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HMM based resource allocation and fuzzy based rate adaptation technique for MANET

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ABSTRACT

In mobile ad hoc network (MANET), each transmission demands different quality of services to reduce the throughput. This can be overcome through effective resource allocation technique in the network. In order to improve the network performance, rate adaptation mechanism is required. Hence, it is proposed the resource allocation and rate adaptation techniques for MANET using MAC protocol. In this technique, the free available bandwidth in the channel is predicted based on the current traffic load of the nodes using hidden Markov model (HMM) technique. New users are admitted after checking the predicted available bandwidth against the demand of each user. The rate adaptation is performed by estimating the physical transmission rate using fuzzy logic technique. By simulation results, it is shown that the proposed technique enhances the network throughput and performance.

1. Introduction

In MANET, the number of mobile nodes communicates through relaying messages. It has ability to form the wireless network among the nodes within the transmission range. It is difficult for a node to join other nodes for forwarding a packet to its destination due to the limited transmission range of wireless network interfaces. No node is in the direct transmission range of other nodes in the network [1].

Transmission power control and transmission rate control are the effective approaches used to understand energy efficient data transmission. MAC protocols along with transmission power control are derived from IEEE 802.11 DCF. With minimum transmission power, data are transmitted to increase energy efficiency of data transmission. The required minimum received power is estimated based on the amount of received power of control frames. In ad hoc networks with multi-rate physical layer like IEEE 802.11b, MAC protocols with transmission rate control are utilized where data are sent in a high data transmission rate to minimize the data transmission time. So that, the energy consumption efficiency of data transmission must be improved [2]. In a mobile network, nodes must have knowledge of their transmission rate to maintain a certain discipline. If there is no appropriate transmission rate approach, then the network has some packet loss. TCP congestion control has an inherent assumption that any packet loss is due to network congestion [9]. To overcome this limitation, the transmission rate based approach in the network is essential.

2. Literature review

Bandai et al. [3] have proposed the energy efficient MAC (EEMAC) protocol based on the adaptive rate and transmission power mechanism in multi-rate mobile ad hoc networks with enhanced energy consumption for data transmission. Each node forms a table that contains the energy efficiency in all combinations of transmission power and rate. The direct and relay transmission sequences are used randomly by exchanging the control packets, snooping the transmission power and rate information available in the table. The relay sequence is accepted as a substitute of direct transmission when the relay transmission by intermediate node is more effective in terms of power consumption. The advantage of this approach is that it can provide high energy efficient data transmission. Yongguang et al. [4] have proposed a practical SNR Guided Rate Adaptation (SGRA) scheme. Since SNR measured in hardware is often uncalibrated, SNR thresholds are hardware dependent. The direct prediction from SNR to frame delivery ratio is frequently done under interference conditions. A systematic measurement-based study is used to confirm that the SNR is generally a good prediction tool for channel quality. The main advantage of this approach is that it achieves the maximum throughput.

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Hongqiang et al. [5] have proposed a new wireless congestion control protocol (WCCP) to support the transport service in multi-hop ad hoc networks where every forwarding node along a traffic flow undergoes inter-node and intra-node fair resource allocation and decides the MAC layer feedback consequently. The end-to-end feedback is determined by the bottleneck node along the flow and is carried back to the source to control its sending rate. The merit of this approach is that WCCP outperforms the traditional TCP in terms of channel utilization, delay, and fairness, and removes the starvation problem. Kazi et al. [6] have proposed a new explicit rate-based congestion control (XRCC) mechanism to support the multimedia streaming applications. XRCC reduces the packet drop caused by network congestion. However, it still suffers from packet drop. The rate feedback can be made accurate by considering the available network bandwidth. The advantage of this approach is that XRCC mechanism performs well compared to TCP congestion control mechanism.

Ping et al. [7] have proposed a new multipath routing protocol called multipath energy-efficient routing (MEER) based on the split multipath routing (SMR) protocol that provides the energy efficiency and protects the nodes from excessively consuming the energy compared to the other nodes in the network. It extends the lifetime of the network. The major advantage of this approach is that it can enhance the mean time to node failure and balance the load on ad hoc networks. Santhi et al. [8] have proposed a power aware QoS multipath routing (PAQMR) protocol for disaster recovery network. It is an enhanced protocol of ad hoc on demand multipath distance vector (AOMDV) routing. It avoids the loop formation in a network and hence reduces congestion in the channel. The performance parameters like energy utilization, end-to-end delay and packet delivery ratio were obtained according to the traffic loads and pass time of the network. The advantage of this approach is that it reduces the power, delay, congestion and maximizes the packet delivery ratio.

3. Problem identification

In our work [13], it is proposed an energy efficient MAC protocol for MANET based on channel utilization and queue size. In this protocol, when the source node desires to transmit the data packet to its destination node, it appends its queue state and channel utilization with RTS frame, and transmits it to the destination by utilizing the utility function. The destination node verifies the RTS frame for error and then sends the CTS frame along with queue state and channel utilization information to source node using utility function. Upon receiving the CTS frame, the source transmits the data packet to the destination node.

Resource allocation is the significant factor in the real-time transmission in MANET as the allocation of the resources is dynamically altered based on the channel variation. Required bandwidth for each user is the main objective of the resource allocation because each transmission needs different quality of services. Hence obtaining the maximum throughput in mobile ad hoc network is difficult. Rate adaptation is the problem of identifying suitable data rate for the sender to transmit the DATA frames and to adjust in varying channel condition. This adaptation provides a complex mechanism for wireless systems to physical layer data rate and robustness to improve the performance. Rate adaptation is taken as a MAC layer mechanism and many algorithms are proposed in which most of them use only MAC layer information that means making rate selection decision based on the frame losses. As an extension to the previous works, the resource allocation and rate adaptation techniques for MANET using the MAC protocol is proposed.

4. Proposed solution

4.1. Overview

In this work, hidden Markov model (HMM) and fuzzy logic techniques are used for resource allocation and physical layer rate adjustment, respectively. In the first phase, the free available bandwidth in the channel is predicted based on the current traffic load of the nodes by using HMM. New users are admitted after checking the predicted available bandwidth against the demand of each user. In the second phase, the channel utilization, queue state, delay and the available free bandwidth are passed as input variables to the fuzzy logic inference engine. The exact PHY rate can be estimated based on the outcome of the fuzzy rules.

4.2. Estimation of channel utilization

Let dist(t) be the distributed inter-frame spacing (DIFS). Let s(t) be the short inter-frame spacing SIFS. Let $r(t)$ represents the Request to Send(RTS) control packet. Let $c(t)$ represents the Clear to Send (CTS) control packet. Let $d(t)$ be the data packet. Let $a(t)$ be the acknowledgement frame(ACK). Let $D_{\mathrm{DIFS}}, D_{\mathrm{SIFS}}, D_{\mathrm{RTS}}, D_{\mathrm{CTS}}, D_d, D_{\mathrm{ACK}}$ be the delay components of DIFS, SIFS, RTS, CTS, data and ACK packets, respectively. The channel utilization of a network per second is computed using the following components [10]. The time taken for transmission and management of the data packets and control frames, the total number of delay components such as distributed inter-frame spacing (DIFS) and short inter-frame spacing (SIFS) are estimated [11]. Then, the channel utilization estimation based on these components are illustrated below.

The channel busy time (T_{chb}) for a data frame (d) is given using Eq. (1).

$$T_{\mathrm{chb}}(d) = D_{\mathrm{DIFS}} + D_d(z, \sigma) \tag{1}$$

where z is size of data frame (in bytes), σ is rate at which the data is transmitted, D_{DIFS} is delay component. T_{chb} of RTS frames, CTS frames, ACK frames are given using Eqs. (2)–(4) respectively.

$$T_{\mathrm{chb}}(\mathrm{RTS}) = D_{\mathrm{RTS}} \tag{2}$$

$$T_{\mathrm{chb}}(\mathrm{CTS}) = D_{\mathrm{SIFS}} + D_{\mathrm{CTS}} \tag{3}$$

$$T_{\mathrm{chb}}(\mathrm{ACK}) = D_{\mathrm{SIFS}} + D_{\mathrm{ACK}} \tag{4}$$

If RTS, CTS, ACK and data packets are encountered during the interval t, the total T_{chb} is given using the following Eq. (5).

$$T_{\mathrm{chb}}(t) = (r(t) * T_{\mathrm{chb}}(\mathrm{RTS})) + (c(t) * T_{\mathrm{CTS}}) + (a(t) * T_{\mathrm{chb}}(\mathrm{ACK}) \\ + (d(t) * T\mathrm{chb}(d)) \tag{5}$$

Thus, channel utilization (CU) at time t, is given using Eq. (6).

$$\mathrm{CU}(t) = \frac{T_{\mathrm{chb}}(t)}{10^6}(100) \tag{6}$$

4.3. Estimation of queue state

The queue state information (Q_k) in the network is obtained by observing the number of packets in the user's buffer from MAC layer [12], where $q_j = k \times 1$ vector with ith component. Eq. (7) denotes the number of packet remaining in node i's buffer.

$$Q_k = [q_j] \tag{7}$$