

Route Breakage Prediction Protocol for Bluetooth Network Recovery

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Abstract: - Bluetooth is low power, low cost and short range wireless technology that is specially designed for personal area networks to replace the cables. To handle the Bluetooth dynamic topology, several routing protocols have been proposed. In this paper, the problem of link breakage is considered. During transmission, the routing link may become broken due to the mobility or failure of the devices. To overcome the problem of link breakage, this paper proposes a Route Breakage Prediction (RBP) Protocol for Bluetooth network recovery that predicts the route breakage on the basis of signal strength before the link breaks. The RBP protocol is compared with the existing protocol and the simulation results reveal that the proposed protocol performs better in terms of reducing data packet loss, minimising delay, increasing network throughput and it takes a minimal route recovery time.

Key-words: - Bluetooth, scatternet, routing, link, breakage prediction and route recovery.

1 Introduction

Wireless networks can be divided into two categories, infrastructure and infrastructure-less. The infrastructure networks are those networks which have immovable and wired access points like cellular network systems in which a base station is fixed that acts as bridge to provide connections to the mobile devices. The other form of wireless network is infrastructure-less, which is also recognized as an ad hoc network. The infrastructure-less networks has no fixed access points.

This study proposes a protocol for routing in an infrastructure-less network, the Bluetooth scatternet. Bluetooth is a wireless technology for short range areas to share different kinds of data. Bluetooth devices are unable to transfer data to each other until they create a Bluetooth network. If two Bluetooth devices want to communicate with each other, they first make a small network known as a piconet in which one device will become the master and the other devices will be its slaves. In a piconet, a maximum of eight Bluetooth devices

connect with each other by sharing a common channel. The piconet supports point-to-point (master to slave) and point-to-multi point (master to slaves) links as in Fig.1 [1]. Bluetooth slave devices cannot communicate directly; they always send their data to the master device. The master device always assigns different time slots with different frequencies to the slave devices.

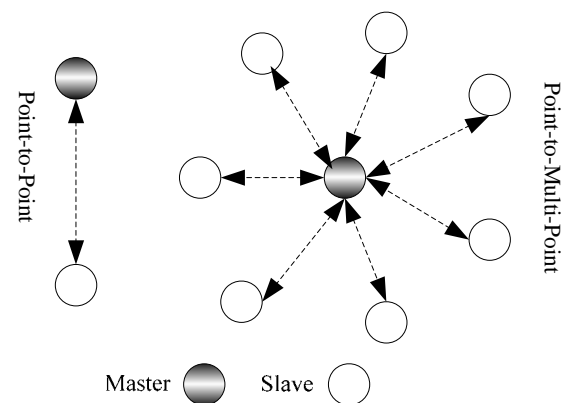


Fig1: Bluetooth Piconet topologies

The time period defined as $625\mu\text{s}$ is the result received by dividing one second into 1600 fragments [3]. The Bluetooth technology allocates time slots by using the Time Division Multiple Access (TDMA) policy. The master device transmits data in an even number of time slots whereas the slave devices transmit data in an odd number of time slots. Piconets are allowed to coincide indecently; the Bluetooth technology requirement makes possible the establishment of connectivity between piconets. A group of connected piconets makes a scatternet [2]. The intermediate device that connects multiple piconets is called a bridge or relay. A bridge device can be master for only one piconet but it can be a slave for more than one piconet.

In a piconet, any couple of source and destination is at most two hops away. A master device maintains the information about all of its slave devices and controls the incoming and outgoing data traffic. In a scatternet, a couple of source and destination devices may be in different piconets so the data packets go through many hops. A number of research papers proposed the routing protocols [4, 5, 6, 7, and 8] for 802.11ad hoc networks, which are concentrated on the on demand route discovery. Chang and Chou [9] for example, propose a BlueLine routing algorithm to decrease the time and path length for direct communication of Bluetooth devices. Considerable amount of work has been done in the area of Bluetooth scatternet routing. The important Bluetooth inter-piconet communication issue is route maintenance for broken links which has not been considered comprehensively.

The rest of the paper is structured as follows: Section II discusses some related and important route maintenance algorithms; Section III discusses the proposed protocol while the simulation and comparison of results are discussed in Section IV. Finally, the conclusion is discussed in Section V.

2 Related works

For intra-piconet communication, the master device plays an important role because all links go through it. During intra-piconet communication, if a master

device moves or fails then all the piconet links will be disconnected. For inter-piconet/scatternet communication, a bridge device is the most important because it is responsible for the communication throughout the scatternets. If a bridge device moves or fails due to any reason then it will disconnect the connection between the piconets. So, there should be an efficient technique that prevents the links from being disconnected and makes new links before there is any link breakage.

Most of the Bluetooth routing protocols provide solutions for route recovery when they predict the link breakage. The main disadvantages with these types of protocols are more time consumption and extra resource utilization.

Ramesh et al. present the idea for route recovery in [10]. During the route detection procedure, the source node constructs two paths. The source node uses the primary path and reserves the other path as a backup that can be used in case of link failure. The DENM protocol [11] presents the idea based on energy level. The master maintains a record of all connected nodes in a table. When the energy level of the master device reaches L_1 , it selects an Auxiliary Master (AxM) from its slave list. Similarly, if the energy level of the bridge device reaches a level L_1 , it informs all connected masters for a Backup Relay (BR). As in Fig. 2, when the energy levels of M_2 and B reach L_1 , the DENM activates the AxM and BR. The DENM protocol provides the solution for route recovery on the basis of energy level. The problem with this technique is that when the nodes communicate frequently, they will lose their energy and disconnect the link earlier. On the basis of energy level, we cannot determine if the nodes are moving or have failed.

An efficient relay reduction and disjoints route construction protocol, LORP [14], modifies the network topology dynamically by minimising unnecessary bridge devices. The LORP also reduces the routing path by considering the routing distance between Bluetooth nodes. As shown in Fig. 2, the source (S_r) sends data to the destination (Dst) through the route $S_r-M(S_1-B_1-M(S_3-Dst))$. In order to reduce the routing path, the LORP repeatedly reconstructs the piconet but it does not perform piconet reconstruction if any node in the

routing path breaks the link due to mobility or failure.

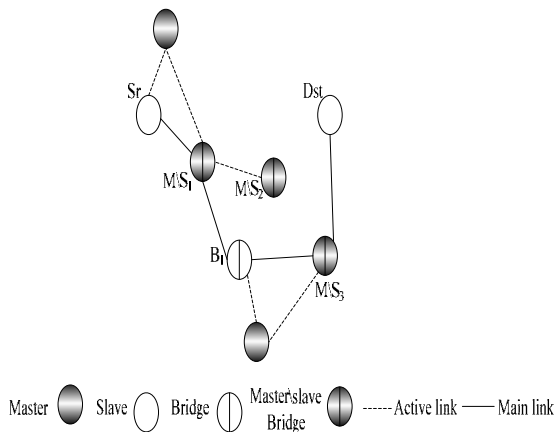


Fig.2: Routing path created by LORP for a pair of Sr and Dst.

3 Proposed Protocol

In this paper, a new Route Breakage Prediction (RBP) protocol before link failure is proposed. The Route Breakage Prediction protocol prevents the loss of data packets and reduces the delay time for recovery. According to the proposed protocol, each master device and bridge device maintains a table. The master device makes the Master Record Table (MRT) that contains the record of all connected slaves whereas the bridge device makes a Bridge Record Table (BRT) that contains the record of all connected masters in the Bluetooth network.

The proposed protocol predicts the link failure on the basis of signal strength. In a Bluetooth network, the master and bridge devices are responsible to make a communication link between the source and destination so each master device selects the Fall-Back Master (FBM) from its connected slaves and each bridge selects a Fall-Back Bridge (FBB). The master device can easily select the FBM from its slaves; the slave device which is within the radio range of all other slaves is selected as the FBM. The bridge device selects the FBB if there is any other bridge device. In case there is no other bridge device, then the proposed protocol performs the role switch operation for the FBB. A threshold value is defined for the signal strength. If the threshold value of the master or bridge device is going to decrease then the master

device will send a request to its FBM to become a new master and inform the other slave devices. The bridge device will send the request to its FBB to become a new bridge and inform the other master devices. Any device which will become a new master or bridge device will first maintain its table. Two tables, MRT and BRT are maintained from configurations such as in Figures 3(a) and 3(b). These tables hold the records of the connected devices.

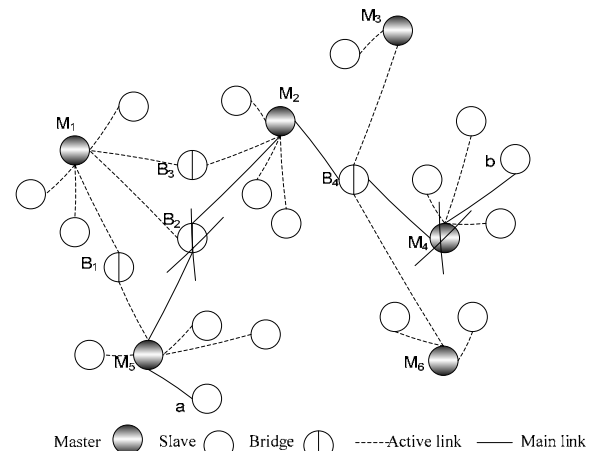


Fig.3 (a): Route breakage prediction in the Bluetooth scatternet

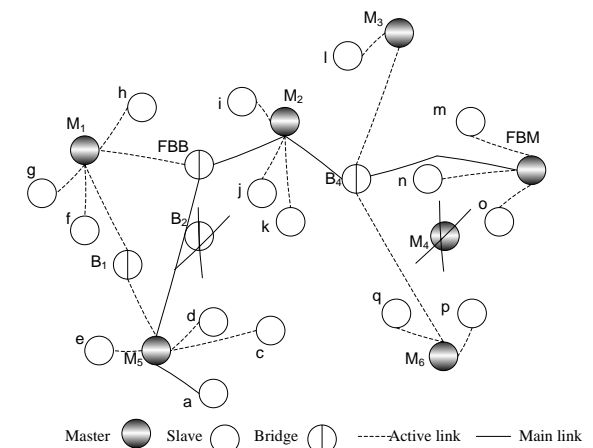


Fig.3 (b): Route recovery before route breakage in the Bluetooth scatternet

In Fig. 3(a) the main transmission link has been established between devices a and b. During transmission, the signal strength of master M_4 and bridge B_2 gradually decreases and finally reaches the limit of the threshold. When the source and destination devices make a main link for

transmission, each intermediate master device and bridge device selects the FBM and FBB. When the signal strength of M_4 and B_2 has decreased, they check their FBM and FBB and then transmit a request packet. After receiving the request from M_4 and B_2 , the FBM and FBB broadcast their status to the other connected devices and establish a new transmission link. In Fig. 3(b), bridge device B_3 is used as the FBB and device b is selected as the FBM. Now, the new transmission link between the source and destination has been established and devices are communicating through their new link.

The main advantage with this technique is that as it predicts the route breakage before the link failure and repairs it, this protocol overcomes the problem of data packet loss and overcomes the problem of delay.

Table 1: Master Record Table

Masters	Signal strength	Slave list	Bridge list	FBM
M_1	$S_{M1-g}^t, S_{M1-h}^t, S_{M1-f}^t$	g, h, f	B_1, B_2, B_3	g
M_2	$S_{M2-i}^t, S_{M2-j}^t, S_{M2-k}^t$	i, j, k	B_2, B_3	j
M_3	S_{M3-l}^t	l	B_4	0
M_4	$S_{M4-b}^t, S_{M4-m}^t, S_{M4-n}^t, S_{M4-o}^t$	b, m, n, o	B_4	b
M_5	$S_{M5-a}^t, S_{M5-c}^t, S_{M5-d}^t, S_{M5-e}^t$	a, c, d, e	B_1, B_2	d
M_6	S_{M6-p}^t, S_{M6-q}^t	p, q	B_4	p

Table 2: Bridge Record Table

Bridges	Signal strength	Master list	Degree	FBB
B_1	S_{B1-M1}^t, S_{B1-M5}^t	M_1, M_5	2	B_3
B_2	$S_{B2-M1}^t, S_{B2-M2}^t, S_{B2-M5}^t$	M_1, M_2, M_5	3	B_3
B_3	S_{B3-M1}^t, S_{B3-M2}^t	M_1, M_2	2	role switch
B_4	$S_{B4-M2}^t, S_{B4-M3}^t, S_{B4-M4}^t, S_{B4-M6}^t$	M_2, M_3, M_4, M_6	4	role switch

4 Simulation results and discussions

The proposed RBP protocol is implemented in the University of Cincinnati's Bluetooth (UCBT) [12] based on the NS-2 simulator [13]. Table 3 contains the list of simulation parameters. Bluetooth nodes

are randomly scattered which are varied from 15 to 90, and 20 pairs of source and destination nodes are used. For each routing link, the CBR traffic model is selected for producing the data traffic, and data packet types DH3 and DH5 are used. The Round Robin (RR) scheduling algorithm is used, and the whole simulation time is set for 200s. The results of the RBP protocol are compared with the results of the LORP protocol.

Table 3: Simulation parameters

Parameters	Assessment
Traffic Model	CBR
Number of nodes	15- 90
Scheduling algorithm	RR
Bluetooth node pairs	20
Simulation time	200s
Network Dimension	80 m x 80 m
Data packet type	DH3, DH5
Communication range	10 m

4.1 Total delay

As the RBP protocol predicts the route breakage before it breaks, it saves the time for rebuilding a new route. In Fig. 4, it is noted that the total delays of the RBP and LORP protocols increase as the numbers of devices per route increase; however, the total delay increases more in the LORP protocol as compared to the RBP protocol. The RBP protocol does not use any rebroadcast mechanism for finding the new route for broken links so it minimises the total delay.

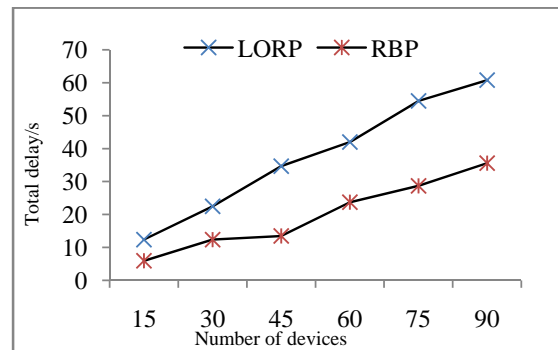


Fig.4: Total delay in the Bluetooth network vs. the Number of devices

4.2 Packet loss

The failure of the data packet rates to reach their destination is called packet loss. In the LORP protocol, during transmission between the source and destination, if a link breaks due to mobility or failure of nodes, it does not provide any solution so it creates the heavy data packet loss. The RBP protocol avoids the problem of data packet loss because it firstly, predicts the link breakage; if weak links are predicted it starts its transmission through another route. Fig.5 shows the packet loss for different numbers of devices and it can be observed that the packet loss of the RBP protocol is less compared to the LORP protocol.

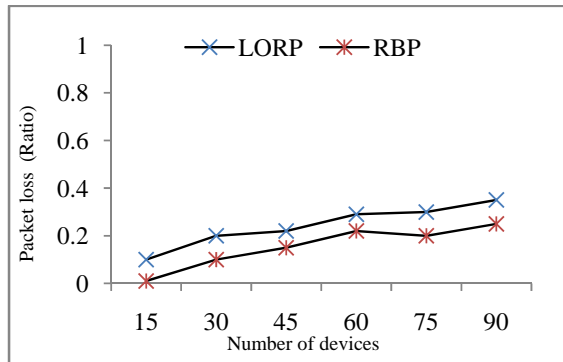


Fig.5: Packet loss vs. Number of devices

4.3 Throughput

The total number of successful data packets, which reach their final destination is known as throughput. During transmission, link breakage affects the throughput of the whole network. Fig. 6 shows the throughput of the RBP and LORP protocols. During simulation, when data is routed by using both the LORP and RBP protocols, it is noted that the RBP protocol delivers the maximum number of data packets as compared to the LORP.

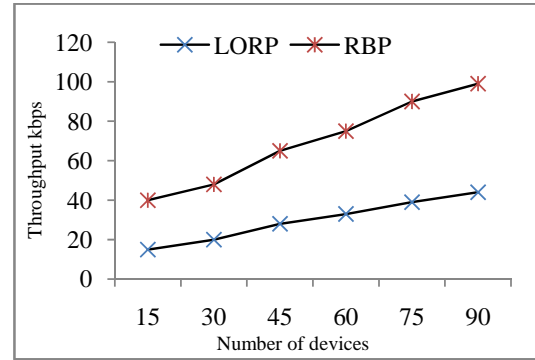


Fig.6: Throughput vs. Number of devices

4.4 Route recovery time

Route recovery time refers to the time need to recover the broken links. It is observed that when links are near to breaking due to the weak signal strength, the LORP does not show any reaction whereas the RBP protocol activates its backup devices to recover the route before it breaks. From Fig. 7, it is clear that the RBP protocol takes less route recovery time as compared to the LORP because the LORP does not have any record of backup devices.

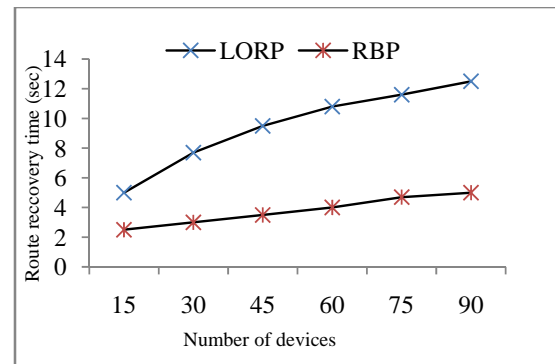


Fig.7: Route recovery time vs. Number of devices

5 Conclusions

For Bluetooth networks, many route recovery techniques have been proposed but the problem with previous techniques is that they were constructing new routes for broken links by using different methods or they do not provide any solution if the routing link breaks. In this paper, a new RBP protocol is proposed and implemented. It predicts the link breakage before the link failure. To construct the main route in the Bluetooth

network for any pair of source and destination devices; master and bridge devices play an important role as intermediate hops. The RBP protocol monitors the signal strength of master and bridge devices and during the main route construction, each master and bridge device selects the FBM and FBB for route recovery. When the signal strength of the master and bridge device decreases and reaches the limit of the threshold value, they inform the Fall-Back devices for activation. The RBP protocol provides the solution for the route recovery before the route breakage. In so doing, the RBP protocol increases the overall network throughput and minimises the packet loss and total delay. Moreover, it takes less route recovery time as compared to the LORP protocol.

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