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[奨励講演] Routing Approach for Quality of Service and Stability in Mobile Ad-hoc Networks

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Abstract　In a highly dynamic network like Mobile Ad-hoc Network (MANET), improving communication quality and provisioning Quality-of-Services (QoS) is a very challenging task. Many researches have shown various techniques to provision QoS in MANET. However, it is often difficult to provide necessary QoS support in MANET because of unstable routes. Due to selecting inappropriate wireless links, route breaks are often observed whereas alternative stable links are readily available to make more stable routes. In this paper, we consider wireless links' capability of carrying packets of different sizes and build routes that is most appropriate for the application data packet sizes. For this, we do not rely on link history which is difficult to acquire in a highly dynamic networking environment like MANET. We also present simulation results to show the validity of our concept and the efficiency achieved.

Keyword　MANET, QoS, Routing, Stability

[奨励講演]モバイルアドホックネットワークにおけるリンクの安定性を考慮したQoS指向ルーティング方式

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あらまし　モバイルアドホックネットワーク（MANET）において，QoS の保証は大きな課題である．ネットワークトポロジの頻繁な変化や無線空間の不安定性などの理由により，MANET においては既存の QoS モデルの適応が困難である．筆者らは，トポロジ変化に伴うルート再構築問題を解決するために，マルチパスルーティング方式を提案している．マルチパスルーティング方式では，複数のルートを構築しておくことで，ルート再構築にかかる処理時間の短縮を目標としている．本論文では，ルート再構築回数の低減を目標とし，リンクの安定性を考慮したルーティング方式を提案し，その評価結果を示す．筆者らが提案しているマルチパスルーティング方式によりルート再構築時間を短縮し，本論文にて提案する QoS 指向ルーティング方式によりルート再構築回数を減らすことで，QoS 保証のためのより安定した MANET プラットフォームを提供する．

キーワード　MANET, QoS, ルーティング, 安定性

1. INTRODUCTION

Mobile Ad-hoc Network (MANET) is a network where mobile nodes with wireless interfaces construct a wireless network on their own. As mobile wireless devices have become a commodity, wider uses of MANET technologies in our daily life is under consideration both in the academia and in the industry.

Due to mobility and wireless links characteristics, topology of the network changes very frequently. Hence, the topology management and the resulting end-to-end routing has been the most difficult but the main task in this research area. Many routing protocols, e.g AODV [1], OLSR [2] have been proposed and well-investigated for topology management and routing in MANET. However, these routing protocols often fail to cope with the mobile nature of MANET and the consequent performance degradation because of route breaks.

In this paper, we consider route stability to reduce the number of route breaks and the consequent re-routing to improve the communication quality in MANET. The conventional routing protocols selects wireless links based on their availability and employ least hop routing. However, unlike the wired or the well-planed wireless networks like cellular, connectivity has more than two states in MANET. Ever changing physical proximity among nodes, use of unlicensed spectrum, interference, noise etc. make the relation between two nodes not only connected or disconnected but also weakly-connected or merely-connected. Mere existence of a wireless link between two nodes do not guarantee the delivery of data packets to the receiver. Because of *Large-scale Fading*, signal power attenuation and path loss are observed due to radio propagation over long distance [3]. This signal power attenuation is not linear over distance and increases abruptly in the Gray zone [4] near the border of the transmission area. As bit error rate (BER) increases with distance, nodes in the Gray zone have lower probability of perfect reception for larger packets. Because most routing protocols employ least hop routing, nodes in the Gray zone have higher probability of being adopted in the routes which results into low packet delivery ratio, repeated link layer (L2) retransmission and frequent route change.

Many approaches have been considered to enhance link and route stability in MANET. However, these approaches either rely on link history or external functions like GPS. We consider it a fairly difficult task to acquire a reliable link history in MANET where nodes are constantly moving, joining or leaving. External functions like GPS increase cost and also difficult to integrate in the available routing protocols without major modification.

In this paper, we propose a simple but effective method to confirm links in order to build suitable end-to-end route for different sizes of application data packets. We show that link stability and the consequent route's stability can be considered as a function of application packet length seen from the Network Layer (L3). By using larger control packets, we remove nodes in the Gray zone when making routes instead of short packets defined in the conventional routing protocols. It is a Network Layer (L3) solution and is completely independent of the underlying access (L2) and wireless media (L1).

In our previous work [5], we have investigated routing protocols weaknesses in handling mobility and presented multipath based robust routing techniques. Multipaths were made in advance for fast rerouting and primary routes are switched to backup routes as soon as they are broken or some quality parameter value degrade. In [5], we showed that it is fairly possible to make necessary multipaths in a link-disjoint manner in moderately dense ad-hoc networks. This work can be used with [5] to enhance network stability further.

The rest of the paper is organized as follows. Section 2 presents related works, Section 3 presents an analysis of link stability, Section 4 gives the details of our proposal. Section 5 presents the simulation results of our proposed method and Section 6 summarizes this work.

2. RELATED WORKS

Associativity Based Routing (ABR) [6] is one of the earliest works to incorporate link stability in ad-hoc routing. A link is considered stable if it exists beyond a threshold value of time. This threshold value is determined from the relative speed and transmission range of the node. Although nothing is particularly said on how the speed is measured, it would be extremely difficult for each node to determine its relative speed with respect to all other nodes around it.

[6] takes an observation approach where every node adopts links after an observation period. Nodes also save link duration they observe to make smart decision. However, considering the highly mobile nature and dynamicity of MANET, these history based approach is not practical as it would be fairly difficult to build a reliable history on the ever-coming and leaving mobile nodes and their links. Besides, [6] shows that the history and the consecutive *link residual time* which is the main criteria for a link adoption depends on the mobility model. This makes it even more difficult for nodes in the same MANET with different mobility patterns. And these stateful approaches consume memory as well as battery for the continuous complex computation necessary for statistical determination of the *link residual time*.

[7] and [8] propose link adoption schemes based on the received signal strength. When a packet is received, every node notes the received signal strength and if it is higher than a predefined threshold, the link is adopted for future transmission. However, signal strength differs according to the wireless media e.g Bluetooth, 802.11x. And, dismissing a link due to a sub-threshold value undermines the full potential of the network as these may also be of good use for smaller packets.

[4] takes a similar approach but takes SNR value as the link stability parameter. It is also a stateful approach and thus needs memory and computational resources.

3. LINK STABILITY

In this paper, we define link stability by a link's capability of carrying a particular size of IP packet seen from the Network Layer (L3). In this section, we show that this capability differs depending on the distance between the transmitting and the receiving node.

Due to *Large Scale Fading* [3], wireless signal experiences attenuation and path loss over distance. Therefore, bit error rate (BER) increases with distance between the transmitter and the receiver [4]. Seeing from the Network Layer (L3), Packet Error Rate (PER) increases with distance and this rate is higher for larger packets as they have more number of bits. However, the PER and distance is not in a linear relation. Within the transmission range (*r*) of a transmitter, there exists a Gray zone (Fig. 1) in which PER decreases exponentially. The width of Gray zone (*d*) depends on the packet size and is wider for larger packets.

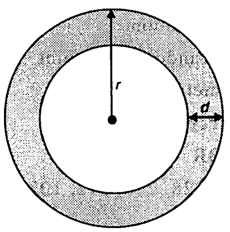

Fig. 1: Gray zone in wireless transmission area

We investigated the packet size-Gray zone relation through simulation in QualNet 3.7 commercial network simulator [10]. QualNet provides a 'closer to reality' propagation and path loss model [11]. Under a 'two-ray ground' propagation model and using 802.11b radio (see Table 1 for details on wireless settings used), we investigated the size of Gray zone for different packet sizes on one wireless link. The result is Fig. 2 which shows packet delivery ratio for 100 packets.

The Gray zone for 1024 byte long packets is 15 meter wider than the one for 64 byte long packets and Gray zone itself can be 30 meter wide even in the minimum case.

Dependency of packet delivery on its size over distance affects MANET's performance because of two reasons. Routing protocols [1], [2] employ control messages e.g HELLO, RREQ to find out neighbors and make routes. Control packets, usually with a size of few tens of bytes, are much smaller than the data packets which are few hundreds of bytes in size. This creates an asymmetry between the control plane and the data plane. Links confirmed by smaller control packets, often fail to carry the data packets which are few times larger in size.

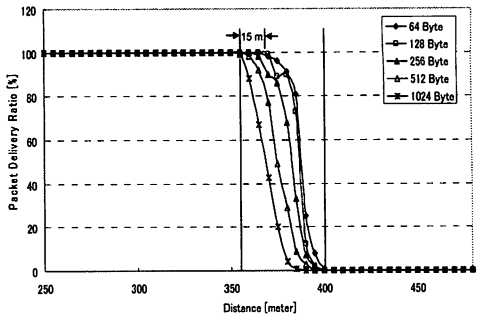

Fig. 2: Size of Gray zone

Secondly, most MANET routing protocols employ *least-hop routing* principle where route with minimum number of intermediate nodes is selected for a destination. This leads to the selection of longer wireless links which ultimately makes the whole route the shortest in hop number but also increases the probability of including nodes in the Gray zones in a route.

4. LINK STABILITY BASED ROUTING

In this section, we present our scheme which is purely a Network Layer (L3) solution to realize link stability based routing. We argue that the routing is the core function of the Network Layer and it should itself be able to determine the quality of its own routes that it provides to the upper layers.

To solve the asymmetry between the control plane and data plane explained in the previous section, we propose to dynamically determine the size of control packets in conformance to the application data packet size for which a route is sought for. We explain our scheme on AODV [1].

AODV searches for route only when it has some data to transmit. AODV broadcasts a Route Request (RREQ) mentioning the intended destination. This RREQ is forwarded at every node receiving the RREQ. The destination or an intermediate node which knows a route to the destination sends back a Route Reply (RREP) to the source. When multiple routes are found, the one with least number of hops is selected.

In our proposal, the source resizes the RREQ to make it equal to the data packet size for which it is about to search a route (Fig. 3). The standard size of RREQ is 24 bytes. If the data packet size is 64 byte for example, the source will add an extra 40 dummy bytes at the end of the RREQ. The principle of this proposal lies on the assumption that, from above example, if a link can transport a 64-byte long control packet, it will have higher probability of being able to deliver a 64 byte long data packet. Therefore, RREQs that reach the destination indeed show the routes that are physically able to deliver a 64 byte long data packet on an end-to-end basis.

When the Network Layer (L3) receives some data to send from the upper layer, as shown in Fig. 3, it determines the size of the data. It has to do it anyway to determine the packet length to write it into the IP header. It then adds some dummy bytes at the end of the RREQ it is about to send to make it as long as the data packet itself. The flooding of RREQ is the same as defined in [1].

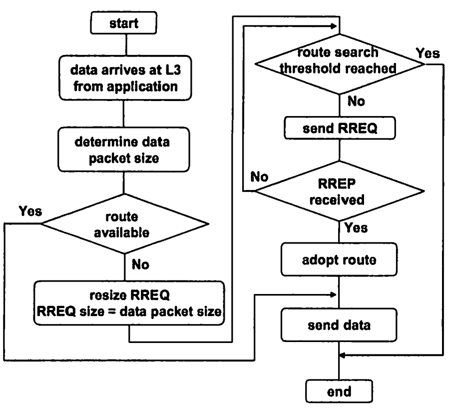

Fig. 3: Flow chart of Link Stability based Routing

When a route is not found with larger RREQ packets, retry is conducted according to original AODV [1] but with the same large RREQ. Please note that, for most up-to-date route information, we do not use route cache. Therefore, all the RREQs in our scheme travel till the destination and the most current capability of the whole route can be investigated.

The RREP and other control packets e.g RERR are not resized in order to keep the overhead minimum.

5. EVALUATION

In order to investigate the effect of our proposal, we carried out extensive simulation on QualNet 3.7 [10] commercial network simulator. 25, 50, 100 and 200 nodes were placed in a 2000 x 2000 sq. meter area. 10 CBR sessions were generated among randomly selected source-destination pairs. Packet sizes used were 64, 128, 256, 512 and 1024 bytes. Simulation time was 200 seconds and sessions were generated randomly within this period. Each session was 10 second long with a transmission rate of 10 packets/sec. Node speed is 1 m/s. We used standard 802.11 MAC and PHY parameters in our simulation. The detail of the simulation scenario is presented in Table 1.

Table 1: Simulation Parameters

Simulation time: 200 second
Area: 2000 X 2000 square meter
Number of nodes: 25, 50, 100, 200
Node placement: random
Mobility mode: random way point
Node speed: 1 meter/sec
Pause time: 2 seconds
Application: CBR
Packet size: 64, 128, 256, 512, 1024 bytes
Session number: 10
Packet per session: 100
Packet transmission rate: 10 packets/sec
Routing protocol: AODV
MAC: MAC802.11
Data rate: 2 Mbps
RTS/CTS: Off
PHY: 802.11b
Transmission power: 15.0 dBm
Receive sensitivity: -89 dBm
Propagation limit: -111.0 dBm
Pathloss model: two-ray ground

Results shown in this section are averaged over 100 runs. For clarity, we present the cases for the packet sizes of 64, 512 and 1024 bytes except Fig. 4 where results for all the packet sizes in Table 1 are presented.

The suffix 'O' points to the results when original AODV was used and 'M' shows the case when our proposal of modified control packet was used. 1024_M shows the case when RREQs of 1024 bytes were used for the same size of data.

In Fig. 4, we plot the number of sessions started in original AODV and our proposal. Number of sessions started i.e, cases where end-to-end routes were found is lower in low node density in both the cases because of the lack in physical routes. In our case, number of successful

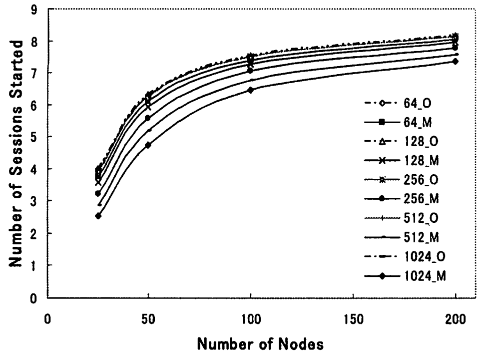

Fig. 4: Number of Sessions successfully started

end-to-end route establishment is lower for all packet sizes. This is because of using large RREQs where routes that are unable to transport the same size of data packets were prevented from being found. We consider this as a positive result. It is better not to admit a session at all than to admit it but not being able to satisfy its requirements.

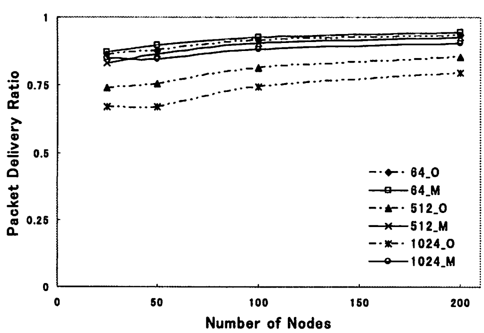

Fig. 5: Packet Delivery Ratio

Fig. 5 shows the Packet Delivery Ratio under different number of nodes i.e, node densities. This Packet Delivery Ratio is determined on the number of packets received at the destinations against the number of packets transmitted from the sources. In our scheme, routes that are unstable are avoided which prevents the consequent packet loss.

Packet Delivery Ratio decreases with data packet size in original AODV and for data packet size of 1024 bytes, it performs the worst. Besides, Packet Delivery Ratio is low in lower node density as links are longer in these cases and larger data packets are often dropped. In our scheme, an improvement of 1%-19% is observed. The improvement is higher for larger data and lower node density which show that our scheme is capable of overcoming the difficulties in original AODV.

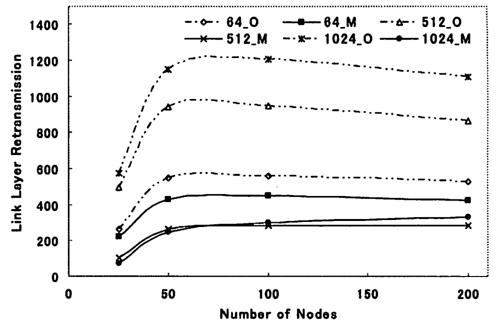

Fig. 6: Link Layer Retransmission

In Fig. 6, we plot link layer (L2) retransmission against different node densities. While using our proposal, 16%-75% reduction in link layer retransmission was observed. This, in conjunction with the result in Fig. 5, is a direct proof of our scheme's ability in selecting stable links. Improvement is higher for larger data packets and lower node densities. As node density becomes higher, links becomes more stable because of shorter distances between nodes. This high reduction in L2 retransmission not only reduces resource consumption from low power mobile nodes but also saves significant bandwidth.

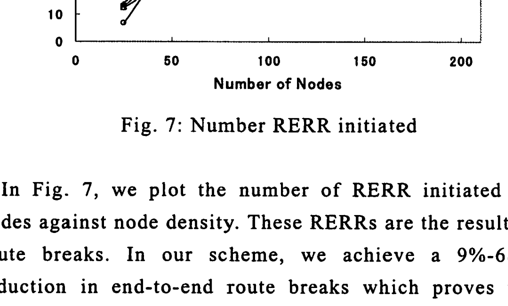

Fig. 7: Number RERR initiated

In Fig. 7, we plot the number of RERR initiated by nodes against node density. These RERRs are the result of route breaks. In our scheme, we achieve a 9%-68% reduction in end-to-end route breaks which proves the efficiency of our scheme in making stable end-to-end routes.

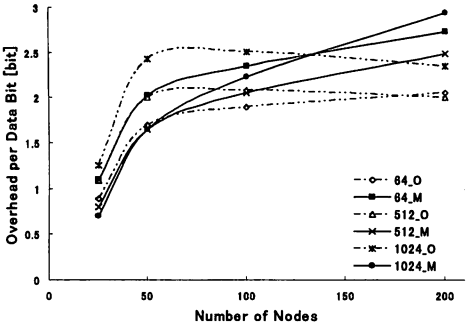

Fig. 8: Control overhead per data bit

Fig. 8 shows the number of control bits necessary to deliver one data bit to the destination.

Total control bits include the total number of link layer retransmissions and all the control signals i.e, RREQ, RREP and RERR. Here, we get a mixed result where the worst case produces a 33% higher overhead and the best case achieves 44% lower overhead. In our scheme, overhead increases for larger packet sizes as RREQ is larger in those cases. Besides, control overhead is higher for node number 200 as most links are comparatively shorter and link layer retransmission becomes fewer. However, although we use 3 – 43 times larger RREQ packets, our proposal produces a 7% increase in overhead on an average over all the packet sizes. It was possible to offset the increase in control overhead by the great reduction in link layer retransmissions (Fig. 6) and other control signals (Fig. 7).

6. SUMMARY

In this paper, we presented a simple stateless scheme for stable routing based on data packet sizes. Our scheme improves packet delivery ratio in pedestrian mobility to as high as 19% with only a 7% increase in bandwidth consumption by control signaling. Besides, consumption of node resources is significantly reduced. Our proposal operates from the Network Layer (L3) and is completely transparent to the underlying layers. We have presented our scheme on AODV without any protocol violation and on least hop routing principle. However, our approach of using larger control packet in unstable wireless environment can be applicable to any wireless routing protocol with minor modification.

Building routes based on stability effectively increases route lifetime which results in less number of route breaks. However, no stability based routing can guarantee route lifetime long enough to complete a session. The route breaks that ultimately occur due to mobility can be handled by multipath approaches presented in our previous work. We consider it indispensable to integrate multiple schemes in MANET to realize a more stable platform on which conventional QoS provisioning and control become possible.

In our future work, we will investigate the increase in node-internal processing generated in our proposal. We would also like to do performance evaluation in congested networks with higher number of sessions to see the affect of using larger control packets.

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