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Cooperative MAC Protocol based on Best Data Rate (CMAC-DR)

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Abstract: As wireless signals are broadcast in nature, which implies that, a broadcast communication purposive to a predetermined destination may be received by a non-intended intermediate station. Cooperative transference, which employ interposed stations to pass on the eavesdropped data to attain the contrast gains, has a substantial capability to revamp the channeling effectiveness in wireless systems. In this it is evident that having cooperation amid stations in a wireless system can accomplish higher throughput with enhanced network lifetime. Proffered work bestows a model for medium access layer called Cooperative MAC protocol based on optimal Data Rate (CMAC-DR). In the proffered work, stations with more data rate aid stations having lesser data rate in their communication by redirecting their congestion. In CMAC-DR model, utilizing the conveyance of eavesdropped information, potential helper stations with more data rate Send out Helper Ready to Send (HRTS), the stations with less data rate maintains a table, called Co-op table of potential helper stations, that can aid in its transmissions. During communication, the source station with low data rate chooses either transmitting by the way of a helper station, so that it lowers the end to end transference delay and increases the throughput or opt only direct transmission, if no potential helper is found or if CMAC-DR becomes an overhead. By analyzing varied simulated scenarios, CMAC-DR evaluates the elevation in the overall network lifetime, throughput and minimization of delay. The CMAC-DR protocol is unambiguous and in accordant with legacy 802.11 also when compared to this, we find improved performance in terms of delay throughput and network lifetime since data rate is considered as relay selection condition.

Index Terms: Wireless Adhoc Systems, Cooperative Transference, Medium Access Control, Data Rate, Throughput, CoopTable, Quality of Service(QoS).

1. Introduction

In contemporary time, wireless systems are advancing into a versatile devices beside immense data executions done by them [1]. Aforesaid accomplishments need fast connectedness and sturdy fault preventiveness [2,3]. Those necessities, besides enormous growth of wireless networks with constrained spectrum availability has evolved into momentous complications like extent crisis and more interventions. This circumstance necessitates an advance in the direction of origination of a modish wireless strategy that can facilitate a more methodical use of the accessible spectrum. While unfolding strategies like “Multiple-Input-Multiple-Output” (MIMO) system, commences to advance the spectrum capability, but its utilization is constricted as its dimensions, price and the power for the compact wireless systems poses certain restrictions [4].

An auxiliary technique called cooperative transference guarantees to furnish some merits of the MIMO with certain restraints. The major objective was to introduce a best relay selection scheme for a multi hop communication between source and destination, there by improvising network performance. Cooperative transference cites in to the synergetic refining and relaying of an eavesdropped data by the stations which are encompassing source station. The perception of cooperative transference is to fully leverage the disseminating complexion of the wireless channel and to create a geographical diversification, specifically transfer variance, thereby attaining immense boost in system robustness, capability, delay, notable depletion in interventions, and extension of coverage scale [5]. The preliminaries of cooperative transference are found at the physical layer, although, the conception of cooperative transference is obtainable in varied dispositions at higher layer protocols. To be able to retrieve the physical layer data and to have swift flexibleness to sustained potency, it is legitimate to instigate the concept of cooperative transference in the layer which is immediate aloft the physical layer, viz. the medium access control (MAC) sublayer.

In cooperative transmission, numerous stations in wireless adhoc system function in adjoint to behave as an effective antenna assembly. Cooperative transference at the physical layer utilizes the broadcast character of the wireless system and eavesdropped information to enhance the effectiveness [6]. The stereotypical MAC models have long-drawn treated this attribute as a complication, preferably considering it as an alternative to overcome many bottlenecks. The methodology of cooperation employs this feature, and fabricate a state-of-the-art MAC model in wireless adhoc systems. The Cooperative MAC protocol based on optimal Data Rate (CMAC-DR) model for IEEE 802.11 wireless adhoc networks avail oneself of both the transfer characteristic of the wireless channel and cooperative distinctiveness. Contemporary 802.11 MAC models are primarily focused on throughput and capability under overloaded circumstances, particularly when every station contains a frame in standby condition, all the time [7]. The studies on “saturated environments” are required to obtain understanding on functioning of the protocol. Moreover, the overloaded consideration is inappropriate for present-day utilizations viz. audio and video streaming.

In CMAC-DR model, we proffer the implementation of cooperation at MAC sublayer by considering a wireless adhoc systems, in which there are potential helper/ Relay stations (RS) through which the data frame from the source station might also get forwarded to the destination station and create a cooperative scenario. We study the performance, by carrying out a broad lay of simulations rooted on the scheme features as these are enumerated below:

- Throughput performance under heavy load.
- Network lifetime.
- Energy consumption.
- Delay performance.

The balance of the paper is systemized as follow: In section-II, analogous studies is chronicled. Section-III deals with the working of the proffered CMAC-DR model. Section-IV deals with the simulation results. The analysis of the performance parameter of proffered model is established in section-V, Section VI provides the interpretation of the proffered model and the possible subsequent considerations.

2. Related Works

According to “IEEE-802.11-Distributed Coordination” Function (DCF)[1], in the wake of a source station recognizing a channel as inactive for a span of Distributed Inter-Frame Space(DIFS), source station will back down from sensing the channel for a duration chosen between 0 and it’s “Contention Window”(CW) [8-9]. Subsequently as the timer finishes, the frame exchanging procedure is initiated. Any intermediate stations eavesdropping any of the control frames (RTS/CTS) obtains the duration info from the frame header, and places its Network allocation vector(NAV). Now this is referred as an exposed station problem in the IEEE 802.11 systems in which all the intermediate stations which are receiving the control frames which are not intending to them [10], will be silenced for the duration specified in the frames. Though certain stations communication of other stations will not be interfered with the current transference, it will not be allowed to do so. Thereby overall network efficiency, throughput, and other Quality of Service(QoS) parameters are degraded.

CoopMAC[2], Cooperative MAC protocol for adhoc wireless systems. This protocol is formed on an aim of involving an intermediate station in an ongoing transmission of the source and destination stations. The intermediate station retransmits the information eavesdropped from the source to the destination [11]. Consequently, lessening the transmission duration for the congestion being managed. In CoopMAC, the relay selection function is done by the source station, it chooses the best intermediate station which dispenses the least transference delay to destination. Substantial simulations depict that CoopMAC enhances the throughput and delay efficiently. For each simulation, stations were arbitrarily localized in an area of radius 350 m. Increasing the network size, coverage range, throughput, reducing source to destination delay and including mobility in accordance with real time scenario was considered as a subsequent study.

DELCMAC[12], The intent of the diversified energy location based cooperative MAC(DEL-CMAC) model is to better the efficiency of mobile adhoc networks MANETs with respect to overall network lifespan and energy. The energy utilization model considers the energy utilization of transceiver circuits along with the transmit amplifier [13]. A diversified utilization-focused optimum relay selection strategy is used to select relay on the basis of locale data and energy remnant. Also, for the purpose of enhancing the structural reuse, a resourceful NAV setting is considered to deal with the varying transference power of the source and intermediate stations. In this paper, considering hidden terminal issue, increased network capacity with more mobility, minimizing the throughput and delay degradation is kept as a future work.

The rDCF model presented in [14] chooses an agile process by publicizing the capability of each intermediate station to help through Hello frames. Nonetheless in both CoopMAC and rDCF, the helper node forwards the frame to the destination, immediately after the reception from source station. But the relay station in [15] transmits the frame only if there is no reception of an ACK from destination indicating that it is unable to decipher the frame of the direct transference. Persistent RCSMA reported in [14] utilizes the function of a diversified and cooperation through automatic retransmission request (ARQ) model. In this model, if the destination station deciphers a data frame containing errors through direct transference from the source station, it requests a transference from any of the intermediate stations which has eavesdropped the original transference.

In Coop MACA protocol [15], it considers packet aggregation and distributed contention based relay selection algorithm to furnish a robust alterations instantaneously for any changes in the network architecture specially for a general mobile situations. The author of the EMR model proposes the consideration of a priority-mapping scheme of existing throughput and unify the information into the control frames in order to choose the optimum relay node.

3. Proffered CMAC-DR Model

For cooperative transference, we mainly focus on a wireless adhoc system, where the stations can enhance their effective quality of service(QoS) by cooperation [16]. In which, every wireless station is presumed to act as a source station as well as a cooperative agent for another station as shown in figure 1. In cooperative wireless system, source station initially transfers their frames to the intermediate helper station, then the helper station proceeds onto forwarding its received data information to the destination station.

The CMAC-DR model is built upon the IEEE-802.11-Distributed-Coordination Function(DCF [17]. The transference powers for all the stations are assumed to be unvaried. Request to send(RTS) and clear to send(CTS) frames can be eavesdropped by other intermediate stations besides the source and destination stations. If source node has a MAC protocol data unit (MPDU) to transmit, it has an option to transfer straight to the destination, or to employ an intermediate helper station for transference [4]. Therefore, in CMAC-DR model, initially as in legacy mode of 802.11, RTS frame will be broadcasted but in which the RTS frame is modified in such a way that it also contains data rate of source station as shown in figure.2. Further including destination even all other stations overhear the RTS frame and gets the data rate of source station. Subsequently modified CTS frame as shown in figure.3. will be sent by destination station by including its data rate.

The potential helper station which has eavesdropped both RTS and CTS frames compares the data rate of the source with its own. If it is of higher data rate than that of the source station, then it enables its cooperation mode and broadcasts HRTS(Helper ready to send) frame in which the data rate of potential helper station will be incorporated in the frame structure (Figure.4.) [18]. Here potential helper station refers to the station which is in the coverage region of both source and destination stations with more data rate than that of the source and also not involving itself with any of communications with any other stations and also not being allocated with NAV from any nearby transmissions [19]. Thereby source station receives the HRTS frames of all the probable helper stations and maintains a Coop table in its cache memory. Further it compares and chooses the best relay station which has the highest data rate to transmit the data frame. As a consequence, increase in the channel efficiency with higher throughput and less delay is achieved [7]. If the source station does not receive an HRTS within its timeout, it will then initiate a straight transference to the destination. An acknowledgement(ACK) is sent to for a correct acceptance, regardless of the event of frame forwarded by an intermediate helper station, or is directly transferred from the source.

It is important to take into account that each station gathers and revises the information about the potential helper station at one's disposal and their respective data rates only when it is required [3]. The CMAC-DR model transacts this issue through cooperation(Co-op) table. The Co-op table will be formed by source node (Table1), for keeping the entry of an information with regards to a potential helper station address viz., 48-bit MAC address and its data rate of direct transference between the potential helper station and destination.

By the virtue of broadcast property of a wireless channel, the destination station will obtain the data frame by both source station and relay station [10]. In the event of destination correlating these two copies to decipher the original information efficiently, then cooperative diversity is completely leveraged. Similar modification is done on the Data packet (Figure.5), so that it get forwarded through the potential relay as per the proffered CMAC-DR model. The Data frame is transmitted by source (SRC) station and from the other direction via a helper station by a process of address exchange mechanism at the helper station i.e., Address1 field in the data frame is replenished with the destination station address and broadcasted with its data rate [20]. The destination node or the station which has sent clear to send (CTS) frame, after successfully decoding the same data frames which have arrived in two subsequent time slots, replies with an

ACK frame so that it acknowledges the affluent acceptance of the data frame either by direct transmission from source side or through the CMAC-DR model. Figure.6. represents the complete action flow of the CMAC-DR model.

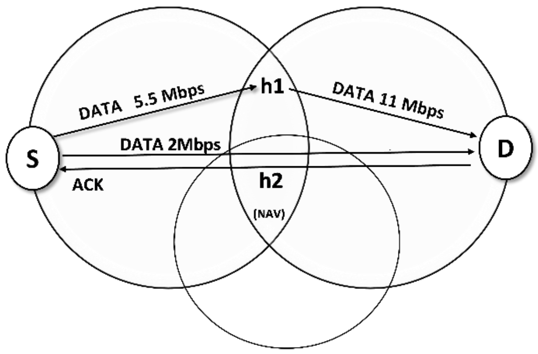

Fig.1. Cooperative scenario

Octets: 2	2	6	6	2	4
Frame control	Duration	Address1 (DA)	Address2 (SA)	Data Rate	FCS

Fig.2. Modified RTS control frame

Octets: 2	2	6	2	4
Frame Control	Duration	Address1 (DA)	Data Rate	FCS

Fig.3. Modified CTS control frame

Octets: 2	2	6	6	2	4
Frame control	Duration	Address1 (DA)	Address2 (SA)	Data Rate	FCS

Fig.4. Frame structure of HRTS control frame

Frame Control	Duration	Address 1 (Helper)	Address 2 (SRC)	Address 3(DST)	Sequence Control	Address 4	Frame body	FCS

Fig.5. Data frame format

Table 1. Fields of CMAC-DR model Co-op table

Helper MAC Address	Data Rate(Mbps)
00:00:00:00:00:02	5.5
00:00:00:00:00:04	2

3.1. Helper Node Control Plane

Determining the helper station among the intermittent capable relay stations is very important and also a bottleneck process in the co-operative transference [21]. The cooperative table is formed by the source station and it will select a helper station depending on the data rate. Once the potential helper selection is completed, it will act as a relay node. The data rate ensures the functionality of the CMAC-DR model, which indicates that how effectively the frame is received at the next station. The Helper control flow of the potential relay station initially will be in an idle mode. When the request to send (RTS) frame with data rate information is transferred by the source station and once the CTS frame is transmitted by the destination containing the data rate information, the potential helper overhearing both the frames, CMAC-DRs the RTS frame header extracts and compares the data rate of the source station with its data rate [22]. If it is more than that of the source, it will enter into the cooperation mode and prepares the Helper Ready to Send (HRTS) frame by adding its data rate information in the frame format and broadcasts it to the source station. Similarly, multiple HRTS frames will be sent to the source station from different capable relay stations.

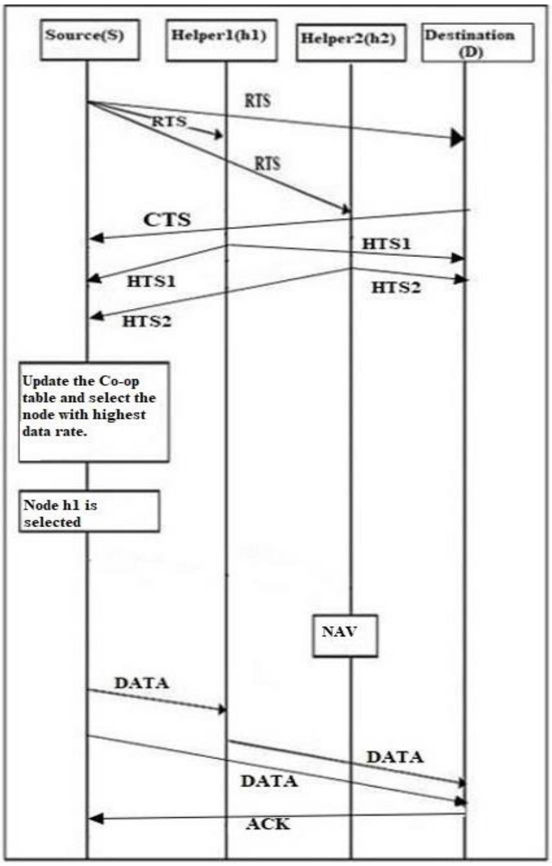

Fig.6. Action flow of CMAC-DR model

3.2. Helper Node Data Plane

Forwarding the data through the selected potential helper station after the exchanging of control frames is a challenging function in the cooperative transference [23]. CMAC-DR model suggests a most appropriate and ideal approach for data forwarding in cooperative transference [24]. The data frame forwarded by the source station is addressed to the selected helper node in which the address of the potential helper is in address field-1 of the data frame. Potential relay/helper station receives the data frame and verifies it whether it is addressed to it, if so, it checks for whether it is in cooperation mode or not. If the potential relay station is in coop mode, it replaces the address of the intended destination in the address field-1 of the data frame and transfers the frame to destination station with its data speed.

3.3. Co-operative Mode Selection

Choosing the transference mode is established by considering three conditions. firstly the intermittent helper nodes checks if it is having any RTS from any of the neighboring node for itself, secondly it is not allocated with Network allocation vector (NAV) from any other station in the network and, thirdly its data rate is more than that of the source station, only if all the above three case are satisfied then cooperative mode will be enabled and broadcasts helper ready to send (HRTS) frame[25].

Algorithm for mode selection by helper nodes

- Initialization.
- Check if it is having any RTS for itself.
- Check if is allocated with NAV from neighboring nodes.
- Check if helper node data rate > source node data rate.
- Transmit helper ready to send (HRTS).
- Else: Be in idle state.

3.4. Actions Performed by Source Node

Initially, source station will be in indolent mode until it has a MPDU to be transferred to the destination [26]. Once the buffer is full and wants to send a frame with body length of l bytes, it first verifies whether the channel is in standby for a DIFS, subsequently the source also waits for its CW to timeout and then it transfers a request to send (RTS) frame in which the data rate information is incorporated to withhold the channel, else it holds back for a random back-off time [27]. If destination side is free for communication it sends a clear to send(CTS) frame with its data rate. If the source station does not obtain a CTS inside “tRTS +tCTS +SIFS”, RTS is re-broadcasted. Next the intermediate potential helper stations broadcast the helper ready to send (HRTS) frames by keeping their data rate information in the control frame. Now the source station waits for another $t_{Back-off}^{max}$+tHRTS+ SIFS, where $t_{Back-off}^{max}$ is the maximum back-off time for a helper node [20]. If it receives a HRTS within the waiting time, based on the information obtained from the HRTS control frames its cooperation table is updated and the station with maximum data rate is chosen as the helper station and MPDU is transferred through it, else direct transmission is done. The acknowledgment(ACK) has to be obtained within "tACK+16(l+ lh)/2R+2SIFS," where lh denotes length of the header in bytes, else source station would carry out an arbitrary back-off procedure [28]. The l and lh are represented in bytes and data rate(R) with bits per second, thereby the overall transference span for a data frame is given by "8(l+ lh)/2R." Figure.6. indicates the timing diagram of the CMAC-DR model. It considers two intermittent helper stations and a destination. TX and RX represents the transmission and reception line of the respective stations. Here tRTS, tCTS, tHRTS, tACK indicates transmission time for RTS, CTS, HRTS, ACK.

Relay selection algorithm by source node

- Obtaining data rate of the potential helper nodes through HRTS frames sent by them.
- Analyzing different data rate information of all the potential intermittent helper stations to get the relay station with highest data rate.
- If a helper station is chosen, transfer the MPDU through it.
- End

3.5. Enactments of Destination Station

The destination station will be in idle condition until it receives a RTS from the source station. Once the RTS is obtained and if it is self-addressed to itself [29], it will transfer a CTS succeeding a short inter-frame space (SIFS). It will then check for any HRTS frames by any intermediate potential helper stations. If yes, the destination station expects data frame from helper station and also from the source by direct transference. Next if the data frame is successfully obtained from the source station, a positive acknowledgement will be sent to the source indicating a successful transference. Similar optimal relay selection with time slot allocation can be viewed in other works [30].

4. Result Analysis

The stations are located spatially in diverse locale; thus, the fading attribute is also considered for all the stations along with channel fading for the network scenario as shown in Figure.7. The various network attributes that are set for the considered simulation scenario is given by Table.2.

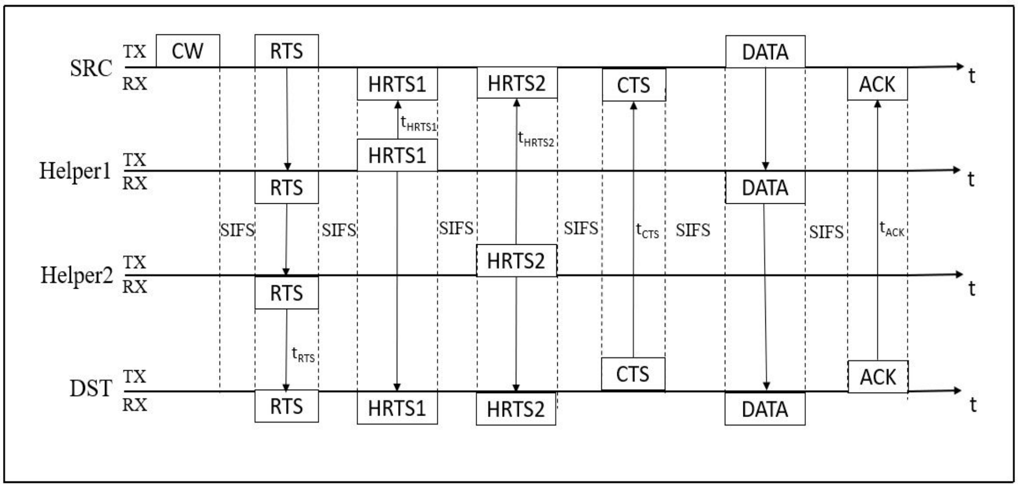

Fig.7. Timing diagram for CMAC-DR model

Simulation results of CMAC-DR model along with legacy 802.11b is evaluated using Qualnet. CMAC-DR model transmits the data frame from source to destination through a helper station based on the data rates. Node number is diversified between 10 to 100 and are located in random in a 600x600 m^2 terrain. The source station transfers packets in the range, 500 to 2313 of size 1024 bytes each with transference rate of 10 packet per second. The simulation time for the scenario considered is 100 seconds. All the stations are enabled with random mobility model. Throughput received, average unicast source to destination delays and total broadcast messages received clearly by the destination station.

Figure.9a. shows that with CMAC-DR model, the throughput given by bits/sec is more as MPDU is transferred cleverly by switching between direct transference and CMAC-DR model.

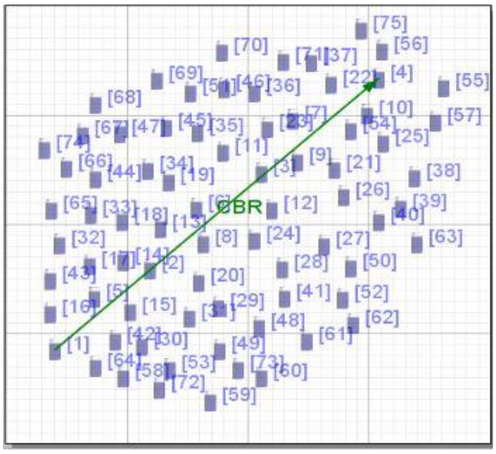

Fig.8. Wireless adhoc system simulation in Qualnet 7.1

Table 2. Simulation parameter

Attributes	Specifications
Node number	10-100
Simulation area (meter sq.)	600x600
Simulation time (seconds)	100
Traffic type	Constant bit rate (CBR)
MAC protocol (wireless)	802.11b
Data rate(MHz)	1, 2, 5.5, 11
Total packets sent	500-2312
Size of each packet	1024

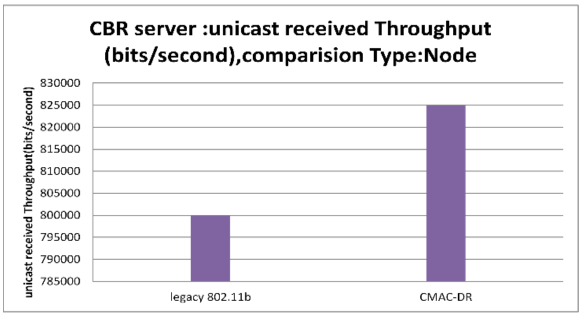

Fig.9a. Throughput of legacy 802.11b vs CMAC-DR model

The received throughput in CMAC-DR model shows increase of 604 metric value in comparison with the IEEE 802.11 protocol for 50 nodes adhoc network. The network lifetime in CMAC-DR model is more, due to the better transference of the MPDU and also because of the availability of stations for long duration.

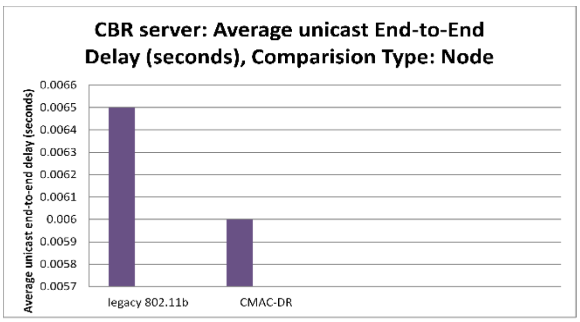

Fig.9b. Delay of legacy 802.11b vs CMAC-DR model

Figure.9b. shows the variation in source to destination delay. In CMAC-DR model frames are transmitted along the best path by choosing best relay node based on the best data rate, as a result delay is reduced in CMAC-DR model. The transmission of frames in legacy 802.11b MAC protocol is only on single-hop communication, whose data rate might be slow due to channel fading and other parameters, so delay is more.

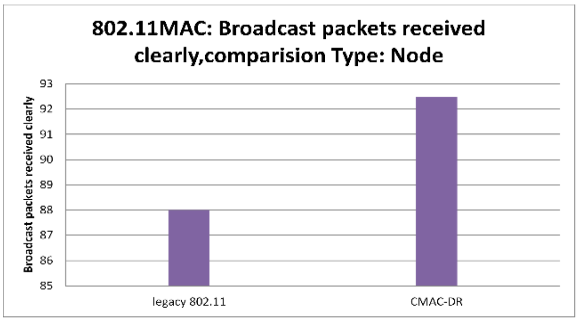

Fig.9c. Broadcast packets received clearly of legacy 802.11b vs CMAC-DR model

Figure.9c. indicates the Broadcast packets received clearly of legacy 802.11b vs CMAC-DR model, Broadcast packets received clearly is more in case of CMAC-DR model because of the employment of both direct transmission mode and also through a potential capable helper station with highest data rate i.e., CMAC-DR model.

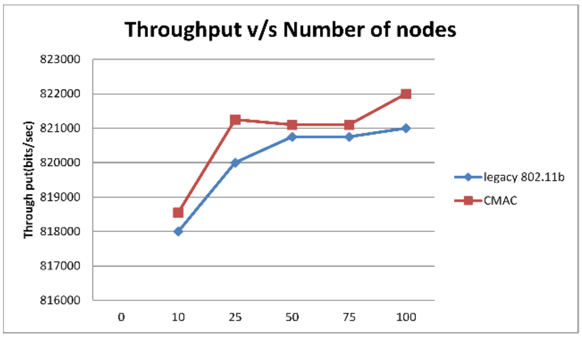

Fig.10a. Contrast in throughput vs number of node

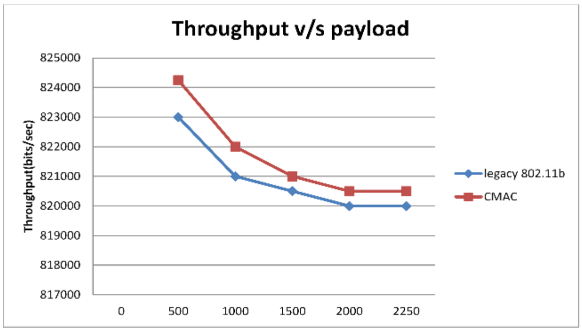

Fig.10b. Contrast in throughput vs payload

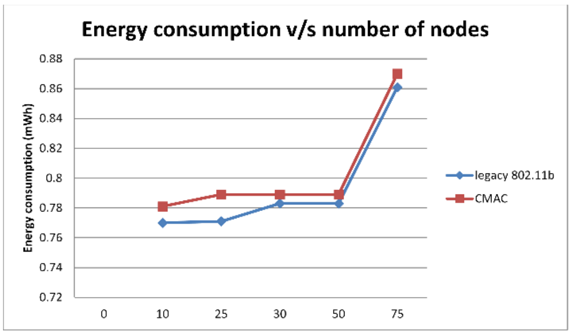

Fig.10c. Contrast in average transmission delay vs number of nodes

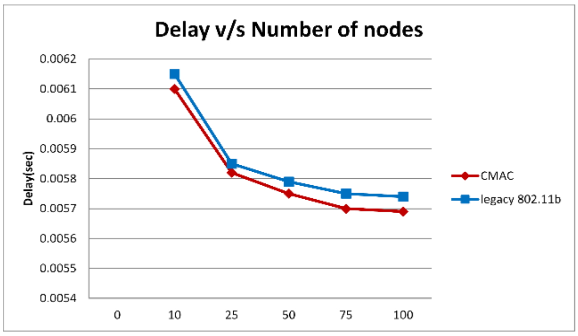

Fig.10d. Contrast in average delay vs number of nodes

The source station transfers 1000 packets to the destination through a wireless channel with various simulation attributes as mentioned in table 2. The simulation is performed for varied set of stations. Figure.10. represents the divergence in QoS, when the of nodes and payloads are varied. Figure. 10(a) & 10(b) indicates the contrast of throughput with node number and payload respectively. Our CMAC-DR model outperforms legacy 802.11b in terms of throughput. The refurbishment is attributed to the inclusion of the data rate as key feature for choosing the capable helper station. The node performance is enhanced, as the source station chooses the intermittent helper station with highest data rate during runtime, which also in turn increases the network lifetime. Average transmission delay provides the information of average latency in successful reception of a data frame. Figure.9c. shows that our CMAC-DR model has less transmission delay than legacy 802.11b, since our model employs a helper station with highest data rate. Also, average delay performance (Figure.10d.) is being enhanced by our CMAC-DR model in comparison with legacy 802.11b protocol. We know that as the number of retransmission limit increases, the delay in successful transmission also increases, we can observe that our CMAC-DR has better delay performance than the legacy 802.11b protocol when the re transmission limit is increased. Our CMAC-DR model is designed and proffered, so as to increase the throughput performance and utilize the channel efficiently for different number of nodes and for variation in payloads with reduced transmission delay. We can infer that CMAC-DR model is finer than IEEE 802.11 protocol by analysing the results obtained from the simulations.

5. Conclusions

The paper proffers CMAC-DR model to enhance the life span of an adhoc network, throughput and delay conduction of the wireless system. The proffered model ensures efficient channel utilization by a station and cleverly selects the capable station with highest data rate for MPDU transference. In a throughput scenario of our CMAC-DR, for a small number of nodes considered, we can see there is 69.2 % increase when compared to Legacy 802.11b and for large number of nodes we can observe 81.2% increase when compared to Legacy 802.11b. When delay of CMAC-DR is compared, for a smaller number of nodes, we can see there is 12.7 % decrease when compared to Legacy 802.11b and for larger number of nodes we can observe 17.3% decrease when compared to Legacy 802.11b.

The CMAC-DR model, precisely selects the mode of data transmission, thus it completely leverages the objective of the cooperative transference i.e., to aid the physical layer to receive the data frame from diverge locale and intelligently extract and combine the data frame so that the quality of transference is enhanced. The aimed objective performance of CMAC-DR model is achieved and it is analysed through numerous simulations and results obtained indicating the enhancement of the system performance. Including different channel fading model, mobility, reducing energy consumption and improving the delay performance is considered as a subsequent study.

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