



RESEARCH ARTICLE

Rule-Based and Cluster-Based Intrusion Detection Technique for Wireless Sensor Network

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Abstract— *Wireless Sensor Networks (WSNs) are playing a fundamental role in emerging pervasive platforms that have potential to host a wide range of next generation civil and military applications. Since WSNs are made up of numerous low-cost and small devices and usually deploy to an open, unprotected and hostile environments, it is vulnerable to security threats and susceptible to physical capture. Thus, it is necessary to use effective mechanisms to protect the network. Intrusion detection system is one of the major and efficient defensive methods against attacks on wireless sensor network. Sensor networks have different characteristics and hence security solutions have to be designed with limited usage of computation and resources. In this paper, the architecture of hybrid intrusion detection system (HIDS) is proposed for wireless sensor networks. In order to get hybrid scheme, the combined version of Cluster-based and Rule-based intrusion detection techniques is used and eventually evaluated the performance of this scheme by simulating the network. A prevention mechanism is used to counteract well-known attacks. The simulation result shows that the scheme performs intrusion detection using hybrid technique and detection graph shows ratings like attack rating, data rating and detection net rating with the attack name and performs better in terms of energy efficiency and detection rate.*

Key Terms: - *Wireless Sensor Network; Rule-based & cluster-based intrusion detection; Hybrid; Anomaly detection; Misuse detection*

I. INTRODUCTION

Wireless Sensor Networks (WSN) is one of the most interesting and promising areas over the past few years. It is often considered as a self-organized network of low cost, power and complex sensor nodes have been typically designed to monitor the environment for physical and chemical changes, disaster regions and climatic conditions. These networks may be very large systems comprised of small sized, low power, low-cost sensor devices that collect detailed information about the physical environment. WSN's perform both routing and sensing activities and are configured in ad hoc mode for communication.

The sensor nodes are light and portable, with sensing abilities, communication and processing board, and are used for sensing in critical applications. Each device has one or more sensors, embedded processor(s), and low-power radio(s), and is normally battery operated value of sensor networks however, lies in using and coordinating a vast number of such devices and allows the implementation of very large sensing tasks. In a usual scenario, these networks are deployed in areas of interest (such as inaccessible terrains or disaster sites) for fine grained monitoring in various classes of applications [1]. The flexibility and self-organization, fault tolerance, high sensing fidelity, low-cost, and rapid deployment characteristics of sensor networks create many new and

exciting application areas for remote sensing WSNs. Following figures (1) shows the cluster-based wireless sensor networks.

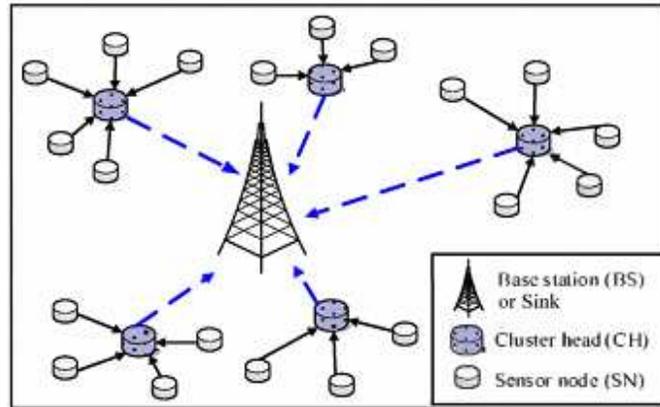


Figure 1. Cluster-Based WSN

WSNs are energy constrained, critical and very susceptible to various routing and malicious attack which include spoofing, sinkhole, selective forwarding, Sybil, wormhole, black hole, and denial of service (DoS) attacks. These have been described in [3]. Prevention mechanisms which include authentication, cryptography, and installation of firewalls have been employed to secure networks. However, these mechanisms only pose a first line of defence and do not provide enough security for wireless networks. This mechanism can be exploited because it has been proved that no matter the amount of prevention techniques incorporated into a network; there will always be weak links. Therefore, there is a need to develop mechanisms that will be added to the existing techniques to provide a better security and guarantee survivability. Hence the development of Intrusion Detection System (IDS) referred to as a second line of defence. Many IDS have been proposed from several researchers and some of them are discussed in the related works. However, a number of them suffer from a high False Positive Rate (FPR) which describes an instance where the IDS falsely report a legal activity as an anomaly. Anomaly detection uses activities that significantly deviate from the normal users or programs' profile, to detect possible instances of attacks. It detects new attacks without necessarily been required to know prior intrusions. In this work, our goal is to simulate IDS for Clustered based WSNs by presenting an approach that provides high detection accuracy with a low FPR.

II. AN INTRUSION DETECTION SYSTEM (IDS)

Intrusion, i.e. unauthorized access or login (to the system, or the network or other resources) [4]; intrusion is a set of actions from internal or external of the network, which violate security aspects (including integrity, confidentiality, availability and authenticity) of a network's resource [5], [6]. Intrusion detection is a process which detecting contradictory activities with security policies to unauthorized access or performance reduction of a system or network [4]; The purpose of intrusion detection process is reviewing, controlling, analysing and representing reports from the system and network activities. Intrusion Detection System (IDS), i.e.:

- It is a hardware, software or combination of both systems; with aggressive-defensive approach to protect secret information, systems and networks [7], [8].
- Usable on host, network [9] and application levels.
- Analyzing traffic, controls communication and ports, detecting attacks and occurrence vandalism, by internal users or external attackers.
- Concluding by using deterministic methods (based on patterns of known attacks) or non-deterministic [8], [9] (to detecting new attacks and anomalies such as determining thresholds);
- Informing and warning to the security manager [6], [7], [10] (sometimes disconnect suspicious communications and block malicious traffic);
- Determining identity of attacker and tracking him/her/it;

The main three functionalities for IDS, including: monitoring (evaluation), analyzing (detection) and reacting (reporting) [5], [7] to the occurring attacks on computer systems and networks. If IDS be configured, correctly; it can represent three types of events: primary identification events (like stealthy scan and file content manipulation), attacks (automatic/ manual or local/remote) and suspicious events. The IDS acts as a network monitor or an alarm. It prevents destruction of the system by raising an alarm before the intruder starts to attack. The two major modules of intrusion detection include anomaly detection and misuse detection [11]. Anomaly detection builds a model of normal behavior, and compares the model with detected behavior. Anomaly

detection has a high detection rate, but the false positive rate is also high. The misuse detection detects the attack type by comparing the past attack behavior and the current attack behavior. The misuse detection has high accuracy but low detection rate. Especially, the misuse detection cannot detect unknown attacks, which are not in the model base. Many researchers discuss the module of hybrid detection to gain both the advantages of anomaly detection and misuse detection [12], [13]. This combination can detect unknown attacks with the high detection rate of anomaly detection and the high accuracy of misuse detection. The Hybrid Intrusion Detection System (HIDS) achieves the goals of high detection rate and low false positive rate. In this section, a HIDS is discussed in a CWSN. Cluster head (CH) is one of SNs in the CWSN but the capability of CH is better than other SNs [14]. Additionally, the CH aggregates the sensed data from other SNs in its own cluster. This makes a target for attackers. However, the CH is used to detect the intruders in our proposed HIDS. This not only decreases the consumption of energy, but also efficiently reduces the amount of information. Therefore, the lifetime of WSN can be prolonged.

A. Requirements for IDS in Sensor Networks

In this section we elaborate on the requirements that an IDS system for sensor networks should satisfy. To do so, one has to consider some specific characteristics of these networks. Each sensor node has limited communication and computational resources and a short radio range. Furthermore, each node is a weak unit that can be easily compromised by an adversary [15], who can then load malicious software to launch an insider attack. In this context, a distributed architecture, based on node cooperation is a desirable solution. In particular, we require that an IDS system for sensor networks must satisfy the following properties:

- 1) Localize auditing: An IDS for sensor networks must work with localized and partial audit data. In sensor networks there are no centralized points (apart from the base station) that can collect global audit data, so this approach fits the sensor network paradigm.
- 2) Minimize resources: An IDS for sensor networks should utilize a small amount of resources. The wireless network does not have stable connections, and physical resources of network and devices, such as bandwidth and power, are limited. Disconnection can happen at any time. In addition, the communication between nodes for intrusion detection purposes should not take too much of the available bandwidth.
- 3) Trust no node: An IDS cannot assume any single node is secure. Unlike wired networks, sensor nodes can be very easily compromised. Therefore, in cooperative algorithms, the IDS must assume that no node can be fully trusted.
- 4) Be truly distributed: That means data collection and analysis is performed on a number of locations. The distributed approach also applies to execution of the detection algorithm and alert correlation.
- 5) Be secure: An IDS should be able to withstand a hostile attack against itself. Compromising a monitoring node and controlling the behavior of the embedded IDS agent should not enable an adversary to revoke a legitimate node from the network, or keep another intruder node undetected.

III. RELATED WORK

A. Attacks in WSN

Attacks can be classified into two main categories, based on the objectives of intrusion [21]. The comparison of attacks in WSN is shown in Table 1 [22], [23], [24]. However, the majority of attack behavior consists of the route updating misbehavior, which influences data transmission. In the application of CWSN, the data is sensed and collected by SNs, and is delivered to CH to aggregate. The aggregated data is then sent to a sink from CH. Therefore, CH is a main target for attack.

Attack Name	Behavior
Spoofed, Altered, or Replayed routing information	Route updating misbehavior
Select forward	Data forwarding misbehavior
Sinkhole	Route updating misbehavior
Sybil	Route updating misbehavior
Wormholes	Route updating misbehavior
Denial of Service	Data forwarding misbehavior
Hello floods	Route updating misbehavior
Acknowledgment spoofing	Route updating misbehavior

TABLE 1: The different types of attacks in WSN

B. Analytic Tool of Intrusion Detection

The proposed HIDS in our research not only efficiently detects attack, but also avoids the waste of resources. First, a large number of packet records is filtered by using the intrusion detection module, and then completes the whole detection. Also with reference to the mode of normal behaviour, the detection module detects the normalcy of current behaviour, as determined by the rules.

The detection module determines if the current behavior is an attack, and the behavior of the attacks. Rule-based presents the thoughts of expert [25]. Because human thought is very complicated, the knowledge could hardly be presented by algorithms. Therefore, a rule-based method is used to analyse results. Additionally, the rules are logged in a rule base after they have been defined. The basic method of expression of rule is "if... then..." that means if "condition" is established and then the "conclusion" will occur.

With the increasing growth in technology, many researchers have proposed several IDSs to secure WSNs. The vulnerabilities associated with wireless networks make it imperative to imbibe IDS in WSNs. [26] Defined IDS as an act of monitoring and detecting unwanted actions or traffic on a network or a device. This is achieved by monitoring the traffic flow on the network. Examples of published work on anomaly detection systems are IDES [27], HAYSTACK [28], and the statistical model used in NIDES/STATS [29] which is a more recent approach and presents a better anomaly detection system compared to the others afore mentioned. A process of developing intrusion detection capabilities for MANET was described in [30]. The authors discussed how to provide detailed information about intrusions from anomaly detection by showing that for attacks; as simple rule can be applied to identify the type of attack and the location of the attacking node. A geometric framework has been presented in [31] to address unsupervised anomaly detection such that for example, when a packet is transmitted and is being analyzed, a decision needs to be made as to whether it is normal or abnormal. To do this, the packet is represented with a set of features which are encoded such that the traffic is mapped to a point a in a feature A , hence $a \in A$. If a packet is seen in separate region where other packets have not been seen, then it is considered an anomalous, otherwise, it is normal.

IV. SYSTEM ARCHITECTURE AND NETWORK MODEL

The proposed HIDS consists of an intrusion detection module and decision making module. Intrusion detection module filters a large number of packet records using the rule based technique. Decision making module is used to take an administrative action on the false node with the help of base station.

A. System Architecture and Network Structure

Here, the new Hybrid Intrusion Detection Model (HIDS) is proposed for Cluster Based Wireless Sensor Network (CWSN). This consists of two modules as shown in Figure 3. First, the Intrusion Detection Engine is used to filter the incoming packets and classify as normal or abnormal. The packets identified as an abnormal are passed to the decision making module. The decision-making module is used to determine whether the intrusion occurs and the type of intrusion or attacks behaviour. Finally, the decision making module returns this information to the base station to follow-up treatment on intruder node. In this proposed model, we use a hierarchical topology that divide the sensor network into clusters, each one having a cluster head (CH) as shown in Figure 4. Here the sensors nodes are fixed and assuming that the cluster heads having the more energy than the other sensor nodes. The objective of this architecture is to save the energy that allows the network life time prolongation and reduce the amount of information in the network. Some of the Cluster-based routing protocols founded in the literature are: LEACH [32], PEGASIS [33] and HEED [34].

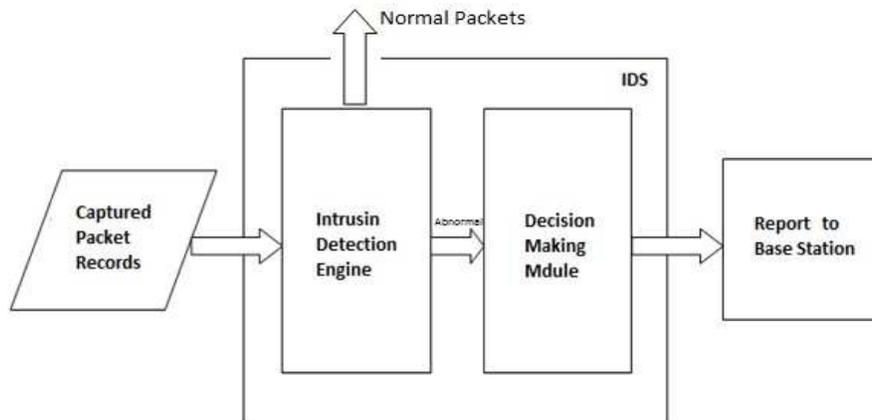


Figure2. Proposed System Architecture

The Figure5 shows the deployment and setting up of the WSN. Here, we used the three types of nodes in the network each of which indicated with different colors. Yellow color shows the Base Station (BS), Green color represents for Cluster Head (CH), all the sensor nodes are indicated by red color and finally the intruder node with blue color in the sensor field. The cluster based technique is used to form clusters in the WSN as shown in the Figure5.

B. IDS Techniques Used

In the proposed Hybrid Approach [35], [36], the two techniques i.e. Cluster-Based and Rule-Based techniques are merged to form Hybrid Intrusion Detection technique. Hybrid detection used to gain the advantages of both Cluster-Based approach and Rule-Based approach. This combination provides simplicity, easy to operate, low consumption of energy and provide high safety. The Hybrid Intrusion Detection System (HIDS) achieves the goals of high detection rate and low false positive rate.

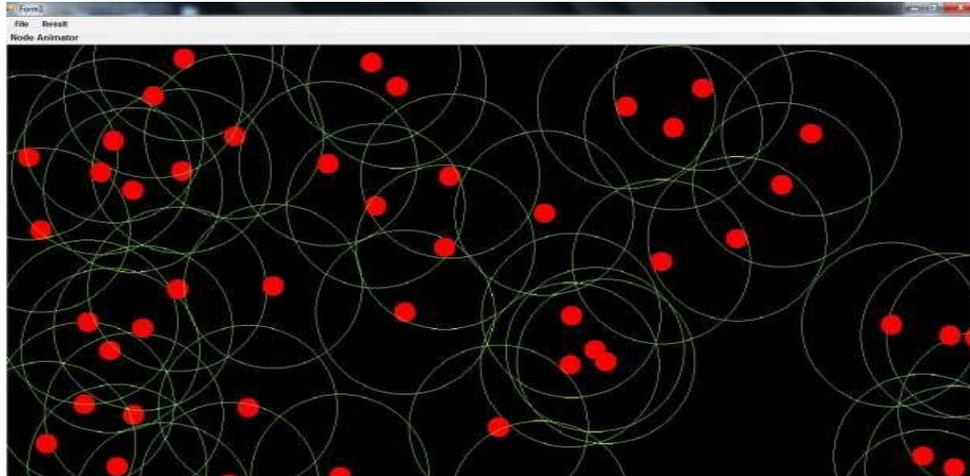


Figure 3: Deployment and Setting up WSN

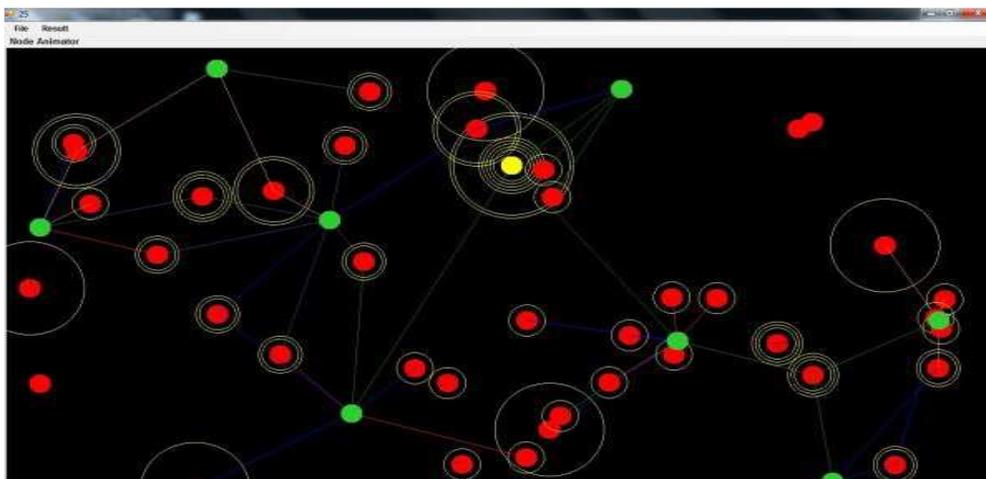


Figure 4. Forming Clusters in WSN

C. Clusters -Based.

Clustering is known as hierarchical of WSN [37]. To divide the network nodes into head cluster and members of nodes is the basic idea. Cluster head is the centre of a cluster. Through cluster head's information fusion and forwarding to the member node of cluster, other members of nodes transmit to the base station.

Function of Base Station:

- 1) All nodes are able to send data to BS via Cluster Head.
- 2) Base station has all the information regarding each Cluster (number and MAC address).

- 3) The removal or addition of any node in a Cluster is monitored by the Base Station. Poll status of each node is received with MAC address.
- 4) Base station runs task of MAC address tracking, MAC address history and management of database.
- 5) The Base Station has the capability to seize the operation of any node in the network.

Function of Cluster Head:

- 1) Cluster Heads keep track of each node and sends periodic status information to the Base Station.
- 2) Cluster heads receives data from its nodes and sends necessary information.
- 3) Cluster Heads (CHs) transmits data to Base Station after performing data reception and compression.

D. Rule-based

Rule -based intrusion detection [9] is the collection and classification of data, the data is placed in a queue, using the FIFO principle. In our model while monitoring the network this rules are selected appropriately and applied to the monitored data. If the rules defining an anomalous condition are satisfied, an intrusion is declared. The algorithm has three phases for detecting intrusions. In the first phase monitor nodes monitors the data. In the second phase the detection rules, are applied, in increasing order of complexity, to the collected information to flag failure. The third phase is the intrusion detection phase, where the number of failure flagged is compared to the expected number of the occasional failures in the network. Occasional failures include data alteration, message loss, and message collision. An intrusion alarm is raised if the number of failures flagged exceeds the expected number of occasional failures. The rule base methods are fast, simple and require less data.

E. Rules and Definition

Development of this IDS to a target cluster-based WSN are divided into three following important steps: (1) preselect, from the available set of rules, those can be used to monitor the features defined by the designer; (2) compare the information required by the preselected rules with the information available at the target network to select rules definitively; and (3) set the parameters of the selected rules with the values of the design definitions. Definitions of the rules used, are presented in the following manner:

Integrity Rule: To avoid data fusion or aggregation by other sensor nodes, the message payload must be the same along the path from its origin to a definition. Attacks where the intruder modifies the contents of a received message can be detected by this rule.

Jamming Rule: The number of collisions associated with a message must be lower than the expected number in the network. The jamming attack, where a node introduces noise into the network to disturb the communication channel, can be detected by this rule.

Interval Rule: If the time interval between the receptions of two consecutive messages is longer or shorter than the allowed time limits, a failure is raised. Two attacks that will probably be detected by this rule are the negligence attack and the exhaustion attack. In the negligence attack, the intruder does not send data messages generated by a tampered node. While in the exhaustion attack, the intruder increments the message - sending rate in order to increase the energy consumption of other nodes in the cluster.

Repetition Rule: The same message can be retransmitted by a node only a limited number of times. This rule can detect an attack where the intruder sends the same message several times, thus promoting a denial of service attack.

Radio Transmission Range: all messages listened to by the monitor node must be originated from one of the nodes within its cluster. Attacks like wormhole and hello flood, where the intruder sends messages to a far located node using a more powerful radio, can be detected by this rule.

Retransmission Rule: The monitor listens to a message, pertaining to one of its neighbours as its next hop, and expects that this node will forward the received message, which does not happen. Two types of attacks that can be detected by this rule are the black hole and the selective forwarding attack. In both of them, the intruder suppresses some or all messages that were supposed to be retransmitted, preventing them from reaching their final destination in the network.

Delay Rule: The retransmission of a message by a monitor's neighbour must occur before a defined timeout. Otherwise, an attack will be detected.

Algorithm 1: Rules application procedure of IDS

- 1: for all messages in data structure array do
- 2: for all rules specific to the message in descending order by weight does
- 3: apply rule to the message;
- 4: if (message == fail) then
- 5: increment failure counter for the node based on weight; [failure counter = failure counter + weight.
- 6: discard message;

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7: break;
8: end if
9: end for
10: discard message;
11: end for
    
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Algorithm 1 shows the procedure of rules application on messages in the network. The algorithms apply rules on all the messages. If message fails according to the rule, then the failure counter will be incremented and discards all the messages.

V. NETWORK SIMULATION AND RESULTS

The above proposed model has been simulated using Visual Studio .Net framework. The simulator can also be used to view the topology generated by the initial self organization algorithm LEACH [32] for setting the WSN as shown in Figure2. A comparison assumed to have the same number of clusters or sensing zones, no packet collisions occurred. It also assumed that there were no packet errors during transmission and reception.

In this proposed architecture, the wireless sensor network is divided into the small clusters. The hierarchical clustering is used to divide the sensor nodes. After the clustering process finished, the cluster head have been selected dynamically according to the current status of the nodes and formed the Cluster based WSN as shown in Figure 3. Generally, the node having highest energy left elected as a cluster head. Simulation runs with the following.

Simulation Parameter		
Sr.No	Parameters	Values
1.	Routing Protocol	AODV
2.	Mac Layer Protocol	802.11
3.	Total No. Of Nodes	50
4.	Traffic Type	CBR
5.	Simulation Topology	1024cm × 768cm
6.	Simulation Time	100 sec
7.	Packet Size	512 Kbytes

Nodes are deployed randomly over an area of 1024 cm X 768 cm. The node closest to the centre of the deployment area is selected as sink or base station (BS), which is resources not limited, secure and safety for any advisory attackers and acts as an administrator for taking appropriate action on the intruder nodes. The network has been simulated with AODV routing protocol with Mac layer 802.11. 50 nodes are taken in the network within the simulation area and constant bit rate of traffic type is used. The network performance is observed for the simulation time 100 seconds. The standard packet size is used i.e. 512 Kbytes

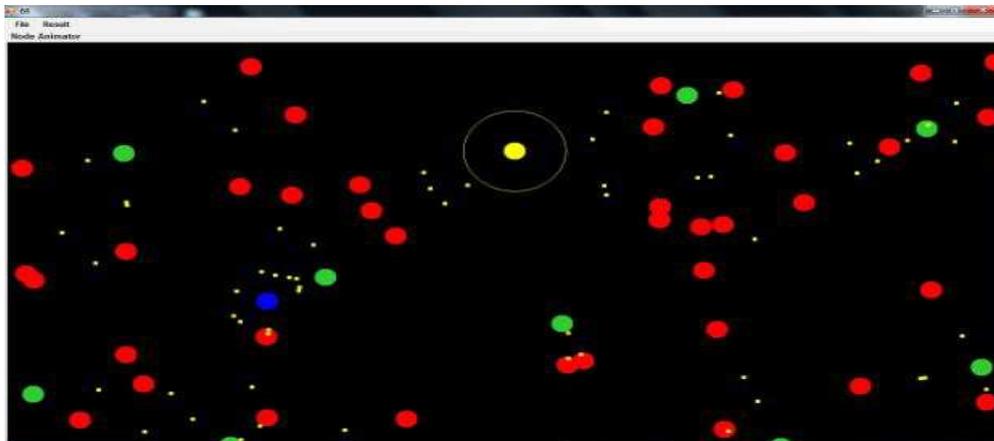


Figure 5. Introducing attacks in WSN

The simulation is run in different scenarios, each scenario has different parameter values, and malicious nodes inject the malicious packets in the whole sensor network as shown in Figure 5. The figure shows the false packets in yellow colour a round malicious node (Blue) are spreading in the whole network. Proposed system must recognize these nodes and refuse their connection for next round as an administrative action against malicious nodes with the help of BS.

VI. CONCLUSION AND FUTURE WORK

Intrusion detection is a hot field of the network security research, and it is a new kind of defence technology of the network security. Here, a new technique based on hybrid detection (i.e. combination of the features of rule-based and cluster-based detection techniques) is used. Hence, a better intrusion detection mechanism is presented in this paper. This proposed intrusion detection architecture is designed to detect attacks. The aim was to improve the detection rate and decrease the false positive rate.

In the future work, further research on this topic will be performed, with detailed simulation of different attack scenarios, in order to test the performance of the proposed model and to make comparison with other current techniques of HIDS. The results will be available in the near future.

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