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A Survey on Searching Range Adaptation for Improving the Throughput in MANET

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Abstract: Improving end-to-end throughput is the main application in multi hop wireless networks. This is the one of the major challenges. Traditional multi hop routing protocols are designed for having the least hop count for an end-to-end connection. This reduces the contending parties that have to share the upper-bounded bandwidth and, therefore, improves the throughput. The examples are the mobile ad hoc networks (MANET), which select a route with the smallest hop count and it will reducing the end-to-end throughput because more nodes have to be included in the routes. The available data rate and the number of active nodes are two conflicting factors that affect network throughput. To improve throughput by selecting routes according to metrics other than hop counts. In this paper, we first analyze the impact of link distance on end-to-end throughput in wireless networks. From the analysis the simulation results show that changing the link distance affects the change in the network throughput. To achieve a high network throughput, a proper link distance (i.e. load density) is required for each hop. According to the load density, ASR can help improve the network performance by adjusting the link distance in the routes.

Keywords: ASR, multi hop wireless networks, load density, data rate control.

I. INTRODUCTION

The main objective of this topic is to improve end-to-end throughput in MANET using Adaptive Searching Range Algorithm (ASR). In this paper, we have studied link distance on network end- to- end throughput in multi rate multi hop wireless networks and which can be obtained from [2]. We built mathematical model for analyzing the end-to-end throughput in different network scenarios. Through analysis and simulation, it is observed that by changing the link distance to an optimum value, the highest network throughput can be reached. In this the least-hop route generally increase the geographical distance for each hop, the maximum signal-to-noise ratio (SNR) at the receiving end becomes low due to the long attenuation path and it will lead to small end-to-end throughput. On the other hand, achieving a high data rate in [1] and by reducing the geographic distance of hops in more contending nodes in the network. Each node then has less opportunity to send data. In this scenario, the available data rate and the active nodes are the two conflicting factors that affect the network throughput for that we have proposed the ASR algorithm to improve the network throughput by adjusting the next hop searching range in route discovery and thus changing the link distance. Link distance that is discussed in [2] is adjusted according to the network load. For example, in a network with low load density, routes selected by ASR are built by hops with a small link distance. Simulation results show that ASR helps to improve the network end-to-end throughput.

II. PROBLEM DEFINITION

Traditional routing protocols such as ad hoc on-demand distance vector (AODV) routing protocol [10] and dynamic source routing (DSR) routing protocol [9] are designed for multi hop wireless networks select a route with the smallest hop count. This implies a large link distance for each hop and a corresponding low-link data rate. Therefore, the end-to-end throughput for the route can be low. Using routes built up with hops of very short link distance can increase the link data rate. However, the throughput may not be improved because more ad hoc nodes have to share the ad hoc channel.

To overcome, we have proposed the ASR algorithm [11] to improve the network throughput by adjusting the next hop searching range in route discovery and thus changing the link distance. Link distance is adjusted according to the network load. For example, in a network with low load density, routes Selected by ASR are built by hops with a small link distance. Simulation results show that ASR helps to improve the network end-to-end throughput. In this paper we also considered link distance for power savings in [2] and [4].

III. RELATED WORK

IMPROVING end-to-end throughput is required particularly for high-data-rate multimedia applications [1] in multi hop wireless networks. However, it remains as one of the major challenges. Traditional multi hop routing protocols are designed for having the least hop count for an end-to-end connection. This reduces the contending parties that have to share the upper bounded bandwidth and, therefore, improves the throughput. The examples are ad hoc on-demand routing protocols, such as ad hoc distance vector (AODV) routing protocol [10] and dynamic source routing (DSR) [9], or position-aided routing protocols, such as greedy perimeter stateless routing (GPSR).

We analyze the impact of link distance on network throughput in simple network scenarios. The link adaptation scheme determines the selected data rate based on the receiving SNR. We first introduce our initial observations on the relationship between the link distance and the end to-end throughput [2] and [4].

Mobile IP networks in [3] is the only the last hop to each mobile node is wireless and communications between nodes must go through the associated base stations (BSs). Each wireless link is established only between the BS and a node in the cell. When the node roams to another cell, the link is handed over to the respective BS to retain the ongoing connection. I have taken various examples related to least hop count in multi hop wireless routing protocols in [6].

IV. HIGH-THROUGHPUT METRICS (HTMS)

A number of HTMs have been proposed by [12] to measure the qualities of wireless links and wireless paths composed of multiple hops. These metrics can be classified into different categories according to different criteria, reflecting their fundamental design and implementation choices. In this section, we give a taxonomy of existing HTMs, and discuss current design of supporting HTMs in DSR routing protocol.

A. A taxonomy of HTMs

We classify high-throughput routing metrics based on the taxonomy that consists of three categories: link quality measurement, path quality measurement and radio model.

Link quality measurement:

A fundamental issue in HTM design is the quality measurement of a wireless link. Existing schemes use a variety of methods to measure link qualities. We summarize these methods into the following three categories:

- Counting packets: A node counts the number of packets received from each neighboring node. These packets are either dedicated probing packets or existing control and data packets. Metrics in this category include ETX , ETT estimated delivery rate (or loss rate) , and so on. We classify ETT in this category because it uses ETX.
- Measuring time: A node measures the time needed to transmit a packet to a neighboring node. For example, the RTT (per-hop Round Trip Time) metric is based on the round trip delay seen by unicast probes between neighboring nodes.
- Measuring distance: In geographic routing, a node may measure the distance to a neighbor and the cost (e.g., power consumption) to transmit a packet to that neighbor. The goal is to obtain a high advance-to-cost ratio. An example of such metrics is normalized advance (NADV).

Path quality measurement:

This refers to the operation of accumulating individual link metrics on a path to obtain an end-to-end metric for that path. The path quality measurement is associated with the method for the link quality measurement.

The following operations are used to calculate a path metric:

- Addition: The path metric is the sum of metrics of each hop. The ETX scheme is a representative of this type.
- Multiplication: The path metric is the product of metrics of each hop. An example is the delivery rate metric.
- Mixed operations: The calculation of path metric involves mixed operations. For example, the ETT scheme applies a tunable weight to reflect the ETT and the channel diversity. In other words, both addition and multiplication are used.

Radio model:

We use this criterion to classify the radio model that an HTM scheme is based on. In existing HTM schemes, two radio models are used: single channel and multiple channels.

- *Single channel*: Nodes in the network are equipped with homogeneous radio cards, and the cards operate on the same channel. The ETX scheme is based on this model.
- *Multiple channels*: Nodes are equipped with heterogeneous radio cards (i.e., different standards such as 802.11a and 802.11b), or equipped with homogeneous radio cards, but the cards operate on different channels. The ETT scheme is proposed to work in the multiple-channel situation.

B. The existing approach to supporting HTMs in DSR

DSR is a natural choice when supporting HTMs in on-demand routing protocols, because an HTM scheme typically needs to collect link state information to calculate the shortest path, in terms of a particular HTM. In DSR, a source node explicitly designates the route to a destination in the header of data packets. Routes are established by recording traversed paths in RREQ (route request) messages and returning discovered paths in RREP (route reply) messages. In general, DSR is modified in the following ways to support an HTM.

- First, when a node forwards a RREQ message, it appends not only its own address, but also the metric of the link (over which it received the RREQ) to the message.
- Second, when a node receives a duplicate RREQ packet, instead of simply discarding it, the node will broadcast the RREQ if the accumulated metric in the message is better than the best metric it has forwarded for this RREQ. This approach increases the overhead of a route discovery, but it is necessary to collect link state information for the shortest-path calculation.
- Third, the source node does not use the routes returned by RREP messages directly. Instead, it stores the replied routes in a link cache, where routes are saved as separate links. Then the source runs Dijkstra’s shortest-path algorithm on the link cache to find the shortest path to the destination.

Based on the above observations and the intuition they are supporting for HTMs in on-demand routing protocols for multi hop wireless networks.

V. PROPOSED FRAMEWORK

In the load based route discovery to achieve a higher network throughput, the link distance requirement should be shorter if the network has a lower load density and should get longer as the network load density increases.

In this section, we explore the idea of adapting the link distance to improve the ad hoc network capacity. We first propose the ASR algorithm, where the searching range for route discovery is determined based on the local network load density.

A. *ASR Algorithm:*

In the ASR algorithm, there are two major procedures regarding route discovery, i.e.,

- a node estimates its local network load density; and
- based on the load density, the node decides its searching range.

It is difficult for a node to obtain the number of connections in an ad hoc network. However, a node can estimate its local network load density by measuring the number of active nodes that are within area. A simple approach to estimate the local load density can be that a node finds out how frequently it senses a transmission. To obtain more precise information, a two-hop local information exchange scheme, as illustrated in Fig. below, is proposed.

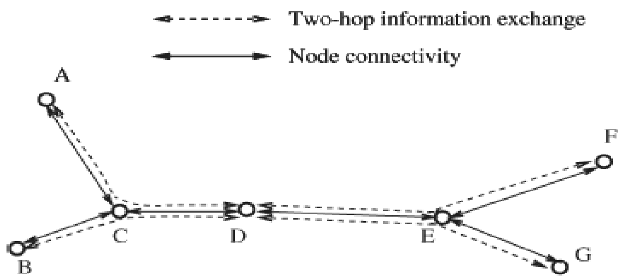

Figure 1: Two-hop exchange information

Each active node sends a message to all the nodes that are within two hops away from itself, indicating that it has queued packets. The time-to-live (TTL) value for this message is set as 2. If a message sender knows any active nodes that are less than two hops away from itself, it includes that information in the message as well. Such an information exchange guarantees that a node is aware of any active node within four hops from itself. For example, in Fig. above, if *A* and *B* are both active nodes, *D* can learn the information because it is two hops away from *A* and *B*. After *D* processes the two-hop information exchange with *F* and *G*, *F* and *G* know that *A* and *B* are active. Through the two hop information exchange, a node can know approximately how many other nodes are contending for the channel with itself. It is more challenging to determine the searching range based on the load densities. As it is difficult to derive an explicit mathematical expression for the relationship between load density and optimum searching range, we obtained such a relationship through extensive simulation

B. *ASR Evaluation:*

In this section, we evaluate how ASR can improve the network performance. The network load is categorized into three categories: low load which means less than 25 connections, medium load when there are 25–40 connections, and high load when there are more than 40 connections. For each active node, the local load is the number of active nodes that are within four hops from itself. The average local load densities in networks with 25 and 40 connections are collected through testing a large number of sample networks. These two values are used as threshold values to determine network load categories.

VI. ANALYSIS

A. *Impact of link distance on end-to-end throughput*

For the analysis part of the ASR we first understand about the impact of link distance on end-to-end throughput, Shannon's theory and the two-ray ground propagation model.

The link adaptation scheme we considered the relationship between the link distance and the end-to-end throughput.

End-to-End Throughput versus Link Distance:

The related knowledge for investigating the relationship between the end-to-end throughput and the link distance is as follows.

- **Shannon's Theory**: Shannon's theory gives the theoretical upper bound for the achievable transmission data rate in a one-hop connection. According to Shannon's theory, the maximum data rate *C* that can be achieved in the channel with a bandwidth of *B* is

$$C = B \log2 (1+pr/nr)$$

Where pr is the receiving power, *nr is* the noise, and *pr/nr* is the receiving SNR. When $pr/nr \leq 1$, *C* is approximately linearly related to *pr/nr*. When *pr/nr* is large, the data rate slowly increases when *pr/nr* increases.

- **Two-Ray Ground Propagation Model**: The two-ray ground propagation model is the radio propagation model often used for the open field. Denoting *pt* to be the transmitting power and *d* to be the distance between a transmitter and its receiver, the receiving power *pr* is

$$p_r = \frac{p_t G_t G_r h_t^2 h_r^2}{d^4} = \frac{kp_t}{d^4}$$

Where *Gt* and *Gr* are antenna gains at the transmitter and receiver, and *ht* and *hr* are the antenna heights, respectively. When the gains and heights are fixed, *k* is a constant. In this model, the signal power attenuates fast (in a fourth-degree polynomial) as the transmission distance increases. The analysis of impact of link distance and end-to-end throughput and ASR routing algorithm, the throughput is improved in MANET using ASR is achieved.

Using High-Throughput metrics which is described in section [IV] in ASR which helps for improvement in end-to-end throughput.

VII. SIMULATION RESULTS

A. *Comparing the performance of GPRS with ASR*

Fig. 2 compares the GPSR that adopts ASR with the basic GPSR and the GPSR using optimum searching ranges. Using optimum search range means an active node adjusts its searching range whenever its local load changes. The GPSR with ASR has a better delivery ratio than the basic GPSR. Its delivery ratio is lower than that in GPSR using optimum searching ranges because ASR is a suboptimum algorithm and uses only one searching range for networks falling into the same load category. However, the performance degradation is marginal.

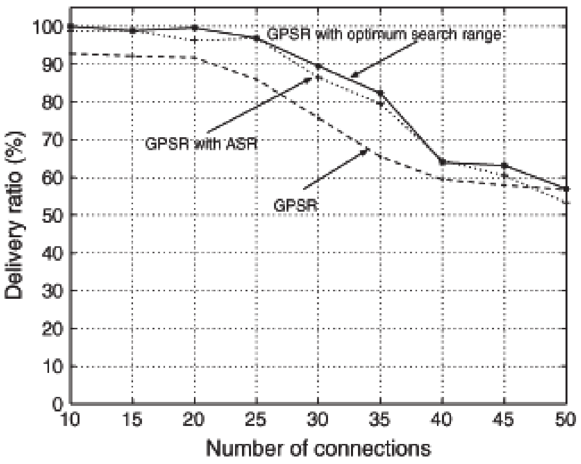

Figure 2: Delivery ratio in GPSR, GPSR with ASR, and GPSR with optimum searching range.

B. *Comparing the performance of AODV with ASR*

The delivery ratios for the basic AODV, the AODV with ASR, and the AODV with optimum searching ranges are compared in Fig. 3

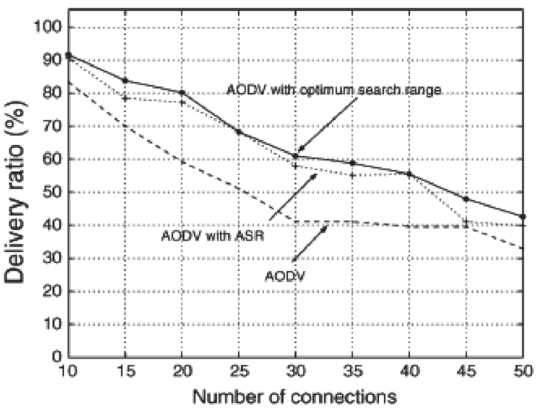

Figure.3: Delivery ratio in AODV, AODV with ASR, and AODV with optimum searching range.

The results show that ASR can also help to improve the AODV throughput. As for delivery ratio, ASR helps the protocols reduce the average packet delay at different network loads.

C. *Throughput Analysis in Networks With Contention-Based Channel Access:*

The analytical model and major observations for saturation throughput in a wireless local area network (wlan) that use CSMA/CA as the channel contention mechanism are presented in [5]. Saturation throughput is defined as the throughput in a network where each node always has queued packets to send. The saturated throughput depends on the number of contending users and the bakeoff schemes. Although the method in [5] is developed for analyzing the single-hop wlan, it can be applied to a multi hop case if the transmitting nodes are within the carrier sense range of each other. Note that the carrier sense range is much larger than the transmission range.

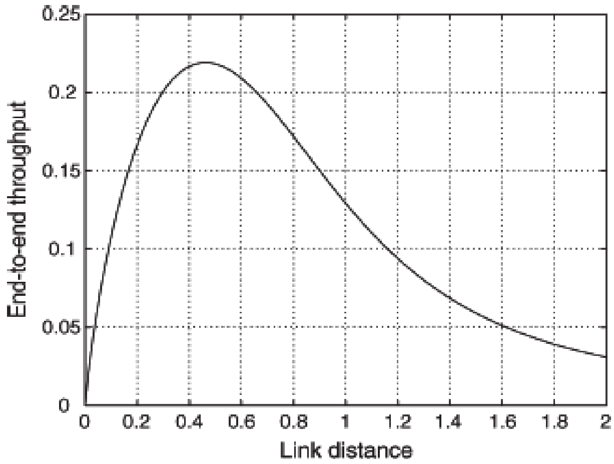

Figure 4: Throughput versus link distance in a general network.

In a multi-rate ad hoc network, multi-hop routes with different link distance result in different end-to-end throughputs. When considering the two-ray ground radio propagation model, if the wireless links in a route have a small SNR at the receiving ends, reducing the link distance can result in a large SNR gains. The data rates in the links can significantly be increased. The overall network end-to-end throughput may be increased. If the link distance has already been short, and the receiving SNR has been high, further reducing the distance does not generate much data rate improvement. In this case, the overall system throughput may decrease because the increase of the number of nodes may be more dominant. This indicates that in a network if the routes are built by hops with a proper link distance, a higher throughput can be achieved than the case when routes are arbitrarily selected.

We further explore the above observations by using a simplified model derived from the results in [7]. According to [7], the throughput for an end-to-end connection in a general wireless network is $\Theta(W/\sqrt{n}\ \log\ n)$, where W is the transmission rate, and n is the number of nodes in the network. We assume that in a network, nodes are evenly distributed, and therefore, the distance between any two neighboring nodes that are within the wireless transmission range is approximately the same. Denoting this distance as d, then $n \propto 1/d2$. Using (2) and (3), the throughput for any end-to-end connection between two ad hoc nodes, which are denoted as η, can be formulated as

$$\eta = \frac{k_1 \ln\left(1 + \frac{k_2}{d^4}\right)}{\sqrt{\frac{k_3}{d^2}\log\frac{k_3}{d^2}}}$$

Where $k1$ depends on the available bandwidth, $k2$ depends on the antenna gain and background noise, and $k3$ depends on the network size. $k2$ and $k3$ determine how η changes when d changes. In Fig. 4, we illustrate the relationship between throughput and link distance. We have used different sets of parameters for $k1$, $K2$, and $k3$, whereas the trends of the obtained curves are similar. It shows that there is an optimum link distance at which the throughput is the highest.

VIII. CONCLUSION

In this paper, we have studied link distance on network end-to-end throughput in multi-rate multi-hop wireless networks. We built mathematics models for analyzing the end-to-end throughput in different network scenarios. The key parameter is the network load density, which is defined as the number of active nodes. It is observed that when the network load density is low, the optimum link distance should be short. Otherwise, the optimum link distance should be longer. Based on this, we have proposed the ASR algorithm to improve the network throughput by adjusting Searching range in route discovery and changing the link distance. Link distance is adjusted according to the network load. However, the throughput may not be improved because more ad hoc nodes have to share the ad hoc channel.

To overcome, we have proposed the ASR algorithm to improve the network throughput by adjusting the next hop searching range in route discovery and thus changing the link distance. Link distance is adjusted according to the network load. According to the load density, ASR can help improve the network performance by adjusting the link distance in the routes. Simulation result shows that ASR helps to improve the network end-to-end throughput.

IX. FUTURE WORK

The future is more challenging to determine the searching range based on the local load densities. As it is difficult to derive an explicit mathematical expression for the relationship between load density and optimum searching range, we obtained such a relationship through extensive simulation. In this paper, we investigated the networks with uniformly distributed node and traffic, where the local load densities for most nodes are approximately the same. Therefore, the searching range determined by any node based on its local load density is approximately the same as by other nodes and can be looked as a global value.

It is neither feasible nor necessary to change the searching range whenever there is any local load variation. Instead, the load can be divided into different categories. In our approach, the local network load density is categorized into three categories, i.e., low load, medium load, and high load. For each category, there is an optimum searching range, which is obtained by simulating sample networks.

Note that ASR is actually a distributed algorithm that tries to improve the global performance through local network procedures. A global searching range is actually not required. Therefore, ASR may also work in networks where traffic is not uniformly distributed, which is normally the case in a real ad hoc network. The relationship between the searching range and the local load density in such a network is more complicated and will be studied in our future work.

In the future, we will further derive the path lifetime based on the analytical results developed in this paper. The probability distribution of the path lifetime in mobile ad hoc networks is even more difficult to derive than link duration since it is dependent on many system parameters, such as spatial distribution, node density, and path connectivity.

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