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DPCA: Data Prioritization and Capacity Assignment in Wireless Sensor Networks

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ABSTRACT Scheduling different types of data packets, such as high or low priority data packets at the sender node, is important for reducing energy and capacity consumptions and end-to-end delay. Current scheduling schemes of wireless sensor networks use preemptive and non-preemptive scheduling algorithms, which incur relatively long end-to-end transmission delay and high processing overhead. Besides, they do not consider the path capacity, which represents the capacity of the network for transferring as much as sensory data to the sink node(s). Consequently, sensory data are routed to the sink node(s), whatever they are more or less, important for supporting domain applications. To remedy this issue, we propose a method, which differentiates between high and low priority when routing sensory data to the sink node(s). Specifically, the priority of sensory data is determined through a novel capacity assignment mechanism. When the network capacity, which depends on the capacity of routing paths, may not be sufficient for supporting the sensory data routing requirement, sensory data with a relatively high priority should be routed to the sink node(s), while that with a relatively low priority may be decreased or prohibited. Experimental evaluation has been conducted, and the result shows that congestion and packets dropping are reduced, when sensory data can be differentiated in their priority and the network traffic is relatively heavy.

INDEX TERMS Wireless sensor networks, path capacity, data prioritization.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) consist of sensor nodes, which are capable of sensing various phenomena. With the occurrence of the desired event, the analog data that sensor nodes have sensed are transmitted to digital signals and are routed to the sink node [1]. Sensor nodes are mostly battery-powered, and they are usually deployed in the area where it is difficult to renew their power source. To support robust operations, senor node is usually densely deployed near the event source and sinks [2]. Congestion may occur when the load in the network is over the available network capacity. For congestion control currently, there are two kinds of methods, which is conducted either by increasing the capacity of the network or by reducing the load in the network. Under specific conditions both methods have advantages and disadvantages. Generally, the resource control method is more efficient when continuously high load demands exist, while the traffic control method is more effective when a transient overload situation arises [3]. Topology aware resource adaptation (TARA) [4] and hierarchical tree alternative path (HTAP) [5] are two profitable struggles that adopt the resource control method. TARA concentrates on the adjustment of the network's supernumerary resources on the congestion situation through capacity analysis model, and consequently mitigate intersection hot spots.

To mitigate the congestion problem, the routing protocol decreases the number of data packets in the network. However, simply dropping data packets will decrease the data fidelity and increase energy dissipation. Conventional congestion control protocols mitigate congestion by decreasing the data transfer rate of child nodes, the packet generation rate of a node produces heavy traffic load. For this purpose, these protocols usually use back-pressure message scheme [6], [7].

Currently some techniques have been developed for congestion control in WSNs, such as energy efficient reliable multi path data transmission in WSNs for healthcare application [8], performance aware congestion control algorithm in WSNs [1], congestion control in WSNs through dynamic alternative path selection [2], congestion control mechanism in WSNs [3], congestion detection technique for multipath routing and load balancing in WSNs [9], priority-based application specific congestion control clustering protocol [1], adaptive buffering scheme to reduce packet loss on densely connected WSNs with mobile sink [10], congestion avoidance and control mechanism for multi-paths routing in WSNs [11], bio-inspired self-adaptive rate control for multi-priority data transmission over WSNs [12]. In proposed schemes authors did not consider path capacity or bottleneck edge capacity, that how to transfer high and low priority data during congestion. For sensor nodes to mitigate collision and congestion and to ensure synchronization slot duration calculation is also important which is not explored extensively in literature. In fact congestion can be avoided by calculating a suitable sending data rate by the base station for every node on the path according to the capacity of bottleneck edge.

To discourse the issues mentioned above, we suggest the prioritization of data and capacity assignment method to mitigate congestion and packets dropping. The contributions of this efforts are presented as follow.

- Given a WSNs, we first differentiate the data packets and then schedule the data packets according to the priorities among several queues. When a sensor node senses a data packet, this packet will be scheduled among a number of levels in the ready queue. We consider three levels of queues including pri_1, pri_2 and pri_3. The high priority data go into pri_1 queue; first come first served scheduling policy will be used to process high priority data. The data which are generated by the lower level nodes go into pri_2 queue. And finally, pri_3 queue contains the low priority data of the sensor nodes which reside at the same level.
- After the allocation of data packets into their corresponding queues, the total path capacity will be calculated. This calculation requires to send a burst of control packets to its parent nodes. Every data packet will be sent after receiving an acknowledgement of the previous packet or time out of the previously sent data packet. The path capacity C_{u_v} is then calculated by dividing the total number of acknowledging packets by time taken. After calculating path capacity, each node sends its path capacity and the parent node ID to a base station (BS). BS maintains a table which keeps each node ID, its parent node ID and path capacity.
- For all sensor nodes to avoid congestion and to ensure synchronization, slot duration will be calculated. To obtain the slot duration, BS chooses the lowest path capacity of a sensor node to successfully send one data packet (denoted Lp_c). For the transmitting node to send one data packet successfully, it needs $1/Lp_c$ seconds. The obtained value will be the slot duration. Data loss and congestion are then avoided by calculating a suitable sending data rate by the base station for every sensor node u. This sending rate may not be beyond the sending capacity of every node in the path towards BS.
- When a sensor node detect an unusual data it marks itself as a congested node, immediately calculate its capacity and forward its capacity and parent node ID to BS. After receiving this message, BS broadcasts a message to all sensor nodes in the path to calculate their capacities and send to BS. After receiving all the new calculated capacities, BS updates its table and forwards the smallest capacity to the congested node to transfer data to BS. The forwarding speed of the congested node may be equal to or less than the smallest capacity along the path to BS.

This paper is organized as follows. Section II describes the related work. Section III presents network energy model and some assumptions, Section IV presents path capacity calculation and allocation of high and low priority data during congestion, Section V evaluates the procedure developed in this paper.

II. RELATED WORK

In WSNs the field of congestion control infatuated researchers alertness due to its prominence, application aspiration completion and avoiding power exhaustion. In the following section up-to-date, important and relevant efforts are presented.

TARA [4] and HTAP [5] are two profitable struggles that adopt the resource control method. TARA concentrates on the adjustment of the network's supernumerary resources in a congestion situation through capacity analysis model, consequently mitigate intersection hot spots. On the other hand, HTAP algorithms make a source-based tree discovers all practicable routes to sink and elect the sensor node with the little buffer used to transfer the deductible packets through it for the purpose to rapidly react to congestion situation. Each of the two algorithms appears to be very efficient in congestion circumstances, but their achievement is affected by the congestion degree in network. In [13], the researchers suggest a Time Division Multiple Access schedule to guarantee rate allocation and fair throughput by taking into consideration the requirements confirmed by network lifetime. The researchers use lexico-graphic Max-Min to put in a clear and definite forms the rate allocation with maximum output and less frame length. Time synchronized channel hopping decide by IETF to sleep, transmit or receive in a slotted manner nodes follow a schedule [14], [15]. In [16], a Traffic Aware Scheduling Algorithm that constructs a consolidated scheduling which depends on the load generated by each node and on the network topology is suggested. In Flush [17], the data is separated into packets and transmit sequentially. The BS scheduler is responsible to avoid interference between flows. To ensure validity and reliability this technique uses hop-by-hop rate control and end-to-end acknowledgement. This method dynamically chooses data rate for sending using bandwidth calculations and for the avoidance of intra-path interference it uses the interference information. In this method only one source at a time can forward data packets.

To extend network life time, Efficient and Robust Serial Query Processing Approach for Large-Scale WSNs [18], proposed serial query processing approach for resource constrain wireless sensor network. The stated approach as compare to other approaches i,e iterative, flooding and distributed approaches have better perform regarding to mitigate communication and to a great extent reserve network resources. But some issues like network topology, communication range between the nodes have an impact on the approach. Congestion Detection and Avoidance (CODA) [19], is a rate control reduction protocol where each node discovers congestion by using both buffer and channel loads. In this method every node controls its data rate by Additive Increase Multiplicative Decrease method. CODA uses two methods: open loop back pressure and closed loop for persistent congestion. But CODA does not consider per source equity. In [20] Congestion Control and Fairness every sensor node uses packet sending time duration for the assessment path capacity. A significant disadvantage of this technique is that the remaining capacities from idle nodes are not accustomed. Quasi-static Centralized Rate Allo [21] try to conclude pleasing and desirable rate for transmission at the BS (Base Station) using communication template, topology information and channel loss ratio. Multi-event Congestion Control Protocol [22] uses schedule time-slots and consecutive data interval. During data time slot nodes transfer data according to the schedule sent from next node. In this method any competition removal can not specify by slot attribution. Capacity Aware Data Transport [23] protocol is same to flush but it observes many data flows. This technique uses Additive Increase Multiplicative Decrease data rate control method by using lower down nodes buffer.

For congestion control in WSNs many struggles concentrate on controlling speed of the resources, adopting the concept of traffic control [24]. A smaller number, but useful efforts considers resource control pattern [4], [5], while an even smaller number of researchers trying to merge both methods [25], [26]. Due to the absence of complexity traffic control is commonly used. By using this procedure in case of congestion the congested nodes transfer a back-pressure message to sources and consequently they decrease the speed with which they transfer packets in the network. This process is efficient to a great extent in a situation where transient congestion condition takes place. Although, source speed reduction is tolerable in some applications. There are various applications where source speed reduction is not applicable and all the data sensed by the sources are required to transfer to the sink [4]. Furthermore, in many applications high traffic probable to be permanent. Therefore the traffic control pattern for congestion control cannot set up adequate solution. An inspiring solution to traffic control problem given by various types of algorithms for congestion control in wireless sensor networks. Algorithms that uses the resource control procedure besides of controlling the speed with which the senders produce data to the network take the benefits of the extraneous deployment of sensor nodes.

A transmission control scheme for media access in sensor networks (ARC) [27], speed alteration is done through an additive increase multiplicative decrease which have a direct relation to the number of proceeding sensor nodes. In ARC the congestion is observed when a node discover that its parent node does not transfer its data traffic. This method tries to mitigate interference by recommending a jitter before sending the data traffic. In [28] the researcher's classified different congestion control techniques into centralized and distributed. Each technique is elaborated using different design parameters for estimating the congestion degree. Kafi *et al.* [29], to mitigate congestion and interference, consider the difference between link capacities during the scheduling process

Quasi-static centralized rate allocation [21] try to figure out favorable and pure quality data traffic transmission speed at the base station using knowledge about communication model, topology and link loss speed. Ghaffari [3] presents a completely covering survey article on the different mechanism which is used for congestion control in wireless sensor network. Multievent congestion control protocol for wireless sensor networks [22] uses consecutive data and scheduling time slots. During data time slot nodes forwards their data packets using a received time slot schedule from next the hop. Only one data packet can be transferred at one slot, therefore slot length shows the data rate at which a node can transfer.

Han *et al.* [33] suggests mobile anchor nodes (MANs) to solve the localization problem, the MANs will be equipped with global positioning system unit, will be broadcast their current locations to help other nodes for localization. Han *et al.* [32] suggests grid-based joint routing and charging algorithm for industrial wireless sensor networks to solve the energy constraint problem.

The aforementioned protocols do not describe the problem of path capacities dissimilarities between sensor nodes that leads to congestion, data loss without any discrimination between high and low priority and fair throughput. In the following section we portray a scheme for controlling congestion and illuminate the prioritization of data and scheduling construction handle by DPCA mechanism.

III. PRELIMINARY

In this section, we present the energy model and propose some assumptions that are use in this paper.

Generally, for modeling the energy consumption in wireless sensor network different models have been proposed. The well adopted first order radio model which is proposed in [30] will be use in this paper for modeling the energy consumption. According to this model for the transmission of a k-bit message within a distance d the consumed energy is given as follows:

$$\begin{aligned} E_{t,x}(k,d) &= E_{tx-elec}(k) + E_{tx-amp}(k,d) \\ &= E_{elec} * k + \epsilon_{amp} * k * d^2 \end{aligned} \tag{1}$$

Similarly for the receiving of k-bit message:

$$E_{Rx}(k) = E_{Rx} - elec(k)E_{Rx}(k) = E_{elec} * k \tag{2}$$

Note that for the receiver and transmit electronics the energy consumption constant is E_{elec}, and for the transmit

TABLE 1. Energy model parameters.

Name	Description
E_{lec}	Transmiter and receiver energy constant
ϵ_{amp}	Transmit amplifier energy consumption
k	Bits in one packet
d	Transmission distance
n	Index of attenuation
r	Radius of communication
$E_{tx}(k, d)$	Energy discharge during the transmission of a k bit packet to a distance d
$E_{Rx}(k)$	Energy discharge to receive k bits
$E_{ij}(k)$	Energy discharge during the transmission of k bits from node i to node j
TTL	The amount of time slots for which the data remain fresh

amplifier the energy consumption constant is an ϵ_{amp}. Thus to transfer a k bit packet from a node i to a neighbor node j the total energy consumption are as follows:

$$E_{ij} = E_{Tx}(k, d) + E_{Rx}(k) \tag{3}$$

The transmitting energy from node i to j is assumed the same as that of the transmitting energy from j to i in other words $E_{ij}K = E_{ji}K$. The parameters used in the energy model is shown in table 1.

A. ASSUMPTIONS

We make the following assumptions.

- Data traffic consists of only real-time data and non-real time data.
- The size of all data packets is same.
- Nodes are considered at various position depends on the number of hop count from a base station.
- The ready queue at each sensor node have maximum three levels, for real-time data priority 1 (pri_1), non-real-time remote data priority 2 (pri_2) and non-real-time local data priority 3 (pri_3) queue is used.
- Queues length will not be the same. The length of pri_1 queue is assumed to be smaller than that of pri_2 and pri_3 queue. However, the length of pri_2 and pri_3 queues will be same.

IV. PROPOSED DATA PRIORITIZATION AND CAPACITY ASSIGNMENT SCHEME

In non- preemptive task scheduling schemes (interchangeably use packet scheduling in this paper) high priority/real time data have to wait for the completion of the task of low priority data. But on the other hand, in preemptive priority scheduling, low priority data packet should keep in starvation for the continuous arrival of high priority data [31]. We propose data prioritization and capacity assignment scheme to ensure compromise between priorities. We present the working principle of the proposed scheme in the next section. DPCA algorithm consists of the following mentioned phases.

- *Priority Assignment:* The proposed scheme assigns two kinds of priorities, namely static or dynamic priority to every data packet in the network.
- Initiation Stage: At the time of network setup the initiation stage runs only once. At this stage the nodes find each other and build their neighbor table.
- *Scheduling Data Packets:* When sensor senses, a data packet, this packet should be scheduled among a number of levels in the ready queue.
- Path Capacity Calculation: At this stage, end-to-end path and bottleneck edge capacity are calculated.
- *Slot Duration:* To ensure synchronization between sender and receiver and to mitigate collision and congestion the sink node calculate slot duration for every sensor node in the network.
- *Data Transmission:* At his stage a node forward data to their parent node according to the bottleneck edge capacity and slot duration.

A. PRIORITY ASSIGNMENT

The proposed scheme assigns two kinds of priorities, namely static and dynamic priority to every packet.

- *Static priority:* Static priority is assigned to the sensor node based on its data value. After storing the threshold value, the sensor node is going to sense the specific application for which it is deployed. The sensed value should be compared with the stored threshold value for assigning priority. The packets which contain the value above or below the threshold value is marked as high priority data packet while the other packets are considered as low priority/normal packets.
- *Dynamic priority:* Dynamic priority is assigned only to reduce end-to-end delay. Normally in a network, there are two types of data, locally generated data and transit data or route through data. In this work transit data, will have higher priority as compared to locally generated data for the purpose to reduce end-to-end delay. To achieve this goal we put the route through data into priority 2 (pri_2) queue while the locally generated data into priority 3 (pri_3) queue.

B. INITIATION STAGE

The initiation stage runs only at the time of the network setup. In this stage, the nodes first expose each other and built their neighbor tables. This stage starts from the sink node. The sink node broadcasts a message which consists of its ID and zero as its depth. Once the neighbor node receives this message, send an acknowledge message back to the sender. The sink node after receiving this acknowledgment message sends again a connect message to the particular sender node. After receiving the connect message the nodes become attentive that it can directly communicate with the sink node. The node marks the sink node as the parent node. The node updates its neighbor table with the level number which is zero and ID of the sink node. The node also sets its level number by adding one to the level number received in the message from the sink node. If a node receives messages from more than one nodes with the same level number, then to break the tie the node calculating energy consumption and distance, and mark the node which has less energy consumption as a parent node. To calculate energy consumption, we use the energy model which is given in the preliminary section of this paper. This process continues until all nodes expose each other. During this process carrier sense, multiple accesses (CSMA) and medium access control (MAC) protocol is used.

C. SCHEDULING DATA PACKETS

Scheduling data packets of a sensor node among several queues are presented in Fig. 1. When the sensor senses, a data packet, this data packet is scheduled among a number of levels in the ready queue. The general working principle of the proposed dynamic capacity assignment and packet scheduling scheme is illustrated in Fig. 1.

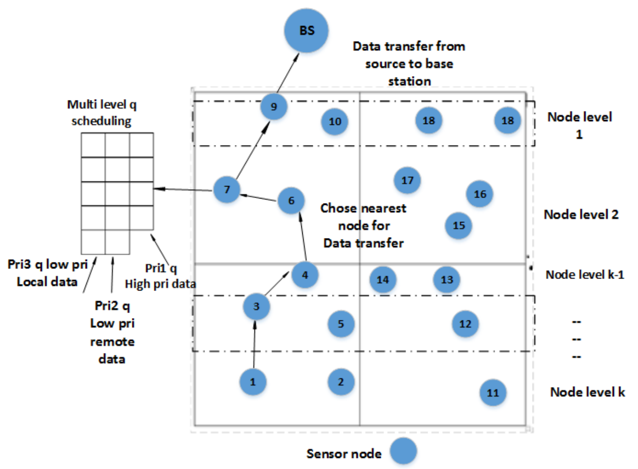

FIGURE 1. According to priority packet scheduling in different levels of queue.

This scheme assumes that the nodes are organized to follow a hierarchical structure. Nodes situated at the same hop distance from the base station are considered at the same level. We considered three level of queues, priority 1 pri_1, priority 2 pri_2 and priority 3 pri_3 queues. The reasons for choosing maximum three queues to process high priority data with no delay is to achieve an overall performance of wireless sensor network. The non real time data which are sensed by the sensor node at lower levels goes to pri_2 queue to achieve minimum end-to-end delay and task waiting time and finally non real time task which generate at the same level and resides at pri_3 queue will be processed.

- *Priority 1 Queue:* The high priority/real time data go to the highest priority queue pri_1 queue, first come first served scheduling scheme will be used to process the high priority or real time data in the highest priority queue.
- *Priority 2 Queue:* The second highest priority queue pri_2 contains the non- real- time data of sensor nodes which resides at lower levels.
- *Priority 3 Queue:* Finally, *priority 3* queue which is the lowest priority queue contains the lower priority or non-real time data of the local sensor nodes which resides at the same level as shown in Fig. 1.

Base on the application requirements in the proposed schemes queue sizes are different. Since context switching and context storage is an extra overhead in preemptive priority scheduling, so as compare to non-preemptive scheduling the size of the ready queue for preemptive priority scheduling is expected to be smaller, because emergency/high priority data rarely occur. When emergency/high priority data occur, it can stop (preempt) the execution of low priority data and can be placed in high priority pri_1 queue and start execution. Since the emergency data rarely occur so the number of preemption is less in number [31]. On the other hand, when the lower level sensor node sense low priority/non-real time data it can be placed in the preempt able *priority*2 queue. The processing of this data can be interrupted by a high priority/real time data and it can also be interrupted by lower priority (*priority*3) data which is not being processed for a long time due to the continues arrival of high priority/real time data. This phenomenon reduces the end to end delay of the data which is sensed at the lower level to the base station. When a sensor node sense two or more tasks at the same level, smaller task have the higher priority is compare to large task at the same level.Each packet has ID which consists of two parts, level ID and node ID. The data packet which arrives at high level queue from lower levels may have high priority then the data packets which generated at higher levels or same level. This phenomenon reduces the end-to-end delay' for the lower level sensed data to reach the base station. For the data which generate at the same level the smaller task may have higher priority than the large one.

Assume that a node n at level *Lj* is sensing high priority data or emergency data. This node forwards the high priority data to the base station through *Lj-1* intermediate levels. The algorithm1 shows that high priority or emergency data goes into pri_1 queue i,e line *1*. The non real time data which is sensed at lower levels goes into pri_2 queue i,e line *9* and the non real time data which is sensed at the same level by the sensor node goes into pri_3 queue i,e line *4, 5, 6*.

D. PATH CAPACITY CALCULATION

After the assignment of data packets into their corresponding queues the sensor node wants to know the total path capacity. End-to-end path capacity can be calculated. As an demonstrative example Fig. 2 will be referenced. In the diagram a solid line between two nodes, x and y show that y is the parent of x in the communication structure and the dotted line

TABLE 2. Nodes, parents and their capacities.

Path no	Node	Parent	Capacity	Node	Parent	Capacity	Bottleneck Edge Capacity
1	i	d	5	d	h	5	
	h	s	20				5
2	j	e	20	e	h	3	
	h	s	20				3
3	k	e	20	e	h	3	
	h	s	20				3
4	t	h	10	h	s	20	10
5	g	e	10	e	s	8	8

Algorithm 1 To Place High Priority and Low Priority Data in Their Corresponding Queue

Require:
C : the set of initial candidate nodes.
S : the set of static sensor nodes.
N_{id}: the set of the neighbors of S_{id}

Ensure:
L : the importance level list of all the probable nodes.

while $Data_{k,i}$ is received by $node_i$ at $level_l$ i,e Lj **do**
  if type($Data_{k,i}$) = high priority **then**
    $Pri_1 \leftarrow Data_{k,i}$
  else if node n is not an the lowest level **then**
    if $data_{k,i}$ is not at the same level **then**
      $Pri_3 \leftarrow Data_{k,i}$
    end if
  else
    $Pri_2 \leftarrow Data_{k,i}$
  end if
end while

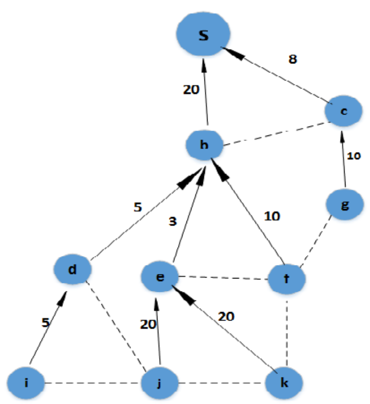

FIGURE 2. Sensor nodes and physical capacity.

only shows the connectivity. The digits besides the arrows in Fig. 2 show path capacity. DPCA is a two step process. Firstly the path capacity between parent and child node can be calculated. The calculated path capacities are then forwarded to base station.

To calculate path capacity each node determine radio link relating it to its parent node. Every node sends burst of data packets in a particular time to its parent node. Every data packet in the burst will be sent after receiving acknowledgement of previous data packet or time out of the previous submitted data packets. The path capacity $C_{u,v}$ is then calculated by dividing the total number of acknowledge packets by time taken. After completion of this step each node sends the calculated path capacity and parent node ID to base station. Base station contains a table which contains entries for all paths form source nodes to base station. The table contain node id, id of parent node and path capacity of the nodes in the path form source node to base station as shown in table II.

E. SLOT DURATION

After the collection of path capacities at the base station the next step is to calculate the slot duration. For all sensor nodes, to avoid congestion and ensure synchronization, slot duration must be uniform during sending and receiving process to achieve synchronization.

To obtain slot duration the base station chooses the lowest path capacity of a node to successfully sent one data packet let be Lp_c. For the transmitting node to send one data packet successfully it needs $1/Lp_c$ seconds.

The obtained value will be the slot duration. Data loss and congestion is then avoided by calculating a suitable sending data rate by the base station for every sensor node u. This sending rate may not beyond the sending capacity of every node in the path towards the base station.

F. DATA TRANSMISSION

When a sensor node detects an unusual or high priority data, first it should mark itself as a congested node, immediately calculate its capacity and forward the capacity and parent node ID to base station. The base station after receiving the message checks their table and broadcast a message to all nodes in the path to send their capacities. When all nodes in the path forward their capacities to base station, the BS compare the new capacities to already existing capacities in the table and update the table accordingly. The BS then want to know the smallest node capacity, and for this purpose, it compares all the path nodes capacities with each other, determines the smallest capacity and transfer to the congested node or high priority data generation node in the path.

After receiving the capacities, the sink node calculate the slot duration to ensure synchronization and to avoid congestion between sending and receiving nodes. For this purpose, the sink node select the smallest capacity of a node in the path form source to sink node from the table, let be C_a. This node needs $1/C_a$ second to transfer one packet successfully. The value obtained will be slot duration and transfer to the congested node which detect unusual event and all other nodes in the path to synchronize their processing speed so that the data may not lost.

The high priority data generation node compares the receiving capacity from the base station to their calculated capacity. If the receiving capacity is less than the congested node capacity, the congested node have to reduce their capacity to receiving or bottleneck edge capacity and transfer only high priority or unusual data to parent node. If the receiving capacity is equal to congested node capacity so the congested node have to transfer only the high priority data according to its capacity. But if the receiving capacity is greater than the congested node capacity, then to reduce end-to-end delay for pri_2 queue data the congested node will transfer the pri_2 and high priority data simultaneously.

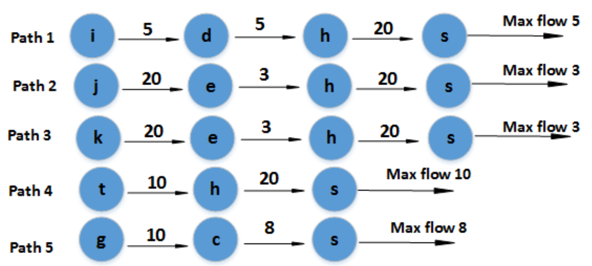

FIGURE 3. **Maximum flow through different paths.**

Referring to Fig. 3 , if node i in $path_1$ which have capacity *5* detect some high priority data, it have to forward only high priority data with their own calculated capacity because the minimum capacity in this path from source to base station is *5*. But if node *j* in $path_2$ detect unusual or high priority data it can't have to forward the data to base station with their own calculated capacity which is *20* because the bottleneck edge is between node e and h which have capacity *3*, therefore node *j* have to reduce the speed according to the bottleneck edge otherwise the high priority data packets will be drop by node e. Similarly node *t* in *path4* will have to transfer both high priority and low priority data simultaneously because the edge between the parent of node t and sink node have capacity *20* which is double of node *t* calculated capacity.

When there is no data packet moving in any edge, the flow of every edge will be zero.

We assume that each edge has a capacity greater than or equal to zero, capacity c(u,v) $\geq$ 0. Each sensor node can forward data packets which are equal to or less then the path capacity not greater than the total path capacity otherwise the data packets will be dropped. If f(u,v) shows the data transfer capacity a of node to be injected into the link then this capacity must be less than or equal to the total path capacity i,e $0 \leq f(u, v) \leq c(u, v)$. It shows that the flow along an edge must be equal to or greater than zero and not more than the maximum capacity.

Algorithm 2 Maximumflow

Require:
- Pc : Path capacity.
- P_{BS} : Total packet transfer to base station.
- P_{Ack} : Total packets acknowledge by base sation.
- T : Time taken.
- SD : Slot Duration.
- SSD :Smallest Slot Duration.

Ensure:
High and low priority data transfer.

```
1:  For every node calculate path capacity, c[x,y]
2:  Pc ← P_Ack/T
3:  SD ← 1/Pc
4:  if advertise SD for a node ≠ existing SD in the table then
5:      update the correspond value in the table
6:  else
7:      no change
8:  end if
9:  SSD ← smallest SD
10: if SSD > SD then
11:     transfer both high and low priority data
12: else if SSD ≤ SD then
13:     Forward only high priority data packets
14:     Forward data packets according to SSD which is calculated in line 4
15: end if
```

Algorithm *2* demonstrate that for every node first path capacity and slot duration will be calculated and sent to the base station as shown in steps *2* and *3*. When the base station receive the path capacity and slot duration for every node, it determine the smallest path capacity and transfer to the node which detect unusual data as shown in step *4*. The congested node compare the smallest slot duration with their own slot duration , if the smallest slot duration is greater than their slot duration than the congested node transfer both high and low priority data simultaneously. But if the smallest slot duration is less then or equal to the slot duration then the congested node transfer only high priority data.

V. IMPLEMENTATION AND EVALUATION

A. ENVIRONMENT SETTINGS

The prototype is implemented by using java programming language to evaluate the performance of the proposed scheme comparing it with first come first served and multilevel queue scheduling scheme. The comparison is made in term of average packet loss and end-to-end delay. We use 120×120 meter surface for our simulation. In this area maximum 110 nodes are deploy in 10 $\times$ 10 grid. The maximum capacity of ready queue for each node is 50 tasks. The tasks are differentiated by their type ID, for example type 0 is used for high priority data. Simulation results are obtained for both real and non

TABLE 3. Parameters settings in experiments.

Parameters	Values
Size of Network	120m × 120m
Nodes	maximum 110
Number of zones	8-10
Transmitter electronics energy consump	50 njoule/bit
Receiving electronics energy consump	50 njoule/bit
Speed	250 kbps
Initial node energy	3 joule
Attenuation coefficient(α)	0.6

real types of data traffic. Table III presents parameter for simulation and their respective values.

B. EXPERIMENTAL EVALUATION

Fig. 4 and 5 show high priority data packets delay and lost from source to destination. We notice that the proposed DPCA performs better than First-Come-First Served (FCFS) and Multilevel Queue (MLQ) Scheduling algorithms. This is because the proposed DPCA preempt pri_2 and pri_3 tasks with the arrival of high priority pri_1 data packets, and directly starts execution of the pri_1 data packets with First-Come-First Served scheduling policy. Also we notice that in case of packets drops the proposed DPCA algorithm performs better than FCFS and MLQ algorithms. This is because DPCA first calculate the path capacity and determines the bottleneck edge capacity, transfer the high priority data packets according to bottleneck edge capacity. Therefore in DPCA there is less possibility to lost high priority data packets as compere to FCFS and MLQ scheduling algorithms.

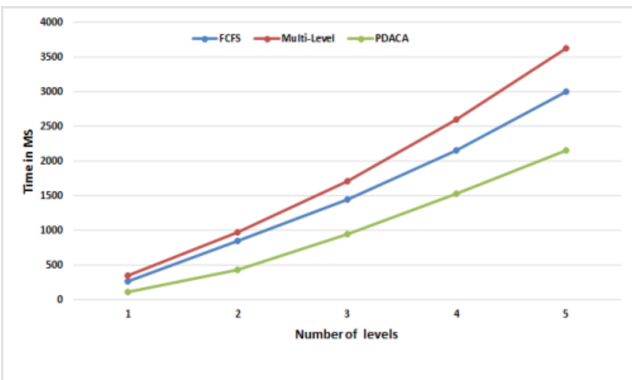

FIGURE 4. High priority data delay from source to destination end-to-end at different levels.

Also in the proposed method to avoid congestion and ensure synchronization it is require for the BS to calculate slot duration. To obtain slot duration, the base station chooses the lowest path capacity of a node to successfully sent one data packet, let be Lp_c. For the transmitting node to send one data packet successfully it needs $1/Lp_c$ seconds. Data loss and congestion is then avoided by calculating a suitable sending data rate by the base station for every sensor node. This sending rate may not beyond the sending capacity of every data transmitting node in the path towards the base station.

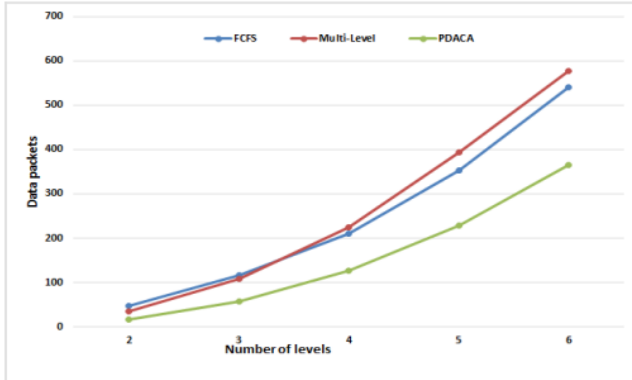

FIGURE 5. From source to destination high priority data lost end-to-end at different levels.

Therefore, in the proposed algorithm high priority data packet drops and delay mitigate to a great extent as compare to FCFS and MLQ scheduling schemes.

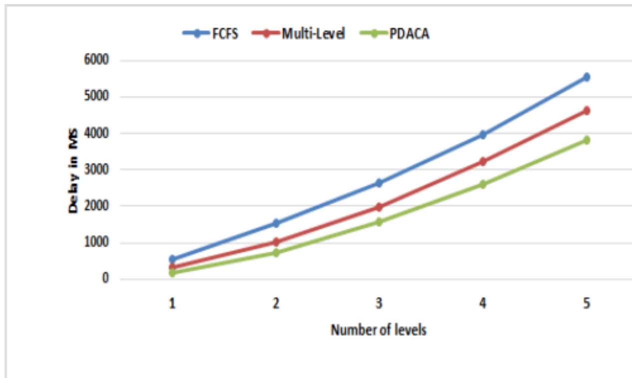

FIGURE 6. Low priority data delay from source to destination end-to-end at different levels.

Also Fig. 6 and 7 demonstrate source to destination delay of pri_2 and pri_3 data. From the results, we find that the proposed DPCA performs satisfactory as compare to FCFS and MLQ scheduling schemes. The proposed scheme gives high priority to data packets which comes from lower levels by putting in pri_2 queue. When there are no high priority data packets in pri_1 queue, then the pri_2 queue directly start execution. Thus the waiting time of the data packets which come from lower levels is significantly reduced.

Fig. 8 and 9 demonstrate high priority data delay and lost at different levels. From the results, it is observed that the proposed DPCA outperforms then the First-come-First Served and Multilevel Queue scheduling schemes. This is because with the arrival of high priority data it directly preempts pri_2 and pri_3 tasks and start execution. When there is high priority data in pri_1 queue, the data packets in pri_2 and pri_3 queue will have to wait until the complete execution of pri_1 queue data. Therefore, high priority data packets lost and delay is significantly reduced at different levels from source to destination.

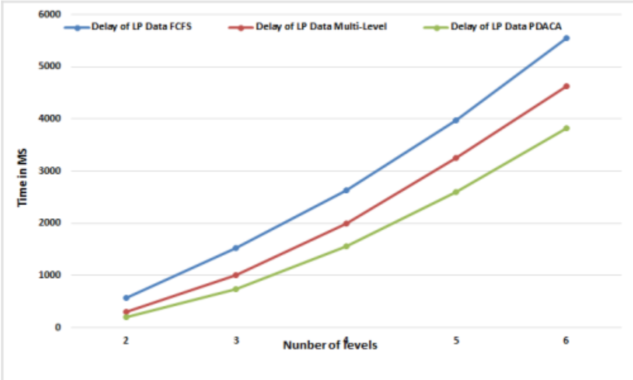

FIGURE 7. ***Pri*$_2$ and *Pri*$_3$ data lost from source to destination end-to-end at different levels.**

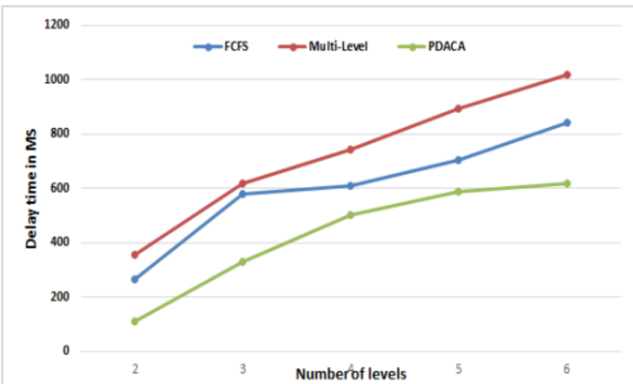

FIGURE 8. **High priority data delay at different levels end-to-end from source to destination.**

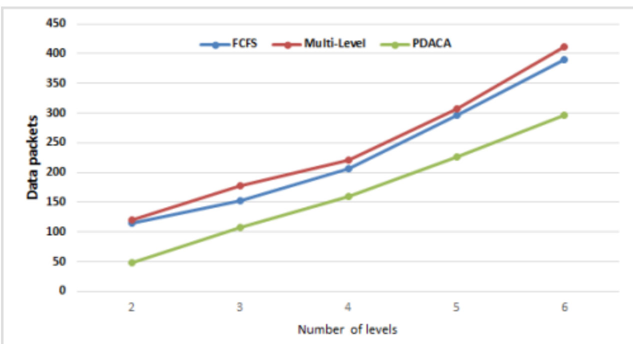

FIGURE 9. **High priority data lost at different levels end-to-end from source to destination.**

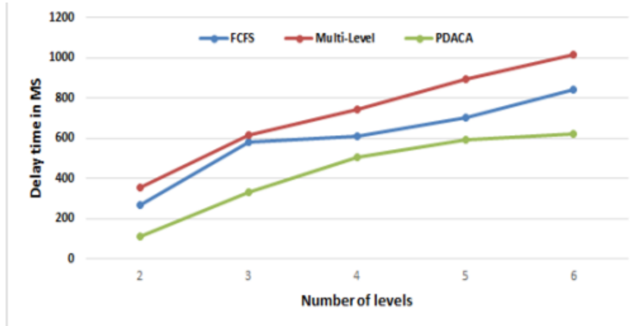

FIGURE 10. ***Pri*$_2$ and *Pri*$_3$ data delay at different levels from source to destination.**

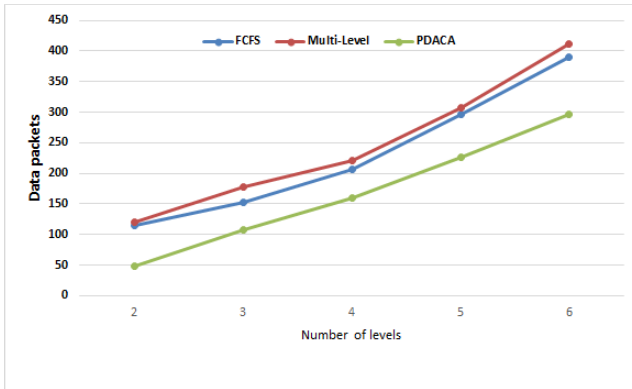

FIGURE 11. ***Pri*$_2$ and *Pri*$_3$ data lost at different levels from source to destination.**

Fig. 10 and 11 demonstrates pri_2 and pri_3 data delay and lost at different levels from source to destination. From the results it is observed that the proposed DPCA outperforms then the First-come-First Served and Multilevel Queue scheduling schemes. This is because the proposed scheme gives high priority to data packets which comes from lower levels by putting in a pri_2 queue. When there are no high priority data packets in pri_1 queue, then the pri_2 queue directly start execution and thus minimize end-to-end delay for the data which comes from lower levels. Thus the waiting time of the data packets which come from lower levels is significantly reduced. Also when a sensor node determine the bottleneck edge capacity and transfer data according to bottleneck edge capacity, therefore the chance of data packets lost is also significantly reduced.

VI. CONCLUSION

In this article, we propose Data Prioritization and Capacity Assignment (DPCA) scheduling scheme for WSNs. In the proposed scheme, each node has three levels of priority queue, except those at the last level of the hierarchy. High priority data packets are placed into the highest priority queue and low priority data packets are placed into other queues. The proposed scheme, calculate the path and bottleneck edge capacity, and transfer data according to bottleneck edge capacity. It guarantees minimum end-to-end data packets lost both for high and low priority data. It also minimizes data packets lost for high and low priority data at different levels from source to destination. The proposed scheme also plays a vital role both for high and low priority data packets delay. It significantly reduce delay for both high and low priority data at different levels and also end-to-end. Experimental evaluation shows that the proposed DPCA outperforms than the existing First-Come-First Served and Multilevel Queue scheduling schemes.

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