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Improving Fairness and throughput by Backing of Time (BoT) function in Wireless ad hoc networks

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Abstract*— This is the era of wireless communication. The world is going through the revolution in wireless communication technology and its many applications. It caught the attention of the media and the imagination of the public. Several wireless communication networks that rely on infrastructure such as cellular networks, Wireless Local Area Networks (WLANs), Wireless Personal Area Networks (WPAN), Bluetooth, Ultra-wideband networks (UWB), Wi-Max are very popular and extend with a very fast pace. In a proposed work, A novel method is proposed to enhance the throughput of the wireless ad hoc network using Backing of Time (BoT) method. This method utilizes the concept of Asymmetric RTS/CTS method in efficient manner according to energy level of wireless nodes. The proposed method is simulated and compared with Standard RTS/CTS and Asymmetric RTS/CTS methods based on parameters like Packet Delivery Ratio, Routing Overhead, E-2-E delay, Throughput and Energy Consumption of the network. The proposed work outperforms to the existing methods and simulation results showed 8.31% of improvement to PDR, 12.12% of improvement to RO, 1.11% of improvement to E-2-E Delay, 1.05% of improvement to throughput, 35.76% of improvement to Energy Consumption.

***Keywords*— WLAN, RTS/CTS, ad hoc network, energy, IEEE 802.11, network simulator 2.**

I. INTRODUCTION

Wireless communication networks have become a very popular and rapidly growing part of the telecommunications industry. In general, a Mobile Ad-hoc network is a group of wireless nodes in motion; establish dynamic connectivity between them without a pre-existing network or centralized administration using IEEE 802.11 technology. More logically, the less wireless network infrastructure is a technological solution for establishing communications in areas where infrastructure is not available or not accessible. A simple Wireless Ad-hoc network is shown in Fig. 1.

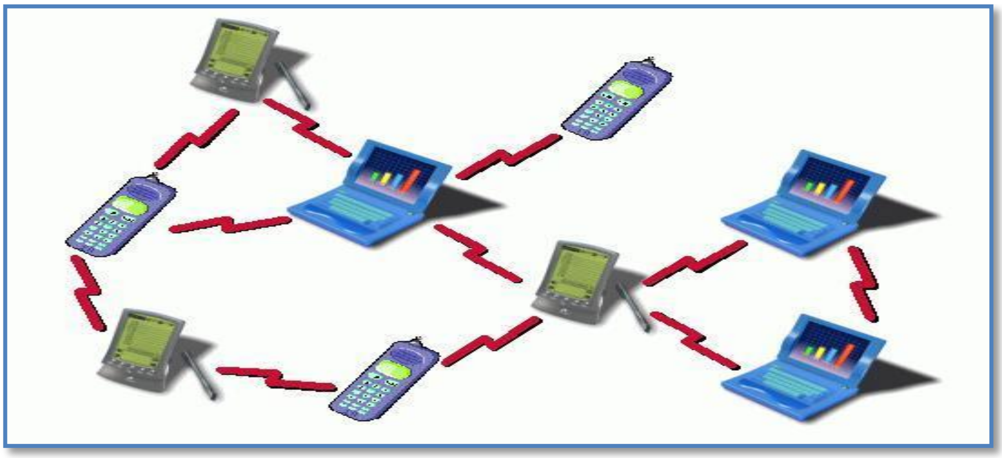

Figure 1: Wireless Ad Hoc Network [eexploria]

MAC protocols developed for wired networks such as Carrier Sense Multiple Access and its variants such as CSMA with collision detection (CSMA / CD) cannot be used directly in wireless networks. In CSMA-based schemas, the transmission node first detects the support to see if it is idle or busy. The node differs from its transmission to avoid a collision with the existing signal, if the vehicle is detected busy. Otherwise, the node begins to transmit its data while continuing to detect the medium. But in wireless networks, collisions occur in the receiving node. As the signal strength in the wireless medium fades proportional to the square of the distance from the transmitter, the presence of the signal on the receiving node may not be clearly detected in the transport other terminals, if out of range.

As shown in Figure 2, node B is in the radius of nodes A and C, but C is in the range of A. Consider the case in which A transmits to node B. The node C, while outside the range a, it is not possible to detect vector and it can send data to B, causing a collision on B. This is known as "hidden terminal problem" because nodes A and C are hidden from each other [1, 2].

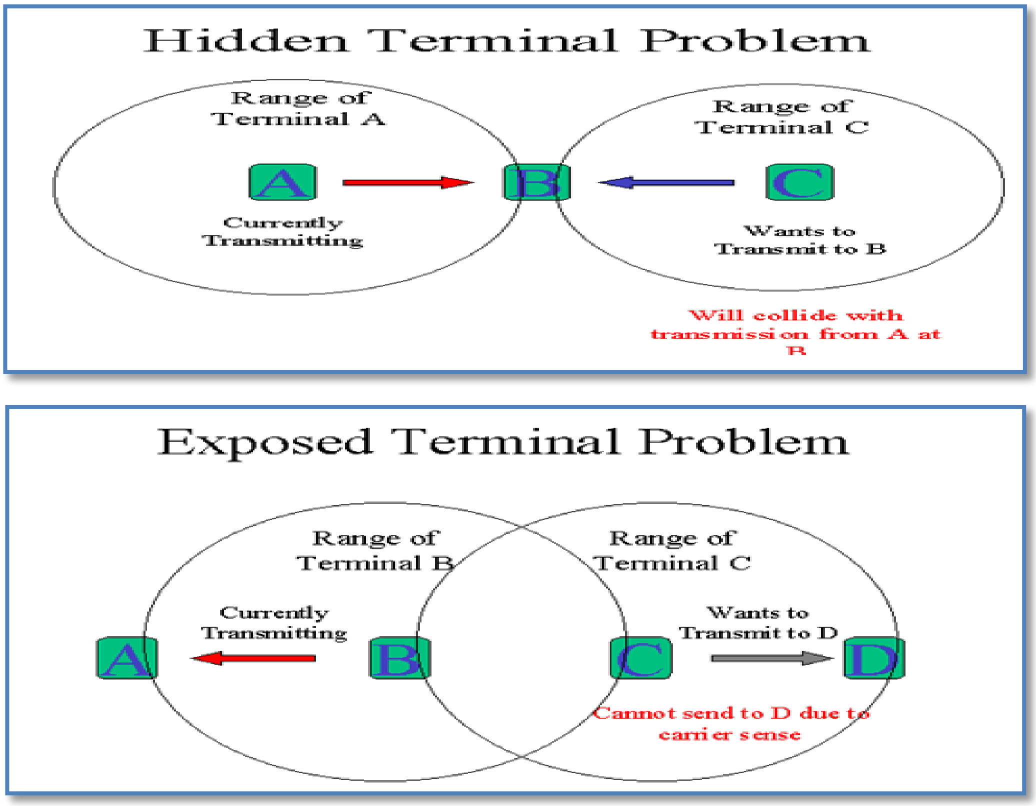

Figure 2: Hidden and exposed terminal problem

Consider another problem we face in wireless networks. In this case, node B is transmitting to node A. Because C is within the range of B, it detects the operator and decides to postpone its transmission. However, this is not necessary because there is no way that the transmission of C can cause a collision in the receiver A. This is known as the "problem of the exposed terminal", since B, being exposed to C, has unnecessarily delayed its transmission. [2].

In addition to the problems mentioned above, ad hoc wireless networks have another limitation for limited power or battery life. This problem is quite serious because once the knot's battery has run out; cannot transmit or receive data. It becomes dead and this affects network connectivity because in the ad hoc network when an intermediate node dies, the entire link must be re-formed. This leads to a large amount of delay, which hinders the performance of the entire system. Therefore, power control is a very important aspect of the Ad hoc wireless network.

II. RELATED WORK

This section presents the basic information related to the work presented in this paper, as a general description of the wireless communication technology and an explanation of the relevant characteristics of the wireless channel, then a critical bibliographic review of the transmission range, power consumption and performance improvement in ad hoc wireless networks introduced. Currently, large studies are concentrated in the mobile ad-hoc wireless network.

The In 2014, ***Prihadi Murdiyat, Kah Seng Chung, King Sun Chan***- proposed an iterative decomposition method for this purpose. They first identified a limited number of basic network configurations of chain topology and determine their respective throughputs through simulation. Then they iteratively decompose the target network configuration into segments, each of which is represented by one of the basic network configurations, to estimate its overall throughput performance. To verify the accuracy of our method, they conduct several simulations in ns-3. Simulation results show that their method is quite accurate and yet very simple. [3]

In 2014, ***Rui Wang and D. Richard Brown*** considered a time-division multiple access scenario in which a wireless access point transmits to a group of users who collect energy and then use this energy to transmit back to the point access. The above approaches have found the optimal time allocation to maximize the sum yield, in the hypothesis that users must use all their power collected in each block of the "collection and transmission" protocol. This document considers the optimal allocation of time and energy to maximize the total throughput of the case when the nodes can save energy for successive blocks. To maximize the total yield in a finite horizon, the initial optimization problem is separated into two subproblems and finally can be formulated into a problem of optimization of the limited standard box, which can be solved efficiently. A narrow upper limit is achieved by relaxing the causality of energy collection. Simulation results are also provided to demonstrate that the energy harvest-and-transmit protocol provides an improved sum performance that increases with the number of transmission blocks. [4]

In 2014, ***Yi Luo, Tharm Ratnarajah***, two-level heterogeneous wireless networks are considered in this document where nodes in the first level are distributed as a Poisson Point (PPP) process. The nodes in the second level are distributed as Poisson Pooled Process (PCP). The nodes in the second level have information on the status of the imperfect channel (CSI) of the top-level node in whose cell Voronoi are located. On the one hand, cross-interference is coordinated with second-level nodes through the interference alignment (IA) approach, where a balance between increasing the number of data streams and increasing the signal / interference (SIR) in each data stream. On the other hand, the remaining interference is modeled by the stochastic geometry and the analytical expressions of the performance are derived. Monte Carlo simulations validate our expressions and show the gain generated by the interference coordination approach. [5].

In 2014, ***Aznor Hanah Abdul Halim, R. Badlishah Ahmad, Mohd Nazri Mohd Warip***- presented and discussed a new network environment that is multiple optical channel, which coupled Ethernet with WDM to decrease the average queuing delay and increases the normalized throughput. The performances of three channels are evaluated with different network parameters using discrete event simulator called OMNeT++. In this paper it has been proved that RS BEB algorithms show the best throughput for three data rates. Moreover, in average queuing delay and RS BEB shows the lowest delay despite the others algorithms. It has been observed from this work that an increase in the number of nodes, the percentage of normalized throughput decreasing is less than 20% for every additional node in the network. [6]

In 2015, ***Konstantinos Samdanis ,Peter Rost ; Andreas Maeder ; Michela Meo ; Christos Verikoukis***- provided an accessible analytical framework that can be used to compare the energy consumption and throughput characteristics of different RAN configurations based on the Long Term Evolution (LTE) family of standards. The technical approach is useful for exploring how an LTE RAN may be upgraded in an energy efficient manner to meet the expected growth in mobile data traffic. The approach also allows particular energy saving techniques to be evaluated, such as deployment techniques (e.g., cell size and RAN topology) and power state techniques (e.g., sleep modes). The analysis uses accurate energy consumption models of base station and access point equipment which account for the load independent as well as load dependent energy consumption effects. The Energy Consumption Gain (ERG) and Throughput Gain (TPG) figures of merit are used together with a new figure of merit called the Energy Throughput Gain (ETG) which reliably accounts for the difference in energy consumption and throughput between two distinct RAN configurations. The energy consumption and throughput performance of a green field RAN deployment scenario that uses different cell sizes and base station types is evaluated. The chapter then explores energy savings obtained from sleepmodes and HetNet deployments. [7]

In 2015, ***A. Sumarudin, Trio Adiono***- proposed an easily configured Wi-Fi wireless sensor network for mesh topology using OLSR (optimized link state protocol). The system is capable to connect between motes with mesh topology. In order to support high data bitrate, multi applications, multi platform, and secure data connection, we implement the system using Raspberry Pi(R) with ARMv7(R) Quad Cores and Wi-Fi interface. For easy of configuration and operation, the system utilized Linux based Raspbian kernel 3.18 operating system. The system has been successfully implemented and verified for real-time soil monitoring system. The system implementation only utilized 1% of processor resources and very responsive for topology regenerating. The QoS performance shows the average jitter is 3.87 ms, the throughput is 8.5 Mbps and the Packet loss is 0.019%. In term of range, the system can reach 175 Meter. The result shows that the proposed WSN can be used for high bit-rate Wi-Fi based on application. [8]

In 2015, ***Istikmal, Adit Kurniawan, Hendrawan***- showed the routing algorithm which not concern with this channel quality cannot adapt well in Mobile Ad hoc Networks (MANET). They evaluated reactive routing protocol in deterministic and probabilistic propagation models, which are two-rayground and shadowing. These models are used to predict the received signal power of each packet. The result shows the degradation of routing protocol performance in more realistic environment, which is shadowing propagation model. Then we used mathematical analysis based on throughput performance related to the probability of error and Signal to Noise Ratio (SNR). Routing protocols face uncertainty in link quality when the topology of the network became dynamic. The routing protocols have to consider channel quality in the link transmission to acquire higher throughput performance. [9]

In 2015***, Andrea Ortiz, Hussein Al-Shatri, Xiang Li***-Two-hop energy harvesting communications are considered. The scenario consists of a source node which wants to send data to a destination node through a half-duplex amplify-and-forward relay station. The source node and the relay station harvest energy from the environment several times and use it to transmit the data. The goal is to find the optimal power allocation that maximizes the throughput at the destination node. They showed that the use of a half-duplex amplify-and-forward relay station leads to a non-convex optimization problem. Therefore, to find the optimal power allocation we propose to reformulate the problem as the difference between two concave functions (D.C. programming). Moreover, a branch-and-bound algorithm is tailored to fit the energy harvesting constraints. They showed that the feasible region has to be adapted to facilitate the branching process. Additionally, they reduced the complexity in the calculation of the bounds by relaxing the problem into a convex problem with a linear objective function. Numerical results compare the performance in different energy harvesting scenarios. [10]

In 2015, ***Mini S. P., S. Viswanatha Rao, Sakuntala S. Pillai*** -evaluated a channel allocation method which improves the overall throughput of 802.11 MAC. This method reduces collision considerably, by allowing each node to select appropriate channel from its 3-hop neighborhood. This method is simulated using NS 2 and results show enhancement in throughput. [11]

In 2015, ***Radha D N, Poonam Vijay Tijare, Manikonda Aparna***- proposed a framework which improves the efficiency of the network using electrical vehicles known as Sencars. The sensor nodes get charged based on optimal energy conditions. An experimental and simulated result has shown the efficiency of network in terms of throughput, packet delivery fraction and other metrics of importance. [12]

In 2016, ***Deepthi, Vaibhav Rajapurohit, Veena S Chakravarthi***- dealt with different techniques used in the low power high throughput MAC design along with PME to achieve low power consumption guaranteeing the targeted performance as per the standard and beyond. The resulting architecture promises to give 24 to 26% less power consumption in Access Point (AP) and Station (STA) configurations. [13]

In 2016, ***Tianyi Wang, Xiong Wang, Xiaohua Tian***- come up with a frame structure with fixed length and establish a network join principle regarding the slot assignment for the newly added node, which avoid the overhead of maintaining extra frame length information among nodes. In addition, we adopt a contention-based channel access mechanism for enhancing the utilization of the idle slots, thus increasing the overall throughput. Finally, simulation results are demonstrated to validate the effectiveness of HD-MAC. [14]

In 2016, ***Xianlong Jiao, Guirong Chen, Xiaodong Wang***- investigated the problem of maximizing uniform multicast throughput (MUMT) for multi-channel dense wireless sensor networks, where all nodes locate within one-hop transmission range and can communicate with each other on multiple orthogonal channels. This kind of networks show wide application in the real world, and maximizing uniform multicast throughput for these networks is worth deep studying. Previous researches have proved MUMT problem is NP-hard. However, previous researches are either hard to implement, or use too many relay nodes to complete the multicast task, and thus incur high overhead or poor performance. To efficiently solve MUMT problem, they adopted the concept of the maximum independent set with the size constraint, and present one novel Single-Broadcast based Multicast algorithm called SBM based on the concept. They proved that SBM algorithm achieves a constant ratio to the theoretical throughput upper bound. Extensive experimental results demonstrate that, SBM performs better than existing work in terms of both the uniform multicast throughput and the total number of transmissions. [15]

In 2016, ***Tien-Wen Sung, Chia-Jung Lee, Sheng-Hui Meng***- presented the architecture of Wireless Distribution System (WDS) in an IEEE 802.11-based environment can avoid the decline of wireless signals and keep the data packet throughput by delivering packets among access points. This paper focuses on WDS and proposes an algorithm of Maximum Independent Set (MIS) to determine the subset of access points and reduce its computation time for wireless data packet transmission and achieving throughput improvement. [16]

In 2017, ***Yun Wen, Hiroshi Fujita, Dai Kimura***- Dynamic sensitivity control (DSC) technology, which adjusts the carrier sense threshold (CST) to encourage more APs and STAs to transmit simultaneously, is considered an effective approach to improve the throughput in densely-deployed WLAN networks. The DSC algorithm should take into account both the increase of transmission opportunity, and the possible transmission rate degradation of related links caused by the consequent interference. Conventional algorithms, which set the CST value to allow simultaneous transmission, only when a required signal to interference plus noise ratio (usually for a high transmission rate) can be guaranteed, are too conservative to improve the throughput. In this paper, they proposed a novel DSC algorithm that enables simultaneous transmissions which lead to improved system throughput even when the transmission rate is degraded. Since whether system throughput can be improved by simultaneous transmission is different for each communication link, they set different CST values for different links instead of setting just one common CST value. They first formulated the throughput of each downlink as a function of related links' CST, and then search a set of CST values for these links to maximize the system throughput. A heuristic procedure is adopted in our algorithm to reduce calculation complexity. From numerical simulation results, it is shown that proposed algorithm can improve the system throughput by up to 30% when compared to a conventional algorithm. [17]

In 2017, ***Guojie Hu, Kui Xu, Youyun Xu*** - focused on the cooperative strategy for multi-source multi-relay system. In order to overcome unreliable wireless channels, they introduced a certain diversity degree by limiting the number of original packets included in one transmission no more than the number of sources. They applied two diversity schemes, which called spatial diversity combined random linear network coding (SDRLNC) and simple spatial diversity (SSD), respectively. They derived bounds of throughput for these two schemes, respectively. Through simulation they got the conclusion that, given a series of parameters, the SDRLNC scheme always has a better performance and there always exists an optimal diversity degree for both schemes for the purpose of obtaining the optimal throughput. [18]

In 2017, ***Abdulaziz Shehab, Mohamed Elhoseny***, build the optimum network structure in cluster-based WSN may differs from round to round depending on a set of sensor nodes factors, i.e, remaining energy, vulnerability index, and the distance from BS. Getting the intended optimum structure is non-trivial process, which includes determining the appropriate number of clusters, electing a cluster head (CH) for each cluster, and assigning each sensor node to a clusters. Recently, several studies propose CH selection protocols with predefined number of clusters. The present work introduces a new Genetic Algorithm (GA) based protocol that aims to get the optimum network structure for single-hop cluster model in WSN. This structure may differ after each round. The results show that the proposed GA-based method leads to more network lifetime and throughput. Also, it is more efficient in the context of a dynamic environment. [19]

In 2017, ***Shota Mizuno, Dairoku Muramatsu, Yasuaki Yuda***- defined different forms of system throughput for the respective service channels considering different service requirements. Based on a definition of the integrated system throughput that combines the system throughput levels of all service channels, this paper proposes the optimum frequency bandwidth allocation method among service channels to maximize the integrated system throughput. Computer simulation results show the effectiveness of the proposed method. [20]

III. PROBLEM IDENTIFICATION

All Some problems are identified in the existing system, which can be listed below:

1. Although it is good idea to decrease the RTS range of nodes in a network to eliminate the exposed node problem, But the RTS range should be decreased to its half may affect the other networks parameter.
2. In existing system, only one networking parameter is considered for performance analysis, other networks parameters should also be considered like Delay, Routing Overhead and Packet Delivery Ratio.
3. Also Energy of nodes could be taken into consideration, as RTS range is decreased so how much would be the lifetime of the network? ; This should be analysed.
4. Future work is left out to look at changing the transmission range of RTS and CTS frames in topologies of mobile, randomly distributed nodes.
5. It eliminates some of the nodes that overhear the RTS frame from the sending node thereby reducing the total number of exposed nodes in the network. When the RTS range is completely included in the CTS range, there are no longer exposed nodes.

By looking into the problems identified in the existing system, it is planned to improve the system by proposing a new method Backing of Time (BOT) method. The Proposed method is enhancement of the existing system with different variation according to different networking parameters. The proposed system gives depth analysis of the system and justifies the improvement of the system through simulation. The proposed system methodology, algorithm, system design is discussed in the next section.

IV. PROPOSED RESERACH METHODOLOGY

The The objective of the research work is to analyze the performance Standard RTS/CTS, Asymmetric RTS/CTS and BoT- RTS/CTS method when the wireless ad-hoc network has to be created for the grid topology and random topology. In order to fulfill the objective a comparative analysis between these three RTS/CTS has to be carried out in the simulated environment created in the NS-2 simulator comprising of 225 nodes and 100 nodes based on the basic network parameters like packet delivery ratio, end to end delay, throughput, routing overhead and energy consumption .

Whenever a sender wants to send information to a destination, it initiates an RTS (Request to Send) packet to request a route, which allows it send the data over a wireless channel. In turn, if destination node found to be free, it then replies with CTS (Clear to Send) packet to source node; then communication started over there. All the nodes involved in a wireless network follow some set of rules to send, receive and forward packet by means of using routing protocol. These routing protocols forms the backbone of communication held in a wireless networks. Some of the mostly use routing protocols are AODV, DSDV, DSR, TORA etc.

In these protocols, the distance table contains the network view of the neighbors of a node. It contains a matrix in which each element contains the distance and the penultimate node signaled by a neighbor for a particular destination. The routing table contains the updated view of the network for all known destinations. They maintain the shortest distance, the predecessor node (penultimate node), the successor node (the next node to reach the destination) and an indicator indicating the status of the route. The status of the route can be a simple (correct) path, a loop (error) or the unmarked (null) destination node. The link cost table contains the cost (for example, the number of hops to reach the destination) for retransmission of messages through each link. The cost of an interrupted connection is infinite. It also contains the number of update periods (intervals between two successive periodic updates) approved by the last successful update of that received link. This is done to detect hop links. The message forwarding list contains an entry for each update message that is retransmitted and manages a counter for each entry.

In a proposed method, the routing table info routing protocols is kept into mind, and the existing system of asymmetric RTS/CTS method is enhanced. The link cost table contains at least three desired path in between source node and destination node. Here, one assumption is considered that there are three possible paths to reach at destination node from source node via neighbor nodes. The working of backing of Time (BoT) is centered here. Suppose initially one path is selected at a time to send the information with packet from path 1, here the timer is set as BOT level -0. The path status may be a simple path (correct), or a loop (error), or the destination node not marked (null). This mechanism also detects the energy level of neighbor nodes, if it’s energy level is between 60 percent to 100 percent, the RTS range and CTS range is kept same i.e. 140 meters.

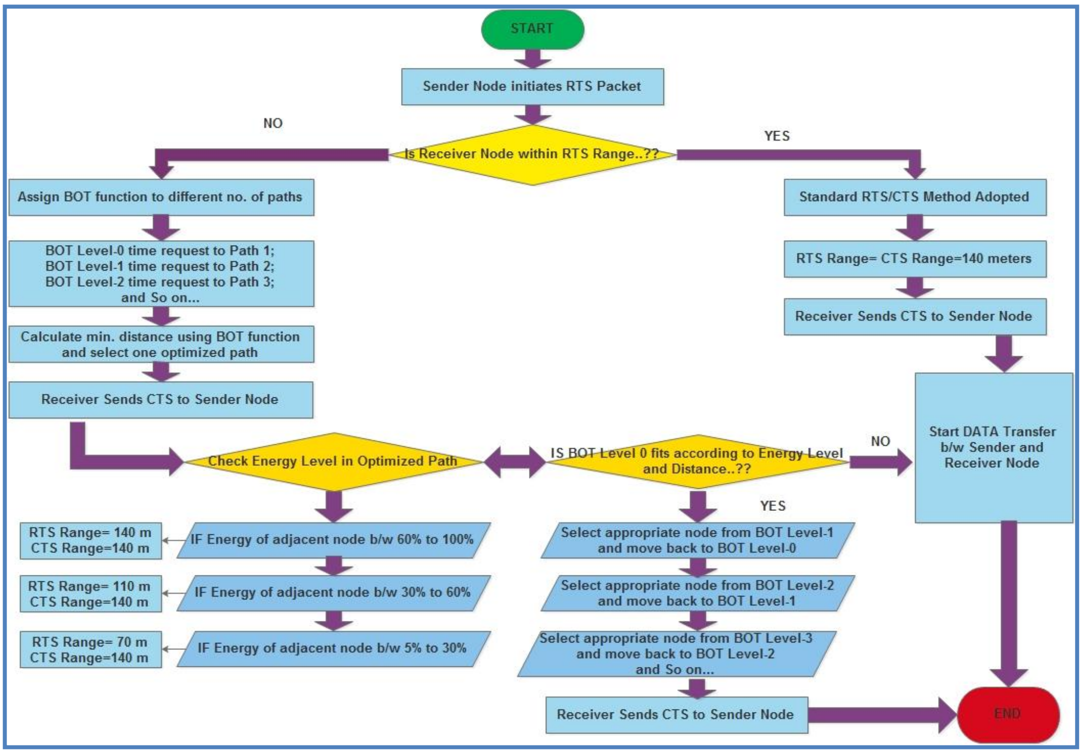

Figure 3: BoT Methodology Flowchart

In The flowchart of proposed BoT (Backing of Time) is shown in figure 3.Then message retransmission list makes an entry for every update message that is to be retransmitted and maintains a counter for each entry. This counter is decremented after every retransmission of an update message.

This process is iterated for Path 2 and Path 3 also and timer is set to BOT level – 1 and BOT level – 2 respectively. If the energy level of neighbor node is between 30 to 60 percent, the RTS range is decreased to 110 meters and CTS range is kept same. This step minimizes the routing overhead of the network created during forwarding packets from sender, receiver and neighbor nodes. If the energy level of neighbor node is between 0 to 30 percent, the RTS range is decreased to 70 meters and CTS range is kept same. This step minimizes the routing overhead of the network created during forwarding packets from sender, receiver and neighbor nodes.

Then counter time of BoT (Backing of Time) is decremented after every retransmission of an update message. Each update message contains a list of updates. A node also marks each node in the routing that has to acknowledge the update message it transmitted. When the counter reaches zero, the entries in the update message for which no acknowledgment was received must be retransmitted and the update message is deleted. Therefore, a node detects a link hop for the number of update periods lost since the last successful transmission. After receiving an update message, a node not only updates the distance to the transmission neighbors, but also checks the distance of the other neighbors, so convergence is much faster.

The idea of name given Backing of Time (BoT) is that usually a routing protocol does not maintain their routing path, once they have opted one path, other path eliminated from the routing table. In proposed BoT method, it is tried to maintain the routing path according to BOT level-0 path, BOT level -1 path and BOT level – 2 paths. BOT level -1 path and BOT level – 2 paths are the path opted for communication, which has been earlier updated in a routing table, do not let it go to next update; that's why the name is decided as this method hold path of previous time selected by the routing protocol. Figure 4 shows the Pseudo code for BoT algorithm.

```
INPUT: BoT Method
Output: Effective communication range & Energy Optimized Path
Step 1: Sender Node sends RTS packet
Step 2: Check Receiver Node is within RTS Range..?
          >>>If Yes, set RTS Range=CTS Range= 140 meters.
          >>> send CTS packet to sender.
          >>> Do communication and go to step 8.
          >>> If no, Check BoT function and go to step 3.
Step 3: Assign BoT function to nodes.
Step 4: Calculate minimum distance and assign BoT timer of BOT level-0, BOT level-1
              and      BOT level-2.
Step 5: Receiver Send CTS packet to Sender Node.
Step 6 : Check Energy Level in Optimized Path..?
          >>> If Energy Level between 60 to 100 percent,
          >>> Assign BoT level -0 path.
          >>>Assign RTS=CTS=140 meters.
>>>else if  Energy Level between 30 to 60 percent,
          >>> Assign BoT level -1 path.
          >>>Assign RTS=110 meters, CTS=140 meters.
>>>else if  Energy Level between 5 to 30 percent,
          >>> Assign BoT level -0 path.
          >>>Assign RTS=70 meters , CTS=140 meters.
Step 7: Start data transfer between sender and receiver node.
Step 8: Stop
```

Figure 4: Pseudo code algorithm for BoT Method

V. PERFORMANCE PARAMETERS

Efficient routing protocols can provide significant benefits to wireless ad hoc networks in terms of both performance and reliability. Routing protocols are evaluated using different performance metrics. They symbolize different characteristics of the overall network performance to achieve the required quality of service (QoS) and describe a number of quantitative metrics that can be used for evaluating the performance of ad hoc networks routing protocols. In this report, five metrics are used for evaluating and comparative study of their effect on overall network performance. The metrics proposed are packet delivery ratio, packet end-to-end delay, routing overhead, and network throughput and energy consumption.

A. Packet Delivery Ratio

Packet Delivery Ratio (PDR) is the ratio between the number of packets transmitted by a CBR traffic source and the number of packets received by a CBR traffic sink. It can be obtained from the total number of data packets arrived at destinations divided by the total data packets sent from source nodes.It deals the loss rate as seen by transfer protocols and as such, it characterizes both the accuracy and efficiency of ad hoc routing protocols. It represents the highest throughput that the network can achieve. The performance is better when the packet delivery ratio is nearer to one.

$$\text{Packet Delay Ratio} = (\sum \text{Number of packets receive} / \sum \text{Number of packets send})*100$$

B. Packet End-to-End Delay

The packet end-to-end delay is the average time that packets take to pass through the network. This is the time from the creation of the packet by the sender up to their reception at the destination's application layer and is expressed in seconds. It is calculated as the total delay duration of all successfully transmitted data packets from source node to destination node. It is measured in seconds or milliseconds. The higher the end-to-end delay metric is, the higher the delay in routing packets and consequently the lower the efficiency of the protocol. It is given by following equation:

$$\text{Delay Time } (t) = N\ ((L)/R)$$

Where, N is total number of senders sending packets, L is length of packets and R is transmission rate.

C. Routing Overhead

Routing Overhead is an important measure of the scalability of protocol, and thus the network. It is defined as the total number of packets transmitted over the network, articulated in bits per second or packets per second. This is the ratio between the total control packets generated to the total data packets during the simulation time. Some sources of routing overhead are network congestion and route error packets. It is the total number of routing packets sent divided by the total number of data packets received. This accounts for the overhead of the routing protocols. The number of total routing packets includes the number of route request packets (RREQ), route reply packets (RREP), route error packets (RERR), acknowledgement packets, hello packets etc., mathematically it is calculated as:

$$\text{Routing Overhead} = (\text{No. of } (RREQ + RREP + RERR + \text{forward Packets}) / (\text{No. of Nodes})$$

The higher the routing overhead metric is the higher the overhead of routing protocol and consequently lower the efficiency of the protocol.

D. Throughput

Throughput is one of the basic parameter which is considered for performance evaluation of the network. It is the average number of successfully delivered data packets on a network. In other words throughput describes as the total number of received packets at the destination out of total transmitted packets. Throughput is calculated in bytes/sec or a data packet per second, mathematically throughput is calculated as:

$$\text{Throughput (bytes/sec)} = (\text{Total no. of received packets at destination} * \text{packet size}) / \text{Total Simulation Time}$$

The higher the Throughput metric is, the higher the value of received routing packets and the higher the efficiency of the protocol. So, the value of throughput should be high as much as possible.

E. Energy Consumption

Limited power supply is the biggest challenge of an Ad-hoc network so if we want to increase the network lifetime (time duration when the first node of the network runs out of energy) as well the node lifetime then we must have an efficient energy management protocol. Energy efficiency can be ensured by the duration of the time over which the network can maintain a certain performance level, which is called as the network lifetime. Routing with maximum lifetime balances all the routes and nodes globally so that the network maintains certain performance level for a longer time. Hence, energy efficiency is not only calculated by the power consumption but in more general it can be measured by the duration of time over which the network can maintain a certain performance level. The total energy consumed, includes the energy consumed by the control packets, to transport one kilobyte of data to its destination node.

$$\text{Total Energy Consumed} = \text{Initial energy} - \text{Energy left at each node.}$$

VI. SIMULATION SETUP & RESULTS

This section focuses on the different RTS/CTS methods analysis with respect to simulation parameters performed in Ns2. The evaluation of results has been considered based on the performance metrics of packet delivery ratio, end-to-end delay, route overhead, throughput and energy consumption which are already defined in the previous section. The simulated results are provided using ms-excel graphs which are formed by varying simulation topology.

Table 1: Simulation parameters setup

Parameters	Value
Simulator Version	Network Simulator 2.35
Mobility Model	Random Way-point
Performance Parameters	Total Energy Consumption, PDR, Throughput, Average E-2-E Delay, Routing Overhead
Methods Analysed	Standard RTS/CTS, Asymmetric RTS/CTS and BoT RTS/CTS
Number of Nodes	3x3 to15x15 nodes
Simulation Time	100 seconds
Traffic Type	CBR
Environment Area	1000 x 1000 meters square
Initial Energy	10.0 Joules
Transmission Energy	0.33 Joules
Idle Energy	0.10 Joules
Data packet Size	512 bytes
Transmission Range	250 meters

A. Result Graphs for Grid Topology

This section gives the results obtained after simulation in Ns-2. Two types of simulation topologies are created. One is Grid Topology and second one is Random Topology.

The figure 5 shows the Packet Delivery Ratio (PDR) Graph for Grid topology. It clearly shows that PDR is higher in case of BoT method as compared to Standard and Asymmetric RTS/CTS method. It is sharply decreased after 8x8 nodes because the no. of nodes increased over the network and there is much more nodes are sent with RREQ messages to find the required destination node as the route is captured due to congestion in the network. The BoT method showed 8.31% improvement than Asymmetric method.

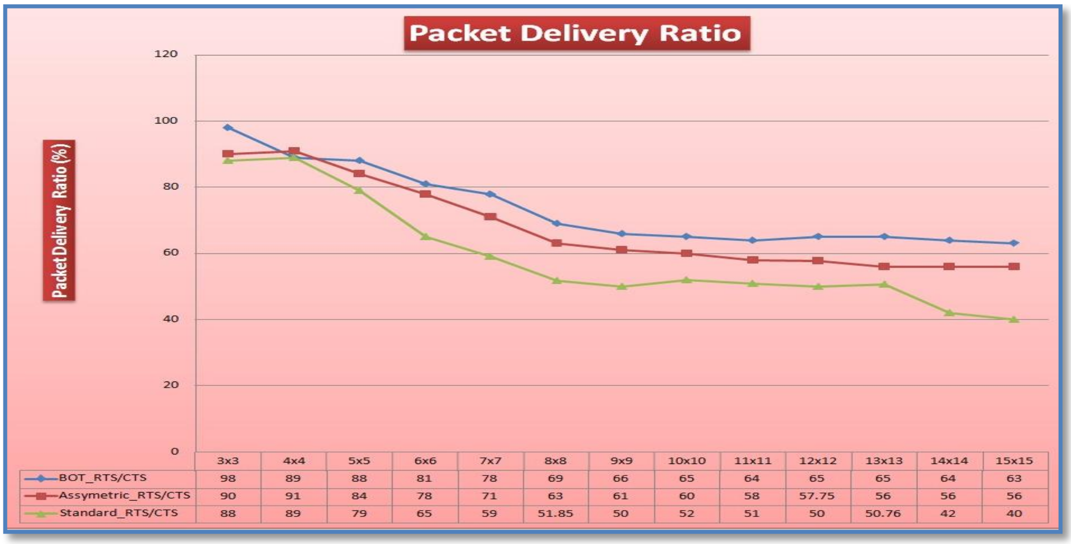

Figure 5: Grid Topology-PDR Graph

The figure 6 shows the Average End to End Delay Graph for Grid topology. It clearly shows that E-2-E Delay is lower in case of BoT method as compared to Standard and Asymmetric RTS/CTS method. It is increasing according to number of nodes increasing because the no. of nodes increased over the network and routing table updating takes little more time as node increases. The BoT method showed 1.1% improvement than Asymmetric method.

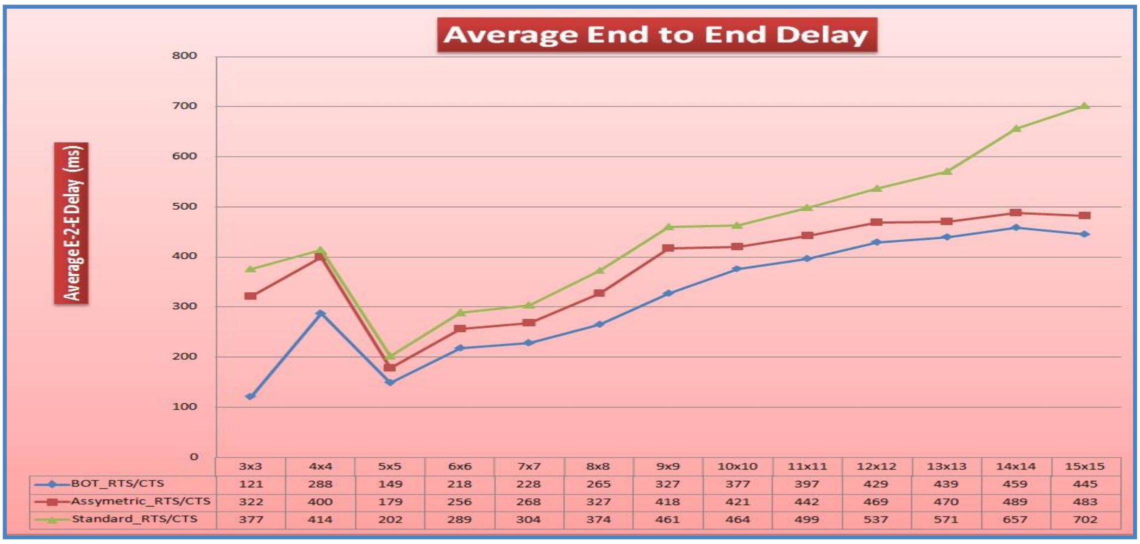

Figure 6: Grid Topology E-2-E Delay Graph

The figure 7 shows the Throughput Graph for Grid topology. It clearly shows that Throughput is slightly higher in case of BoT method as compared to Standard and Asymmetric RTS/CTS method. It is increasing according to number of nodes increasing because no. of packets to be sent over the network is dropping over larger networks for all scenarios. The BoT method showed 1.05% improvement than Asymmetric method.

Figure 7: Grid Topology-Throughput Graph

The figure 8 shows the Routing Overhead (RO) Graph for Grid topology. It clearly shows that Routing Overhead (RO) is lower in case of BoT method as compared to Standard and Asymmetric RTS/CTS method. It is increasing according to number of nodes increasing since the number of route request and route send packets increase as the number of vehicles increase to communicate with each other.. The BoT method showed 12.12% improvement than Asymmetric method.

Figure 8: Grid Topology-RO Graph

The figure 9 shows the Average Energy Consumption Graph for Grid topology. It clearly shows that Average Energy Consumption is higher in case of BoT method as compared to Standard and Asymmetric RTS/CTS method. It is increasing according to number of nodes increasing since the number of route request and route send packets increase as the number of vehicles increase to communicate with each other.. The BoT method showed 35.76% improvement than Asymmetric method.

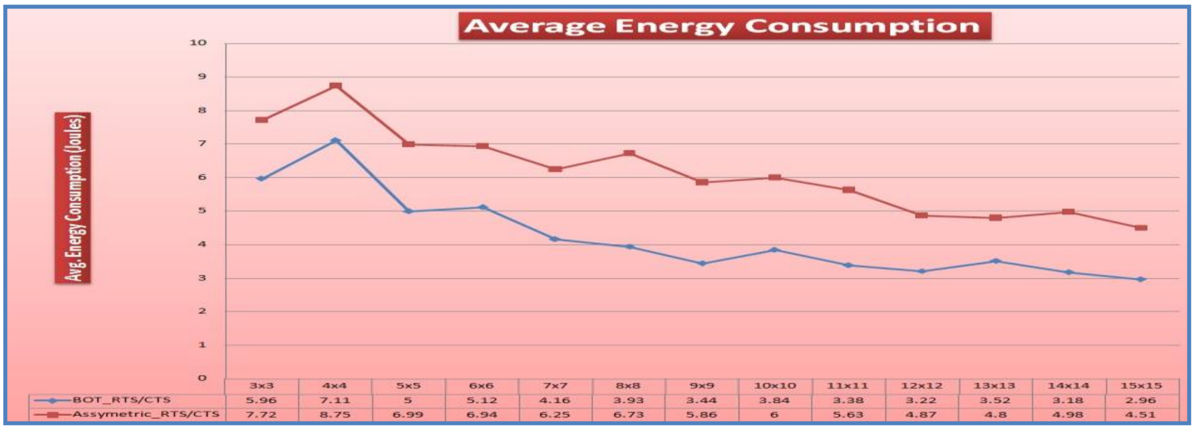

Figure 9: Grid Topology-Average Energy Consumption Graph

B. **Results Graph for Random Topology**

The figure 10 shows the Packet Delivery Ratio (PDR) Graph for random topology. It clearly shows that PDR is higher in case of BoT method as compared to Standard and Asymmetric RTS/CTS method. It is sharply decreased after 8x8 nodes because the no. of nodes increased over the network and there is much more nodes are sent with RREQ messages to find the required destination node as the route is captured due to congestion in the network. The BoT method showed 5.06% improvement than Asymmetric method.

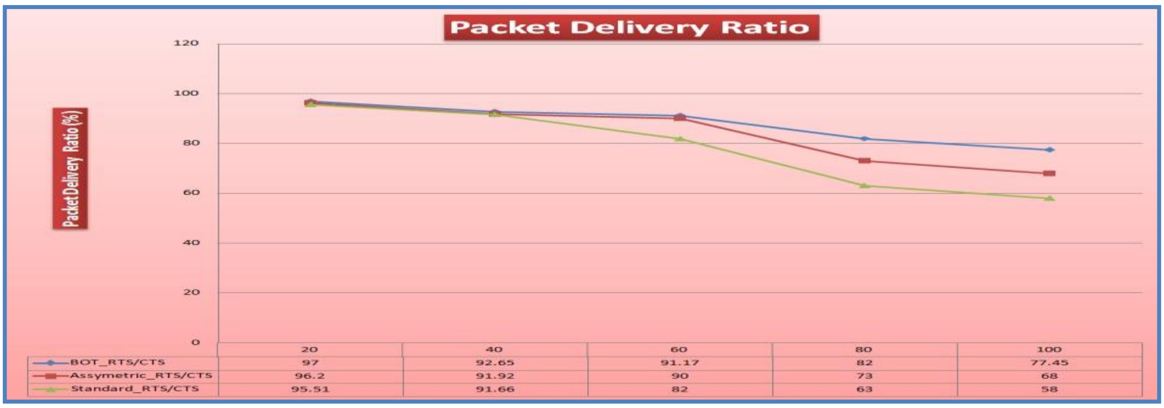

Figure 10: Random Topology-PDR Graph

The figure 11 shows the Average End to End Delay Graph for Random topology. It clearly shows that PDR is higher in case of BoT method as compared to Standard and Asymmetric RTS/CTS method. It is sharply decreased after 8x8 nodes because the no. of nodes increased over the network and there is much more nodes are sent with RREQ messages to find the required destination node as the route is captured due to congestion in the network. The BoT method showed 9.12% improvement than Asymmetric method.

Figure 11: Random Topology-E-2-E Delay Graph

The figure 12 shows the Throughput Graph for random topology. It clearly shows that Throughput is slightly higher in case of BoT method as compared to Standard and Asymmetric RTS/CTS method. It is increasing according to number of nodes increasing because no. of packets to be sent over the network is dropping over larger networks for all scenarios. The BoT method showed 6.56% improvement than Asymmetric method.

Figure 12: Random Topology-Throughput Graph

The figure 13 shows the Routing Overhead (RO) Graph for Grid topology. It clearly shows that Routing Overhead (RO) is lower in case of BoT method as compared to Standard and Asymmetric RTS/CTS method. It is increasing according to number of nodes increasing since the number of route request and route send packets increase as the number of vehicles increase to communicate with each other.. The BoT method showed 12.84% improvement than Asymmetric method.

Figure 13: Random Topology-RO Graph

The figure 14 shows the Average Energy Consumption Graph for Grid topology. It clearly shows that Average Energy Consumption is higher in case of BoT method as compared to Standard and Asymmetric RTS/CTS method. It is increasing according to number of nodes increasing since the number of route request and route send packets increase as the number of vehicles increase to communicate with each other.. The BoT method showed 13.77% improvement than Asymmetric method.

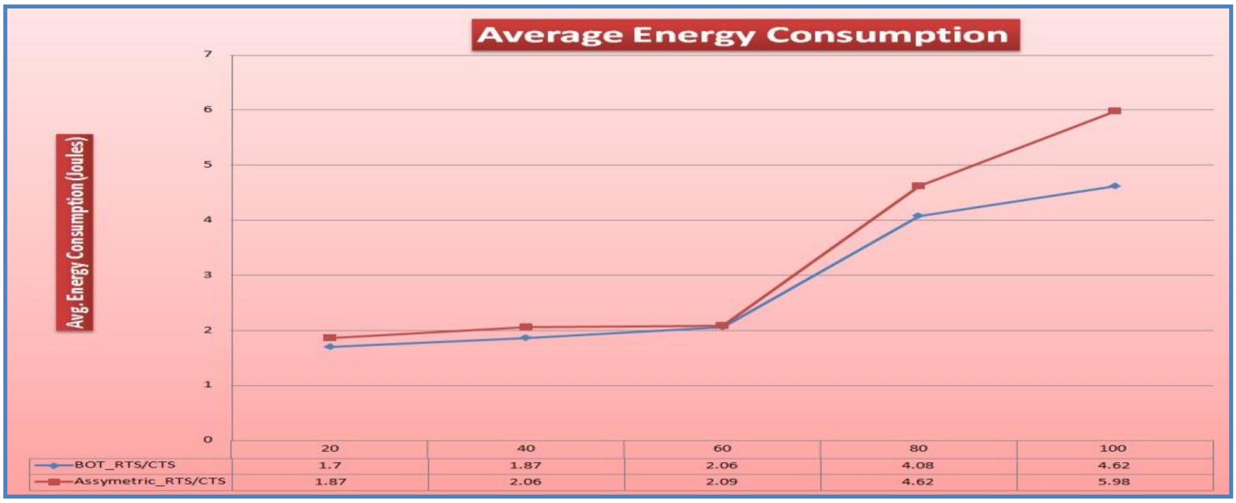

Figure 14: Random Topology-Average Energy Consumption Graph

VII. CONCLUSION & FUTURE WORK

On the basis of results in network simulation environment, BoT RTS/CTS method shows to have the overall best performance because it provides almost identical results in all scenarios. It has an improvement of Standard RTS/CTS and Asymmetric RTS/CTS and has advantages of both of them. BoT RTS/CTS performs better in case of packet delivery ratio and gives considerably less delay. It outperforms Standard RTS/CTS and Asymmetric RTS/CTS with prominent difference in delay.

BoT RTS/CTS has small end-to-end delays, so, it is more suitable for real-time applications than other RTS/CTS methods. However, the performance of BoT RTS/CTS, in terms of control overhead and throughput is more sensitive to network and application profiles than the other protocols we studied. Thus, BoT RTS/CTS is not suggested for applications that require a routing protocol whose performance is robust over wide variety of conditions.

Standard RTS/CTS is preferable for moderate traffic with moderate mobility. It had lowest control overhead in terms of number of control packets. This makes it suitable for bandwidth and power constraint network. However in terms of byte Standard RTS/CTS has a significant overhead as it packets size are large carrying full routing information.

Asymmetric RTS/CTS performs better when mobile nodes increased and has a equivalent throughput as compared to BoT RTS/CTS. It is suitable for operation in large highly dynamic mobile network environment with dense population of nodes.

The simulation is performed over two kinds of topologies with varying number of nodes. The Following table 2 shows the comparative table for all three RTS/CTS method, it also shows the percentage of improvement of BoT RTS/CTS over Asymmetric RTS/CTS method.

Table 2: Simulation Results for Grid Topology

Parameter	Standard RTS/CTS	Asymmetric RTS/CTS	BoT RTS/CTS	Percentage of Improvement
PDR	59.09	67.82	73.46	**8.31 %**
End to End Delay	414.38	380.3	384.53	**1.11 %**
Throughput	4914.15	5191.38	5246.3	**1.05 %**
Routing Overhead	3948.23	3517.92	3091.38	**12.12 %**
Average Energy Consumption	nil	6.16	3.95	**35.76 %**

Following table 3 shows the comparative table for all three RTS/CTS method, it also shows the percentage of improvement of BoT RTS/CTS over Asymmetric RTS/CTS method.

Table 3: Simulation Results for Random Topology

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As a special type of network, infrastructure less wireless ad hoc networks has received increasing research attention in recent years. There are many active research projects concerned with such networks. This section focuses on promising future research directions based on current research.

Further study of node mobility is also a promising research direction. Such a study might aid in the design of simulation mobility models, improve estimates of link and path lifetimes, and improve the performance of wireless ad hoc networks. More extensive simulation studies can be used to compare different protocols and different RTS/CTS methods. Analysis and conclusions can guide users when they choose RTS/CTS methods for their wireless ad hoc networks applications and aid designers in improving communication over network.

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