EFFECTIVE ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORKS USING CRT-LEACH ALGORITHM

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ABSTRACT

Wireless Sensor Networks (WSNs) consist of huge number of sensor nodes dispersed in a domain of enthusiasm with at least one sink for watching the environment and physical situation. These sensor hubs are circulated in threatening conditions and are unprotected to deficiencies, for example, power dissemination, equipment glitches, communication link errors and malicious attacks, among others. It has been established that essentialness, speed and unwavering quality are the chief test in the usefulness of WSNs as they are controlled with compelled imperativeness and restricted equipment assets. Accordingly, it is necessary to structure vitality proficient steering conventions for WSNs applications. Chinese Remainder Theorem (CRT)- based packet splitting integrated with Low-Energy Adaptive Clustering Hierarchy (LEACH) algorithm routing protocol was proposed so as to decrease vitality utilization during correspondence and improve message dependability in WSNs. The consequences of exploratory reproductions show that the proposed structure delivered powerful directing convention for WSNs when contrasted with existing routing protocols to the extent essentialness usage, speed, equipment necessities and transformation delay continuously WSNs.

Keywords*: Chinese Remainder Theorem, Energy Consumption, Residue Number System, Routing Protocol, Wireless Sensor Network*

1. Introduction

Wireless Sensor Networks (WSNs) comprise of dispersed system of colossal amount of subjectively sorted out sensor nodes, which have characteristic computational, stockpiling and transmission proficiencies that work in an unpleasant mode and accumulate data of eagerness from its encompassing (Jindal, 2018). By and large, WSNs are remote system comprising of spatially scattered self-sufficient gadgets, utilizing sensors to observe physical and ecological circumstances, for example, temperature, sound, pressure, wind headings, among others, and helpfully send their detected data over the system to a base station (sink) for additional handling (Khodabande *et al*, 2014; Sharma & Sharma, 2016). In WSNs applications, essentialness usage is the significant test on the grounds that the sensor hubs have insufficient wellspring of

intensity, which is hard to supplant or even renew after appropriation (Demigha *et al*, 2011; Barati *et al*, 2014; Lee *et al.*, 2016). Thus, WSNs routing protocols should be arranged in a vitality effective way. Correspondingly, data aggregation is another significant test influencing rate and dependability of WSNs, along these lines, there is a need to dispose of data aggregation during message transmitting. By and large, WSNs are utilized to gather crucial data from the earth and are required   to survive hub disappointments and consistent activity within the sight of flaws.

Different routing protocols have been adopted to diminish power utilization and give rapid activities continuously WSNs. Low Energy Adaptive Clustering Hierarchy (LEACH) algorithm is the first and best vitality productive hierarchical clustering algorithm for WSNs that was proposed for decreasing power utilization (Hamamreh *et al.*, 2018). By and by, message collection in LEACH for the most part causes delay in sending got parcels from the CH to the sink. Chinese Remainder Theorem (CRT) has been used as a component to decrease transmission imperativeness and augmentation immovable quality in WSNs. RNS is a non-weighted number framework that could be used for vitality productive and solid WSN activities since it offers carry-free, parallel, high-speed, secure and fault tolerant arithmetic operations. Along these lines, CRT can be integrated to LEACH so as to decrease power utilization, dispose of information conglomeration, and improve organize unwavering quality since it offers boundless potential for fast computer arithmetic (Gbolagade & Cotofana, 2009).

In order to design proficient routing protocol, Chinese Remainder Theorem (CRT)-based packet splitting incorporated with Low-Energy Adaptive Clustering Hierarchy (LEACH) algorithm was anticipated. The structure incorporates Local Closet First (LCF), so as to choose nearest bunch individuals and used the moduli set $\{2^{n+1}-1, 2^n, 2^n-1\}$ to break the detected information by every node and send proportional deposits to the Cluster Head (CH). This lessens correspondence clog and wipes out information conglomeration. Thus, the CH correspondingly utilizes LCF to send the residues to neighbouring CH until it gets to the base station. At the point when the base station gets the residues of the sent message from a CH, it modifies the message by using the moduli set which fills in as the mystery key. The recreation results show that CRT-LEACH outflanks existing routing protocols regarding imperativeness usage, speed, equipment necessities and deferral in changing over the residues all of which have direct impact on the unwavering quality of the sensor arrangement.

2.   Literature Review

Various investigations have been done to explore different territories in essentialness usage and speed for solid WSNs. Those explorers have acquired new assignments providing high speed, secured and reliable message identifying and communication in WSNs. In any case, Ye *et al.* (2018) analyzed a REliable reSIDuE number framework based information transmission instrument (RESIDENT) for WSNs to improve information correspondence consistency through hybrid Automatic Repeat reQuests (ARQ) in hop-by-hop circumstances. An epic disentangle plot was intended to diminish the algorithm unpredictability and afterward consolidated ARQ so as to improve information correspondence consistency. The recreation results showed that RESIDENT improves correspondence unwavering quality regarding measure of parcel got and start to finish delay however with less imperativeness used in low bundle gathering rate situations.

Moreover, Hamamreh *et al.* (2018) present another vitality-mindful algorithm named Minimum Residual Hop Capacity (MRHC). The algorithm was fused into the most normally utilized convention called Low Energy Adaptive Cluster Hierarchical (LEACH) in the transmission procedure inside groups. This diminished vitality used in the transmission procedure, expanded arrange lifetime and improved the measure of information conveyed to the base station. For the most part, hubs impart inside groups through multi-jump interchanges and information is sent through different hubs in the bunch until it arrives at the CH. This outcome in hardly any copies of a comparative bundle could get to the CH, henceforth there is requirement for information total which ordinarily causes correspondence delay between the CH and the sink. Moreover, Han *et al.* (2015) inspected a guess algorithm with incontestable execution proportions dependent on another information design called Time-Reliability-Power space. The model considers a few viewpoints containing obligation cycling, remote communication advantage, problematic connections, and unreliable links, just as giving ensured execution limits to vitality proficient dependable information dispersal in obligation cycle WSNs. Simulation results exhibited the viable effectiveness of the calculations when contrasted and other cutting edge algorithms. Be that as it may, obligation cycle approach consistently brings about an extended hub multifaceted nature and framework inaction.

Habibi & Salehnamadi (2016) proposed an improved moduli-set $\{2^n-1, 2^n+1, 2^{pn}-1\}$ reverse converter dependent on the CRT algorithm. The proposed moduli set improves unpredictability of circuit vitality utilization however there is a need to lessen equipment prerequisites, improve the speed and apply it to WSNs. Finally, Mohammad *et al.* (2017) proposed Syncast, a convention to improve coordinated transmission by abusing catch impact over multi-channels. The assessment shows that Syncast gives a vigorous, dependable, and versatile information dispersal of enormous bundles with lower start to finish defer and up to 92% diminished radio-on-schedule. It is seen that since no single methodology has given vitality effective and broad dependability support for WSNs. Henceforth, it is fundamental to build up an improved vitality proficient directing convention that would upgrade the transformation speed with negligible equipment necessities and decreased energy use so as to improve unwavering quality in WSNs.

3. Research Methodology

The best vitality productive algorithm for WSNs-Low Energy Adaptive Clustering Hierarchy (LEACH) protocol was modified by consolidating CRT to the first LEACH algorithm so as to eliminate data aggregation. The CRT-based sending strategy involves parting the messages sent by the source node utilizing the moduli set with the goal that the most extreme number of pieces per bundle that a hub needs to send is diminished, along these lines the system life range can be extended. Transmission vitality was saved by diminishing the measure of bundle and the quantity of parcels communicated through the system. Vitality use can likewise be protected by lessening the quantity of assignments that the node needs to execute. In LEACH CRT-based parcel parting algorithm, the residues would be sent rather than the real message; in this manner, gatecrashers would not perceive the data bundle.

In the proposed framework, the sensor hubs are isolated into bunches and the sensor hub with higher assets is chosen as the Cluster Head (CH). The CH organizes all the activities within its cluster. It is likewise the duty of the CH to accumulate data from group hubs and send

to another CH until the message arrives at the base station. Every sensor hub utilizes the moduli set to part the detected information into some littler parcels which are autonomous and tasks can be performed on them independently and simultaneously. The residues of the detected message concerning the moduli set are communicated rather than the detected message itself. Subsequently, less parcels are sent, and this would make the computations more straightforward, a lot quicker and power utilization is decreased.
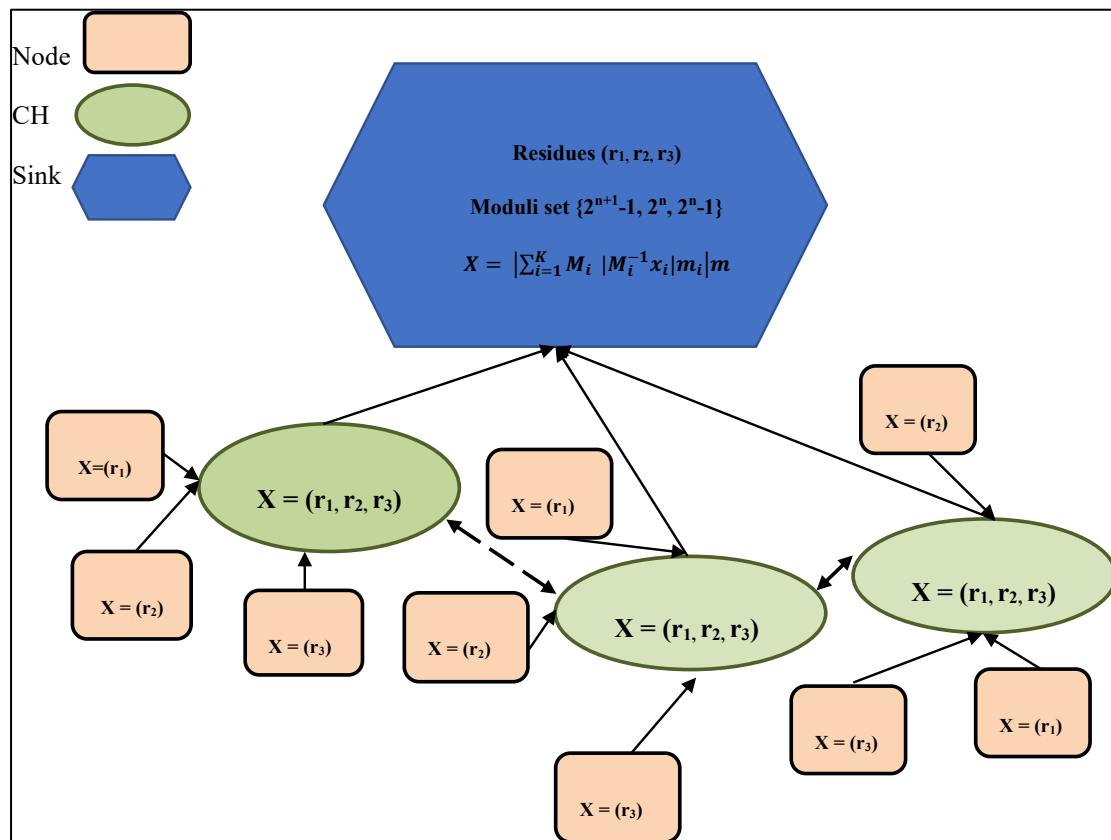

Figure 1. Efficient Routing Protocol for CRT-LEACH

Nonetheless, the sensor hubs would send a build-up of the detected information dependent on its Id in the group to the CH, this has disposed of the requirement for data aggregation. At that point, CH would gather all the residues from all the hubs in its group and send to another CH or the sink. The sink having the information that the CH in the system would send the deposits, rather than the first message would disentangle the received parcels so as to recuperate the real message as appeared in figure 1.

Considering the way that the imperativeness use is relative to the quantity of pieces passed on at that point, accepting n the quantity of pieces in the first message, and nCRTmax (the greatest number of pieces of a CRT part), that is;

$$nCRT_{max} = max\left(\left\lceil log_2\left(pi\right)\right\rceil\right)$$

(1)

and considering a theoretical maximum energy reduction factor (MERF) given by:

$$MERF = \frac{n - nCRT_{max}}{n} \tag{2}$$

the energy consumption while transmitting will be given as:

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d) \tag{3}$$

$$E_{Tx}(k,d) = E_{elec} * k + \epsilon_{amp} k * d^2 \tag{4}$$

Where k is the number of packet bits, and d is the distance between sender and receiver, and energy dissipated at the receiver side is:

$$E_{Rx}(k) = E_{Rx-elec}(k) \tag{5}$$

$$E_{Rx}(k) = E_{elec} * k \tag{6}$$

Similarly, energy efficiency is characterized as the aggregate unused vitality level of hubs in the system. Node vitality consumption is defined as the communication (transmitting and receiving) energy the network consumes excluding the idle energy. Assume a continuous time between t_1 and t_2 for the energy consumption measurement. Residual energy in time t is defined by omitting consumed energy in Δt, from the initial battery power in t-Δt. Thus, the energy consumption will be determined in Δt as:

$$\begin{cases} E_{residual},i(t_2) = E_{residual},i(t_1) - E_{consumed},i(\triangle t) \\ E_{consumed},i(\triangle t) = \frac{\partial E_{residual},i(t)}{\partial t} \triangle t \\ \triangle t = t_2 - t_1 \end{cases} \tag{7}$$

Energy consumption of the cpu in an active state depends on the number of processed bits (b_{proc}), its operating voltage and frequency, is:

$$e_{1,ctive}(\Delta t) = F_1(f, b_{proc.}) \tag{8}$$

Moreover, power consumption of a hub unit in an active state relies on the sensor radius (r_{sense}), the data generation rate (g_{sense}), and the number of generated bits (b_{sense}) as:

$$e_{2,ctive} \Delta t = F_2(r_{sense}, g_{sense}, b_{sense}) \tag{9}$$

In addition, vitality consumption of a memory unit in an active state depends on the number of stored bits (b_{store}), the number of memory read (e_{rd}) and write (e_{wt}), and the duration of storage (t_{store}) is:

$$e3,_{ctive} \Delta t = (F_3 b_{store}, e_{(rd)}, e_{(wt)}, t_{store}) \tag{10}$$

Furthermore, energy consumption of nodes from a sink constituent viewpoint can be formulated as:

$$E_{snk,}(\Delta t) = K(e_i(snk)) \tag{11}$$

where $e_i(snk)$ shows energy consumed by each node to communicate with the sink and perform the sink's requests. Lastly, power utilization of the transceiver unit for message transmission in an active state depends on the number of received (b_{Rx}) and transmitted bits (b_{Tx}), and the amount of needed energy for coding (e_{code}) and decoding packets (e_{decode}) as:

$$e4,_{ctive} \Delta t = F_4(b_{Rx}, b_{Tx}, e_{(code)}, e_{(decode)}) \tag{12}$$

For the purpose of illustration, considering n = 2 for the moduli set $\{2^{n+1}-1, 2^n, 2^n-1\}$ the moduli set is {7, 4, 3}. Assume message X = 52 is to be transmitted from different sensor nodes in a cluster to CH using the moduli set above, the transmitted residues are calculated as follows x_i = X mod m_i:

$$x_1 = X \text{ mod } m_1 = |52|_7 = 3$$

$$x_2 = X \text{ mod } m_2 = |52|_4 = 0$$

$$x_3 = X \text{ mod } m_3 = |52|_3 = 1$$

At that point, by CRT-based bundle parting, rather than communicating X = 52 (110100), x1= 3 (11), x2 = 0(0) and x3 =1(1) are sent by every hub. Notwithstanding, it merits referencing that in the above outline, 6 pieces are required to represent X, while a limit of 2 pieces are required to represent every xi. Thus, if rather than X, xi numbers, with xi = X (mod mi), are sent in a WSN, the most extreme essentialness devoured by every hub for the transmission can be altogether diminished. At last, in view of this model utilizing equ. 3.2, it could be derived that specific level of vitality could be spared utilizing this CRT-based sending procedure (MERF = 6-2/6 * 100 = 66.67%). It could likewise be commonly expressed that CRT-based procedure is more successful than a straightforward LEACH parting and FEC-based parting methods where excess must be added to the first bundle by expanding the all out number of pieces.

4. Energy Efficient CRT- LEACH Routing Protocol Algorithms

At the distribution and initialization stage, the sink indicates the organization geography mode by arranging the system into groups. Therefore, the sensor hub, outfitted with a greater number of assets than different hubs, is chosen as the CH. The sink thus specifies the quantity of hub in each group with their distinguishing identification number (ID) and into what number of parts the detected bundles can be part into. At that point, there is a trade of Initialization Messages (IMs), starting with the base station which of course is the CL_{ID} = 1, where CL_{ID} is the cluster

number. So also, every hub that acknowledges an IM from its neighbours with a succession number SN = k, has a place with group k and sends the IM with an expanded SN = SN + 1 along with its own location and the rundown of the hubs that are used as forwarders. Because of the received IMs, LCF is utilized to choose the group individuals and toward the finish of the procedure, every hub in the system realizes its own CH and bunch individuals. Likewise, it is normal that the sink realizes the moduli set m_i with the particular ultimate objective to reproduce the real bundle. Nonetheless, initialization is consistently set off just a single time. Ordinarily, the CH is liable for effective correspondence between its bunch individuals and different CHs. The distribution and initialization stage calculation is given in Algorithm 1:

Algorithm 1:   The Distribution and Initialization Stage

Initialize SN=1   // To reset an initialized message

While message IM arrives at a node$_i$
do   //IM is initialization message
If CL_{ID} = 1   //base station is the only node in CL_{ID} = 1
Then transmit IM with SN=2 to the next CL_{ID} at startup
Increase SN=SN+1
else

Initialize an array of neighbour with all accessible nodes in the cluster
Use LCF algorithm to select closest nodes for each cluster
Send Join-Request messages
Assign node ID to nodes that accept Join-Request messages
Increase degree of the node, ID = ID + 1
Assign as CH if the residual resources is the highest
end if

            Get IM with corresponding CL_{ID}=j
            Transmit IM to the next CL_{ID}
            Increase CL_{ID} =CL_{ID} +1

All hubs that receives the IM with SN=i assume to belong to CL_{ID}=j
Repeat until all nodes are reached
end do

Split and Forward stage operation activated

A group part speaks with its CH which thus speaks with different CHs or the sink of the system. Thusly, the recognizable proof of CHs must be done in a manner that draws out the lifetime of the whole system and improves the general versatility of the system. Be that as it may, the parcel parting and sending calculation is given in Algorithm 2:

Algorithm 2:   Splitting and Forwarding Stage

While Node$_i$ sensed message
do
If cluster member = 1
Then send packet without splitting
else

Use CRT with the moduli set to split the packet into number of members in the cluster

Send X$_i$ = x(mod m$_i$) to CH

    If cluster node = CH
    Gather the packets in order to have all the residues
    Use LCF to forward x$_i$ to another CH until it gets to the Sink

    elseif node = sink

Then reconstruct using
End if
End do

Conversely, the sensor nodes send a residue of the sensed data based on its Id in the cluster to the CH, this eliminates the need for data aggregation. Finally, when the CH receives all the residues, it congregates them, and in turn forwards them to another CH or to the sink for further processing. The sink finally reconstructs the received residues to its original message using the moduli set and message ID.

5.   Evaluation and Discussion of Results

To assess the execution of the hubs, simulations were performed on Probabilistic Wireless Network Simulator (Prowler) running under MATLAB. MATLAB offers working together conditions with numerous solid and exact implicit numerical capacities. So also, Prowler provides a stress-free way of application prototyping and is capable of simulating wireless distributed systems. Various quantities of sensor hubs were conveyed arbitrarily beginning from 10 out of a detecting field of 150 x 150 square meters. All the sensor hubs were identified with a remarkable id and it was normal that each sensor hub is fixed after sending. Each sensor node had obliged battery imperativeness, while the available vitality at the sink is reasonably unfathomable. At the underlying stage, 10 Joules of essentialness was allocated to every node and a short time later, imbuement of the framework with subjectively made message parcels.
The consequences of the proposed algorithm were contrasted and other vitality productive calculations for WSNs. Drain convention and most limited way results calculation were considered under similar reproduction boundaries. Figure 2 demonstrates 100 sensor

center points that were reliably scattered over a 150m × 150m region. Package transport extents were found out in the light of the quantity of groups sent and packages gotten. The message breaking was performed only a solitary time by the node and sent the sub groups to the CH.
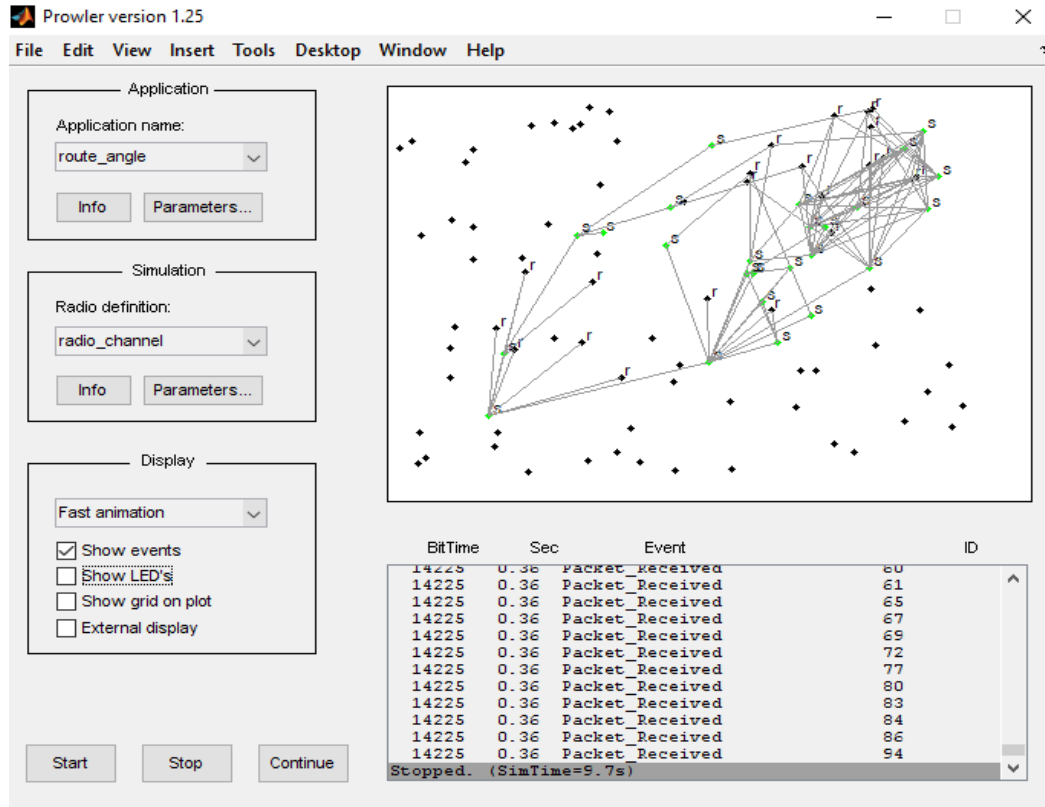

Figure 2. Sensor nodes deployed in Sensor Field

Packet Delivery Ratio (PDR) was calculated from the results obtained from simulating the proposed algorithm with two other algorithms using Equation 13 for different numbers of sensor nodes, starting from 10 to 50. Figure 3 shows PDR for three different approaches. The proposed CRT-LEACH approach achieved the greatest PDR when compared with other investigated approaches.

$$PDR = \frac{Number\ of\ Received\ Packets}{Number\ of\ Transmitted\ Packets} \qquad (13)$$
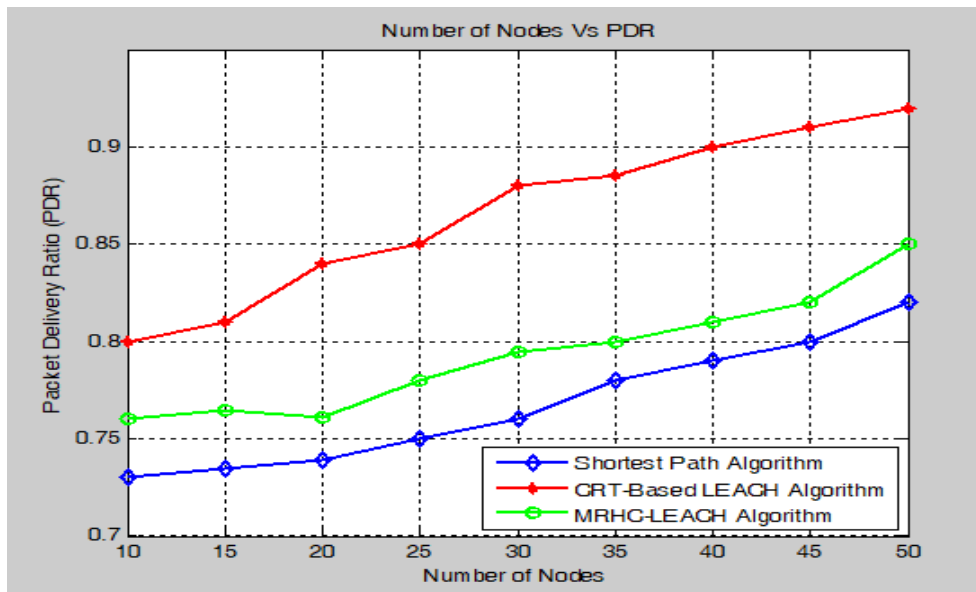
Figure 3. Number of Sensor Nodes Deployed vs PDR

The delay in receiving the sent message when different numbers of nodes were deployed using different techniques was calculated using:

$$\mathbf{End-to-End\ Delay} = \frac{\sum(Arrive\ time\ -\ Send\ time)}{\sum(Number\ of\ Connection)}$$

(14)

Figure 4 shows the delay in receiving the sent message when message packets were sent from source to sink. The CRT-LEACH based forwarding technique reduced the delay in packet forwarding compared to the existing approaches, which has higher delay in packet forwarding.
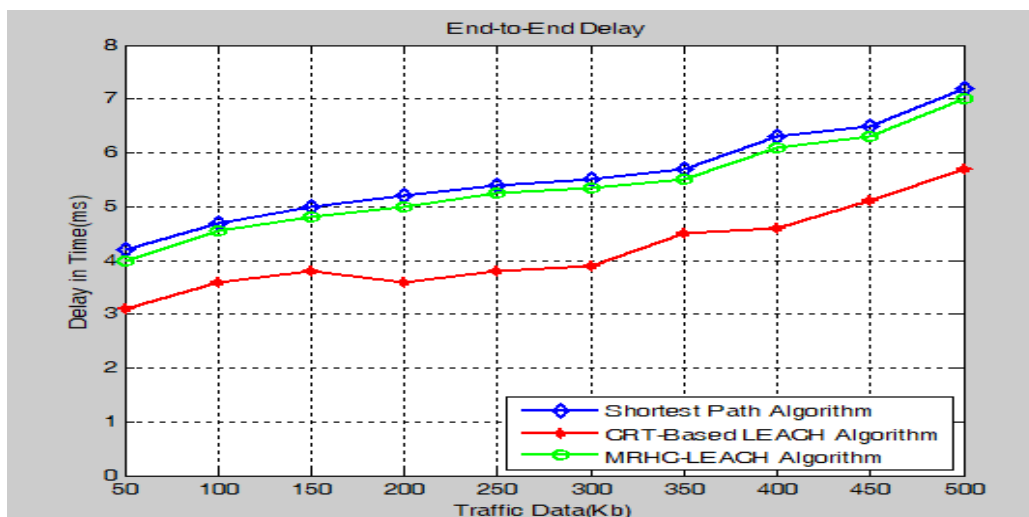
Figure 4. End-to-End Delay

In addition, the percentage packet lost was calculated for different numbers of nodes using

Parcel Lost = Number of Packets send – Number of Packets Received

Figure 5 displays the percentage packet lost when packets were sent over different approaches. As shown in the Figure, proposed CRT-based LEACH approach minimizes packet loss when compared with other investigated approaches that generate high packet loss.
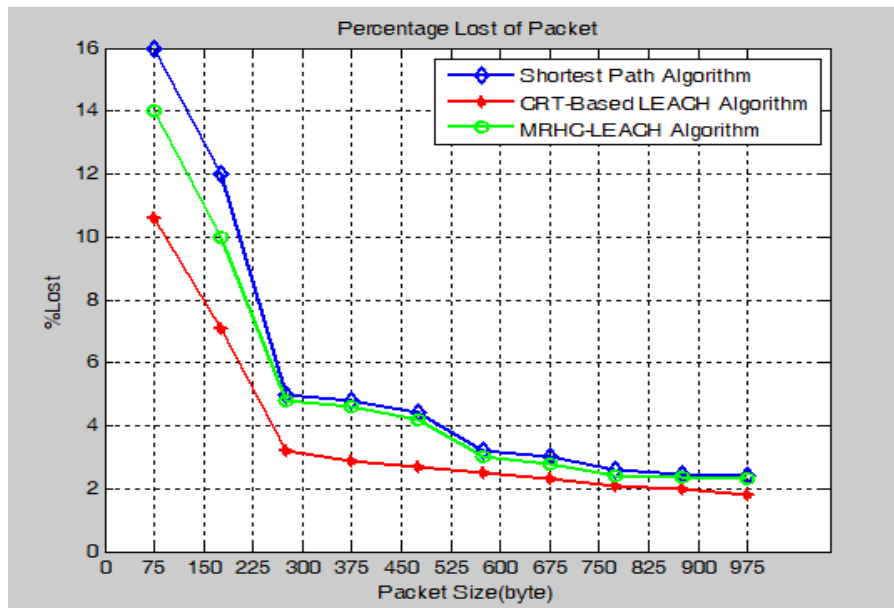

Figure 5. Percentage Packet Lost

Figure 6 displays the energy consumption by each node using three different approaches. In proposed CRT-based LEACH forwarding technique energy efficiency, reach the level of 0.17 while MRHC-LEACH and shortest path techniques attain 0.224 and 0.275 respectively.
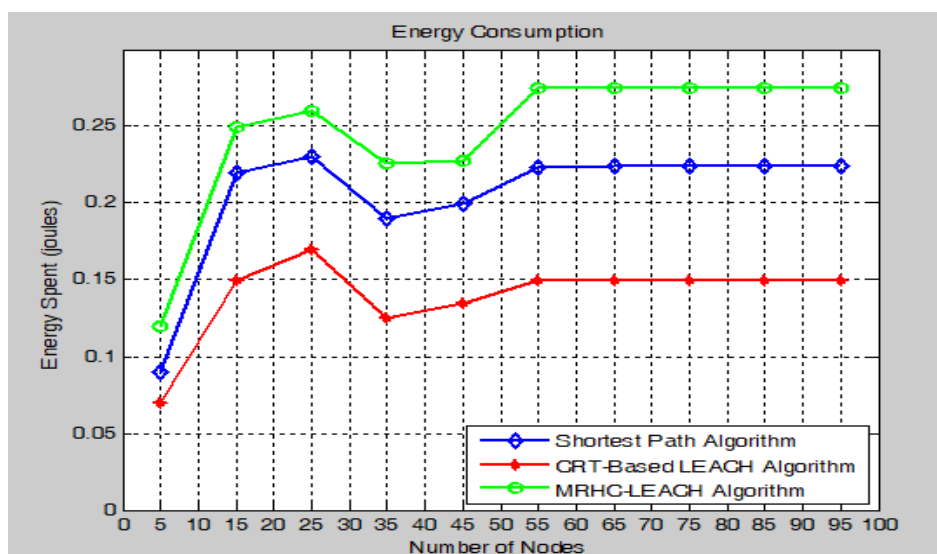

Figure 6. Energy Consumption by Each Node

In addition, figure 7 demonstrates the network lifetime for various number of sensor nodes (i.e., n = 10…100) for the proposed scheme and two other schemes. Network lifetime is usually the lifespan of the first node in all sensor nodes that depletes its energy.
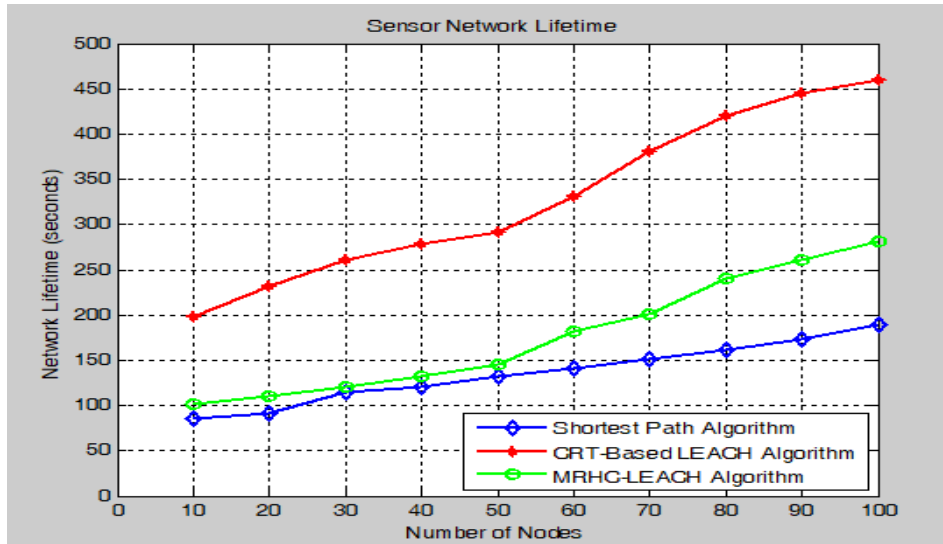

Figure 7. Sensor Network Lifetime

 A hub's vitality is viewed as depleted when 99% of the sensor's underlying vitality has been used. The proposed plot accomplishes a more drawn out lifetime than the other two algorithms for any quantities of nodes. The results demonstrate that the energy scattering in the proposed conspire were expanding at a less rate than the two algorithms as the correspondence inside the group in the proposed conspire expanded the use of vitality in the distribution and ready stage. Finally, throughput of the framework, as indicated by the amount of information sent to the sink was likewise assessed. Throughput is the absolute entirety of parcel passed on separated by the all out number of proliferation time. In this way, Throughput = N/1000, where N is the amount of pieces got successfully by all accepting hubs. The main route for messages to arrive at the sink is through the CHs, and when there are no CH, the information can't be transferred to the base station straightforwardly from the hubs.

Figure 8 shows the measure of data sent to the sink through the CH. The reproduction results show that CRT-based LEACH has the most elevated worth, which is 18% and 27% more than other two algorithms researched individually. Along these lines, CRT-based LEACH guarantees the assurance of CHs in each round and ensures a pathway for the detected information to be sent to the base station. Finally, the absence of CH could happen persistently in the briefest way. This is as a result of their dependence on the hub's to send message to one another until it gets to the sink.
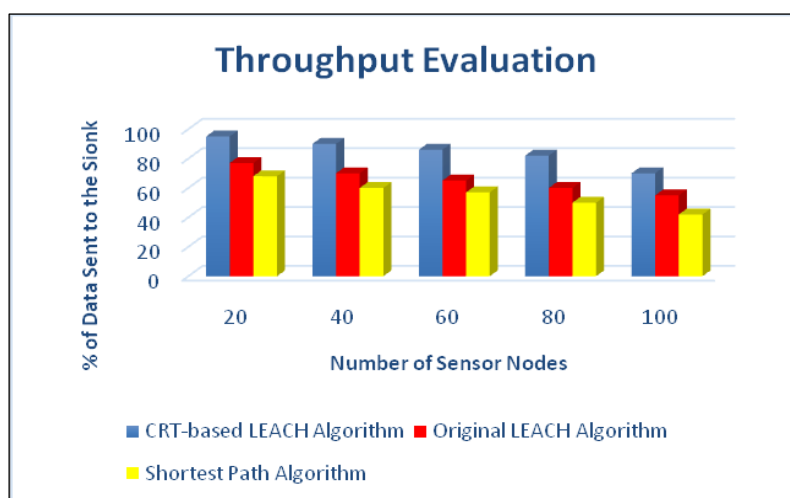
Figure 8. Quantity of Sent Data to the Base Station

5. Conclusion

WSNs consist of spatially conveyed self-ruling gadgets utilizing sensors to monitor physical or natural conditions, for example, sound, weight, temperature, etc, that helpfully go their information through the system to a sink. A proficient arrangement of WSN relies upon fruitful usage of dependability systems. Taking everything into account, this work presents an effective routing protocol for lessening the general force utilization of WSN applications utilizing CRT-based bundle breaking sending procedure with LEACH. A model was intended for every one of the constituents from PDR, start to finish delay, bundle loss, power utilization, network lifetime and throughput. Likewise, by enhancing the imperativeness of the overall model concerning all segment boundaries permit an equalization of vitality usage among all nodes, enhance the vitality utilization among them and support the system lifetime for the proposed application. CRT-LEACH beats existing routing protocol as far as speed, essentialness usage and transformation delay continuously WSNs. Consequently, CRT-LEACH has matchless quality as far as equipment necessities, change deferral and speed of tasks in correlation with the other steering convention analyzed.

References

Barati, A., Movaghar, A., & Sabaei, M. (2014). Energy efficient and high-speed error control scheme for real time wireless sensor networks. *International Journal of Distributed Sensor Networks,* 2014, 1–9.

Demigha, O., Slimane, H. O., Bouziani, A. & Hidouci, W. (2011). Energy efficient target tracking in wireless sensor networks with limited sensing range. *The Sixth International Conference on Systems and Networks Communications,* ICSNC.

Gbolagade, K. A. & Contofana, D. S. (2009). A reverse converter for the new 4-moduli Set. *Proceedings of 2009 16th IEEE International Conference on Electronics, Circuits and Systems (ICECS)*:113–116.

Habibi, N. & Salehnamadi, M. R. (2016). An improved RNS reverse converter in three-moduli set. *Journal of Computer & Robotics, 9*(2): 27–32.

Hamamreh, R. A, Haji, M. M & Qutob, A. A. (2018). An energy-efficient clustering routing protocol for WSN based on MRHC. *International Journal of Digital Information and Wireless Communications (IJDIWC)*, *8*(3): 214–222.

Han, K., Luo, J*., Xiang, L., Xiao M., & Huang, L. (2015). Achieving energy efficiency and reliability for data dissemination in duty-cycled WSNs. *IEEE/ACM Transactions on Networking, 23*(4): 1041–1052.

Jindal, V. (2018). History and architecture of Wireless sensor networks for ubiquitous computing. *International Journal of Advanced Research in Computer Engineering & Technology (IJARCET), 7(2):*214–217.

Khodabande, P., Toofani, H., Zarei, B. & Farzin, M. (2013). Multicast data transmission using residue number system: Energy consumption reduction in wireless sensor networks. *International Journal of Latest Trends in Computing, 1*(2): 157–160.

Lee, H., Min, S. D., Choi, M. & Lee, D. (2016). Multi-agent system for fault tolerance in wireless sensor networks. *KSII Transactions on Internet and Information Systems, 10*(3): 1321-1332.

Mohammad, M., Doddavenkatappa, M., & Chan, M. C. (2017). Improving performance of synchronous transmission-based protocols using capture effect over multichannels. *ACM Transactions on Sensor Networks (TOSN)*, 13(2), 1–26.

Sharma, A., & Sharma, S. (2016). A comparative review on reliability and fault tolerance enhancement protocols in wireless sensor networks. *International Research Journal of Engineering and Technology (IRJET)*, *3*(1), 622–626.

Ye, R., Boukerche, A., Wang, H., Zhou, X. & Yan, B. (2018). RESIDENT: A reliable residue number system-based data transmission mechanism for wireless sensor networks. *Wireless Networks*, *24*(2): 597–610.