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Joint Congestion Control and Packet Scheduling in Wireless Sensor Network

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Abstract

Background: Congestion is the most important starting place for packet drop, escalating queuing delay, small throughput, retransmission of packets, and hence utilization of extra energy, also running down of communication resources. With the aim of surpassing this complication, Joint Congestion Control and Packet Scheduling (JCCPS) mechanism with the help of Space-Time Division Multiple Access (STDMA) is proposed in this research work. **Methods:** Here, an extended version which makes use of both cluster and tree based strategy is formulated. This builds a node-centric approach that makes a load balanced tree in WSNs of asymmetric structural design. **Results:** The proposed approach results in less congestion in the complete network, boosts the throughput and at the same time increases the packet delivery ratio (pdr) and also diminishes delay. Moreover, it also boosts network efficiency by the way of increased delivery of packets. Load balancing, network lifetime, and scalability are essential constraints for numerous data collecting sensor network applications. Furthermore, the proposed STDMA packet scheduling approach has enhanced working than the existing schedulers in accordance with the average task waiting time and end-to-end delay. **Conclusion:** The proposed JCCPS protocol is very effective to determine the constraints which influence the network.

Keywords: Congestion Control, Clustering, Cluster Tree Topology, Load Balancing, Packet Scheduling and Congestion Control Protocol, Space-Time Division Multiple Access

1. Introduction

Wireless Sensor Network (WSN) includes a bulky amount of small, reduced power, arbitrarily spreaded sensor nodes. WSN incorporates a potential of sensing, performs useful operations and communication through a wireless channel and to tolerate within problematical atmosphere like excessive noise, defective/lifeless sensor node, etc. Sensor networks at present acquired substantial interest, since there is considerable potential structure for data collection in the scenario of pervasive computing. In this particular field, WSNs take part an extraordinary responsibility in environmental observation, home automation, military, health and supplementary applications. Several categories of data are produced and sent in WSN to the Base Station (BS) through nodes. These kind of nodes could be motionless or moving. They might be familiar with their locality. WSN are categorized into two groups in accordance with the data compilation and communication. In case of event dependent system sensor nodes, broadcasts the data to the BS during the time of event happens, simultaneously data packets are accounted to BS from time to time in accordance with the data flow. In case if huge numbers of sensor nodes are in process concurrently in sending the data, at that point of time data traffic raises than the existing potential of network, this cause congestion. The foremost causes of congestion comprise interference, buffer overflow and channel contention, many to one feature (i.e. multiple sources and single sink)[1].

Congestion is said to take place in WSN when the inward traffic load happens to be higher when compared to the existing network potential[2]. The structural design features of the node and its network root for congestion[3]. The features of a node which possibly will cause congestion are slow processor, inadequate energy and limited memory of nodes. Sensor nodes have inadequate memory

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in the type of buffers. In a node, if the incoming rate is higher than its outgoing rate, it must drop packets as a result of the inadequate potential of buffers. In addition, sluggish processors also source for congestion because queues might well increase as a result of them, although there is adequate network potential. The restricted energy of nodes leads them to shift to sleep state in case if they are not in the receiving or transmitting mode. The structural design features of network which possibly will cause congestion are many to one quality, event driven characteristic, channel interference and reporting rate. As a result of many to one quality of WSNs, congestion takes place in the nodes close to the sink at the same time as packets from the network converge there. WSNs can comprise two categories of flows: event driven or periodic[4]. In case of event driven flows, they have unpredictable reporting rate at the same time periodic flows encompass steady reporting rate. In both these kind of flows, the congestion setback takes place on increasing the reporting rate. In WSNs, channel contention takes place by reason of the shared communication channel. It possibly will take place between the packets of similar flow or flows run away all the way through the identical vicinity. This congestion also cause collision setback. The complication of scheduling collision-free broadcasts through a node (regarded as node activation) to the entire neighbors exclusive of any additional packet interfering during transmission is vital. The complication has been originated in certain manner that only single node is allocated to a particular time slot. Numerous scheduling approaches for TDMA protocol with diverse objective have been formulated for WSNs. Even though there are numerous TDMA based MAC layer protocols formulated for WSNs, there is no single protocol acknowledged as a standard. The major source for this is that the MAC protocol preference might, normally, be application oriented, which indicates that there will not be one specific MAC for WSNs. One more source is the deficient in consistency at subordinate layers (physical layer) and the (physical) sensor hardware. In general, TDMA has a normal benefit of collision-free medium access, on the other hand in certain protocols this cause interference because of slot reuse.

Time synchronization is necessary in these protocols as a result of clock drift complication. Adjustment to topology transformations is an additional trouble faced by TDMA system as these transformations are generated by introduction of new incoming nodes, collapse of battery powers busted links as a result of obstruction, the sleep agendas of relay nodes, and scheduling generated by clustering approaches. The slot on the other hand, is not simple to transform the slot allocation inside a decentralized atmosphere for conventional TDMA, because the entire nodes must have the same judgment on the slot allocations. Familiar wireless networking knowledge also recommends that link-level performance alone possibly will give misleading conclusions regarding the system performance. A comparable conclusion can be drawn for the upper layers also. Therefore, the more layers take part in the decision, the more effective the system. For example, the routing path could be selected in accordance with the collision data from the medium access layer. Furthermore, layering of the network protocols generates overheads for every layer, which leads to more energy utilization for every packet. As a result, incorporation of the layers is too a potential research field that requires to be investigated further comprehensively.

In this research work, a well-organized Joint Congestion Control and Packet Scheduling (JCCPS) proposed to accomplish elevated throughput and packet delivery ratio (pdr), also reducing interruption. Here, in the beginning the cluster tree topology is constructed with the assistance of modified Fuzzy C Means Clustering. The Load balancing strategy also executed for the cluster tree topology. This approach is employed for the purpose of detecting the congestion by means of the constraints like queue length, packet service ratio and so on. Following the congestion discovery, congestion control is executed. The packets are scheduled in this approach with the help of STDMA protocol. Accordingly, the complication of congestion is reduced, in addition the TDMA complications are solved. Fairness can be accomplished by means of packet scheduling (also indicated as queue management) at each sensor node. In the subsequent sections, demonstrated how the joint congestion control and packet scheduling (JCCPS) is implemented.

The following sections are organized as follows: Section describes II related works. Section III contains Working of implemented JCCPS Protocol. Section IV explains the experimental results and discussions. Section VI contains the conclusion.

2. Related Works

Several scheduling approaches are proposed for expanding the life span of WSN. The author in[5] formulated a new scheme for task allotment in wireless sensor actor network which promise that the task complete their activities sooner than their time limit ends.

Tirkawi and Fischer[6] formulated scheduling in nodes reliant on their depth from BS in order that these nodes can have better possibility to take part in sensing. Priority dependent low power task scheduling based on battery model & task model was formulated in[7] to lessen energy consumption of the tasks. Congestion control is an additional significant concern that is supposed to be considered in transport protocols. Congestion is a basic complication in WSNs.

Peng, Soong, and Wang[8] provided the TDMA with a scheduling matrix. The row of the matrix indicates the length of the frame at the same time the column of the matrix indicates nodes. The elements of the matrix indicate transmission authorization.

Momeni, Sharifi and Sedighian[5] optimized the number of rows that indicates to the frame length with Tabu search and greedy algorithm. This scheme can diminish the average latency and generate high throughput in a dense area.

Peng, Soong and Wang[8] demonstrated that the scheduling matrix optimization is an NP complete setback. They also formulated an approximation scheme, Mean Field Anneal (MFA) for the purpose of optimizing the schedule matrix. The matrix optimization is segmented into two stages: minimize frame length and maximize throughput.

Salcedo-Sanz, Bousono-Calzon and Figueiras-Vidal[10] reduced the frame length with a Neural Network (NN), furthermore increased throughput with a Genetic Algorithm (GA), while Yeo, Lee and Kim[11] implemented the Sequence Vertex Coloring (SVC) in both stages. Shi and Wang[12] formulated a hybrid approach which integrated Back-tracking Sequential Coloring (BSC) and Noisy Chaotic Neural Network (NCNN) for the purpose of optimizing the scheduling matrix. BSC-NCNN provides the nominal average time delay, in the mean time the NN-GA offers higher throughput.

Ahmad and Shoba[13,14] recommended an idea to keep away from packet collision. The network topology is indicated by a Finite State Machine (FSM). The collections of nodes are grouped with the maximal compatibles and incompatibles conception. This approach begins by setting up an amount of groups that equals the amount of nodes. Subsequently, integrate groups together under the provision that no nodes in the similar group are neighbor nodes. At last, the entire sensor nodes are clustered in several groups and they can transmit packet simultaneously without any collision. The amount of groups is frame delay at the same time the summation of number of node in the entire groups is throughput. This concept leads to reduce latency and maximize throughput. Congestion in WSNs and WMSNs that can cause packet failures and amplified transmission latency has a straight influence on the energy effectiveness and application QoS, and as a result must be well controlled in Akyildiz, Tommaso and Chowdhury[15].

CODA (Congestion Detection and Avoidance) Wan, Eisenman and Campbell[16] is a kind of congestion mitigation approach that employs both buffer use and channel load for computing congestion intensities in the network. It employs two approached for managing mutually persistent and transient congestions. CODA executes rate modification with the use of conventional TCP-like AIMD (Additive Increase Multiplicative Decrease) scheme and accordingly causes the incidence of packet loss.

Fusion Hull, Jamieson and Balakrishnan[17] discovers congestion by means of measuring the queue length. It manages congestion by integrating three methods; hop-by-hop flow control, prioritized MAC and source rate limiting. Fusion declares to accomplish better throughput and fairness at high offered load.

Ee and Bajcsy[18] formulated a congestion control approach which makes use of packet service time to deduce existing service rate and consequently discovers congestion in all intermediary sensor nodes. This scheme manages congestion in a hop-by-hop style and employs accurate rate modification depending on its existing service rate and amount of child nodes. Alternatively, it is not possible to make use of existing link capacity competently, in case if certain nodes are in sleep status.

Siphon[19] formulated a new congestion mitigation scheme which finds out congestion by way of queue length. On the other hand, instead of exploiting any rate modification scheme, it makes use of traffic redirection for the purpose of diminishing congestion. At present, a node-priority dependent congestion control scheme, PCCP[20] was formulated. This scheme sets up a regimented congestion discovery scheme by considering mutually node and link level congestion. On the other hand, there is no method for managing prioritized heterogeneous traffic.

3. Materials and Methods

The proposed work having following modules:

1. Clustering method for generating cluster tree topology

2. Node-centric load balancing process is carried out for the purpose of consistently allocate packet traffic
3. Discovery Phase (preserving database of each node).
4. Congestion detection and congestion notification phase
5. Congestion Control Module to circumvent congestion on a multi path of data
6. Execution of the STDMA Scheduling Algorithm.

3.1. Network Model

In a vast quantity of sensor nodes sense the incident and the data are sent through sink node that will utilize the neighborhood or is linked to a different network by means of gateway. BS functions like a gateway in the midst of sensor nodes and end users. The child node contains numerous parents. These parent nodes consist of the route information from their child nodes known as transit traffic and comprise its individual originating data known as source traffic. The data traffic directs multipath from source to destination node. In this process, parent nodes allocate the bandwidth to its subsequent child nodes. Here, dynamically allocated arbitrary precedence to packets. Consider a WSN includes a large number of multi-purpose nodes which are organized in a particular objective region. Every node has the ability to sense different categories of data simultaneously and transmits those to the BC. Figure 1 illustrates a network model. Congestion control is considered in this network setting.

3.1.1. Parameters

Choosing suitable parameter for any particular WSN is an additional challenge. However, at this point it is essential to suggest those parameters which are frequent for fairly the entire WSN which are provided as given below:

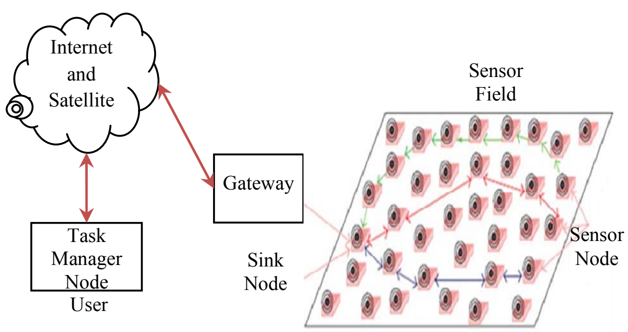

Figure 1: Sample Network Model

a) Distance
One of the most important features for WSN is distance. It is proper to exploit Mahalanobis distance from the BS to every node. The maximum the distance more energy is necessary to data interchange.

b) Cluster Head Selection
Following the centroid locations are decided in the clustering development, take nodes which are at the close distance and in addition the subsequent close distance from the centroid. The node with maximum energy is taken as cluster head. When more than one node in the two levels has the maximum energy, then the node close to the centroid is chosen as cluster head
The major phases or blocks of the proposed approach is

- Tree Constructing Phase,
- Self-Organized Data Collecting and Transmitting Phase, and
- Information Exchanging Phase.

Clustering using Modified FPCM
For the purpose of carrying out clustering, the sensor nodes are divided into several clusters. All the clusters are controlled by a node indicated as Cluster Head (CH) and remaining nodes are indicated as cluster nodes. These cluster nodes do not keep in touch openly with the sink node. It must transmit the gathered data to CH. In turn CH will combine the data obtained through cluster nodes and sends it to BS. As a result diminishes the energy utilization and number of messages communicated to BS. In addition, amount of active nodes in communication is diminished. At this stage, Modified Fuzzy Possibility C-Means Clustering (MFPCM) builds up a clustering method based on the energy of the nodes with the aim of extending the life span of WSN. Here made certain assumptions for the appropriate process of the proposed algorithm. The foremost assumption made is that the BS has no restrictions on its energy resources and the entire nodes primarily have the similar energy available. The function of a WSN begins with the cluster set up stage, the clusters of sensor nodes are generated, subsequent to the data transmission stage, at this stage cluster nodes will send the gathered information to CH. Every CH combines the data obtained from cluster nodes and transmits to BS. The proposed algorithm is explained as follows:
Modified Fuzzy C Means Clustering
One of the most vital parts is the selection of appropriate objective function for the accomplishment of the cluster

performance and to achieve enhanced clustering. Consequently, the clustering optimization depends on the objective function to be employed for the purpose of clustering. In order to achieve a proper objective function, the subsequent set of conditions is taken into account:

The distance in the middle of the clusters and data points distributed to them must be diminished

The distance in the middle of the clusters must be diminished

The desirability in the midst of data and clusters is indicated through the objective function. Besides, Wen-Liang Hung formulated a novel scheme known as Modified Suppressed Fuzzy C-Means, it enhances the performance of FCM to the highest degree as an effect of a prototype-driven learning of parameter α. In this learning process of α is reliant on an exponential separation strength among the clusters and is tuned during iteration. The α is provided as given below:

$$\alpha = \exp\left(-\min_{i\neq k}\frac{\left\|v_i - v_k\right\|^2}{\beta}\right) \tag{1}$$

where, β indicates a normalized name with the intention that β is considered as a sample variance. β is provided as given below:

$$\beta = \frac{\sum_{j=1}^{n}\left\|x_j - \bar{x}\right\|^2}{n} \text{ where } \bar{x} = \frac{\sum_{j=n}^{n} x_j}{n} \tag{2}$$

In contrast, the report which must be given at this point is the more familiar value utilized for this constraint by the entire data at every iteration, which might be offered in fault. Accordingly, the weight constraint is established for the purpose of finding a more familiar value for a. Otherwise every point of the data set incorporates a weight in connection with every cluster. Accordingly, the use of weight permits enhanced classification. So, the weight is found out as provided below:

$$w_{ij} = \exp\left(-\frac{\left\|x_j - v_i\right\|^2}{\left(\sum_{j=1}^{n}\left\|x_j - \bar{v}\right\|\right).\frac{c}{n}}\right) \tag{3}$$

Where, w_{ji} represents the weight of the point j compliant with class i. It is utilized for the purpose of adjusting the fuzzy and typical partition. The complete techniques described thus far are iterative in nature, for the reason that it is unfeasible to transform the objective functions approximated straightly. Otherwise in order to group a data point, it is essential that cluster centroid has to be closer to the data point, it is membership; and in order to determine the centroids, the typicality is employed for lessening the unnecessary source of outliers. The objective function comprises of two functions:

1. Fuzzy function and implementation of fuzziness weighting exponent,
2. Possibililstic function and implementation of typical weighting exponent

However, the both the coefficients in the objective function are utilized as exhibitor of membership and typicality. Here, a novel association, comparatively strange, presents an exceedingly quick decline in the working and considerably improves the membership and the typicality at the time they are inclined close to 1 and diminish this degree at the time they are about to 0. This relationship is to put forward Weighting exponent as exhibitor of distance in the two beneath objective functions. MFPCM's objective function is given as follows:

$$J_{MFPCM} = \sum_{i=1}^{c}\sum_{j=1}^{n}\left(\mu_{ij}^{m}\, w_{ij}^{m}\, d^{2m}\left(x_j v\right) + t_{ij}^{\eta}\, w_{ij}^{\eta}\, d^{2n}\left(x_j, v_i\right)\right) \tag{4}$$

U = {μ_{ij}} indicates a fuzzy partition matrix, and is provided as follows:

$$\mu_{ij} = \left[\sum_{k=1}^{c}\left(\frac{d\left(X_j, v_i\right)}{d\left(X_j, v_k\right)}\right)^{\frac{2m}{m-1}}\right]^{-1} \tag{5}$$

T = {t_{ij}} indicates a typical partition matrix, is provided as follows:

$$t_{ij} = \left[\sum_{k=1}^{n}\left(\frac{d\left(X_j, v_i\right)}{d\left(X_j, v_k\right)}\right)^{\frac{2\eta}{\eta-1}}\right]^{-1} \tag{6}$$

V = {v_i} indicates c centers of the clusters, is provided as follows:

$$v_i = \frac{\sum_{j=1}^{n}\left(\mu_{ij}^{m} w_{ij}^{m} + t_{ij}^{\eta} w_{ij}^{\eta}\right).x_j}{\sum_{j=1}^{n}\left(\mu_{ij}^{m} w_{ij}^{m} + t_{ij}^{\eta}\, w_{ij}^{\eta}\right)} \tag{7}$$

With this clustering the nodes in network model is grouped into k number of clusters and the CHs in each cluster are selected. Towards the end of this stage, information regarding the entire cluster nodes is given to

CH. The CH can extend the battery life of the individual sensors and can lessen the rate of energy utilization by scheduling actions in the cluster. It is vital to recognize that, this phase is carried out once; as a result direct communication among cluster nodes and the CH is insignificant.

Cluster Tree Constructing Phase

During this phase, cluster tree is generated with the result of cluster creation by means of MFPCM which is discussed in previous section. In a routing tree structure, for each cluster node a path to its CH is decided. CH is familiar with location of the entire nodes positioned in its cluster. Tree configuration is explained briefly in subsequent steps and the paradigm of cluster tree topology is exposed in Figure 2.

Every CH produces sample packet and transmit it to BS. The sample packet includes CH ID and distance among the BS and CH. The distance among the nodes is computed with the help of Minkowski Distance.

$$\mathrm{dist}\left(CH_i, BS\right) = \sqrt[\frac{1}{r}]{\sum_{i=1}^{n} \left|CH_1 - BS\right|^r} \tag{8}$$

Where, r indicates a parameter, n indicates the number of dimensions for CH node CH_i and BS.

In accordance with the distance among the nodes and BS, the nodes are organized in ascending order. The node with regard to the shortest distance is presumed as a root node and it broad cast its ID and coordinates to remaining CH as root node ID and root coordinates.

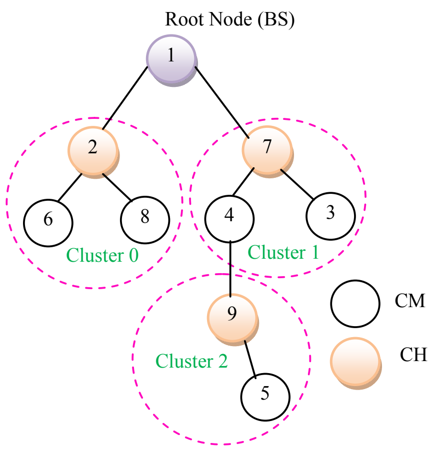

Figure 2: Cluster Tree Topology

Another time the distance among the CH and remaining Cluster Members (CM) are computed with the help of Minkowski Distance and organize the nodes depending on the distance.

$$\mathrm{dist}\left(CH_i, CM_i\right) = \sqrt[\frac{1}{r}]{\sum_{i=1}^{n} \left|CH_1 - CM_1\right|^r} \tag{9}$$

The suitable shortest distance (CH_i, CM_1) is taken as left node and next shortest distance is taken as right node.

This procedure is carried on until the number of nodes terminates in cluster.

Balancing in cluster tree topology

Following the creation of tree, the load balancing procedure is started. The WSN routing tree is originated in the BS. At the same time, the load of child sensor nodes appends to the load of every upstream parent in the same tree. Consequently, the nodes close to the BS potentially be the most deeply loaded. The objective of node-centric load balancing scheme is to consistently allocate packet traffic produced by nodes throughout the several branches of the routing tree.

In order to determine how efficiently the load is stabilized all through the several branches of a routing tree, the Hölder's Inequalities is chosen as the load balancing metric. The characterization of the Hölder's Inequalities is provided as given below: for all $a \subseteq C^N$ and $b \subseteq C^N$,

$$a = \{a_1, a_2, a_3, \dots, a_n\} \tag{10}$$

$$b = \{b_1, b_2, b_3, \dots, b_n\} \tag{11}$$

and

$$a_1 \geq a_2 \geq a_3 \geq \cdots \geq a_n \tag{12}$$

$$b_1 \geq b_2 \geq b_3 \geq \cdots \geq b_n \tag{13}$$

As a result,

$$n \sum_{k=1}^{n} a_k b_k \geq \left(\sum_{k=1}^{n} a_k\right)\left(\sum_{k=1}^{n} b_k\right) \tag{14}$$

Consider W_i indicate the weight (increasing load) on the i th branch of the routing tree. Generate a vector of the weights $w = \{w_1, w_2, w_3, \dots, w_n\}$. To evaluate the quantity of balance between several branch weights of w, take a = b = w. At this point, the inequalities must happen to be,

$$n \sum_{i=1}^{n} w_i^2 \geq \left(\sum_{i=1}^{n} w_1\right)^2 \tag{15}$$

$$1 \geq \frac{\left(\sum_{i=1}^{n} w_i\right)^2}{n\sum_{i=1}^{n} w_i^2}$$

with equality if and only if $w_1 = w_2 = w_3 = ... = w_n$ for very w_k, $k \in [1,n]$ and E must be largest. The balance factor θ employed in the approach is given as,

$$\theta = \frac{\left(\sum_{i=1}^{n} W_i\right)^2}{n\sum_{i=1}^{n} W_1^2} \tag{16}$$

Since the weights in every branch meet to similar value, explicitly, the load all through the several branches of the routing tree happens to be further stabilized; the balance factor monotonically enhances in the direction of 1. If the weights of entire branches are identical, the outcome of the inequality is supposed to be 1, i.e. the highest value.

Together with the weight the residual energy is also computed for every node. The formula employed for energy computation is given below,

$$E_i = \left\lceil \frac{\text{residual}_{\text{Energy}(i)}}{\alpha} \right\rceil \tag{17}$$

Where, E_i represents an estimated energy value instead of a factual one and i indicates the ID of every node. α represents a fixed variable which reveals the minimum energy unit and it is transformed in accordance with the requirements. By taking the network life span as the time, the primary node in the network fails (dies), with load balancing and the entire nodes being exhausted of energy gradually and consistently causing the entire nodes to die almost together. With the help of this process, one can lower maintenance cost and enhance overall performance.

3.2. Proposed Joint Packet Scheduling and Congestion Control Mechanism

Here, the Packet Scheduling Algorithm (PSA) is the method that plans the entire packets from application layer and network layer with the aim of lessening network congestion in the data link layer to circumvent the packet collision. Congestion in networks indicates the data packets are sent starting from the source to target through several paths. Those paths are making an uncertainty to take the packets when the over one packet received in the target or intermediate nodes. This condition called congestion that will drop the packet and take time delay in the networks. In the mean time, when PSA is executed, congestion can be managed, this leads packet collision minimization. Here, STDMA-based methods are focused. TDMA scheduling is one of the energy efficient approaches employed in WSNs. Every node is assigned a time period for data transmissions. The major negative aspect of this pure TDMA is the under-exploitation of the bandwidth. In order to circumvent this complication, several solutions providing bandwidth spatial reuse are formulated (STDMA: Spatial Reuse TDMA)). The flowchart for the complete work is shown in Figure 3.

3.3. Proposed Congestion Detection and Congestion Control

3.3.1. Congestion detection

Congestion detection ensures the incidence of congestion and also the positions of congestion take place. Congestion is identified through the assistance of several constraints like packet delivery time, packet service ratio, queue length, and node delay etc[19]. Queue construction points out that the packet incoming rate is not same as the packet outgoing rate. Consequently, with the aim of detecting congestion, a threshold boundary is fixed and when queue length goes beyond that threshold, it points out congestion. Queue length is an efficient determination of congestion detection along with the link layer acknowledgements permitted.

$$QO(i) = \frac{nQ}{Q} \tag{18}$$

Packet service ratio P_i is portrayed as the ratio of average packet service rate P_i^R and packet scheduling rate P_i^{SC} in all sensor node i.

$$P_i = {P_i^R}/{P_i^{SC}} \tag{19}$$

At this point, the packet service rate P_i^R is always the converse of packet service time is t_i^S. t_i^S indicates the time used by a node to work on that particular packet. When packet service time happens to be bigger than the packet inter arrival time, then queue mounts and causes queuing interruption.

$$t_i^S = (1 - w_s) \times t_i^S + w_s \times \text{inst}\left(t_i^S\right) \tag{20}$$

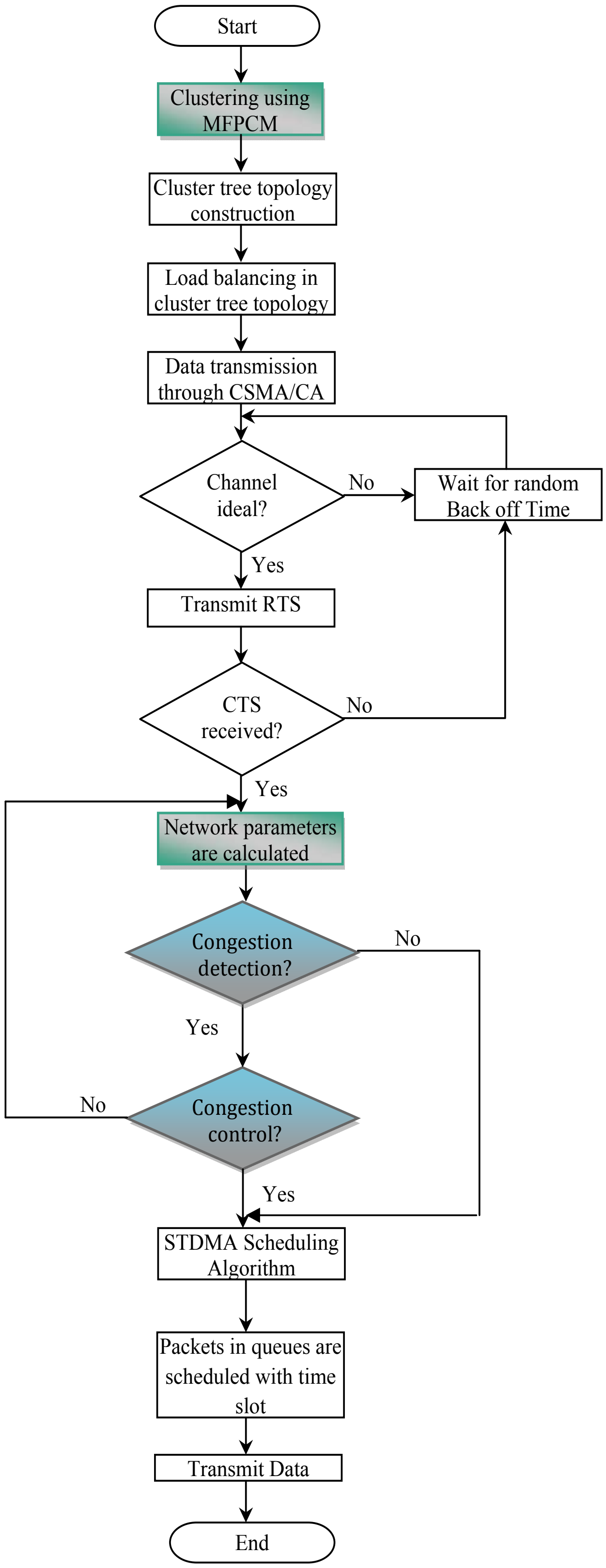

Figure 3: Flow chart of overall work

Packet delivery time provides the time utilized by a packet to reach the buffer of subsequent node from the buffer of previous node[19]. This comprises transmission time together with the reception time and service time. A node delay indicates the interruption a packet experienced at a particular node. When packet gets postponement than anticipated time, it points out congestion. In accordance with the threshold value of the several parameters the congestion is detected in the network.

3.3.2. Congestion Notification Phase

Explicit congestion notification is hardly ever employed as a result of the inadequate sensor energy. Congestion message which is being transmitted might be a single bit or detailed data. In the scenario of single bit notification, Additive Increase Multiplicative Decrease (AIMD) is employed for the purpose of rate modification, at the same time in the scenario of detailed notification; accurate rate modification will be applied. Once the congestion is recognized, then congestion notification message is created and transmitted to the sink, source and destination nodes. When the source node is received a congestion notification messages subsequently the source node looks for alternate path.

3.3.3. Congestion Control

The proposed Joint Congestion Control and Packet Scheduling (JCCPS) recognize the congestion in network traffic. There are three categories of congestion. They are Slightly Congested (SC), Not Congested (NC) and Fairly Congested (FC) by means of two threshold values. Congestion mitigation will not be executed for the NC level, since the sensor nodes enclose sufficient potential to manage the network traffic. The proposed congestion mitigation approach is triggered if the network is in SC or FC condition. This mitigation approach automatically chooses the alternate route for the purpose of diminishing the congestion among source and destination.

3.3.4. Alternate Path Selection

The proposed algorithm decides an alternate route when congestion considers a number of fundamental performance parameters. This approach also considers the node's congestion condition (both regarding buffer occupancy and packet service rate). With the aim of avoiding congestion, every candidate congested receiver is transmitting a backpressure packet to the correspondent node.

As a result, the sender discontinues the broadcast of packets to the candidate congested receiver and looks for its nearby table to discover the slightest congested receiver with the intention of continuing the broadcast of data. In the scenario of the dynamic transformation of the receivers, it guides to the formation of new routes from the source to the sink.

3.3.5. Queue Occupancy

The node will transmit STOP message to its neighbors when its buffer achieves the threshold and would restart the transmission of packets to it by broadcasting START message to its neighbors.

3.4. STDMA Packet Scheduling

At first, the sensor network is partitioned into numerous scalable geographical cells (similar to cellular networks). In case of STDMA, partitioned the space into virtual geographic cells known as space slots, which are clustered into periodically replicating virtual frames (space frames) with the intention of assisting spatial use again, and simultaneously time slots are distributed to space slots (Figure 4) produce the cuter tree topology. Every time slot is planned to hold the broadcast of one preset-size packet and a guard time, resembling the greatest differential propagation delay among couple of nodes in the network.

In nature, STDMA is a topology-transparent, given that time slot distribution is in accordance with every node's immediate physical position, accordingly enabling it 'orthogonal' to connection alterations. Accordingly,

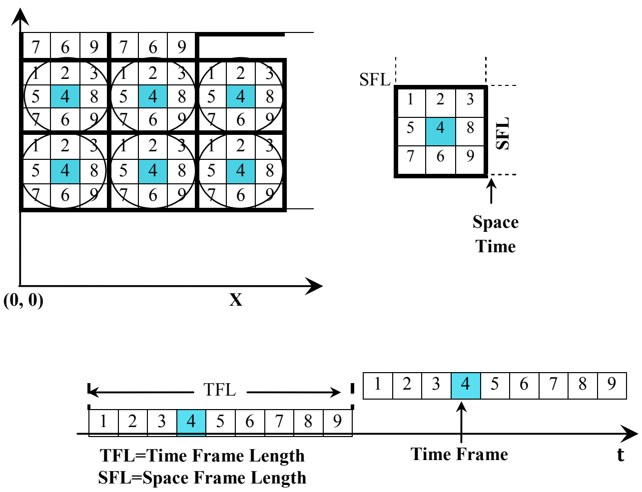

Figure 4: Graphical illustration of STDMA

STDMA is also 'position-activated', while against to 'node-activated'. Each space slot is allotted their respective time slot, and all node basically 'inherits' the time slot allotted to the existing space slot. In case when k(k>1) nodes are co-situated inside the parallel space-slot, subsequently it switch transmitting at some point in their allotted time slot on a basis of round-robin nature, accordingly, each node transmits once (at some point in its allotted time-slot) each k time frames. Besides, STDMA is a kind of 2-tier hierarchical TDMA protocol: during the preliminary TDMA tier, time is 'looping' above space slots; during the second TDMA tier, the time is 'looping' above the node IDs placed inside that particular space slot. The space frame is built with the intention that SSD (Figure 4), the gap in the midst of space slots which are allotted the similar time slot ("simultaneous" space slots) is beyond 2 times the highest broadcast limit; accordingly, by any means two instantaneous transmitters will not engage any receivers. As a result, STDMA promises that there is simply one active transmitter in a particular 2-hop neighborhood, in any exact time-slot, prevailing over restriction.

(a). Accordingly, STDMA can be united willingly with RTS/CTS handshaking systems, for synchronizing collision-free link establishment of data time slots inside a two-hop neighborhood. Additionally, since the upper bound examination is done here which exhibits, the highest amount of time slots along with 2 successive transmissions through a node is linearly bounded via the highest network degree (D), prevailing over restriction.

(b). At last, STDMA is fundamentally flexible to inconsistent network capacities and will preserve networks of boundless volume, prevailing over restriction.

(c). Suppose SFIL points out the Space Frame Integer Length (SFIL). Consequently, the Space Slot Length (SSL) is given as: $SSL = \frac{SSD}{SFIL - 1}$. Suppose Time Slot Sequence Number point out a running time slot counter. Subsequently, TSSN(t) is given as:

$$TSSN(t) = t_F * TFL + t \text{ ,where } t_s = Mod\left[\frac{TSSN(t)}{TFL}\right] + 1$$

and $t_F = Floor\left[\frac{TSSN(t)}{TFL}\right]$

Transmission power ceilings are present in this method, which is represented as $P_{max,n}$, for all active node i in a specific timeslot. Alternatively, $P_{max,n}$ represents the required transmission power to accomplish a provided $\gamma_{0,ij}$ simultaneously surpassing the maximum propagation path loss, L_{max}, accordingly $P_{max,n} = \gamma_{0,ij} L_{max}$. Consider (x,y) represent the existing position of a specific node, n and given as: $H(x) = \text{ceiling}\left[\frac{\text{mod}\left(\frac{P_{max,n}}{SFL}\right)}{SSL}\right]$

$$V(y) = \text{ceiling}\left[\frac{\text{mod}\left(\frac{y}{SFL}\right)}{SSL}\right] \quad (21)$$

$$S_n(x,y) = \left[\left(V(y)-1\right) * (SFIL) + H(x)\right] \quad (22)$$

As a result, the results provided in the following can be improved to accurately obtain the fact that time slots are integer numbers by adding ceilings where essential. Subsequently, the collection of time slots assigned to node n at a particular time t which must meet the condition: $t_s = S_n(x,y)$. Suppose S(i,t) points out the amount of nodes which are co-positioned inside space slot (i) at a particular time t. Every node n persistently safeguards an organized ID record of the complete nodes (together with itself) co-positioned in the space slot (i), as well as distributes itself a distinctive Conflict Resolution Index (CRI), its limit is from 0 to (i.e., conditional on the comparative numerical order of node n's ID in the organized ID list) so as to make easy collision-free time slot distribution in the midst of the nodes which are co-positioned in space slot (i). Next, the collection of time slots allotted to node n must meet: $\text{Mod}\left[\frac{t_F}{S(i,t)}\right] = CRI(n)$.

4. Experimental Results

Consider there exist 20 sensor nodes that are arbitrarily organized in 400 × 400 meter region. The transmission limit of all nodes is just about 40 meter. Nodes present inside that limit of other node are considered as neighbors. Initially simulation carried out for scheduling 10 maximum priority packets and subsequently schedule packets with least priority. This kind of priority based scheduling and congestion control protocol's network functioning is evaluated in accordance with the following: Throughput, Delay and packet drop ratio (pdr). The results are exposed in the structure of graphs and are discussed below:

4.1. Throughput

Figure 5 demonstrates the evaluation graph of the throughput values of the General Self-Organized Tree-Based routing, Energy-Balance based routing, Improved General Self-Organized Tree-Based routing, Cluster tree Packet Scheduling based routing and Packet Scheduling and Congestion Control Protocol. If the transmission time is maximum, then throughput will be smaller and it becomes clear from the formula employed for throughput.

$$\text{Throughput} = \left(\frac{\text{Size of the packet}}{\text{Transmission time}}\right) \quad (23)$$

With the assistance of this priority based scheduling, waiting time of each packet will be diminished in accordance with their priority. As a result, the throughput will always be high for this system. The results are shown in Figure 5.

4.2. Delay

It indicates the delay mandatory to send the data packet starting from source to destination. It is specified as the ratio of overall distance from source to destination (Dsd) to transmission speed (Spd) and it is computed as given below,

$$\text{Propagation Delay} = \frac{Dsd}{Spd} \quad (24)$$

The graphical representation of packet delay comparison is shown in the fig 6. The graph reveals that

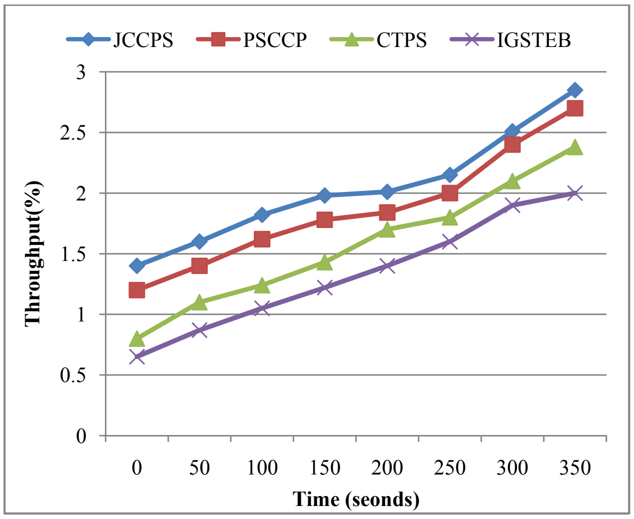

Figure 5: Throughput Comparison Results

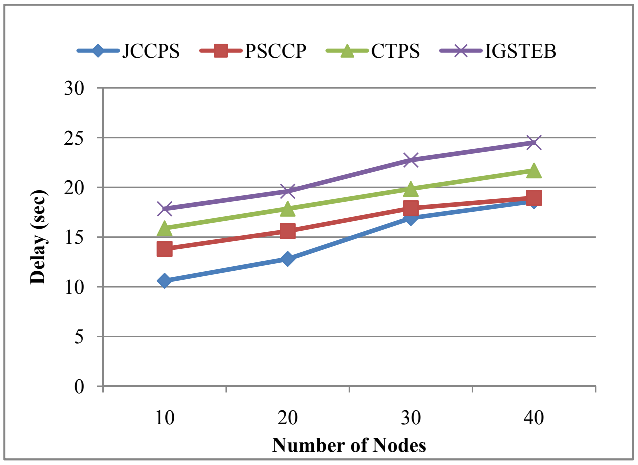

Figure 6: Packet Delay Comparison Results

the proposed protocol is better when compared to the existing protocols such as IGSTEB, CTPS, PSCCP and JCCPS. The packet delay of the proposed JCCPS is lesser when compared with existing algorithms such as IGSTEB, CTPS, and PSCCP.

4.3. Packet Drop Ratio

Packet loss takes place when one or more data packets passing through a network are unsuccessful in arriving at the target. The graphical representation of packet drop ratio comparison is provided in the Figure 7. The graph shows that the proposed protocol is better when compared to the existing protocols such as IGSTEB, CTPS, PSCCP and JCCPS. The packet drop of the proposed JCCPS is lesser when compared with existing algorithms such as IGSTEB, CTPS, and PSCCP.

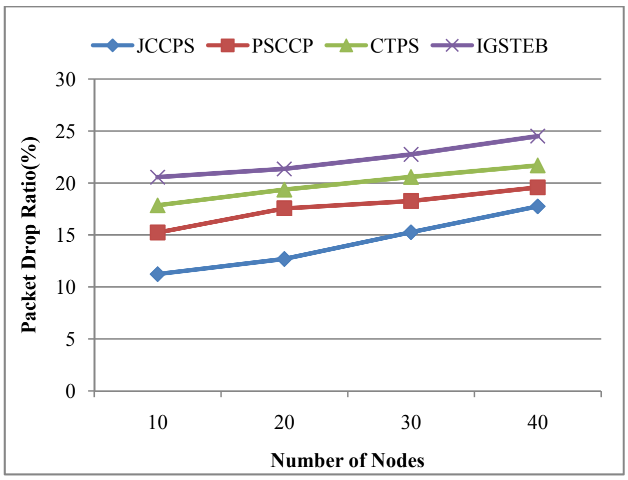

Figure 7: Packet Drop Ratio Comparison Results

4.4. Average Waiting Time

The average waiting time exploited by a job or a data packet will be computed as ratio of the total time exploited by that specific job to send from source to target all the way through number of intermediary nodes to the amount of nodes the job has sent through and consequently it is nothing however the ratio of overall end to end delay of a specific task to the number of nodes (or levels) the task has surpassed from beginning to end to arrive at BS and is provided as Average Waiting Time (AWT),

$$AWT = \frac{\text{Total Time Taken to Reach BS}}{\text{Number of Nodes}} \quad (25)$$

Figure 8 reveals that the proposed JCCPS scheduling approach performs better than the remaining scheduling approaches for real time data based on average waiting time confirming low average waiting time for the data packets because priority is prearranged to real time data packets, however, in other scheduling approaches this preference is not provided. However, the major restrictions in the JCCPS approach is the prerequisites of energy in the network, this approach fairly low efficient based on energy when compared against other two approaches, since the approach necessitates a small number of processing time slots to separate the data packets into three dissimilar queues depending on their priorities together with context saving and switching during preemption. However, the mounting requirement for WSN-based solutions which handle applications that are real time

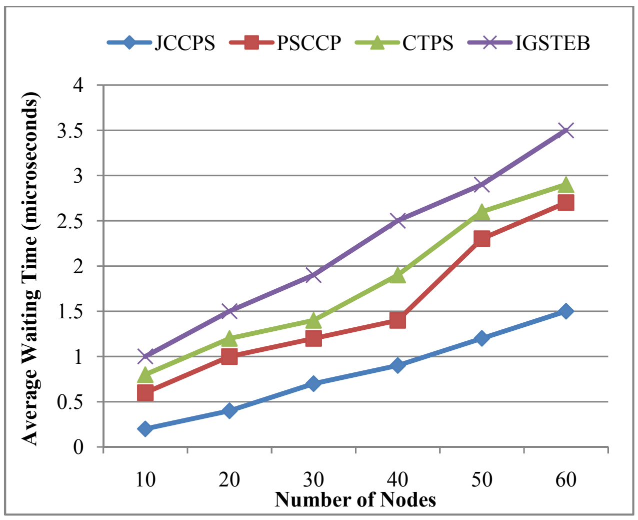

Figure 8: AWT Comparison Results

and in addition guarantee them with least average waiting time and end to end data transmission delay. Hence, the proposed JCCPS protocol is regarded as the high efficient scheme for better performance.

5. Conclusion

To conclude, the proposed Joint Congestion Control and Packet Scheduling (JCCPS) considerably enhance network efficiency, throughput together with packet delivery ratio and minimize delay. In this work, Space-Time Division Multiple Access (STDMA) is presented for WSN, the primary position-based approach in TDMA scheduling. This scheme is a topology-transparent scheduling protocol which promises a distinctive transmitter inside the cluster tree topology. This approach applied for the cluster tree topology which is generated with the help of MFCM. The complication of scheduling collision-free broadcasts by means of a node (known as node activation) to the entire neighbors with no other packet interfere in its communication is resolved with the help of this proposed JCCPS protocol in WSN. Simulation results revealed that packet scheduling based congestion detection and avoidance protocol requires less AWT and packet delay and accomplishes maximum throughput and packet delivery ratio as compared against other previous IGSTEB, CTPS and PSCCP protocols.

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