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Performance Analysis of Routing Metrics for Multi Radio Multi Channel in Wireless Mesh Networks

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Abstract

Wireless mesh is a collection of wireless devices that can communicate with peers in single or multiple hops. Mesh networks are self-configuring systems where each Access Point (AP) can relay messages on behalf of others, thus increasing the range, utilizing Multiple Radios over mesh routers increases capacity and available bandwidth. Efficient utilization of Multiple Radios is assured through proper channel assignment and routing schemas. Routing metrics are used for selection of routes obtained by routing protocols. Routing metrics provide measurable values that can be used to judge how useful a route will be, quantitative value assigned by routing metrics indicate the specific characteristics of the route.

Index terms— communicate, bandwidth, protocols

1 INTRODUCTION

ireless mesh networks (WMNs) are dynamically self-organized and self-configured, in which the nodes automatically establishing an Ad Hoc network and maintaining the mesh connectivity. WMNs are comprised of three types of nodes Mesh router, Mesh Gateways and Mesh client. Mesh router (MR) relay packets to / from other mesh routers and clients.

Mesh Gateway is a mesh router that connects other mesh router to internet through high speed wired link. Mesh clients connects to nearest mesh routers for access internet.

Wireless mesh networks have, in the recent years, increased in popularity due to their properties of self configuration, self healing and robustness. The motivation to build high throughput mesh networks has been fuelled by the relatively low cost of network hardware. This has allowed routers to incorporate two or more Radio interfaces on a single node in order to increase throughput and tackle the problems of cochannel interference in dense networks. Wireless mesh networks can be categorized into three basic types according to architecture and topology.

Client Mesh Networks are essentially the same as traditional Mobile Ad-hoc Networks (MANET) **??**2], in which the entire network consists of mobile client devices which implement routing and forwarding functionalities themselves.

In Infrastructure Mesh Networks, dedicated infrastructure nodes (Mesh Routers) provide a multi-hop wireless backbone infrastructure. Mesh Routers are typically equipped with Multiple Radio interfaces and are generally less resource constrained than client devices (Mesh Clients). In an Infrastructure Mesh Network, client devices do not perform any routing or forwarding functionality, and simply access the network via the nearest Mesh Router.

Hybrid Mesh Networks blend features from Client Mesh and Infrastructure Mesh Networks. Mesh Routers in Hybrid Mesh configurations still form the backbone of the topology and may provide backhaul access to external networks. However, in order to increase the reach of the network, client devices can be involved in routing. For example, if a client is not within communication range of a Mesh Router, another client device can act as a relay to the nearest router.

Recently, a lot of research effort has been focused on multi Radio wireless mesh networks. Due to the relatively low cost of commodity wireless hardware such as Radio interfaces based on IEEE 802.11 standards, it is now feasible to include Multiple Radios on a single node. By operating these interfaces on W © 2011 Global Journals Inc. (US) be significantly increased, and overcomes the limitation of half duplex operation of single-Radio nodes. However, routing protocols must be designed to take advantage of the availability of multiple interfaces efficiently.

Routing protocols are at the heart of Wireless Mesh Networks and control the formation, configuration and maintenance of the topology of the network.

Much of the development of protocols for wireless mesh networks has been derived from protocols developed within the IETF MANET working group. As the MANET protocols are designed for highly dynamic scenarios and therefore provide self-healing and self-configuring capabilities, they are also highly desirable in the context of wireless mesh networks. Routing metrics are a key element of any routing protocol since they determine the creation of network paths.

In this paper, we provide an extensive qualitative comparison of the most relevant routing metrics for multi-Radio wireless mesh networks.

2 II.

3 METRIC COMPONENTS

In this section, we identify and discuss the key components that can be utilized to compose a routing metric for multi-Radio wireless mesh networks.

4 a) Number of Hops

Hop count can serve as a routing metric in itself, such as in most MANET routing protocols, but can also be a component in a more complex metric. Hop count as a routing metric for wireless mesh networks has significant limitations. It has been shown in [5] that a path with a higher number of high-quality links demonstrates significant performance improvements over a shorter path comprised of low-quality links. Additionally, the authors of [6] found that hop count tends to route through a few centrally-located nodes, leading to congestion and hot spots.

5 b) Link Capacity

Measuring the link capacity gives the metric a view at the current throughput capability of a link. There are a few ways this can be done, from actively probing the link to measuring transfer speeds, to relying on the Radio interface's current rate. Furthermore, as most Radio interfaces have the ability to automatically lower their transmission speeds in order to deal with lossy links, finding links with higher capacity will lower medium access time and increase the performance of the topology [7]. c) Link Quality Finding high-quality links will greatly improve the overall performance of a path through higher transfer speeds and lower error rates. Link quality can be measured in a number of ways. The most common metrics are Signal to Noise Ratio (SNR) and Packet Loss Rate (PLR). This information is typically available from the device driver of a wireless interface. Alternatively, the PLR value can be determined through active probing [8].

6 d) Channel Diversity

Using the same channel on multiple consecutive hops of a path results in significant cochannel interference, and in a reduction of overall throughput. Ideally, all links of a path within interference range of each other should be operating on nonoverlapping channels, resulting in significant performance gains [9,10]. The extent to which this can be achieved can be expressed as channel diversity.

Obviously, channel diversity is only relevant for multi-Radio networks, since in single-Radio networks all interfaces are required to operate on the same channel to guarantee connectivity.

7 III.

8 ROUTING METRICS

In this section, we will describe the major routing metrics for multi-Radio mesh networks. We will begin by describing some metrics applicable to single-Radio mesh networks as much of the later work is based on these metrics.

A metric is a measurement of performance in some product or system, such as a program or a network. A router use metrics to make routing decisions and metric is one of the fields in a typical routing table. The metric consists of any value used by routing algorithms to determine the best route among multiple routes to a destination. It is typically based on such information as bandwidth, hop count, path cost, delay, load, MTU (maximum transmission unit), reliability and communication cost. A hop is the number of links or routers that are crossed en route to the destination. MTU is the largest packet size, measured in bytes, which can be transmitted over a network.

Routing metrics are assigned to routes obtained by routing protocols to provide measurable values that can be used to judge how useful (how low cost) a route will be. Metrics provide a quantitative value to indicate the specific characteristics of the route.

9 a) Hop Count

This is the base metric used in most MANET [2] protocols and is a simple measure of the number of hops between the source and destination of a path.

However, hop count maintains a very limited view of links, ignoring issues such as link load and link quality. De Couto et al. [5] showed that a route with a higher number of short links can outperform a route with a smaller number of long distance and therefore lower quality links. This can lead the hop count metric to choose paths with low throughput and cause poor medium utilization, as slower links will take more time to send packets.

Furthermore, hop count tends to select long distance links with low quality, which typically already operate at the lowest possible rate, due the link layer's auto rate mechanism. This leaves the auto rate mechanism no further flexibility in dealing with channel quality fluctuations, resulting in reduced link and path reliability [7].

Hop count does not take into account link load, link capacity, link quality, channel diversity or other specific node characteristics. Neither does it consider any form of interference.

While it has been shown that the hop count is not necessarily an optimal metric to establish high throughput paths [8], comparisons have demonstrated that under scenarios of high mobility, hop count can outperform other load-dependent metrics [4].

Hop count is also a metric with high stability, and further has the isotonicity property, which allows minimum weight paths to be found efficiently.

10 b) ETX

Expected Transmission Count (ETX) [8] is a measure of link and path quality. It simply considers the number of times unicast packets need to be transmitted and re-transmitted at the MAC layer to successfully traverse a link.

The ETX path metric is simply the sum of the ETX values of the individual links. ETX considers the number of transmission in both directions of a link, since the successful transmission of a unicast frame requires the transmission of the frame in one direction plus the successfully transmission of an acknowledgement in the reverse direction.

The ETX metric for a single link is defined as shown below, where df is the measured rate or probability that a packet will be successfully delivered in the forward direction and dr denotes the probability that the corresponding acknowledgement packet is successfully received. Assuming these two probabilities are independent, we can say that the probability of a successful transmission, including Acknowledgement, is df * dr . By utilizing the inverse of this value, the ETX calculation, defined below, provides a minimum-weight cost to higher quality links:?????? = 1 ???? * ????

ETX is mostly determined by means of active probing, in which the number of successfully received packets is compared with the number of packets sent in a given time window, which is typically around 10 seconds [8].

While ETX outperforms hop count in single-Radio and single-rate networks, it does not perform well in multi-rate and multi-Radio networks due to its lack of knowledge of co-channel interference and its insensitivity to different link rates or capacities **??**16]. As a consequence, ETX tends to select links with lower rate.

Links with lower transmission rates take up more medium time to transmit data and forces neighboring nodes to back off from their own transmissions. This phenomenon leads to poor medium fairness in the network [7].

Additionally, ETX does not consider the load of a link and will therefore route through heavily loaded nodes without due consideration, leading to unbalanced resource usage. ETX does not discriminate between node types and makes no attempt to minimize intra-flow interference by choosing channel-diverse paths. It has been shown in [4] that in highly-mobile single Radio environments, ETX demonstrates poor agility due to the long time window over which it is obtained. However, ETX does deal with inter-flow interference indirectly, through the measurements of link-layer losses. Links with a high level of interference will have a higher packet loss rate and therefore a higher ETX value. EXT is isotonic, and therefore allows efficient calculation of minimum weight and loop-free paths.

As many implementations of ETX [8] utilize small broadcast probe packets to detect losses there lies an issue where the measurements do not accurately reflect the loss rate of actual traffic due to the smaller size of the probe packets compared to the average packet size of network traffic.

These effects could be mitigated by utilizing a cross-layer approach and directly obtaining the number of retransmissions from the link layer.

11 c) ETT

The Expected Transmission Time (ETT) metric [10] is designed to augment ETX [8] by considering the different link rates or capacities. This allows ETT to overcome the limitation of ETX that it cannot discriminate between links with similar loss rates but have a massive disparity in terms of bandwidth. This is particularly useful in multi-rate networks. ETT is simply the expected time to successfully transmit a packet at the MAC layer and is defined as follows for a single link: ETT=ETX* ?? ?? S denotes the average size of a packet and B the current link bandwidth. The ETT path metric is obtained by adding up all the ETT values of the individual links in the path.

ETT retains many of the properties of ETX, but can increase the throughput of the path through the measurements of link capacities, and therefore increase the overall performance of the network.

However, ETT still does not consider link load explicitly and therefore cannot avoid routing traffic through already heavily loaded nodes and links.

ETT was not designed for multi-Radio networks and therefore does not attempt to minimize intra-flow interference by choosing channel diverse-paths.

To resolve above issue we evaluate a new metric called Weighted Cumulative ETT (WCETT) for routing in multi-Radio, multi hop wireless networks.

The goal of WCETT metric is to choose a highthroughput path between a source and destination. Metric assigns weights to individual links based on the Expected Transmission Time (ETT) of a packet over the link. The individual link weights are combined into a path metric called Weighted Cumulative ETT (WCETT) explicitly consider interference among links that use the same channel, link quality and minimum hop-count. It can achieve good tradeoff between delay and throughput because it considers channels with good quality and channel diversity in the same routing protocol.

IV.

12 COMPUTING PATH METRIC a) Design Goals

? Consider both loss rate and bandwidth. ? Path metric combining weight of individual links should be increasing. ? The path metric accounts for the reduction in throughput due to interference among links that operate on the same channel.

In keeping with the design goals, we assigns a weight to each link that is equal to the expected amount of time it would take to successfully transmit a packet of some fixed size S on that link. This time depends on the link bandwidth and loss rate. For now, let us assume that given a link i from node x to node y, we know how to calculate the expected transmission time (ETT) of the packet on this link. We denote this value by ETTi. The next question is how to combine the individual ETT link weights of hops along a path into a metric that reflects the overall "goodness" of the path.

Our path metric is called Weighted Cumulative ETT (WCETT).In keeping with our second design goal, we want WCETT to increase in value as we add more links to an existing path. If we set WCETT to be the sum of the ETTs of all hops on the path, this property will be ensured. Furthermore, the total sum of ETTs has a physical meaning as well: it is an estimate of the end-toend delay experienced by a packet traveling along that path. Thus, for a path consisting of n hops, we may say:?????????? = ? ?????? ?? ??=1

However, we also want WCETT to consider the impact of channel diversity. Simply adding up ETTs will not ensure this property, since we are not distinguishing between hops that are on different channels. To reflect this, our metric will require an additional term.

Consider a two-hop path, in which both hops interfere with one another. In other words, only one of the hops can operate at a time. Assume that each hop has a bandwidth of B. If we ignore packet losses for the moment, then the expected transmission time of a packet along each hop will also be equal. Let us denote this by T. Note that T is inversely proportional to B. Due to interference, the maximum bandwidth a flow can achieve along this path is equal to B/2. Since T is inversely proportional to B, the notion of the reduced bandwidth along the path can be captured by giving the path a weight that is equal to the sum of the packet transmission times on the interfering hops; in this case 2*T.

We can generalize this intuition by assuming that that if two hops on a path are on the same channel then they always interfere with one another. This assumption is usually true for short paths, but the assumption is somewhat pessimistic for longer paths.

Consider an n-hop path. Assume that the system has a total of k channels. Define Xj as:???? = ? ???????? 1 ? ?? ? ?? ?????? ?? ???? ???? ????????????? ??

Thus, Xj is the sum of transmission times of hops on channel j. The total path throughput will be dominated by the bottleneck channel, which has the largest Xj. Thus, it is tempting to simply use the following definition for WCETT:WCETT = max X j 1?j?k

It is easy to see that this metric will favor paths that are more channel-diverse. However, it is evident that the value of this metric will not always increase as more hops are added to the path, because additional hops using non-bottleneck channels do not affect the value of the metric. So this metric achieves our third design goal but not the second goal.

We can combine the desirable properties of the two metrics described in Equations (**??**) and (**??**) by taking their weighted average: Where ? is a tunable parameter subject to 0 ? ? ? 1. There are a two possible ways to interpret the expression in Equation. First, we can view it as a tradeoff between global good and selfishness. The first term is the sum of transmission times along all hops in the network. This reflects the total resource consumption along this path, where the resource being consumed is the "air time." The second term reflects the set of hops that will have the most impact on the throughput of this path. The weighted average can be viewed as an attempt to balance the two. Note that this average implicitly assumes that the network is not too heavily loaded. If every channel is being fully utilized, then simply minimizing overall resource consumption (setting ? = 0) may be preferable.?????????? = (1 ? ??) ? ???? + ?? * max 1 ? j ? k

Second, we can view Equation (**??**) as a tradeoff between throughput and delay. The first term can be considered as a measure of the latency of this path. The second term, since it represents the impact of bottleneck hops, can be viewed as a measure of path throughput. The weighted average is an attempt to strike a balance between the two.

V.

13 COMPARISION AND SIMULATION RESULTS

The simulation is conducted in three different scenarios. In the first scenario, the comparison of the three routing metrics is compared in various numbers of nodes. In the second scenario, the routing metrics are evaluated in different network load. In the third scenario, the routing protocols are evaluated in single Radio and multi Radio support. In the above graph we took number of nodes on X-axis and throughput in Y-axis to compare the routing metrics. When we observe the throughput of WCETT, ETT and hop count routing metrics, the WCETT performance is better than the remaining routing metrics hop count and ETT.

ii. Number of the Nodes Vs End-to-end delay In the above graph we took number of nodes on X-axis and end-to-end delay in Y-axis to compare the routing metrics. When we observe the end-to-end delay of WCETT, ETT and hop count routing metrics, the WCETT end-to-end delay is lower than the remaining routing metrics hop count and ETT, but the hop count end-to-end delay is very high when compare to WCETT.

iii. Number of the Nodes Vs Packet deliver ratio In the above graph we took number of nodes on X-axis and packet delivery ratio in Y-axis to compare the routing metrics. When we observe the packet delivery ratio of WCETT, ETT and hop count routing metrics, when we take the nodes as 30 the packet delivery ratio of hop count is greater than that of remaining metrics, but when we compare the overall packet delivery ratio of WCETT is higher than that of the remaining routing metrics. In the above graph we took the total flow load on X-axis and throughput in Y-axis to compare the routing metrics. When we observe the throughput of WCETT, ETT and hop count routing metrics, the WCETT performance is better than the remaining routing metrics hop count and ETT. In the above graph we took the total flows load on X-axis and end-to-end delay in Y-axis to compare the routing metrics. When we observe the end-to-end delay of WCETT, ETT and hop count routing metrics, the endto-end delay is vary based on the loads, but the overall WCETT end-to-end delay is lower than the remaining routing metrics hop count and ETT.

iii. Load Vs Packet delivery ratio In the above graph we took the total load on Xaxis and packet delivery ratio in Y-axis to compare the routing metrics. When we observe the packet delivery ratio of WCETT, ETT and hop count routing metrics, when you take load as 2.5 the packet delivery ratio of hop count is greater than that of remaining metrics, but when we compare the overall packet delivery ratio of WCETT is higher than that of remaining routing metrics. When we see the above graph we come to know that the HOPCOUNT multi Radio throughput is greater than that of single Radio throughput. The same thing is happened in other two routing metrics. But when we compare the three routing metrics the throughput of WCETT is greater than that of other two single Radio and multi Radio throughput.

14 VI.

15 CONCLUSION a) Summary

We discussed importance of channel diversity by addressing limitations of hop count and ETT. It also shown that when nodes are equipped with Multiple Radios, it is important to select channel diverse paths in addition to accounting for the loss rate and bandwidth of individual links. Initially we implemented multi Radio, multichannel support for an AODV then its WCETT routing metric is incorporated to improve quality of route selection. We performed simulation for various scenarios in NS2 in order to show that performance of well known routing metrics hop count, ETT, WCETT with and without multi Radio and multichannel support. Our results shown that WCETT outperforms Hop count, ETT. WCETT allows us to trade off channel diversity and path length by changing the value of the control parameter ?.

We experimented with different values of control parameter for analyzing performance in terms of throughput, end-to-end delay, and load and packet delivery ratio. It is shown that the routing Metric WCETT 0 500 0.5 1 1.5 2 2.5 3 3. ? Because of the second term in WCETT equation, WCETT is not isotonic .i.e. it may not guarantee optimal and loop free path to destination. If a metric is not isotonic, then it is very difficult to use with link state routing protocols it can be implement further enhance of WCETT.

A new routing metric can be proposed which addresses above said limitations. [1] [2] [3] [4]

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[3] © 2011 Global Journals Inc. (US) Global Journal of Computer Science and Technology Volume XI Issue XXIII Version I 33 2011 December Performance Analysis of Routing Metrics for Multi Radio Multi Channel in Wireless Mesh Networks

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Figure 1:

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