Research Journal of Applied Sciences, Engineering and Technology 7(16): 3266-3272, 2014
DOI:10.19026/rjaset.7.670
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: July 25, 2013 Accepted: September 05, 2013 Published: April 25, 2014

Research Article

Channel Based Adaptive Rate Control Technique for MANET

[1]R. Bharathiraja, [2]S. Karthik and [3]V.P. Arunachalam
[1]Anna University, Coimbatore, India
[2]Department of Computer Science Engineering, SNS College of Technology, Sathy Main Road, Coimbatore-641035, India
[3]SNS College of Technology, Coimbatore-641035, India

Abstract: In Mobile Ad hoc Networks (MANET), most of the existing works does not consider energy efficiency during selecting the appropriate route. Hence in MANET selecting the appropriate route and also maintaining energy efficiency is very important. Hence in order to overcome these issues, in this study we propose Channel Based Adaptive Rate Control technique for MANET. Here the most appropriate links is selected to transmit the node with efficient power consumption. The node broadcasts the information of its outgoing and incoming links in N_{SET} instead of waiting for the feedback informattion from receiver. The number of packets transmitted in a channel access time is maximized by implementing the benefit ratio in rate selection algorithm. This study also introduces node cooperation, in node cooperation the node determines the feasibility of new rate setting determined by rate selection algorithm and it carries out new setting if it is feasible by following help, ack, reject and accept method. By simulation results we show that the proposed approach is power efficient and also increases the trasmission rate.

Keywords: Channel Based Adaptive Rate Control (CBARC), Constant Bit Rate (CBR), information exchange algorithm, Mobile Ad Hoc Networks (MANET), node cooperation algorithm, rate selection algorithm

INTRODUCTION

MANET: MANET stands for "Mobile Adhoc Network". It is a self-configuring infrastructure less network of mobile devices connected by wireless links (Saravanan and Ravichandran, 2012). In today era, mobile communication is becoming an integral component of life style. Along with other forms of wireless networks, mobile ad hoc and mesh networks provide a flexible but economical platform for short and mid range era. Chen *et al*. (2007) MANET is proposed as a new technique for delivering telecommunications for geographical areas where fixed wireless servers are difficult to be located. The development of ad hoc networks made possible a lot of applications that depend critically on the availability of wireless services in remote areas. The possible applications are rescue groups, medical applications on remote regions and military operations in battlefield (Oliveira and Pardalos, 2004).

This type of network is capable of forming a temporary network, without the need of a central administration or standard support devices in conventional network. In order to ensure network for future during rescue and emergency operations, these network establishes network everywhere without depending on irrelevant hardware. These networks build, operate and with the constituent wireless nodes. As these nodes have only limited transmission range, they depend on its neighboring nodes to forward packet. Sharma and Bhadauria (2011) in Ad hoc networks, robust and efficient communication techniques for high speed data transmission are required. If the channel state information is available to the transmitter, the transmission scheme can be adapted to the channel characteristics to provide important performance improvements in centralized random access wireless networks (Uchida *et al*., 2007).

Rate control techniques: Rate adaption can be defined as the problem of determining an appropriate data rate for the sender to send DATA frames and to adjust to varying channel condition. As the nature of channel condition is transient, rate control mechanism must be responsive to the changes with small overhead. Rate adaptation provides a critical mechanism for wireless systems to physical layer data rate and robustness to maximize the performance. In general, rate adaption is considered as a Mac layer mechanism and many algorithms are proposed also in which most of them exploit only MAC layer information that means making rate selection decision based on the frame losses.

Rate adaption is the process of switching data rates vigorously based on channel conditions, with the aim of selecting the rate that will provide the maximum throughput feasible for given channel condition. This

Corresponding Author: R. Bharathiraja, Anna University, Coimbatore, India

mechanism is used to improve the performance of wireless networks that suffer from fading and interference. The main components of the rate adaption process are channel estimation and the rate selection. Channel quality estimation involves measuring the time varying channel over a suitable period and predicting the behavior of the channel. Rate selection includes using the channel quality estimations to select an appropriate rate.

The major two issues in the channel estimation process are identifying metrics to be used as indicators of channel quality like SNR, signal strength, symbol error rate, BER and the algorithms to be used for channel prediction. The effectiveness of rate adaption depends on the accuracy of channel quality estimation. If once good estimates are generated, it is important to use them before they expire and hence it will be advantageous to minimize delay between the time of the channel estimate and the time the packet is transmitted with selected data rate.

In a network without rate control, a user can potentially dominate the network resources by pouring large amounts of data into the network that not only causes congestion but also injustice to the other users. Hence it is important to develop a reliable rate control strategy for efficient management of future wireless networks. The main aim of rate control is to fully utilize the available capacity of the network and to ensure fairness and QoS for the users.

The wireless networks are expected to support applications with high data rate requirements. As the wireless spectrum is scarce, it is important to fully utilize the potential capacity of the network. Higher data rates are generally achieved by more efficient modulation scheme. The performance of a modulation scheme is measured by its ability to preserve the accuracy of the encoded data (Saravanan and Ravichandran, 2012; Chen *et al*., 2007; Zhang *et al*., 2008; Narayanan and Rani, 2013; Lin and Shroff, 2004).

LITERATURE REVIEW

Zhang *et al*. (2008) have first conducted a systematic measurement-based study to confirm that in general SNR is a good prediction tool for channel quality and identified two key challenges for this to be used in practice:

- The SNR measures in hardware are often uncelebrated and thus the SNR thresholds are hardware dependent.
- The direct prediction from SNR to Frame Delivery Ratio (FDR) is often over optimistic under interference conditions.

Based on these observations, they have presented a novel practical SNR Guided Rate Adaptation (SGRA) scheme. They have implemented and evaluated SGRA in a real test-bed and compared it with other three algorithms: ARF, RRAA and HRC. Their results show that SGRA outperforms the other three algorithms in all cases they have tested. The drawback of this study is that they have not considered the metrics like end to end delay, bandwidth utilization and energy efficiency.

Wang *et al*. (2007) have studied the problem of using the rate adaptation technique to achieve energy efficiency in an IEEE 802.11-based multi-hop network. Specifically, they formulate it as an optimization problem that is minimizing the total transmission power over transmission data rates, subject to the traffic requirements of all the nodes in a multi-hop network. Interestingly, they have shown that this problem is actually a well-known multiple-choice knapsack problem, which is proven to be an NP-hard problem. Therefore, instead of finding an optimal solution, which is NP-hard, they seek a suboptimal solution. Their key technique to attack this problem is distributed Cooperative Rate Adaptation (CRA). Here, they promote node cooperation due to their observation that the inequality in no cooperative channel contention among nodes caused by hidden terminal phenomenon in a multi-hop network tends to result in energy inefficiency. Under this design philosophy, they propose a distributed CRA scheme and prove that it converges. Simulation results show that our CRA scheme can reduce power consumption up to 86% as compared to the existing (no cooperative) algorithm. The drawback of this study is that in the node cooperation technique for rate adaption, they have not considered metrics like routing overhead, delay and bandwidth utilization.

Bandai *et al*. (2008) have proposed a novel MAC protocol with transmission power and rate control to realize high energy efficient data transmission. In the proposed protocol, each node prepares a table that includes energy efficiency of all combinations of transmission power and rate. The table is only based on the specification of the network card without exact estimation of network topology and traffic. By exchanging control frames and looking up the transmission power and rate table, direct and relay transmission sequence are used arbitrarily. They have showed that the proposed protocol can realize high energy efficient data transmission via simulations. From this study we can enhance the future work for energy efficiency in different rate adaptive mechanism.

Wu *et al*. (2009) have proposed an auto rate protocol based on congestion detection called Auto Rate based on Congestion Detection (ARCD). In the ARCD protocol, congestion level is detected at the receiving nodes and fed back to the sending nodes along with the rate selection information and then the sending nodes transmit a limited number of back to back packets at appropriates rates. The simulation results show that the ARCD protocol can not only improve the throughput and packet delivery ratio of Ad hoc networks by taking full advantage of channel condition, but also achieve hop by hop congestion control. The drawback of this study is that the proposed protocol doesn't consider the metrics like bandwidth and energy efficiency.

Zhou *et al*. (2011) have proposed a novel Link-utility-based Cooperative MAC (LC-MAC) protocol with distributed helper (i.e., partner or relay) for wireless multi-hop networks. Since both throughput and energy efficiency are the key issues in wireless networks, link-utility in this study is defined as link throughput minus energy consumption to jointly consider rate adaptation and power control. Transmitter and each helper candidate calculate their own maximum achievable link-utility values independently and execute the distributed three-stage back off scheme. The one that first expires its backoff timer (maximizes the link-utility) will be selected as the best node, meanwhile the optimal transmission type (i.e., one-phase cooperative transmission, two-phase cooperative transmission or direct transmission), rate and power are uniquely determined by the best node (i.e., partner, relay or transmitter), which is very different from that of sender-based and receiver-based rate adaptation schemes. Extensive simulation results show that compared with CRBAR and RBAR, LC-MAC can significantly improve throughput and energy efficiency. The drawback of this study is that they have not considered the metric end to end delay in the proposed method.

METHODOLOGY

Overview: In this study, we propose Channel Based Adaptive Rate Control technique for MANET. Here the most appropriate links is selected to transmit the node with efficient power consumption. The node broadcasts the information of its outgoing and incoming links in N_{SET} instead of waiting for the feedback informattion from receiver. The number of packets transmitted in a channel access time is maximized by implementing the benefit ratio in rate selection algorithm. In node cooperation a node determines the feasibility of new rate setting determined by rate selection algorithm and it carries out new setting if it is feasible by following help, ack, reject and accept method.

System design: Initially, we consider that each node contains neighbor set N_{SET}. In our previous study, the N_{SET} contains the set of neighbors with their optimal transmission power values.

Information exchange algorithm: The information needed for calculation of the new rate selection algorithm is provided by the "Information Exchange Algorithm". The link information consists of the information like channel time for satisfying the traffic requirements and the corresponding power consumption under all possible PHY rates.

The Fig. 1 shows the chain topology of the nodes and the traffic pattern. It shows the geographical distances between the nodes and the traffic rate required between two nodes.

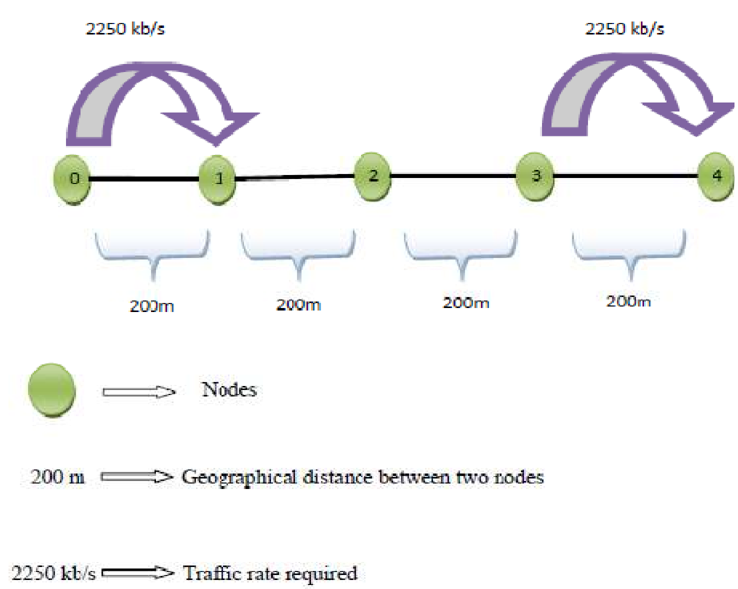

Fig. 1: Chain topology and traffic pattern

Table 1: Link information of the Fig. 1

Information of link (1, 2)

Rate index	PHY rate (Mb/sec)	Channel time (sec)	Power consumption (mW)
0	54	0.374	6.643
1	48	0.380	5.776
2	36	0.397	2.961
3	24	0.432	1.727
4	18	0.467	1.176
5	12	0.537	1.087
6	9	0.607	0.928
7	6	0.747	1.053

Based on the above Fig. 1, the approximate values of the PHY rate, Channel Time and Power consumption are mentioned in the Table 1.

The node broadcasts the information of its outgoing and incoming links in N_{SET} instead of waiting for the feedback informattion from receiver. The node will also broadcast the information about the cliques in the conflict graph with maximum power level; this represents the channel time constraints.

Rate selection algorithm: At each node, the main problem is divided into sub-problems. This sub-problem at each node is a multi choice knapsack problem and it is NP hard. The rate Selection Algorithm is designed below to solve this problem.

Algorithm:

Step 1: As the initial setting, set the PHY rate for each link in A's maximum interference range to the highest value.

Step 2: For each link within A's maximum interference range, select a PHY rate which has highest $\frac{\Delta E}{\Delta T}$, where ΔE denotes energy reduction and ΔT denotes the channel time increase as compared to the current setting. Then choose the link that has largest $\frac{\Delta E}{\Delta T}$ among all the links within A's maximum interference range. It should be considered that the ΔE should be greater than 0. If the setting $\Delta E > 0$ is not found, then the algorithm ends.

Step 3: Check whether the new PHY rate of the link is feasible by Eq. (1). If it is feasible, select the new rate setting otherwise reset to the previous setting.

Step 4: Go to step 2:

$$\sum_{(i,j)\in S} Channel\ Time_{(i,j)}\big(R(i,j)\big) \le 1 \qquad (1)$$

Here S∈ {all max cliques in the conflict graph}

R-> PHY rate of link (i, j)

The node A uses the rate selection algorithm to calculate the most energy efficient setting of PHY rates for all the links in its maximum interference range.

The detailed explanation of the rate selection algorithm is as follows. If there are K available PHY rates, which are indexed from 0 to K-1 in the descending order. Suppose if the link 1 switches its rate from i to j, then the benefit of such switching is defined as benefit ratio of replacing rate I with j on link 1 and the benefit ratio is defined as given below:

$$benefit\_ratio(l,i,j) = \begin{cases} \frac{power\_consumption\ (l,i) - power\_consumption\ (l,j)}{channel\_time\ (l,j) - channel\_time\ (l,i)} & i \neq j \\ 0, & i = j \end{cases} \qquad (2)$$

Here channel_time (*l*, *i*) is the needed channel time for satisfying the traffic requirements on l under rate I which is obtained by Eq. (3) given below:

$$channel\ time_{(s,d)}\big(R(s,d)\big) = \frac{\lambda(s,d)}{packet\_size}\big(t_{DIFS} + tRTS+2*tSIFS+tCTS+tDATARs,d+tACK \qquad (3)$$

Power_consumption (*l*, *i*) is the power consumption on l under rate I and i9s given by the Eq. (4) given below:

$$En_{(s,d)}\big(R(s,d)\big) = \frac{\lambda(s,d)}{packet\_size}\big[P_t(base\_rate) * tRTS+tCTS+tACK+PtRs,d*tDATARs,d \qquad (4)$$

packet_size is the length of a payload packet in each DATA frame.

$t_{RTS} + t_{CTS} + t_{ACK}$ are the transmission duration of an RTS frame, a CTS frame and an ACK frame, respectively.

And $t_{DATA}\big(R(s,d)\big)$ is the transmission duration of a DATA frame at the PHY rate R (s, d), which is given by below Eq. (5):

$$t_{DATA}\big(R(s,d)\big) = t_{PLCP} + \frac{packet\_size + overhead\_size}{R(s,d)} \qquad (5)$$

Here,

t_{PLCP} = The transmission duration of the PHY header of a DATA frame

$overhead\_size$ = The length of the overhead of a DATA frame

The physical meaning of benefit ratio is pictorially represented as shown below in the Fig. 2.

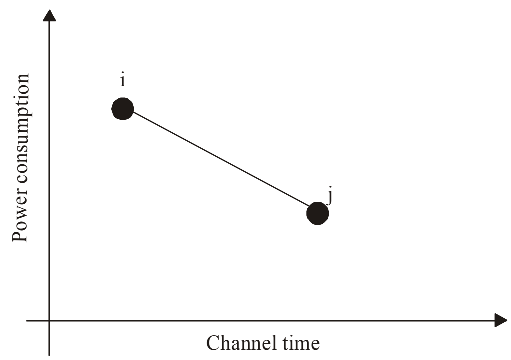

Fig. 2: Representation of benefit ratio

Node cooperation algorithm: Here the node selection algorithm is applied to help the node to determine the feasibility of a new rate setting which is determined above using rate selection algorithm. Now the algorithm follows the new settings when it is feasible and those steps are as given below.

HELP: Once the new rate setting is obtained and then the node finds out all the links that need rate adaptation and sends each of them a HELP message. Hence the HELP message contains the new rate of all involved links.

ACK and REJECT: When the HELP message is received, the node will check whether the new rate setting is feasible in its maximum interference range. It is possible that the new rate setting is not feasible for this node that receives the HELP message, since the interference range of this node may be different from that of the seeking-help node. Once the node receives the HELP message then the feasibility of the new rate setting will be justified by sending the ACK message to the seeking-help node. Or else it will reply with a REJECT message to that node to notify declination of the new setting.

APPLY: Once the seeking-help node gets a REJECT message, it will cancel the current candidate solution and recalculates a new solution by excluding the no feasible one. If the seeking-help node gets ACK messages from all the helpers then adjusts its PHY rate according to the current solution and sends an APPLY message with the new rates to all the helpers. Now the helper also adjusts its PHY rate upon receiving the APPLY message.

Advantages:

- The adaptive rate control technique increase in throughput
- Our approach decrease the routing overhead
- It increases the performance gain in terms of energy efficiency and transmission rates of data

Table 2: Simulation settings

No. of nodes	200
Area size	500×500
Mac	Modified 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	10.3 J
Transmission range	250 m
Rate	100, 200, 300, 400 and 500 kb

SIMULATION RESULTS

Simulation parameters: We evaluate our Channel Based Adaptive Rate Control technique (CBARC) technique through Network simulator (NS-2) (network simulator: http:///www.isi.edu/nsnam/ns). We use a square region of 500×500 sqm, in which nodes are placed using a uniform distribution. The number of nodes is 200. We assign the power levels of the nodes such that the transmission range is 250 m. We have modified the standard 802.11 CSMA MAC protocol to include the adaptive power control technique. The simulated traffic is Constant Bit Rate (CBR).

The following Table 2 summarizes the simulation parameters used.

Performance metrics: We compare the performance of our proposed CBARC method with DCRA method (Wang *et al*., 2007). We evaluate mainly the performance according to the following metrics:

Packet delivery ratio: It is the total number of packets received by the receiver during the transmission.

Average end-to-end delay: The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

Average energy consumption: The average energy consumed by the nodes in receiving and sending the packets.

Bandwidth: It is the number of bits transmitted through the channel.

Based on transmission rate: Initially, we vary the transmission rate as 100, 200, 300, 400 and 500 Kb, respectively for 200 nodes.

Figure 3 shows the received bandwidth of CBARC and DCRA techniques for rate scenario. We can conclude that the received bandwidth of our proposed CBARC approach has 31% of higher than DCRA approach.

Figure 4 shows the fairness of CBARC and DCRA techniques for rate scenario. We can conclude that the fairness of our proposed CBARC approach has 21% of higher than DCRA approach.

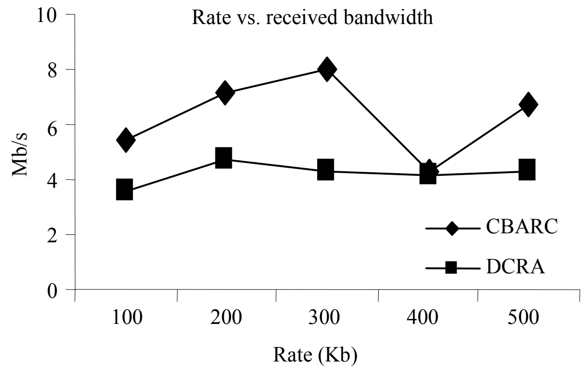

Fig. 3: Rate vs. received bandwidth

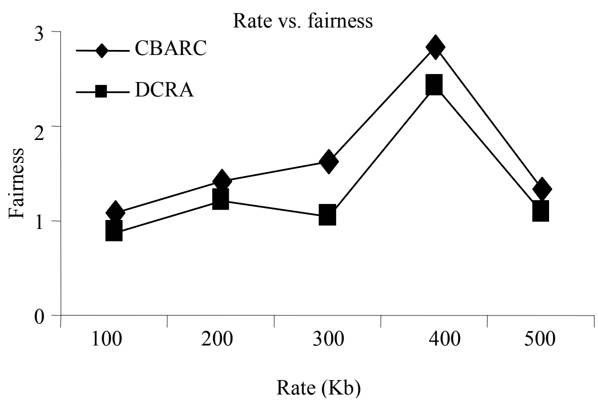

Fig. 4: Rate vs. fairness

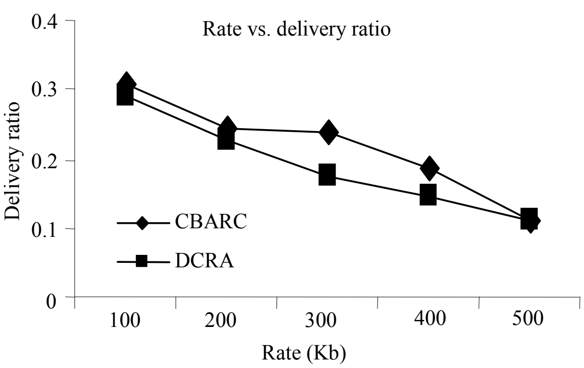

Fig. 5: Rate vs. delivery ratio

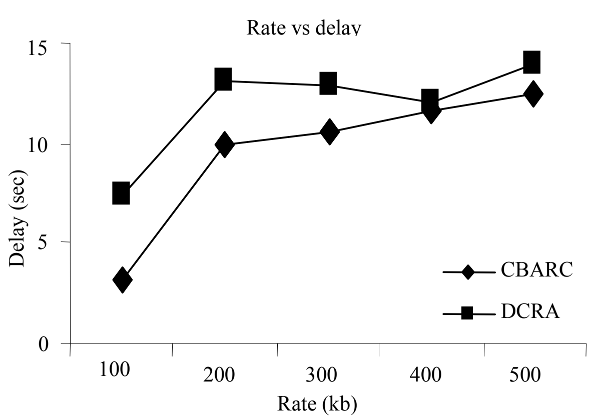

Fig. 6: Rate vs. delay

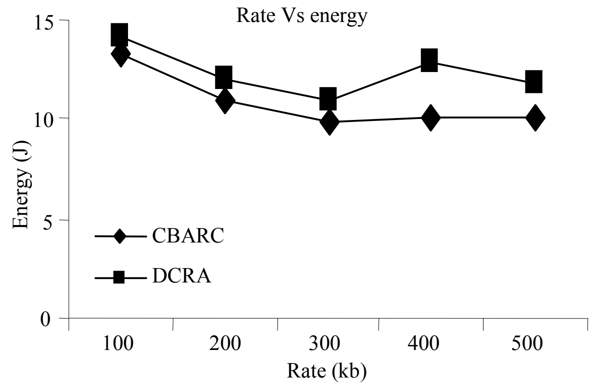

Fig. 7: Rate vs. energy consumption

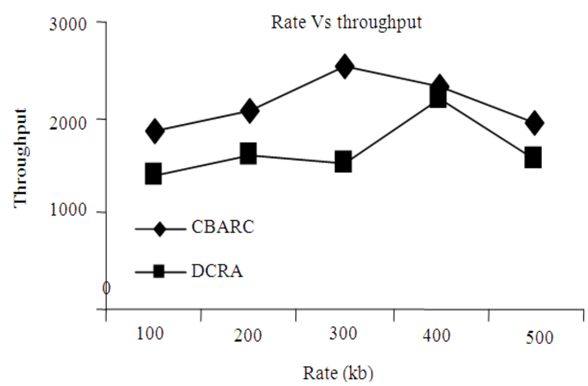

Fig. 8: Rate vs. throughput

Figure 5 shows the delivery ratio of CBARC and DCRA techniques for rate scenario. We can conclude that the delivery ratio of our proposed CBARC approach has 13% of higher than DCRA approach.

Figure 6 shows the delay of CBARC and DCRA techniques for rate scenario. We can conclude that the delay of our proposed CBARC approach has 23% of higher than DCRA approach.

Figure 7 shows the energy consumption of CBARC and DCRA techniques for rate scenario. We can conclude that the energy consumption of our proposed CBARC approach has 13% of higher than DCRA approach.

Figure 8 shows the throughput of CBARC and DCRA techniques for rate scenario. We can conclude that the throughput of our proposed CBARC approach has 22% of higher than DCRA approach.

CONCLUSION AND RECOMMENDATIONS

In this study, we have proposed a Channel Based Adaptive Rate Control technique for MANET in which the most appropriate links is choosen to transmit the node with efficient power consumption. The node broadcasts the information of its outgoing and incoming links in N_{SET} instead of waiting for the feedback informattion from receiver. The number of packets transmitted in a channel access time is maximized by implementing the benefit ratio in rate selection algorithm. In node cooperation a node determines the feasibility of new rate setting determined by rate selection algorithm and it carries out new setting if it is feasible by following help, ack, reject and accept method. By simulation results we show that the proposed approach is power efficient and also increases the trasmission rate. In our future study, effective scheduling algorithms for resource reservation and starvation avoidance can be proposed.

REFERENCES

Bandai, M., S. Maeda and T. Watanabe, 2008. Energy efficient MAC protocol with power and rate control in multi-rate ad hoc networks. Proceeding of IEEE Vehicular Technology Conference (VTC, 2008), pp: 66-70.

Chen, Y.P., J. Zhang and A.N. Ngugi, 2007. An efficient rate-adaptive MAC for IEEE 802.11. Proceeding of 3rd International Conference on Mobile Ad-Hoc and Sensor Networks, pp: 233-243.

Lin, X. and N.B. Shroff, 2004. Joint rate control and scheduling in multihop wireless networks. Technical Report, Purdue University. Retrieved form: http://min.ecn.purdue.edu/linx/papers.html.

Narayanan, S. and T. Rani, 2013. Cross-layer based routing and rate control using fuzzy decision systems in MANET. Int. Rev. Comput. Software, 8(2): 642-652.

Oliveira, C.A.S. and P.M. Pardalos, 2004. A distributed optimization algorithm for power control in wireless ad hoc networks. Proceeding of 18th IEEE International Parallel and Distributed Processing Symposium, pp: 26-30.

Saravanan, K. and T. Ravichandran, 2012. Data rate control algorithm for MAC protocol in 802.11 multi hop ad hoc networks. Int. J. Sci. Eng. Res., 3(5): 1295-1302.

Sharma, V.S. and S.S. Bhadauria, 2011. Congestion and power control technique based on mobile agent and effect of varying rates in MANET. Int. J. Adv. Comput. Sci. Inform. Technol., 1(1): 134.

Uchida, S., K. Naito, K. Mori and H. Kobayashi, 2007. A Rate-adaptive MAC protocol based on TCP throughput for ad hoc networks in fading channels. Proceeding of 4th International Conference on Cybernetics and Information Technologies, Systems and Applications (CITSA, 2007), pp: 236-251.

Wang, K., F. Yang, Q. Zhang and D.O. Wu, 2007. Distributed cooperative rate adaptation for energy efficiency in IEEE 802.11-based multihop networks. IEEE T. Veh. Technol., 56(2): 888-898.

Wu, W., Z. Zhang, X. Sha and C. He, 2009. Auto rate MAC protocol based on congestion detection for wireless ad hoc networks. Inform. Technol. J., 8(8): 1205-1212.

Zhang, J., K. Tan, J. Zhao and H. Wu, 2008. A practical SNR-guided rate adaptation. Proceeding of the 27th IEEE Conference on Computer Communications INFOCOM. Phoenix, ISSN: 0743-166X.

Zhou, Y., J. Liu, L. Zheng, C. Zhai and H. Chen, 2011. Link-utility-based cooperative MAC protocol for wireless multi-hop networks. IEEE T. Wirel. Commun., 10(3): 995-1005.