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ANALYSIS OF CONTINUOUS CONNECTIVITY IN MOBILE MULTIHOP RELAY NETWORK

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Abstract

Mobile Multihop Relay (MMR) network is an attractive and low-cost solution for expanding service coverage and enhancing throughput of the conventional single hop network. However, mobility of Mobile Station (MS) in MMR network might lead to performance degradation in terms of Quality of Service (QoS). Selecting an appropriate Relay Station (RS) that can support data transmission for high mobility MS to enhance QoS is one of the challenges in MMR network. The main goal of the work is to develop and enhance relay selection mechanisms that can assure continuous connectivity while ensuring QoS in MMR network using NCTUns simulation tools. The approach is to develop and enhance a relay selection for MS with continuous connectivity in non-transparent relay. In this approach, the standard network entry procedure is modified to allow continuous connectivity with reduced signaling messages whenever MS joins RS that is out of Multihop Relay Base Station (MRBS) coverage and the relay selection is based on Signal to Noise Ratio (SNR). The proposed relay selection mechanism that utilized Cross Layer Design (CLD) concept to select RS with good link quality for data transmission. The proposed network model of MMR network is analyzed mathematically using queuing theory approach. Theoretical analysis of the M/D/1 queuing model is compared with the simulation to validate that the simulation is working correctly. The result shows that the simulation performances conform to the theoretical value very closely, which prove the consistency of the simulation platform. Therefore, correctness of the simulation model is validated. Thus, the rest of the work is carried out through simulation on NCTUns.

Keywords: Continuous connectivity, Mobile multihop relay, Mobility, Relay selection.

1. Introduction

IEEE 802.16j documentation classifies two types of RS operation modes in MMR network commonly known as transparent relay mode and non-transparent relay mode [1]. In transparent relay mode, MRBS transmits user data to MS through intermediate RSs while broadcast management messages are transmitted directly to MS. MS that is synchronized with MRBS receives the broadcast management messages from MRBS since transparent RS does not transmit preamble and broadcast management messages. Therefore, MS is not aware of the existence of RS even though MS communicates with MRBS through transparent RS. For this type of operation mode, MS should be located in the coverage area of MRBS as illustrated in Fig. 1. Only centralized scheduling mode is allowed to be employed in this RS mode.

In contrast to transparent RS, the RS operating in non-transparent relay mode transmits management messages as well as user data to other MS [2]. In this work, non-transparent relay modes in MMR networks are considered.

In MMR network, there are possibilities that several RSs are deployed with each of them has small coverage range. Moving MS may encounter connection loss condition, frequent handoff with RS and service interruption during data transmission. When moving MS roams and joins new RS, it needs to perform re-synchronization to integrate with the new RS before it participates in data transmission. In non-transparent relay mode, re-synchronization required complex signaling messages exchange during the network entry procedure. This circumstance leads to high average ETE delay due to complex signaling messages process.

2. Related Work

MMR network has gained notable research attention from academia and industry as a potential primary technology for Broadband Wireless Access (BWA) because it offer coverage extension and capacity enhancement in IEEE 802.16 networks [3-5]. MMR network is a standard for BWA at high speed and low cost development by IEEE 802.16's Relay Task Group [6, 7]. Besides, the power of MS can be preserved because MS is connected to the nearest RS instead of connected to MRBS located outside the coverage range of MS [8]. Moreover, the deployment of RS is more cost effective compared to MRBS [9, 10]. In a nutshell, a low cost RS entity in MMR network is introduced to help extend the coverage range, improve service, boost network capacity, reduce terminal power consumption and eliminate dead spots.

Research has been done for relay selection mechanism based on link quality, load demand, bandwidth availability and buffer status in MMR network [11-14]. But, most of the research work is meant for relay selection in transparent mode. In non-transparent relay mode, the connection is not always guaranteed. As MS moves, it may experiences connection loss or throughput degradation while transmitting data packets towards the destination node. In [15-17] authors suggested minimizing loss by selecting potential RS that relies on channel condition. In addition, when high mobility MS moves, MS needs to establish connection frequently with the network through lengthy network entry procedures, thus, causing higher delay. In order to further lessen the possibilities of connection loss and throughput degradation in highly mobile network, a proper relay selection that can adapt to user mobility and support rapid changing connectivity with reduce signaling is proposed.

3. Methodology

3.1. Phase 1: Developed node mobility function

The first phase is to develop the node mobility function in non-transparent relay mode. The aim is to ensure continuous connectivity whenever MS joins RS that is out of MRBS coverage range.

The additional process defined as connectivity procedure allows MS to join new RS when it lost the coverage range of the previous RS. If MS wants to join new RS, it only needs to reorganize with the new RS without performing the long network entry procedure with the MRBS. The connectivity procedure reduces the exchange of signaling messages to establish connection between MS and new RS. By avoiding the lengthy network entry procedure in non-transparent mode MMR network, the signaling messages can be significantly reduced and minimize delay.

In non-transparent relay mode, when MS joins RS that is out of MRBS coverage range, MS needs to be recognized by RS and MRBS. When MRBS detects a topology update due to node mobility, MRBS needs to perform re-synchronization with all RS and MS. Assume the network topology is as shown in Fig. 1. In this case, MS has possibly lost connection when it moves out of RS1 coverage range. As the moving MS joins RS2, it needs to be recognized by RS2.

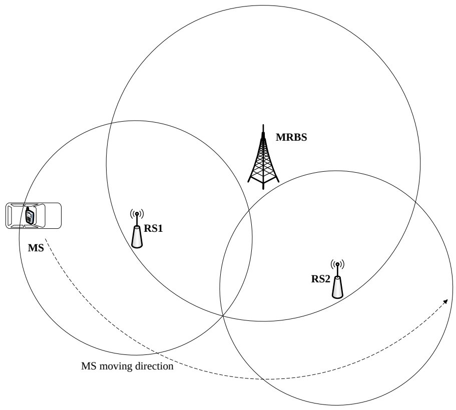

Fig. 1. Network topology for the proposed connectivity procedure.

The connectivity procedure is applied whenever MS roams to another RS that is out of MRBS coverage range. Figure 2 illustrates the timing diagram of connectivity procedure in non-transparent relay mode. The same message is exchanged between MS and MRBS through RS as in [6, 18]. Assume that the connection is already established for data forwarding. MS starts sending DT-FWD to MRBS through RS1. However, MS can possibly move outside RS1 coverage range and the connection might loss due to mobility of MS.

Additional process is introduced in the network entry procedure defined as connectivity procedure that allows MS to join RS2 when it moves out of RS1 coverage range. As the connection between MS and RS1 is loss or terminated, MS needs to wait for T48 timer expiration before retries to perform network entry procedure again. When T48 is expires, MS continue scanning for DL channel from

RS2. T48 is a timeout wait for DT-FWD. Two types of signaling messages namely REQ-SYNC and REP-SYNC are introduced in the connectivity procedure. MS sends REQ-SYNC message and wait for synchronize opportunity from RS2. Referring to Fig. 2, MS needs to be recognized by RS2 if MS want to join RS2. RS2 will reply with REP-SYNC message (RS2 has recognized MS) and MS is permitted to continue transmit data packets toward MRBS. Therefore, the modified network entry procedure can reduce signaling messages exchange because MS does not needs to perform the network entry procedure again when MS join RS2 that is out of MRBS coverage range.

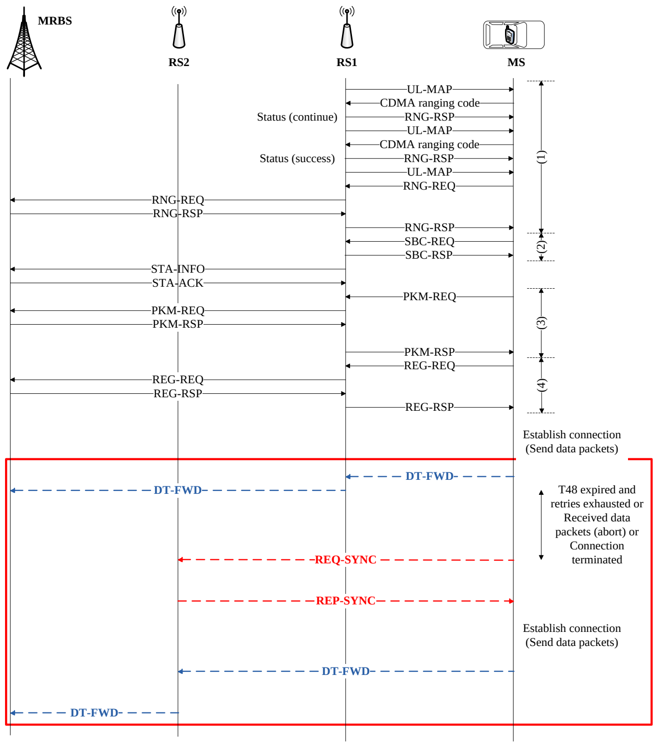

Fig. 2. Modified network entry procedure.

3.2. Phase 2: Developed relay selection mechanism

The second phase is to develop relay selection mechanism that relies on link quality between MS and RS. The link quality parameter from Physical (PHY) layer that is Signal to Noise Ratio (SNR) information is used in Medium Access Control (MAC) layer to select a suitable RS among all available RSs for data transmission. RS with the highest SNR is selected to forward data packets towards MRBS. The implementation of such design achieves performance improvement especially in MMR network.

If several RS available in MS coverage range, MRBS assigned an appropriate RS with the highest SNR to attach with the MS. At the beginning, the received SNR is compared with the SNR threshold i.e., 5dB [19]. If the received SNR is fall below than 5dB, RSs are discarded from the network.

4. Analytical and Simulation Study of MMR Network Model

In this section, the mathematical study of the network model is conducted to validate the discrete simulation study of the network model. The aim of this performance evaluation is to verify the simulation model with the M/D/1 queuing model. The output obtained from theoretical is expected to justify the results of the discrete simulation-based performance study using NCTUns simulator.

The proposed network model of MMR network is analyzed mathematically using queuing theory approach. Network topology as shown in Fig. 3 is evaluated with consideration of M/D/1 queuing model. Similar modeling assumption is considered for both theoretical and simulation, where the packet arrival process at nodes are assumed to follow Poisson distribution with arrival rate, λ.

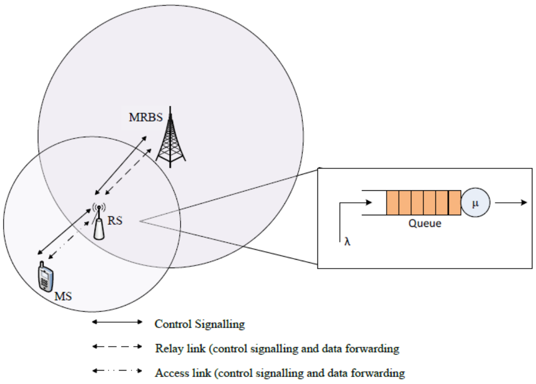

Fig. 3. A simple network topology to validate with queuing model.

These packets are serviced in deterministic manner at a rate of μ. The size of packets is set to be constant at 128 bytes. In addition, it is also assumed that the system consists of a single server with infinite buffer size. Therefore, it can support infinite number of packets in the system. In M/D/1 queuing model, the packets are queued up in the buffer and are serviced in the order of their arrival similar to First-In-First-Out (FIFO) concept. Each packet is serviced consecutively only after the packet that arrives before it has been scheduled.

Some important performance measures for the M/D/1 queuing model can be simplified as follows:

- The average number of packets in the queue, L_q

$$L_q = \frac{\rho^2}{2(1-\rho)} \tag{1}$$

- The average number of packets in the system, L

$$L = L_q + \rho \tag{2}$$

- The average waiting time in the queue, wT_q

$$wT_q = \frac{\rho}{2\mu(1-\rho)} \tag{3}$$

- The average waiting time in the system, wT

$$wT = \frac{2-\rho}{2\mu(1-\rho)} \tag{4}$$

where ρ is considered as a traffic load of the node and represented as $\rho = \frac{\lambda}{\pi}$.

Theoretical analysis of the M/D/1 queuing model is compared with the simulation to validate that the simulation is working correctly and thus can be used as an evaluation tool to study the performance of the proposed relay selection mechanism in non-transparent relay MMR network.

5. Analysis of MMR Network Model

Figures 4 and 5 present the average total time of packets stay in the system and the average packets waiting time in the queue, respectively. Both graphs show similar results for theoretical and simulation although the average total time and average waiting time for traffic load below ρ = 0.6 slightly differed. Figures 6 and 7 depict the average number of packets in the system and the average number of packets in the queue, respectively. For both graphs, the simulation performances conform to the theoretical value very closely, which prove the consistency of the simulation platform. Based on these results, it is clearly shown that the performances obtained by using theoretical analysis and simulation analysis are well matched. Therefore, correctness of the simulation model is validated. Consequently, the rest of the work is carried out through simulation on NCTUns.

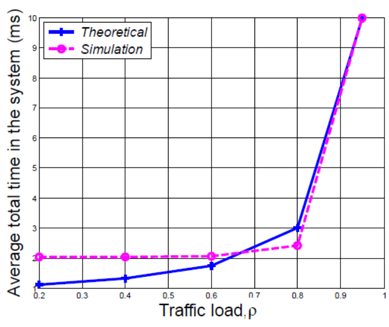

Fig. 4. Average total time in the system.

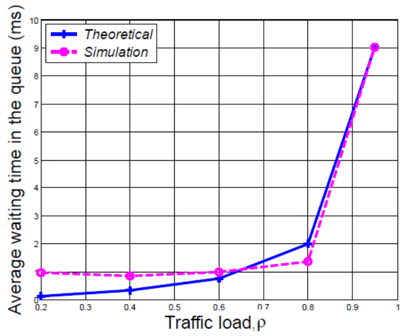

Fig. 5. Average waiting time in the queue.

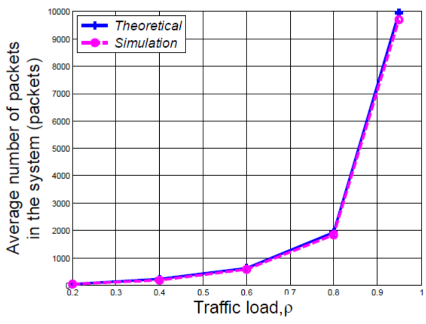

Fig. 6. Average number of packets in the system.

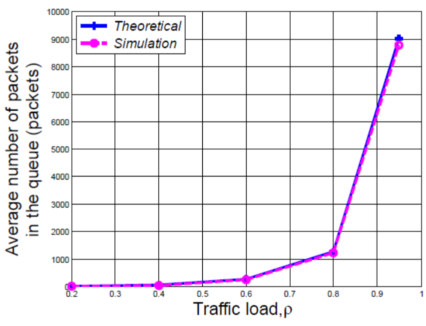

Fig. 7. Average number of packets in the queue.

6. Conclusions

In order to further lessen the possibilities of connection loss and throughput degradation in highly mobile network, a proper relay selection that can adapt to user mobility and support rapid changing connectivity with reduce signaling is proposed. M/D/1 queue model is used to validate the reliability of simulation model used in this work. The findings show that the results obtained for both theoretical and simulation models are similar. Therefore, the consistency of the simulation model is validated.

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