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An efficient reconfigurable geographic routing congestion control algorithm for wireless sensor networks

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ABSTRACT

In recent times, huge data is transferred from source to destination through multi path in wireless sensor networks (WSNs). Due to this more congestion occurs in the communication path. Hence, original data will be lost and delay problems arise at receiver end. The above-mentioned drawbacks can be overcome by the proposed efficient reconfigurable geographic routing congestion control (RgRCC) algorithm for wireless sensor networks. the proposed algorithm efficiently finds the node's congestion status with the help queue length's threshold level along with its change rate. Apart from this, the proposed algorithm re-routes the communication path to avoid congestion and enhances the strength of scalability of data communication in WSNs. The proposed algorithm frequently updates the distance between the nodes and by-pass routing holes, common for geographical routing. when the nodes are at the edge of the hole, it will create congestion between the nodes in WSNs. Apart from this, more nodes sink due to congestion. it can be reduced with the help of the proposed RgRCC algorithm. As per the simulation analysis, the proposed work indicates improved performance in comparison to conventional algorithm. By effectively identifying the data congestion in WSNs with high scalability rate as compared to conventional methods

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1. INTRODUCTION

The sink node and the sensor node are the two types of nodes in wireless sensor networks (WSNs). Sensors are minor in magnitude, restricted in energy and less in amount. They gather data and direct them to the sink node jump by jump. The sink accumulates data which is sensed and move it to the viewer. Congestion is unavoidable in such kind of structure [1]. A hovel or in other words a hole would form once the node energy in an area is drained. Such hovels extremely disturb functioning of the given network and could also breakdown the complete network. Hence, it is essential to evade congestion. The traffic and the resource control are two kinds of techniques of congestion control [2]. In the case of a traffic regulating technique, the source of data fine-tunes the transfer rate to avoid the data congestion. The data packets will go through other paths that are not congested, to the sink in resource control technique. Rapidly discovering fresh appropriate next hop nodes is tough. The novel next hop node quickly gets congested and drained [3]. The algorithm of routing in geographic area has little overhead of routing and respectable scalability and is ideal for significant networks, however it does not deliberate congestion regulation. The objective of such work is to find out a resource regulation technique having improved scalability by means of routing in geographic arena. In reconfigurable geographic routing congestion control (RgRCC), every system frequently checks its individual acceptance queue length and residual energy [4]. The advantages and novelties of RgRCC include little overhead, respectable scalability. The proposed algorithm has the sink armed with a superior communication system such that it sends a query packet to the whole network with a solo Jump. In case a packet comes near a node, the node shall select a neighbor nearer to the sink as the subsequent jump. The node's congestion position of a node is decided according to change rate and reception queue length. Computation of the threshold value for queue length is carefully designed. Such technique shows the jamming position of the system very precisely [5]. A novel algorithm to update distance to avoid hovel is projected. The content of the work is planned as below. The investigation would be done on control of congestion related works and the geographic routing technique is summarized in section 2. The network prototype design is explained in section 3. The RgRCC algorithm is explained in section 4. The results of simulation is depicted in section 5. Section 6 has the conclusion.

2. LITERATURE REVIEW

The prevailing congestion control methods are coarsely separated as traffic and resource control. These two kinds of approaches have certain advantages Many applications produce huge quantity of concurrent data. In case there is decrease of sending rate by the source node, the complaint of concurrent data attainment cannot be achieved. Congestion control and energy-balanced scheme based on the hierarchy (CcEbH) and dynamic alternative path selection scheme (DAiPAS) are worthy resolutions [6]. To precisely sense congestion, we can observe that CcEbH employs a fresh congestion discovery technique. The DAiPaS algorithm depends on a hierarchical level that similarly starts at the sink. During occurrence of congestion at the overloading system, a 'flag decision' algorithm is embraced by the DAlPaS algorithm by considering many parameters. By using this procedure, the packets are obligated to alter their way to evade triggering congestion in the acceptance node [7]. In earlier procedures, we see numerous resource regulating methods for unravelling jamming issues. Since, their routing complexity is very huge and scalability is not robust. Hence, they are not appropriate for big networks. Here, a congestion regulating procedure depending on geographical position routing is premeditated [8].

3. NETWORK MODEL

Let us consider a compactly positioned nodes in WSN. Further, nodes are disseminated arbitrarily and uniformly in the location of observation. The network contains one sink [9]. Carrier sense multiple access/collision detection (CSMA/CD) protocol aides the link layer. The sink node is armed with high-power transmission kit. As the distance increases, the signal strength becomes feebler [10]. On the basis of nodes to sink distance, the hierarchical organization is shaped impulsively, as shown in Figure 1.

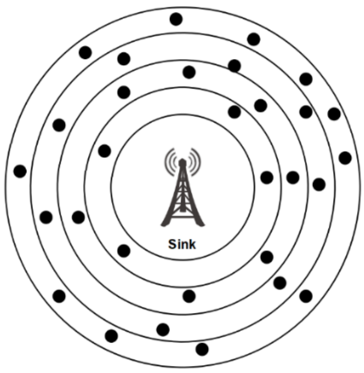

Figure 1. Fundamental structure of sink node and remaining nodes in WSNs

4. CONGESTION CONTROL MECHANISM

Here, a congestion regulating procedure depending on geographical routing is projected. This has the neighbor table's institution and the next hop selection. Here, a congestion regulating procedure depending on geographical routing is projected. This has the neighbor table's institution and the next hop selection. the congestion control maintains the optimized path distance between the nodes and reduces the power dissipation in the network.

4.1. Structure format neighbor node table

Every node intermittently transmits Hello communications to its single-hop neighbor node. This communication contains the following info: node ID and flag, length of queue and its varying rate, remaining energy, distance to sink [11]. The Hello communique will be transmitted to all neighbor nodes, if the Hello cycle is outstanding. After receiving a Hello communique from its neighbors, a node inscribes the said substances to its neighbor table, as shown in Table 1.

Table 1. Neighbor table data

Node ID	Distance	Residual energy	Queue length	Change rate	Flag

In each Hello cycle, a node will determine the rate change of queuing length status (detailed in section 1), determine residual energy (detailed in section 2), calculate distance between nodes and sink (detailed in section 3), determine pseudo edge nodes of the hole status. The flag value becomes 0, if present, else the flag value is set to 1 (detailed in section 4). Due to this check of the condition in the network will be reduces the power dissipation and loss of information.

4.2. Queue length varying rate

Maximum congestion discovery methods will take the measurement of the queue length and after this forecast jamming as per if the queue length surpasses a definite threshold. The difficulty in such technique is after surpassing of the threshold by queue length, the preceding process reflects that jamming is identified and subsequent actions are considered. Nevertheless, in case the queue length drips swiftly in subsequent time, jamming will not occur, hence we can say that congestion control is redundant [12]. This work suggests to show the grade of congestion with the help of queue length and its varying rate. As shown in (1) helps to determine Queue length changing rate.

$$q = \frac{C_{ql} - C_{lc}}{C} \tag{1}$$

where q is represented as rate of change of queue length, C_{ql} is described as rate of change of current queue length, C_{lc} is identified as last check's queue length and C is queue capacity. If $q > 0$, the assessment is larger, the length of the queue upsurges is faster, and very possibly congestion occurs. In case $q < 0$, depicts that length of the queue is lessening, jamming is doubtful. To some degree, q could show the point of congestion [13].

Let q_{total} is represented as total queue length and it is defined as ratio of the rate of change of current queue length and queue capacity is given in (2).

$$q_{total} = \frac{C_{ql}}{C} \tag{2}$$

The value of q and q_{total} is determined by nodes at the finish of every Hello cycle [14]. The threshold is evaluated by taking mean of queue length of each neighbor. For a node having m neighbor nodes, depicted as $n_1, n_2, n_3, n_4, \dots \dots \dots \dots \dots . . n_m$, the queue lengths of neighbor nodes are $q_1, q_2, q_3, q_4, \dots \dots \dots \dots \dots \dots q_m$. Let q_{th} is represent as queue threshold and is shown in (3):

$$Q_{th} = \frac{\sum_{i=1}^{m} q_i}{m} \tag{3}$$

By observing neighbor table, a node having the queue length less than q_{th} will be chosen as the substitute node of the subsequent hop.

4.3. Effect of remaining energy on the subsequent hop assortment

Few nodes, due to where they are located, would send and obtain data very frequently compared to other nodes, hence causing death prematurely. Subsequent to its loss, few of its neighbors might not get a substitute relay node in order to communicate information to the sink. Routing hovels are built, ultimately resulting in the complete network's premature death [15]. The energy of the nodes is dispensed as uniformly as conceivable for hovel evasion. The threshold energy is modified. The node with more energy than this threshold becomes the substitute node of the subsequent hop [16]. The threshold energy is not constant however vigorously fixed as per the neighbors. With the decrease of the remaining energy of the entire network, the threshold also lowers and it is represented in (4).

$$E_{th} = \frac{\sum_{i=1}^{m} E_i}{m} \quad (4)$$

where E_{th} is described as the threshold of energy, E_i is the residual energy of the n_i in the neighbour table. The n_i becomes active node for upcoming next hop when $E_i > E_{th}$.

4.4. Length to the sink and the distance apprising method

The distance of node to sink is computed over the foundation signal strength of the sink. In case there is a sink's query packet obtained by a node, the node computes and marks sink distance. Also, when a packet comes near the brink of the hole, it should avoid the hovel to touch the sink. The by-pass distance should be higher than the novel linear distance. Its neighbor nodes would select the subsequent hop as per the lengthened distance to evade the hovel. Hence, this part will debate in what way to compute this detour distance [17].

Consider a node with 'm' neighbor nodes $n_1, n_2, n_3, n_4, \dots \dots \dots \dots \dots n_m$. The distance between the sink and the neighbor nodes are $d_1, d_2, d_3, d_4, \dots \dots \dots \dots \dots \dots . d_m$. The values of queue lengths are $q_1, q_2, q_3, q_4, \dots \dots \dots \dots \dots \dots q_m$. The residual energy is $E_1, E_2, E_3, E_4, \dots \dots \dots \dots \dots \dots . E_m$. The queue length changing rate are $w_1, w_2, w_3, w_4, \dots \dots \dots \dots \dots \dots \dots \dots \dots w_m$. The group of all neighbor nodes are expressed in (5).

$$S = \{n_1, n_2, n_3, n_4, \dots \dots \dots \dots \dots \dots \dots . n_m\} \quad (5)$$

Let Sub_A remain a subset of S. If the distance between of all nodes in Sub_A are less then present node, then this condition is represented in (6).

$$Sub_A = \{n_i \in S | d_i < d\} \quad (6)$$

where 'd' is the current node to sink distance. When a node discovers its Sub_A , there is a hindrance in the face of it [18]. The node is termed as the edge node of the hole (ENH). The packet from this node should evade the hovel to touch the sink. the linear distance is lesser than the detour distance. Due to this, the linear distance cannot be directed to the neighbors but the detour distance must be directed to the neighbors [19]. To obtain detour distance, a distance apprising procedure is initiated. The closest node to the sink in the neighbor table is selected as the apprising node initially. Computation of the fresh distance is done using (7).

$$d = d_{nei} + d_{oh} \quad (7)$$

Once a node directs a Hello note to its neighbors, the efficient d in Hello communique is achieved. Hence, every one of its neighbors will come to know that its distance to the sink has grown lengthier. In case the apprising node is similar to the ENH, its 'd' neighbor would be recomputed [20]. Such assessment will upsurge.

If the present node obtains the Hello communique from apprising node, it would apprise its d as per the novel 'd' neighbor. Subsequent to many circles of Hello communiques, the ENH distance would achieve a comparatively steady state [21]. Let such procedure be termed as the distance apprise method of ENH. We consider Figure 2 as an illustration to show such apprise method. Figure 2 shows the homogeneously dispersal of the nodes in the lattice. Presuming the length of every lattice is one, the all-out communication assortment of every node is lesser then two [22]. The black node describes a node with energy drained, i.e., a hole. The distance is 4 between sink and node 13. Table 2 shows the distance of every neighboring node of node 13 and the sink.

Subsequent to finding the neighbor table, node 13 finds the distance of the neighbors to be greater than its individual. It would be the ENH. Hence, it starts the distance apprising procedure. It selects node 12 as the apprising node [23]. As shown in (8) gives the altered distance of node 13.

$$d_{13} = \sqrt{17} + 1 \quad (8)$$

Afterwards, this distance is sent to every neighbor of node 13. After receiving the Hello communique, node 12 will change its neighbor table, as shown in Table 3. Node 12 also discovers the distance of every neighbor is higher compared to its individual. This is also ENH. It commences the distance apprising procedure. It selects node 11 as the apprising node and alters the distance like shown in (9).

$$d_{12} = \sqrt[2]{6} + 1 \quad (9)$$

Likewise, node 14 alters the distance as (10):

$$d_{14} = \sqrt[2]{6} + 1 \quad (10)$$

Accordingly, equation (11) shows the resultant

$$d_{13} = d_{12} + 1 = \sqrt[2]{6} + 2 \quad (11)$$

During this juncture, the distance amongst the neighbor nodes of node 6 and the sink is shown in Table 4. Due to the identification of sink nodes have been reduces the power dissipation, loss information, less attenuation and more accurate with more efficiency.

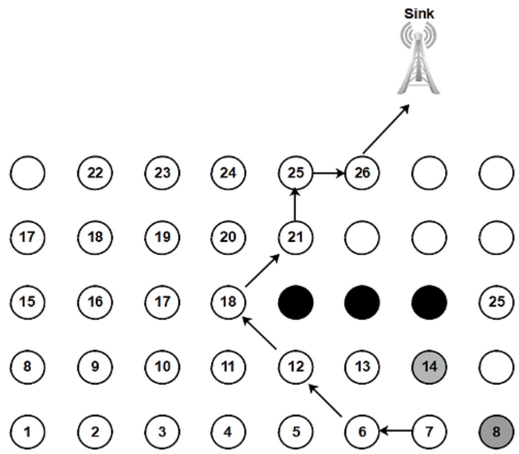

Figure 2. Fundamental wireless sensor network model of ENH process

Table 2. The distance between the sink and the neighboring nodes of node 13

Node ID	4	6	7	12	14
Distance	$\sqrt{27}$	6	$\sqrt{27}$	$\sqrt{18}$	$\sqrt{18}$

Table 3. The distance between the sink and the neighbors of node 12

Node ID	4	6	4	12	14
Distance	$\sqrt{27}$	6	$\sqrt{29}$	$\sqrt[2]{6}$	$\sqrt{17+1}$

Table 4. the distance between sink and the neighbors of node 6

Node ID	4	7	12	13	14
Distance	$\sqrt{27}$	$\sqrt{27}$	$\sqrt[2]{6}+1$	$\sqrt[2]{6}+1$	$\sqrt[2]{6}+1$

Node 5 in Figure 1 is not unswervingly together to the hole. It is observed that the distance of all neighbors are higher than its individual [24]. It is also the ENH. Node 4 is selected as its apprising node. Its distance is altered as given in **(**12).

$$d_5 = \sqrt{27} + 1 \quad (12)$$

After many sequences of Hello messages are transferred, the distance amid nodes 12, 13, 14 will finally be as shown in the (13) to (16).

$$d_{12} = \sqrt[2]{6} + 1 \quad (13)$$

$$d_{13} = \sqrt[2]{6} + 2 \quad (14)$$

$$d_{14} = \sqrt[2]{6} + 1 \quad (15)$$

$$d_5 = \sqrt{27} + 1 \quad (16)$$

4.5. A hole's pseudo-edge node

Section 4.1 has described 'S' as the group of every neighbor node of the present node and Sub_A is the group of nodes in the neighbour table with a distance less than the present node, $Sub_A \subseteq S$. Apart from this, there are two other subgroups of S:

Subset Sub_B: the nodes' queue distance in this set is found to be lower than the queue's threshold, as shown in (17).

$$Sub_B = \{n_i \in S | q_i < q_{th}\} \quad (17)$$

Subset Sub_C: the residual energy of the nodes in this set is greater than the threshold energy, as shown in (18).

$$Sub_C = \{n_i \in S | E_i < E_{th}\} \quad (18)$$

Let $S_F = Sub_A \cap Sub_B \cap Sub_C$

Let us assume $S_F = Sub_A \cap Sub_B \cap Sub_C$ If $S_F \neq \emptyset$, we can determine the next hop, which infers that there exist neighbor nodes nearer to the sink, being low congested with improved residual Energy. If $S_F = \emptyset$, determination of suitable next hop is not possible. If $Sub_A \neq \emptyset$ and $S_F = \emptyset$, there exists neighbor nodes near to the sinks whose length is more than the threshold length or the residual energy lower than energy threshold [25]. None of the neighbor nodes can be selected as the subsequent hop. We name such present node the pseudo-edge node of the hovel (PENH). With lapse of some stint, the condition of the system deviates. The queue dimension of few nodes drops. The threshold of the energy will decline as the energy of every neighbor node reduces. The remaining energy of the node is higher than the threshold. The PENH would come back to regular. In case the node discovers that it is a PENH, the flag is reset to 0 in the Hello message to tell every neighbor node not send any packets to this node at this instant. Subsequently, when the node comes back to normal, it will fix the flag to 1 in the Hello communique to tell every neighbor node recommencing of receiving packets has been initiated. The procedure to produce a Hello message is seen in Figure 3.

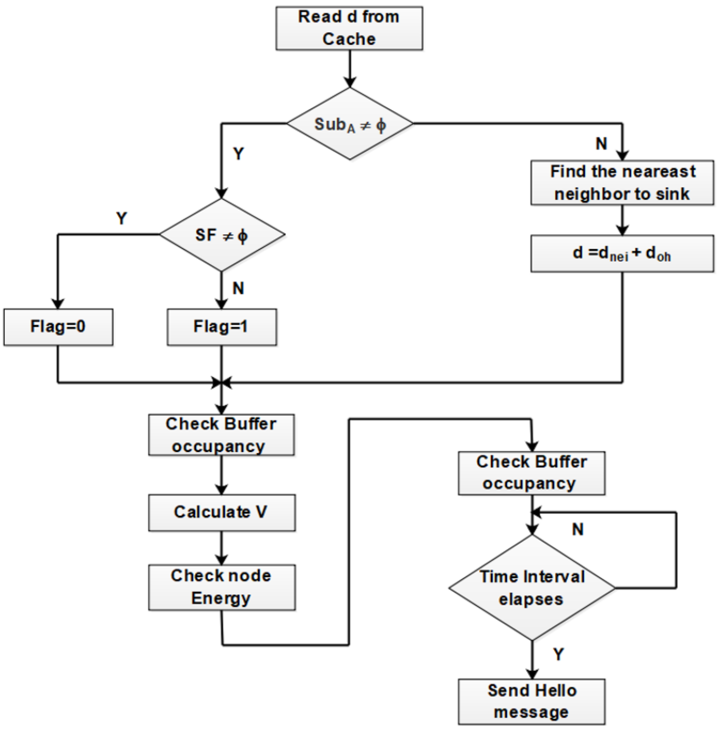

Figure 3. Hello message communication process flow chart

4.6. Subsequent hop selection

With the discussion in section 4, we observe that in case a node discovers the distance of all neighbor nodes to be higher than its individual distance, it would upsurge its individual distance to get neighbor nodes nearer to the sink. In case a node has nearer neighbors, nonetheless the length of the queue of all nearer neighbors are inappropriate, it would tell all neighbor nodes to deny sending it packets. Subsequent to that action, every node will have the appropriate subsequent hop, i.e., $S_F \neq \emptyset$. We select the node with the minutest queue altering rate as the subsequent jump node, i.e., $s_{next} = S_F$ and q_{next} is the maximum.

In the neighbor table of node 15, the closest node to the sink is node 25. Upon node 25 congestion, node 15 does not have the accurate succeeding hop to select. Node 15 befits the PENH. Further, the flag of node 15 is reset to 0 in its Hello communique. If a Hello communique is received by node 6 from node 15, then this alters its neighbor table, as shows in Table 5. The distances of nodes 6, 13, and 14 are shown in Table 5 after distance is updated. Now packet initiation happens from node 6 to the sink. The neighbor table of node 6 is shown in Table 6. If packet arrives at node 17, then node 19 is the next hop. Table 7 shows the neighbor table of node 19.

Figure 2 clearly shows the neighbor nodes for node 6, such as node 7, 12, 13, 14 in ENH process. After ENH process, the distance starts to update which is a larger distance and lesser towards node 6. it also identifies where congestion has occurred and residual energy is not considered in WSN. The identification process and selection of next-hop process is observed in Figure 4.

Table 5. Neighbor node 7 performance parameter and analysis

Node ID	Distance	Residual energy	Queue length	Change rate	Flag
8	$\sqrt{30}$	68%	22%	7%	1
6	$\sqrt{27}+1$	86%	0	0	1
13	$\sqrt[2]{6}+2$	86%	12%	-3%	1
14	$\sqrt[2]{6}+1$	68%	55%	0	1
15	$\sqrt[2]{6}$	86%	12%	9%	0

Table 6. Neighbor node 6 performance parameter and analysis

Node ID	Distance	Residual energy	Queue length	Change rate	Flag
8	$\sqrt{27}$	82%	22%	5%	1
6	$\sqrt{27}$	87%	0	0	0
13	$\sqrt[2]{6}+1$	86%	12%	-3%	1
14	$\sqrt[2]{6}+2$	66%	48%	-3	1
15	$\sqrt[2]{6}+1$	62%	12%	8%	1

Table 7. Neighbor node 19 performance parameter and analysis

Node ID	Distance	Residual energy	Queue length	Change rate	Flag
17	$\sqrt[3]{4}$	65%	22%	5%	1
19	$\sqrt[4]{3}$	65%	0	0	1
21	$\sqrt{6}$	86%	21%	21%	1
22	$\sqrt{11}$	65%	58%	-4%	1
24	$\sqrt{4}$	82%	11%	-3%	1
25	$\sqrt{3}$	82%	21%	6%	1

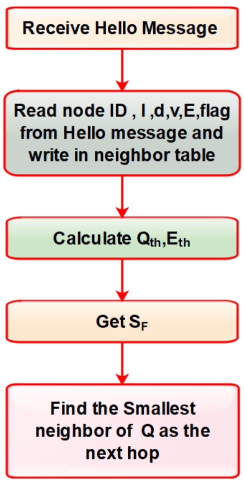

Figure 4. Next hop selection process

5. PERFORMANCE ANALYSIS

Here, RgRCC is assessed by simulation by means of MATLAB RA2021. The functioning of the RgRCC procedure is equated over CcEbH and no congestion control (No CC) procedures. RgRCC and CcEbH are all resource regulating approaches. All these deliberate remaining energies. Due to the resemblance, we liken such two approaches. Nodes are positioned arbitrarily over a 1025×1025 field. The positioned nodes are 150. The space maintained between nodes is 100. A 10×10 lattice is used for node organization. The higher fragment of the area is selected for positioning of sink.

The sink node has communication assortment of 1,500 meters. The shared node has omnidirectional antenna. The wireless passage utilizes 802.11 MAC protocol. The buffer magnitude is 100 packets. Table 8 summarizes the remaining factors.

With the upsurge in transmission rate of source node, there is variation in percentage of received percentage of the sink. The obtained packet ratio deliberates the algorithm's regulator jamming capability. Figure 5 shows the received packet ratio performance analysis between proposed method and conventional methods.

From Figure 6, it is observed that sink throughput performance analysis between proposed method and conventional methods and upon zero regulation of the congestion, there will be faster reduction in performance. Figure 7 shows that the average end-to-end delay alters with the increase of the transfer rate of the source node. In addition to this, the average end-to-end delay increases with zero regulation of congestion. If the energy finished nodes upsurges and the network cannot communicate any packets, then the remaining energy of the enduring nodes are verified next. This amount deliberates if the node energy is completely used. The outputs are depicted in Table 9. The remaining energy of RgRCC reduces, as seen in Table 9.

Table 8. Performance analysis parameter

Particulars	Range
MDTR (kbps)	300
Packet size (bits)	1024
MAC	CSMA/CD
Buffer size (Bytes)	512k
Transmission power (dbm)	3

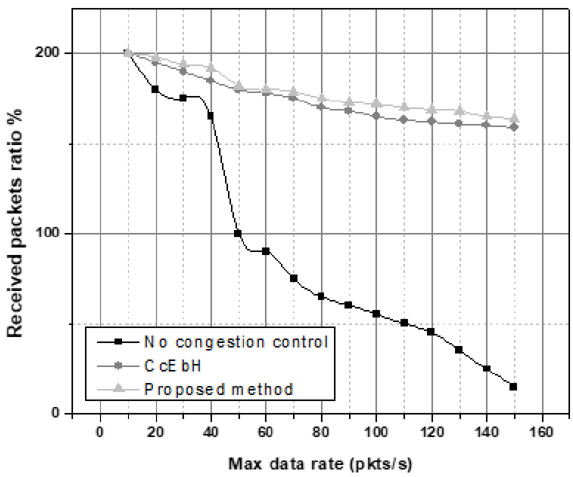

Figure 5. Received packet ratio performance analysis between proposed method and conventional methods

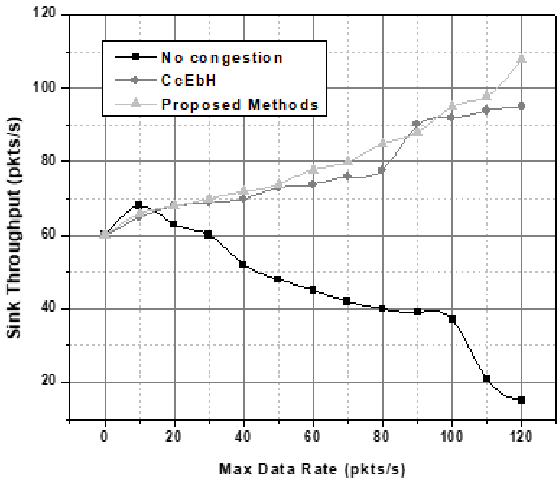

Figure 6. Sink throughput performance analysis between proposed method and conventional methods

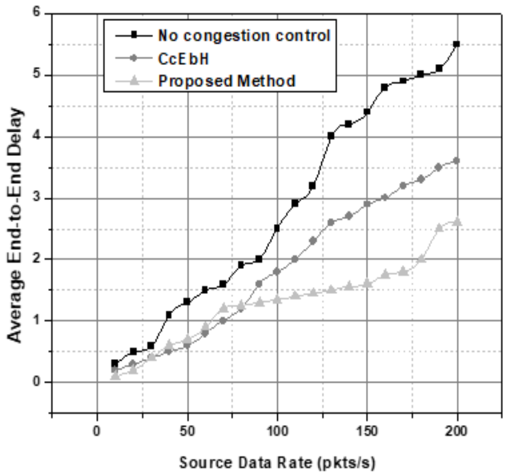

Figure 7. Performance analysis between proposed method and conventional methods with respect to average end-to-end delay

Table 9. Comparison of residual energy with various algorithm

Algorithm	Residual energy
No congestion	51.2% ± 5.3
CcEbH	3.2% ± 0.04
Proposed method	2.1% ± 0.01

6. CONCLUSION

In this research work, an efficient RgRCC controls congestion in WSNs. The proposed method frequently updates the status of congestion of each path and also builds the updated neighbor table for every single node. The proposed method builds the neighbor table with respect to congestion, distance, and residual energy in WSNs. The proposed method efficiently identifies the sink's closest hop. The sink throughput analysis between the proposed method and conventional method shows that the proposed method is 6% and 3% more efficient as compared to no congestion and CcEbH respectively. As per the simulation analysis, for the average end-to-end delay, the proposed method reduces it to 5% and 2% as compared to no congestion and CcEbH respectively. The proposed RgRCC has dynamically selected the next hop and also identified the nearby sink, nodes with more energy, path having less forward error noise and also less congested path in WSNs. As per simulation verification and validation, the RgRCC reduces the congestion and optimal energy utilization between nodes, reduces the power dissipation and also identifies the bypass holes.

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