A NOVEL STRATEGY FOR HIGH THROUGHPUT IN WIRELESS Ad- Hoc NETWORKS

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<u>Summary Report on the Ph.D. Thesis</u>

A Novel Strategy for High Throughput in Wireless Ad-Hoc Networks

Area of the research work:

This work describes how to find high-throughput routes in multi-hop wireless packet networks. Using the *Potential Transmission Count (PTC)* metric presented here, routing protocols can find multi-hop routes that have up to twice the throughput of those found using the minimum hop-count metric. Most routing protocols minimize the hop-count1 metric, which is the number of wireless links in a route, regardless of the performance of each link. Since multi-hop wireless networks likely contain many lossy links, routes preferred by the hop-count metric also often contain lossy links, which reduce throughput. The PTC metric is based on the loss ratio of each link in a route, as well as the number of links in a route. Because it prefers shorter routes with better links, PTC selects high-throughput routes.

Contributions of this Work:

The main contribution of this work is the design, implementation, and evaluation of the estimated potential transmission count (PTC) metric, which is designed to enable routing protocols to find high-throughput routes. The PTC of a route is the total number of packet transmissions and retransmissions required to send a packet across the route, assuming that each link in the route retransmits the packet until it is successfully received across the link. PTC is designed for links with link-layer acknowledgments (ACKs) and retransmissions.

The PTC metric for a route is calculated using measurements of the lossless of each link in the route. Routing protocols select routes with the minimum PTC. For short routes (up to and including 3-hop routes), the minimum- PTC route is the maximum-throughput route; for longer routes, the minimum- PTC route is still a high-throughput route. The design of the PTC metric does not depend on a particular routing protocol it is compatible to work with any protocol to enhance the capacity of network; last chapter shows that PTC improves the throughput of both Dynamic Source Routing (DSR), an on-demand source routing protocol, and Destination-Sequenced Distance-Vector (DSDV) routing, a proactive table-driven distance-vector routing protocol. We also present a set of design changes and implementation techniques that allow DSR and DSDV to work well with PTC.

Additional contributions are a detailed exploration of the performance of minimum hop-count routing on a wireless test using 802.11b radios, and a simple model of how link loss ratios vary with packet size. The throughput problem (experimental test) explains why minimum hop-count often finds routes with significantly less throughput than the best available throughput, and quantifies the throughput difference between the typical minimum hop-count route and the highest throughput route. Wireless model shows how to use a few link loss ratio measurements to predict loss ratios at different packet sizes; these predictions can be used to decrease the protocol overhead of the PTC metric, by allowing PTC to measure links with small packets. PTC is also likely improving network capacity. In order to demonstrate that PTC is effective, PTC evaluation presents measurements taken from the test network.

These measurements show that PTC improves the throughput of multi-hop routes by up to a factor of two over the minimum hop-count metric. PTC provides the most improvement for paths with two or more hops, suggesting that PTC offers increased benefit as networks grow larger and paths become longer. However, the protocols and experiments described in this work do *not* use the radios in infrastructure mode. Instead, the radios are used in a *peer-to-peer* mode where they can directly send and receive packets from any radio which might be in range. This mode is also sometimes called *ad hoc* mode. The 802.11 standard refers to radios operating in this mode as an Independent Basic Service Set (IBSS).

The Throughput Problem

Most existing wireless routing protocols use the minimum hop-count route metric: they select routes with the fewest links. The minimum hop-count metric implicitly assumes that links either work well, or do not work at all and that all working links are equivalent. Furthermore, most protocols assume links that deliver routing control packets such as DSDV route updates or DSR route queries will also successfully deliver data packets.

However, these assumptions are incorrect for multi-hop wireless networks with omnidirectional antennas. Unlike wired and wireless networks with point-to- point links, where the performance of each link can be tightly controlled and engineered, networks with omnidirectional antennas have many wireless links with a wide range of intermediate loss ratios. These lossy links are not useful for data, but deliver enough routing control packets so that the routing protocol uses the link. Measurements in illustrate the even distribution of link loss ratios for an indoor 802.11 test; others have measured similarly even distributions for an outdoor 802.11 network, and for indoor and outdoor sensor networks.

Wireless Model

This model gives a simplified description of how digital radios transmit and receive data packets, along with a description of the sorts of problems radios face when transmitting packets. The purpose of this chapter is two-fold: first, to give a rough sense of why the packet losses and second, to explain the experimentally observed fact that packet loss probabilities vary with the size of the packet. As we will see the accuracy of the PTC metric proposed can be improved by properly accounting for packet sizes. This describes a model that accurately predicts loss ratios at different packet sizes based on the measured loss ratios at two other sizes. Since the model is based on the operation of digital packet radios, we start with a description of how radios work.

PTC Evaluation

This evaluation presents experimental results that show that PTC often finds higher throughput paths than minimum hop-count, particularly between distant nodes. It also explores the effects of a few individual design decisions in the PTC algorithm, and explains why there is a performance gap between the throughput of the routes with the lowest PTC, and the ‘best’ routes found by searching the network.

We evaluated PTC by running three kinds of experiments. *Routing protocol tests* evaluate how well PTC improved the performance of the DSR and DSDV protocols. *Static throughput tests* show how the underlying throughput of a particular route can change quickly over time, which is a fundamental limitation on how well PTC can predict which route to use. *Single link tests* characterize the accuracy of PTC predictions over a single link at a time, as well as illustrate how delivery ratios of a single link can vary quickly, which also affect how accurately PTC can choose good routes. The following sections describe each set

The impact of the research work on academics/industry:

The ideas presented in this work are motivated by experiments on a relatively large-scale test, with 5 or 6 times more nodes and an order of magnitude more links than the tests used in most previous work. The links have many different qualities, evenly spread from best to worst, and that there is no easy division of links into ‘good’ and ‘bad’ categories. However, experiments on smaller tests are not as likely to reveal such a wide distribution of link quality, and previous work has been more focused on categorizing links as ‘good’ or ‘bad’. In contrast, the mechanisms and protocols introduced in this work are specifically designed to accommodate and take advantage of links of all qualities.

We assume that the loss ratio of a given link cannot be controlled by the system. More sophisticated hardware might allow transmit power levels to be changed to make links better behaved. Existing systems exploit this idea, often with a focus on minimizing the energy consumption required to successfully deliver data. Energy consumption is primarily a concern for sensor networks, where radio transmissions consume the majority of each node's energy budget. Fixed data networks like those we consider are not likely to be concerned with energy consumption. However, fixed networks can benefit by using power control to reduce transmission ranges and increase network capacity.

The main contribution of this work is a simple way for multi-hop wireless routing protocols to choose high-throughput paths in networks with link-layer retransmissions. By measuring the delivery ratios of each link in a route using fixed size broadcast packets, protocols can estimate the throughput of the route as the inverse of that route's expected transmission count, which is called PTC. The PTC of a route R is calculated as

Where and are the measured delivery ratios in the forward and reverse directions of each link i in R.

The inverse of PTC predicts throughput for routes with small to medium hop-counts. Since at most one node in those routes can transmit at any time, the throughput of the route is limited by the number of transmissions, or equivalently, time, required to transmit each packet over the route. Measurements on a real test-bed network show that PTC helps the DSR and DSDV routing protocol find routes with significantly higher throughput than the default minimum hop-count metric. The overhead of the PTC delivery ratio probes depends on the spatial density of the network, and is relatively small compared to the amount of data traffic that can be sent over each link.

Finally, this work proposed a simple model for how link delivery ratios vary with packet size. The packet delivery Pp for a packet with n data symbols is

$$P_p\,(n) = P_f \times$$

Where Pf is the per-packet probability that a receiver successfully acquires and synchronizes to a packet frame, and Ps is the per-symbol probability that the receiver successfully decodes that symbol. Measurements on the test show that this model can accurately predict the delivery ratios at many packet sizes using measurements at two packet sizes over each link.

Report

- Omni directional Antenna
- Many Radio can reduce link bit-rate for increased reliability
- Maximum link capacity 15 to 25 packets per second
- 18 different Ethernet size from 50 to 15 1mbps. How many packets it received of each size from each sender. The delivery ratio of each packets size over each link is calculated as the number of packets of that size received over the link divided by the number of packets of that size.
- PTC= $1/(d_f \times d_r)$, d_f = Data packets successfully arrives, d_r = Probability that the ACK successfully
- Protocol Changes
  - Weighted setting time (WST)
  - Does not use link-level feed back
  - Full dumps are never sent on a triggered updates
  - Delay use-is that a route is not used until it is allowed to be advertised. That is, a new route is not used until 2xWST has expired.

List of Publications/Conferences (2008-2012)

S. No.	Title of research Paper	Name of Journals/Publications	Volume No./ Page No.	ISBN/ISSN	Paper Status
1	A Novel Strategy for High Throughput in Ad Hoc Networks using Potential transmission Count (PTC) Metric	WSEAS (The World Scientific and Engineering Academy and Society, Canada)	Issue 8, Volume 10/Page No.223-232	ISSN: 1109-2742	Published
2	Experimentally Modified Protocols with Transmission Count Metric for Efficient Throughput in Ad-Hoc Networks	UBICC (Ubiquitous Computing and Communication Journal), USA	Volume 6 No.2/ Page No.807-813	ISSN: 1992-8424	Published
3	Throughput Increments Phenomena in Ad Hoc Network using Potential transmission Count (PTC) Metric with Protocols	IEEE Explore ICCCT-2011 MNNIT Allahabad	2nd IEEE International/Page No. 562-567	978-1-4577-1386-611$26.00© 2011 IEEE	Published
4	A WiMAX Segmentation for 3rd Generation N/W Simulator	IEEE Explore ICCCT-2010 MNNIT Allahabad	Paper 257 Session 2/Page No. 135-140	978-1-4244-9032-5/10/$26.00 ©2010 IEEE	Publishe d
5	A Count Metric Strategy with Protocols to Increase Throughput in Ad Hoc Networks	IEEE Microwave Theory and Technique Society India chapter/ NECE-2010	MITS-Gwalior Page No.-131	NVIS Technologies Pvt. Ltd. IEEE India council	Published
6	An Effective Technique of Routing for MANETs	IEEE Microwave Theory and Technique Society India chapter/ NECE-2010	MITS-Gwalior Page No.-106	NVIS Technologies Pvt. Ltd. IEEE India council	Published
7	A NOVEL COMPARISION AND SIMULATION OF ROUTING PROTOCOLS IN Ad-hoc NETWORKS	UBICC, IJARCS, INNS International Conference on Issues and Challenges in Networking, Intelligence and Computing Technologies (ICNICT' 2011)	Page No.-683-686	ISSN: 978-93-81126-27-1	Published

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Ph.D. Scholar