International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 11s
DOI: https://doi.org/10.17762/ijritcc.v11i11s.8083
Article Received: 24 June 2023 Revised: 22 August 2023 Accepted: 02 September 2023

Quality of Service Aware Dynamic Bandwidth Allocation for Rate Control in WSN

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Abstract— Different types of data can be generated by Wireless Sensor Networks (WSNs) in both Real-Time (RT) and Non-RT (NRT) scenarios. The combination of these factors, along with the limited bandwidth available, necessitates careful management of these categories in order to reduce congestion. Due to this, a Proficient Rate Control and Fair Bandwidth Allocation (PRC-FBA) method has been created that prioritizes certain types of traffic and creates a virtual queue for them.In PRC-FBA, the Signal-to-Noise and Interference Ratio (SINR) model is applied to the problem of bandwidth allocation in WSN in an effort to find a compromise between equity and performance. Then, a brand-new bandwidth utility factor is defined with regard to equity and effectivenes. The FBA method in PRC-FBA is devoped for only improving throughput, but not considering delay. However, delay is the main factors for trasnmiitng NRT packets. This paper offers a PRC with Quality of Service (QoS) aware Dynamic Bandwidth Allocation (PRC-QDBA) approach for allocating bandwidth while prioritizing packets based on their traffic classes. This model employs a QoS associated dynamic bandwidth allocation strategy which efficiently distributes the unused time slots among the required nodes. The distribution technique is performed based on hierarchical manner utilizing a parent-child association of tree topology. The parent node receives traffic indication maps (TIMs) from the children nodes and adopts them to allocate time slots based on their demamds. If the parent node is unable to allocate the required slots, it creates a TIM that indicating the demands and transfer it to its immediate parent node. This increases the entire performance rate of RT traffic. Furthermore, this model assures the packet forwarding for previously accepted flows by allowing node transmission based on ancestral connection capabilities. Finally, simulation results demonstartes that the suggested model significantly increases the throughput and delay for bandwidth allocation while also enabling QoS support for RT traffic in WSNs.

Keywords- WSN, Congestion handling, PRC, Bandwidth Demand, Throughput, Delay.

I. INTRODUCTION

In order to construct WSNs, a large number of sensors with a low power consumption must be configured. Using a wireless connection, each sensor may take in data from its surrounding nodes and relay it to others in the same area. Because of its flexibility and honesty, it makes an effort to make use of accurate data recorded by agents and managed by a central controller. As a result, a system of trustworthy information exchange can be established. The reliability of this type of network is ensured by a plethora of helpful measures which is utilized for different RT applications like medical procedures, agricultural modeling, emergency monitoring, etc. All sensor nodes are fully equipped with the necessary features for data transmission [1]. Congestion can increase the risk of data loss, degrade data integrity and cause performance inconsistencies, even when such nodes use their full bandwidth. The link and node are two levels of congestion in WSNs. The node level congestion occurs when an average packet rate causes the data buffer size to grow above its intended capacity. Therefore, there is significant delay and data loss during transmission. Link-level congestion occurs when more than two sensors are using a medium at once. It leads to higher queuing latency, power use and a lower efficiency. Because of this, these issues are among the most challenging in standard data transport setups. Congestion must be identified and managed to combat these issues, which improves the dependability of data transport [2-3]. Congestion management relies on controlling traffic through the WSN. Many protocols were developed to handle the three primary operations of congestion recognition, notification and rate adaption. Congestion Detection and Avoidance (CODA) [4], Priority-based Congestion

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Control Protocol (PCCP) [5], Active Queue Management (AQM) [6] and Fairness Rate Control (FRC) [7] were the most well-known congestion management protocols. Priority, traffic density and bandwidth use formed the foundations of these protocols. However, it is still difficult to reduce traffic by transmitting both RT and NRT data.

To get over this difficulty, a DDRC method dependent on the DDR between the sink and source nodes needs to be created. When the DDR at the sink is combined with the WP of the traffic type, a WPDDRC method is provided [8]. The goal of this method was to manage both RT and NRT network traffic in tandem. To facilitate the RT traffic class over the NRT packets, WPDDRC has updated the cumulative priority by specifying the WP of traffic kinds with a higher-order DRC described by different nodes. However, this method does not consider the issue of equitable bandwidth allocation while dealing with congestion in WSNs.

So, the PRC-FBA strategy was developed to prioritize the traffic types and FBA in WSNs. The SINR model is used to identify the tradeoff among the fairness and performance. In this model, a new utility parameter for bandwidth is developed to prioritize the efficiency and fairness. Mutually computing node relationships and time slot assignment provides an approximate solution. The challenge is presented as disruptive programming problem with a two-stage methodology, the primary phase calculating connections between nodes and the secondary phase allocating timeslots to maximize utility factors. This improves network efficiency and achieves a more equitable bandwidth distribution in WSNs. But, the FBA method in PRC-FBA was developed for only improving throughput, but not considering delay. However, delay is the main factors for transmitting NRT packets.

In order to solve this, this article develops PRC-QDBA approach to improve the throughput and delay for bandwidth allocation while prioritizing packets according to their traffic classes. The unused time slots are effectively distributed among the needed nodes using QDBA mechanism. This method follows parent-child connection of a tree topology for the hierarchical distribution tasks. The parent node gets TIMs from the child nodes, which it utilizes to assign time slots in accordance with their requests. The parent node creates a TIM stating the demand and transfer it to the adjacent parent node if it is unable to allot the required slots. This model effectively allows transmission of nodes depending on ancestral link capacity which ensures the packet directing towards the accepted flows. In this way, the throughput and delay is improvised for bandwidth allocation and facilitates QoS support for RT traffic in WSNs.

This paper's remaining sections are laid out as follows: Congestion management in WSNs and related works are discussed in Section 2. In Section 3, the PRC-QDBA procedure is outlined and its stimulation evaluation with existing models are exhibited in Section 4. Section 5 provides a summary of the paper which also includes the suggestions for further research.

II. LITERATURE SURVEY

The throughput can be maximized with the help of the Reliable, Efficient, Fair and Interference-Aware Congestion Control (REFIACC) technique [10]. This method avoided interferences by timing the transmission and it also ensured that all nodes used the available bandwidth fairly. By taking facility differences between paths into account during scheduling, we have been able to avoid inter- and intra-route disruptions. To get the most out of the available bandwidth, linear programming has been used. Despite attempts to prioritize traffic, average throughput remained below expectations.

A congestion avoidance strategy based on Packet Priority Intimation (PPI) bits in each data packet has been proposed [11]. The goal was to send more urgent data with as minimum latency as possible. An Ad-hoc On-demand Distance Vector (AODV) routing approach was used to find the smallest path from the initial point to the target node. However, the time and effort required for computation were substantial.

A two-stage cognitive network congestion scheme [12] has been designed by the TOPSIS and response surface mechanism. Initially, the MAC layer buffer occupancy fraction and congestion condition of the downstream node were calculated. Upstream nodes received these ranges and used the TOPSIS to rank their neighbors and choose the next set of assisting nodes. In addition, a response surface optimization regression analysis was used to get the optimal transfer ratio. However, it placed a heavy computational strain and had low energy efficiency.

A novel approach for fairness-aware congestion management [13] was developed to reduce the energy consumption of WSNs by modifying their specific number motile nodes, position and speed. In addition, the reporting rate was adjusted to accommodate the buffer availability of each node and ease the existing congestion. However, the packet loss ratio remained high and the packet delivery rate (PDR) was poor.

The Dynamic Hybrid Slot-Size BA (DHSSBA) technology [14] was developed to decrease the data delay and jitter variance of RT congestion in an Ethernet passive visible network. This method dynamically allotted each optical network module's prime time period for priority traffic. Additional bandwidth from the unassigned portion of the time cycle was utilised if the window size needed by the highly prioritized optical network which exceeds the largest assigned window size. The best-effort traffic was negatively impacted by the increased latency.

To improve multicast transmission's throughput, quality of service and fairness, a new congestion avoidance technique called Extended Logarithmic Increase and Multiplicative Decrease (ELIMD) [15] was developed. The method used queue delay, packet loss and network performance to control congestion. In addition, the Adaptive IMD (AIMD) framework was employed to provide constant throughput from a multicast source to the destination's receiver. Stability, fairness and security were all areas where the performance fell short.

In order to provide data transfer at an optimal rate while minimizing energy consumption, a new congestion handling approach [16] was presented. Energy consumption was kept to a minimum by employing cluster routing and the rate-based congestion handling strategy. In the first stage, a combination of the K-means and Greedy best first search algorithms was used to group similar nodes together. The firefly optimization then performed the necessary rate adjusting to ensure the highest possible packet delivery ratio. Finally, ant colony optimization-based routing enabled the maximum possible data transmission rates. However, this was not a success for energy efficiency.

The Fuzzy Sliding Mode congestion Controller (FSMC) [17] was designed to handle congestion in the Transmission Control Protocol (TCP) by using a cross-layer congestion management model among the Transmission and Media Access Control (MAC) layers. Then, Fuzzy-SMC was suggested for managing queue sizes in overburdened nodes and mitigating the effects of external uncertain interferences. However, the network was less reliable.

III. PROPOSED METHODOLOGY

The PRC-QDBA method is briefly explained here. Let's pretend that the WSN in question has P parent nodes (represented by $a_1, \dots, a_P$) and C child nodes (represented by $u_1, \dots, u_C$) spread out evenly across the coverage area. In addition, a_i is a node that processes the results of the PRC-FBA and obtains the utility factor for allocating the timeslots to u_j. Consider a wireless system that operates on time slots but has limited bandwidth. r_{ij} describes the bit rate between sources a_i and u_j. I_{ij} is the sum of all interference experienced by node j as a result of node i. Under the SINR paradigm, wireless connection efficiency is denoted by I_{ij} and is tied to interference from other wireless connections.

$$I_{ij} = g\left(SINR\left(\frac{RSS_{ij}}{\sum_{p\in[1,P];c\in[1,C],c\neq j} RSS_{pc}+N_0}\right)\right) \quad (1)$$

Received Signal Strength (RSS) from parent node p to child node c is denoted by RSS_{pc} in Eqn. (1), while RSS from parent node i to child node j is denoted by RSS_{ij} and g thus represents an ascending operation. In particular, nodes with indexes p and i are parents, while nodes with indexes c and j are children. To represent the conditions of the wireless medium, a standard model is used.

$$RSS = E_t - l_w(d_0) - 10\eta \log\left({}^{d}/_{d_0}\right) \quad (2)$$

In Eqn. (2), E_t stands for the transfer energy, l_w for the path loss, $l_w(d_0) - 10\eta \log\left({}^{d}/_{d_0}\right)$ signifies the log-distance radio transmission system which is a large-scale route loss model that uses logarithm distance. d_0 is denoted as the reference distance for the received energy, where d represents the interval between the initial and terminal nodes and η represents the route loss coefficient. The transfer period is calculated once time slots have been assigned using an algorithm.

A. Problem Formation

The fairness statistic known as Jain's index is a measure of the range over which resources are distributed.

$$f(X) = \frac{\left[\sum_{i=1}^{p} x_i\right]^2}{p\sum_{i=1}^{p} x_i^2} \quad (3)$$

In Eqn. (3), x_i represents the allocated resource for individual $i = 1, \dots, p$ and $X = (x_1, \dots, x_n)$. The formulation to determine equitable bandwidth sharing is shown in Eqn. (4):

$$f(X) = \frac{\left[\sum_{j=1}^{c} b_j\right]^2}{c\sum_{i=1}^{c} b_j^2} \quad (4)$$

The formulation is defined as follows in this PRC-QDBA:

$$f(x,p) = \sum_{j\in U} \omega_j \log b_j \quad (5)$$

In Eqn. (5), U represents the group of nodes and b_j represents the node-specific effective bandwidth allocation. Let's pretend that the relationship between u_j and a_i is denoted by x_{ij} and that $b_j = \sum_{i=1}^{K} x_{ij} p_{ij} r_{ij}$. Due to physical limitations, a child node can only establish a synchronous connection with a single parent node. As such, $x_{ij} \in \{0,1\}$, t_{ij} indicates the transition time that a_i allocates to u_j and ω_j indicates the weight of u_j, which reflects the traffic class priority of u_j in WSN.

Since there is free reign over the quantity used to calculate Jain's fairness index, we can build a Logarithmic Utility Function (LUF) for bandwidth. It's defined in Eqn. (6),

$$LUF: f(x,p) = \frac{\left[\sum_{j=1}^{C} (\omega_j \log b_j)\right]^2}{C\sum_{j=1}^{C} (\omega_j \log b_j)^2} \quad (6)$$

Notably, LUF derives from the utility factor to ensure equitable bandwidth allocation. This LUF is assigned by taking the equality of every $\omega_j \log b_j$. Since each distributable resource has the form $\omega_j \log b_j$, the LUF is Jain's index and u_j is the utility factor. The ultimate goal of the LUF is to provide a form of equality that makes $\omega_j \log b_j$ as similar to zero as possible. Therefore, everyone has an equal opportunity to transmit the same quantity of data. However, this might results

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with the unexpected result of users with lower bit rates using up a larger proportion of the medium for a longer period of time than users with higher bit rates, severely lowering network efficiency. Therefore, time-based fairness is implemented and the network's efficiency improves as a result of everyone being allotted the same amount of transfer time. Along with b_j and the transfer time T , the throughput may be calculated. Maximum bandwidth is defined as:

$$\frac{\sum_{j=1}^{C} b_j}{T} = \frac{\sum_{j=1}^{C} b_j}{T_{a_i}} = \frac{\sum_{j=1}^{C}\sum_{i=1}^{P} x_{ij}t_{ij}r_{ij}}{\sum_{j=1}^{C} x_{ij}p_{ij}} = \sum_{j=1}^{C}\sum_{i=1}^{P} x_{ij}p_{ij}r_{ij}$$
(7)

The transmission time at parent node a_i is denoted by T_{a_i} in Eqn. (7). If the parent nodes may operate in parallel, then the transfer period for the WSN is $T = T_{a_i}$, where a and i are the times at which the parent nodes can send and receive data. $\sum_{j=1}^{C} x_{ij}t_{ij} = 1$ is the same thing as saying that $T_{a_i} = \sum_{j=1}^{C} x_{ij}t_{ij} = 1$. Network throughput and fairness are always at odds with one another. Two utility considerations, including fairness and network throughput, are taken into account in this work. The weighted sum of two fitness values is used as a single fitness factor to strike a balance between equality and throughput.

Non-linear programming is used to solve the bandwidth distribution problem. The goal is to share the available bandwidth while striking a balance between equity and performance. These formulations for optimization are as follows in Eqn. (8) to Eqn. (14):

$$\max \frac{\left[\sum_{j=1}^{C}(\omega_j \log(\sum_{i=1}^{P} x_{ij}t_{ij}r_{ij}))\right]^2}{C\sum_{j=1}^{C}(\omega_j \log(\sum_{i=1}^{P} x_{ij}t_{ij}r_{ij}))^2} \quad (8)$$

$$\max \sum_{i,j=1}^{C}\sum_{i=1}^{P} x_{ij}t_{ij}r_{ij} \quad (9)$$

$$\text{subject to } \sum_{i=1}^{P} x_{ij} = 1 \quad (10)$$

$$x_{ij} \in \{0,1\} \quad (11)$$

$$\sum_{j=1}^{C} x_{ij}t_{ij} = 1 \quad (12)$$

$$t_{ij} \in [0,1] \quad (13)$$

$$i \in [1, P], j \in [1, C] \quad (14)$$

The challenge of dynamic bandwidth allocation is illustrative expression of NP-hard issues. Increasing LUF for equity is the key utilitarian element, while throughput improvements are secondary. Since it is assumed that r_{ij} is known, we can instead apply the bandwidth distribution b_j to the connection x_{ij} and the transfer time assignment t_{ij} . According to the constraints (10) and (11), u_j can only have one parent node, a_i. The constraint (12) states that a_i has a transfer period of 1 and the constraint (13) states that p_{ij} can take on values between 0 and 1. Last but not least, constraint (14) specifies that node indices i and j are, respectively, the parent and child indices.

B. Quality of service (QoS) aware Dynamic Bandwidth Allocation (QDBA)

QDBA is deployed in response to the bandwidth requirements of the children nodes. Through TIM, the bandwidth requirement of children nodes are transmitted to the parent. A parent node will try to allocate time slots in line with the TIMs it gets from its offspring. If a parent node doesn't have enough slots to assign to its children, it will generate a TIM indicating the problem and deliver it to the node's adjacent parent. This separates the requirements of the child nodes into two groups like Quality (Q)-demand and Supplementary (S)-demand. The Q-demand describes the entire bandwidth request for latency and bandwidth-sensitive RT traffic, whereas the S-demand describes the need for NRT (best-effort) traffic. The combined requests will decide the amount of slots availability for the next action. TIMs are transmitted to the final transmission channel of the node using either customized packets or regular data packets. TIMs will be transmitted if there is no available transmission slots during the node's contention slot.

QDBA initiates when a parent node has acquired TIMs from all of its children which involves constructing transmission schedules for those children while attempting to fulfill the bandwidth requirements. The rescheduling systems give more priority to, before trying to schedule the S-demands to Q-demands than S-demands. Therefore, a parent node decides the Q-demands of all its children. The parent node generates the schedule and distributes it to all of its children. One example of a decentralized scheduling mechanism is when a parent creates transmitting strategies for its 1-hop children and delivers them without affecting the neighboring nodes.

The behavior of the clusters in a parent-child connection is consistent with one another excluding the cluster that contains the leaf nodes. There are R_k^Z nodes in cluster k on level Z, so that, $R_k^Z - 1$ are direct children of any specific node of the parent. The number of clusters in the network at any given level Z is f. $N_{p_k}^Z$ is the parent node in a k cluster of level Z and $N_{i_k}^Z$ is the i^{th} child node in the same cluster given that $0 < c < R_k^Z$. If the cluster's parent node $N_{p_k}^Z$ has a transmission slot S_k in a certain time cycle T_c, then the children of that particular node might utilize the slot provided at the transition times t_i and t_j independently to one another.

The slot allocation procedure is initiated by the source node, which performs the action of central coordinator. T_c is split evenly among the source and its 1-hop children nodes with an execution that the source which has superior transmission abilities to deliver the traffic beyond the network.

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Consequently, if the aggregate number of slots in a provided multiple access time period is α, then the bandwidth allocation acquired by the i^{th} node of children in the k with Z may be indicated as $\alpha_{N_{i_k}^Z}$ in Eq. (15)

$$\alpha_{N_{i_k}^Z} = \frac{\alpha_{N_{p_k}^Z}}{R_k^Z}$$
(15)

Consider the demand from the i^{th} children node in the cluster $N_{i_k}^Z$ be $\beta_{N_{i_k}^Z}$ and the slot allotted to the cluster parent $N_{p_k}^Z$ be $\alpha_{N_{p_k}^Z}$ As a result, we the slots assigned the child node $N_{i_k}^Z$ is computed as follows.

$$\alpha_{N_{p_k}^Z} = min(\beta_{N_{i_k}^Z}, \alpha_{N_{p_t}^L} * \frac{\beta_{N_{i_k}^Z}}{\sum_{j=0}^{R_t^L} \beta_{N_{i_k}^Z}})$$
(16)

In the above Eq. (16), $\alpha_{N_{i_k}^Z}$ is the bandwidth share with total number of i^{th} node belonging to k^{th} cluster of level Z. When a child model's Q- demands are less than the bandwidth allocated to it, as it returns the S- bandwidth to its parent so that the other nodes might adopts the unexploited slots. In certain cases, only upto 80% of their entire bandwidth is made accessible. The remaining 20% will be followed up to the subsequent node. This mechanism is termed as bandwidth delivery. If the total bandwidth requirements of its children exceed the available bandwidth, the available bandwidth is divided fairly among the children, and the parent receives any requests for further bandwidth. The process of demanding for the subsidiary slots are similar for the children reassuring their parent that for their bandwidth necessities. The leaf nodes ultimately initiate the dynamic slot scheduling process, which continues until the root of the 1-hop children carried out in a hierarchical manner. The fig. 1 depicts the flow chart of this proposed model.

Algorithm: QDBA method

Input: Multi access time frame (T_r), Slots assigned to N_t (α_{N_k}), $Q -$ demand for i^{th} node (γ_i), $S -$ demand for i^{th} node (β_i)

Output: Bandwidth demand of every child node, transfer period and relationship data

1. $\overset{Q}{\alpha_{N_k}} \leftarrow 0.8 * \alpha_{N_k}$; $\overset{S}{\alpha_{N_k}} \leftarrow 0.2 * \alpha_{N_k}$; N_c: $Child\ number$
2. $c \leftarrow 0; \gamma^c \leftarrow 0; \beta^c \leftarrow 0; N_c \leftarrow 0$
3. While $c < N$ do
4. $\gamma^c \leftarrow \gamma^c + \gamma_i$
5. $\beta^c \leftarrow \beta^c + \beta_i$
6. Increment c
7. End while
8. For all T_c in T_r do
9. If t_i is allocated to N_k then
10. $f \leftarrow (N_c + +) mod\ n$
11. $v \leftarrow 0$
12. While $R < N$ do
13. If ($\alpha_f > 0$ & $\overset{Q}{\alpha_{N_k}} > 0$)
14. Allocate $t_{(i+1)mod2}$ to $Child\ [f]$
15. Reduce α_f, $\overset{Q}{\alpha_{N_k}}$
16. If $\overset{Q}{\alpha_{N_k}} = 0$ then
17. RESOURCE_REQUEST ($\overset{Q}{\alpha_{N_k}}, \alpha_{N_k}, \gamma^c, \beta^c$)

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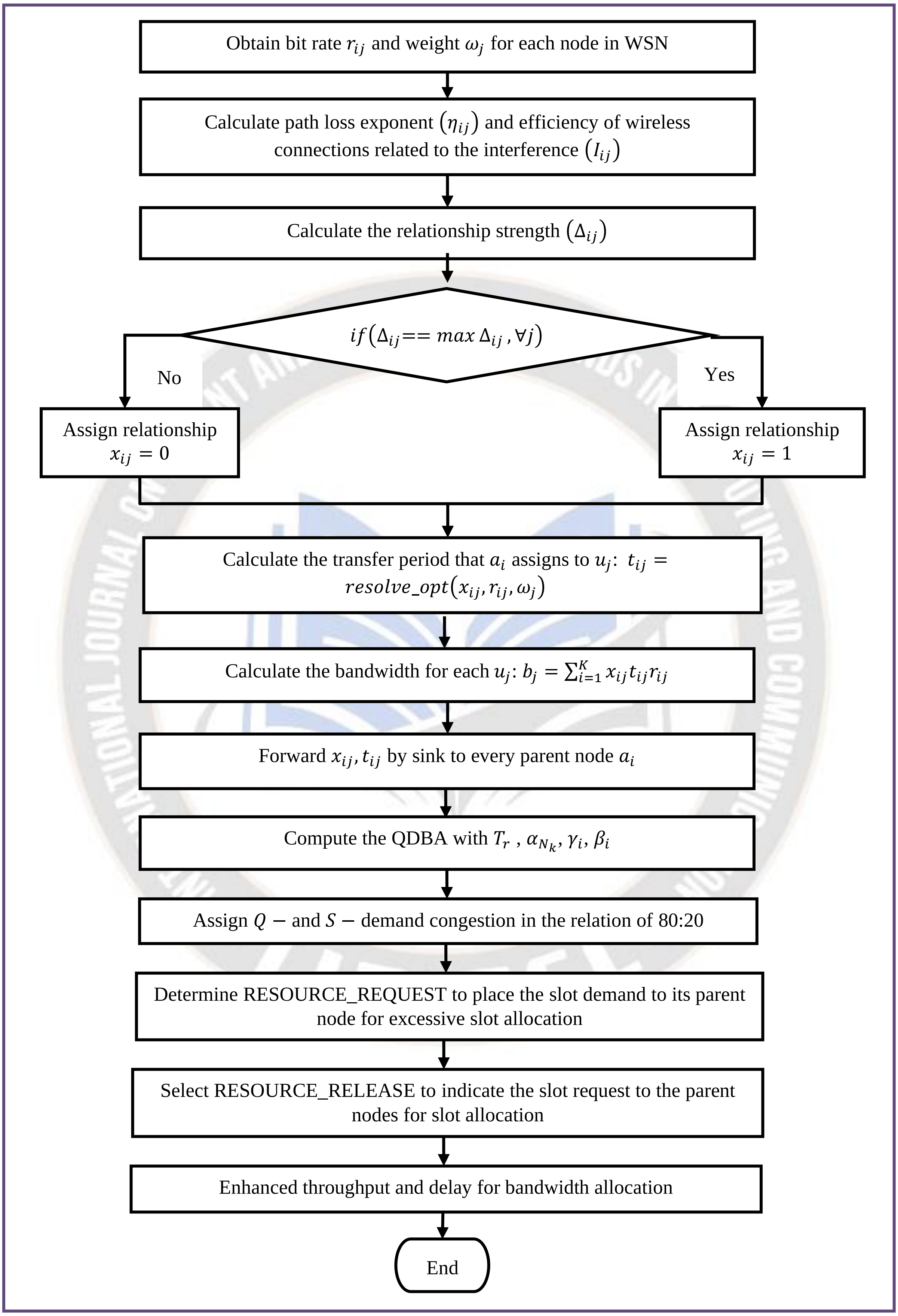

Figure 1. Flowchart of PRC-QDBA model

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18. end if
19. break loop
20. End if
21. end while
22. If $R = N$ then
23. $R \leftarrow 0$
24. While $R < N$ do
25. If ($\beta_f > 0$ & ($\overset{S}{\alpha_{N_k}} + \overset{Q}{\alpha_{N_k}}$) > 0 then
26. Allocate $t_{(i+1)mod2}$ to $Child\ [f]$
27. Decrement $\beta_f, \overset{S}{\alpha_k} + \overset{Q}{\alpha_{N_k}}$
28. Break loop
29. End if
30. End while
31. End if
32. End if
33. End for
34. If ($\overset{Q}{\alpha_{N_k}} + \overset{S}{\alpha_{N_k}}$) > 0 then
35. RESOURCE_RELEASE (p_{N_k}, α_{N_k})
36. End if
37. RESOURCE_REQUEST ($\overset{Q}{\alpha_{N_k}}, \alpha_{N_k}, \gamma^c, \beta^c$)
38. $\alpha_{N_k} \leftarrow \gamma^c + \beta^c$
39. End procedure
40. Procedure RESOURCE_RELEASE ($\overset{Q}{\alpha_{N_k}}, \overset{S}{\alpha_{N_k}}, \gamma^c, \beta^c$)
41. Divulge the rest ($\overset{Q}{\alpha_{N_k}} + \overset{S}{\alpha_{N_k}}$) number of slots
42. $\alpha_{N_t} \leftarrow (\gamma^c + \beta^c) - (\overset{Q}{\alpha_{N_k}} + \overset{S}{\alpha_{N_k}})$
43. End procedure

The aforementioned algorithm defines the framework of dynamic slot allocation tasks. A total of α_{N_k} slots with respect to T_r are being distributed by the cluster head of cluster k, N_k. Before giving the other slot to any of the children node, this algorithm verifies whether the node has a slot assigned to it. The bandwidth α_{N_k} is distributed in an 80:20 ratio between Q-demand and S-demand traffic. After the slots are assigned for $Q-$demand, any available slots will be allocated to $S-$demand.

The time periods between $Q-$ and $S-$ demand traffic are denoted by $\overset{Q}{\alpha_{N_k}}$ and $\overset{S}{\alpha_{N_k}}$ correspondingly. The parent node calculates the complete $Q-$ and $S-$ demand and represented it as γ^c and β^c based on the $Q-$ demand (γ_i) and $S-$ demand (β_i) achieved from of all its children nodes considering $Child\ [0..(N-1)]$. It satisfies the $Q-$ demand of all of its children by selecting the optimal shots from among those in $\overset{Q}{\alpha_{N_k}}$. The S-demand of all child nodes is allotted 20% of the bandwidth are consistently framed for S-demand $\overset{S}{\alpha_{N_k}}$, especially satisfying the criteria of $Q-$ demand. After the slots allocation, some slots are left unused are assigned to S-demand for improvising the RT traffic in WSNs.

The RESOURCE_RELEASE mechanism sends unused time slots from children nodes to parents for usage in a high-state cluster. If a child node's Q-demand does not meet the criterion, the cumulative slot demand ($\gamma^c + \beta^c$) is allocated to the immediate parent node for insufficient slot allocation. This is effectively handled by RESOURCE_REQUEST. A parent node distributes the Q-demand of child nodes in a round-robin manner. As a result, the unused slots of the children nodes are quickly reallocated to the other active nodes. The objective of resource request and release is implicitly met by shifting the increased slot demand to the parent and assigning unused slots in a round-robin manner. This improves throughput and latency for bandwidth allocation and enhances the QoS support for RT traffic in WSNs.

IV. SIMULATION RESULT

In this part, the PRC-QDBA is implemented in Network Simulator version 2.35 (NS2.35) and its efficacy is compared to the PRC-FBA [9], DHSSBA [14], WPDDRC [8] and DDRC [8] techniques. The evaluation is conducted based on throughput, packet loss, End-to-End (E2E) latency, queue size and source data transfer rate adjustment. Table 1 provides a list of the simulation parameters utilized in this system.

Table 1. Simulation Parameters

Parameter	Range
Simulation area	$1000\times1000m^2$
Number of nodes	50
MAC layer	IEEE802.11
Communication range	300m
Traffic source	CBR
Number of traffic categories	4
Packet size	200bytes
Data rate	2Mbps
Transmission power	285.63mW
Operating frequency	5GHz
Routing protocol	AODV
Mobility model	Random walk
Mobility speed	10m/s
Simulation time	120sec

A. Throughput

It measures how much information a target can take in during a given time period.

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$$Throughput = \frac{Total\ amount\ of\ data\ accepted\ by\ the\ target}{Time} \quad (17)$$

Fig. 2 shows the throughput (in Kbps) for different simulation times (in sec) for the DDRC, WPDDRC, DHSSBA, PRC and PRC-FBA methods. The results show that PRC-QDBA outperforms than other competing methods in terms of throughput. In 120s simulation time, PRC-QDBA outperforms DDRC, WPDDRC, DHSSBA and PRC-FBA methods by 13.19%, 9.57%, 7.1% and 5.1%, respectively, in terms of throughput. This is made possible by giving different types of traffic equal bandwidth and priority in each virtual queue across the network.

B. Packet Loss

It refers to information that was lost or never received during a transmission.

$$packet\ loss = \frac{Amount\ of\ lost\ data}{amount\ of\ lost\ data + Amount\ of\ accepted\ data} \quad (18)$$

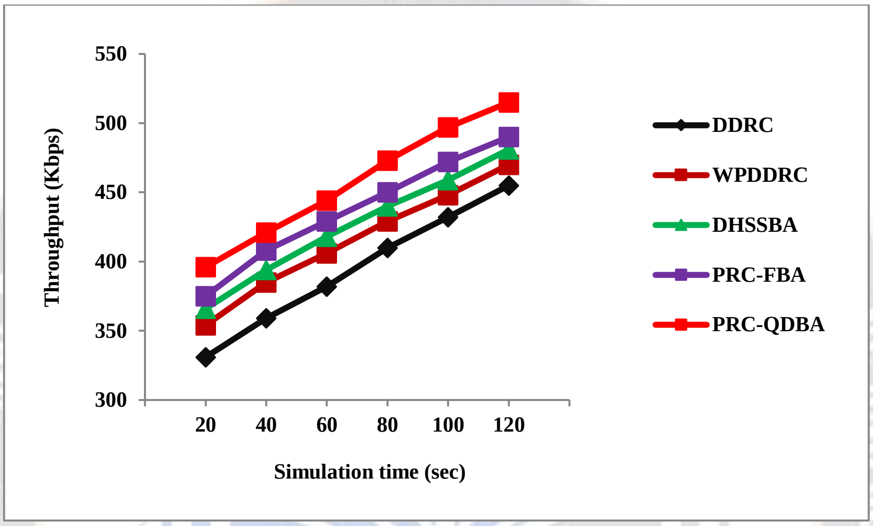

Figure 2. Throughput vs. Simulation Time

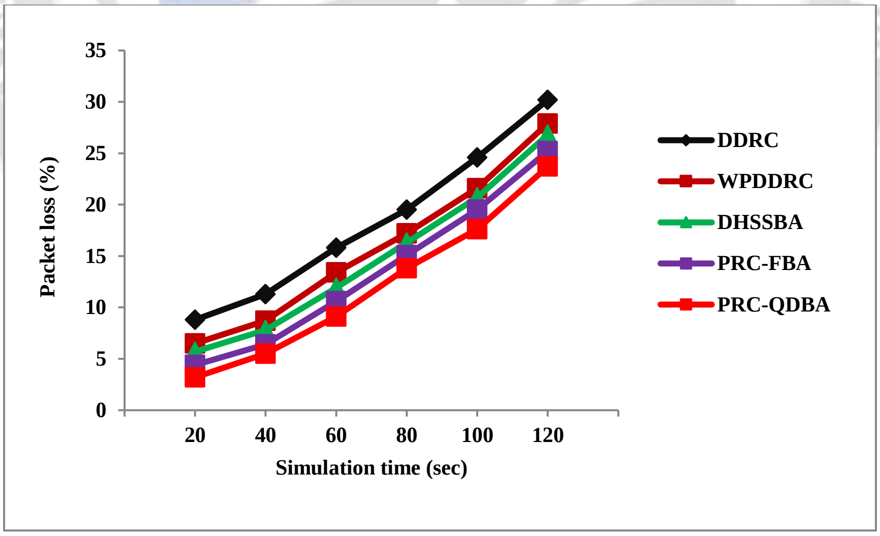

Figure 3. Packet Loss vs. Simulation Time

Fig. 3 compares the packet loss (%) over different simulation times (in seconds) for the DDRC, WPDDRC, DHSSBA, PRC-FBA and PRC-QDBA methods. There is evidence here to suggest that PRC-QDBA achieves lower packet loss than alternative methods. While consider the stimulation time of 120sec, PRC-QDBA results with 21.5% reduction in packet loss compared to DDRC, 15.1% reduction compared to WPDDRC, 11.6% reduction compared to DHSSBA and 6% reduction compared to PRC-FBA. Therefore, lower the results of PRC-QDBA packet loss can be

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 11s
DOI: https://doi.org/10.17762/ijritcc.v11i11s.8083
***Article Received:** 24 June 2023 **Revised:** 22 August 2023 **Accepted:** 02 September 2023*

attributed to by applied in many virtual queues and each node's bandwidth allocation in relieving WSN congestion.

C. End-to-end Delay

The time it takes for information to travel from its source to its destination.

$$E2E\ Delay = Time_{sink} - Time_{origin} \quad (19)$$

With respect to Eqn. (19), $Time_{sink}$ represents the time it took for the sink to take the data and $Time_{origin}$ represents the time it took for the origin to convey the data.

Fig. 4 shows the E2E delay (in msec) for different simulation times (in sec) for the DDRC, WPDDRC, DHSSBA, PRC- FBA and PRC-QDBA methods. When compared to the other methods, the PRC-QDBA have resulted to be lowest E2E delay. In a 120sec simulation time, PRC-QDBA reduces E2E latency by 13.1%, 9.5%, 7.5% and 6% compared to DDRC, WPDDRC, DHSSBA and PRC - FBA methods. Hence, the lower E2E delay corresponds with the maximum throughput and the less packet loss.

D. Queue Size

The quantity of information waiting to be processed. When there are several people waiting, the wait time increases.

Fig. 5 shows the average number of packets in the queue for each of the DDRC, WPDDRC, DHSSBA, PRC and PRC-FBA methods as the simulation time (in seconds) changes. The results show that the PRC-QDBA method produces the shortest average queue length (mean queue size) among the tested methods.

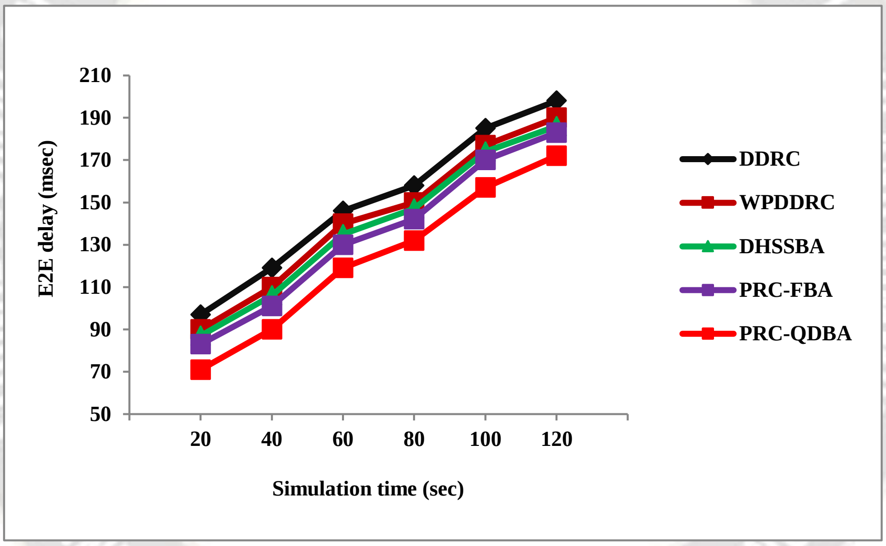

Figure 4. E2E Delay vs. Simulation Time

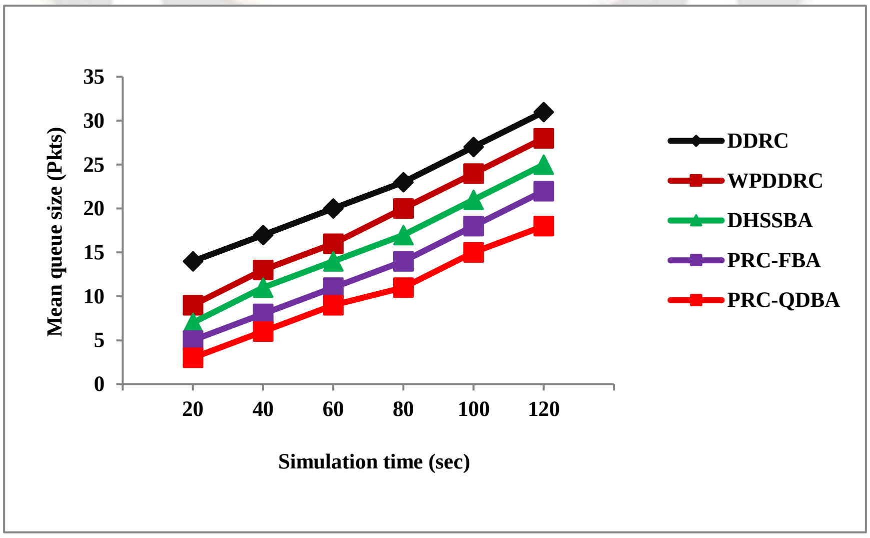

Figure 5. Mean Queue Size vs. Simulation Time

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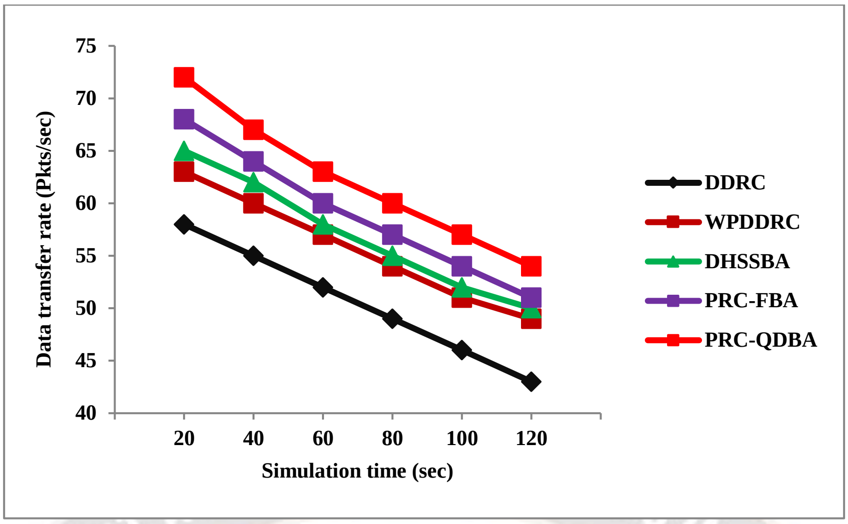

Figure 6. Data Transfer Rate vs. Simulation Time

The mean queue size of PRC-QDBA is 41.9%, 35.7%, 28% and 18.2% smaller than DDRC, WPDDRC, DHSSBA and PRC-FBA methods for the simulation time of 120 sec. Consequently, there can be a decline in packet loss and E2E latency if the minimum queue length is increased. It is clear that the PRC-FBA stabilizes the queue length around a target value and provides more stability for the mean queue size.

E. Data Transfer Rate Adjustment

Congestion and buffer overflow in WSN are managed by the data transfer rate at the source.

Fig. 6 shows the packets-per-second (pps) data transfer rate for different simulation times (in sec) for DDRC, WPDDRC, DHSSBA, PRC-FBA and PRC-QDBA. The results of this study show that the PRC-QDBA method, with its efficient rate adjustment and bandwidth distribution, provides the maximum data transfer rate. PRC-QDBA has a data rate that is 25.6%, 10.2%, 8% and 5.9% higher than DDRC, WPDDRC, DHSSBA and PRC-FBA method for the stimulation period of 120 sec. It is observed that that PRC-QDBA can reduce the data transfer rate may progressively lower the data transfer rate compared to the nodes' initial transfer rate. Therefore, the highest priority traffic classes are correctly transmitted without any congestion before lowering the transfer rate.

V. CONCLUSION

This paper proposes a PRC-QDBA approach for allocating bandwidth while selecting packets based on traffic types. Initially, the challenges faced in WSNs bandwidth distribution is investigated using the SINR model in an attempt to find a balance among fairness and efficiency in the network. Then, QDBA was utilized to disperse unused time slots across nodes by utilizing a hierarchical tree structure. The parent node acquires TIMs from the children nodes and allocates spaces in accordance with their demands. If it is unable to assign slots, it initiates TIM stating the demand and transmits it to its adjacent parent node, improving RT traffic throughput. Finally, PRC-QDBA technique surpasses traditional models in terms of throughput and delay in WSN bandwidth allocation for efficient bandwidth allocation and enables QoS support for RT traffic in WSNs.

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