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Retransmission DBTMA Protocol With Fast Retransmission Strategy to Improve the Performance of MANETs

M. SIVARAM[1], V. PORKODI[2], AMIN SALIH MOHAMMED[1], V. MANIKANDAN[1], AND N. YUVARAJ[3]

[1]Department of Computer Networking, Lebanese French University, Erbil 44001, Iraq
[2]Department of Information Technology, Lebanese French University, Erbil 44001, Iraq
[3]Department of Computer Science and Engineering, St. Peter's Institute of Higher Education and Research, Chennai 600054, India

Corresponding author: M. Sivaram (sivaram.murugan@lfu.edu.krd)

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ABSTRACT The Mobile Ad-hoc Networks (MANETs) are often visible to the exposed terminal problem and hidden terminal problem, which exist due to non-transitivity in media access control schemes. This affects the utilization of channel and throughput in media access control protocols, e.g., dual busy tone multiple access protocol (DBTMA). Hence, to improve the fairness and throughput performance of the DBTMA it is very necessary to address the problems associated with hidden and exposed terminals. Hence, in this paper, the quality of service (QoS) is improved by enhancing the capability of the DBTMA for better network service in the MANETs. The proposed method uses an improved DBTMA called Retransmission Dual Busy Tone Multiple Access (RDBTMA) protocol. This is based on two elements namely: busy tones and Ready To Send/Clear to Send (RTS/CTS) dialogues. In addition to this fast retransmission, a strategy is used further to improve its effectiveness. The retransmission strategy is adopted using negative acknowledgment after the collision occurred by the hidden nodes. A hidden node, where the collision occurs at access point, listens to the NACK signal and uses the signal to determine the requirement fast retransmission scheme. The proposed method is simulated and compared against existing methods in terms of various network parameters. The results show that the proposed RDBTMA protocol is effective in terms of the improved QoS in terms of network throughput (21.9%), packet delivery ratio (17.8%), 14.9% less packet loss, and 38% less route discovery delay than the existing methods.

INDEX TERMS Dual busy tone multiple access protocol, mobile ad-hoc networks, quality of service.

I. INTRODUCTION

The wireless ad-hoc multi-hop networks permit a limited range of wireless network devices that includes sensor nodes or mobile devices communicate with each other through remote destinations without any proper network infrastructure. The multi-hop network relay permits the nodes in a wireless network to carry forward the packets until it reaches the destination node. Hence, the power is conserved that compromises the overall throughput of the wireless system.

The wireless ad-hoc network performance could be understood in terms of optimizing the protocol designs. To achieve such designs, the most accurate and efficient analytical model is made essential. The multi-hop MANETs with random access is quite difficult to analyse, since, there exist a random contention and hidden terminals between the nodes in the network. In recent literature, the throughput of the link in multi-hop MANETs is investigated through approximated models and simulations. Additionally, there exists a delay in DBTMA layers due to random contention and hidden terminals, which is not analytically studied.

If a node is hidden outside the range of transmission of a sender and if it lies within the receiver range, then this is considered as hidden terminal. Since the transmission of mobile node range is limited, multiple transmitters within the same receiver range could not have known about the existence of other transmissions. In this way, the nodes are considered to be hidden from each other. The nodes transmit in/around

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at the same time and the real problem is that they do not recognize that there is a collision in its transmissions on the way to the receiver.

The exposed terminal is one, which lies in the transmission range and lies outside the reception range. The exposed node leads to underutilization of network bandwidth/capacity.

Quality of Service is an important parameter that decides the trusted immediate nodes or hops. Routing through such nodes or hops should be efficient enough to deliver the packets to destination without intrusion. Certain defence, search and rescue operations required a better QoS, however, the availability of such QoS services is inhibited due to several constraints in MANETs. Here the present study discusses the major issues in MANETs namely: hidden terminal problem and exposed terminal problem [1], which affects significantly the QoS performance MANETs.

Wireless ad-hoc networks are gaining much importance in wireless communications. This significant wireless communication uses a nodal structure for communication establishment, which even acts as routers in transferring packets from source to destination nodes in ad-hoc networks. The main problem associated with the routing protocols of MANETs includes hidden terminal and exposed terminal problem. This routing problem in MANETs leads to high complexity due to the moving nodes and henceforth the solutions to such complexity are introduced to improve the performance of the networks. This study concentrates mainly on modified DBTMA protocol and its functionality in MANETs with discussions made specifically selected EDCA protocol and that ends with their comparison.

To address the problem of the hidden terminal and exposed terminal problem, numerous solutions were proposed that will be discussed in section 2. To improve the fairness and throughput performance of DBTMA protocol, problems associated with hidden and exposed terminals needs to be addressed. Due to non-transitivity in MAC schemes, the hidden and exposed terminal problem occurs. This affects the utilization of channel and throughput in MAC protocols e.g. DBTMA.

CSMA previously senses the carrier that transmits for reducing the collision probability. However, each node in CSMA cannot hear to the other receivers in the networks, since it is a prerequisite. Dual Busy tone multiple access could help in alleviating the hidden and exposed terminal problem in networks. To achieve this, Request to send (RTS) and clear to send (CTS) are introduced to solve these terminal issues. Here, channel acquisition is done using packet scheduling strategy to solve the collision issues due to terminal problems.

A suitable and efficient MAC protocol is needed to achieve better fairness level that could overcome such problems without negotiating the performance in MANETs. With such motivation, a modified protocol is developed that achieves the major goals of the proposed study. Hence, to solve the issues of collision, channel utilization and throughput degradation: dual busy tone multiple access or DBTMA technique is used. This is based on two elements namely: busy tones and RTS/CTS dialogues. In addition to this, a fast retransmission strategy is used further to improve its effectiveness.

The prime objective of the work is to improve the Quality of Service parameter for better network service in MANETs.

The proposed analytical framework for the RDBTMA protocol involves threefold contribution, which is discussed in this chapter. Initially, modelling of throughput link for random access MANETs through the formulation uses an analytical model. Secondly, the measurement of the proposed RDBTMA delay in MANETs is carried out. Depending on the results, a fast retransmission strategy is allocated to improve the system with lesser delay. Finally, a streamlined disk model is used to solve the hidden terminal problems occurring in between the nodes leading to collisions.

When applied the proposed analytical model revealed its important insight in MANETs in terms of collision avoidance due to the hidden terminal problem. The impact of transmission range in MANET adjustment leads to the throughput and delay of parametric measurements. Thus, the possibility of adjusting the range of transmission for optimizing the performance of the whole network is high provided there exists node density in the network. The performance evaluation of the proposed RDBTMA analytical model is verified using extensive simulations. The analytical and simulation outcomes deliver significant recommendations for protocol optimization and network planning in MANETs.

The contribution of the work is described below: the study presents a critical analytical model that quantifies the performance of DBTMA protocol in terms of both delay and throughput in multi-hop MANETs. The association of random contention and the hidden terminal problem is taken into consideration while modelling the DBTMA protocol. The analytical model considers suitably the distribution of MANET nodes randomly at various locations within the range of networks. The analytical framework for RDBTMA is proposed as an extension of EDCA protocol to analyze its performance.

The outline of the paper is given as follows: Section 2 provides the related works. Section 3 discusses the problem definition with network setting. Section 4 describes the proposed work. Section 5 evaluates the proposed work and section 6 concludes the paper.

II. RELATED WORKS

A. TECHNIQUES ON EDCA COLLISION AVOIDANCE

Khalim Amjad Meerja & Abdallah Shami (2007) [2] proposed certain modifications in avoiding collision through AC_VO queuing mechanism. This mechanism is proposed to improve the video and data performance with lesser effects. The size of the contention window is not changed, which is proposed in IEEE 802.11e drafts since it affects the performance. Further, a collision avoidance enhanced scheme for AC_VO queue is proposed that improve the throughput performance of the voice traffic systems. The other ECAEDCA mechanisms include access category queue for video communication, best effort services and background mechanism.

The four channel access categories use standard EDCA collision avoidance procedure in all its IEEE 802.11e architecture. This is a backward compatible scheme that compliant QSTAs to make the ECA-EDCA to existing standard IEEE 802.11e wireless stations with legacy. The delay and jitter results are calculated to find the performance of the technique over the saturated and non-saturated condition. However, variations in graphs seem no much change with the EDCA technique.

Mohamad El Masri & Slim Abdellatif (2009) [3] studied collision effects and virtual management for EDCA fairness properties. The collision management is analysed in terms of EDCA Markov Chain model and its corresponding effects, thus reducing the EDCA unfairness. As a whole, collision management mechanisms for two collisions: the former one is a classical or real collision that occurs with two or more access categories, which are active over two or more stations that try to access simultaneously the channel medium. The latter one is the internal or virtual collision that occurs with two access categories over the same station and that access the medium simultaneously. EDCA's for collision management introduces access iniquity related directly to traffic profile of local station. However, as the virtual collision probability increases, the throughput reduces and that affects the performance of the channel.

Shih-Wei Pan & Jung-Shyr Wu (2009) [4] consider arbitration inter-frame space events among backoff procedure. This method evaluates the throughput (saturation) of EDCA based 802.11e over traffic conditions in a heterogeneous scenario. The model works purely on differentiated arbitration inter-frame space. This uses time slot in discrete intervals that investigates the external time of the collision with CTS frame length and time of transmission as a dependent factor. This mechanism uses basic MAC protocol for 802.11 communication and that performs CSMA/CA with a binary exponential backoff procedure that accesses the wireless channel. The analysis is carried out over conditions like ideal channel, single-hop heterogeneous and saturation traffic. However, this method is not suitable for multi-hop networks.

B. TECHNIQUES ON EDCA FAIRNESS PROBLEM

Seung-Seok Kang & Matt W. Mutka (2001) [5] had proposed a modified back-off algorithm for service differentiation over three different classes of traffic flows with certain modifications. The three classes include Gold class, silver class and bronze class. The gold class traffic flows chooses the waiting time in a random manner from small time slots (reserved). This class possess the highest transmission probability for transmitting the data packets. The silver class traffic flow performs in a better manner, such that the reception of packets performs relatively better than the bronze class. Since the waiting time (selected) for the packets and the class is divided by the back-off designated parameter. This results in obtaining the wireless medium with higher rate through higher packet class. The back-off parameters in this technique allow the traffic flow class design and the varied back-off behaviour on packets flow classes to perform well in wireless networks. Here, the RTS/CTS based CSMA network is used that resolves the contention window using a binary exponential back-off algorithm. However, the technique is not fitted for different transport protocols.

Ian Dangerfield et al. (2006) [6] demonstrate a method that measures the single way delay in IEEE 802.11e hardware testbed. The standard IEEE 802.11b networks with defined MAC settings in greedy data traffic environment seizes the bandwidth from the voice calls of the low-rate level. This technique studied well the delay that affects the performance of the system in context with voice call protection. This competes against the data traffic in IEEE 802.11 network infrastructure. The competing data stations induce the loss rate of voice calls that exceed 10%. This leads to an increased level of voice call quality and decreased call dropping. However, this method analysis only a single way delay, however, this method is not compatible with higher-end systems.

Jeng Farn Lee et al. (2007) [7] proposed a model for differentiated services or Differentiated ServiceEDCA for IEEE 802.11e wireless networks. The Differentiated Service EDCA is provided with stringent priority access and fair weighted service. The stringent priority services for higher traffic priorities are carefully designed with proper settings for the EDCA parameter sets. The method is designed with traffic priorities at a very lower rate. The proportional QoS service is further enabled using back-off interval determination as per the distributed scheduling discipline. A model with hierarchical sharing link method for 802.11e networks is designed with different amounts of resource line allocations to the access points and the mobile stations. This technique works well with IEEE 802.11 system in terms of higher allocation of capacity.

Inanc Inan et al. (2008) [9] proposed an analytical model that uses accurate contention window, arbitration interframe space value and differentiation transmit opportunity over various traffic loads for EDCA functionality. The EDCA scheme uses CSMA/CA as a fundamental access scheme with and slotted BEB mechanism. The MAC layer effects over different buffer size are evaluated for the performance of the proposed system. The analytical model for the estimation of the IEEE 802.11e EDCA performance accepts that each access station has backlog data, which is ready for transmission in saturation or buffer time. This EDCA saturation model predicts well the accuracy of traffic loads from light to heavily loaded non-saturated access channels. However, the use of call admission control strategy could be adopted to further improve the QoS, which is absent in the current system.

José Villalón et al. (2008) [10] introduced an 802.11eQoS protocol that provides QoS provisioning to all multimedia communication. This protocol interoperates correctly with legacy DCF stations. A design on the in-depth analysis of both standards (IEEE 802.11 and 802.11e) with numerous operational modes is prepared. This ensures maximum operation compatibility while a transition from IEEE 802.11 to 802.11e. This makes the presence of the hybrid scenario during transition during which both the standard coexists.

The incompatible and deficiency in providing QoS issues are eradicated using 802.11e compliant mechanism that is supported under the above scenario. The main objective lies in designing a mechanism that guarantees QoS, which is required by the time-constrained applications in spite of the load and configuration 802.11 and 802.11ecompliant stations. Performance is calculated using comparative evaluation over services like video, voice, background, best-effort and traffic generated by legacy IEEE 802.11 DCF stations. The performance of this method is higher than other methods due to its higher priority channel access, however, it possesses incompatibility in standard 802.112 specification.

Gennaro Boggia et al. (2009) [11] proposed an extended EDCAscheme for 802.11e wireless networks. This method performs dynamic bandwidth allocation in a distributed manner overall wireless stations. This guarantees the real-time traffic flows on absolute and average delays. Specifically, each station estimates the required bandwidth for the exploitation of a control scheme (closed-loop). The queue length of the transmission is regarded as the required feedback signal. It is noteworthy that this scheme possesses very less complexity, where each node of wireless networks uses a linear control algorithm. This method suits well for QoS provisioning in wireless networks and Call Admission Control algorithm is combined with the proposed model. The theoretical investigation on the maximum and average packet delay bounds as a function of parameters is evaluated. This method is effective in increasing the throughput of the network and provides an ideal solution to one way packet delay, frame collision and admitted the flow

Shah Ahsanuzzaman Md. Tariq & Fabrizio Granelli (2010) [12] evaluated the EDCA performance for QoS provisioning in 802.11e wireless networks. The method evaluates various EDCA collision aspects and compares them with legacy 802.11 using different threshold values. This scheme provides differentiated channel access with varied types of traffic. The method supports well the real-time application with strict QoS provisioning. The generation of the small values of the contention window generates packet drops at higher rates and higher collision probability rate while transmitting AC_VO packets. Due to this, the modified EDCA mechanism significantly suffers from an unsuccessful transmission.

Pradyot Kanti Hazra & Asok De (2011) [13] proposed enhanced EDCAprotocol for IEEE 802.11e wireless networks. This method supports access category with QoS differentiation. However, EDCA does not provide stringent QoS requirements over real-time traffic applications. The enhanced EDCA protocol provides QoS provisioning using frame concatenation based on additive transmission opportunity and that uses acknowledging of the block. The enhancements form an analytical model that provides EDCA performance evaluation using 3D Markov chain model. The EDCA contemporary models fully support the small feature subset. The frame concatenation is further enhanced with the block acknowledgement strategy provides higher throughput with lowered delay. The stealing of throughput from higher access channels by the lower access channels further improves well the system for hard real-time applications.

Saeed Rashwand & Jelena Mišic (2012) [14] studied the allocation of TXOP and impacts on the parameter of AIFS over a single hop 802.11e EDCA wireless network. The measurements were made under variable load offered load conditions. The load that is offered is altered using parametric changes in its arrival process and the population of nodes. The process of arrival is varied in terms of altering the size of burst distribution, frame size, burst size (mean), and rates of arrival. The investigation of the parametric effects on offered load over its stability in network and non-saturation boundaries is carried out in 802.11e EDCA wireless networks. The results are evaluated in terms of offered load interaction over its associated MAC parameters. This method suggests the network parameters range that preserve the stability of the network could achieve diversity in QoS.

C. TECHNIQUES ON EDCA THROUGHPUT DEGRADATION

D. Vassis and G. Kormentzas (2005) [15] presented an analytical model for evaluating the performance of 802.11e EDCA wireless scheme. The method is evaluated over finite load conditions under the basis delay metrics on numerous instances. This includes media access, queuing and total delay. The estimation of throughput parameters is proceeded with estimating of Tsi and Tci over fundamental access mechanism. Here, the RTS/CTS dialogue mechanism is permitted and the hybrid case involves the employment of RTS threshold over both transmission mechanisms. However, this method increases significantly the total delay for the lower priority classes. Due to which, the middle priority classes are affected in a minimal amount.

Albert Banchs & Luca Vollero (2006) [16] addressed the optimal EDCA configuration issues. The analysis is made over real-time traffic, where EDCA is used as insensitive delay applications. The performance of EDCA purely depends on the throughput results. To achieve this, initially, a model is analysed to calculate the throughput distribution over IEEE 802.11e EDCA wireless LANs. An optimal configuration is designed for EDCA using weighted max-min fairness criteria. The access stations are allocated with throughput that is proportional to the assigned weight that offers different price and quality for accessing the data in wireless LAN. Avoiding AIFS collision could improve the effective throughput allocation than the contention window mechanism.

Koukoutsidis et al. [17] proposed a joint parameter setting to increase the bandwidth capacity and to optimize the performance of WLAN networks under QoS constraints. A suitable analytical model is constructed in a saturation and non-saturation condition that provides a detailed estimation on channel access parameters like throughput and mean delay. The two classes of wireless network station include lower and higher QoS demand is considered that optimises the network based on average constraints and measures. A solution on Pareto optimal pair is taken into account over for the supported stations over two classes for varied configurations of the parametric set and the typical values of a load. Further, the examination on the selection of optimal parametric set for both the class in the form of elastic traffic with delay-sensitive class with fixed parameters is considered. However, the capacity of WLAN networks is undermined due to the drastic changes in service differentiation. Increasing, total successful frames through TXOP increases the variance in delay since the access over initial frame delay is large comparatively. Increased variance in transmission results in loss of timeout during retransmission even high layered protocol that possesses dynamic flow control. Here, a basic channel is considered without RTS/CTS to achieve better results. The results over high layered channel access provide much loss of generality that reduces the performance.

Cano et al. [18] evaluated various educating algorithms for comparing it in its flow level response in a rigid and elastic flow. The performance of these algorithms had limited access to packet level metrics like delay, throughput and impact of transmission and collision probability. Results prove that the comparison algorithms adapt better for dynamic wireless LANs with the total number and active flow type, which is designed with variable objectives. These significantly provide higher QoS performance than static objective and single objective configurations.

Kosek-Szott et al. [19] presents a mathematical model for 802.11 EDC function. The model combines the backoff slots probability with proper frame handling. The traffic differentiation is allowed with prioritized traffic access parameters namely AIFSN and contention window. Further, a new modelling AIFS differentiation method is proposed over different traffic classes. Finally, the model or a mechanism with 4-way handshake seems uncomplicated. Furthermore, the association of basic channel access and RTS/CTS access with varied retransmission limits are used for comparison purpose. This method works better for smaller and larger nodes and smaller and larger frame sizes over varied types of traffic.

Peng et al. [20] proposed an analytical model that analyses the performance of EDCA protocol for an 802.11e wireless LAN standard. The system uses the 4-dimensional Markov chain model that supports a smaller EDCA features subset with very limited accuracy. The model covers well the noticeable features of EDCA like multiple EDCA features access categories, back-off after transmission, internal collision and discarding frame after the maximum limit of retransmission. A mechanism of pre-back-off carrier sensing and freezing delayed states back-off counter is proposed further. The incorporation of various back-off and carrier sensing parameters over each active access channel is carried out for various service differentiation. The throughput saturation and delay in frame access over individual access category for RTS/CTS and basic access modes are evaluated. RTS/CTS mode performs well than basic access mode in terms of delay and throughput with less collision rate.

Ruscelli et al. [21] proposed an approach that addresses the scheduling constraints over VBR traffic streams. A scheduler called named the overboost uses HCF Controlled Channel Access for negotiating the bandwidths over a minimum level and deals with traffic streams. This method requires larger bandwidth than the one that is negotiated and that redirects the bandwidth in n excess for EDCA functionality. The performance evaluation using this method proved that the overboost method for EDCA improved the QoS provisioning using HCF Control schedulers. This is analysed during the transmission of variable bit rate traffic streams.

Chakraborty et al. [22] proposed a probabilistic approach for providing proportional fairness that does not solve non-concave and non-linear global optimization. Each node uses a load estimation strategy for estimating the traffic load. The channel that is required to share the node is proportional to traffic load and the total channel share (normalized) over entire contended nodes is made lesser than 1 in order to satisfy the constraints of the group. The architecture and contention are explored for deducing the channel share of nodes that are meshed. A probabilistic approach for tuning the contention window is used as a difference between actual and required channel share. Then the nodes possessing higher traffic load accrues an increased channel share. Hence, a Markov Chain based discrete time modelling deduces the network throughput and fairness works better than 802.11s EDCA method.

D. TECHNIQUES ON EDCA HIDDEN TERMINAL PROBLEM

Kim et al. [23] proposes an effective method that uses deterministic priority channel access for improving the performance of QoS performance using EDCA mechanism. The channel access of certain multimedia applications is guaranteed using deterministic priority. This uses busy tone signalling that limits the lower priority traffic during transmissions. The traffic with higher priority possesses certain packets that should be transmitted. To sense the flows, the packet transmission over the hidden terminal is considered. Once the packets collide, the access point sends a negative acknowledgement packet as a fundamental access method or it uses negative CTS signalling packets for the RTS/CTS access method. Flow outside the range of transmission transmits a single packet that could detect the transmission of packets from negative acknowledgement or Negative CTS. The cost of the extra signal improves the performance of the proposed scheme over the 802.11e standard. The performance results proved that the technique is effective and that possess higher throughput with lowered delay and jitter. This keeps the probability of collision in a lower range regardless of its contention levels.

Liu and Saadawi [24] combined both the analytical analysis using the throughput of saturated and non-saturated values over 802.11e wireless networks. The method is analysed in terms of the presence of hidden stations and provides extension using Markov chain analysis over IEEE 802.11 under various conditions. The performance evaluation over saturation throughput on different stations with varying access categories shows performance degradation in the RTS/CTS mechanism than the basic access mechanism.

III. PROBLEM DEFINITION

In this section, the network setting with a brief overview of the hidden terminal problem in wireless networks is presented. The effect of the mobility of the nodes over DBTMA protocols is discussed further.

A. NETWORK SETTING

Initially, it is assumed that the nodes in wireless networks are distributed randomly according to in a 2D area and that follows Poisson distribution function. The active nodes in the network are saturated and often it possesses the available packets with the same length for transmission purpose.

Hence, carrier sense multiple access - collision avoidance (CSMA/ CA) with DBTMA protocol is considered as a proposed approach. The approach is valid for sensing non-carrier protocols like Aloha etc. Prior to transmission, the MANET nodes adapt back-off algorithm. The value of time step, T and the propagation delay, δ are assumed equal. Additionally, the nodes in wireless networks are assumed as identical, which possess a similar range of transmission R and collisions at the receiver's end. This condition occurs when the nearest nodes < R transmits the data packets concurrently. The hidden terminal problem is discussed in the resulting subsection.

B. HIDDEN TERMINAL PROBLEM

MANETs are obviously susceptible to the hidden terminal problem. The terminal problem in wireless networks arises from nodes, which are distinctively located inside the sensing region of the off-range source node and the destination node.

The conventional solutions employed in minimizing the multi-tier cell interference, occurring due to hidden terminals are resolved using RTS/ CTS dialogue mechanism. The nodes pair could reserve the necessary resources of wireless networking through the exchange of RTS/CTS dialogue mechanism. The other nodes within the network range receive RTS/CTS packet needs to concede the packet transmissions.

The impact of the hidden terminal problem is estimated by defining the wireless network region, where possibly the hidden terminals exist. The illustration of the hidden terminal problem within the sensing range is shown in Fig.1. This shows the transmission of packets from the source node S to the respective destination node D. The area/region that is shaded explains the probable existence of hidden terminals could reside. The geometry of the wireless region is calculated easily with geometry as shown here:

$$A_H(r) = \pi R^2 - 2R^2 \left[\frac{r}{2R}\sqrt{1-\left(\frac{r}{2R}\right)^2} - \arccos\left(\frac{r}{2R}\right) \right] \quad (1)$$

where, r denotes the distance between source node S and the destination node D. This could possess/hold a value in the range $0 \leq r \leq R$. It is further assumed that the source node or the sender selects suitable destination node from its neighbouring nodes at a probability of equal rate and the associated probability density function at a distance r locates well the receiver node and this is assumed as:

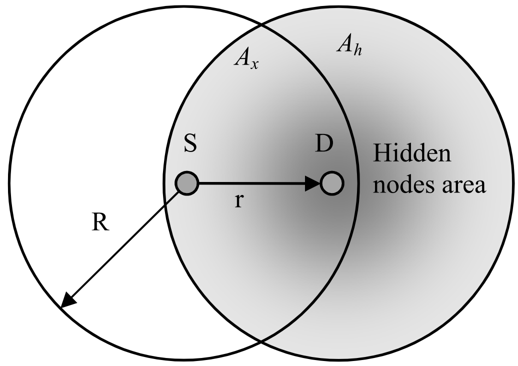

FIGURE 1. Hidden terminal region – an illustration.

$$p_r(r) = \frac{2r}{R^2}; 0 \leq r \leq R \quad (2)$$

Henceforth, the average value of the area of available hidden terminals A_{ht} is expressed as:

$$A_h = \int_0^R p_r(r)\, A_H(r)\, dr = \frac{2}{R^2}\int_0^R rA_H(r)\, dr \quad (3)$$

Substitute the Eq. (1) in Eq. (3), the final area of hidden terminals/nodes are obtained using:

$$A_h = \frac{3\sqrt{3}}{4}R^2 \quad (4)$$

C. EFFECT OF MOBILITY ON DBTMA PROTOCOLS

The mobility in the wireless MANET affects the DBTMA protocol and its routing. Though the routing protocol deals with connectivity change among the nodes, DBTMA protocols are affected if DBTMA time scale frame transmission is the same as the network time scale changes. However, the completion time of DBTMA transaction is short compared to the network connectivity time scale changes that arise from the mobility of nodes in wireless network/MANETs. The mobility of nodes creates a limited impact on DBTMA protocol and it offers greater impact over other routing protocols of MANET.

IV. PROPOSED METHOD

A. DBTMA PROTOCOL

This section discusses the Busy Tone Signal based Protocol in relevance to the present study. The signals may be one or two that silences the hidden nodes during transmission of packets. The protocol can be categorized into single channel based and multiple channel based. The former requires standard hardware design and latter with complex hardware design. The former channel is fully or partially interoperable with 802.11 standards. This protocol provides easier identification of busy tones rather than traditional MAC protocols and provides better QoS support.

B. GENERAL CHARACTERISTICS OF DBTMA

The generic and most stringent characteristics of DBTMA protocol is briefed as follows:

DBTMA avoids collisions through the RTS/CTS scheme and it utilizes spatial reuse and significantly increases the capacity of the channel [8]. DBTMA protocol provides adequate resource in monitoring the continuous channel. It does not entail the reception of successful RTS/CTS scheme using interfering potential nodes for preventing collisions. In addition to the RTS/CTS scheme, two outband busy tones are used. The purpose of these busy tones is to notify the neighbouring nodes in continuous transmission. A node that senses the dual busy tones concedes the usage of the channel at the specified direction by the dual busy tone [25]. DBTMA protocol support feasible and flexible communication with better QoS provisioning in MANETs. The dual busy-tone signalling in DBTMA is considered more effective than handshaking protocols. The implementation at physical layer seems difficult in DBTMA protocol [26]. DBTMA protocol supports the various services with requirements like dissimilar delay while offering hidden terminals. The protocol offers lower complexity than other AODV protocols with more flexibility that adapts the status of the network to achieve optimum throughput. This is difficult for an 802.11 network since it poses limitations at its physical layer [26]. It provides synchronized multiple nodes access to shared wireless communication medium with higher network utilization that doubles the network capacity [27].

C. RDBTMA PROTOCOL

The study proposed Retransmission Dual Busy-tone Multiple Access (RDBTMA) for improving the throughput using faster retransmission strategy. The hidden node problem degrades the throughput of MANETs significantly leading to the collision. The usage of RTS/CTS dialogue mechanism avoids collisions in these networks. Overhead in this network occurs due to higher data rates that arise from the exchange of control frames. Hence, a faster retransmission algorithm is adopted over MANETs. The negative acknowledgement (NACK) control frame helps the receiver to detect collided packets caused due to hidden nodes. The notification of NACK to nodes successfully aided the communication in MANETs to takes lesser time than RTS/CTS dialogue mechanism. Due to NACK, the probability of collisions due to hidden nodes is lowered even if the data rates are high. The throughput of the proposed RDBTMA scheme proves to be higher with a reduced average waiting time.

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The fact that the collision of packet occurs is due to the high traffic load. This collision occurs in between RTS dialogues because of increased busy tone detection delay. Initially, the network is configured with an ID for each node. The implementation of control packets namely RTS/CTS lead to the origin of routing information. The nodes that are idle and do not transmit the packets are given the IDLE state. Then the node transmits information is given the CONTEND state. The node accessing channel raises BT_t or Transmitter Busy Tone, indicating the RTS existence towards the end node. Until the existence of BT_t, another node could transmit RTS, during which the alternative nodes stop its transmission.

Once, the RTS is picking from a transmitter, the receiver, in turn, sends CTS control signal or Clear To Send to its sender or transmitter. The receiver also raises the BT_r or Receiver Busy-Tone along with CTS to be sent to the transmitter. Next, the data packet transmission is initiated. However, if another node needs to send the data, RTS is raised that lags the detection of the busy tone of available send node that is initiated already. This probably increases the delay and leads to packet collision (RTS). A notification namely Virtual Collision Identifier or VCI is sent to Virtual Collision Resolver or VCR that generates faster retransmission of RTS packet. This is purely based on timing calculation in VCI. The VCR backs off the timer and retransmits the packets faster.

Sequence numbers are given to each data packets that form a queue. The queue length is used to calculate the timer in the network. Upon the detection of the collision, packet loss occurs and leads to the initiation of Faster Retransmission algorithm. A cumulative acknowledgement (CACK) indicates the reception of entire data packets. The fast retransmission brings a smaller delay in retransmission as the acknowledgement for the packet that possesses fewer fields. Congestion occurs if duplicate acknowledgements receive in large number and that fast retransmission.

Retransmission DBTMA or RDBTMA is a modified protocol of DBTMA that uses fast retransmission strategy to avoid collision of packets. The proposed RDBTMA protocol avoids hidden terminal problem using faster retransmission strategy. This results in increased throughput than conventional DBTMA and EDCA schemes.

D. DBTMA PROTOCOL

The DBTMA scheme uses RTS/CTS dialogue mechanism for establishing a communication between two neighbouring nodes. Also, two busy narrowband tones are used that notifies the neighbouring nodes with current communication. The busy tones are: transmit busy tone (BT_t) and receive

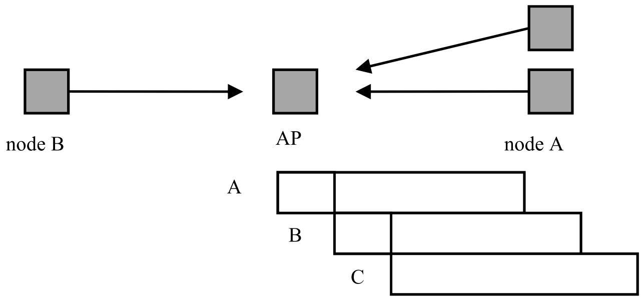

FIGURE 2. Hidden collision from nodes A and B. If B's packet arrives at the access point (AP) after it has successfully received the medium access control (MAC) header of A's packet, the AP can obtain the information on node A.

busy tone (BT_r). The busy tones cover the narrow bandwidth with small and negligible overhead and hence the bandwidth consumption is neglected during performance evaluation.

Consider, Node A with a DATA packet to be transmitted to neighbouring node B. Prior to transmission, if the node does not sense the BT signal, then the RTS packet is transmitted to node B. Upon the reception of RTS packet by the node B, it decides whether to receive BT_t signal or to reject it. However, if the BT signals are not sensed, the reception of the packet will initiate. Hence, BT is setup and it replies to corresponding node A using CTS packet.

Once the A node receives CTS packet, BT_t signal is been set up and DATA packet is transmitted to B node. The dual busy tones are reset once the process of transmission gets completed.

The dual busy tone technique helps in monitoring the channel using neighbouring nodes. The nodes that are within the transmission range of B node, e.g., node C and D senses the BT and back-off. This case considers even a RTS/CTS dialogue mechanism between node A and B are not correctly received. This occurs due to interference in transmissions from node D. This leads to the problem of a hidden terminal between the nodes in the network.

E. FAST RETRANSMISSION

This section provides a detailed description of faster retransmission scheme. A collision that occurs due to hidden nodes is denoted as a hidden collision. Assume, node A is hidden from B and C nodes, however, B and C are visible to each other. Here, the collisions in hidden nodes are taken into consideration (Fig.2).

In a single base station, collision in hidden nodes occur over AP's or access points, which possess no hidden nodes. Since the AP nodes are inside the range of transmission. The subsequent section provides a clear explanation on detecting collisions at AP nodes and presents the details on faster retransmission mechanism.

1) FAST RETRANSMISSION MECHANISM

A new control frame or negative acknowledgement (NACK) is used for faster retransmission scheme. A hidden node, where the collision occurs at access point listens to the NACK signal and uses the signal to determine the requirement fast retransmission scheme. Four-bit type and field subtypes are used in distinguishing the frames of the MAC layer. The control frames come under type 01 and then it is subdivided into four types of subsets. In IEEE 802.11 MAC layer, the value of subtypes for each control frame is set small and the new control frame is defined, which is devoid of any modification (Table 1). The NACK for notifying the collisions possess 1001 subtype field, and the remaining frame structure has the subtype field, which is to the subtype field of ACK. Nodes overhearing the NACK has not initiated its transmission, due to NACK's duration field.

TABLE 1. Control frames.

Subtype	Symbol	Description
1001	NACK	Negative acknowledgement
1010	RTS	Request to Send
1011	CTS	Clear to Send
1101	1101	Acknowledgement

Once the collision occurs due to hidden nodes and if there exist adequate time in decoding the header layer of the first packet in MAC, then the access point detects the collision due to hidden nodes. The extraction of information occurs after decoding the first frame of the MAC header. The access points, then send NACK to its initial transmitter, even if the nodes inclusive of the hidden nodes receives the NACK signal. Once the NACK signal is received, the initial transmitter retransmits after waiting for PIS (Point Inter-frame Sequence). The initial transmitter instantaneously starts its faster retransmission, even though it already has ongoing legacy retransmission.

When a node offers an SIS or PIS, the priority access to each channel is found to be at a higher rate. This guarantees the lack of colliding nodes in IEEE 802.11 MAC layer. Once the initial transmitter ends its retransmission strategy, the access points react to the sender by transmitting an ACK signal. The second transmitter responds to the ACK signal and then retransmission occurs with the null back-off timer after waiting for DIS frame. Since there exist a null back-off time, the transmission data could be sent to its receiver by the second sender without any contention. The retransmission occurring at the second transmitter results in collision of during transmissions by another sender, since; there exist more than one sender (Fig.3).

Collisions occur at the second transmitter in a consecutive manner, leading to a lower probability of detection. Additionally, if multiple collisions occur due to hidden nodes, the initial transmitter retransmits the packets successfully. The faster retransmission scheme thus reduces the time of retransmitting the packets and the pseudocode for the retransmission algorithm is given below.

Assume that exist two transmitters A and B, both the transmitters are related in terms of an access point and hidden from each other. In faster retransmission scheme, when a collision occurs due to hidden nodes, the access points detect

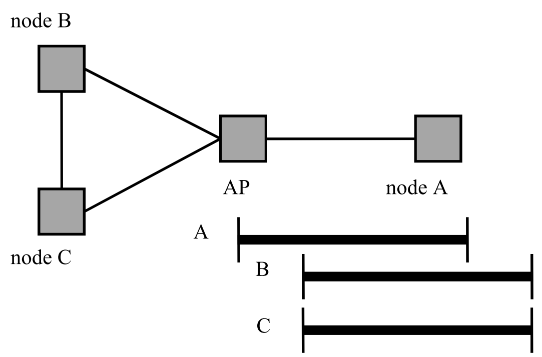

FIGURE 3. Multiple hidden collisions resulting from the same back-off time. In this case, the frames from nodes B and C collide again. AP: access point.

Algorithm 1 Transmitter

Data Frame Transmission
Waiting for ACK signal
If the timer discovers the timeout in ACK, then
Retransmission is initiated,
Else Stop retransmission
End
If NACK receives NACK then
Fast retransmission is started
Else if NACK receives NACK then
Faster retransmission is started
Else wait till the process gets completed
End

the collision and send a NACK signal to A. This data after such signalling is retransmitted without any contentions in the network. When node A listen to corresponding ACK for retransmission, data is been retransmits out from it.

Assume, an ideal environment with two nodes, which is hidden from each other transmits a single frame to access point. Hence, the time required to transmit the packet is analysed. The total time taken by DBTMA scheme with RTS/CTS dialogue mechanism is given as:

$$T = T_{RT} + T_C$$
$$T_{RT} = 2(SIS + DIS + CW + DATA + ACK) + Timeout$$

where, T_{RT}- legacy retransmission time, *SIS*– Short Inter-frame space-time, *DIS*– Distributed Inter-frame space-time, *CW*– Contention Window probability, *DATA*–Transmission time of data, *ACK*– Acknowledgement time and *Timeout*-predetermined ACK timeout.

$$T_{RTS/CTS} = 2(Control + T_T) + PCW \cdot \delta$$

where, $Control = \mathrm{T}_{CTS} + \mathrm{T}_{RTS} + 2SIS$

$$T_T = DATA + SIS + ACK \quad (5)$$

where, *Control*- time for exchanging of control frames and T_T- single data transmission time.

$$T_{FR} = C + T_{F\_R\_T}$$

Algorithm 2 Receiver

Signal is received
If preamble correlation occurs then
If the control flag is set high then
Collision occurs at hidden nodes
Preparation of NACK signal
Else send the entire symbols to MAC layer
Else if (control flag) on then
Sending the entire symbols to the MAC layer
End
Else ignore the process
End

TABLE 2. Physical parameters.

Physical layer	Rate	unit
Data rate of channel	54	Mbps
Payload of packet	500	Byte
SIS	16	µs
PIS	25	µs
DIS	34	µs
slot time	9	µs
Propagation delay	1	µs
Timeout	32	µs
Min Contention Window	15	CW
max Contention Window	1023	CW
m	7	-
Basic data rate	5	Mbps

$$T_{F\_R\_T} = 3SIS + 2(DATA + ACK)PIS + DIS + NACK + \delta$$

where, C is the Collision timing duration and $T_{F\_R\_T}$ is the Faster Retransmission time

Ideally, the probability of expectation on collision is $\mathrm{E}[P_{CW}] = 8$ and $\mathrm{C} = 0.5\ DATA$ and $Timeout = SIS + \mathrm{ACK}$. The node that starts retransmission after waiting time is equal to total sum of SIS and ACK frame transmission time.

V. VALIDATION AND PERFORMANCE EVALUATION

The throughput and delay metrics of DBTMA with faster retransmission strategy is compared with conventional EDCA technique. Simulations are performed using Network Simulator-version 2.3 (NS-2.3) that uses parameters like route discovery delay and time, packet loss ratio, throughput and other related metrics etc., between the EDCA, DBTMA and RDBTMA. Simulation results are given using NS-2.3 by comparing the parameters like delay, packet loss ratio, throughput, etc., between the EDCA, DBTMA and RDBTMA. Each simulation results signifies an average value over 50 random runs. The considered data rate of the channel is 1 Mbps and nodes of 1000∗1000 are used to simulate all the four protocols at the MAC layer.

The physical and packet parametric value of the proposed system design used in the current study is summarized in Table 2, and Table 3, respectively.

The parameters fulfil the specification of IEEE 802.11 DBTMA protocol. The nodes are randomly distributed in 2D Poisson distributions around $1000 \times 1000\ \mathrm{m}^2$ area. The entire

TABLE 3. Packet parameters.

Parameters	Value	Unit
MAC header	272	Bits
PHY header	192	Bits
ACK	304	Bits
RTS	352	Bits
CTS	304	Bits

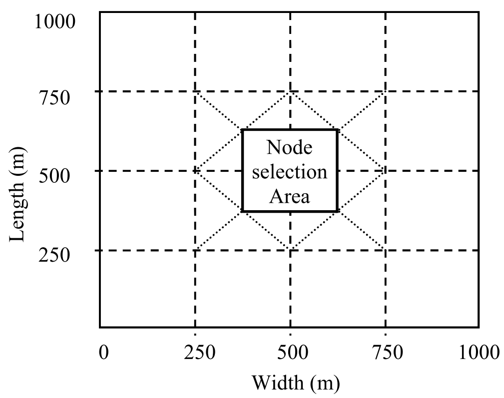

FIGURE 4. A random snapshot of node distribution in simulations. They are presented by the square in the middle includes nodes under test.

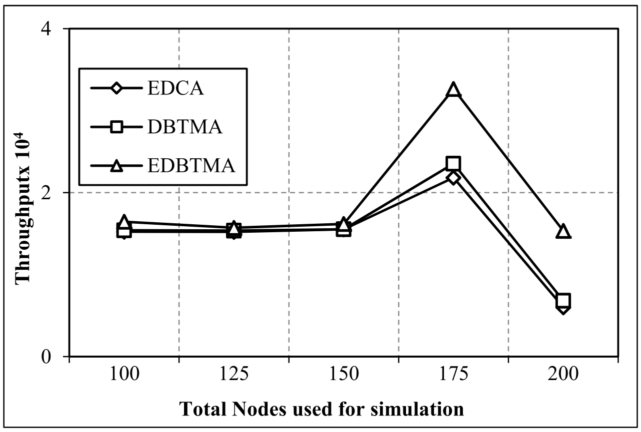

FIGURE 5. Per-hop throughput.

nodes are equivalent and the effect arises from edges are avoided by considering the transmissions from the network centre.

Thus, the density at the network space centre is divided into 16 sectors and the node assumes random distribution according to Poisson distribution. The CBR traffic is loaded over each node that possesses high data rates for achieving traffic saturation.

A. NETWORK THROUGHPUT

The Fig.5 shows the attained network throughput at a hop in the network. The density of the node is maintained at the rate of 0.001024 node/m^2. Since, (16 × 64 nodes)/(250 × 250 × 16 m^2)) = 0.001024 node/m^2. The value of the range is varied between 0 m to 250 m, which is the width of the network. It is clear from the throughput results that the accuracy of the protocol is validated in terms of the simulation results.

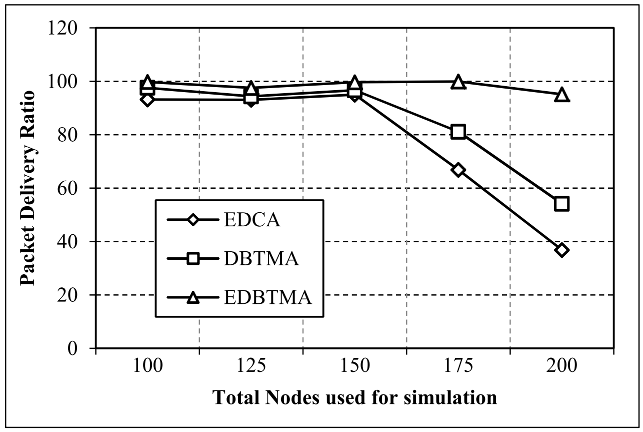

FIGURE 6. Packet Delivery Ratio.

Also, it is noticed that smaller transmission range, finds it difficult to identify the node and the probability is very low. This affects the throughput to be very low and widening the range of nodes transmission increased the throughput. Once the throughput reaches the maximum/peak, it declines due to the increase in the number of nodes within the transmission range. Another criterion in choosing minimum nodes is that with larger transmission range, the probability of identifying the nodes increases within the range. Thus more hidden terminals and more contending nodes further results in lowering the throughput rate and high collision rate.

The packet delivery ratio impacts the throughput to an increased extent, as the nodes increases, the performance is hit due to increased hidden terminals and contention window. However, the proposed RDBTMA scheme provides higher packet delivery ratio than the conventional schemes. This is shown in Fig.6.

B. ROUTE DISCOVERY DELAY

The delay shown in Fig.8 represents the DBTMA delay experienced by the packet from its transmission time to its successful reception time.

From the results, it is concluded that with an increase in transmission range, the delay increases further. Since more retransmissions occurring due to collisions further prolong the route discovery delay. Further, the densities of node possess a greater influence over route discovery delay. The delay rate gets increased as the node is densified and results in multiple collisions. However, as the total nodes in the network are set 175 and the packet is set as 3202, the delay gets decreased further. It can also be concluded that with more densification at more nodes, the packet transmission happens with lesser delay. The results gave an overview that transmission and sensing range can be adjusted for optimizing the network performance with maximised throughput with RDBTMA route discovery delay.

The network throughputs of RDBTMA scheme possess higher value than conventional RTS /CTS schemes. Since the control overhead for exchanging frames is quite high, the hidden collision probability is low with higher rates, then the

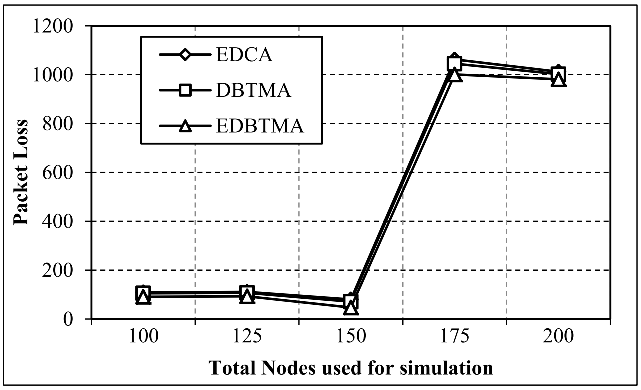

FIGURE 7. Packet Loss Comparisons.

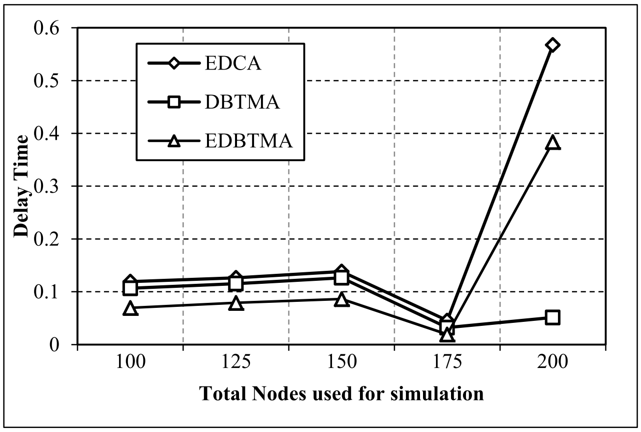

FIGURE 8. Route Discovery Delay – Comparisons.

RTS/CTS schemes lead to lower throughput in the network. Multiple iterations proved that the RDBTMA protocol has better throughput that RTS/CTS dialogue mechanism. This is proved in terms of faster retransmission strategy, even if the nodes collide. However, the network throughput decreased sharply the total nodes in the network increased and the solution for eliminating hidden node problems is completely a nightmare.

VI. CONCLUSION

In this paper, an accurate analytical model is presented to compute the network throughput and delay in MANETs. The results proved that there exists a quantitative relationship between the route discovery delay and network throughput performance in MANETs. The presence of NACK signalling helps in compensating the collisions due to hidden nodes. Also, the probability of collisions occurring due to hidden terminal degrades and thus increases the throughput of the network with shorter waiting.

The total processing time using faster retransmission strategy is sharply decreased with the increasing data rate. Since the transmission time of each data is reduced with an increased data rate. However, RTS/CTS causes time wastage owing to the large control overhead in high data rate wireless networks. Therefore, the proposed faster transmission scheme over RTS/CTS dialogue mechanism in DBTMA is consumed lesser time the conventional techniques with RTS/CTS.

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M. SIVARAM received the B.E. degree in computer science and engineering from the Bharat Niketan Engineering College, Madurai Kamaraj University, Madurai, in 2002, the M.Tech. degree in computer science and engineering from the National Institute of Technology, Trichy, in 2007, and the Ph.D. degree in information and communication engineering from Anna University,Chennai, in 2014. He has nearly 18 years of experience in teaching both UG and PG program. He is currently a Professor with the Department of Computer Networking, Lebanese French University, Erbil. His fields of interests are data mining, image retrieval, information retrieval, data fusion, image processing, and artificial intelligence. He has published over 20 papers in international and national journals, and conferences.

V. PORKODI received the B.Sc. degree in computer science and engineering from Periyar University, Salem, in 2001, the M.Sc. degree in computer science and engineering from Periyar University, Salem, in 2003, and the M.E. degree in computer science engineering from Anna University, in 2009. She has nearly nine years of experience in teaching both UG and PG program. She is currently an Assistant professor with the Department of Information Technology, Lebanese French University, Erbil. She has published over four papers in international and national journals, and conferences. Her fields of interests are data mining, image processing, and information retrieval.

AMIN SALIH MOHAMMED received the bachelor's and master's degrees from the Kharkiv National University of Radio Electronics, and the Ph.D. degree from the Kharkiv National University of Radio Electronics, in 2012. He has nearly 15 years of experience in teaching both UG and PG program. He is currently an Assistant Professor with the Department of Computer Networking, Lebanese French University, and the University of Salahaddin-Erbil. He has published over 26 papers in international and national journals, and conferences. His fields of interests include wireless networks, ad-hoc networks, and information security.

V. MANIKANDAN received the M.Sc. degree (IT) from Periyar University, Salem, in 2005, and the M.E. (CSE) degree from Anna University, Chennai, in 2008. He has nearly 10 years of experience in teaching both UG and PG programs. He is currently an Assistant professor with the Department of Computer Networking, Lebanese French University, Erbil. He has published over five papers in international and national journals, and conference. His fields of interests are data mining, image processing, and information retrieval.

N. YUVARAJ received the B.E. degree in computer science engineering from the Coimbatore Institute of Engineering and Technology, Anna University, India, in 2010, and the M.E. degree in computer science engineering from the Sri Shakthi Institute of Engineering and Technology, Anna University, in 2012. He is currently pursuing the Ph.D. degree in computer science engineering with the St. Peter's Institute of Higher Education and Research, India. He has published several research articles in conference proceedings and international journals. His research interests include data mining, wireless sensor networks, the Internet of Things, big data, and mobile computing.