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RCGS: Enhanced Relative Coordinate Geo-forwarding Scheme using Clear Channel Assessment Threshold to Detour Routing Holes in Wireless Sensor Networks

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Abstract

Wireless Sensor Networks areformed of several small sensor nodes capable of sensing and measuring the environmental phenomenon. These sensor networks are deployed in hostile environment which presents various anomalies during the deployment phase. It suffers from the routing hole, an area which is not covered by any node in the direction nearer to the destination. Geographic routing is considered as an attractive method for routing in sensor network since it uses only geographical information to make the packet forwarding decision. Currently, most of the geographic routing uses face based routing to recover the holes. Face routing employs planarization of entire network before forwarding the packets over the network. Thus it leads to the suboptimal performance of the networks. This paper presents a survey on different routing hole handling techniques and also the urgent issues to be solved. Later we propose a relative coordinate geo-forwarding scheme to resolve the routing hole problem by using relative co-ordinate system. It avoids the planarization of network thus minimizes the suboptimal performance of the network. Simulation results show the performance of the proposed approach along with the Clear Channel Assessment Threshold.

Keywords: *WSNs, Routing hole, Geographic routing, localization.*

I. Introduction

From decades Wireless Sensor Networks (WSNs) are gaining more attention of the world because of its advances in mobile and wireless communication technology. WSNs are generally designed for information gathering for remote areas where maintaining and replacing a sensor node is a tedious job [3][4][7]. WSNs consists of distributed autonomous sensor nodes that monitors physical or environmental condition based on application demand and report the gathered information to a sink or multiple sink. Many kinds of hole can occur during this process due to the node failure. This causes the routing hole in the network and resulting in the performance degradation of the network [7][8][9][15].

Various position based routing algorithms have been designed to fulfil the demands of networks and their real time applications by recovering the routing holes. Geographic routing is one of the elegant method to forward the packet in a sensor network [2][3]. The important characteristic of geographic routing is to use the geographic or location information of the node to make the routing decision. Hence it is considered as a most attractive routing approach of WSNs. Geographic routing only uses the location information of source, destination and neighbour nodes. Hence it uses very less amount of routing information and no energy is utilized for routing discovery, request and response, less memory utilization, less traffic overhead, less time consumption[9][10][16]. Geographic routing is also called as position based or localized routing [1][3][5].Location aware-services, geographic information system and content- centric networking are some of the application of geographic routing[2].

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It is different from source routing where the sender makes use of mapped network and specifies within the packet header that the packet has to travel through. In geographic routing the travel process is localized and distributed. Hence each node involves in the process of routing that contributes to make decision for routing. It avoids the maintenance of route for entire network by using the geographical information obtain by the localization approach or GPS[1][2].

Initially, geographic routing employs greedy forwarding mode to forward the packet towards destination. Then it shifts to bypass mode if there is a routing hole, the region which doesn't have any node to forward the packet in the direction of the destination[4][7][8][14].This situation is also called as local minimum phenomenon[18][22][23][25].

From decades many routing hole avoiding techniques have been proposed by employing flood based routing[6], geometric routing[2], face routing [9]. These methods are essential for geographic routing to achieve the required objectives of routing. Generally, the most prominently using geographic approach is face routing geographic approaches since it guarantees packet delivery. But face routing approach presents some issues, that ought to be resolved, including more energy consumption, maximum utilization of memory, extra routing expenditure which leads to suboptimal performance of the network[25][26].

Various kinds of face-based routing approaches have been proposed to recover the routing holes. It starts with greedy forwarding and exploits face routing approach to bypass the hole. The basic idea behind face routing is exploit the planar sub graph to forward the packet. Planarization of entire network before sending the packet avoids the crossing links to avoid the loop in the network. Gabriel Graph(GG) or Relative Neighbourhood Graph(RNG) which can be used to design planer graphs. Figure-1 and Figure-2 shows the GG graph and RNG graph respectively. Later the most prominent left hand rule or right hand rule can be used to deliver the packet over the possible adjacent faces of the sub graph. Face routing bypass the holes in network but it has to maintain planner graph on every node of the network, which leads to the suboptimal performance. Because the information about planar graphs are used only by those nodes which are affected by local minimum phenomenon[18][27][28][29].

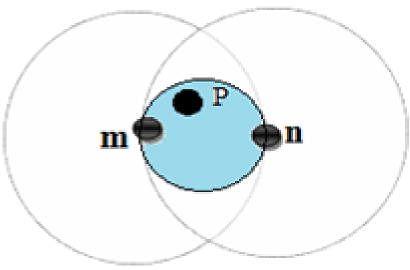

Figure-1 Gabriel Graph

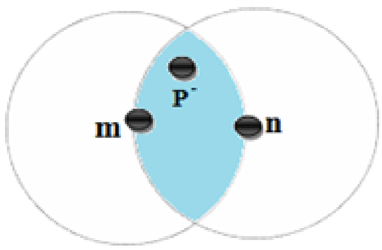

Figure-2 RNG graph

GG is defined as- "An edge $E_{m,n}$ exists between vertices *m* and *n* if there is no vertex *p* is there within the circular region whose diameter is *mn"***.** In equation form

$$\forall\ p \neq m,n : d^2(m,n) \leq [d^2(m,p), d^2(n,p)] \qquad (1)$$

RNG is defined as "An edge $E_{m,n}$ exists between vertices *m* and *n* if the distance between the vertex is less than or equal to the distance between every other vertex *p* and whichever of *m* and *n* is farther from vertex *p"*. In equation form.

$$\forall\ p \neq m,n : d(m,n) \leq \max[d(m,p), d(n,p)] \qquad (2)$$

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Even though the traditional face-routing guarantee packet delivery it suffers from some urgent issues that have to be resolved. The face routing approach requires additional bandwidth for the transmission of packet and also additional memory is requires to maintain planar graph and information about its neighbour node.

Since it needs the entire network to be planarized and maintain planar sub graph on each node, including the node which does not take part in the routing. It also enables significant low density in the network connectivity. Hence it leads to the suboptimal performance of the network including more packet loss ratio and more delay in the network. The main reason behind this is elimination of crossing links and strongly connected edges from the network during planarization. Hence planarization is not a good practice. These major issues are standing as crucial problem with face-based routing approach. Even through some approaches like BOUNDHOLE[17], Curve Sticks[3] are proposed to overcome from this issues but these solutions cannot address them fully. These approaches are not much scalable and efficient towards the recent applications of WSNs with mobility feature.

In this paper, the existing face based routing approaches are represented and based on the observations made, a new approach RCGS (Relative Coordinate Geo-forwarding Scheme) is presented to bypass routing holes. RCGS detours the routing hole by using relative co-ordinate system. So that it avoids the planarization of entire network. Since it eliminates the planar sub graph of the network it preserves the optimality of the route.

The remaining part of the paper is structured as follows. The following section gives a survey on routing hole avoidance techniques that are exist in the literature. Next section provides the detailed design of RCGS. The performance analysis of the proposed approach is given in the next section. The last section summarizes and concludes the paper.

II. Related Work

This section provides a overview on various techniques which are used to overcome from the problem of routing holes in WSNs using geographic routing approach.

B.Karp et. al. [18] proposed a scheme Greedy Perimeter Stateless Routing (GPSR) to increase the scalability of the network. The packet uses greedy forwarding approach to route from source to destination. Position information of the nodes and routers are used to make decision about the packet forwarding. GPSR is a stateless protocol because it uses only geographic information but not the state information. Face routing or perimeter routing is used when greedy forwarding fails to forward the packet to the destination. This perimeter forwarding is applied for the planarization graph, that are constructed using RNG or GG graph. Faces of the sub graphs contains both interior graph and exterior graph which can be used to forward the packet by right hand rule.

Compass routing -II begins with the basic greedy forwarding. Whenever it encounters local minimum phenomenon problem, it switches to face routing and it uses least deviation angle link between the current forwarder and the destination. FACE-I and FACE-II are the next version of Compass routing-II which uses planar sub graph and right hand rule to transmit the data from source to destination. Here they state that the face routing guarantees the packet delivery[27].

Fabian Kuhn et. al [30] introduced Greedy Other Adaptive Face Routing (GOAFR, GOAFR+). It is a extension of Compass Routing II. It starts with greedy forwarding and switches to face routing or perimeter routing. It employs fall back mechanism meaning that it can fall back to the greedy forwarding from perimeter forwarding without exploring the faces of sub graph. The planar graphs are constructed by GG graph and RNG graph. It also maintains two counters. First counter is used to keep the count of nodes which are far away from the destination node. Another one is used to count the number of attended nodes that are nearer to the destination during face routing. Based on these two counters it decides whether it has to continue with face routing or go back to greedy mode.

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De.Couto et al [29] introduced a approach called Intermediate Node Forwarding which uses Negative Acknowledgement (NAKs) to know about the packet drop. It traverse the packet around routing hole by using unequal radio ranges. The current node which is forwarding the packet will get the feedback about the packet drop using NAKs. Even though it is an efficient approach to bypass routing holes, it leads to protocol over head due to NAKs.

Y.Yu et.al [28] proposed Geographic and Energy Aware Routing (GEAR). Generally it follows two steps. In the first step the energy-aware next-hop neighbour selection scheme is used to forward the packet to the destination. In the second step recursive geographical or flooding is used to distribute the packet. In GEAR, two types of cost are used. They are estimated cost and learned cost. The estimated cost will be the default cost if there is no learned cost available. The recursive geographical forwarding is used in case of high density sensor network instead of restricted flooding. GEAR works well in the small wireless sensor networks.

The BOUNDHOLE technique was proposed to overcome from routing holes. A TENT rule is used to determine the stuck nodes in a network. If the node is determined as stuck using TENT rule, then it uses BOUNDHOLE to overcome from the problem. As with face routing this technique also needs to maintain boundary information of the hole on the nodes[17].

A Curve Stick technique follows three phases. The first phase is engaging phase which is similar to the greedy forwarding mode. When the packet does not reach the destination it encounters local minimum phenomenon. Then it falls in to CS boundary traversal phase where it has to maintain the information about the boundary which leads to the suboptimal performance of the network[3].

ALBA-R was mainly proposed for converge casting in WSNs. It features the cross-layer structure of the geographic routing for load balancing and relay selection. Adaptive Load Balancing Algorithm and Rainbow together resolves the problem of routing hole. This is both localized and distributed techniques. It combines traffic load balancing ,MAC ,position routing, handling of dead ends, awake-asleep mode and back to back data packet transmission to achieve an efficient data collection scheme. To increase the rate of forwarding the traffic and to decrease the end-to-end delay ,it relies on the cross-layer selection scheme. So that the favouring nodes can send the traffic more reliably and effectively, based on the link quality.

The Rainbow scheme which is designed to deal with dead ends is completely distributed and less overhead. It does so by forwarding the packets around holes without maintaining the planar topology. The Rainbow scheme has developed to guarantee the delivery of the packet under increased length of route. The comparison with the rotation sweep and some other set of proposed mechanisms to avoid connectivity holes. Rainbow gives a more robust way to handle dead end scenarios[4].

III. RCGS- A Relative Coordinate Geo-forwarding Scheme

According to the exploratory analysis most of the geographic routing methods use face routing approach to overcome from routing holes. The idea behind face routing approach is to apply the planarization algorithm to eliminate the intersected edges and to create a well planarized graph for the entire network.

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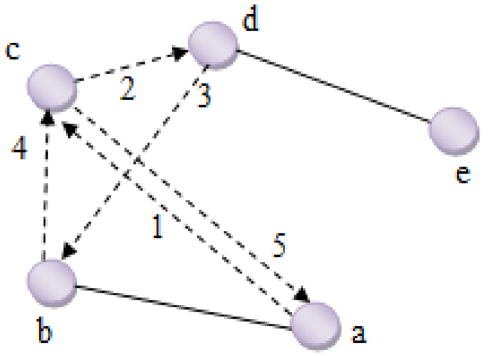

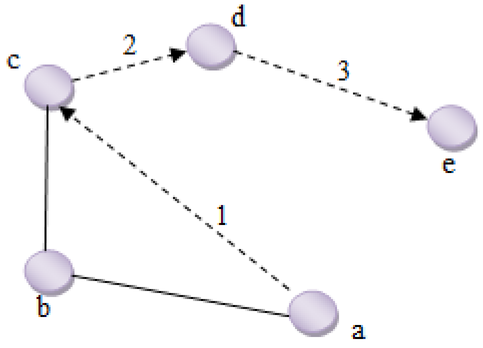

Figure -3(a) Original network with routing loop Figure-3(b) Planarized network

The figure 3(a) clearly shows that the packet from source node a forwards via a->c->d->b->c->a by applying the right hand rule in clockwise order. But there exists a routing loop between a,c,d and b nodes. To avoid this edge bd can be removed by using the planarization technique as shown in figure 3(b). Hence the packet forwarding between a,c can take place correctly via a->c->d->e. The planar graph gives the same efficiency as the original network without crossing edges, but it presents sparse connectivity because of the network planarization.

The face routing approach is built on some of the mechanisms to achieve its designing goals like each node must knows its own location information, location of its neighbouring nodes and destination's location. Even though the face routing approach overcomes from the local minimum problem of greedy method and presents guarantee delivery of packets, it suffers from some issues. It promotes low density of network connectivity. Hence achieves the suboptimal network performance like longer packet delivery ratio and larger packet loss. It requires additional bandwidth which is used for transmission of the packets. Since it maintains location information of neighbour node and a local planer graph on each node, it needs large memory. All these issues of face routing approach presents communication overhead in the network[11][13][15].

Many approaches like BOUNDHOLE[17],CS[3],GEAR[28] are proposed to overcome from this problem. But these proposed approaches cannot consider them into account fully. Since the face routing approach is the most widely used approach the above specified issues must be addressed[31].

Based on these criteria we are proposing a Relative Coordinate Geo-forwarding Scheme RCGS, a novel approach to overcome from these issues.

The basic idea behind RCGS is to recuperate from the routing holes by avoiding the planarization of whole network and to achieve the route optimality. The Figure -4 illustrates the idealised architecture of RCGS.

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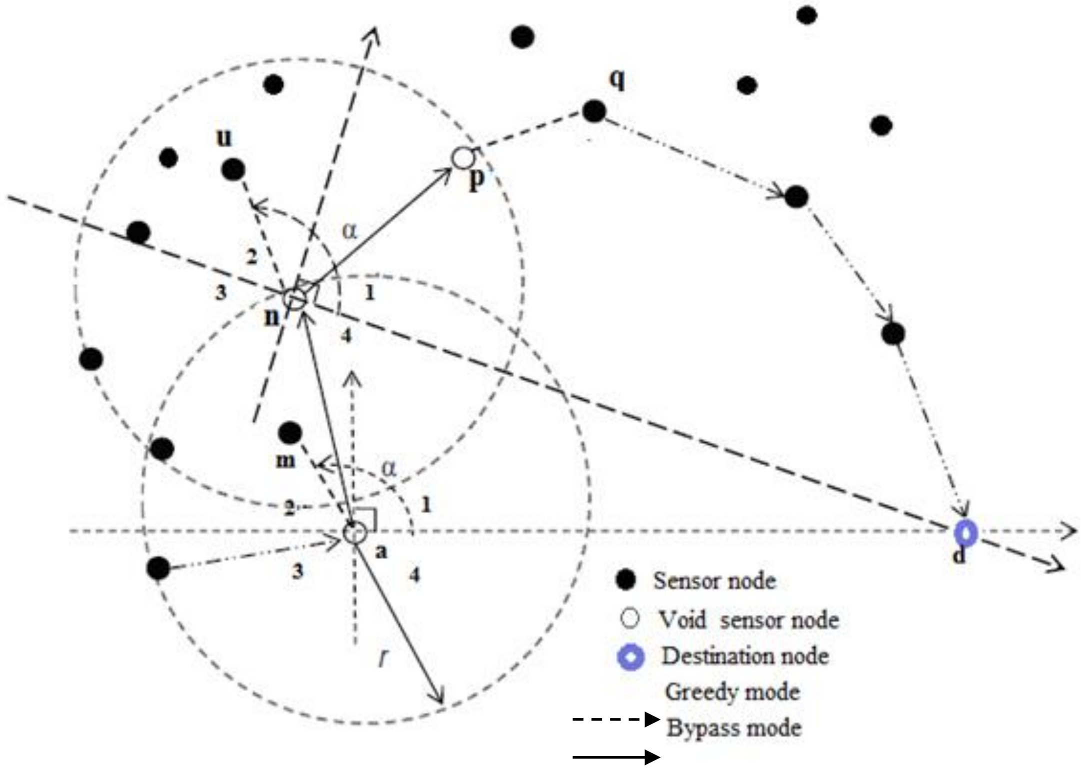

Figure-4 Architecture of RCGS [1]

The RCGS uses Relative Coordinate System to recuperate the routing hole. The Relative Coordinate system is defined as a perpendicular location on the position of node a, destination node d and their neighbours. The horizontal line of RCS(a,d) is determined as x-axis from node a to node d and y-axis intersects by a perpendicular line at node a. Given any node m which is a neighbour to node a, its position obtained from a GPS or any other location service act as its coordinate in RCS(a,d) and it belongs to any one region among 1,2,3 or 4 of RCS(a,d) identified by its position as shown in figure 4. The RCGS works in two phases namely: Greedy forwarding phase and Hole bypass phase.

In the first phase, the request and response messages are used to identify best next-hop relay which is nearer to the destination node. Once the sender sends the request message, only the neighbour node which is in the relay region receive the message and broadcast a response message using discrete delay function. The node which has a lesser delay will first broadcast the response message and the remaining nodes snooping the response message think that already some other node has sent the response and they will quit the connection process. If the sender doesn't receive any response message from the relay region it thinks that there is a presence of routing hole and switches to the hole bypass phase. Here it uses Relative Coordinate System to divide the network into four regions thus every node in the regions 1,2,3 and 4 will take part in the selection process of next-hop relay using an angle based delay contention. So the very first node in counter clockwise will respond first. By considering this four region, the current forwarder will select the node as the next-hop relay which is presented at the minimum angle between forwarder -neighbour and destination. Then it will send the data to it. The same procedure continues until either the packet reaches the destination node or the restart of greedy forwarding phase. Algorithm-1 illustrate the algorithm for RCGS.

Algorithm : 1 Relative Coordinate Georouting

Require: *reqmsg*,*respmsg* where *reqmsg* is the request message and *respmsg* is the response message, *w* is the any advanced neighbour , source *u* and destination *v*

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1. start
2.*a* broadcasts *reqmeg*(a_{loc},d_{des})
3. *b* sets delay time t_{max}
4. **if** *b* has minimum t_{max} **then**
5. broadcast *respmsg* and update best candidate and unicast the packet to *w*
6. **else**
7. occurrence of routing hole
8. **end if**// switch to bypass mode
9. based on *RCS(a,d)* divide the network into four regions
10. Current forwarder chooses the nodes which provides minimum angle between forwarder - neighbour and destination as next hop.
11. unicast the date
12. **if** data reached the destination *d* then
13.terminate
14. **else**
15. repeat from step 9
16. **end if**

Hence Relative Coordinate System will stand as a novel geographic routing method to avoid routing hole issues in WSNs by eliminating planarization of the entire network. Hence it will achieve the optimality of the network.

Greedy forwarding

Consider node *a* that needs to send data to the destination node *d*. At the beginning it broadcasts the RREQ message which includes its own geographical information and the geographical information and the geographical information of node *d*. The source node broadcasts the RREQ message to all the nodes which are in its radio range. On receiving the RREQ each neighbour node b sets the timer to

$[1-\frac{d(a,b)}{r}]\times t_{max}$ to send the RREP message.

Each RREQ message contains its own location. To ensure the reception of RREP message at node a the maximum waiting time is chosen from the neighbour in *r(a,d)* where *r* is the maximum range of transmission. Each node replays in different time interval based on the various advance to avoid the collision, where advance d(a,b) is obtained by forwarding the packet from node *a* to node *b* towards node *d*. It is identified as *d(a,d)-d(b-d)* where *d* indicates the distance. So that *d(a,b)=d(a,d)-d(b,d)* where *d(a,d)>d(b,d)* so that it can send packet using positive progress.

Obviously the node *m* in the figure-4 with maximum advance with respect to the destination node broadcasts first. If overhearing a RREP that was broadcasted before by any other candidate than *b* is due, then node *b* discards the corresponding RREP message. Otherwise, broadcasts RREP only when it is in due. On receiving the RREP message *b*, the node *a* updates the best neighbour to forward the packet if $d(a,f_a)<d(a,b)$ where f_a is the best candidate determined by *a*. Then it unicast the message to *b*.

Bypass mode

When the source node a broadcast RREQ message, it sets the timer to t_{max} and it starts the timer. It waits for RREP message until the timer exceeds t_{max}. If it does not receive any RREP message, it

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considers that a routing hole is occurred. In this situation, a node act as a void node since it doesn't have any node which is nearer to the destination.

To overcome from the routing hole, node a adds the location information in to the header of the packet. Then it uses the relative coordinate system to divide the entire network in to four parts. It calculates *RCS(a,d*). Then it broadcasts RREQ message that includes its own location information , location of node *d*, *RCS(a,d)* and information about the bypass mode.

For any node *m* in *RCS(a,d)* where <*mad* is its deflection angle. We call α =< *mad;* so that

$$\cos \alpha = \beta = \frac{d(a,m)^2 + d(a,d)^2 - d(m,d)^2}{2d(a,m) \times d(a,d)} \quad (3)$$

Then

$$\alpha = \begin{cases} \arccos \beta, & \text{if node m in the part 1 or 2} \\ \pi + \arccos \beta, & \text{if node m in the part 3} \end{cases} \quad (4)$$

On receiving the RREQ message, node m examines whether it is in *RCS(a,d).* If *m*∉ *RCS(a,d),*it discards the RREQ message. Otherwise it uses equation 4.

Then the node *m* broadcasts the RREP message which includes its location information and value of *α.* The left hand rule or right hand rule can be consider to traverse the angle α based on the application. Before the t_{max} of m expires, if it overhears any other RREP message from other nodes then it discards RREP messages. It acknowledge the node *a* about the expiry of t_{max} of nose *m*. When t_{max} is due, a chooses node *n* which is having the minimum angle with respect to *d* as shown in figure 4. Then *a* sends the packet towards upstream forwarder. On receiving the packet from *a*, node *n* identifies whether it has to forward the packet in bypass mode. It check the distance between (a,d) and (n,d). If *d(a,d)< d(n.d)* it route the packet in bypass mode. If so, it uses *RCS(n,d)* to identify the next forwarder. It selects *p* as the next forwarder. The location information is added by the node *n* to avoid loop. So that it can check whether it has received the message once again.

Then it forward the packet toward upstream. This process continues until it reaches the destination or it restarts the greedy mode.

IV. Performance Evaluation

The coherence and productiveness of the RCGS is estimated using NS-3.25 simulator. The simulation parameters used to implement RCGS are shown in table 1.

Table-1 Simulation parameters

Parameters	Values
Platform	Ubuntu 16.04
Simulation tool	NS-3.25
Simulation Area	1000*1000
Number of nodes	25,50,100
Transmission range	20 meters
Utility used	PyViz
Packet size	600 bytes
Node deployment	Grid form

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Channel type	Wifi channel
MAC protocol	IEEE802.11
Network Protocol	IPv4

Initially a module is created by using a command **./create-module.py rcgs** where rcgs is the name of the module. Then build entire ns-3.25 package using a command **./waf build**. Run the script within a scratch folder by using a command **./waf --run scratch/rcgs** .

During simulation 25,50 and 100 mobile sensor nodes are deployed in various time interval. The implemented RCGS is compared with the added feature Clear Channel Assessment Threshold(CCAT) to evaluate the performance of RCGS. Because of the versatile nature of WSNs, it is presenting itself in the research domain. While configuration of network topology needs more careful attention for optimal data transmission. The experiment examines this phenomenon by employing CCAT. It shows that varying such threshold value influences the entire efficiency of the network. By using this, mis-configuration of a single node will not impact on the network all time.

The time interval to forward the packet is varied from 5sec to 100sec. As the time increases the throughput additionally will increase in greedy forwarding. Generally, throughput is described as total number of data packets despatched consistent with unit of time. It is measured in terms of bits/sec. When a node moves out from the range, the throughput will gradually decreases and also the throughput increases if the node get an efficient path by the coordination of other node in bypass mode. Figure-5 indicates that throughput of RCGS and it also shows that the added CCAT improves the throughput according to the various time interval.

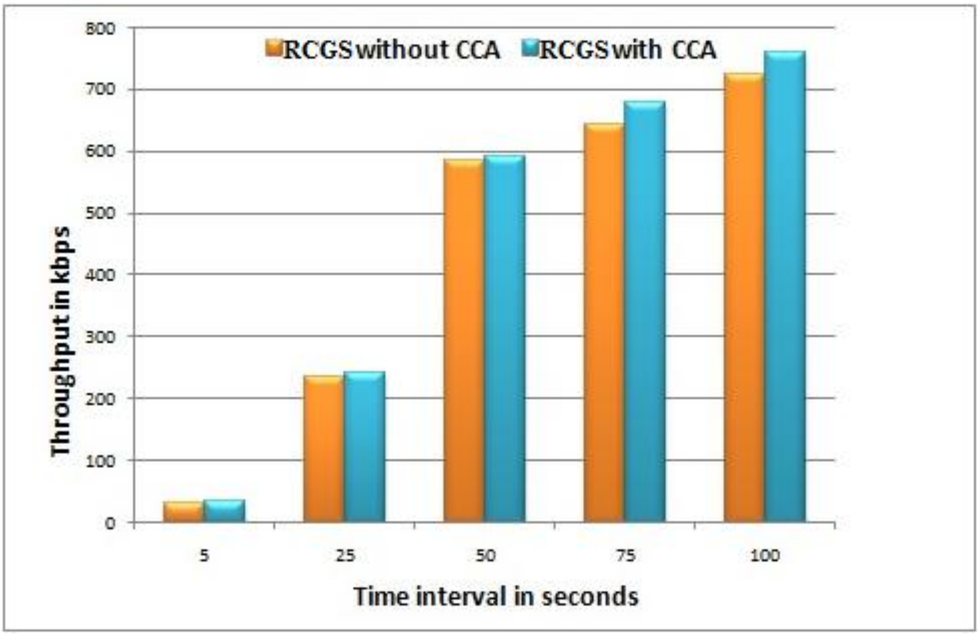

Figure-5 Throughput v/s time interval

Delay is termed as the average latency of the packet to transmit from source node to the intended destination . Average delay in RCGS is showed in Figure-6. The delay in RCGS is less compared to any other geographic routing approach. In other approaches the routing decision is dependent on the topological information. Where as in RCGS, it uses only geographical information and avoids planarization of network. Hence RCGS outperforms than other approaches. Since adding CCAT increases the efficiency of the network by providing the high throughput, it decreases the delay compared to normal RCGS.

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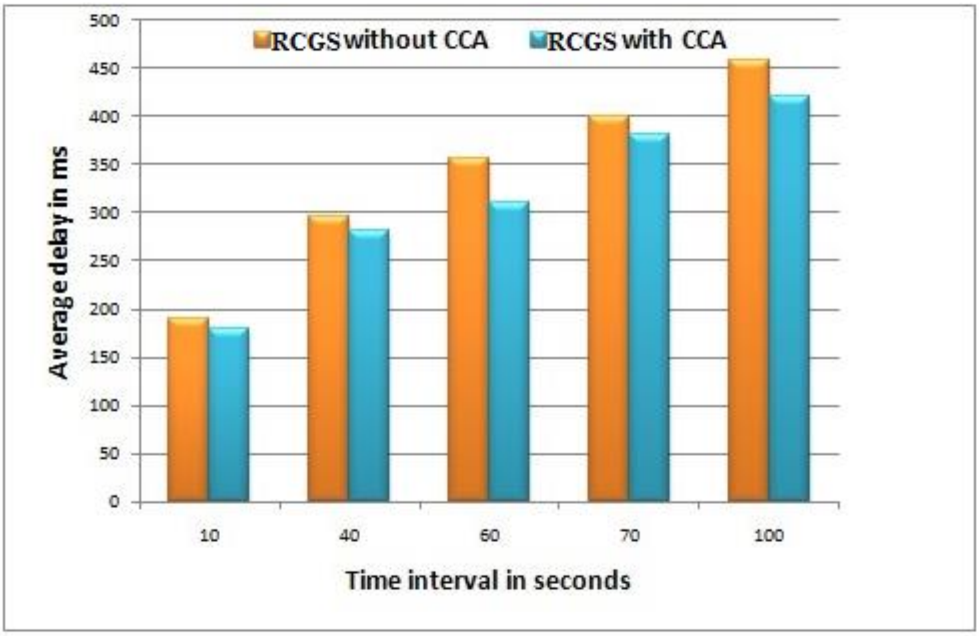

Figure-6 Time interval v/s delay

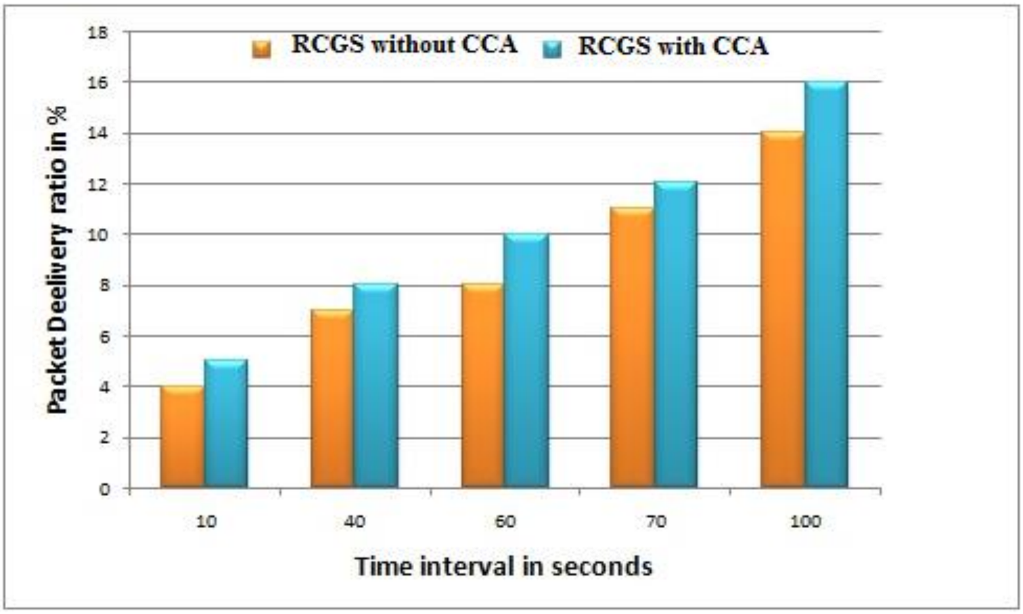

Figure-7 Time v/s PDR

Figure 7 shows the Packet Delivery Ratio(PDR) of RCGS and RCGS with CCAT. As the time interval increases the number of delivery of packet are also increases in RCGS. Since it doesn't employ planarization graph, the packet delivery ratio is more. As the CCAT decreases the delay and increases the throughput, the PDR with CCAT will have higher PDR.

V .**Conclusion**

In WSNs different types of anomalies can occur due to random deployment of nodes, obstruction and physical destructions. As holes present a serious problem on the performance of the

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network, it has to be resolved. Geographic routing approach is one of the commonly used schemes to overcome from the holes problem. Because of its stateless, scalable and localized features it has been adopted widely in the field of research. The most commonly used approaches of geographical routing are greedy forwarding approach and face routing approach . Even though face routing approach is the commonly accepted routing mechanism it suffers from some urgent issues that has to be solved. This paper presented a novel idealized RCGS approach to overcome from these issues. This approach can be used to detour routing holes by taking consideration of relative coordinate mechanism. Simulation consequences of RCGS suggests that, since it avoids the planarization of entire network, it preserves the path optimality and also the comparison says that by employing Clear Channel Assessment Threshold the efficiency of the network can be increased in terms of throughput, average delay and packet delivery ratio.

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