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Comparative Analysis of Routing Metrics for Network Communication

Ijaz Ali Shoukat, Abdullah Al-Dhelaan, Mohsin Iftikhar

Computer Science Department, College of Computer and Information Sciences
King Saud University, P.O. Box. 51178, Riyadh 11543, Saudi Arabia

Abstract: This article contributes the comprehensive evaluation of routing metrics. Usually, rich quality link facilitates efficient response even with more number of hop-counts rather to a poor quality link that has smaller number of hop-counts. Hop-counts metric is preferably used in routing functions due to its simplicity and stability. No other routing metric persists with these two capabilities. But the question is that whether this metric always gives accurate and optimal outcomes? Can this metric alone be employed to get optimal performance? We made an effort to examine several routing metrics under several technical parameters such as load sensitivity, load balancing, packet loss ratio, packet rate, packet size, isotonic property, link quality, inter-flow and intra-flow interface etc. We analyzed which of the selected routing metrics provides optimal routing services with optimal performance? Moreover, to predict, when hop-count metric gives best performance in the presence of what kinds of prominent technical parameters? Our research effort is inspired by prior studies related to hop-count and bandwidth approximation practices in routing applications.

Key words: Hop-count · Round-trip-time · ETX · ETT · WCETT

INTRODUCTION

Routing metrics are the eye of router to select optimal route among multiple mesh of routes. Dynamic routing discovery and automatic rate adaption are the potential issues in managing of network routes. The authors of study [1] closely interlinks these two problems with rich dependencies by opposing the prior arguments of no relationship between these two. Route discovery always preferred smaller number of hop-counts but this discovery is not always adequate as concerns with this study. More often cache possesses several links with same count of hops toward similar node that always prefer to choose shortest path [2] but in case of any un-expected error or failure, the source node may not be predict another fresh link route with similar number of hops.

Variety of routing metrics like hop-count, round-trip-time, queue length, Expected Transmission Count (ETX), Expected Transmission Time (ETT) and Weighted-Cumulative-ETT persist to guide the router to select optimal path. But, lowest administrative distance (hop-counts) is the preferred metric in distance vector routing protocols that usually considered as superior rather to the other metrics. Hop count metric calculate minimum number of hops between host and destination to select optimal path. Minimum count of hops is also considered an adequate decision to filter traffic in Wireless Mesh Networks (WMNs) [3]. Hop-count metric has been evaluated by the authors of study [3] under four parameters such as throughput, jitter, packet lost and end-to-end latencies. Moreover, in ad-hoc networks hop count metric is utilized to choose shortest distance path but this metric associates several limitations that declares it as insensitive to predict link capacity, packet loss, link quality, data rates and channel diversity as discussed in study [3]. A link with good quality and bulky capacity can facilitate optimal performance (throughput) rather to a route with limited number of hops which means the hop-count metric is un-reliable in this scenario. If there are two paths one is has fast link speed with 5 hop counts and other has 3 hop counts with slow link speed. The fast link provides best performance with 5 hops rather to 3 hop counts with slow link speed [4]. This statement is quite noteworthy against hop-count metric.

It has been reported in study [5-8] ETX provides best performance as compared to hop-count metric and RTT is

Corresponding Author: Ijaz Ali Shoukat, Computer Science Department, College of Computer and Information Sciences, King Saud University, P.O. Box. 51178, Riyadh 11543, Saudi Arabia.

marginally poor in performance. ETX choose bulky loaded route with limited number of hops but it did not give sufficient information about the link quality (free, busy) [9]. Round-trip-time (RTT metric calculates the RTT time of each subsequent neighbor node. The efficiency of RTT metric relies on load and extra load may leads the route to instable condition (self-interface). Moreover, this metric associates over-burden of RTT calculations. Its instability and self-interface issues are discussed in studies [5, 10]. Expected Transmission Count (ETX) measures the packet loss rate between two adjacent nodes to guess the required retransmission of unicast packets. This metric associates little chances of suffering in to instable condition of self-interface as agreed by the authors of study [5]. Best routing protocol necessarily be dealt with certain sort of factors like throughput, interface compatibility and isotonicity as supported by the authors of study [11]. The authors of studies [12, 13] have reported that limited number of hop-counts does not grantee a good throughput. Due to simplicity and stability, hop-counts metric is preferably utilized in routing algorithms but hop-counts metric does not always permit the provision of highest throughput [14]. This is another noteworthy discrepancy associated with hop-counts metric. Moreover, hop-counts metric did not have any parameter to decide whether there was a packet loss or not and similarly, it did not have any bandwidth measuring parameter too [14].

Re-direction of internet traffics over multiple routes triggers the happening of jitter which degrade the performance in real time applications [14]. Remote traffic on internet is progressively rising; the size of indexed web contents was estimated more than 25 billion of web pages [15] in January 2011. Bulky internet traffic and mesh natured complex internet connectivity are the greater sources of delay and load. The authors of study [16] declares packet loss metric as a prime metric as compared to the delay metric because packet dropping rate results higher latency, poor bandwidth, feeble throughput, poor response and large queue length. Errors on network layer are directly proportional to the round trip latencies of data packets in bandwidth greedy network applications [17]. The response of any remote server will be as poor as will be the network's errors and due to poor response, users have to bear more degree of latencies with more number of hits and session failures [17]. Furthermore, it has been reported in study [17], 40% failures happen due to the failure of network devices, 70% due to link failures, 10% due to link jumps and cumulatively the network error ratio has been recorded 1.23% against every 100 user requests. In wireless mesh network, hop count metric has been proved worst against delay and pack dropping rate parameters however, Expected transmission count (ETX) has been shown best and RTT is shown better as depicted in Figure 1 [18].

RTT metric possesses higher load sensitivity. Due to bulky load, RTT sometimes results worst performance even with only one hop count. Therefore, RTT is not a stable metric and often got self-interface instability condition. Frequent removal of poor quality links may lead the route to have a condition of no route which requires route discovery policies to be commenced in future routing protocols. The probability of happening link failure is more on poor quality link as compared to the link having good speed. The performance of hop count metric is directly proportion to the link speed. High link speed

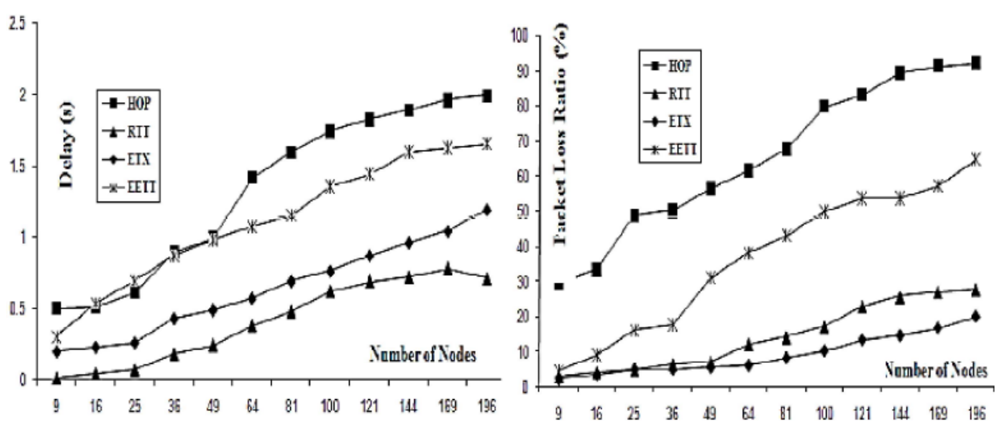

Fig. 1: Routing Metric Comparison with Delay and Packet Loss ratio

Table 1: Comparison of routing metrics [7][11] [12] [5, 9, 20]

Technical Factors	Hop Count	Round trip time (RTT)	Expected Transmission Count (ETX)	Expected Transmission Time (ETT)	Weighted Cumulative ETT
Load sensitivity	v	v	×	×	×
Load balancing	×	v	×	×	×
Delay (among 50 nodes)	Highest	Average		High	Low
Throughput	×	×	v	High	Highest
Scalability	×			High	High
Packet rate variances	Low	×	×	High	High
Packet loss accountability	×	×	v	v	v
inter-flow interference (interference between neighboring nodes)	×	×	×	×	×
Isotonic property	v	v	v	v	×
Intra-Flow interface Problem	×	×	v	×	v
Handling of Link Quality	×	v	v	v	v
Handling of Link capacity	×	×	×	v	v
Handling of Packet Size	×		×	v	v
Highly Stable	v	×	×	×	×
Simplicity	v	×	×	×	×

with more number of hops can provide better performance rather to a slow link with smaller number of hops. However, Hop count metric possesses two unbeaten advantages such that its simplicity and stability.

Bulky load triggers the congestion with more number of hop counts and service latency but congestion free load does not necessarily cause of more hop counts with higher RTT [19]. RTT always increases in the presence of both conditions either load or congestion. In 2011, researchers have been reported that in between normal and loaded situation if the difference of hop-counts is greater than 2 and normal RTT value has been gotten an additional increment of half of normal RTT, then there will necessarily be congestion [19]. High load cannot be resulted into congestion unless above mentioned condition will be fulfilled because hop-count metric has direct relation congestion [19]. The ultimate objectives of having no congestion is to minimize the number of hop-counts, end-to-end latencies to boost up the throughput without having any packet loss but this metric (hop-count) does not have any parameter to predict whether the link is active or dead. The core objective of this study is to evaluate selected set of routing metrics under 15 technical factors in order to predict optimal routing metric. Next section of this study represents the comprehensive comparison of selected routing metrics.

Comparison of Routing Metric: All selected routing metrics have been compared under 15 technical factors as discussed in Table 1. Load sensitivity, delay, throughput, isotonic property, Intra-flow interface, link quality and packet loss accountability are the main parameters to create differentiation among the selected routing metrics. Isotonic means the optimal and loop free path is guaranteed between source and destination. Sometimes, two links have the same path in the router's interface which creates the problem of intra-flow interface. This problem can be managed by choosing diverse (different) channel path. However, the inter-flow interface is an intermediate interface between neighboring nodes.

Next section of this article provides a comprehensive discussion and analysis on all selected set of routing metrics by employing the comparison of Table 1. In this way we have categorized the best routing metric under 15 technical parameters.

DISCUSSION

According to the summarized analysis of Table 1, hop-count metric is load sensitive and did not handle link quality, link capacity, intra-flow interface problem and scalability. Moreover, hop-count metric is also poor in performance characteristics such as its delay is high, it cannot balance the traffic load, it gives poor throughput with highest delay and cannot handle packet size as well as packet loss ratio. However, in case of stability, simplicity and shortest route identification, hop-count metric is better as compare to all other routing metrics. Round-trip-time (RTT) is also load sensitive and cannot handle packet size, throughput link quality, link capacity, packet loss probability, packet rate variations, inter-flow and intra-flow interface issues but it can balance load with average delay. Moreover, the best characteristic of RTT is that it can identify link quality with active or dead link provision. All other routing metric can handle link quality except hop-count metric. Similarly, all selected routing metrics are isotonic except Weighted Cumulative Expected Transmission Time (WCETT). All set of selected routing metrics cannot balance the load of traffic except RTT metric.

There is a close completion between ETX and ETT metric. ETX is not a load sensitive metric and can handle link quality, packet loss ratio and intra-flow interface problem but it cannot handle link capacity, packet size, packet rate variances and inter-flow interface issues. ETT is superior to ETX because it can handle intra-flow interface problem, link capacity and packet size as compared to ETX. Moreover, ETT has high throughput and scalability rather to ETX metric but ETT has higher delay and packet variances as compared to ETX. WCETT has all characteristics like ETT with positive edge of low delay but it associates two major issues in terms of isotonic and intra-flow interface characteristics. Due to these characteristics, WCETT metric possesses the possibility of forward loop occurrence and path conflicts in case of same path for two links, that's why it is one step down to the ETT in performance rank. Hop-count metric is not reliable always and alone it cannot provide optimal performance. It is an ideal metric only in case of having no fear of link quality and intra-flow interface problem because of its shortest route, simplicity and stability characteristics which make it prominent as compared to all other routing metrics.

CONCLUSION

Off-course, hop-count metric has three prominent properties (shortest route, simplicity and stability) but link quality is the most significant metric rather to these properties because a shortest hopped route may has poor performance as compared to good quality link even it has long route. Therefore, hop-count metric is not reliable always and alone it cannot facilitate optimal performance because its performance is dependent on link quality. RTT can balance load and handle link quality but it cannot cover many of discussed significant parameters. ETX associates the major drawback of intra-flow interface problem as compared to ETT and WCETT also associates two non-ignorable drawbacks in terms of isotonic and intra-flow interface characteristics. Due to these characteristics, WCETT metric possesses the possibility of forward loop occurrence and path conflicts in case of same path for two links. Therefore, ETT routing metric possesses the capability of handling maximum significant parameters as compared to all other metrics. Hence, ETT is a best routing metric rather to hop-count, RTT, ETX and WCETT.

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