

Detection and Prevention of Sink hole attack by swarm optimization in wireless sensor network

Anuj Thakur¹, Monika Pathania²

^{1,2} *Computer Science Engineering, Bells Institute Of Management & Technology, Meli Shimla, INDIA*

Abstract- Wireless sensor network is most emerging field for the research because of its large scope and optimization of power and energy. WSN is used in every field of different purposes like surveillance, monitoring and tracking etc. Due to large network and huge number of nodes connected to each other on network WSN also need a secure communication link. This research work based on the sink-hole attack detection and optimization of the network by using different parameters. In this work a detailed description of attacks in wireless sensor network is presented and after this detailed literature review on the related approaches is resented. The review of different approaches and their methodology helps to improve the methodology of the work and helps to enhance the knowledge related to different types of attacks and their solution on WSN. This work presented the work on the optimization of energy and reduction in delay and packet loss during the communication on network. The optimization performed by using the grey wolf optimization algorithm which is a global optimizer which optimizes the results for effective and efficient outcomes. It improves the packet delivery rate, throughput and reduces the energy consumption and delay.

Keywords- Wireless Sensor Network, *Wireless Sensor and Actor Networks*, Denial-of-Service, Grey Wolf Optimization

I. INTRODUCTION

Wireless Sensor Network is a type of wireless network, which includes a large number of circulating, self-directed, minute, low powered devices named sensor nodes. It is a network of devices that can communicate the information gathered by the wireless links. The data is forwarded through multiple nodes with a gateway and the data is connected to other networks like wireless Ethernet [2, 3]. These networks are used to control physical or environmental conditions like sound, pressure, temperature etc.

1.1 Characteristics of WSN

(1) *Dynamic Network Topology*: Due to wireless connection network there is no any topology for the nodes that are connected or nodes that connects after an interval of time.

(2) *Less Communication Failures*: Communication failure rate is less in the wireless sensor network due to its dynamic nature, if a connection is failed then communication does not affected by it. It communicates with another connection.

(3) *Limited Power Consumption*

Nodes in the WSN can store very less amount of energy in it.

(4) *Heterogeneity of nodes*: Large numbers of nodes are able to connect in this network due to its wireless nature.

(5) *Deployment at large Scale*: It is easy to deploy in large area because no any additional hardware is required.

(6) *Scalable node capacity*: In wireless sensor network capacity of nodes are scalable and only limited by bandwidth of gateway node.

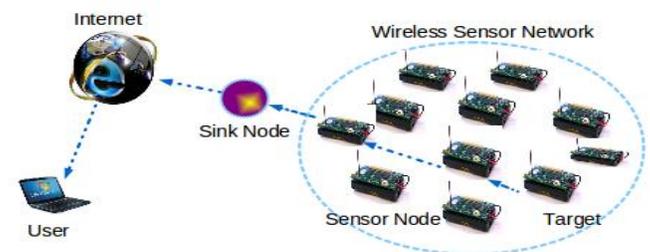


Figure 1 Wireless Sensor Network

1.2 WSN Architecture

There are three main components in WSN: nodes, gateways and software. Spatially distributed measured node's interface with sensors to monitor assets. The collected data transmit to gateway wirelessly, and can operate independently. It is connected to a host system where we can collect data, process, analyse and present our measurement data by using software. To extend WSN distance and reliability special type of measurement node is used such as router node [6, 7]. WSN is a widely used system because of its low costs and high efficiency. In a typical wireless sensor network (WSN), sensor nodes consist of sensing, communicating, and data processing components. Sensor nodes can be used in numerous industrial, military, and agricultural applications, such as transportation traffic monitoring, environmental monitoring, smart offices, and battlefield surveillance.

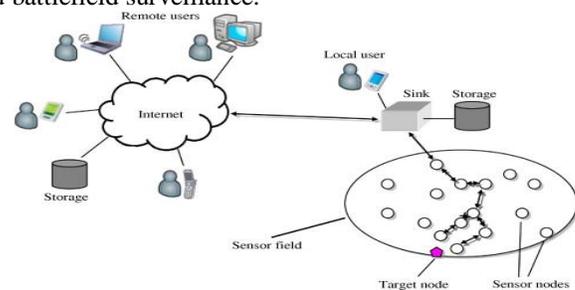


Figure 2 WSN Architecture

1.3 Design Issues in WSN

Following are the main design issues in the WSN which affects the performance of the system.

(1) *Network Dynamic*: Routing of the messages between the nodes in WSN is more challenging task for the node stability and route stability. Stability factor is an important optimization factor with energy and bandwidth. The event can be static or dynamic it depends on the application.

(2) *Node Deployment*: Node deployment in the wireless sensor actor network is deterministic or self-organizing. The nodes and sensors are deployed manually in deterministic approach and pre-deterministic paths are used for data routing. In self organizing nodes are scattered randomly in ad-hoc manner.

(3) *Data Fusion*: The combination of data from different sources using a function such as min, max and average. These functions are done on sensor nodes for data reduction. Achieving the energy-efficient data fusion approach is a major problem for the heterogeneous network [1].

(4) *Network Lifetime*: The life time of the WSN is limited due to the functioning of actor nodes from battery source. Basically the life time is defined as the percentage of dead nodes below thresholds.

(5) *Packet Delay*: The actor node’s function in WSN is to act on the sensed data quickly and perform the required operation. It is also a design issue to design the protocols which does not considers any delay in network and nodes gives best response.

(6) *Reliability*: The reliability of the nodes is giving the correct response by the actor nodes. Every actor nodes has a predefined time period in which it reconstructs the event, understand its intensity, location and coverage. Sometimes the data sensed command may be lost due to congestion, bad connectivity and bit error.

(7) *Mobility*: In WSN, nodes are used to reduce the delay, complete the task on time and also distributed failure recovery [1].

1.4 Attacks on Wireless Sensor Networks

Wireless sensor network is used in various fields for the effective communication process in which user sends their information from one node to another node. Sometimes a user sends the secret information, data on the wireless network, it is very important to send this information very safely [11, 12]. In this network sensor nodes used wireless communication and it is easy to eavesdrop [13]. The attacker can easily inject malicious messages into the network.

Types of Attacks in WSN

(1) *Grey Hole Attack*: This attack is modification of black hole attack. In this attack attacker node behaves like a normal node for discovering route in the network. After it discovers the route then it drop the infected packets in network. This attack is difficult to detect because packet is dropped with certainty [4].

(2) *Wormhole Attack*: In wormhole attack, the attacker can record the data packets at one location in the network and retransmit the data from another route of the data [8].

Wormhole attack is a serious issue that occurred into the wireless sensor network. In the figure [5] the tunnel may be a wired link or wireless link between two nodes, this creates an illusion that the end point are very close to each other [2]. A wormhole attack has two modes.

1. Hidden mode
2. Participation mode

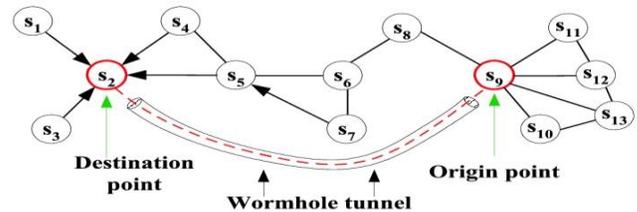


Figure 3 Wormhole Attack

(3) *Sink Hole Attack*: in this attack incorrect information of the routing is send to the nodes as it is low cost and it provides proper destination node. Due to incorrect routing information it leads to packet loss and manipulation in original data packets. This attack disturbs all the network process because nodes are sometime dependent on each other for information [4, 9][10].

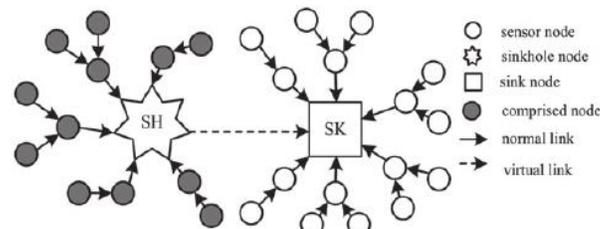


Figure 4 Sinkhole Attack

There are two types of sink hole attack one is simple sink hole attack and other is using worm hole attack. The simple sink hole attack, malicious neighbour node behaves itself as a best route to the base station and attract the other nodes to use this route frequently. During this route malicious node is able to tamper the data which is a big challenge in security of network.

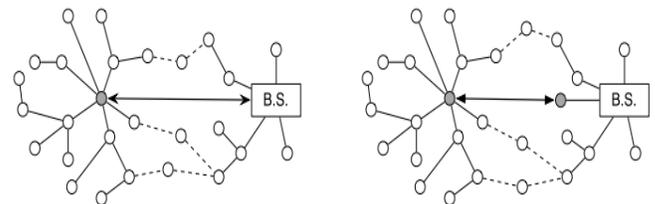


Figure 5 Sinkhole attack (a) and (b) Sink hole using worm hole attack

(4) *Link spoofing Attack*: In this attack a fake link is displayed with the neighbouring node which disturbs the routing process with the other nodes. Malicious code is sent over this link and it drops the data packets. This type of attack can be detected by OLSR protocol because it determined the node which sends the

malicious code. In this types of attack message is completely lost [3].

(5) *Grey Hole Attack*: This attack is modification of black hole attack. In this attack attacker node behaves like a normal node for discovering route in the network. After it discovers the route then it drop the infected packets in network. This attack is difficult to detect because packet is dropped with certainty [4].

(6) *Black Hole Attack*: In this type of attack, attacker supposed to communicate packets in the network rather than discard the packets.

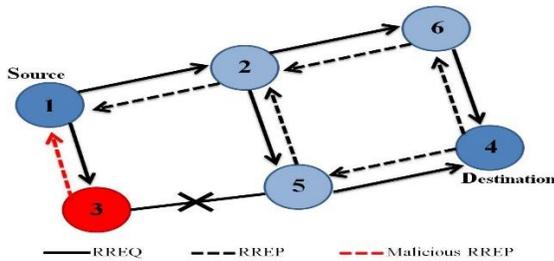


Figure 6 Black Hole Attack

The reason behind this attack is that a node is compromised from different number of causes. In this attack, packets are dropped from the loss network. It is not easy to detect this type of attacks [3].

II. RELATED WORK

Zhang, Zhaohui, et al. [1] (2018) explained an energy efficient sinkhole detection approach which detects the malicious node effectively than the existing nodes. In this approach frequency of all nodes is established by m routes with optimal hops from per node to sink node. This method is based on the dynamic programming. This approach enhanced the detection rate and false positive rate. Devibala, K., et al. [2] (2018) proposed neighbor constraint traffic centric approach which is used to detect sinkhole attack and improve the quality of the WSN.

It identifies the malicious node by the data send by neighbor node. It verifies the location of the node from where data is send to the node. This method provides sinkhole detection with high throughput and packet delivery ratio. Mittal et al. [3] (2018) proposed the major goal to analyze the effective protocol for the wireless sensor network. This analysis shows that the access control method and authentication methods are used in the WSN. This analysis shows that most of the approaches are based on the public key cryptography, which is the most expensive method. This paper provides a detailed comparative analysis of protocols with their advantages and disadvantages of each other. Yasin, N. Mohammed, et al. [4] (2017) described the anomaly detection approach which detects the sinkhole attack in wireless sensor networks. This type of attack is not easy to detect due virtual path of the node. In this work Acceptance Acknowledgement approach is used to activate the digital signature system. This approach does not make any impact on the network and provides high detection

rate of the malicious node. Saghar et al. [5] (2017) proposed the RAEED protocol which is used to detect the simple and intelligent tunnel attacks. This protocol helps to reduce the problem of DOS attack which disturbs the data routing and forward the data comes from the sink node. In future this work will be enhanced by applying formal methods to verify the communication issues. Saghar et al. [6] (2017) focused on the security issues of the wireless sensor network. It considers the Denial-of-Service attack on the data during the routing process. In this type of attack, the attacker attracts the traffic towards it and prevents the data from the neighbouring node. This paper provides a protocol for the DOS attacks called as RAEED. It detects the simple and intelligent tunnel attacks very effectively. Jan, Mian, et al. [7] (2017) proposed a lightweight payload-based mutual authentication approach for a cluster based wireless sensor network. This is also called as PAWN approach. During the implementation process, it is implanted in two steps. First, the optimal percentages of the cluster heads are selected authenticated and allowed to communicate with the neighbouring nodes. Second, each cluster head is in a role of server and provides the authentication to the nearby nodes. This scheme is validated with various schemes and the results show that if performed very well. Kumar et al. [8] (2017) proposed a localization algorithm which prevents from the Wormhole attack in the wireless sensor network. This algorithm is used to identify the unauthorized nodes by using the distance estimation method and Maximum Likelihood Estimation (MLE) to calculate the required location. The results in comparison show that this algorithm performed better than the existing algorithms. Vidhya, et al. [9] (2017) worked on the detection of sinkhole attack in AODV routing. This method uses energy power consumption in AODV and external energy by using battery. In this work MD5 algorithm is proposed for sink hole attack detection which prevent the network from the sever attack. This algorithm checks the energy transmitted by the node to the other nodes. This algorithm work effectively and enhance the packet delivery rate and throughput. It reduces the end to end delay in the network. Jahandoust, et al. [10] (2017) described the adaptive sinkhole aware algorithm in wireless sensor network. This work is based on the finding probability of affected nodes by sinkhole attack. In this the routing of the nodes is based on AODV protocols to route packets over the most reliable nodes. The subjective model identifies the behavior of the nodes in data receiving and sending. The behavior of whole network is observed by using probabilistic automation and captures the behavior of the network which is generated at the base station. The result of the proposed approach provides low packet loss rate and effective routing between the reliable nodes. Kalnoor, et al. [11] (2017) worked on the clustered network in wireless sensor network to detect the sinkhole attack. This method is based on the agent-based quality of service to detect the sinkhole attack. The agent-based approach detects the attack effectively and enhances the

network performance. Agent based protocol is very helpful to provides the effective performance and throughput. Saranya et al. [12] (2017) In this paper, the author focused on the packet scheduling technique for the ad-hoc on demand distance vector (AODV) protocol. In this transitional node starts the packet scheduling and manage the memory, according to the flow of data. Data packets are stored and route repaired by the intermediate node. In the proposed scheme data packets are utilized by backup routes not to dropping it. Ma, Rui, et al. [13] (2017) Proposed two types of defense strategies that are based on the monitoring the behavior of neighboring node and location information of the neighboring node. In this paper, the concept of packet encapsulation is used to provide the most effective method for wormhole attack. Running a state is simulated under the normal condition and wormhole condition by using OMNET++ simulation environment. In wormhole attack, the running state applies to defense method which is based on location information and monitoring the neighbor node. The analysis results of the simulation show that it works effectively on the attacks in WSN.

III. THE PROPOSED METHOD

3.1 Proposed Methodology

- Step1 :** Deploy the wireless Sensor network.
- Step2 :** Apply the leach routing process.
Leach is basically a clustering based protocol which is used to reduce the energy dissipation in the networks
- Step3 :** Simulate the sink hole attack on the wireless Sensor network and parallel optimize by GWO algorithm.
- Step4 :** Initialize the grey wolf optimization

{
Initialize the generation counter u and randomly initialize the population of wolf P_i in which P_i(1, 2, 3,.....n).

*Initialize the value of P₀ randomly.
 Initialize parameters a, A and C.*

}
 Calculate the Fitness of the each wolf
P_α = 1st Best wolf
P_β = The 2nd best wolf
P_δ = The 3rd best wolf

- **Update the fitness function.**
*Update the chaotic map equation for each search agent
 Update the position of current wolf using*

Eq. (4)
end for
*Update Parameters a, A and C.
 Calculate the fitness of all wolves
 Update P_α, P_β, P_δ.*

- Check the objective function
Replace the worst fit wolf with the best fit wolf
u=u+1

end While
 Return P_α

- Check it optimize or not it optimized then analysis the time and dead node otherwise check the counter is greater than 0 or not. If the counter value is less than not converge and ignore the node during routing. Else again initialize the value at GWO.

3.2 Proposed methodology: Flowchart

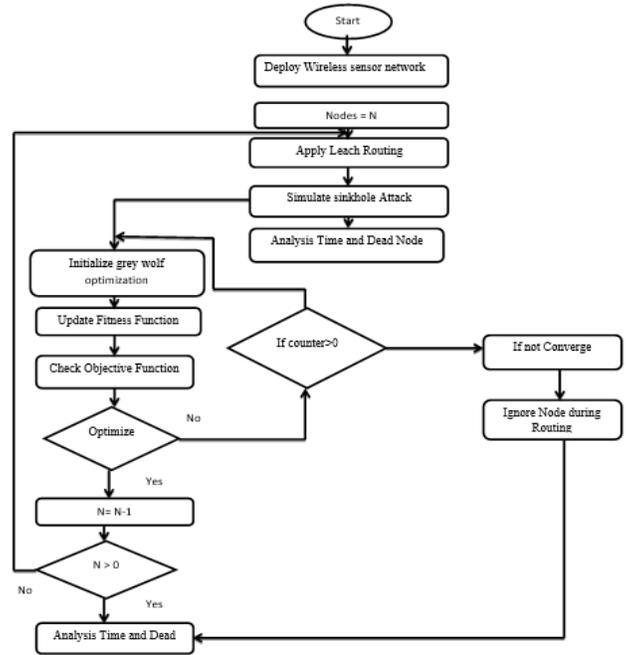


Figure 7 Proposed Flowchart

3.3 Algorithm Used

Grey Wolf Optimization: GWO algorithm is a bio-inspired algorithm which is based on the leadership and hunting behavior of the wolves in the pack. The grey wolves prefer to live in the pack which is a group of approximate 5-12 wolves. In the pack each member has social dominant and consisting according to four different levels. The below given figure shows the social hierarchy of the wolves which plays and important role in hunting.

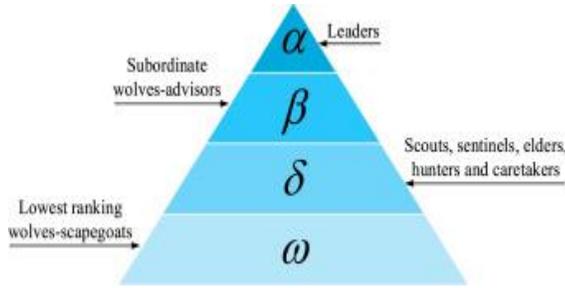


Figure 8 GWO Hierarchy [36]

1. The wolves on the first level are called alpha wolves (α) and they are leaders in the hierarchy. Wolves at this level are the guides to the hunting process in which other wolves seek, follow and hunt and work as a team. Decision making is the main task that is performed by the alpha wolves and the order by the alpha wolves is followed by all members of the pack.
2. Second level wolves are called beta (β). These wolves are called subordinates and advisors of alpha nodes. The beta wolf council helps in decision making. Beta wolves transmit alpha control to the entire packet and transmit the return to alpha.
3. The wolves of the third level are called Delta wolves (δ) and called scouts. Scout wolves at this level are responsible for monitoring boundaries and territory.
4. The last and fourth level of the hierarchy are called Omega (ω). They are also called scapegoats and they must submit to all the other dominant wolves. These wolves follow the other three wolves.

IV. RESULT ANALYSIS

4.1 Simulation Environment

Parameters	Value
Network Size	100 x 100 sq. mtr.
Nodes	450
Capacity of Queue	40 Packets
Model of Mobility	Random way mobility model
Number of Maximum retransmissions allowed	03
Node's initial energy	5
Packets Size	128 bytes
Rate of Data	300 kb/s
Node's Sensing range	35 m
Time of Simulation	5 min
Average Simulation Run	06
Routing Protocol of QoS	Leach with GWO
Location of Base Station	(0,500)
Power of Transmitter	12.3 mW
Power of Receiver	13.4 mW

4.2 Result Analysis of Proposed Work

4.2.1 Alive Nodes

Table I Alive nodes in Existing Algorithm and GWO-Sink

No of Nodes	Without Optimization	Optimization with GWO SINK
10	100	100
20	100	100
30	97	100
40	96	100
50	90	100
60	85	98
70	80	89
80	40	62
90	14	29
100	1	5

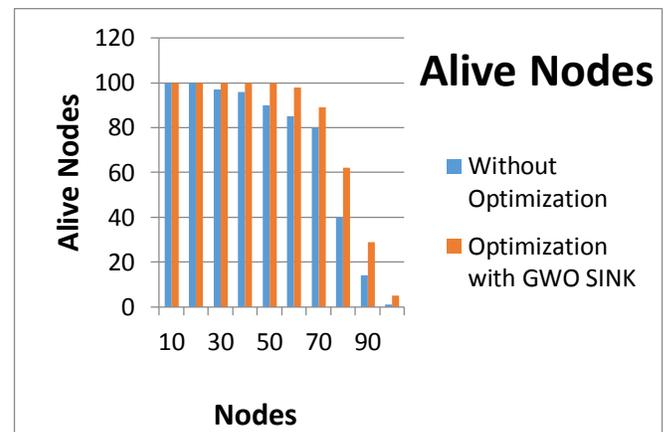


Figure 9 Alive nodes in Existing Algorithm and GWO-Sink

The above given figure 9 depicts the total number of alive nodes in the existing and proposed GWO-Sink Approach. The blue bar of the graph represents the alive nodes in existing approach and red bar represents the alive nodes in GWO-Sink. The alive nodes in GWO-Sink are high than the existing which enhance the efficiency of the network.

4.2.1 Throughput

Throughput of the nodes shows the total packet delivered over the number of packet send in the given duration.

$$\text{Throughput} = \frac{\text{No.of Delivered packet} * \text{Packet Size} * 8}{\text{Total Duration of Simulation}}$$

Table II Throughput in Existing Algorithm and GWO-Sink

No of Nodes	Without Optimization	Optimization with GWO SINK
10	1000	1000
20	1850	1850
30	2700	2820

40	3600	3750
50	4200	4300
60	5100	5250
70	5720	5880
80	6200	6500
90	6500	6900
100	6950	8550

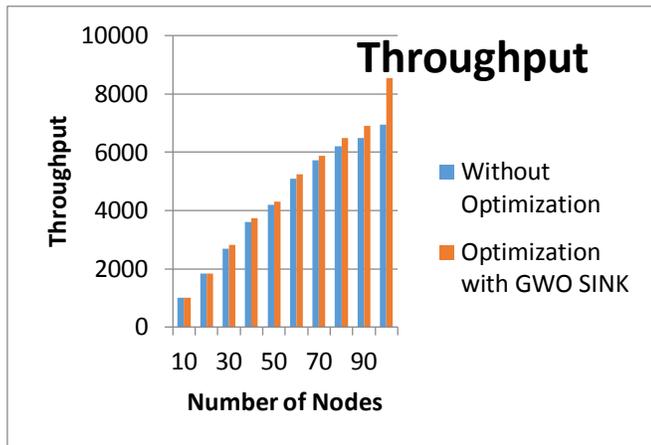


Figure 10 Throughputs in Existing Algorithm and GWO-Sink

The above given figure 10 depicts the throughput in the existing and proposed GWO-Sink Approach. The blue bar of the graph represents the throughput of existing approach and red bar represents the throughput of GWO-Sink. The throughput of GWO-Sink is high than the existing approach which enhanced the efficiency of the network. This is due to the grey wolf optimization algorithm which provides the optimal nodes during the data transfer which takes less time in packet delivery and enhance the throughput of the network.

4.2.3 Dead Nodes

Table III Dead Nodes in Existing Algorithm and GWO-Sink

No of Nodes	Without Optimization	Optimization with GWO SINK
10	00	00
20	00	00
30	2	00
40	3	00
50	11	00
60	15	03
70	19	09
80	57	34
90	80	69
100	99	97

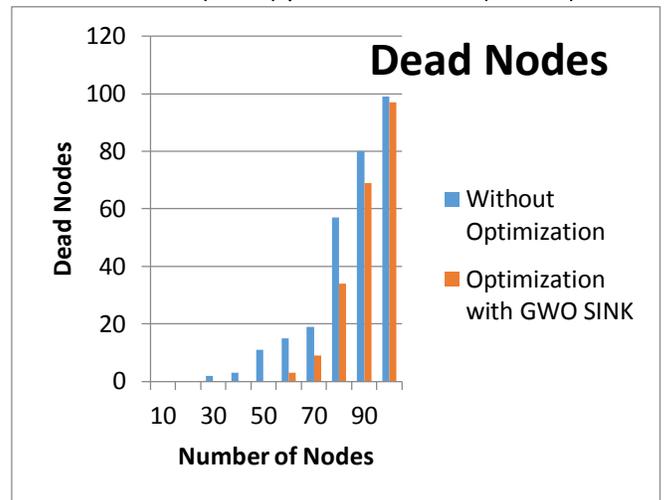


Figure 11 Dead Nodes in Existing Algorithm and GWO-Sink

The above given figure 11 depicts the total number of dead nodes in the existing and proposed GWO-Sink Approach. The blue bar of the graph represents the dead nodes in existing approach and red bar represents the dead nodes in GWO-Sink. The dead nodes in GWO-Sink are less than the existing which enhance the efficiency of the network because if dead node if high then the performance of network is degraded.

4.2.4 Time Delay

Time delay is the time period which taken by the node for the specific packet. It shows that time delay is less than network produce effective throughput.

$$Time\ Delay = Packet\ Sending\ Time\ (in\ m/sec) + Packet\ Delivery\ Time\ (in\ m/sec)$$

Table IV Time Delay in Existing Algorithm and GWO-Sink

No of Nodes	Without Optimization	Optimization with GWO SINK
10	100	95
20	200	192
30	297	288
40	420	400
50	499	496
60	585	570
70	685	640
80	750	720
90	800	780
100	890	810

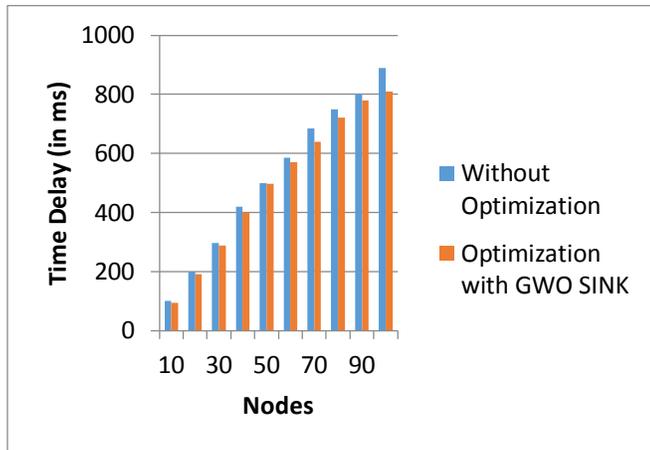
Figure 12 Time Delay in Existing Algorithm and GWO-Sink

The above given figure 12 depicts the time delay in the existing and proposed GWO-Sink Approach. The blue bar of the graph represents the time delay in existing approach and red bar

represents the time delay in GWO-Sink. The time delay in the proposed GWO-Sink approach is less than existing approach which improves the network quality because if delay is less than packets deliver fast and enhance the communication process.

4.2.5 Energy Consumption

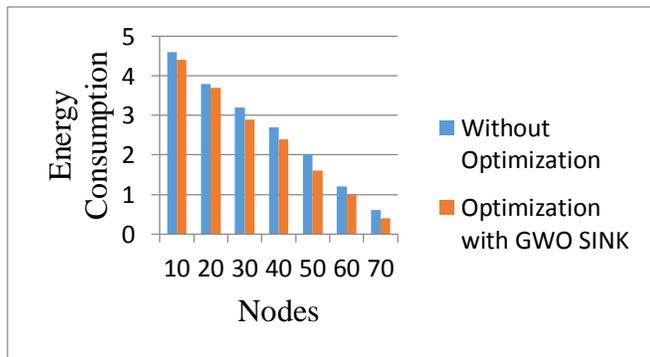
The below given table represents the total energy consumed by the nodes to transmit the data packets. If the nodes consume lot of energy then it is costly and less efficient. The proposed algorithm consumes less energy as compare to existing approach.



$$\text{Energy Consumption} = \text{Packet Sending Energy} + \text{Packet Delivery Energy}$$

Table V Energy Consumption in Existing Algorithm and GWO-Sink

No of Nodes	Without Optimization	Optimization with GWO SINK
10	4.6	4.4
20	3.8	3.7
30	3.2	2.9
40	2.7	2.4
50	2.0	1.6



60	1.2	1.0
70	0.6	0.4

Figure 13 Energy Consumption in Existing Algorithm and GWO-Sink

The above given figure 13 depicts the energy consumption in the existing and proposed GWO-Sink Approach. The blue bar of the graph represents the energy consumption in existing approach and red bar represents the energy consumption in GWO-Sink. The energy consumption in the proposed GWO-Sink approach is less than existing approach which improves the network quality because if energy consumption is less than it also uses low resources which improves network quality.

4.2.6 Count of Cluster Heads

Cluster is a group of nodes and the group of clusters has a cluster head which controls the activities of the nodes in the clusters. The high numbers of clusters shows the high number of working or active node in the network. The number of cluster heads in the proposed algorithm is high.

Table VI Cluster heads in Existing Algorithm and GWO-Sink

No of Nodes	Without Optimization	Optimization with GWO SINK
10	9.2	13.4
20	10.1	12.7
30	11.7	12.5
40	10.8	12.3
50	11.2	11.9
60	8.7	9.2
70	6.1	7.8
80	4.6	5.8
90	2.8	4.1
100	0.0	2.1

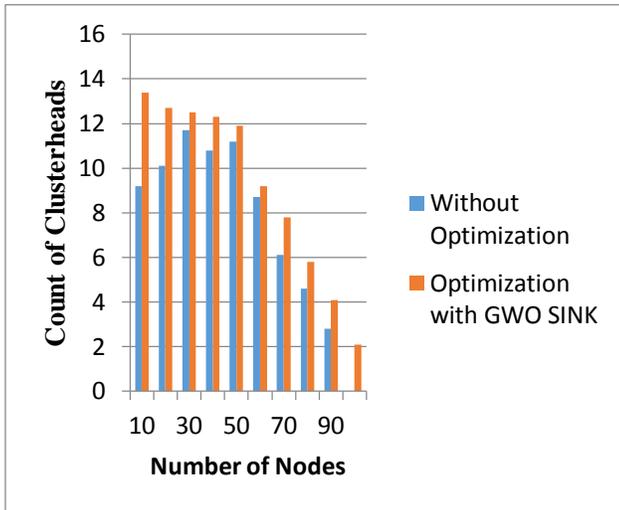


Figure 14 Cluster Heads in Existing Algorithm and GWO-Sink

The above given figure 14 depicts the energy consumption in the existing and proposed GWO-Sink Approach. The blue bar of the graph represents the energy consumption in existing approach and red bar represents the energy consumption in GWO-Sink.

4.2.7 Packet Delivery Rate

Packet delivery rate is defined as the total packet delivered in the given slot of time. It shows the efficiency of the network by sending more packets in less time. It is calculated by using following formula:

$$PDR (Packet\ delivery\ rate) = \frac{Total\ number\ of\ Packets\ Send}{Time\ (msec)}$$

Table VII: Packet Delivery Rate in Existing Algorithm and GWO-Sink

No of Nodes	Without Optimization	Optimization with GWO SINK
10	800	1100
20	780	1050
30	750	980
40	730	900
50	690	720
60	540	700
70	400	1375
80	350	1740
90	110	2100
100	50	2400

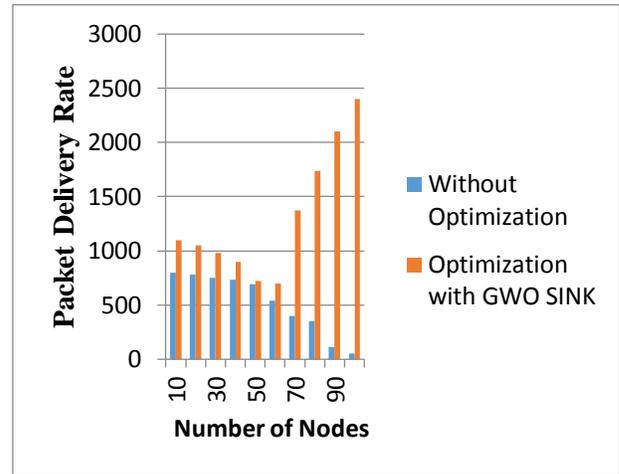


Figure 15: Packet Delivery Rate in Existing Algorithm and GWO-Sink

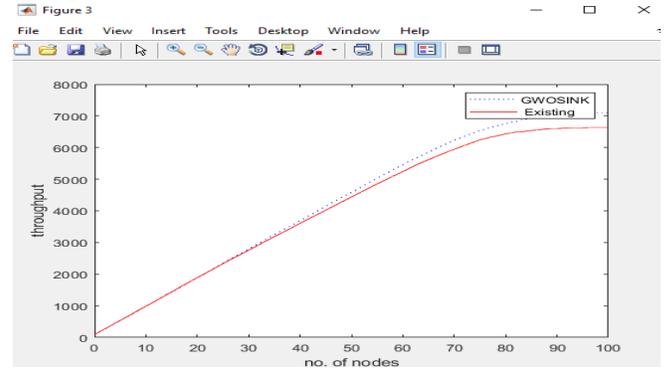
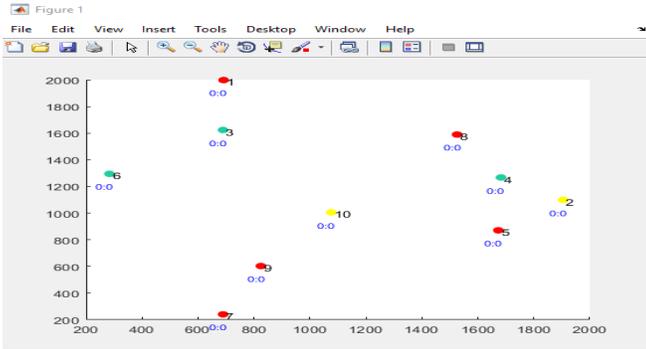
The above given figure 15 depicts the packet delivery rate of the existing and proposed GWO-Sink Approach. The blue bar of the graph represents the packet delivery rate of the existing approach and red bar represents the packet delivery rate of GWO-Sink. The packet delivery rate of the proposed approach is better than existing approach which makes communication more effective. This is due to effective GWO result and it improves the packet delivery rate.

4.3 Comparison of the Previous Work

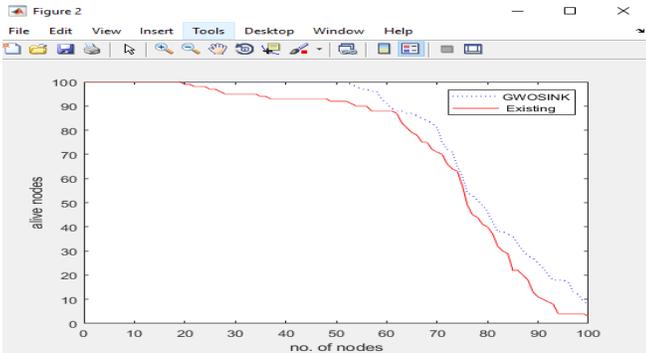
The table given below depicts the overall result of the existing and proposed approach on various metrics. The analysis based on the alive nodes in the network, throughput of the network, dead nodes on the network, time delay, and packet delivery rate. The alive node shows the total available node during the communication on network which is high in the GWO approach. The throughput defines the total packet delivered in the given time which is more in GWO approach. The dead nodes are that node which does not active or not performs any function in the network they are high in the existing method and less in proposed approach. The time delay in the existing approach is high during data transfer and it also enhances the packet delivery rate and reduces the efficiency. The time delay, throughput, and packet delivery rate is improved by the grey wolf optimization algorithm in the proposed work and it also shown in the above defined graphs and their outcomes as represented in table VII.

4.4 Simulation of Result Work

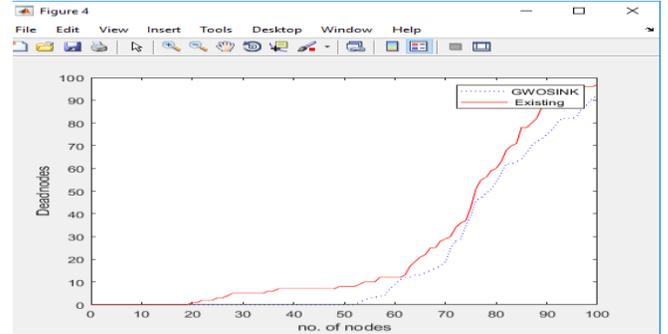
4.4.1 Nodes



4.4.2 Alive Nodes



4.4.4 Dead Nodes

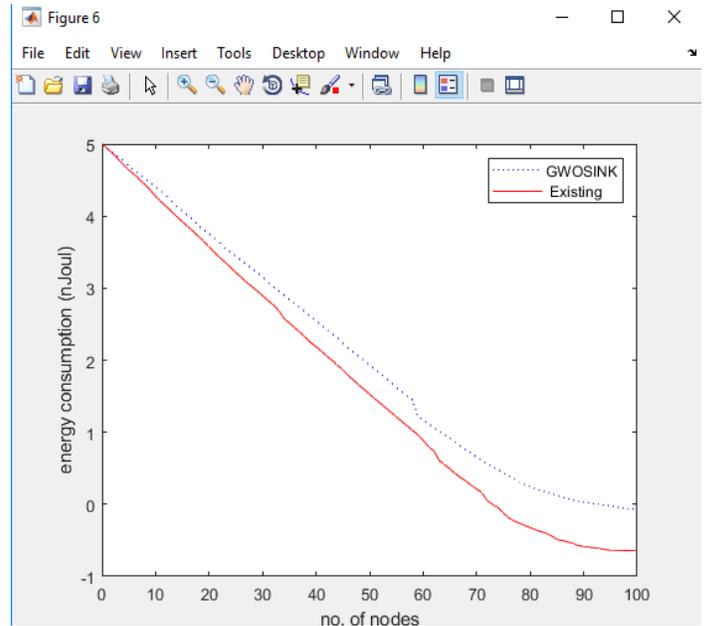
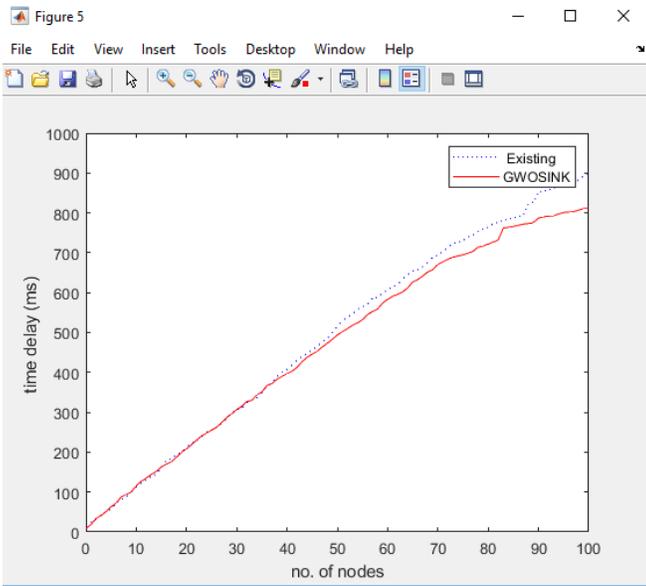


4.4.3 Throughput

Table VIII Overall results Analysis table of Existing approach and proposed GWO-Sink approach

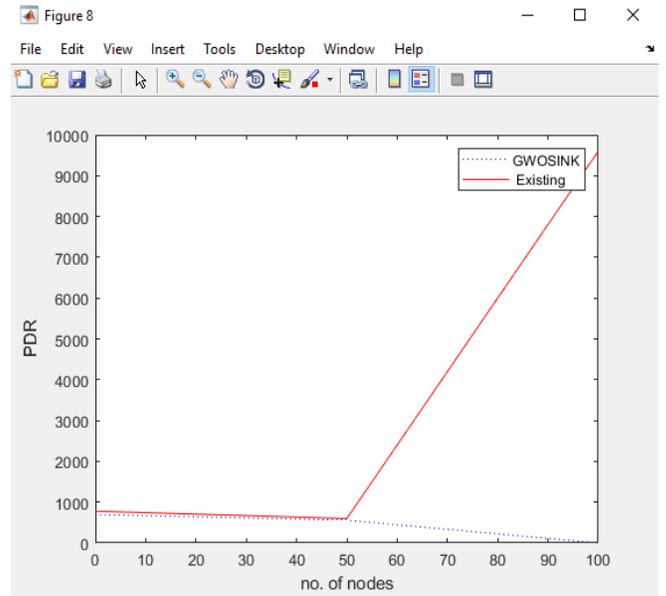
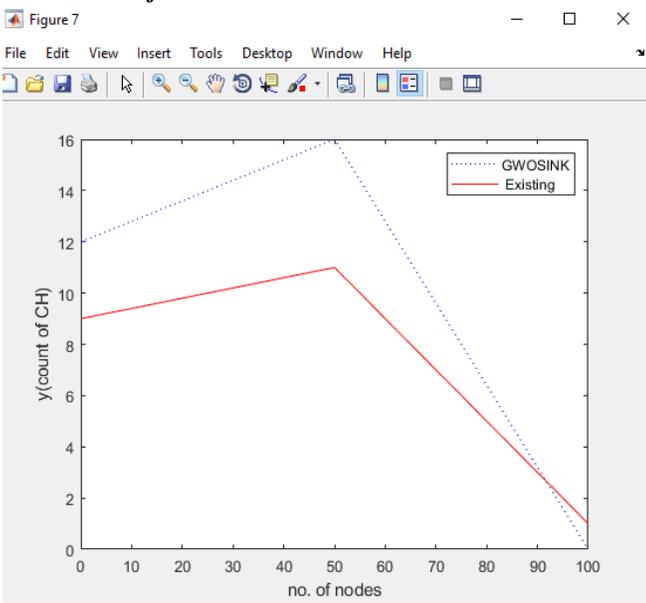
No of Nodes	Alive Nodes		Throughput		Dead Nodes		Time Delay		Packet Delivery Rate	
	Without Optimization	Optimization with GWO SINK								
10	100	100	1000	1000	00	00	100	95	800	1100
20	100	100	1850	1850	00	00	200	192	780	1050
30	97	100	2700	2820	2	00	297	288	750	980
40	96	100	3600	3750	3	00	420	400	730	900
50	90	100	4200	4300	11	00	499	496	690	720
60	85	98	5100	5250	15	03	585	570	540	700
70	80	89	5720	5880	19	9	685	640	400	1375
80	40	62	6200	6500	57	34	750	720	350	1740
90	14	29	6500	6900	80	69	800	780	110	2100
100	1	5	6950	8550	99	97	890	810	50	2400

4.4.5 Time Delay



4.4.6 Energy Consumed

4.4.7 Count of Cluster Heads



consumption and improve the network quality. It enhanced the packet delivery rate and number of cluster heads in wireless sensor network.

4.4.8 Packet Delivery rate

IV CONCLUSION

Wireless sensor network (WSN) contains sensor nodes which mainly used for sensing, communicating and data processing. Sensor nodes can be used in many fields like industries, military, and agricultural applications, such as transportation traffic monitoring, environmental monitoring, smart offices, and battlefield surveillance. In these applications, sensors are deployed in an ad-hoc manner and operate autonomously. In these unattended environments, these sensors cannot be easily replaced or recharged, and energy consumption is the most

critical problem that must be considered. This research work done on the wireless sensor network by using the concept of leach routing of nodes and optimize the routing process by using Grey Wolf Optimization algorithm. The GWO algorithm provides the optimal results. The optimal result provided by GWO reduced the time delay, dead nodes and energy

networks." *Concurrency and Computation: Practice and Experience* 29.17 (2017).

- [13]. Kumar, Gulshan, Mritunjay Kumar Rai, and Rahul Saha. "Securing range free localization against wormhole attack using distance estimation and maximum likelihood estimation in Wireless Sensor Networks." *Journal of Network and Computer Applications* 99 (2017): pp: 10-16.

V REFERENCES

- [1]. Zhang, Zhaohui, et al. "M optimal routes hops strategy: detecting sinkhole attacks in wireless sensor networks." *Cluster Computing* (2018): pp:1-9.
- [2]. Mitigation approach for quality of service improvement in wireless sensor networks." *Industry Interactive Innovations in Science, Engineering and Technology*. Springer, Singapore, 2018, pp:357-366.
- [3]. Mittal, Vikas, Sunil Gupta, and Tanupriya Choudhury. "Comparative Analysis of Authentication and Access Control Protocols Against Malicious Attacks in Wireless Sensor Networks." *Smart Computing and Informatics*. Springer, Singapore, 2018, pp:255-262.
- [4]. Yasin, N. Mohammed, et al. "ADSMS: Anomaly Detection Scheme for Mitigating Sink Hole Attack in Wireless Sensor Network." *Technical Advancements in Computers and Communications (ICTACC), 2017 International Conference on*. IEEE, 2017 pp. 154-159.
- [5]. Saghar, Kashif, Hunaina Farid, and Ahmed Bouridane. "Formally verified solution to resolve tunnel attacks in wireless sensor network." *Applied Sciences and Technology (IBCAST), 2017 14th International Bhurban Conference on*. IEEE, 2017, pp. 448-455.
- [6]. Vidhya, S., and T. Sasilatha. "Sinkhole Attack Detection in WSN using Pure MD5 Algorithm." *Indian Journal of Science and Technology* 10.24 (2017).
- [7]. Jahandoust, Ghazaleh, and Fatemeh Ghassemi. "An adaptive sinkhole aware algorithm in wireless sensor networks." *Ad Hoc Networks* 59 (2017) pp: 24-34.
- [8]. Kalnoor, Gauri, Jayashree Agarkhed, and Siddarama R. Patil. "Agent-Based QoS Routing for Intrusion Detection of Sinkhole Attack in Clustered Wireless Sensor Networks." *Proceedings of the First International Conference on Computational Intelligence and Informatics*. Springer, Singapore, 2017, pp. 571-583.
- [9]. Saranya, P., Abin P. Varghese, and R. S. Balaji. "DETECTING AND PREVENTING THE WORMHOLE ATTACKS IN WIRELESS SENSOR NETWORK." *traffic* 3.04 (2017).
- [10]. Ma, Rui, et al. "Defenses against Wormhole Attacks in Wireless Sensor Networks." *International Conference on Network and System Security*. Springer, Cham, 2017, pp. 413-426.
- [11]. Saghar, Kashif, Hunaina Farid, and Ahmed Bouridane. "Formally verified solution to resolve tunnel attacks in wireless sensor network." *Applied Sciences and Technology (IBCAST), 2017 14th International Bhurban Conference on*. IEEE, 2017, pp. 448-455.
- [12]. Jan, Mian, et al. "PAWN: a payload-based mutual authentication scheme for wireless sensor