mu_k$$

where σ_k and μ_k are standard deviation and mean respectively for the kth link.

$$s = \mathrm{sqrt}(-2 \ln(r1)) \cos(2 \, \mathrm{pi} * r2)$$

where (r1, r2) is a pair of random numbers in the range (0, 1) and s is the desired sample from the standardized normal distribution. For estimating each FT_k corresponding to a typical link k, a sample of s_i is created by implementing a random number generator where i varies from 1 to N_s. For each link an independent set of σ_k and μ_k are assumed based on network dynamics. Implementing these N_s samples, statistics for each link with assumed standard deviation σ and mean as μ are estimated as N_s FTs for each link.

Algorithm for time measure between two consecutive MDs over MANET:

Step 1 For k = 1 to m (for m links).
Step 2 For i= 1 to N_s (for each FT with given source MD and destination MD).
Step 3 Generate N_s samples of stochastic time ***FT*** for moving packets between two immediate MDs (Assume σ and μ samples for each link).
Step 4 Each Intermediate MD append its address + FT of the previous link to create the *RouteSearch* packet.
Step 5 At the destination the *RouteSearch* packet contains the traversed paths with their respective cummulative forwarding time (CFT).
Step 6 The destination selects the path with minimum CFT as shortest route and send back the *SelectRoute* packet.

Generally, shortest path routing algorithms for FT determination estimates time by replacing the sample by its mean value that results in an over optimistic result, DLFR promises to remove this discrepancy by replacing the mean value of the FT by the standardized probability distribution that matches the flavour of MANET's stochastic mobility patterns. It offers a more realistic decision for computation of time period for each packet forwarding, i.e., moving from one MD to next MD. As shown in Algorithm 1.1, DLFR generate this stochastic FT for each link with assumed standard deviation and mean.(Box-Muller Transformation). The network consists of ***n*** (50) MDs with ***m*** (25) possible lınks, ***m (25) sets of*** N_s ***(70)*** FTs are to be generated, hence a constant set of N_s ***(70)*** random samples are required from standardized normal distribution for each link in the network and 25 (links) pairs of assumed (σ_k, μ_k) with ***k*** varying from 1 to 25 are required. Also as a pair of random number is consumed in generation of a single ***s*** so a total of 2* N_s random numbers are required for implementing DLFR.

5. Simulation Study

To evaluate the effectiveness of DLFR, we simulate the scheme and compare it to the *Associativity-Based Routing (ABR).* ABR [16] classifies a link as stable or unstable based on link age. Each node determines the age of a link with its neighbors based on the number of beacons periodically received from that neighbor. We implemented the DLFR and ABR protocols in the *ns*-2 (version 2.28) simulator [17]. We study the two major performance metrics namely the *Packet delivery ratio* (ratio of the number of packets delivered to the destination to those generated by the CBR sources) and *End-to-end delay per packet* (average of the delay incurred by all the packets that originate at the source and are delivered at the destination).

Table 1 Simulation parameters.

Network Size	1500 m x 300 m
Nodes	50
Transmission Range	250 m
Link Bandwidth	2 Mbps
Minimum Node Speed	0 m/s
Pause Time	0 Second
Maximum Node Speed	1, 5, 10, 15, 20, 30 m /s
Data Packet Size	512 bytes

At low and moderate mobility, ABR incur lower end-to-end delay per packet compared to DLFR (figure 2). This could be attributed to the higher route relaying load on the nodes in the case of DLFR. Thus, we see a reliability-delay tradeoff at low and moderate velocities. Larger the desire for stability, larger is the end-to-end delay per packet that would be incurred.

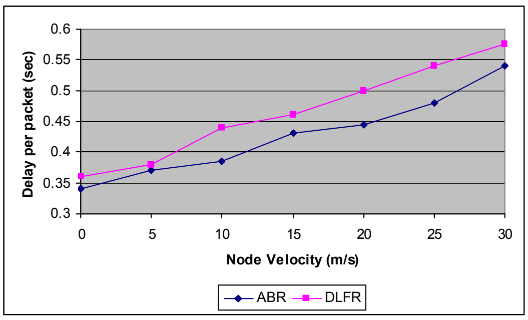

Figure 2: Delay per packet.

DLFR reduces this tradeoff to a certain extent by reflecting a more realistic criterion for estimating the forward time per hop to a reasonable limit and achieves less failure prone routes. DLFR matches delay incurred by ABR at low and moderate velocities. In the wake of a route failure, ABR tries to do a local route repair before going for a global route discovery. During this phase, data packets need to be buffered at intermediate nodes. But local repair is successful only at low velocities. As the velocity increases, local route repairs become unsuccessful and global route discovery needs to be initiated. The data packets stored in the buffer of intermediate nodes timeout and get dropped. As a result the packet delivery ratio, which is the ratio of the number of data packets successfully delivered to the destination to that of the total number of data packets originating at the source, decreases at a faster rate compared to that of the relatively more stable DLFR (figure 3). The packet delivery ratio, decreases at a faster rate in ABR compared to that of the relatively more stable DLFR.

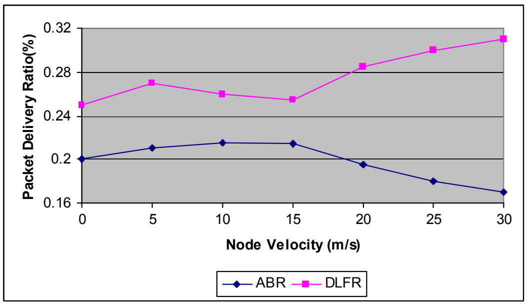

Figure 2: Packet Delivery Ratio

The inherent stability is reflected by a Box Muller Transformation followed by the FT metric of the routes chosen by DLFR.

6. Conclusions

The major conclusion that could be drawn is that the strategies that are exclusively based on the knowledge of the past topology changes are not enough to select highly reliable routes. It is not enough to predict the future of a link based on how long the link existed so far. We need to estimate the forward time of a packet over a typical link. Higher the stability, higher is the end-to-end delay per packet. DLFR reduces this tradeoff to a certain extent by maintaining a proper balance between the route propagation load and route reliability. Also due to more realistic estimates of the CFT per candidate route, higher packet delivery ratio is achieved.

References

[1] Ramanathan and J. Redi, “A Brief Overview of Ad Hoc Networks: Challenges and Directions,” IEEE

Commununications. Magazine., vol. 40, no. 5, May. 2002.
[2] M. E. Steenstrup, "Routing under uncertainty: a comparative study," in Proceedings of IEEE Wireless Communications and Networking Conference, vol. 1, pp. 112-116, 2000.
[3] C. Ying, Q. Lv, Y. Liu, and M. Shi, "Routing protocols overview and design issues for self-organized network," in Proceedings of International Conference on Communication Technology, vol. 2, pp. 1298-1303, 2000.
[4] Yih-Chun Hu, David B. Johnson, and Adrian Perrig., "SEAD: Secure Efficient Distance Vector Routing for Mobile Wireless Ad Hoc Networks" in Proceedings of the 4th IEEE Workshop on Mobile Computing Systems & Applications (WMCSA 2002), IEEE, Calicoon, NY.
[5] K.-W. Chin, J. Judge, A. Williams, and R. Kermode, "Implementation experiences with MANET routing protocols." ACM/SIGCOMM Computer Communications Review, Nov. 2002.
[6] "Wireless open shortest path first," http://hipserver.mct.phantomworks.org/ ietf/ospf.
[7] P. J. *et al.*, "Optimized link state routing protocol (olsr)," RFC, http://www.ietf.org/rfc/rfc3626.txt.
[8] D. J. *et al.*, "The dynamic source routing protocol (dsr) for mobile ad hoc networks for ipv4," RFC, http://www.ietf.org/rfc/rfc4728.txt.
[9] C. P. *et al.*, "Ad hoc on-demand distance vector (aodv) routing," RFC http://www.ietf.org/rfc/rfc3561.txt.
[10] I. C. *et al.*, "Dynamic manet on-demand (dymo) routing," February 2007, internet Draft, http://www.ietf.org/internet-drafts/draft-ietf-manet-dymo-08.txt
[11] L. K. H. Takagi, "Optimal transmission ranges for randomly distributed packet radio terminals," *IEEE Transactions on Communications*, vol. 32, no. 3, pp. 246–257, March 1984.
[12] http://www.icir.org/bkarp/gpsr/gpsr.html).
[13] Y.B. Ko and N. H. Vaidya, "Location-aided routing (lar) in mobile ad hoc networks," in Proceedings of the 4th annual ACM/IEEE international conference on Mobile computing and networking (MOBICOM'98), 1998, pp. 66–75.
[14] Z. H. *et al.*, "Zone routing protocol (zrp)," July 2002, internet Draft, http://tools.ietf.org/id/draft-ietf-manet-zone-zrp-04.txt.
[15] N. Nikaein, C. Bonnet, and N. Nikaein, "Hybrid ad hoc routing protocol (harp)," in Proceedings of the International Symposium on Telecommunications (IST'01), 2001.
[16] C-K. Toh, "Associativity-Based Routing for Ad hoc Mobile Networks," IEEE Personal Communications, Vol. 4, No. 2, pp. 103 – 139, March 1997.
[17] K.Fall, K. Varadhan, " The ns Manual", The VINT Project, A Collaboration between researchers at UC Berkley, LBL,USC/ISI and Xerox PARC.

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