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Research paper

Priority based Distributed Scheduling for Congestion and Collision Avoidance in WSN

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Abstract

In wireless sensor network (WSN), data scheduling, is impeded by congestion and packet collision. In order to overcome these issues, in this paper, a Priority based Distributed Scheduling for Congestion and Collision Avoidance in WSN has been proposed. In this technique, the system in which data packets generated by sensor nodes are categorized into high and low priority based on the importance of the data and time stamp. To prevent collision, a receiver backed or initiated MAC protocol is applied. Further, the congestion status of the network is checked cluster wise and node with the least congestion level is selected as the head of cluster group (CH). If the congestion status is high, then distributed storage maintenance (DSM) mechanism is applied. According to DSM, some gateway nodes which are nearer to the CH are chosen and the high priority packets are sent to those nodes for storing using the packet exchange policy. With the help of simulation it has been proved that this approach minimizes the congestion and the intra cluster collisions.

1. Introduction

1.1. Wireless Sensor Network (WSN)

The network consists of a vast collection of independent, small and inexpensive sensor nodes deployed over a wide area that may vary depending upon the application need. The sensor nodes perform their intended tasks without any disruption, which includes monitoring the area where they are deployed and pass on the sensed data to the sink node in a finite number of hops as shown in figure 1. The most important characteristics of the network are unified collection of sensed information, information passing with finite number of hops and relaying data from many nodes to one node. The sensor network finds its application in diverse fields ranging from environment monitoring to image sensing. [1][2].

1.2. Congestion Control in WSN

Congestion in wireless sensor network can cause data packet loss and increase in the transmission time of the data packets. As a result of this there is an increase in the energy consumption and a dip in the Quality of Service. Hence congestion has to be controlled. Congestion in wireless sensor network may be caused by two factors. It may be caused by the congestion occurring at the node level and at the link level. Node level congestion is caused when there is an overflow of data packets in the buffer of the node which results in the loss of data and a hike in the buffering time. Loss of data can be overcome by retransmitting the data resulting in an increased energy consumption. Link level congestion is caused when the medium is utilized by the nodes simultaneously by techniques like CSMA/CD which result in increased data service time and a dip in the optimum link usage. These two issues leading to congestion have to be controlled to improve energy consumption and quality of service [3].

1.3 Distributed Scheduling in WSN

In the recent times centralized and distributed scheduling are proposed as the variants of the TDMA scheduling. Both the variants have their own pros and cons. The major advantage of the distributed scheme is that the construction of the conflict graph for the wireless sensor network is not made mandatory. The slot collisions that occurred during the assignment of the slots to the nodes are locally fixed. In the distributed scheduling scheme the network nodes declare the conflict free slots with their n-hop nodes. The scheme makes use of the protocol interference model which takes the two hop nodes into account. The presence of the intermittent (uneven) wireless interference makes it difficult to eliminate the collision among the nodes for the slots. Although performance of the scheme can be increased by disseminating information to other nodes through multiple hops, cost expended towards energy and communication is still high. (To more hop nodes the performance of the scheme can be increased but with a compromise in the cost of energy and communication.) Further the wireless communication collision leads to loss of the control packet affecting the slot assignment task. Hence these schemes cannot provide reliability in performance with respect to data collection and efficient utilization of energy. There is also the possibility of the loss of control packet utilized in the fixing of slots due to. Hence these schemes cannot assure better enactment of information gathering and energy competence [4].

1.4 Previous Work

In our earlier work [12], a technique utilizing fuzzy logic and back pressure routing algorithm to mitigate congestion was proposed. The congestion level of each node was determined by a decision model based on fuzzy logic. The approach utilized three factors to determine the congestion level namely the total number of participants, amount of buffer occupied at the parent nodes and the amount of the traffic.

In the cluster based routing using back pressure algorithm, depending on the congestion level of the nodes, clusters were formed and their heads selected. In this paper we propose a priority based distributed scheduling for congestion and collision avoidance which is actually an extension to our prior work.

2. Literature Review

Akbar Majidi et al [5] proposed a technique to mitigate congestion utilizing a routing algorithm based on back pressure and categorization of the services in the sensor networks. The approach is based on dynamic discovery of the path. The path selection in a node is based on the queue backlog of the next node after monitoring it and adjusting the transmission rate according to it. Different services are allocated with different priority levels to ensure a differentiation in the service employing the routing algorithm. In this approach there is a reduction in the data delivery ratio.

Cagatay Sonmez et al [6] proposed a technique to find out the occurrence of congestion using fuzzy logic. In this approach congestion level is measured by combining three indicators together. A novel approach was employed for quality adaptation, delivery of frames and delay performance benefit. The employed protocol makes use of cross layer functionalities and data exchanges. In spite of this the approach was not able to reduce the frame drop level.

A scheduling scheme based on the sleep awake state of the nodes was proposed by Ehsan Gholami et al. [7]. Depending upon the current (prevailing) network scenario, (circumstances) nodes update their scheduling in a distributed way (manner). The approach does not provide solutions to inter and intra cluster collisions and minimal utilization of sleep-awake frequency.

Tayseer Alkhdour et al. [10] have suggested an ideal cross-layer arrangement solution for periodic wireless sensor network applications. The suggested solution was successful in resolving optimal cross-layer combined routing and scheduling issues. The design is based on an Integer Linear Program (ILP) model. The purpose of the model is to maximize the period of the network and the usage of energy-efficient distributed scheduling. The mentioned model is applied for resolving issues in various network environments. The approach does not concentrate on delay that leads to additional cost.

Junchao Ma et al. [11] have proposed a link scheduling technique to sort out the issues in data collection in wireless sensor networks. The approach utilized minimum number of time slots. The approach also reduced the energy consumed by nodes while transiting from one state to another. The problem is proved to be NP-complete. Algorithms bounded with appropriate theoretical parameters to yield efficient performance are presented in centralized as well as distributed variants for both homogeneous and heterogeneous networks. In this approach the average delay increases proportionately with the transmission range but with a compromise in the throughput.

Joseph Manoj et al, have proposed the Feature selection is the approach of choosing subset of given dataset based on some feature. It can be used to minimize dimensions of the huge data set. So that it removes unnecessary data in the data source and produces prediction or output accurately in big data analytics. In the proposed work, feature selection algorithm process is implemented for text categorization using the algorithms and colony optimizations (ACO) and artificial neural network (ANN).

3. Proposed Solution

3.1 Overview

This work focuses on designing a Priority based Distributed Scheduling for Congestion and Collision Avoidance in WSN. In this technique, the system in which data packets generated by sensor nodes are categorized as high and low priority based on the importance of the data and time stamp [8].

In collision avoidance phase, a receiver initiated MAC protocol is applied in which each sensor node broadcasts an altruistic back off request (ABR) [9] for the beacon packet from the receiver. The ABR consists of node id and the priority of packets. On receiving the ABR, a node N_i checks its priority with that of the received ABR priority. If the ABR contains a higher priority packet than the node N_i, then N_i, after understanding its position, backs off, granting the beacon to node with high priority ABR, else it ignores the request. This guarantees the mitigation of intra-cluster collisions for higher priority packets and reducing idle listening with low overhead.

Further the congestion status of the network is checked and the node having the least congestion level is selected as the head of the cluster. If the congestion status is high, then distributed storage maintenance (DSM) mechanism [8] is applied. According to DSM, some gateway nodes which are nearer to the CH are chosen and the high priority packets are stored at those nodes using the packet exchange policy.

The diagrammatic representation of the approach is depicted in figure 1.

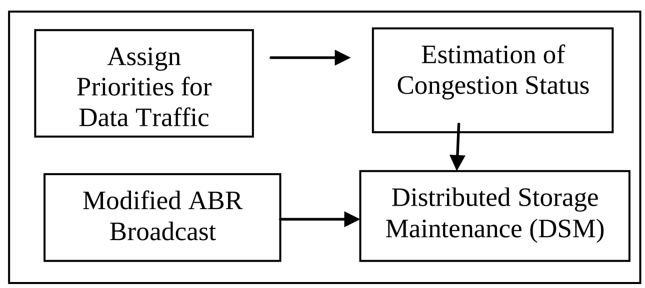

Figure-1: Block Diagram

3.2 System Model

The vast collection of sensor nodes present in wireless sensor network, unceasingly monitor their configured surroundings and produce data packets in regular intervals. The generated data packets are categorized as high and low priority based on the importance of the data and time stamp.

Let the function F (PR) denote the priority of the data packet P

Let E represent the pre-defined buffer space near the sink

Let N_i and N_j be the neighbor nodes respectively

Let G and TS denote the data importance and timestamp respectively

Using the rules in the following table 1, we assign the priorities to the data packet

Table 1: Data Priority

Rules	G	TS	F(PR)
1	Low	Low	Low
2	Low	High	Low
3	High	Low	High
4	High	High	High

Rule 1 implies that less important data with less time stamp is offered low priority
Rule 2 implies that less important data with maximum time stamp is offered low priority
Rule 3 implies that more important data with less time stamp is offered high priority
Rule 4 implies that more important data with maximum time stamp is offered high priority

3.3 Collision Avoidance

We employ a receiver initiated MAC protocol to prevent the collision. The steps involved in this technique are as follows:

1. Each sensor node broadcasts an Altruistic Back off Request (AB_REQ) for the beacon packet from the receiver.

The format of AB_REQ is shown in below table 2

Table 2: Altruistic Back off Request

Node ID	Priority of the Packet

The AB_REQ consists of node id and the priority of packets. (Note the priority of the data packet is estimated in the previous section)

2. On receiving the AB_REQ, a waiting node N_i checks its data priority with that of the AB_REQ.

3. The node N_i altruistically backs off if the data priority of the received AB_REQ is greater than its own and grants the beacon to the node producing the high priority data packets. If it is not the case the node N_i overlooks the request.

This technique guarantees the mitigation of intra-cluster collisions for higher priority packets and reducing idle listening with low overhead.

3.4 Congestion Detection and Backpressure Routing

Fuzzy logic was used to determine the congestion level of the node. The fuzzy membership function takes three inputs namely the number of participants, amount of buffer occupied at the parent nodes and the amount of traffic. Through the fuzzification of the inputs and subsequent processing by interference, the level of congestion at each node is found out which is followed by defuzzification. The outputs are combined which forms the new fuzzy sets. [12]
Based on fuzzy output the node with the least congestion level is selected as the head of the cluster (CH). The head of the cluster plays the role of gateway node for determining the path for the data transmission. The members of the clusters play the role of interior nodes.

Let C (i) is a cluster that contains a node N_i.

N_i denotes a node which can act as a gateway (G) or an interior node (I).
N_i is a gateway of C (i), if there is a node N_j such that N_j does not belong to C (i) and (N_i, N_j) is an element of V, where V is the set comprising the network links.
If N_i is not a gateway node, then it is an interior node.
Let X_i is the set comprising of all nodes in the cluster excluding N_j denoted by

$X_i = G_i \cup I_i \setminus \{N_i\}$

The source node and the destination nodes are represented by S and D.

Let $K_S^D[t]$ is the rate at which a flow of packets is generated from S to D at a time t.
Let R_{tx} [t] is the transmission rate of the link at a time t.

Let $x_g^D[t]$ and $\hat{x}_g^D[t]$ are the number of packets that can be held in the regulated queue and the real queue.

Cluster based back pressure routing approach includes the following phases:

1. Initially at time interval t, the source S splits the flow K_S^D into $\{K_S^{g,D}[t]\}_{g\in\{0\}UG(D)}$ such that

$$\{K_S^{g,D}[t]\} = \begin{cases} K_S^D, & g = g^* \\ 0, & g \neq g^* \end{cases} \tag{1}$$

Where $g^*=\arg\min_{g\in\{0\}UG(D)} X_S^{g,D}[t]$
Where g* > 0, in which g* is the least congested best node to route data packets involving gateway and g*= 0 indicates the best node without involving the gateway node.

2. After receiving the packet flow $\{K_S^{g,D}[t]\}_{g\in\{0\}UG(D)}$, at t the source places it into the queue g of S

3. For each destination D, the gateway node g maintains two queues one real and one regulated where D is an interior node.

4. At the time t, the packet transmission rate from real to regulated queue is estimated by

$$\lambda_g^D[t] = (1+\sigma)\sum_{S:[S.D]\in F} K_S^{g,D}[t] \tag{2}$$

In which σ is a constant greater than 0.

5. The value $\{W_{ij}\}$ of the Back pressure scheduler is computed using the parameters congestion level (CS), nodal level differences (α_{ij}), queue level differences (β_{ij}) and routing status (γ_{ij}).

$$W_{ij} \rightarrow F\{CS, \alpha_{ij}, \beta_{ij}, \gamma_{ij}\} \tag{3}$$

$$W_{ij} = \max\{W_{ij}\} \tag{4}$$

$$W_{ij} = CS_{ij} + \alpha_{ij} + \beta_{ij} + \gamma_{ij} \tag{5}$$

The value of W_{ij} is determined for all near-by nodes and the node having maximum value is selected for transmitting the data packets from the queue of N_i to N_j over the link (N_i , N_j) at the rate, W_{ij}.
Figure-2 shows the formation of the clusters and the selection of the cluster head.

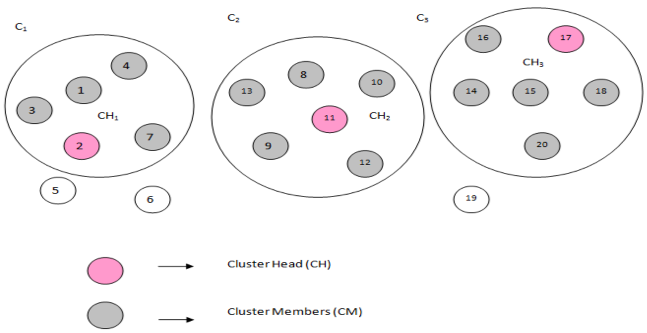

Figure-2: Cluster Formation and CH selection

3.5 Handling High Congestion Level

Let N_i and N_j be the neighbor node within the cluster
Let d_i and d_j be the distance of the node N_i and N_j from CH
Let P_i and P_j be the packets in N_i and N_j
Let P_{hi} be the packet with higher priority with high congestion level of all neighbors N_j of N_i ($d_j > d_i$)
Let P_{li} be the packet with lower priority with high congestion level of all neighbors N_j of N_i ($d_j < d_i$)
Let P_{xi} be the packet with higher priority with high congestion level of all neighbors N_j of N_i ($d_j = d_i$)
Let P_{yi} be the packet with lower priority with high congestion level of all neighbors N_j of N_i ($d_j = d_i$)
When the congestion level is high, distributed storage maintenance (DSM) mechanism is applied. It involves the following process:
The gateway nodes which are nearer to the CH are selected. The high priority packets are stored at those nodes using the packet exchange policy rules.

Rule 1

If f (P_{hi})>f (P_i))
Then
N_i exchanges the packet with P_{hi}
End if

Rule 2

If f (P_i)) > f (P_{li})
Then
N_i exchanges the packet with P_{li}
End if

Rule 3

If f (P_{xi}) > f (P_{li})
Then
P_{xi} and P_{li} are exchanged.
End if

Rule 4

If f (P_{hi})> f (P_{yi})
Then
P_{hi} and P_{yi} are exchanged.
End if

During multiple events, the node should prioritize the rules in the following order as the node exchange with different distance is preferred first.

- Rule 1
- Rule 2
- Rule 3
- Rule 4

The data packet exchange involves the following steps:

1. When N_i wants to exchange a data packet with N_j, it transmits request to send message (RTS) to N_j.

$$N_i \xrightarrow{RTS} N_j$$

2. N_j upon accepting the message sends a clear to send (CTS) message to N_i.

$$N_j \xrightarrow{CTS} N_i$$

3. Upon receiving the confirmation message, N_i and N_j performs data exchange.
4. When N_i already contains a packet, it will try sending the packet to any neighbor N_j with $d_j < d_i$.
5. When N_j receives a packet,

If F (P_j) = -1

Then
N_j accepts the packet

Else if F (P_j) $\geq$ F (P_i)

N_j drops the packet
Replaces P_j by P_i, (if F (P_i) > F (P_j))
End if

End if

Thus the higher priority of packets from the nodes with high congestion level are transmitted quickly whereas the lower priority packets with high congestion will be either dropped (in worst case scenario) are scheduled later.

4. Simulation Results

4.1 Simulation Parameters

The proposed Priority based Distributed Scheduling for Congestion and Collision Avoidance (PDSCCA) approach is simulated using NS2 Simulator. The utilized Medium Access Control layer is IEEE 802.11 as it is capable of notifying about the breakage in the link that is about to happen in the network layer. The packet transmission rate is varied in the scale of 25Kb from 50Kb to 150 Kb. Simulation activity is carried out over an area measuring 1000 X 1000 meter and for a period of 50 seconds.

The parameters used are depicted in the following table 1

Table 3: Simulation parameters

Total nodes	100
Region	1000 X 1000
Medium Access Control Protocol	802.11
Period of simulation	50 sec
Source of traffic	CBR
Transmission rate	50,75,100,125 and 150Kb
Propagation	TwoRayGround
Antenna	OmniAntenna
Initial Energy	8.5J
Power of Transmission	0.660
Power of Reception	0.395

4.2 Performance Metrics

The proposed PDSCCA approach's performance is evaluated using the parameters like average end to end latency, data drop, residual energy and average packet delivery ratio. The proposed approach is compared with the ABR [9] approach.
Average end to end latency: End to End latency is measured as an average over all successfully received packets from source to destination.
Data drop: Gives the measure of total number of packets dropped during transit.
Residual energy: Gives a measure of energy left out in each node after transmitting data.
Average packet delivery ratio: Gives an average measure of number of packets delivered correctly out of total number of packets sent.

4.3 Results & Analysis

The results of the simulation is shown in the following section.

A. Scenario 1 (varying the transmission rates for 50 nodes)
The transmission rate is varied from 50 Kb to 150Kb in the span of 25Kb for 50 nodes.

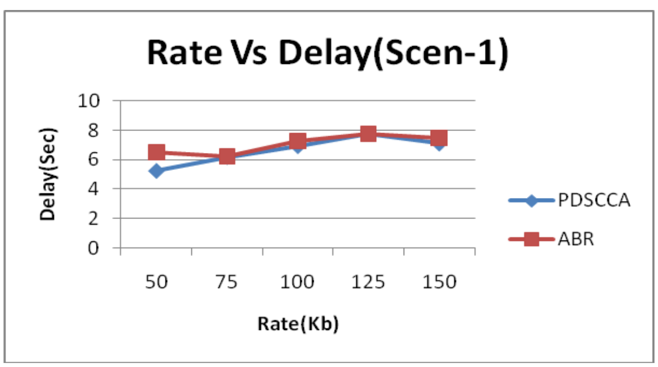

Figure-3: Transmission rate Vs Transmission delay

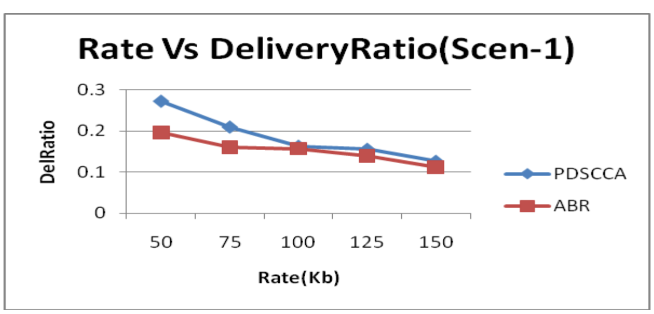

Figure-4: Transmission rate Vs Packet delivery ratio

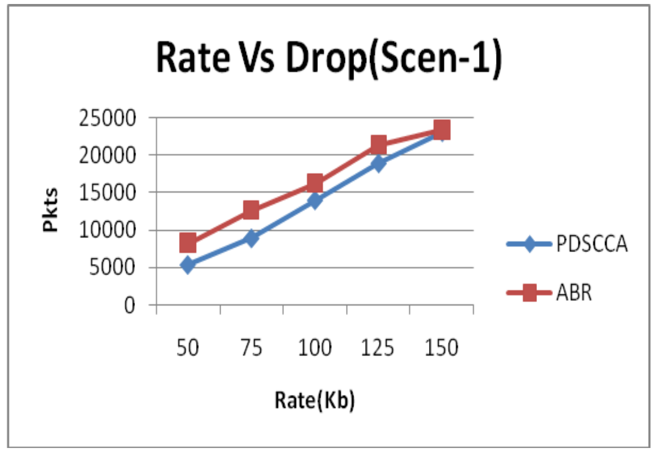

Figure-5: Transmission rate Vs Data drop

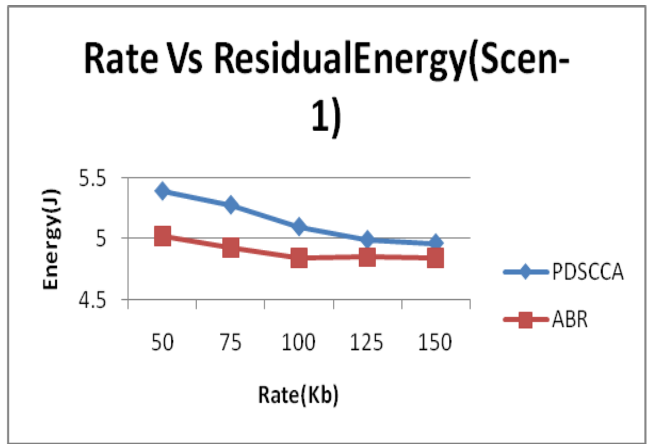

Figure-6: Transmission rate Vs Residual energy

The above mentioned figures from 3 to 6 compares the CBR traffic in PDSCCA and ABR approach with respect to Transmission delay, packet delivery ratio, data drop and residual energy by changing the transmission rate in scale of 25Kb starting from 50Kb to 150Kb. By this comparison it is shown that the proposed PDSCCA betters the ABR approach by 6% with respect to transmission delay, 15% with respect to delivery ratio, 17% with respect to packet drop and 5% with respect to residual energy.

B Scenario 2 (varying the transmission rates for 100 nodes)
The transmission rate is varied from 50 Kb to 150Kb in the span of 25Kb for 100 nodes.

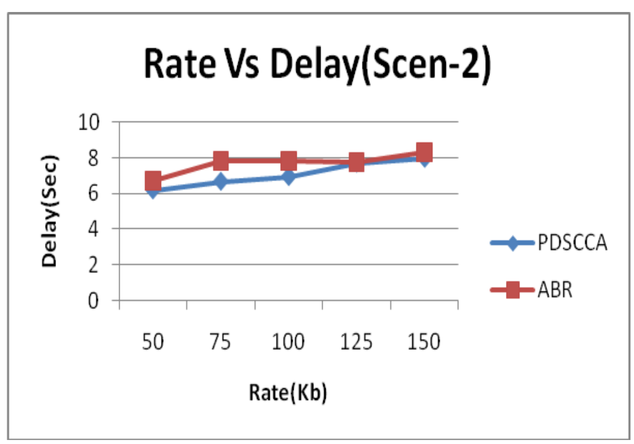

Figure-7: Transmission rate Vs Transmission delay

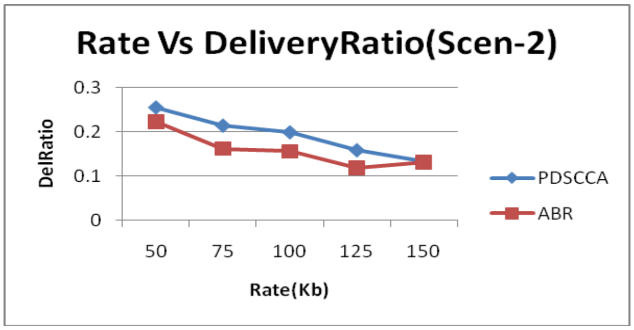

Figure-8: Transmission rate Vs Packet delivery ratio

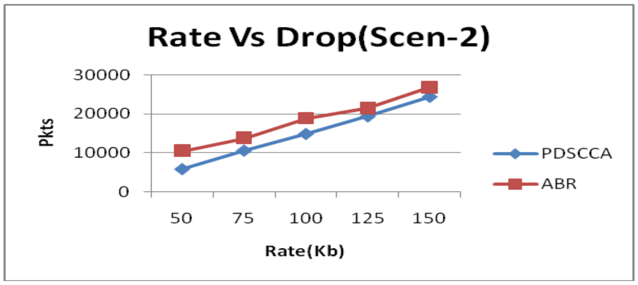

Figure-9: Transmission rate Vs Data drop

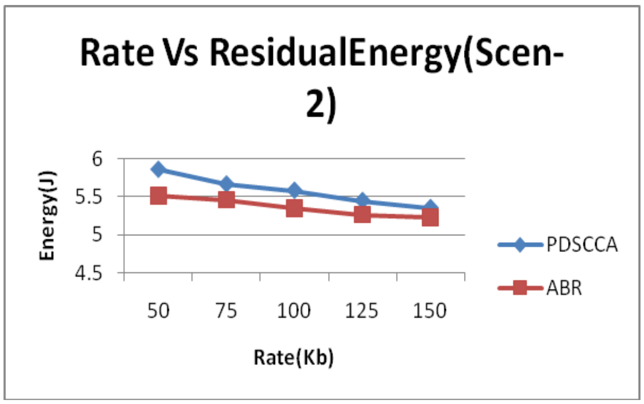

Figure-10: Transmission rate Vs Residual energy

The above mentioned figures from 6 to 9 compares the CBR traffic in PDSCCA and ABR approach with respect to Transmission delay, packet delivery ratio, data drop and residual energy by changing the transmission rate in scale of 25Kb starting from 50Kb to 150Kb. By this comparison it is shown that the proposed PDSCCA betters the ABR approach by 8% with respect to transmission delay, 17% with respect to delivery ratio, 21% with respect to packet drop and 4% with respect to residual energy.

5. Conclusion

A Priority based Distributed Scheduling for Congestion and Collision Avoidance has been proposed to overcome the issues of packet loss and congestion during data scheduling in WSN. In this technique, the data packets generated by sensor nodes are categorized as high and low priority based on payload and time stamp. During congestion a distributed storage maintenance mechanism is applied through which high priority data are transferred to gateway nodes near the cluster head for successful transmission using packet exchange policy. Our simulation results prove that the proposed approach minimizes the congestion and the intra cluster collisions when compared with ABR approach.

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