International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 5629-5642

http://www.ripublication.com

Link-Utility-Based Improved Back off Cooperative MAC Protocol for Distributed Dynamic Slot Allocation in MANET

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Abstract

In Mobile Ad hoc Network (MANET), the existing scheduling technique schedules the flows based on the assigned priority. However, there is no standard approach for allocating the number of slots for each flow. Hence in this paper, we propose a Link-Utility-Based Cooperative MAC Protocol for Distributed Dynamic Slot Allocation in MANET. A distributed TDMA system is revisited to make use of an extended interference model. The extended interference model combines the graph-based interference model with the SINR-based interference model. A fully dynamic slot scheduling and allocation scheme mainly depends on slot request and release. Distributed schemes combine two approaches namely, proactive approach and reactive approach. By simulation results, we have shown that the proposed technique minimizes the delay and maximizes the throughput.

1. Introduction

1.1. MANET

A Mobile Ad hoc Network (MANET) is an infrastructure-less wireless temporary network comprising of Mobile Hosts (MHs) capable of communicating with each other by relaying messages through multi hop wireless links without any centralized coordinator such as Base Stations (BSs) or Access Points (APs) [1, 2, 3, 6, 7, 9]. MANET has its application in rescue missions and military field [1]. Nodes can communicate via a single-hop or multi-hop paths in a peer-to-peer form. Nodes can operate both as hosts and routers since the communication between two pairs of nodes takes place through intermediate nodes called routers [3]. Communication of mobile nodes over wide range of distance is accomplished by merging the routing functionality with each mobile node in MANET [6]. The routing protocols can be categorized into table driven (proactive) and on-demand (reactive). Routing table is maintained at every node in table-driven, whereas in on-demand, the state information is acquired when needed [3]. MANET establishes the networks everywhere, which do not depend on the irrelevant hardware to avoid being an ideal candidate during rescue and emergency operations. Wireless nodes, that built, operate and maintain these networks, possess only a limited transmission range and hence rely on its neighboring nodes to forward packets [9]. As the mobile nodes are battery powered, the process of re-supplying the energy is difficult [8].

Issues

A wide area of multimedia and real time applications of MANET require Quality of Service (QoS) support, which include bandwidth, end-to-end delay, delay jitter and bit error rate [3, 4, 7, 10]. This task often requires acceptable channel conditions, QoS-aware mechanisms for channel access, and identification of proper forwarding (transmit) nodes and measures for congestion prevention and management in those nodes [10]. The main issues in MANET are its fast changing topology and the lack of global information since the addition and deletion of mobile nodes affects designing the routing paths as MH possess only its neighboring information due to its transmission capability, such as transmission range, battery power, etc [2, 3]. A routing protocol for MANETs should be capable of tolerating the dynamic variation of topology. Hence, stability becomes an issue particularly for routing with QoS provision [2, 3, 4].

1.2. Resource Allocation in MANET

Inefficient resource allocation causes heavy losses to the service providers and results in inadequate user proficiency. Efficient resource allocation techniques are needed for improving and automating the QoS of the network. If the traffic varies significantly in telecommunication networks, then the resource allocated in the static manner which takes hours to months time, is inadequate or under-exploited [9]. Multicast plays a vital role in many advanced MANET applications. QoS multicast routing discovers a multicast tree rooted from the source node and spanning to all destination nodes, with every internal path from the source to the destination meeting the QoS requirements. But the limited bandwidth of a wireless node makes a single multicast tree even after meeting the QoS requirements be unavailable and QoS multicast routing may be blocked. Most of the MANET routing protocols focus on finding a feasible route path from a source to a destination [1].

An efficient bandwidth allocation scheme should guarantee successful collision less data transmissions and enhance the channel spatial reuse to maximize the system throughput. Bandwidth is a scarce resource to be shared either dynamically depending on the amount of data to be transferred to or from each node or deterministically by assigning a fixed number of slots to each cell, as in a cellular network. A fixed number of slots, a portion of bandwidth are assigned to certain nodes (or groups of nodes) to have an exclusive access to the assigned bandwidth in deterministic assignment whereas the dynamic assignment shares the bandwidth into the required number of slots, which can be altered depending on the occurred events of the network. Thus, providing a QoS (bandwidth, delay, jitter) guarantee. However, traditional bandwidth allocation is pre-planned. Hence, it is less adaptive to traffic load variations and network topology changes [11].

1.3. TDMA based Resource Allocation

TDMA is an access method used to ensure conflict-free transmissions under any traffic loading. In this approach, time is slotted, and the slots are grouped as frames. These time slots are assigned to mobile nodes orthogonally for providing contention-free medium access [6, 8]. QoS guarantees like bandwidth reservation, flow control and fairness are provided by scheduling the slots. However, it has several disadvantages such as higher end-to-end delay (delay for short), lower throughput and synchronization [8].

Assigning/scheduling the specific time slots to mobile nodes is major issue of TDMA MAC. Time slots should be reserved or assigned already in a distributed manner, as there is no centralized coordinator in MANET. All the mobile nodes have to be synchronized with time to utilize the regular time slots. The delay-sensitive and real-time data communication over multi-hop links needs MANET to support QoS [6].

There are certain issues in QoS routing on TDMA-based MANETs such as hidden terminal problem, exposed terminal problem and slots shortage problems [2].

1.4. Motivations and Novelty of the work

In our first work, we have proposed Link-Utility-Based Improved Backoff Cooperative MAC Protocol for MANET. In this MAC protocol, when nodes along the transmitting path lie in the different transmission region, then cooperative transmission is invoked by the corresponding node. Cooperative paths are selected by finding link utility value, which is computed in terms of transmission type, rate, power, link lifetime and bandwidth. Our LIBC-MAC makes use of cooperative communication and avails three kinds of transmission namely CT1, CT2 and the direct path between source and destination. When nodes along the transmitting path lie in different transmission region, then the cooperative transmission is invoked by the corresponding node.

In the next work, we have developed Joint per flow-scheduling routing algorithm in Link-Utility-Based Improved Backoff Cooperative MAC Protocol for MANET. By using this algorithm, we can assign as many slots as possible to the network flows and by assigning more slots, we can increase the network utilization. In the joint per flow-scheduling routing algorithm, we give the priority to the flows based on optimal transmission rate, optimal transmission power and the number of slots allocated at each flow. We pop up the flow from the priority queue that is allocated the small number of slots. This is performed to offer fairness during scheduling.

Joint per flow-scheduling routing algorithm schedules the flows based on the assigned priority. However, the limitation of this algorithm is that it did not provide any technique for allocating the number of slots for each flow. As it is significant to allocate the number of slots for each flow before scheduling the flows, Link-Utility-Based Cooperative MAC Protocol with Slot Reuse in MANET is proposed. This protocol can reduce the TDMA frame length. The slot already used by a link can be reused by another link. This can reduce the delay and overhead. This protocol can be applied to the networks with limited resources and more number of users.

Even though the TDMA based resource allocation is discussed in some existing works, there is no technique that combines the resource allocation with the link utility based improved backoff cooperative MAC protocol. In addition, the existing work did not consider the parameters such as data rate, link lifetime and packet loss rate at each link for slot reuse. This is the novelty of the proposed work. The slot allocation can increase the throughput by avoiding interference in the network.

The paper is organised as follows: Section 2 provides an overview of the related work in the literature. Section 3 presents the proposed Link-Utility-Based Improved Back off Cooperative MAC Protocol with Slot Reuse in MANET. Simulation results are presented and discussed in section 4. Section 5 concludes the paper.

2. Literature Review

Neng-Chung Wanga and Chao-Yang [1] have proposed a Multi-path QoS Multicast Routing (MQMR) protocol for MANETs, which offers dynamic time slot control using a multi-path tree or a uni-path tree to satisfy the bandwidth requirements of a call. The final multi-path QoS multicast tree meets the QoS requirements, and the aggregate bandwidth of the paths meets the bandwidth requirements of a call. Each destination utilizes a decision rule to get rid of the hidden terminal problem or insufficient bandwidth in the bandwidth reservation process. Moreover, a bandwidth reservation scheme is used for choosing the reserved time slots on each node in the multi-path QoS multicast tree. Simulation results demonstrate the effectiveness of MQMR in reducing network blocking and improving the call success ratio. However, with a high mobility speed, there is a chance of breaking the related links.

Vishnu Kumar Sharma et al [9] have proposed an agent based bandwidth reservation technique for MANET. The source mobile agent starts forwarding the data packets through the path with minimum cost, congestion and bandwidth. Each node's status is collected at the destination including the bottleneck bandwidth field and the intermediate node computes the available bandwidth on the link and then the data packet is feedback to the source. If available bandwidth exceeds bottleneck bandwidth, then the bandwidth reservation for the flow will be done in resource reservation technique. Rate control is performed using rate monitoring and adjustment methodologies for the congested flows. Resource allocation technique reduces the losses and improves the network performance that is revealed by simulation results.

Ridha Ouni [11] have proposed a QoS-aware mechanism, which combines signaling, reservation and recovery processes for providing the QoS guarantees required while coexisting with other services in TDMA/FDD mobile networks and evaluated its performance in terms of various metrics. This mechanism provides efficient bandwidth utilization with four different types of services. The advantages in designing a simple and effective bandwidth allocation mechanism are revealed through the simulation results. The proposed DSAP enhances channel throughput, achieves lower call blocking probability and stabilizes cell delay variation when comparing to other TDM mechanisms. DSAP improves resource utilization by more than 25%. However, the CBR call blocking probability brutally increases when the CBR traffic load exceeds 50%. In this case, there are not enough non-guaranteed time slots that can be used as resources for the new CBR calls.

Javad Akbari Torkestani et al [12] have designed a dynamic frame length CDMA/TDMA scheme for clustered wireless ad hoc networks with unknown traffic parameters. In this scheme, cluster-heads organize the collision-free intra-cluster communications using a TDMA scheme, and a CDMA scheme is overlaid on the TDMA for organizing the interference-free inter-cluster communications. Cluster formation, code assignment and slot assignment are encountered to design such scheme. Three algorithms are proposed here to solve the addressed problems based on learning automata. By proposed clustering algorithm, the wireless hosts are grouped into non-overlapping clusters. Then, by the proposed code assignment algorithm (considering the concept of code spatial reuse), an interference-free code is assigned to each cluster. Finally, by slot assignment algorithm, each cluster member is assigned a fraction of TDMA frame proportional to its traffic load. Simulation results show that CDMA/TDMA scheme outperforms the existing methods in terms of almost all metrics of interest, specifically, under bursty traffic condition. However, the average waiting time for packet transmission increases as the number of hosts increases.

Yang Wei-dong et al [13] have proposed a novel Adaptive Time Division Multiple Access (TDMA) Slot Assignment Protocol (ATSA) for vehicular ad-hoc networks, which divides the different sets of time slots according to the vehicles moving in opposite directions. When a node accesses the networks, it choices a frame length and competes a slot based on its direction and position of communication with the other nodes. The frame length is dynamically doubled or shortened using binary tree algorithm, and the ratio of two slot sets is adjusted to decrease the probability of transmission collisions. The theoretical analysis proved that ATSA protocol can reduce the time delay at least 20% than the Media Access Control protocol for Vehicular Ad-hoc Networks (VeMAC) and 30% than the ad-hoc. The simulation experiment demonstrated ATSA‘s good scalability and the collisions would be reduced about 50% than VeMAC, channel utilization is significantly improved than several existing protocols.

Sung Park and Denh Sy [14] introduced two novel control slot scheduling approaches called Network Entry Based Scheduling (NEBS) and Virtual Slot Scheduling (VSLOT), for creating dynamic contention free TDMA schedules. These schemes are ideal for exchanging control information in MANET and Wireless Mesh Networks (WMN) so that dynamic resource needs of participating nodes can be rapidly accommodated for QoS guarantees and each participating node can converge to a consistent TDMA schedule, which is optimum for the topology and resource demand of a dynamic wireless network environment. The algorithms are independent of topology and require only one and two hop data for creating both fair and efficient TDMA schedules that dynamically adapt to changing wireless network topologies. However, they are susceptible to collisions.

Liqi Shi and Abraham O. Fapojuwo [15] have proposed a nonlinear cross-layer optimization model including the network, MAC and physical layers to reduce overall energy consumption, thus solving the scheduling problem in clustered Wireless Sensor Networks (WSNs). It aims at providing network-wide optimized TDMA schedules that can achieve high power efficiency, zero conflict and reduced end-to-end delay. An algorithm is presented for deriving the TDMA schedules using slot reuse concept to achieve minimum TDMA frame length, based on the network-wide flow distribution defined by optimization model and transmission power on every link. This solution reduces the energy consumption and delay significantly, while satisfying a specified reliability objective simultaneously. However, due to the large per-hop transmission distance, the power cost increment is more significant and dominant compared to the small gain in frame length reduction.

3. Proposed Solution

3.1. Overview

In this paper, we propose a Link-Utility-Based Cooperative MAC Protocol with Slot Reuse in MANET. Initially a TDMA slot allocation technique is performed based on data rate, link lifetime and packet loss rate at each link. If the data rate and link lifetime is greater than the maximum threshold and packet loss rate is less than the minimum threshold, then the TDMA slots will be allocated to the nodes in the discovered path. The node delay in the network can be reduced by reducing the TDMA frame length using slot reuse technique.

3.2. Estimation of Metrics

3.2.1. Estimation of Data Rate

The data rate (DR) is estimated using the following Eq (1)

$$DR = x / d \quad (1)$$

where
x = data size
d = channel dela

The channel delay is estimated using following Eq (2)

$$d = T_m + T_{tx} \quad (2)$$

where
T_m = MAC Contention time
T_{tx} = data Transmission time

3.2.2. Estimation of Link Lifetime

End-to-End link condition is considered as Link Life time value (LL). Let LL_i, LLj… LLn be the link life time value of nodes between i and j. Then, the link life time value along the path is described as,

$$LL = \min(L_i, L_j, ..., L_n) \quad (3)$$

The minimum cumulative value of LL along the path is known as link life time value. In other words, it is the interval of continuous connection time amongst node and its neighbor node.

Let N_1 be the node with transmission range R_{tx} and N_2 be another node, which is within the transmission range of N_1 at time $t_{n.}$ Presume at t_{n+1} ($t_{n+1} > t_n$), node N_2 moves from the transmission range (R_{tx}) of $N_{1.}$ Here, t_n is known as link origination time and t_{n+1} is termed as link termination time. The life time of the link is estimated as the difference between link origination and link termination time. Residual life time of a link can be symbolized as,

$$LL = \left(\sum_{t>a} (N_L * t) / \sum_{t>L} N_L\right) - L \quad (4)$$

In equation (9), N_L be the number of links with link duration t secs and L be the current link age.

3.2.3. Estimation of Packet Loss Rate

The packet loss ratio is defined as the ratio of the appropriately received data packets to the data packet transferred, which is measured over a path among source to destination. It is expressed in terms of dropped packets.

$$PLR_i = 1 - \frac{DP_{rx}}{DP_{tx}} \quad (5)$$

Where

P_{tx} = data packet transmitted sent over a link

P_{rx} = data packet received by the subsequent node.

3.2.4. Node delay

The Node Delay (ND) is estimated, which is the difference of the time at which the first data packet arrives at node and time at which the last data packet leaves the nodes.

$$ND(z_1, z_2) = \begin{cases} z_2 - z_1, z_2 > z_1, & z_1, z_2 \in [1, Z] \\ Z - z_1 + z_2, z_2 < z_1 \end{cases} \quad (6)$$

If z_1 and z_2 are independent of each other, then the average delay experienced by the delayed data packet at node will be given using the following equation

$$\frac{\sum_{z_2=1, z_2 \neq z_1}^{Z} ND(z_1, z_2)}{Z-1} = \frac{Z}{2}, z_1 \in [1, Z] \qquad (7)$$

3.3. The Distributed Dynamic Slot Allocation Scheme

It is a fully dynamic slot scheduling and allocation scheme. This scheme mainly depends on slot request and release. This scheme combines the two approaches:

- Proactive approach
- Reactive approach

3.3.1. Proactive Approach

The proactive approach utilizes the readily available information to guide decisions on selecting/requesting the slots. The slots have the highest probability of producing error-free transmissions. This approach picks non-conflicting transmission allocations in the first place. Nodes request slots based on the distributed slot information.

Algorithm

Step 1: Every node reports slot ownership information at minimum once per cycle. These slot status information ensures that the nodes request non-conflicting node-scheduled transmission allocations over a 2-hop neighborhood using simultaneous link-scheduled transmissions, if possible.
Step 2: Spatial slot reuse based on the graph interference model takes place, when transmitters during node-scheduling or receivers during link scheduling are divided by a distance of at least 3 hops.
Step 3: Since neighborhood slot information is collected, a node derives and maintains a set of slots it considers available for request. This set has all the slots that have been reported with the available status by the neighbors.
Step 4: A node selects the slots to request from that set.

In addition, this protocol supports reactive approach.

3.3.1.1. Extended Pro-active Approach

Proactive approach is extended by including the channel quality information in a node’s periodic slot status report. This is done for slots, which are advertised as available.

Algorithm

Step 1: In order to maintain less overhead, each slot status is expressed using a 3-bit code. Only 2 of the 3 bits were used to indicate the slots status as available.
Step 2: The remaining third bit is used to report the slot channel quality value. Here, bit value of ‘0’ indicates “good” slot i.e. slot is considered interference-free, whereas a bit value of 1 indicates a “bad” slot i.e. a strong enough interfering signal has been

detected in the slot.

Step 3: This supplementary information refines the available for request slots set maintained by a node. The set includes the slots reported as available good by each neighbor. While making a request, a node will proactively select slots that are truly interference-free at that time.

There is no penalty paid in additional overhead cost. The cost lies with the increased complexity in the structure of the cross-layering solution.

3.3.2. Reactive Approach

The reactive approach provides corrections, whenever conflicts are detected. Conflicts may rise from sudden changes in node mobility. Re-active approach is implemented by specifying a comprehensive conflict detection and resolution scheme. Decisions made by this scheme translate into nodes issuing slot preemptions to slot requests.

Algorithm

Step 1: As these approaches depend on the graph interference model, the available slots considered by the protocol were unusable due to the interference from remote nodes.

Step 2: In many situations, decisions are made to perform slot reuse led to an increase in the number of collisions and yielded sub-optimal performance.

Step 3: The channel quality information estimated from the cross-layering technique was included in proactive and reactive approaches to improve the slot allocation and scheduling scheme.

3.3.2.1. Extended Re-active Approach

As the operating conditions of adhoc networks vary over time, slot schedules that were collision/interference free may suddenly not be anymore. This approach is extended by considering the channel quality in the conflict resolution scheme. The parameter is integrated to direct the slot preemption decisions. From the beginning, the slot preemption mechanism was used as a mechanism to resolve slot-scheduling conflicts. This mechanism is used to notify a sending node of bad slot receptions.

Algorithm

Step 1: A node will issue a preemption message to a neighbor for which signal reception on specific slot has fallen below the SNR threshold.

Step 2: On receiving the preemption message, those “bad” slots are immediately released by the transmitting node.

Step 3: Similarly, the channel quality value is considered within the slot approval process.

Step 4: Nodes verify their latest slot channel quality values before approving or objecting to a request, as the interference conditions may change between the time the original slot selection is done and the time a neighbor makes its approval or objection decision.

Step 5: An approval is sent, if no slot ownership conflict is found and the slot channel quality is good. An objection is sent otherwise.

4. Simulation Results

4.1. Simulation Parameters

We evaluate our Link-Utility-Based Cooperative MAC Protocol for Distributed Dynamic Slot Allocation (LIBCTDDSA) through NS-2 [16]. We use a bounded region of 1000 x 1000 sqm, in which we place the nodes using a uniform distribution. The number of nodes is 50. We assign the power levels of the nodes such that the transmission ranges as 250 meters. In our simulation, the channel capacity of mobile hosts is set to the same value: 2 Mbps. We use the Distributed Coordination Function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol. The simulated traffic is Constant Bit Rate (CBR).

The following table summarizes the simulation parameters used.

No. of Nodes	50.
Area Size	1000 X 1000
MAC	802.11
Simulation Time	50 sec
Traffic Source	CBR
Packet Size	500
Transmit Power	0.660 w
Receiving Power	0.395 w
Idle Power	0.035 w
Initial Energy	5.1 J
Transmission Rate	250m
Routing Protocol	AODV
Flows	2, 4, 6 and 8.
Rate	50,100,150,200 and 250 Kb.

4.2. Performance Metrics

We compare the performance of our proposed LIBCTDDSA is compared with Dynamic slot assignment protocol (DSAP) [11]. We evaluate mainly the performance metrics: Packet Delivery Ratio, Average Energy Consumption, End-to-End-Delay, Bandwidth Utilization and Throughput.

4.3. Results

The transmission rate is varied as 50, 100, 150, 200 and 250 Kb.

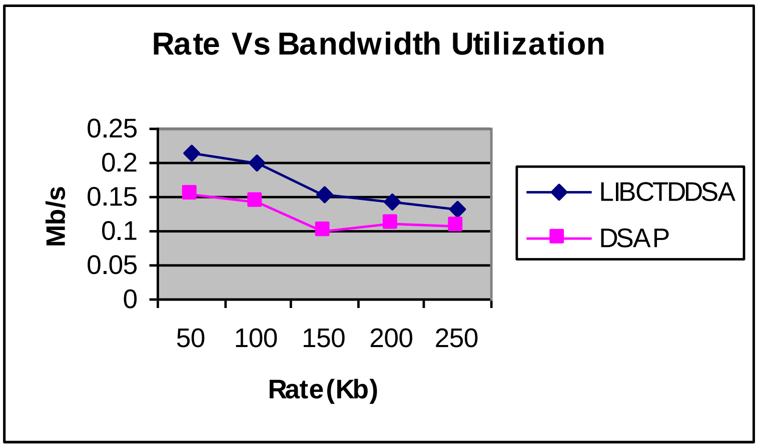

Fig 2: Rate Vs Bandwidth Utilization

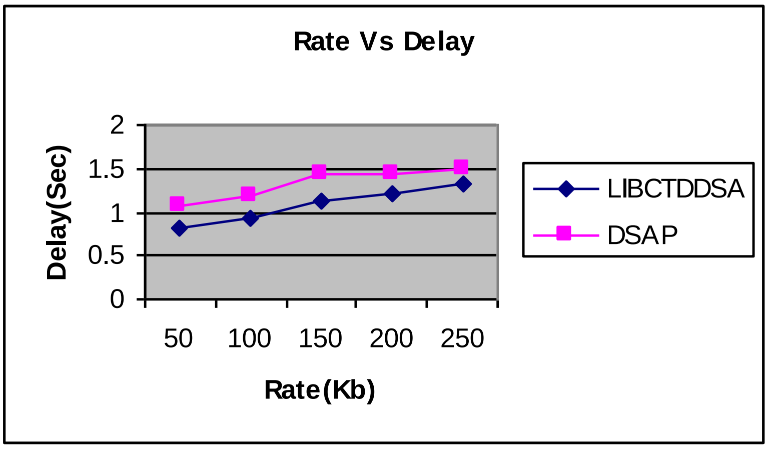

Fig 3: Rate Vs Delay

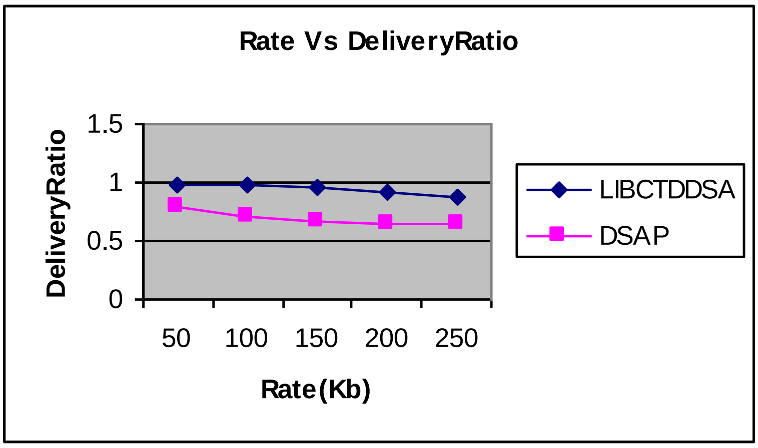

Fig 4: Rate Vs Delivery Ratio

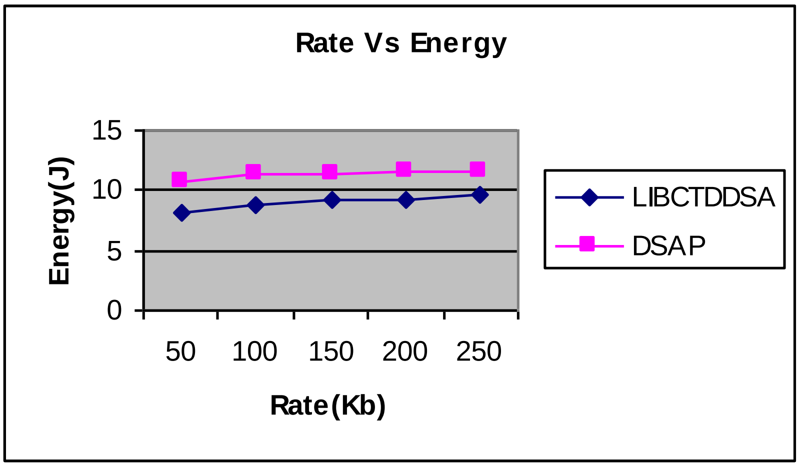

Fig 5: Rate Vs Energy Consumption

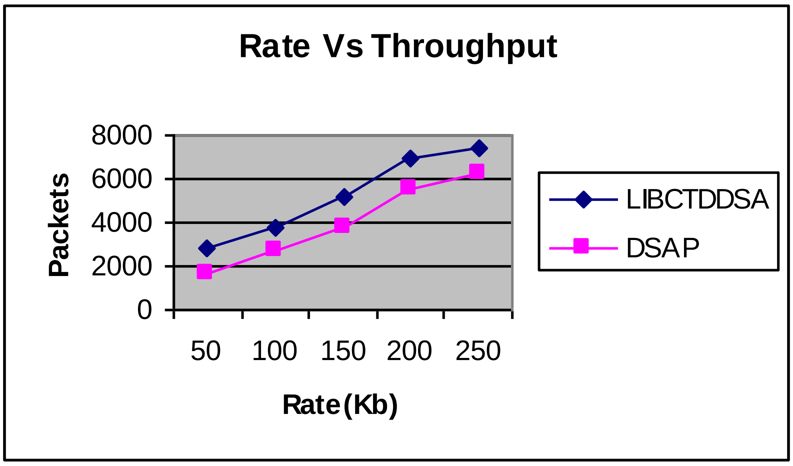

Fig 6: Rate Vs Throughput

Figure 2 shows the bandwidth utilization of LIBCTDDSA and DSAP techniques for different rate scenario. It can be seen that the bandwidth utilization of the proposed LIBCTDDSA approach is 26% higher than DSAP approach.

Figure 3 shows the delay of LIBCTDDSA and DSAP techniques for different rate scenario. The figure shows that delay of LIBCTDDSA protocol is 18% less than DSAP approach.

Figure 4 shows the delivery ratio of LIBCTDDSA and DSAP techniques for different rate scenario. From the figure, we can see that delivery ratio of LIBCTDDSA protocol is 26% higher than DSAP approach.

Figure 5 shows the energy consumption of LIBCTDDSA and DSAP techniques for different rate scenario. It can be seen from the figure that the energy consumption of LIBCTDDSA protocol is 20% less than DSAP approach.

Figure 6 shows the throughput of LIBCTDDSA and DSAP techniques for different rate scenario. The throughput of LIBCTDDSA protocol is 26% higher than DSAP approach.

5. Conclusion

In this paper, a Link-Utility-Based Cooperative MAC Protocol with Distributed Dynamic Slot Allocation in MANET has been proposed where a fully dynamic slot scheduling and allocation scheme is used. This scheme mainly depends on slot request and release. Distributed schemes combine two approaches namely, proactive approach and reactive approach. Results show that network performance of the graph-based model rapidly degrades as the spectral-efficiency mode increases. The impact is even greater with decreasing values of the path loss exponent. By simulation results, we have shown that the proposed technique minimizes the delay and maximizes the throughput.

References

[1] Neng-Chung Wanga and Chao-Yang Lee, "A multi-path QoS multicast routing protocol with slot assignment for mobile ad hoc networks", Information Sciences © 2012 Elsevier.

[2] Kuei-Ping Shih, Chih-Yung Chang, Yen-Da Chen and Tsung-Han Chuang, "Dynamic bandwidth allocation for QoS routing on TDMA-based mobile ad hoc networks", 2006, Computer Communications, ©2005 Elsevier.

[3] Neng-ChungWang and Chao-YangLee, "A reliable QoS aware routing protocol with slot assignment for mobile adhoc networks", Journal of Network and Computer Applications, 2009, No: 32, pp.1153–1166, ©2009 Elsevier.

[4] Annitha N and Pushpavalli M, "A Quality Of Service Based Admission Control Scheme For Manets", International Journal of Latest Research in Science and Technology, Vol.1, Issue 4, pp.379-382 ,November-December 2012.

[5] M. Coupechoux, B. Baynat, C. Bonnet, and V. Kumar, "Modeling of a Slotted MAC Protocol for MANETs", Workshop on Mobile Ad Hoc Networking and Computing, Sophia Antipolis, France, March 6, 2003.

[6] Myunghwan Seo, Hyungweon Cho, Jongho Park, Jihyoung Ahn, Bumkwi Choi, and Tae-Jin Lee, "Distributed TDMA MAC Protocol with Source-Driven Combined Resource Allocation in Ad Hoc Networks", ICN 2011 : The Tenth International Conference on Networks, The Netherlands Antilles.

[7] Imad Jawhar and Jie Wu, "QoS Support in TDMA-based Mobile Ad Hoc Networks", Journal of Computer Science and Technology, Volume 20 Issue 6, November 2005, Pages 797 – 810.

[8] Wei-Chih Harry Lin and Shuoh-Ren Tsai, "Multi-Ring Cyclic Scheduling for Spatial-TDMA Energy-Saving MAC Protocol in MANET", VTC Spring 2006: 673-677

[9] Vishnu Kumar Sharma and Dr. Sarita Singh Bhadauria, "Agent based Bandwidth Reservation Routing Technique in Mobile Ad Hoc Networks", (IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 2, No. 12, 2011.

[10] S. Sivavakeesar and G. Pavlou, "Two-way Admission Control and Resource Allocation for Quality of Service Support in Location-Aided Mobile Ad Hoc Networks", Mobile Computing and Communications Review, Volume 10, Number 1, pp. 44-57, ACM, January 2006.

[11] Ridha Ouni, "Dynamic slot assignment protocol for QoS support on TDMA-based mobile networks", Computer Standards & Interfaces 34 (2012) 146–155, © 2011 Elsevier B.V.

[12] Javad Akbari Torkestani and Mohammad Reza Meybodi, "An efficient cluster-based CDMA/TDMA scheme for wireless mobile ad-hoc networks: A learning automata approach", Journal of Network and Computer Applications 33, 2010, pp. 477–490.

[13] Yang Wei-dong, LI Pan, LIU yan, ZHU Hong-song, "Adaptive TDMA slot assignment protocol for vehicular ad-hoc networks", © 2013 The Journal of China Universities of Posts and Telecommunications, Volume 20, Issue 1, February 2013, Pages 11–18, 25.

[14] Sung Park and Denh Sy, "Dynamic Control Slot Scheduling Algorithms For TDMA Based Mobile Ad Hoc Networks", Military Communications Conference (MILCOM), 2008, IEEE, San Diego, CA.

[15] Liqi Shi and Abraham O. Fapojuwo, "TDMA Scheduling with Optimized Energy Efficiency and Minimum Delay in Clustered Wireless Sensor Networks", IEEE Transactions On Mobile Computing, VOL. 9, NO. 7, JULY 2010.

[16] Network Simulator: http:///www.isi.edu/nsnam/ns