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Game Theory based Channel Assignment and Load balancing for Cognitive Radio Ad-hoc Networks

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Abstract: ***Though various works have been done for handling end-to-end congestion control in traditional wireless adhoc networks, they lead to abnormal delay in Cognitive Radio Networks (CRN) due to the extra delaycaused by PU activities. While assigning channels along the route towards destination, channel availability, channel quality and channel switching delay should be considered. In this paper, we propose a Game theory based Channel Assignment and Load balancing(GTCALB) technique for multicast routing for CRAHN. In this technique, a channel matrix is constructed for each link with probability of channel availability, delay cost and channel quality. Then Game theory model is applied for each link in which a utility function is derived for each channel. Then the link with minimum overload is selected with a channel having maximum utility function. The proposed GTCALB technique is applied for each route, during the multicast route discovery. By NS2 simulation, it is shown that the GTCALB technique reduces the end-to-end delay and increases the throughput and packet delivery ratio for the constructed multicast routes.***

Keywords: CRAN; Game Theory; Channel; Load balancing; GTCALB

I. INTRODUCTION

A cognitive radio is an intellectualtransistor that wisdoms its surroundings to getcertainbroadcastfactors of other transistors. The novel networking modelwhich containsintellectualtransistors is called as a cognitive radio network (CRN) [1]. Itexploits the bandunscrupulouslyretrieving the approved band deprived ofmeddling with the presentoperators. In a CRN, the CR sporadicallyexamins the band so that the SU can practice the indolentnetwork to connect after approximating the co-channel meddling [2]. Numerous lessons emphasis on enhancingspecificbroadcastfactors of a cognitive radio [3].

Networkconsignmentplans are vital in defining how these networks are exploited proficiently in severalsystems. Every nodule is alloted one or additionalidlenetworks. To accomplishnetworkconsignmentcorrectly, suitablepolicies are established to assign the presentnetworks. Anelementarynecessity for networkconsignment is to evadeintrusionsincedissimilarassociations or operators cannot utilise the similarnetwork within their broadcast range at the same time [4].

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By integrating the spectrum resources into a sub-channel scalegroup, a livelybanddistributionprocedure was establishedeven though it is able tomake the most of the networkexploitation, the suppleness is missing in this procedure. [5]. There are numerous other factorsthat perform a mainpart in allowing the SU to select the finestnetworks out of accessiblenetworks for effectual communication [6]. Cognitive Radio (CR) skill can be united with ad hoc systems, which is termed as cognitive radio ad hoc networks (CRAHNs), in which wireless strategies can energeticallycreatesystemsby means of the availablerange assigned to PUs deprived of the necessity of secureorganisations. Owing to the varyingbandaccessibility and activesystem topology, direction-findingpresents a noteworthytask in CRAHNs [9].

Alikepredictable wireless nets, cramming may also happening CRAHN when unfilled transportation capacity surpasses accessibleability [7]. Henceforth it consequences inviolent retransmission,queueing suspension or the delaying of novel movements, which unswervingly influence system constancy.So as to promise the equality in the course of the SU´s broadcast period, capacity harmonising need to be measured [8].

II. RELATED WORKS

Vani Shrivastav et al [1] have suggested a game theoretic-based prototype accessibleby means of the idea of Nash Equilibrium for banddistribution. In this exemplary, intrusion and quantity of transistors on every singleconnection are well-thought-out as factors for planning the game. Aprocedure for networkdistributionamid the operators is also offered. It is witnessed from the imitation investigation that the schemeachievesacceptably regardingsystemexploitation. Also, the Taguchiprocess is put to use and an investigation of change (ANOVA) is done, demonstrating that the strategyfactorsconsidered in our suggestedtechnique are meaningful.

Jie Jia et al [6] have offered a scientificdesign to constitute the multifaceteddealings amongst the consequence of systemintrusion, connectiondimensions and movementpreservation. Moreover, a nested developmentplan is suggested to resolve the difficult issue, together with a hereditarymethod for networkdistribution, a hereditarymethod for patharrangement and an idealtrackassortmentprocedure to discoversupreme bandwidth track. With an intention tosafeguard the discretecogency and recklessmeeting, both the grouping and sequence-based programmingguidelines are aimed with appropriaterestraint control mechanisms.

Widespreadimitationconsequences are obtainable to validate the efficacy of their procedure.

Md. Jalil Piran et al [9] have suggested a technique for networkdistribution depending on audio-visual content necessities and the excellence of the accessiblenetworks in cognitive radio networks (CRNs).

Their aim is to protectsystem bandwidth and attainsuperioraudio-visualprovision. In this technique, the content is distributed into groups depending on actdifficulty and PSNR. To allotnetwork to the groups over multichannel CRNs, they initiallywant to recognise the proprietor'saction and then exploit the unscrupuloushabitconsequently. Then, they plot the accessiblebandoccasions to the content groupsas stated by both the excellence of the networks and the necessities of the groups. Then, a misrepresentation developmentprototype is builtbased on the systembroadcastappliance.

Yuting Wang et al [10] have anticipated a combined network as sortment and steering procedure, known as CSRP to make sure the path steadiness and decrease path dormancy amid intellectual operators. The network obtainability according to ancient evidence and the networks wapping suspension are exploited as the network choice principles to select the end wise unswerving path that holds extraordinary statistics distribution likelihoods and little post-ponements.

Mahassin Mohamed Ahmed Osman et al [11] have suggested a covetous heuristic procedure known as Load Balanced Spectrum and Transmission Range Aware Clustering (LB-STRAC) . LB-STRAC objects to allocate the capacityimpartiallyamid the cluster-heads and also to assign the bandhonestlyamongst the createdgroups. It comprises of two stages. The earlygroupbuildingstagedoespreliminarysegregation of a system into groups, and the groupassociationexplanationstagelinks the standard nodules into groups in such a way that backup the capacityharmonising.

Dan Wang et al [12] have anticipated a newendwisecramming control system termed ECCO, thatdeliberates the exclusive characteristics in multi-hop CR ad hoc systems likebanddetecting, networkmeeting, and approvedoperatoractions. The usualpackage round trip time (RTT) for multi-hop CR ad hoc systems is obtained.

III. PROBLEM IDENTIFICATION AND PROPOSED SOLUTION

In our previous work [13], an energy efficient multicast route establishment protocol using AODV with PSO has been proposed. In this protocol, MAODV protocol is applied for multicast route discovery and energy efficient routes are selected for transmission.

As an extension to this paper, this work aims to assign channels to the multicast routes in a load balanced way.

While assigning channels along the route towards destination, the following parameters are to be considered:

- Channel availability
- Expected Channel Quality
- Link Load
- Channel switching delay

In congestion aware channel allocation [6], the link capacity andflow conservation constraints are checked for allocating the channel to a link. However, since it uses Genetic Algorithm (GA) for solving the optimization problem, it involves huge computation complexity and time.

Though various works have been done for handling end-to-end congestion control in traditional wireless adhoc networks, they lead to abnormal delay in CRN due to the extra delaycaused by PU activities. Hence the average RTT should be computed in terms of the channel rendezvousdelay, MAC layer delay, service delay and queuing delay [12].

In [10], the channel availability and switching delay parameters are considered for channel selection. However, it did not consider channel quality and load.

In order to solve these issues, we propose a Game theory based Channel Assignment and Load balancing technique for multicast routing in CRAHNS.

IV. GAME THEORY BASED CHANNEL ASSIGNMENT AND LOAD BALANCING TECHNIQUE

A Overview

In this technique, a channel matrix A is constructed for each link with the following details:Channel number, probability of availability P(a), delay cost (DC) which is sum of channel switching delay and MAC layer delayand channel quality in terms of expected SINR (ESINR).

Then Game theory model is applied for each link. In this model, from the details of matrix A, a utility function will be derived for each channel in terms of P(a), DC and ESINR.Before estimating the strategy of each player, the link overload (OL) is estimated for each link. Then the link with minimum overload is selected with a channel having maximum utility function.

The proposed technique will be applied for each route, during the multicast route discovery. By NS2 simulation, it will be shown that the proposed technique reduces the end-to-end delay and increases the throughput and packet delivery ratio for the constructed multicast routes.

B Construction of Channel Matrix

The channel availability of each channel Ch_i is given by [10]

$$P_i(a) = Px_i(a).Py_i(a) \qquad (1)$$

where Px_i and Py_i represent the available probability ofnode x and node y at channel Ch_i, respectively.

After a cognitive node transmits data throughchannel Ch_i, $P_i(a)$ is updated usingthe following equation:

$$P_i(a) = \begin{cases} p_i^{'} + (1 - p_i^{'}).p_{ini}, successful \\ p_i^{'}.\gamma, Others \end{cases}$$

(2)

Where p'$_i$ represents the channel before updating and p_i represents the channel after updating, γ is the channel availabilityupdate factor fixed basedon network traffic history information.

The channel switching delay for channel Ch_i is given by [10]

$$SD_i = SDx_i + SDy_i \quad (3)$$

where SDx_i and SDy_i represent the switching delay of node x andnode y to channel Ch_i, respectively.

The MAC layer delay is defined as the averagemedium access delay or is the contention delay [12].

The average MAC layer delay of channel $Ch_i$is given by

$$D_{mac}(i) = P_{idle}(T_{sense})\,[T_{sense} + T_{ave} + T_{RTS} + T_{CTS}] + T_{MACK} + [\,(1-P_{idle})\,(T_{sense})\,(T_{tr}-T_{sense}) \quad (4)$$

Where,

$P_{idle}(T_{sense})$ indicates that the channel is idle duringthe sensing time T_{sense}.

T_{ave} is the expected delay occurred in the backoff period.

T_{RTS} and T_{CTS} denotes the duration of the RTS and the CTS, respectively

T_{MACK} isthe duration of the MAC layer acknowledgement

The idle time $P_{idle}(t)$ is given by

$$P_{idle}(t) = e^{-\lambda_p t}$$

Where λ_p is the packet arrival rate of PU.

Then the cumulative delay cost DC of channel Chi is given by

$$DC_i = SD_i + D_{mac}(i) \quad (5)$$

The channel quality is estimated in terms of expected SINR.

The ESINR of link k at channel $Ch_i$is given as [2]

$$ESINR_i(k) = \frac{p_k.h_{kj}}{\sum_{j=1}^{n} p_j.h_{jk} + n} \quad (6)$$

Where,

p_k is the transmission power of transmitter k

h_{ij} is the path-loss between the transmitter j and receiver k

n is the noise power

Then the channel matrix A(l) is constructed for link l as

$$A = \begin{pmatrix} 1 & P_1(a) & DC_1 & ESINR_1 \\ 2 & P_2(a) & DC_2 & ESINR_2 \\ \ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots\ldots\ldots \\ \ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots\ldots\ldots \\ m & P_m(a) & DC_m & ESINR_M \end{pmatrix}$$

C Estimation of Link Overload

Link over load (OL) indicates the difference of link capacity $LC_{ij}$and GL_{ij}aggregate traffic load on each linke_{ij}. [6]

$$OL_{ij} = LC_{ij} - \sum_{s \in S} f_{ij}^{s} \quad (7)$$

Where f_{ij}^{s} is the traffic demand for session s through the link e_{ij}

The link capacity LC_{ij} can be defined as the sum ofeffective capacity within all the channels $Ch_1, Ch_2, \ldots Ch_m$.

$$LC_{ij} = \sum_{c=1}^{m} LC_{ij}(c)$$

The effective channel capacity of link l_{ij} for a channel c is calculated as

$$LC_{ij}(c) = \frac{x_{ij}^{c}.H_c}{1+N_{ij}(c)}\log_2\left(1+\frac{P_t d(ij)^{-\gamma}}{P_N}\right) \quad (8)$$

Where

x_{ij}^{c} is the link channel allocation variable for assigning the channel c for link e_{ij}

H_c denotes the bandwidth of the channel c

P_t and P_N are the transmission and the noise powers respectively

$d(ij)^{-\gamma}$ denotes the gain of the link transmission

$N_{ij}(c)$ indicates the set of the interference links of channel c

D Estimation of Channel Utility Function

From the details of channel matrix A, a utility function will be derived for each channel in terms of P(a), DC and ESINR as given by

$$U_{ij}(c) = \frac{[w_1.P(a) + w_2.ESINR]}{(w_{3.}.DC)} \quad (9)$$

where U(c) is the utility of channel c for the link e_{ij} and w1,w2 and w3 are constants in the range of [0,1[.

E Optimization Constraints for a Link

For each link e_{ij} , the following optimization constraints are checked:

(i) Minimize OL_{ij} such that OL_i< M
(ii) Choose the channel k such that $U_{ij}(k)$ is maximum.

F. Multicast Route Discovery using MAODV

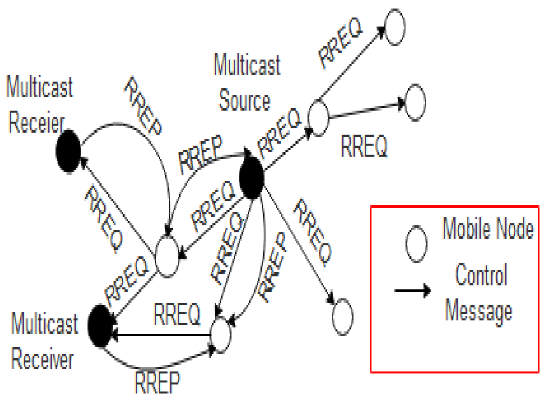

Figure.1 MAODV protocol structure

The MAODV protocol structure is shown in Figures1, which is used to determine multicast diagram in CRAHN. MAODV utilise Route Request (RREQ) and Route Reply (RREP) packages. If RREQ is not a combinedappeal, restructuredsteeringroute can retortunswervingly at any nodule. After the steeringprocedure, the PSO procedure is put on to the path for path development whichadvances the vitalityingestion of the CR system.

G Game Theory Model

Ssdemarcated in game concept,in a game, thequantity of performersinterrelatealong withspecifiedguidelines. Those troupes may possibly be single, collections, corporations, links and so on. Their communications will have an influence on every singleperformer and on the entirecluster of performers, i.e. they are inter-reliant.

A game in normal form consists of:

1. A finite number of players.

2. A strategy set assigned to each player.

3. A settlement or efficacypurpose, which allots a definitesettlement to every singleperformer based up on his scheme and the approach of the other performers

Hence the game theory model can be stated in its general form as

$$G = [\{S_j, R_j\}, \{A_j\}, \{UF_j\}]$$

where $\{S_j, R_j\}$ is the set of players,$\{A_j\}$ is the set of actions of the players and $\{UF_j\}$ representtheir utility functions.The exemplary is a non-cooperative game, where performerscreateliberatedverdicts to enhance their efficacypurposes.

For transmitting the multicast data from a sender S to the set of receivers $\{R_1,R_2,...R_k\}$, the multicast tree is established using MAODV. For each path towards the receivers, channels can be assigned to each link using the following algorithm.

Algorithm: Game theory modelfor channel assignment

1. The game starts at time t
2. For each link l of the path along S to {Rj},
3. If OL (l) <= M, where M is the minimum threshold value for OL
4. Estimate the channel matrix A(l)
5. For each channelc
6. Determine the utility function U(c)using Eq. (9)
7. If U(c)>= Max(U), (where Max(U) is the maximum utility function),
8. Select the channelc
9. End if
10. End For
11. If no such channel exists, then
12. Select an alternate link
13. Else
14. Channel c is assigned to link l

15. End if
16. Else
17. Select an alternate link
18. End if
19. End For

V. EXPERIMENTWL RESULTS

A ExperimentalSettings

The simulation of proposed GTCALB technique is conducted in Ns-2 and it is compared with Congestion-aware Channel Allocation with Route Scheduling (CCARS) [6] protocol. The performance is evaluated with respect to End-to-End Delay (E2D), Packet Delivery Ratio (PDR), packet drop and throughput.The simulation topology is shown in Figure 1 and various simulation settings are listed in Table 1.

Number of Nodes	100
Size of the topology	1500 X 300m
MAC protocol	IEEE 802.22 contention based MAC
Traffic type	Constant Bit Rate
Number of SU flows	6 to 24
Packet size	512 Bytes
Data sending Rate	100 to 500Kb/s
Number of channels	5
Number of interfaces	3

Table 1 Simulation settings

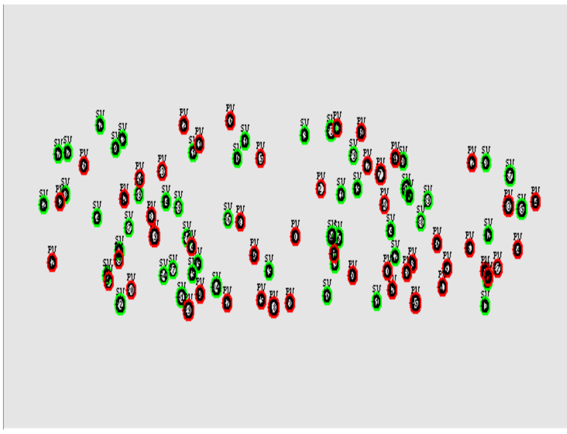

Figure 1 Simulation Topology

B. Varying the SU Flows

In this section, the performance of the two techniques is evaluated by varying the SU data flows from 6 to 24.

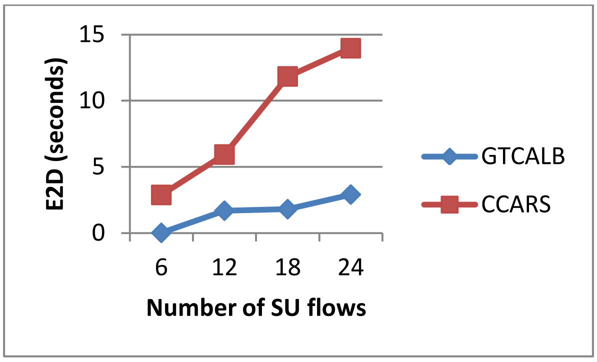

Figure 2 E2D for varying SU Flows

The graph showing the results of E2D for varying the flows, is shown in Figure 2. The figure depicts that the E2D of GTCALB ranges from 0.01 to 0.90 seconds and E2D of CCARSranges from 2.8 to 13.9 seconds. Ultimately, the E2D of GTCALB is 90% less when compared to CCARS.

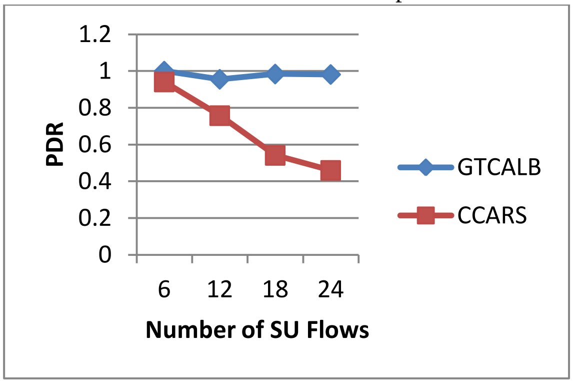

Figure 3 PDR for varying SU Flows

The graph showing the results of PDRfor varying the flows, is shown in Figure 3. The figure depicts that the PDR of GTCALB ranges from 0.99 to 0.98 and PDR of CCARSranges from 0.94 to 0.45. Ultimately, the PDR of GTCALB is 31% higher when compared to CCARS.

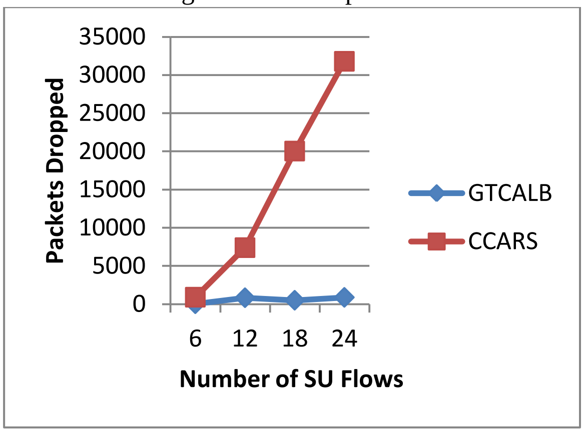

Figure 4 PacketDrop for varying SU Flows

The graph showing the results of Packet Dropfor varying the flows, is shown in Figure 4. The figure depicts that the Packet Drop of GTCALB ranges from 43 to 877 and Packet Drop of CCARSranges from 897 to 31782. Ultimately, the Packet Drop of GTCALB is 95% less when compared to CCARS.

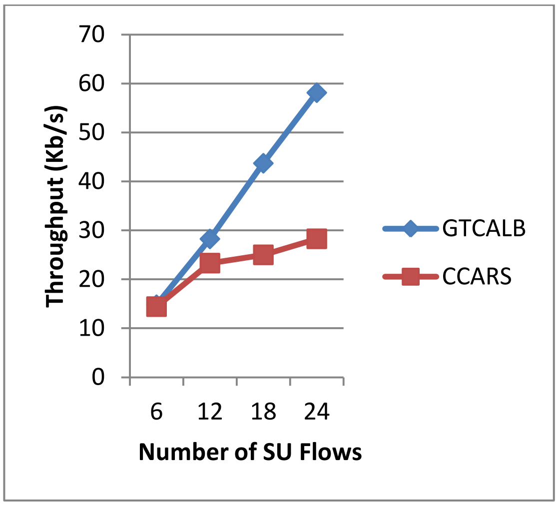

Figure 5 Throughput for varying SU Flows

The graph showing the results of throughput for varying the flows, is shown in Figure 5. The figure depicts that the throughput of GTCALB ranges from 14.8 to 58.1 and throughput of CCARS ranges from 14.4 to 28.2. Ultimately, the throughput of GTCALB is 29% higher when compared to CCARS.

C. Varying the Data Sending Rate

In this section, the performance of the two techniques is evaluated by varying the data sending rate from 100 to 500 Kb/s.

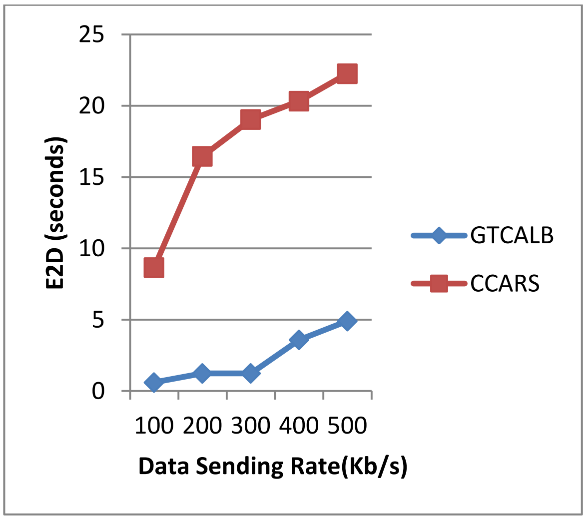

Figure 6 E2D for varying data sending rate

The graph showing the results of E2D for varying the rate, is shown in Figure 6. The figure depicts that the E2D of GTCALB ranges from 0.6 to 4.9 seconds and E2D of CCARS ranges from 8.6 to 22.2 seconds. Ultimately, the E2D of GTCALB is 88% less when compared to CCARS.

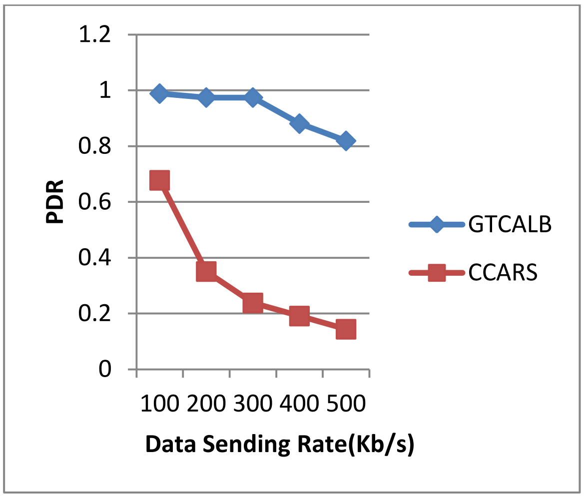

Figure 7 PDR for varying data sending rate

The graph showing the results of PDR for varying the rate, is shown in Figure 7. The figure depicts that the PDR of GTCALB ranges from 0.98 to 0.81 and PDR of CCARS ranges from 0.67 to 0.14. Ultimately, the PDR of GTCALB is 66% higher when compared to CCARS.

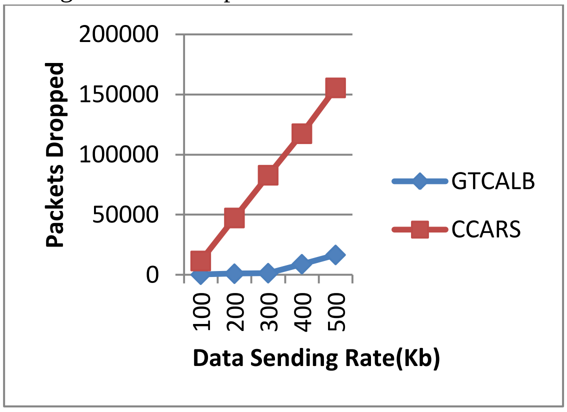

Figure 8 Packet Drop for varying data sending rate

The graph showing the results of Packet Drop for varying the rate, is shown in Figure 8. The figure depicts that the Packet Drop of GTCALB ranges from 267 to 16680 and Packet Drop of CCARS ranges from 11659 to 155492. Ultimately, the Packet Drop of GTCALB is 95% less when compared to CCARS.

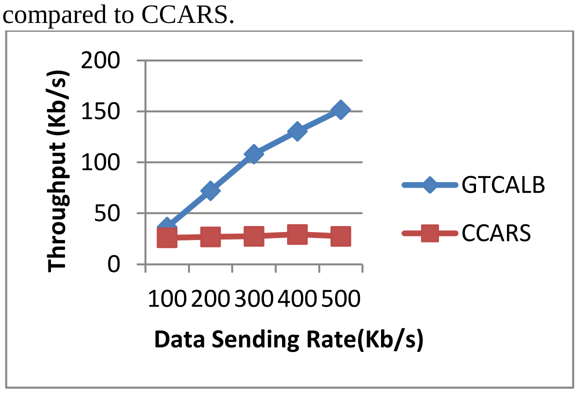

Figure 9 Throughput for varying data sending rate

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The graph showing the results of throughput for varying the rate, is shown in Figure 9. The figure depicts that the throughput of GTCALB ranges from 36.5 to 151.5 and throughput of CCARS ranges from 26.0 to 27.3. Ultimately, the throughput of GTCALB is 65% higher when compared to CCARS.

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