ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Priority Based Congestion Control Protocol and Fair Rate Allocation in WSN

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Abstract

Due to event-driven nature of Wireless Sensor Network, network load enhances which leads to congestion. As a result of congestion, network suffers from energy wastage, throughput reduction and packet loss. In order to overcome these issues, we have proposed a Priority Based Congestion Control Protocol and Fair Rate Allocation in WSN. In the proposed technique, an efficient route establishment and auxiliary routing is used based on the priority of the traffic. To achieve the fair rate allocation to the flow, intermediates nodes are classified into near-source node and near-sink node. Based on the available bandwidth and incoming rate, near-source node fairly allocates available resources to avoid congestion. Near-Sink node estimate queue occupancy and allocate resources based on the level occupancy. Also, hop by hop backpressure signal is used to suppress the exceeded data.

Keywords: Congestion control, Wireless sensor network, Faire rate allocation, Priority based.

Introduction

Wireless Sensor Network consists of set of tiny nodes that are self-organized and equipped with embedded computing devices interfacing with sensors/actuators. It communicates with each other using wireless channel to observe events in the real world. Each sensor node has three functions: sensing phenomena in the environment in which it is deployed, processing of the sensed data and transmission over short distance. WSNs are widely used in the applications such as military surveillance, industrial detection, environment monitoring, health care, agriculture, scientific research, telemedicine monitoring, intelligent transportation, home automation, factory monitoring, energy conservation and target tracking etc.[1] [2].

Issues

- Storage capacity and the processing speed
- Energy conservation
- Limited bandwidth
- Low-quality communications
- Scalability
- Unstructured and time-varying network topology
- Battery replacement is impossible in many sensor networks due to the inaccessible or hostile environments. [3].

Congestion in WSN

Congestion occurs in a sensor node when data traffic becomes heavier, many sources like buffer overflow, concurrent transmission, packet collision, many to one nature and coherent nature of traffic load exceeds the channel capacity. So packets might be put into the node's buffer and have to wait for access to the medium that is shared by a number of communication entities [4].There are mainly two types of congestion in WSNs. The first type is the node-level congestion due to buffer overflow in node can result in packet drop and queue delay this leads to retransmission if required and consumes additional energy. Second type of link-level congestion occurs when wireless channels are shared by several nodes using Carrier Sense Multiple Access (CSMA)-like protocols and thus collisions among sensor nodes can occur when multiple sensor nodes try to occupy the channel concurrently. It increases packet service time and decreases both link utilization and overall throughput, and wastes energy at the sensor nodes [5] [6].

Issues [7]

- Throughput impairment
- Increasing the consumption of limited energy
- Dropping of packets and retransmission at the nodes
- Delay in data transmission
- Decreasing the guarantee of the network quality of service

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Congestion Control in WSN

Congestion control technique is based on adjusting the transmission rate at source nodes. It can be classified into end-to-end congestion control and hop by-hop congestion control. End-to-end congestion control performs exact rate adjustment at source and intermediate nodes according to current QoS level at sink node. The drawback of end-to-end congestion control mechanism is that it heavily relies on round-trip time (RTT), which results in slow response and low convergence. In contrast, hop-by-hop congestion control has faster response but difficult to adjust the packet-forwarding rate [8]

Literature review

Akbar Majidi and Hamid Mirvaziri [9] have proposed a Mechanism for Congestion Control in Wireless Multimedia Sensor Networks for reducing congestion in the network by free resources to set accurate rates and priority data needs by using a priority mechanism. Proposed algorithm is applied to the nodes near the base station after the congestion detection mechanism detected the congestion. In a network high priority traffic is generated only for a short period of time while low priority traffic usually exists in the network and produce thousands of packets generated periodically. For such environments, service differentiation in wireless multimedia sensor networks becomes an important problem. Here the proposed method is applied only for nodes near the base station, it is necessary to consider a different priority of each node for each traffic source. So it affects the normal throughput also proposed algorithm is not applied emergency case congestion may takes place.

Xiaoyan Yin et al [10] have developed fairness-aware congestion control (FACC) to adjust the sending rate of each flow and save the precious resource at the nodes close to the sink by categorizing all intermediate sensor nodes into near-source nodes and near sink nodes for achieving fair bandwidth allocation. Near-source nodes maintain a per-flow state and allocate fair rate to each passing flow by comparing the incoming rate of each flow and the fair bandwidth share. Near-sink nodes do not need to maintain a per-flow state and use a lightweight probabilistic dropping algorithm based on queue occupancy and hit frequency. FACC requires that each flow receives a fair share of the available bandwidth according to its generating rate. However, in WSNs, both the sending rates and the network load are time varying. Thus, it is very impractical to allocate a fixed rate to each flow. When the network load exceeds the available bandwidth congestion occurs.

SamanehAlikhanzadeh and Mohammad HosseinYaghmaee [11] have proposed Learning Automata Protocol for Bidirectional Congestion Control. Each node equipped with learning automata selects an action and adjusts its rate based on the responses receives from environment that is every intermediate node is always interacting with environment and based on buffer occupancy performs appropriate action corresponding to increasing or decreasing rate according to responses with either a favourable or an unfavourable feedback signal which received from environment that sensor works on it. For performing the operation it mainly depends upon the feedback signal from the environment for adjusting its rate. Variation of data rate, bandwidth share and network load affects the information from the environment so it is not suitable in emergency case. It does not provide reliable end-to-end data delivery from every sensor to a sink.

Liqiang Tao and Fengqi Yu [12] have developed an energy efficient congestion control scheme for sensor networks called ECODA by extending the CODA which consists of two mechanisms: (i) Use dual buffer thresholds and weighted buffer difference for congestion detection (ii) Dynamically estimate channel loading with an implicit manner and optimize channel utilization. If channel loading is high, a packet has great probability of collision. After collision, the MAC layer initiates a retransmission. ECODA achieves high channel utilization which leads to packet retransmissions. So it consumes additional energy. Because Nodes in a WSN are deployed with limited battery energy and therefore enhancement of network lifetime by minimizing energy-usage is of utmost importance.

DiptiPatil and Sudhir N. Dhage [13] have proposed Priority-based Congestion Control Protocol for upstream congestion control. The PCCP creates priority index based on importance of each node and sends this information to all the nodes which measures the congestion degree as the ratio of packet inter-arrival time to the packet service time. PCCP utilizes a cross-layer optimization and imposes a hop-by-hop approach to control congestion. PCCP achieves efficient congestion control and flexible weighted fairness for both single-path and multipath routing. However, in WSNs data are normally generated and sent to the sink periodically. When an important event is triggered burst of data traffic can

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
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be suddenly generated. So, different data packets might have different importance. For packets with higher importance, the network should make more effort in delivering them.

CharalambosSergiou and VasosVassiliou [14] have proposed a Source-Based Routing Trees for Efficient Congestion Control in Wireless Sensor Networks. It explains about Sink-Based Tree Creation and Source-Based Tree Creation. In sink based tree creation sink is treated as a root and source is considered as a root in source based tree creation. If congestion or node failure occurs in root node it degrades the overall network performance. Selection of root node must maintain the throughput of nodes to the maximum possible level without packet drops. Also it has some dis advantages when constructing source-based trees such as Location Awareness, Higher Level Connection Availability and Number of nodes kept in neighbour table. From the graph a Source-based tree provides longer delays and consumes more energy.
Peng Du et al [15] have proposed Active Congestion Help (ACOH) mechanism to find redundant resources and build an auxiliary routing when congestion occur. For fairness and flow balancing, Adaptive Flow Allocation algorithm (AF) is designed to distribute flow as adaptive proportion between the main routing and the auxiliary. When part of the data flow which exceeds the network maximum throughput can't be received by sink for that introduced hop-by-hop backpressure in ACOH to suppress the generation of these data. However, this mechanism involves too much resource and consumes more additional energy for every step by step process, which is very limit in WSN.

Problem identification and proposed solution

In our previous work, we have proposed a hierarchical tree based congestion control protocol using fuzzy logic for heterogeneous traffic in WSN. Initially, the hierarchical tree is constructed using topology control algorithm. Then the congestion detection is performed using fuzzy logic technique based on the parameters such as packet service ratio, number of contenders and buffer occupancy. In order to control the congestion, a dynamic rate adaptation or adjustment is performed. If rate adjustment is not feasible, then source selects the alternate path from the established hierarchical tree. However, it does not provide fair rate allocation for each traffic flow and alternate path may not be discovered always.

Overview

So as an extension work, we proposed a Priority Based Congestion Control Protocol and Fair Rate Allocation for WSN.

- All intermediate sensor nodes are categorized into near-source nodes and near sink nodes [10].
- For route establishment [7], the transfer confirmation is done depends on the high priority confirmation (sensitive traffic) and low priority confirmation (non-sensitive traffic) of the sensed event. In data forwarding, sensitive and non-sensitive routing tables are created in which the data recorded from the events observed by nodes are given to the sink.
- When congestion occurs, build an auxiliary routing [15] so that partial data flow can round the congestion node to non-congestion branch.
- For congestion control, near source and near sink modules [10] are used for allocating a fair rate to each passing flow in effective proportion. Near-source node compares the incoming rate of each flow and the fair bandwidth share for adjusting the transmission rate by using channel busyness ratio as a metric. Near-sink nodes use a lightweight probabilistic dropping algorithm based on queue occupancy and hit frequency.
- When part of the data exceeds the network throughput or the rate of a particular flow is higher than that of others can't be received by sink for that hop-by-hop backpressure signal [10] is transmitted towards the source to suppress the generation of these data.
- Fig.1 represents the proposed block diagram. First, the classification of intermediate node is done into near-source node and near-sink node. After, that route establishment is done for the intermediate node. To efficiently detect the congestion auxiliary routing is established. For fair rate of allocation, near-source and near-sink congestion control module is designed. To suppress the exceeding data hop by hop backpressure signal is implemented.

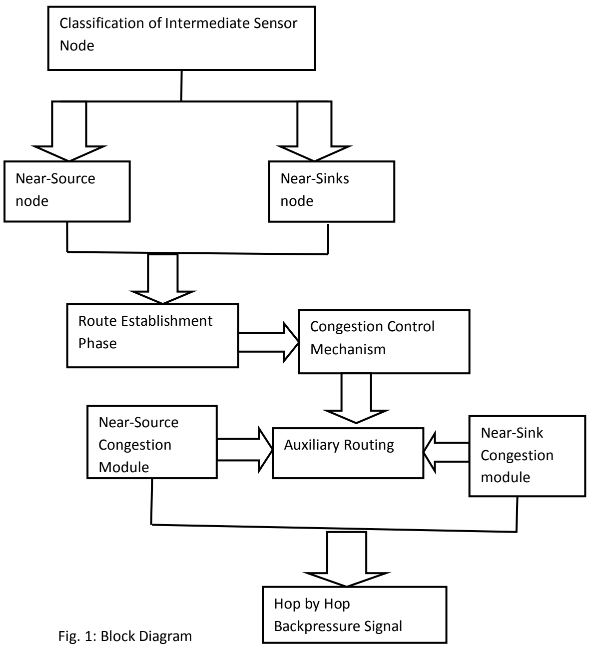

Fig. 1: Block Diagram

Classification of intermediate sensor nodes

Due to the event-driven unique characteristics of WSNs, a large number of flows can be generated when any events occur. To attain a multidimensional view of the object region, it is must to assure that each flow transmits its data to the sink in a fair manner. However, a pool of sensors producing high-rate data can easily crush the network such that the network is unable to operate effectively. Hence, it is essential to offer a fair rate allocation for each traffic flow.

To achieve a fair rate allocation for traffic flow, we have classified the intermediate sensor node into near source node and near sink node [10]. The main aim is to adjust the sending rate of each flow immediately as well as save the scarce resource at the node close to the sink.

Near-source nodes are those nodes which are close to the source. They maintain a per-flow state and allot an almost fair rate to each passing flow by evaluating the incoming rate of each flow and fair bandwidth share.

Near –sink nodes do not require maintaining a per-flow state and employ a lightweight probabilistic algorithm according to queue occupancy and hit frequency.

To classify the intermediate node, optional field is used. Here, each and every source node sets its label field (for example label=K) for every packet. This label signifies how far away this particular packet is from sensing field. Each forwarding node upgrades the label field by subtracting one (label=label-1), as soon as it receives a packet till the label field equals zero.

During a fixed interval of time, every intermediate node estimates the ratio P_R as:

$$P_R = \frac{\#of\ packets(label > 0)}{\#of\ total\ delvering\ packets} \quad (1)$$

Obviously, the larger P_R is, the closer the node is to the source nodes. Hence, the intermediate node is a near-source node in case P_R is no less than a threshold P_R (for e.g. 90%). Else, the intermediate node is a near-sink node.

In WSNs, a flow generally navigates a few hops from its source to the sink. Here, the intermediate nodes cooperate with each other to transmit the packet to the sink. Moreover, these nodes take on different roles and employ different processes for different objectives. The classification between near-source nodes and near sink nodes depends on sink as well as QoS requirement. For example, in case the convolution on the near-source node and energy efficiency are matters, a smaller K is used to offer less near-source nodes and more near-sink nodes. Also, in case the energy is not limited, we can set larger K to control possible congestion.

Route establishment phase

This section describes about the route establishment phase. After, the classification of intermediate nodes, route establishment is done in order to efficiently maintain the routes to sink through the intermediate nodes.

Once the source node is selected, packets are transmitted. As the packets move along the route, it creates a routing table. The transfer confirmation mainly depends on the priority of the sensed event. The transfer confirmations are based two types of confirmation: high priority confirmation (sensitive traffic) and low priority confirmation (non-sensitive traffic).

During this phase, two tables are constructed. Routing table of each node maintains the best routes to the sink through the near-sink nodes. By considering the maximum number of neighbors for each node in WSN, the routing table will be practical and small.

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
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When a node receives a packet with high priority, it creates a high priority record for the packet in the routing table. This table consist of the following components as shown in Table1.

- Sender (the source node receiving packet with high priority)
- Receiver (the destination node for the packet with high priority)
- Source Node (the node sensing the event which is final destination of the packet)
- Type of application (this component is used in the networks designed for multiple applications.

Table: 1

Routing Table			
Sender	Receiver	Source Node	Type of application

The component is for high priority packets and the process continue till the packet reaches source node. Moreover, at the end of the route establishment, a record is placed in the sensitive route establishment routing table for each source.

Next we will explain about the creation of low priority traffic routing table. From, the record updated by the intermediate nodes, the sink considers the record chosen in relation to the source. For each of these records, the probability PSR_i is calculated using equation (2)

$$PSR_i = \frac{LR_i / HN_i}{\sum_k (LR_k / HN_k)} \qquad (2)$$

Where LR_i is the route length between node i and sink node

Also HN_i is the number of hop count for the ith record route

PSR_i is the route selection probability of selecting the record as the next hop for low priority packet.

Once PSR_i is found for all records with the proposed source, then two records are selected based on probability. Then, low priority packet based on the new record is sent to these records. A number of different routes are selected so that fairness is observed in energy consumption of the intermediate nodes. Each intermediate node receives a packet with low priority and updates it in its routing table. Then through a process alike sink, near-sink nodes are selected and data packet is sent to them. All the exclusive characteristics are recorded in non-sensitive route establishment routing records.

Data forwarding phase

Once the route establishment is done, sensitive and non-sensitive routing tables are also formed. Each intermediate node including source comprised of sensitive and non-sensitive routing table. The significance of this protocol lies in multipath routing and hence can distribute packets through more than one path.

Based on the type of sensed event, the source node can broadcasts its data to the sink after receiving sensitive traffic from the route establishment phase. As already mentioned, all nodes including the source node have two different types of routing table. Sensitive routing table is used for transmitting sensitive data and non-sensitive routing table is used for transmitting non-sensitive data.

For sensitive traffic, there is only one record towards the sink for each source. Each node receives sensitive traffic from the node in question and makes use of the traffic to send the record to the next hop.

However, this is not the case with non-sensitive traffic. Here, there will more than one record for each source in the table and each record has a probability PSR_i based on which the next hop is selected. The greater the PSR_i in the record, more likely it will be selected. Finally, a record will be selected as the next hop and data are transmitted to this record.

Congestion control mechanism

This section describes about the routing method adopted, to handle the congestion occurrence in the network.

Enhanced auxiliary routing

The main aim is to create an auxiliary routing so that half of the data flow can turn the congestion node to non-congestion branch based on the sensitive and non-sensitive traffic. In order to avoid any kind of routing loop, we consider number of hop count as an important indicator.

Here, the congestion control routing frames consist of three essential command frames:

- In case, the congestion occurs at some intermediate nodes in the network, then it will broadcast a CONGESTION frame to all the prior one-hop children nodes.
- Then, the children nodes instantly radio all neighbour nodes with a HELP frame which

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
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contains the hops parameter (node itself to the sink node).

- The neighbour receiving HELP frame will give a feedback, HELP_REPLY frame under two conditions:
  - First, its hop count is not greater than number of hop count in HELP frame
  - Second, it is not congestive

The HELP_REPLY frame consists of the hop and other major indicator represented as ER.

Finally, as per the feedback information, children node selects one neighbour with the highest fitness as the auxiliary node. At this particular point, an auxiliary link is established absolutely.

ER means assistance expectation, we describe it as:

$$ER = R_{send} - R_{recv} \quad (3)$$

Here, R_{send} represents the expected maximum output rate of auxiliary node at current running time.

Also, R_{recv} represents instant input rate of auxiliary node. Both, these parameters are even available for the MAC layer.

A help node may receive obtain multiple HELP_REPLY frames, hence it is essential to select the auxiliary node with higher fitness to update the auxiliary link. This process is done by comparing:

- The hop parameters and choosing the auxiliary node which has smaller hops count to the sink node.
- In case, the hops parameters are equivalent, choose the auxiliary node which has larger ER value.

Frame instruction of the above mentioned three command frames are listed in Table.2. They are actually short broadcasts frame and Time to Live (TTL value as 1). Hence, the establishment of the auxiliary link will be very prompt process. The CONGESTION frame has two states: TRUE means occurrence of congestion and FALSE means relieving congestion.

Table: 2

Name	Frame ID	Frame Instruction		
CONGESTION	0xoo	State	R_{send}	$R_{receive}$
HELP	0x02	hops		
HELP_REPLY	0x04	hops	R_{send}	$R_{receive}$
BP	0x08	state	R_{send}	$R_{receive}$

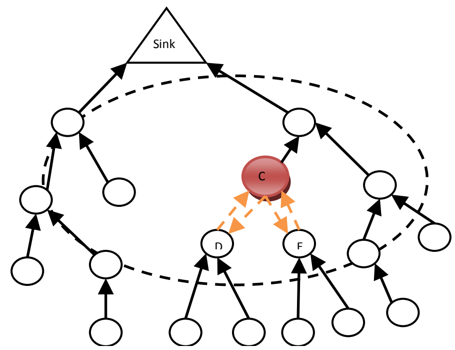

Fig.2 (a) Congestion Occurrence at node C

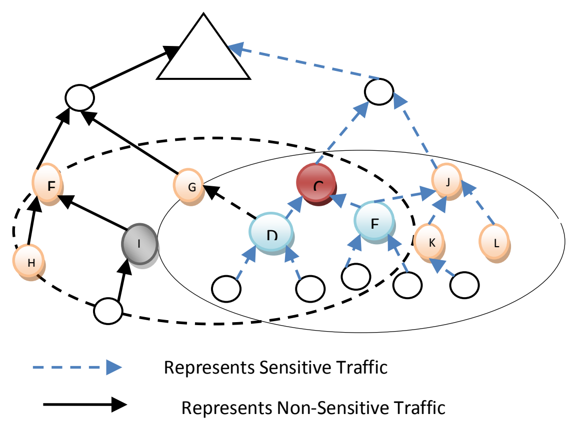

Fig.2 (b): Illustration of Congestion Control Mechanism

Illustration of the whole process is shown in Fig.2 (a) and 2(b). Congestion is occurring at the near-sink node C because of the large amount of data flow, and then node C transmits to inform node D and E. The node D and E radio the nearby neighbors with HELP frame after receiving the CONGESTION frame of true state. Wait for the nodes which have greater ho count than D and E, the node F, G, H and J, K, L respectively feedback HELP_REPLY frames to D and E. The node I do not reply due to occurrence of the congestion. Taking D for example, F and G has smaller hops (that is 2 < 3), hence H is excluded. As a

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greater ER value of the node G, the auxiliary link of D to G is established.

Near-Source module for fair rate allocation in auxiliary tree

This section describes about the effective congestion management by allocating a fair rate to each passing flow in effective proportion for the nodes in the auxiliary tree to control the congestion. The near-source node considers Channel busyness ratio B_R as a metric to differentiate congestion status and network utilization for the IEEE 802.11 MAC. For this, first calculate the available bandwidth resource and the incoming rate of each flow. Hence, an effective transmission control mechanism is developed based on the above mentioned metrics.

Estimation of available bandwidth

Channel busyness ratio B_R is described as the ratio of time intervals while the channel is busy due to successful transmission or collision to total time taken, gives a good early sign of network congestion. It has been observed that, channel utilization for the best possible point is almost same for different numbers of active nodes and packet sizes that means 95% (with request to send/clear to send). Based on that, set a threshold TH_b, to 92% and leave 3% space for saturation. Once selecting the TH_b value, we can easily calculate the available bandwidth of each node which is denoted as DW_a as follows:

$$DW_a = \begin{cases} 0 & B_R \geq TH_b \\ DW(TH_b - B_R)\overline{data/T_t} & B_R < TH_b \end{cases} \quad (4)$$

Where DW represents the transmission rate in bits per second for the DATA packet.

Data represents the average payload size estimated by the channel occupancy time

T_t represents average time of a successful transmission at the MAC layer.

Hence, as long as the channel busyness ratio does not exceed the threshold, the node will not function in the overload status and the free bandwidth can be utilized to accommodate more traffic without resulting in severe MAC conflict. This available bandwidth can be used by each and every node including observed node.

Estimation of the arrival rate

At each near-source node, an exponential averaging as given in equation (5) is used to calculate the rate of flow. Assume that t_i^j represents the arrival time of the jth packet flow i and L be the packet length. The calculated rate of flow i that means R_i is updated while the jth packet is received as

$$R_i^j = (1 - e^{-\frac{T_i^j}{J}})\frac{L}{T_i^j} + 1 - e^{-\frac{T_i^j}{J}} R_i^{J-1} \quad (5)$$

Where $T_i^j = t_i^j - t_i^{j-1}$ represents the inter packet arrival time and J represents constant. The selection of J value is critical. First, a small J value makes the system immediately adapt to rate fluctuations and large J value filters the noise and evade potential instability.

Second, J value should be large enough such that calculated rate remains fairly accurate even after packet traverses multiple links. This is all because the delay jitter modifies the packet inter-arrival arrangement that may result in an increased difference between the calculated rate and the existing rate. To neutralize this affect, as a rule of Thumb, J should be one order of magnitude greater than delay jitter practised by a flow over a certain time interval of the same size.

Finally, J should not be larger than the average duration of flow. It has been proved that, by using parameter $e^{-\frac{T_i^j}{J}}$, under a wide spectrum of condition, the estimated rate will asymptotically converge to real state.

Near-sink node module for fair rate allocation in auxiliary tree

This section describe about the fair flow allocation mechanism by near-sink module.

Stateless fair queue management technique

Every near-sink node is a hotspot with a high probability due to dynamic nature of WSNs. Hence, the resource of near-sink node is more significant. We discover a simple and effective technique to implement transmission control for near-sink nodes. Here, preset two threshold Q_a and Q_H for queue occupancy. Once new packet arrives, the near-sink node estimates hit frequency H (t) by evaluating whether the packet is from the same flow as one of the P packets arbitrarily selected from the buffer. The hit frequency is increased by one in case one of the packet and the newly arrived packet belong to the same flow.

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
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Spontaneously, a higher hit frequency H (t) means a larger number of packets exist in the buffer for a particular flow. To gain fairness, give more probability to those flows with lower occupancy. Hence, the arriving packets that belong to higher occupancy flows have higher dropping probabilities. Estimate the dropping probability P_d of the arriving packet based on hit frequency H (t) as follows:

$$P_d = \begin{cases} 0 & Q(t) < Q_a \\ H(t)/G & Q_a \le Q(t) < Q_H \\ 1 & Q(t) \ge Q_H \end{cases} \quad (5)$$

Hop by hop backpressure signal

In case, a part of data exceeds the network throughput or the incoming flow is higher than that of the others such and sink is unable to handle the flow, then hop by hop back pressure signal is broadcasted to suppress the generation of these data.

If packets are dropped and the queue occupancy lies between Q_a and Q_H, then it indicates that rate of particular flow is still greater than that of others and needs to be reduced further. To handle this, simply reduce the sending rate of the corresponding source node. In case queue occupancy exceeds Q_H then the arriving packet is dropped, which represents that the traffic is overpowering, and require decreasing the rate of all passing flows.

In order to feed the network condition information back to consequent source node, the near sink node produces a Warning Message (WM) comprised of flow ID and a node ID as long as packet loss occurs. The WM as a backpressure signal is ultimately transmitted to a certain near-source node as shown in Fig. 3. Lastly, the near-source node takes the .consequent abovementioned actions

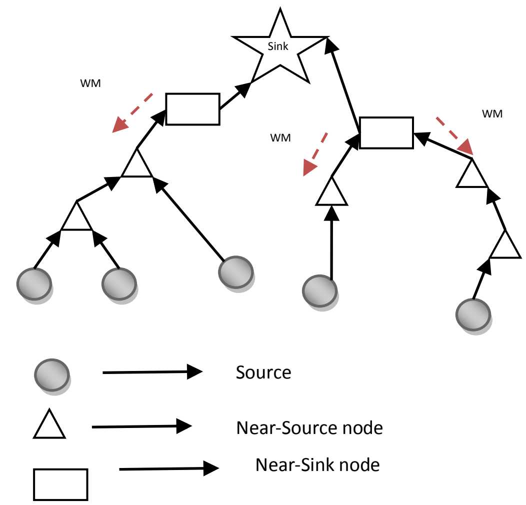

Fig.3 Demonstration of Hop by Hop backpressure Signal

The overall algorithm

//Classification of intermediate node//

1. *For each node N*
2. *Set label=K*
3. *Update the label field (label=label-1)*
4. *Continue till label=0;*
5. *Estimate* P_R
6. *If* P_R *is not less than Threshold*
7. *Then consider as near-source node*
8. *Else*
9. *Consider it as near-sink node*

//Route Establishment Phase//

10. *Construct routing table for high priority confirmation (sensitive traffic) and low priority confirmation (non-sensitive traffic).*
11. *If node N receives high priority confirmation*
12. *Then it updates the routing table with component (sender, receiver, Source Node, Type of applications.*
13. *For low priority traffic, estimate route selection probability* PSR_i *for the proposed source*
14. *Select low priority packet based on the new record*

// Data forwarding Phase//

15. *For sensitive traffic forward one record for each source*

16. For non-sensitive traffic forwards data packet based on PSR_i

// Auxiliary Routing//

17. If congestion occurs, send CONGESTION frame to all prior one-hop children
18. Children nodes broadcasts HELP frame to all neighbor nodes
19. Node receiving HELP frame reply with HELP_REPLY
20. If(Hop Count is not greater than number of hop count in HELP frame & not Congestive)
21. Select auxiliary node
22. Choose node with higher fitness
23. Compare hop count
24. Node N with smaller hop count to sink is selected as auxiliary node
25. If hop parameter are equivalent
26. Compare ER value
27. N with lager ER value is selected as auxiliary node.

// Near Source Module For fair rate allocation//

//Estimate the available bandwidth//

28. If the channel busyness ratio doesn't exceeds TH_b
29. Then, use the available bandwidth
30. If it exceeds
31. Then congestion occurs

//Estimate arrival rate//

32. Determine the rate of flow
33. Neutralize the rate of fluctuation

// Near-Sink Module for fair rate allocation//

34. Preset queue occupancy as Q_a and Q_H
35. On new packet arrival, near-sink node estimates H(t)
36. Evaluate packet is from same flow
37. If packet is from same flow, then increase hit frequency by one
38. Higher H(t) means large number of packets in buffer
39. Give more probability to packet with lower occupancy
40. Estimate the dropping probability

// Hop by Hop backpressure Signal//

41. If packet are dropped queue occupancy lies between Q_a and Q_H
42. Then rate of flow is greater than others
43. Reduce the sending rate of corresponding source node
44. If queue occupancy exceeds Q_H, then arriving packet is dropped
45. To update the network status sink node produces WM with flow ID and node ID

Simulation results

Simulation model and parameters

The Network Simulator (NS2) [16], is used to simulate the proposed architecture. In the simulation, 50 mobile nodes move in a 1000 meter x 1000 meter region for 50 seconds of simulation time. All nodes have the same transmission range of 250 meters. The simulated traffic is Constant Bit Rate (CBR).

The simulation settings and parameters are summarized in table.

No. of Nodes	50
Area Size	1000 X 1000
Mac	IEEE 802.11
Transmission Range	250m
Simulation Time	50 sec
Traffic Source	CBR
Packet Size	512
Flows	2,4,6,8 and 10
Initial Energy	8.5J
Transmission Power	0.660
Receiving Power	0.395
Rate	50Kb

Performance Metrics

The proposed Priority Based Congestion Control Protocol for Fair Rate Allocation (PBCCFRA) is compared with the Fairness-Aware Congestion Control Scheme (FACC) [10]. The performance is evaluated mainly, according to the following metrics.

- **Packet Delivery Ratio:** It is the ratio between the number of packets received and the number of packets sent.
- **Packet Drop**: It refers the average number of packets dropped during the transmission
- **Energy Consumption**: It is the amount of energy consumed by the nodes to transmit the data packets to the receiver.
- **Delay**: It is the amount of time taken by the nodes to transmit the data packets.

Results

1) Based on Flows

In our first experiment we vary the number of flows as 2,4,6,8 and 10.

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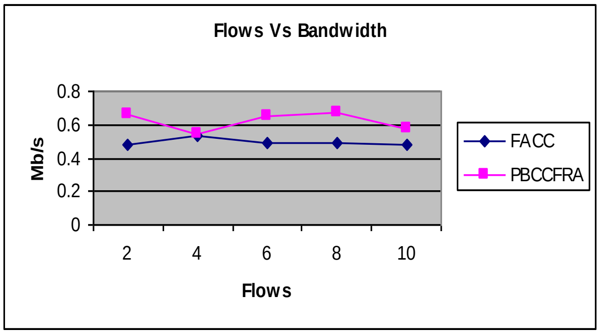

Fig 4: Flows Vs Bandwidth

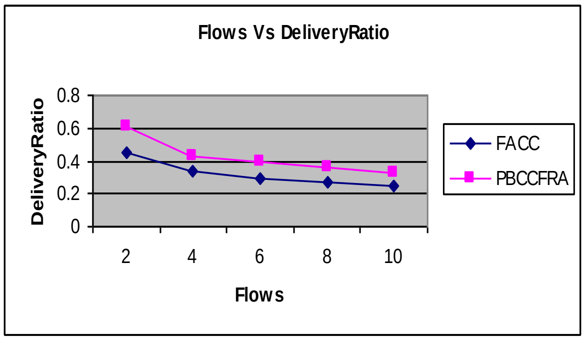

Fig 5: Flows Vs Delivery Ratio

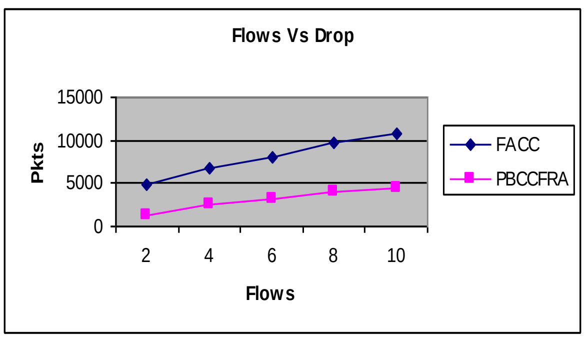

Fig 6: Flows Vs Drop

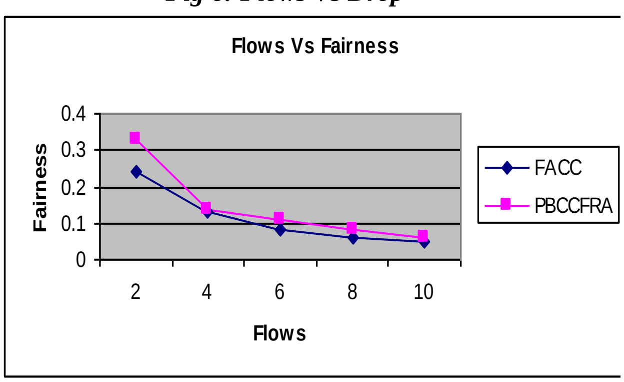

Fig 7: Flows Vs Fairness

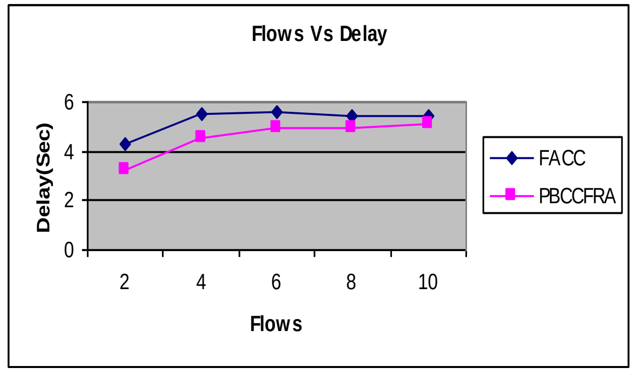

Fig 8: Flows Vs Delay

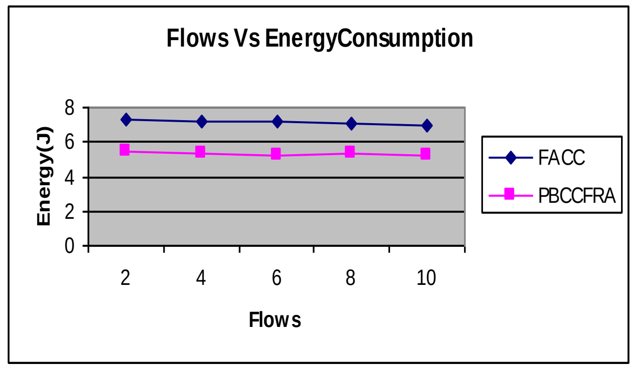

Fig 9: Flows Vs Energy Consumption

Figure 4 shows the received bandwidth of PBCCFRA and FACC techniques for different number of flows scenario. We can conclude that the received bandwidth of our proposed PBCCFRA approach has 19% of higher than FACC approach.

Figure 5 shows the delivery ratio of PBCCFRA and FACC techniques for different number of flows scenario. We can conclude that the delivery ratio of our proposed PBCCFRA approach has 25% of higher than FACC approach.

Figure 6 shows the drop of PBCCFRA and FACC techniques for different number of flows scenario. We can conclude that the drop of our proposed PBCCFRA approach has 63% of less than FACC approach.

Figure 7 shows the fairness of PBCCFRA and FACC techniques for different number of flows scenario. We can conclude that the fairness of our proposed PBCCFRA approach has 19% of higher than FACC approach.

Figure 8 shows the delay of PBCCFRA and FACC techniques for different number of flows scenario. We can conclude that the delay of our proposed PBCCFRA approach has 14% of less than FACC approach.

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

Figure 9 shows the energy consumption of PBCCFRA and FACC techniques for different number of flows scenario. We can conclude that the energy consumption of our proposed PBCCFRA approach has 26% of less than FACC approach.

Conclusion

In this paper, we have proposed a Priority Based Congestion Control Protocol and Fair Rate Allocation in WSN. In our proposed method an efficient route establishment is done based on the priority of the traffic to transmit the packet. For efficient congestion control, auxiliary tree is constructed to transfer some of the data of lower priority to non-congestion branch. For fair rate of allocation the intermediate nodes are classified in to near-source node and near-sink node to transmit the packet. Near source node considers the channel busyness ratio to detect any kind of congestion. Based on the bandwidth allocation and incoming rate of flow near-source node fairly allocate the available resources . Near-Sink nodes check for the queue occupancy and allocate available space to the packet with low occupancy. In case, the rate of data flow exceeds hop by hop backpressure signal technique is used to control the overwhelming data.

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Acknowledgements

We are very much thankful to authors of FACC paper.

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