Design & Development of a Distributed Energy-EfficientCooperative Routing Protocol in WSNS Using MPCR

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Abstract

In this paper, a design & development of a distributed energy-efficient cooperative routing protocol in WSNs using MPCR is presented in brief along with the simulated results.

Keywords – WSN, Static, Dynamic, Packets, Authentication, Sensor, Node, Distribution, Network, Key, Message Authentication Code Protocol, Security, Routing, Management, Sink, Cryptography, Source, Energy, Router, Attacker, Base Station, Machine condition monitoring, Industrial wireless sensor networks, Cooperative communication, Medium access control, Indoor industrial monitoring, Energy efficiency, Space time block, Stability.

I. Introduction

As of late, the benefits of the cooperative network communications in the WSN's physical layer have been investigated. Be that as it may, the effect of cooperative network communications on the plan of the top most layers of the WSN has not been surely known at this point and also not that much investigated. Development of routing algos using cooperative mechanisms in wireless networked systems has increased a lot of enthusiasm because of its capacity to incorporate the communicative idea of the developing the structured power proficient routing algos [51].

The majority of the current participation algos which have been developed are based on the steering calculations are executed by finding a very shortest route (similar to the djistraks algo) first and then afterwards improving the route course utilizing cooperative network communications in the WSN's. All things considered, these routed algos don't completely misuse the benefits of computer wireless networked communications, since the ideal optimal path or the route probably won't be like the shortest ones in the WSN network zone [51].

Right now, in this paper, we have developed an improvised minimum power cooperative routing algo, to be specific, called as the Minimum Power Cooperative Routing (MPCR) concept, which utilizes the wireless networked cooperative communication concepts while building the minimum power route to transfer the data packets to the sink from the source. Revised or improvised MPCR algo also develops the min-power path in the WSN zone, which ensures certain throughput, as a shortest path from the source to the goal joining all the sensor nodes which are having minimum power along its path. In this way, any distributed shortest path algo can be used to locate the ideal cooperative path with polynomial intricacy [51].

Utilizing this improvised investigation, we can come to a conclusion that the improvised MPCR algo can accomplish power sparing of 60 % in ordinary WSN systems and 40 % in grid frameworked WSN systems contrasted with the current paths or the routes based on the shortest paths from s to d. From the NS-2 simulation results when the developed algo is incorporated & run, the results show that there minimum power cooperative routing based algorithm can save 40 % of the power in the WSN in comparison with other cooperative based routing protocols [51].

II Mathematical model

The mathematical model [51] that is being used in our simulation work is mentioned as follows. The network model along with the problem is defined using the mathematical means as:

$$\min_{\omega \in \Omega} \sum_{\omega_i \in \omega}^{For\ all\ \omega} P_{\omega_i}$$

The end to end throughput for a particular route request is modelled as the minimum of the throughput values of all the hops in the network zone as:

$$\eta_{\omega} = \min_{\omega \in \Omega} \left(\eta_{\omega_i} \right)$$

The direct transmission mathematical model is given by:

$$r_{i,j}^{D} = \left(\sqrt{P^{D} d_{i,j}^{-\alpha}} \right) h_{i,j} s + n_{i,j}$$

The destination source's mathematical model (receiver end) is given as:

$$r_{x,z}^{C} = \left(\sqrt{P^{C} d_{x,z}^{-\alpha}} \right) h_{x,z} s + n_{x,z}$$

$$r_{x,y}^{C} = \left(\sqrt{P^{C} d_{x,y}^{-\alpha}} \right) h_{x,y} s + n_{x,y}$$

$$r_{y,z}^{C} = \left(\sqrt{P^{C} d_{y,z}^{-\alpha}} \right) h_{y,z} s + n_{y,z}$$

The nodal power / energy required for the data transmission could be modelled as:

$$P_i = \min_{j \in N(i)} \left(P_{i,j} + P_j \right) \ \&$$

$$E = P_i \times t = \min_{j \in N(i)} \left(P_{i,j} + P_j \right) \times t$$

It has to be noted that all these equations are used in the development of the routing protocol in the simulation [51].

III Overview of the proposed work done

The work done could be categorized into different phases such as:

- Discovery phase,
- Request phase,
- Routing phase &
- Transmission phase

which are explained one after the other in succession. Basically, in this research paper, we are going to concentrate on the cooperative routing mechanisms in wireless sensor networks using distributed concepts by choosing the cooperative nodes. These cooperative nodes will be acting as energy efficient nodes because they are going to save lot of energy & power and distribute a lot of packets. That's why we call it as a distributive energy efficient cooperative node routing mechanism of transmitting the data packets.

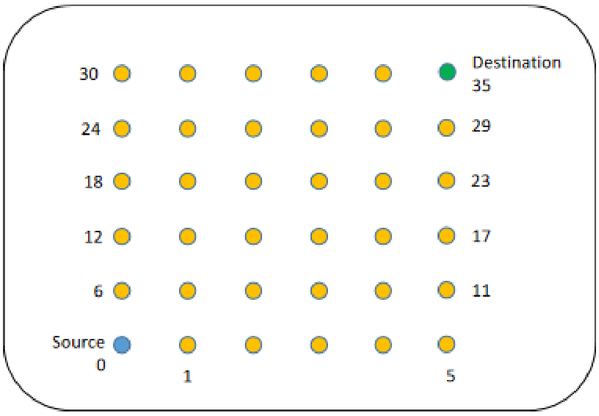

Fig. 1 : Layout of the sensor nodes

We know that power is the rate of work that is being done by a sensor node in transmission of the data packets & energy is the capacity of the sensor node to do transfer the data packets, i.e., energy = power × time. In order to achieve this distributive nature of the modal transfer of the data packets using minimum energy concept, we are going to use the improvised MPCR algorithm and this algo gives better results compared to the existing algos developed by other authors / researchers. Once the NAM window is clicked, the network is going to be deployed, the node deployment starts at the pre-set locations in the NAM window.

Two kinds of nodes exist in the research work, one is direct nodes (node to node communication or direct transmissions), when we take the help of other node, it is called as a cooperative node (cooperative node communications OR cooperative transmissions). First, we are going to find out all the direct nodes from the s to the d. Next, we are going to find the cooperative nodes. 36 nodes are taken in process, starting from 0 to 35 arranged in a layer of matrix of (6 × 6) as shown in Fig. 1.

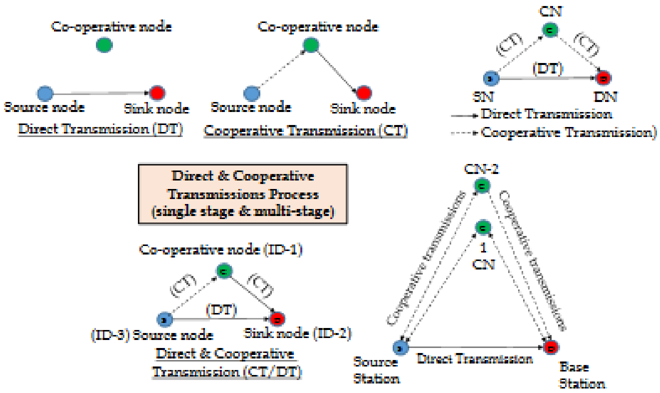

Fig. 2 : Direct & cooperative transmission of data packets from source (0^{th} node) to destination (35^{th} node) in WSN (different modes)

Source	Neighbour	SX-Position	SY-Position	H-Distance (d)
0	1	20	10	100
0	2	20	10	200
0	6	20	10	110
0	7	20	10	148
0	8	20	10	228
0	12	20	10	220
0	13	20	10	241
0	14	20	10	297
:				
:				

Table 1 : Data showing the details of the source node with its neigbours

First the nodes will have to be discovered in the network starting from the source. Once, all the nodes have been discovered, a 'hello' packet will be sent from the source to the destination thro' the neighbours. Once all the nodes have been discovered, we can come to know who are the neighbours of the particular node chosen, what is the position of it from other nodes, etc...which can be checked from the 'neighbour file' containing the routing informations regarding positions. The distance will be calculated using the Euclidean distance concepts. This neighbouring node details are given in the table no. 1 only for the source node '0', similarly the table 1 can be developed for the other nodes also in the network.

Nodes are going to communicate with each other & also togetherly. Depending upon the routing table, the data packets will be transmitted to which is the neigbouring node. The rings shown in the Figs. 6 to 13 are nothing but the radio transmissions. The nodes has been configured with the antenna layer, physical layer, mac layer, link layers & propagation layers, etc..

Due to the layers only, the nodes are going to communicate like normal devices, which is called as the trace information. Whatever the communication is happening can be viewed from the NAM window which is provided at the bottom of the simulation screen which shows which packet is sent from which node to which node. For example, in the Fig. 6 shown, the following process is being carried out showing how the nodes are being communicated with each other &

how the data is being transmitted from one node to another node as:

- Node 9 sending hello packet to neighbour 10
- Node 10 sending hello packet to its neighbor 9
- Node 11 sending hello packets to its neighbour 10

Next, whichever nodes are being communicated they turn to green from black. Fig. 6 shows that nodes 0 to 13 are communicating with each other. The Fig. 7 shows that nodes 0 to 20 are communicating with each other. Once, the process is over, all the nodes have been communicated with each other as shown in the Fig. 8, all the nodes turn green showing that communication has happened, in the sense all the nodes are in active state and not in the sleep mode and they can be able to further transmit the data packets.

The next phase is the routing phase. Still now, it was called as the discovery phase (here, all the nodes have been discovered – showing green). In the routing phase, the nodes are giving request to their neigbours. It has to be understood in this juncture that why the nodes are giving a route request to its neighbour is to find out whether it is the shortest path or not (Dijistra's algo applied). This algo is going to find the distance between each nodes. Then, finally, it will find the neighbouring node towards the destination mode, which is the closed node. To travel from s to d, what is the min distance is calculated by our routing protocol.

In order to achieve this, the nodes are giving a request to their neighbours, which is called as the request phase. In the request phase, all the shortest nodes towards the destination from the source could be found out by our improvised routing algo whether they are closest or not. To find out the shortest path, 2 modes as shown in the Figs. 11-13 can be applied, viz., DT or CT. Using our revised algorithm, the nodes shown in the blue colour could be used for the direct transmission (DT). For ex., 35-34-21-13-0.

For this a cooperative mechanism has to be figured out. 0th node is giving the route request to the neighbour node 13, which in turn is giving route request to its neigbours 7 & 14 (called as cooperative nodes). These cooperative nodes will be further useful for the data transmission purposes. 13th node will give a final confirmation to the 0th node showing that these are my cooperative nodes.

Further, the data can be transmitted to the destination thro' these cooperative nodes also. For ex., 14 is giving route request to its neighbour nodes 20, 27 & 21. The nodes 20 & 27 acts as the cooperative nodes for 21. Then, it will give a confirmation to the 13th node showing data transfer can be done. The same process will be repeated for 34th node also which also gives a route request to its neighbours 28 & 33. Path is configured using the cooperative nodes as 0-13-20-27-34-35. The nodes 28 & 33 acts as the cooperative nodes for 34.

These cooperative nodes are the ones which consumes less energy. Now, whatever the data has to be propagated will be initiated once the shortest path with least energy/power is found out.

Once the request phase process is over, the transmission phase starts. All the nodes will be now ready for transmission purposes using the cooperative methodology developed in the algorithm. Whatever the data is to be sent is being distributed and sent to all the nodes as shown in the Figs. 11-13 thus showing that the data transfer rate is speeded up.

Apart from the direct nodes, the cooperative nodes also participate in the transmission. This process is what is called as distributed routing (lot of data can be distributed amongst the nodes) so that the throughput will increase and the energy consumption will be lessened as more nodes are participating in the data transfer process, both using DT as well as using CT (for ex., 0-13-20-27-34-35 & 0-7-14-21-28-35).

The speed of the simulation can be increased by increasing the small rectangular bar provided at the upper right hand corner of the NAM window. The concept of this work is designed like both the use of CT & DT, that's why the process is being called as distributed in nature (Fig. 6 – 14).

Thus, it can be argued that the proposed system is giving better results compared to the work done by others (existing systems). The whole data is getting transmitted which can be seen from the processes in the bottom of the NAM window. Like this, we can send whatever datas are there from the s to the d. Once, the simulation is over, the status of the network is shown as in the Fig. 14.

IV Chronology of the simulation process & the DFD/Flow-Chart

The flow-chart / data flow diagram shown in the Fig. 3 Is used for the simulation purposes and the following chronology of events is used in the design process.

- Start
- Define Node Configuration parameters
- Set Channel/Wireless Channel Type
- Set Propagation & radio-propagation model
- Set Network interface type (Physical/Wireless)
- Set MAC type layer
- Set interface queue type
- Set link layer type
- Set antenna model
- Set max packet in ifq
- Set number of mobile nodes = 36
- Set DSR routing protocol
- Set 630 X axis distance
- Set 570 Y axis distance
- Set Energy Model - Initial Energy
- Set Initial energy in Joules
- Create Simulator Object

- Create NAM File
- Create Multiple Trace
- Create Topology
- Creating GOD (General Operation Director) Object
- Configuring the Nodes in the Topology
- Create the sensor nodes
- Assign the node positions
- Calculate the distance
- Start sending hello packets
- Initiate Routing Phase
- Start Route-Request packets giving
- Initiate the transmitting phase
- Plot the graphs

V NS-2 Simulation results & discussions with the execution steps

In this research work, we have proposed a data centric multipath routing protocol developed in WSNs using CBR, MPCR with enhancement in their life times with distributed concepts and reduced energies of the nodes. The coding (script writing) w.r.t. the wireless sensor network is developed in the NS2 tool by writing .tcl scripts and once it is completed, it is tested for its effectiveness as per the algo steps given below from s1 to s14. Simulation results are observed both for the individual parameters as well as for the comparision ones.

1. The coding is done in the .tcl scripting incorporating the developed hybrid protocol.
2. The developed code is saved in a particular folder in the Ubuntu environment.
3. Ubuntu is started (Fig. 4).
4. At the terminal, commands like sudo –s is being used to enter the kernel (Fig. 4).
5. Password is being set (Fig. 4).
6. The source code in which the directory / folder is present is changed using the change directory cd command and entered (Fig. 4).
7. The code is run using ns filename.tcl (Fig. 4).
8. The command window of the NS-2 simulator appears with the simulator start button along with the network animator (Fig. 4).
9. Once the simulation is started, the sensor node deployment within the ‘n’ number of cluster heads along with the base station, sink, source, etc.... & the ‘m’ attacker nodes appears on the NS-2 animator screen (Fig. 5).
10. Data transfer starts from the source (normally 0), nodes starts sending & receiving the data packets as per the algorithm developed .... seen in the form of concentric circles (Fig. 6 – 8).
11. Simulation takes couple of minutes, passes different stages of data packets sending, verification, encryption, decryption from the source to the sink (Fig. 9 – 13).
12. Once the data transfer is fully successful, all the nodes turns red indicating the 100 %

success rate
(Fig. 14).

13. Results are observed at the command prompt (terminal) by using the results visualizations
chmod 777 results.sh & ./results.sh (Fig. 15 – 22) or sometimes the result observation command can be directly embedded into the code at the end of the program.

14. Output graphs showing all the parameters such as Plot of packet delivery ratio (PDR) as a function
of time (Fig. 15), Plot of throughput as a function of time (Fig. 16), Plot of energy consumed by the
sensor nodes as a f/n of time (Fig. 17), Plot of packet drop delay as a function of time (Fig. 18), Plot showing the comparision of packet delivery ratio with the existing ones (Fig. 19), Plot of packet-loss comparison v/s time with the existing systems (Fig. 20), Plot of energy consumed v/s time & comparison with the existing systems (Fig. 21), Plot of throughput v/s time & comparison with the existing methods (Fig. 22) ... are observed with a simulation step size of 5 ms, thus showing the effectivity of proposed methodology (Figs. 19 – 22).

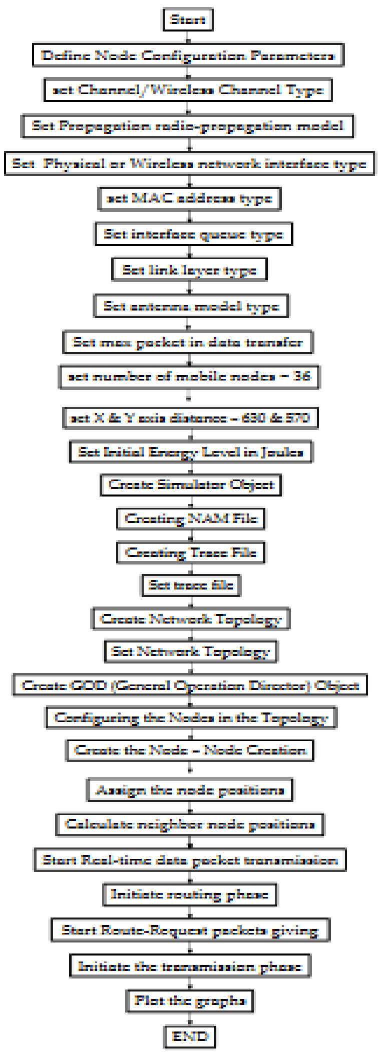

Fig. 3 : Flow chart / data flow diagram of the distributed routing scheme process

The Fig. 22 & shows the graph of throughput & throughput comparison v/s time. Throughput is nothing but the number of packets received in bits / millisecond, thus showing that in our proposed system, we are getting maximum throughput (100). From the sim results, it can be observed that the throughput is more than compared to the other 2 existing systems. The Fig. 19 shows the graph of packet delivery ratio v/s time. In the PDR comparisons, the packet delivery ratio is compared with the shortest path mechanism & the normal mechanism. In the proposed system, better results are observed than others (green color & blue color) as the existing systems are not producing that much throughputs. The Fig. 20 shows the graph of packet loss comparison v/s time w.r.t. the works done by others. As there is no packet loss, the curve (red) is straight showing better results as the cooperative mechanisms are being used for the transmission purposes. In the existing systems (shortest path & the normal system), lot of losses are observed (peaks), hence the curves are up and down.

The Fig. 21 & shows the graph of energy consumption comparison v/s time, which shows that energy consumption in the proposed system is less in our case (saving lot of energy) compared to the normal ones & the shortest path ones because of the incorporation of the routing protocol using the cooperative nodes. In the existing systems, the energy reduces very quickly and is not that much efficient.

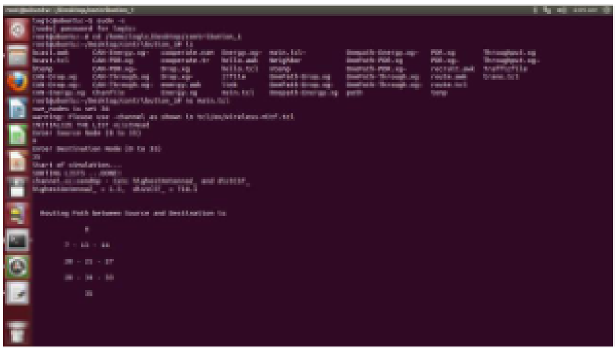

Fig. 4 : Command prompt showing the process of execution of the simulation process, routing path b/w the source & destination, 0 – 7 – 13 – 14 – 20 – 21 – 27 – 28 – 34 – 33 – 35

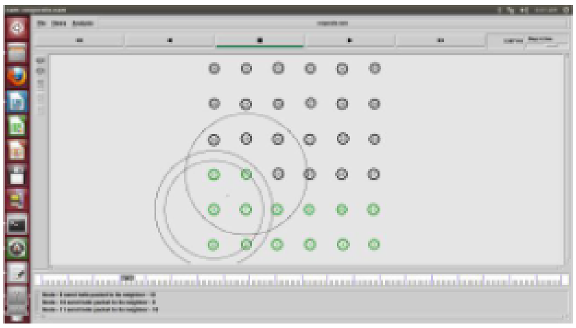

Fig. 6 : Sensor nodes in the discovery phase of verification of all the nodes upto say 13th node, concentric circles indicating the route request for the neighbouring nodes

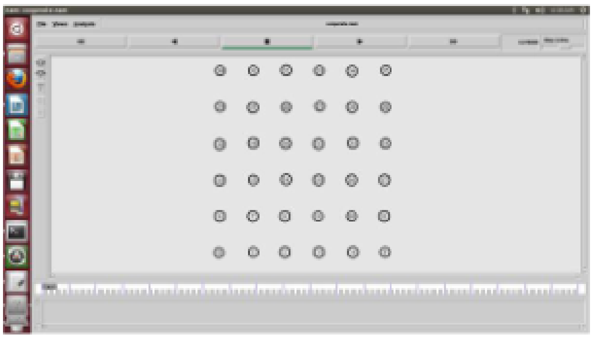

Fig. 5 : Layout of the sensor nodes (0-Source) & (35-Sink) in matrix of (6 × 6) with their positions in the form of (x, y)

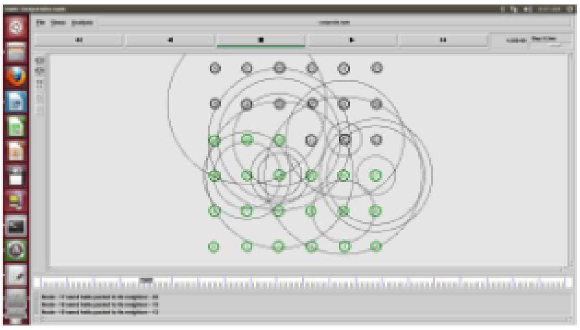

Fig. 7 : Sensor nodes in the discovery phase of verification of all the nodes upto say 20th node, concentric circles indicating the route request for the neighbouring nodes by sending the hello packets

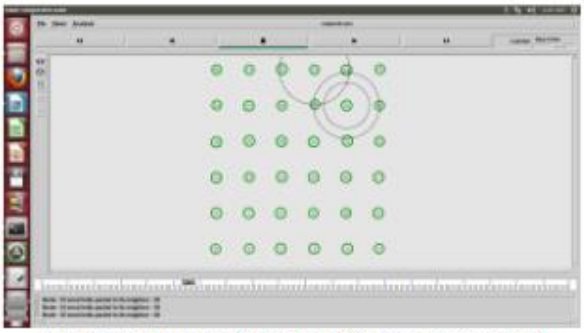

Fig. 8 : Sensor nodes in the discovery phase of verification of all the nodes upto say 35th node, concentric circles indicating the route request for the neighbouring nodes (indicates completion of the discovery phase)

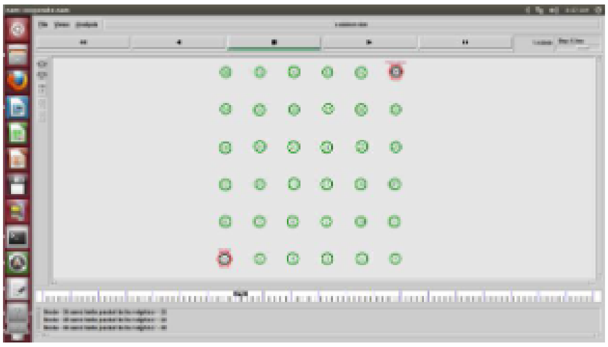

Fig. 9 : Start of the simulation process showing the sensor node (0) & the sink node (35) or the destination, the start process of the sending of the hello packets using route requests

Fig. 10 : Source node sending the route request packets to the neighbouring cooperative node (cooperative transmission) & the direct nodes (direct transmission) via the shortest path – 1st phase of data packet transfer from *s* to *d*

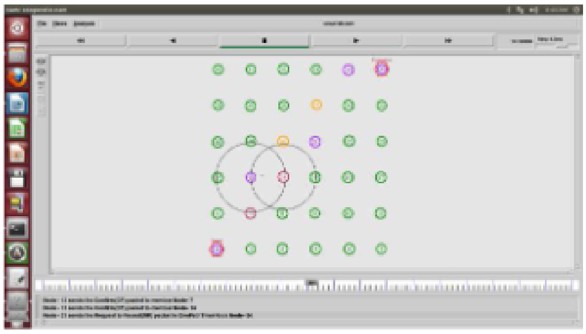

Fig. 11 : Source node sending the route request packets to the neighbouring cooperative node (cooperative transmission) & the direct nodes (direct transmission) via the shortest path – 2nd phase of data packet transfer from *s* to *d*

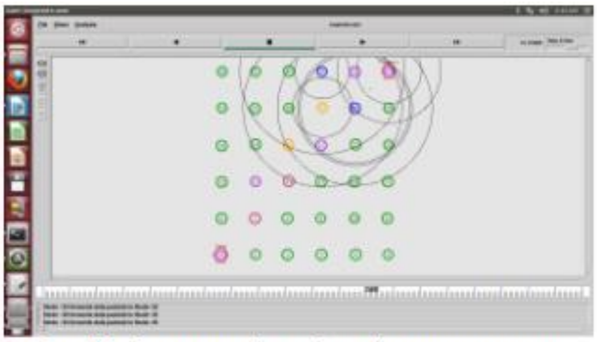

Fig. 12 : Source node sending the route request packets to the neighbouring cooperative node (cooperative transmission) & the direct nodes (direct transmission) via the shortest path – 3rd phase of data packet transfer from *s* to *d*

Fig. 13 : Source node sending the route request packets to the neighbouring cooperative node (cooperative transmission) & the direct nodes (direct transmission) via the shortest path – 4th phase of data packet transfer from *s* to *d*

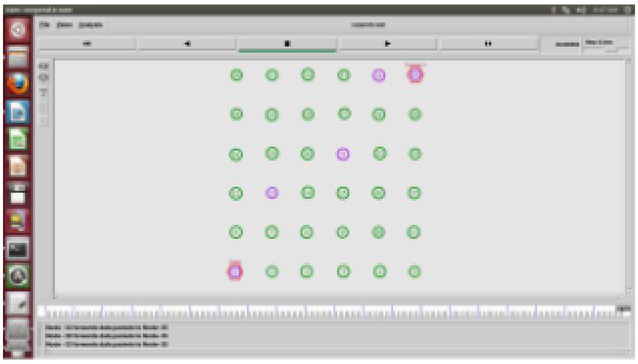

Fig. 14 : Source node sending the route request packets to the neighbouring cooperative node (cooperative transmission) & the direct nodes (direct transmission) via the shortest path – final phase of data packet transfer from *s* to *d* showing the shortest

VI Conclusions

In this research paper, the design & development of a data centric multipath routing protocols in WSNs
using CBR, MPCR with enhancement in their lifetimes and reduced energies is being presented. The
simulation results shows the effectivity of the methodology adopted. Here, an improvised / enhanced version of the CBR, MPCR protocol development for the WSNs and by comparing its performance with existing system by using some rejuvenated & improvised routing security routing protocol schemes is presented. From the results, it can be inferred that after each round, the number of data packets received by the sink increases, thus reducing the power energy consumption, thus providing a better throughput.

From the results of the throughput, it can be inferred that in our proposed system, we are getting maximum throughput (100) & it is more than compared to the other 2 existing systems. In the PDR comparisons, the packet delivery ratio is compared with the shortest path mechanism & the normal mechanism. In the proposed system, better results are observed than others as the existing systems are not producing that much throughputs. As there is no packet loss, the curve is straight showing better results as the cooperative mechanisms are being used for the transmission purposes.

In the existing systems (shortest path & the normal system), lot of losses are observed (peaks), hence the curves are up and down. The energy consumption in the proposed system is very less in our case (saving lot of energy) compared to the normal ones & the shortest path ones because of the incorporation of the routing protocol using the cooperative nodes. In the existing systems, the energy reduces very quickly and is not that much efficient.

Time	PDR (proposed)
0	0
7	1
9	1
11	1
13	1
15	1
17	1
19	1
21	1
23	1

Table 2 : Quantitative results of the PDR v/s time

Time	Proposed-Throughput
0	0
5	0
7	0.6144
9	1.024
11	1.024
13	15.3599
15	39.936
17	64.512
19	89.0879
21	100.1472
23	100.1472

Table 3 : Quantitative results of the throughput v/s time

Time	Proposed (Energy consumed)
2	99.6764
4	99.8999
6	99.706
8	99.5528
10	99.4678
12	99.4225
14	99.0802
16	98.4441
18	97.8073

Table 4 : Quantitative results of the energy consumed v/s time

Time	Proposed (drop) – straight line
0	0
5	0
7	0
9	0
11	0
13	0
15	0
17	0
19	0
21	0
23	0

Table 5 : Quantitative results of the no. of packets dropped t v/s time

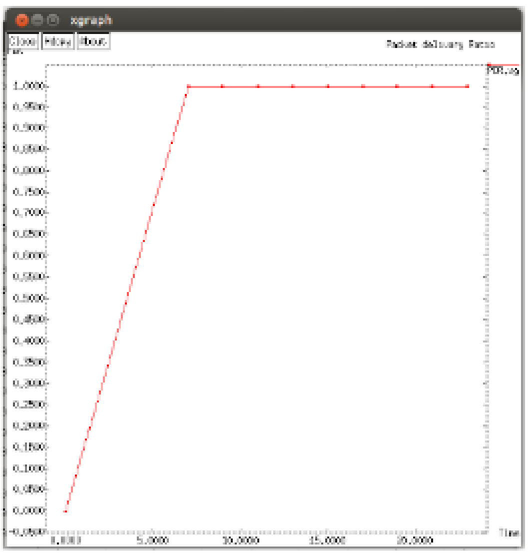

Fig. 15 : Plot of packet delivery ratio (PDR) as a function of time

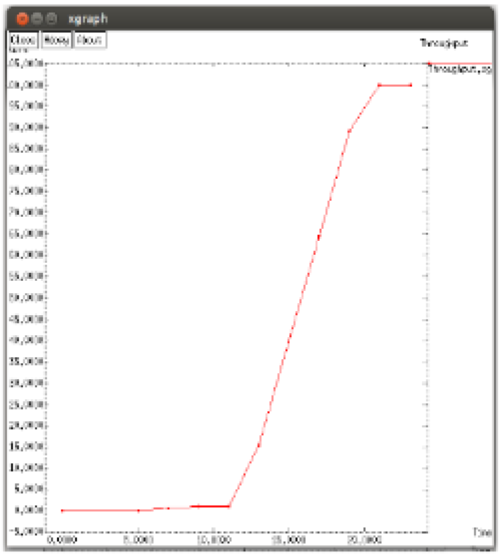

Fig. 16 : Plot of throughput as a function of time

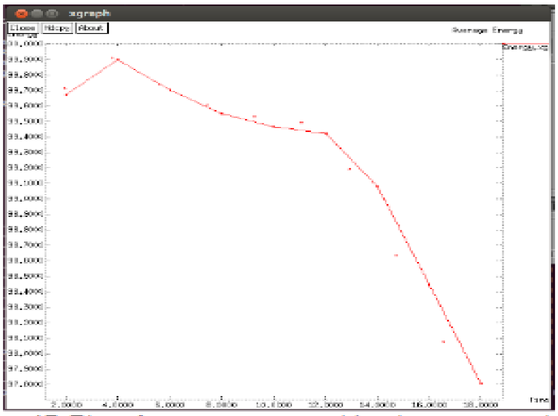

Fig. 17: Plot of energy consumed by the sensor nodes as a function of time

CAN	One-path	PDR	PDR (proposed)
0	0	0	0
7	1	1	1
9	0.9487	1	1
11	1	1	1
13	0.9694	0.97	1
15	0.9341	1	1
17	1	1	1
19	1	1	1
21	1	1	1
23	1	1	1

Table 6 : Quantitative results of the PDR v/s time & comparision with the existing systems

In this research paper, we have investigated the impact of the cooperative communications on the
MPC problem in WSNs. For any of the given s-d pair, the optimum route will require the minm end to end
transmission energy/power while guaranteeing a certain throughput and hence the developed algo uses
this cooperative concepts while the route is being constructed form the s to d. The results shows the
efficiency & the profoundness of the methodology that is being developed. The quantitative results
shown in the tables 2 to 9 shows the effectiveness of our proposed methodology.

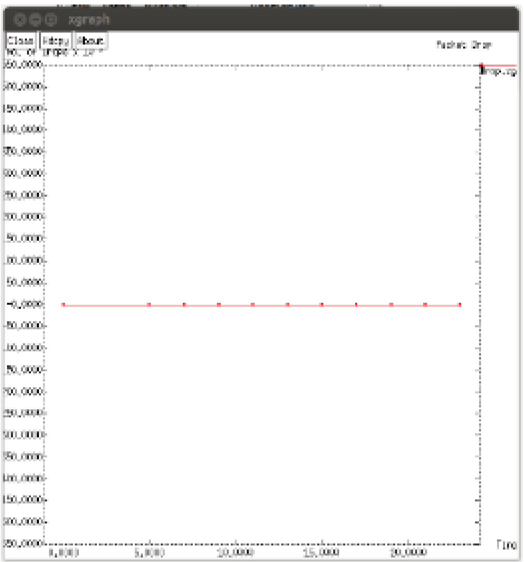

Fig. 18 : Plot of packet drop delay as a function of time

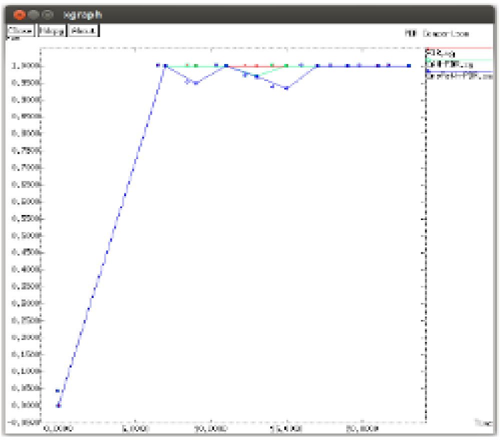

Fig. 19 : Plot showing the comparision of packet delivery ratio with the existing ones, PDD is compared with the shortest path algo (green) & the normal mechanism (blue), proposed showing the better results compared to the others as existing systems are not producing much throughputs

CAN	One-path	Drop	Proposed (drop)
0	0	0	0
5	0	0	0
7	0	0	0
9	6	0	0
11	0	0	0
13	21	13	0
15	65	0	0
17	0	0	0
19	0	0	0
21	0	0	0
23	0	0	0

Table 7 : Quantitative results of the no. of packets dropped v/s time & comparision with the existing systems

CAN	CAN-Energy	CAN-One-path Energy	Proposed (Energy)
2	99.7843	99.7874	99.6764
4	99.2493	99.5214	99.8999
6	97.7318	98.5559	99.706
8			99.5528
10	96.3103	96.9594	99.4678
12	94.9505	94.6328	99.4225
14	93.5165	92.1794	99.0802
16			98.4441
18			97.8073

Table 8 : Quantitative results of the energy consumed v/s time & comparision with the existing systems

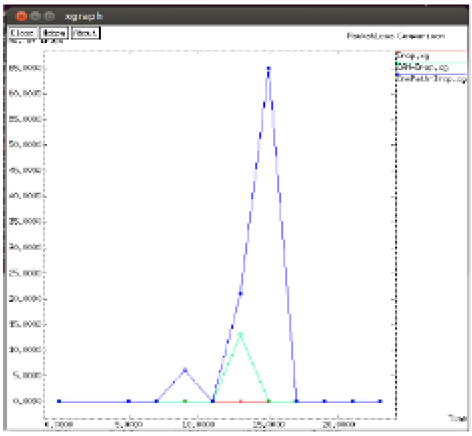

Fig. 20 : Plot of packet-loss comparision v/s time with the existing systems, proposed (red) showing better results compared to (shortest path – green & the normal system - blue), showing better results as the cooperative mechanisms are being used for the transmission purposes

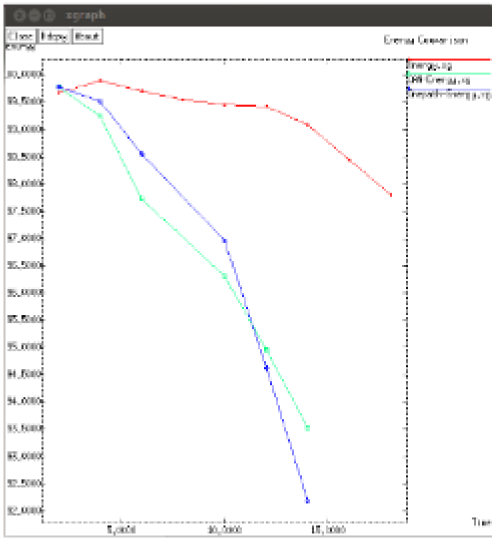

Fig. 21 : Plot of energy consumed v/s time & comparision with the existing systems

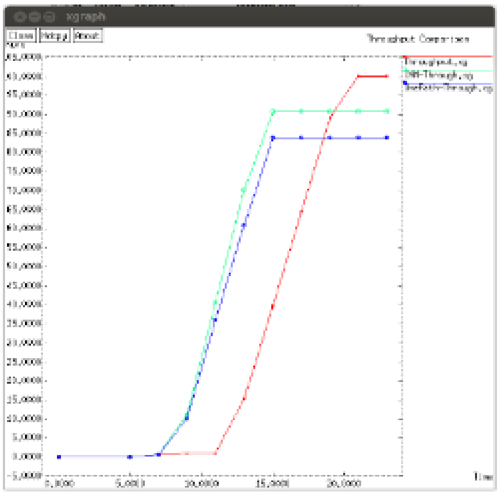

Fig. 22 : Plot of throughput v/s time & comparision with the existing methods

One path	Throughput	CAN	Proposed-Throughput
0	0	0	0
5	0	0	0
7	0.61439	0.6143	0.6144
9	10.1904	11.2639	1.024
11	36.0912	40.7552	1.024
13	60.8975	70.2463	15.3599
15	83.9711	90.7263	39.936
17	83.9711	90.7263	64.512
19	83.9711	90.7263	89.0879
21	83.9711	90.7263	100.1472
23	83.9711	90.7263	100.1472

Table 9 : Quantitative results of the throughput v/s time & comparision with the existing systems

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