LifeNet: A Flexible Ad hoc Networking Solution for Transient Environments

Hrushikesh Mehendale, Ashwin Paranjpe, and Santosh Vempala
hrushi@gatech.edu, ashwin.p@gatech.edu, and vempala@cc.gatech.edu
College of Computing, Georgia Institute of Technology, Atlanta, GA, USA

ABSTRACT

We demonstrate a new ad hoc routing method that can handle transience such as node-mobility, obstructions and node failures. It has controlled management overhead, and is platform-independent (our demo includes phones, routers, and laptops running different operating systems). It achieves reliability and flexibility at the expense of throughput. It is ideal for scenarios where the reliability of connectivity is critical and bandwidth requirements are low. For e.g., disaster relief operations and sensor networks. Along with applications, we exhibit measurements to illustrate the advantages of our approach in dealing with transience.

Categories and Subject Descriptors:
C.1.1 Computer-Communication Networks: Network Architecture and Design - Wireless Communication
C.2.2 Computer-Communication Networks: Network Protocols - Routing Protocols
General Terms: Design, Experimentation, Measurement, Reliability.
Keywords: MANETs, Reliable routing, Minimum infrastructure.

1. INTRODUCTION

Multihop ad hoc wireless networks have not delivered on their promise, especially for bandwidth-intensive applications. This is in part due to the inherent capacity limitations of multihop TCP communication ([5]). Recent implementation efforts have achieved substantial throughput improvements at the expense of flexibility and reliability ([2, 4]). However, the improvements are still not good enough to warrant real-life use, especially with mobile nodes. The goal of this demo is to suggest that if the constraint of high throughput is relaxed, it is possible to realize ad hoc networks that are flexible and reliable under transience. Moreover, such networks have natural use cases for e.g. communication in disaster relief operations, wireless sensor networks such as forest fire detection networks, smart-home networks, etc. By transience, we refer to the changing state of a network along the following dimensions: (1) changing network topology due to mobility, (2) changing physical obstructions, (3) node failures and new nodes joining the network and (4) interference.

In this demo, we propose to present a new routing metric called *'Reachability'* and a new routing protocol based on it, called *'Flexible Routing'*. Reachability is suitable for transient environments because it accurately captures transience, is easy to compute and maintain, enables a compact representation of the entire network graph at individual nodes, and facilitates routing. Flexible Routing is a multipath routing protocol that uses pairwise-reachabilities to reliably deliver packets under varying degrees of transience. It trades throughput for availability and reliability.

SIGCOMM'11, August 15–19, 2011, Toronto, Ontario, Canada.
ACM 978-1-4503-0797-0/11/08.

2. REACHABILITY

Our routing method is based on the notion of *reachability*, a directional metric, which captures the effects of transience in a single numerical value. Roughly speaking, it measures the end-to-end, multipath probability that a packet transmitted by a source node reaches the destination node. It is important to note that this probability should be over all possible paths and not any single path (unlike previous routing metrics, e.g., [3]).

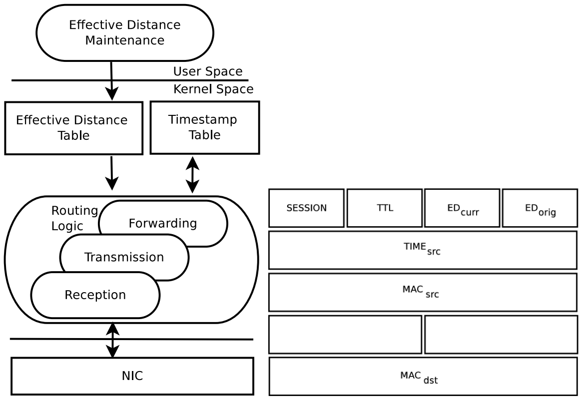
Definition. Reachability(A,B,T,L) of node B from node A is defined as the expected number of packet copies received by B for every packet originated at A and diffused in the network for at most L hops in time interval T.

Reachability can be efficiently measured by exploiting the broadcast nature of the wireless channel. To measure reachabilities of all other nodes, a node SRC transmits a packet to the broadcast MAC address with a pre-defined Time-to-Live (TTL) value. Nodes receiving this packet diffuse it further into the network until the TTL field of all the packet copies reaches zero. Thus, a node that is well-connected or highly reachable from SRC receives more packet copies than a node which is not. We map reachability to a finite value, roughly its inverse, and call it *Effective Distance.*

$$ED = \begin{cases} 100/R & \text{if } R > 1 \\ 255 - (155R) & \textit{otherwise} \end{cases}$$

3. FLEXIBLE ROUTING

Idea. Maintaining paths explicitly is not practical under transience. Hence the core routing decision for flexible routing is *"Whether or not to forward?"* instead of *"Which node to forward the packet to?"*. Each node maintains a compact table ($O(n)$ size) of pairwise effective distance values computed from receiving control packets, and uses these to selectively forward data packets, effectively pruning a flooding tree. Although paths are not being created or maintained, this opportunistic approach ensures that the packets end



(a) Architecture of Flexible Routing (b) Flexible Routing Header

Figure 1: Flexible Routing Layer 2.5 Architecture and Header

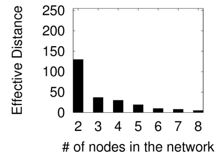
up traveling along multiple available paths towards the destination. This approach is network-aware and hence different from controlled flooding, directed diffusion, probabilistic flooding or broadcast-storm techniques. In other words, the routing algorithm ensures that packets on the network are forwarded by only those nodes that are likely to increase the chances of the packets reaching their destination.

Design and Implementation. We extend the mobile ad hoc networking framework proposed in ([6]). Packets on the network carry an additional header (Figure 1(b)). The routing functionality can be broadly divided into two categories - *ED Table Maintenance (EDM)* and *Routing*. ED Table (EDT) is implemented in user space. Routing uses data from EDT to make routing and forwarding decisions (Figure 1(a)). Nodes make the forwarding decision by comparing the effective distance in the received packet (ED_{curr}, Figure 1(b)) with the effective distance to their final destination. A non-duplicate packet is forwarded only if the EDT distance is within a threshold of the packet distance. Duplicate packets require a second stricter check. Broadcast storms in dense network zones are avoided by probabilistic forwarding rules based on the EDT. Layer 2.5 approach allows interoperability with different MAC technologies. The current implementation uses 802.11 a/b/g in ad hoc mode.

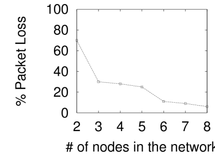
4. CONCLUSION

A preliminary evaluation of reachability and flexible routing was conducted in a university building environment on a network of eight nodes. Results (Figure 2) show that reachability captures (1) the phenomenon of increased connectivity as network scales (Figure 2(a)), (2) the effect of degraded connectivity after node failures (Figure 2(c)) and (3) node mobility. Moreover, flexible routing utilizes reachability to (i) strengthen routing as the network scales (Figure 2(b)), (ii) gracefully degrade its performance as node failures happen (Figure 2(d)) and (iii) maintain performance for changing node positions.

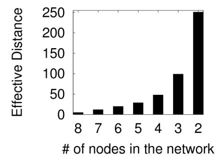
Scaling flexible routing to larger sized networks would require addressing challenges such as achieving desired consistency in topology information (EDT) and energy conservation. By focusing on availability under eventual consistency,



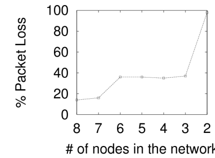
(a) Reachability captures increased connectivity as the network grows



(b) Flexible routing utilizes reachability to improve packet loss as the network grows



(c) Reachability captures node failures



(d) Flexible routing gracefully degrades under node failures

Figure 2: Evaluation Results

our approach aims to achieve a practical trade-off between the mutually conflicting goals of reliability, efficiency and usability. Our technology, packaged as LifeNet [1], is currently being field-evaluated for disaster communication applications.

Acknowledgment. We are grateful to Mike Best, Ashok Jhunjhunwala and Shibu Mani for helpful discussions, to Sanjit Biswas for 50 Meraki nodes, and to the NCIIA for a sustainable vision grant supporting this work.

5. REFERENCES

[1] Lifenet website: "http://www.thelifenetwork.org".

[2] S. Biswas and R. Morris. Exor: Opportunistic multi-hop routing for wireless networks. In *Proc. SIGCOMM*, pages 133–144, 2005.

[3] Douglas S. J. De Couto, Daniel Aguayo, John Bicket, and Robert Morris. A high-throughput path metric for multi-hop wireless routing. In *Proceedings of the 9th annual international conference on Mobile computing and networking*, MobiCom '03, pages 134–146, New York, NY, USA, 2003. ACM.

[4] R. Draves, J. Padhye, and B. Zill. Routing in multi-radio, multi-hop wireless mesh networks. In *MobiCom '04: Proceedings of the 10th annual international conference on Mobile computing and networking*, pages 114–128, New York, NY, USA, 2004. ACM.

[5] Jinyang Li, Charles Blake, Douglas S. J. De Couto, Hu I. Lee, and Robert Morris. Capacity of Ad Hoc wireless networks. In *MobiCom '01: Proceedings of the 7th annual international conference on Mobile computing and networking*, pages 61–69, New York, NY, USA, 2001. ACM.

[6] Ashwin Paranjpe and Santosh Vempala. Mymanet: A customizable mobile ad hoc network. In *NSDR '09*, Big Sky, Montana, USA, 2009. ACM.