

Real Time Warehouse Pest Control and Management Using WSNs

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Abstract : Insect infestation in warehouse storing grains, groceries and other agricultural products caused by unscientific storage attracts insects, rodents etc affecting the income of farmers adversely. The economic loss is not only measured by the amount of grain consumed by pests but contamination and their excreta nearby storage makes the grain unfit for Human consumption as well. Introducing automation in the pest monitoring decreases damaging of stored grains as manual monitoring of pest is neither effective nor accurate and proper steps can be taken to control these pests. Real time control and Management of infestation from insects and rodents by Wireless Sensor Networks is a invited solution for the future.

Index Terms- Grain Pest, Smart Monitoring, CO₂ Sensor, Sound Sensor, Optical Dust Sensor, Odour Sensor, RH and Temperature sensor, PIR Sensor, NS2.

I. INTRODUCTION

The Problem of feeding to growing human population will never end by huge production of crops, proper storage of crop is equally important. Millions of tons of food-grains are getting damaged due to lack of scientific knowledge. Loss accompanies both quality and quantity of food-grains that are stored either for future consumption or to be used as seed for next cropping season, making it essential to ensure that grain should be protected from any drop either in quality or quantity, [1]. Approximately, between one-quarter and one-third of the world's grain are lost every year during storage because of insect attack including those grains which are not lost completely, but are severely reduced in quality by insect damage. Preferably, pest feeds on outer grain embryos, reducing the protein content of feeded grain and lowering the percentage of seeds which germinate, [2].

1.1. Stored Grain Pests

The worst pests that attacks, consumes and contaminate the stored grain making it unfit for consumption are "Stored Grain Pests", They fall into two main insect orders: Coleoptera (beetles) and Lepidoptera (moths). Within both groups, some species are considered as Primary pest attacking the whole grain, while some are Secondary pests responsible for initial damage of grains, [3], [4].

- *Primary Storage Pest:* They are capable of penetrating and infesting intact kernels of grain, and have immature stages that can readily develop within a kernel of grain. Primary coleopteran pests including Grain weevils (*Sitophilus granarius*, *S. oryzae*, *S. zeamais*), the lesser grain borer (*Rhyzopertha dominica*) and the saw-toothed grain beetle (*Oryzaephilus surinamensis*), Angoumois grain moth (*Sitotroga cerealella*), Khapra beetle (*Trogoderma granarium*) comes under Primary storage pests.
- *Secondary Storage Pest:* They cannot infest whole grain but feeds on broken kernels and grain damaged by primary storage pests. In general, the immature stages of these species are responsible for causing external damage to the grain. It includes the flour beetles (*Tribolium castaneum* and *T.confusum*), Flat grain beetle (*Cryptolestes minutus*).



Fig. 1 : Warehouse

1.2 Rodents

Commensal rodents, such as rats and mice, can enter warehouses through small cracks and holes the size of a quarter (rats) or dime (mice).

Rats-Rats can pose a major health risk to stored grain and human health too. These large rodents are common carriers of a large number of diseases, in addition to carrying other insects, mites, and fleas. Their urine and fecal pellets can contaminate any food or water they come in contact with. If not eradicated, rats can cause severe damage to the structure of the warehouse. Beyond their destructive feeding habits, they enjoy nesting in building structures. Rats will also gnaw on just about anything they can get their paws on: insulation, beams, wires, furniture, air ducts, floorboards, and more.

Mice

Mice are generally much smaller than rats and also do not like to be seen out in the open. Their presence is often made known by the odors, small tracks, chewed furniture, and droppings they leave throughout the house.

II. EXISTING MANAGEMENT OF STORED GRAIN PEST

Following are the few methods for the management of grain pest [5], [6]:

- 2.1) Prestorage Procedure
- 2.2) Protecting Stored Grain
- 2.3) Handling Infested Grain
- 2.4) Fumigation

2.1) Prestorage Procedure: Insect management for stored grain depends on good sanitation. Generally, stored grain infestation develops from few pest present inside or nearby storage bins. So, thoroughly cleaning of bins should be done before harvesting. Cracks in the walls, crevices around door or similar voids is to be treated. Old and new grains should not be mixed. Presence of less foreign materials and a moisture content of 13 % or less is suitable for storage of grains. Reducing the temperature to 60 °F stops insect reproduction and lowering to 50 °F stops feeding of insects.

2.2) Protecting Stored Grain: Applying grain Protectant to the bulk grain as it augured into the storage bin after drying offers protection for one season may considered for more than 6 months. It is effective for both Beetle and Caterpillars. Centynal, Diacon II, diatomaceous earth, pyrethrums, or Storicide II can be used on small grains. Actellic can be used on corn or grain sorghum, but not on small grains. Storicide II gives the protection up to one year, and is effective on all common grain-infesting pests except the lesser grain borer. Pyrethrum has very short residual protection, not suitable for long-term storage. No effective protectant for the lesser grain borer in stored small grains is available. To keep the pesticide barrier intact, do not disturb the grain after treatment. Inspect the grain at monthly intervals frequently.

2.3) Handling Infested Grain: In case, grains are infested, first try to cool it to less than 50 °F, either fed to livestock or discard it if seriously damaged. Only for secondary storage pest, the infested grain can be treated with grain protectant and can be moved to the clean bin. Moving grains is costly, time consuming and needs more space. Also, there is a risk if control measure is not taken properly, movement will spread to nearby grains too.

2.4) Fumigation: Fumigants are the gases that penetrate the grain and kill insects both on and in the grain. They are toxic to man and animals, so should be applied only by trained and experienced operators. It is very sensitive to poor technique causing many failures. Also, it is dangerous and provides no residual protection. Properly conducted fumigation will stop insect infestation and effectively reduce the pest populations. Infested grain that cannot be handled should be fumigated. Aluminum phosphide (such as Phostoxin and Fumitoxin) or magnesium phosphide are the best in many cases. A tightly sealed storage for 5 days are normally required for phosphide fumigation (at least 200 ppm), depending on temperature. Sealing of the bin is very important as adding more than the recommended amount is not making up for a leaky bin. Other fumigation options include ProFume, which requires training and certification from Dow Agro Sciences to apply, and ECO2FUME can be used by certified applicators only. Storicide II, a protectant can be applied after fumigation for residual control.

III. RELATED WORK

Luca Bencini et al., [7] design a system to show the effectiveness to monitor common parameters in heterogeneous network by using simple and cheap sensors consisting WSN technology and TCP-IP protocol. Wireless node sends data to a master node every 15 minutes through a GPRS gateway board. These data are stored in a database and can be queried by anywhere in the world.

Rolando A. Cardenas Tamayo et al. [8], design a decision support system for crop monitoring using WSNs, provide real-time information about the crop status, surrounding environment and potential risks such as pests and diseases. Moreover, an experimental evaluation acceptance model (TAM) based on the technology using the prototype with a group of potential users is carried out for evaluation of a predictive model for pests and diseases. This allowed to gather their perception about usefulness, ease and intention of use, as well as the scope of the predictive model and its reliability.

Lijun Yu et al. [9], developed a wireless sensor network to test and control temperature and humidity of the barn. The variable information is gathered by humidity and temperature sensor and transferring of packets takes place using ZigBee among all the nodes and sent it to PC showing temperature and humidity of the barn in the upper machine. In PC threshold parameters are set before. In case parameter is more corresponding adjustments are made.

JingXia Wang and JianDong Tang [10], designed and implemented a WSN monitoring system for grain depot using XBee/XBee Pro module with integrated wireless RF chip and protocol stack. The design is characterized by simple hardware interface, AT commands and self organized mesh network, can monitor temperature and humidity in the grain depot including data collection, transmission and storage.

A. Togola et al. [11], carried a study to assess the damage caused to rice stored on-farm and evaluate the economic risk. 65 stocks of paddy rice were inspected and sampled followed by an agronomic survey to determine producer perceptions in a farming environment about the economic impact of stored rice pests. The finding shows 5.47 % of loss in the southern region, 1.64 % in the northern region and 4.07 % in the central region in 6 months likely to cause an estimated loss of 21, 315 FCFA (Franc of the African Financial Community) per ton of paddy in the Southern region, compared to losses of 8,088 FCFA in the Northern region. According to Farmers 36.92 % of damage is caused to stored rice.

Qianqian Yuan [12], proposed a design plan based on ZigBee wireless network to provide effective and intelligent storage of food. The design integrates, SCM technology, Computer technology, Sensor technology and wireless communication technology including STC89C52 microcontroller, SHT11 as an integrated temperature and humidity sensor using ZigBee as the data transmission. Each granary consists of humidity and temperature sensor module Host is connected to ZigBee coordinator as the data terminal, forming a ZigBee wireless network together with ZigBee nodes of the field controller. The ZigBee coordinator is connected to RS232 interface through the monitoring host and the status information of each granary passes through the ZigBee network, finally reaches the monitoring host to be displayed. The monitoring host coordinates and controls all processes of the whole system, provides man-machine interface, analyzes, calculates and stores all collected data. The host can also send control command to the whole network, which will be then broadcast by the Zigbee coordinator. Once the command is received, the sensing node will perform corresponding control.

Yun Shi et.al,[13], proposed a disease and insect pest control system based on IOT considering three levels and three systems. The system consists of sensor nodes, communication system, Internet, information service terminal and monitoring software and hardware system, and the system structure .Sensor nodes are laid on targeted farmland areas and collected environmental signals are treated as a source of information. The platform includes administrators ,experts and ordinary visitors, they can login to the remote server and choose to view the real time data, historical data, and remote parameters . These data are analyzed by the agricultural expert.

Storing grain in cylindrical steel silos (bins) equipped with a properly designed aeration system and using grain monitoring sensors (moisture, temperature, headspace condensation, CO₂, phosphine and insect sensors) and automated fan control can maintain optimum grain quality for long periods, [14].

Maier et. al. [15], carried a study to monitor the CO₂ level for early detection of grain spoilage in ground piles or bunkers. Four CO₂ sensors were installed and connected to the master radios that receives signal from the sensors and data transmitted via wireless network to master radio connected to a PC located near 300 m away. at the top near vents and at the base of each tank. The CO₂ levels varies from 500 ppm (0.05 %) to 5,000 ppm and higher levels of up to 2.5 % were recorded . The higher levels of CO₂ were confirmed by the extent of spoilage ranges from 15 to 25 % when maize was moved out from the large tank.

Neethirajan et al. [16], developed a carbon dioxide sensor using polyaniline boronic acid conducting polymer as the electrically conductive region of the sensor demonstrated it for detecting spoilage of stored grain. The developed sensor measures within the range 380- 2400 ppm of CO₂ concentration level. It was evaluated for the temperature (-25 degree C to simulate storage of grains and operates between +10 - 55 degree C) and Relative Humidity ranges from 20-70 % . The developed conducting polymer carbon dioxide sensor results in effective response, recovery time, sensitivity, selectivity, stability and response slope on exposing to various Carbon Dioxide levels inside simulated grain bulk conditions.

Senlin Geng et al., [17], The creeping sound of 20 *Alphitobius diaperinus* Panzer in wheat and 20 *Tribolium castaneum* Herbst adults in corn, are detected with random acoustic source model of the stored grain insects. The original sound signals were reproduced to obtain de-noised signals and the power spectrum analysis are made. This model found to be effective for the insect creeping and detection with discrete power spectrum having highest frequency 1600 Hz. the main frequency in former is 205 Hz and for later main frequency is 350 Hz and highest frequency is 800Hz, this may be used to differentiate different types of insect in stored grains.

Gonzales et. al., [18], examined the adverse storage condition of wheat using Relative Humidity (RH), Temperature and Carbon Dioxide Sensors(CO₂) . A mock up storage bin 6.86m high for wheat was constructed , Sensors were placed at various depth in the storage. CO₂ sensors found to be indirectly effective in detecting moist grain conditions as the large amount of CO₂ generated from the wet grain. CO₂ levels monitored at the exhaust of the aeration duct were generally adequate in determining adverse storage conditions. The equilibrium moisture content (EMC) of wheat, determined from RH and T, gave reasonably accurate measurements of grain MC. EMC measurements also shows effective in determination of moisture changes in the grain due to the moisture front movement from the high moisture grain.

Carlos Cambra et.al, [19], presents the design of a smart IOT communication system for detecting rodents. The system is based on low energy consumption and low cost RF communication microcontrollers. A large number of devices connected in real time are deployed to monitor rodent pests mainly in food industries and agricultural activities. The movements of rodents and the trapping estimation for periodical dates are remotely by accessing to the multimedia platform through mobile phone or via computer. The bandwidth consumed for different configurations as well as the detection of rodents is done by using Passive Infrared (PIR) sensor.

Saeed Azfar, Adnan Nadeem, Abdul Basit, et al, [20], " Pest detection and control techniques using wireless sensor network has surveyed with the following results:-

Pest Control Method

- Pesticides
- Biological

- Natural Chemical
- Genetic
- WSNs

Pest Control Method	Cost	Environment friendly	Human Health	Product quality	Labour saving	effectiveness
Pesticides / Chemical	Low	Low	Low	Low	Low	High
Biological	Medium	High	High	Medium	Medium	Medium
Genetic	Medium	High	High	Medium	Medium	Medium
Integrated Pest Management	High	Medium	Medium	High	High	High
WSNs	Medium	High	High	High	High	Medium

Comparison and analysis of pest control methods encouraged to use WSN for effective pest control in developing countries with affordable cost. Focus in future is to design and implement WSNs test bed for pest monitoring and control system.

IV. PROPOSED REAL TIME PEST CONTROL

4.1 Wireless Sensor Networks

Wireless sensor networks (WSNs) are the most challenging and exciting research areas. A Wireless Sensor Network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions. The WSN is built of nodes ranges from few to several hundreds or even thousands of nodes, each connected to one or several sensors. Each sensor nodes consists of several parts like a microcontroller, radio transceiver, with an internal antenna or connection to an external antenna, an electronic circuit for interfacing with the sensors and an energy source like battery or an embedded form of energy harvesting. Wireless sensors are used in variety of fields which includes military, healthcare, environmental, biological, home, agricultural another commercial applications. With the huge advancement in the sensor technology, WSN are capable of sensing, actuating, and relaying the collected information. This had made are makeable impact everywhere.

4.3 Sensors used in the proposed work :-

- CO₂ Sensor
- Sound Sensor
- Optical Dust Sensor
- Odour Sensor
- RH and Temperature sensor
- PIR Sensor

4.3.1 CO₂ Sensor

K30 10,000ppm CO₂ Sensor-

The **K30** is the most stable, accurate and low-cost NDIR (Non-Dispersive Infra Red) carbon dioxide sensor. An infrared (IR) lamp directs waves of light through a tube filled with air toward an IR light detector, that measures the amount of IR light hitting it. As the light passes through the tube, gas molecules that are the same size as the wavelength absorb the IR light only, while letting other wavelengths. Remaining light hits an optical filter that absorbs every wavelength of light except the exact wavelength absorbed by CO₂. Finally, an IR detector reads the amount of light that was not absorbed by the CO₂ molecules or the optical filter. The difference between the amount of light radiated by the IR lamp and the amount of IR light received by the detector is measured that is proportional to the number of CO₂ molecules in the air inside the tube.

While growing, respiring moulds and insects produce CO₂, moisture and heat. Temperature sensors activate caused by mould growth or insect infestation indicating the presence of grain spoilage. **K30** sensors detects moulds and insects during respiration as CO₂ moves with air currents during infestation. Safe grain storage usually results in CO₂ concentrations below 600 ppm, while concentrations of above 600 indicate the onset of mould grain growth and above 1500 ppm indicates severe infestations.

4.3.2 Sound Sensor

Sound Sensor (RKI 1303)

The sound sensor module provides an easy way to detect sound and is generally used for detecting sound intensity. This module can be used for security, switch and monitoring applications, accuracy can be easily adjusted for the convenience of usage. It uses a microphone which supplies the input to an amplifier, peak detector and buffer. As the sensor detects a sound, it processes an output signal voltage which is sent to a microcontroller then performs necessary processing. It works by monitoring the noise level of all Pests and Rodents as they make some noise. In case the noise level of the pest crosses the threshold, a sensor transmits that information to authorized system for accurately indicating the infestation area, helps to detect infestation at a very early stage, thus greatly reducing grain damage.

4.3.3 Optical Dust Sensor

GP2Y1010AU0F specifications are suitable for the proposed research work is a dust sensor using optical sensing system. An infrared emitting diode (IRED) and an phototransistor are diagonally arranged into this device effectively detects the reflected

light of. very fine particle dust in air in the form of pulse pattern of output voltage. The value of dust density for detection is a value of the density of dust measured by digital dust monitor

Pests feed on stored grain causes dust particles in the warehouse and movement of rodents leave traces of dust particles behind. An infrared emitting diode and a phototransistor are diagonally arranged into this device, to detect the reflected light of dust in air.

4.3.4 Odour Sensor

VOC sensor (MQ138 gas sensors)

Organic chemicals that are present in the gaseous phase at room temperature are Volatile Organic Compounds(VOCs), covers a wide range of chemical compounds including both naturally occurring or manmade. Although, VOCs are usually not acutely toxic but they often cause long-term health effects from continuous low level exposure. MQ138 sensors is used here .

MQ 138

Sensing Material of MQ138 gas sensor is SnO_2 . when VOC gas exists, the sensor's conductivity gets higher along with the Gas concentration rising. Users can convert the change of conductivity to correspond output signal of gas concentration through a simple circuit. Detection Range: 5-500 ppm.

Application

They are used in Breath alcohol detector, solvent detectors ,Air quality control equipments for buildings/offices, are suitable for detecting of n-Hexane, Benzene, NH_3 , alcohol, smoke, CO, etc.

Features

Wide detecting scope, Fast response and High sensitivity, Stable and long life, Simple drive circuit.

The spoiled stored grain products emits several volatile gases, that can be detected by VOC sensor , in case exceeding the threshold value.

4.3.5 RH and Temperature Sensor

A humidity sensor or hygrometer senses, measures and reports both moisture and air temperature. The ratio of moisture in the air to the highest amount of moisture at a particular air temperature is called relative humidity an important factor for comfort.

DHT11

The DHT11 is a basic, ultra low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). It's fairly simple to use, but requires careful timing to grab data. The only real downside of this sensor is you can only get new data from it once every 2 seconds.

Temperatures below 60°F prevent insect activities, while higher temperatures allow for increased insect growth and breeding. Relative humidity (RH) is an indirect way to measure the moisture content of grain based on equilibrium moisture content (EMC) equations predict the grain moisture content with higher accuracy

4.3.6 PIR sensor

PIR sensor detects an object moving within 10m from the sensor approximately. This is an average value, as the actual detection range is between 5m and 12m. PIR are fundamentally made of a pyroelectric sensor, that detects the level of infrared radiation.

The Passive Infrared Sensor (PIR) sensor module is used for motion detection referred as "PIR", "Pyroelectric", "Passive Infrared" and "IR Motion" sensor. The module has an on-board pyroelectric sensor, conditioning circuitry and a dome shaped Fresnel lens used to sense movement of people, animals or other objects.

PIR sensors are effective for detecting rodents. In case both slots detect the same amount of IR the sensor is idle, the ambient IR radiated from the room or walls or outdoors first intercepts one half of the PIR sensor, that causes a positive differential change between the two halves. In case, warm body leaves the sensing area, the reverse happens generating a negative differential change.

Specifications:

- Voltage: 5V – 20V
- Power Consumption: 65mA
- TTL output: 3.3V, 0V
- Delay time: Adjustable (.3->5min)
- Lock time: 0.2 sec
- Trigger methods: L – disable repeat trigger, H enable repeat trigger
- Sensing range: less than 120 degree, within 7 meters
- Temperature: – 15 ~ +70
- Dimension: 32*24 mm, distance between screw 28mm, M2, Lens dimension in diameter: 23mm

4.2 Ad hoc On-Demand Distance Vector (AODV) protocol

AODV is an On-Demand protocol capable of providing unicast, multicast, and broadcast communication. AODV allow users to find and maintain routes to other users in the network whenever such routes are required. The number of hops is counted by the source node for the data packets to be sent through each node and flooding its neighbor nodes with route requests acknowledged and forwarded to their neighbor nodes by creating temporary paths between them. Immediately after receiving an acknowledgement from the destination, the source node established a path between the source and the destination with the minimum number of hops. The route request sent to each node contains a number sequence used to identify the data being sent out and in case it is necessary to resend, it is useful in multiple ways. In case the same data has to be sent, only the sequence number needs to be sent to the node which in turn will resend the data identified by the sequence. In addition, each request has a

certain lifetime or time to live which defines the maximum number of times a data packet can be resent until it expires, it also helps in removing temporary paths that was created at the start of transmission.

4.4 Proposed Block Diagram

A warehouse is considered equipped with sensor unit consisting CO₂ sensor, Sound sensor, Optical Dust sensor, Odour Sensor, Relative Humidity (RH) sensor and Temperature sensor. All sensors unit are connected to the Central Pest Monitoring System(CPMS). A threshold value is set for the real time monitoring of pests depending upon different characteristics of pest and environmental condition dynamically. In case the presence of pests is sensed, alarm is raised by the Central Pest Monitoring system(CPMS) to take further action to control pest in warehouse.

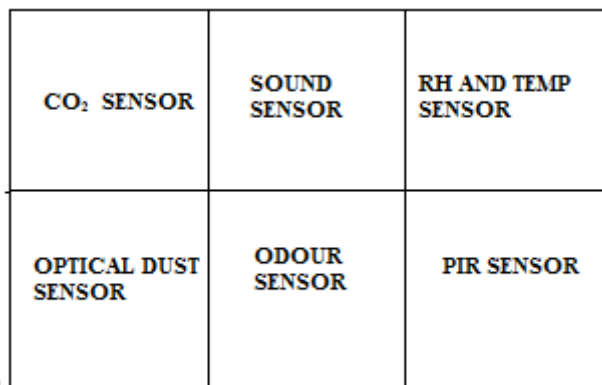


Fig. 2 : Sensor Unit

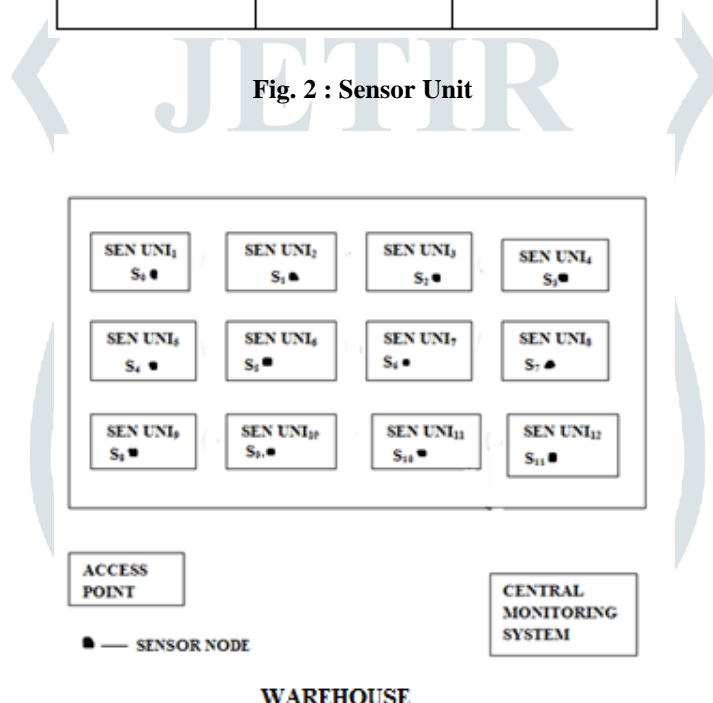


Fig.3 :- Block diagram depicting the Pest identification in Warehouse using WSNs.

Sensor Units are deployed in the warehouse as shown in the above block diagram. Each block belongs to different types of stored grain are equipped with sensors unit consisting of CO₂, Sound, Optical Dust, RH and Temperature Sensor connected to CPMS through Wireless Sensors Network from the access point using AODV protocol for communication.

Different stored grains and products considered in this research:

STORED GRAINS		PRODUCTS
A	-----	Wheat
B	-----	Rice
C	-----	Maize
D	-----	Suji
E	-----	Lentils
F	-----	Maize
G	-----	Barley
H	-----	Oats
I	-----	Peanuts
J	-----	Chickpeas
K	-----	Soyabeans
L	-----	Beans

V. FLOW CHART

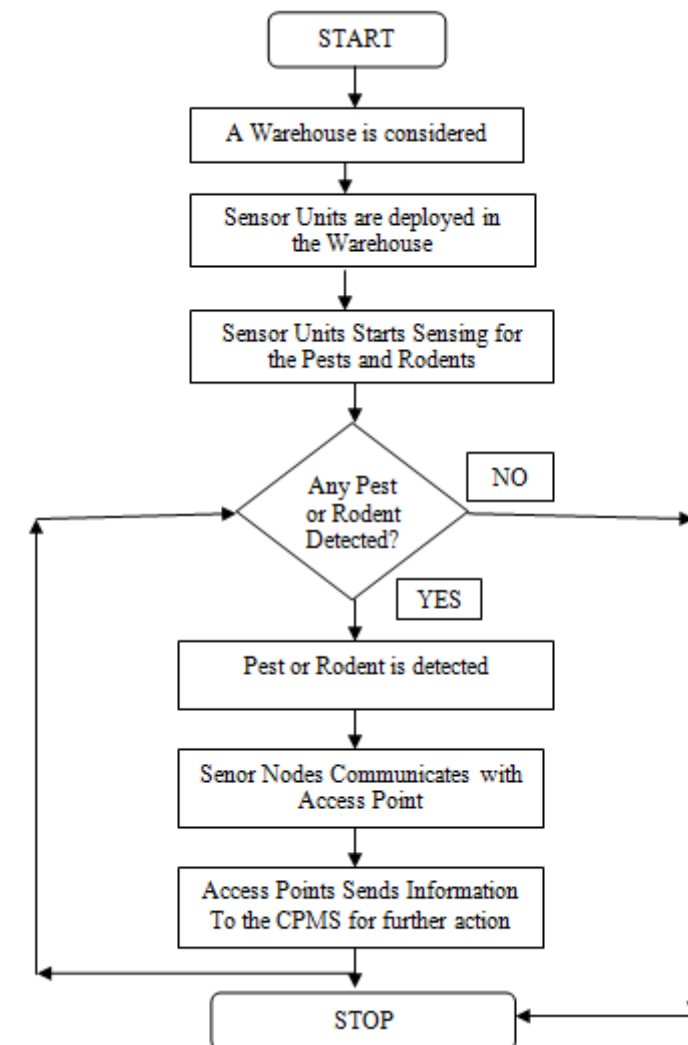


Fig:- Flow Chart for the Proposed work

VI. SIMULATION AND RESULTS

The proposed method is implemented using NS2 (network simulator) software. NS or the network simulator (also popularly called NS2) is an open source discrete event network simulator. NS2 has continuously gained tremendous interest from industry, academia, and government. NS is used in the simulation of routing protocols others and is heavily employed in ad-hoc networking research. NS2 supports popular network protocols, offering simulation results for wired and wireless networks alike.

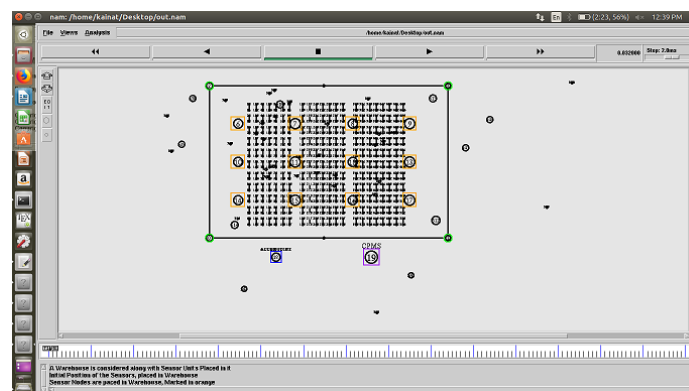


Fig. :6.1

Initial condition of the Warehouse: Warehouse containing stored Grains is considered. Sensor Units are deployed marked in Orange and Hexagon in shape. Inactive Pests and Rodents are Black initially. Access Points connecting all the sensor units consisting of different sensors are in Blue and the Central Pest Monitoring System (CPMS) is marked in Purple, Fig 6.1.

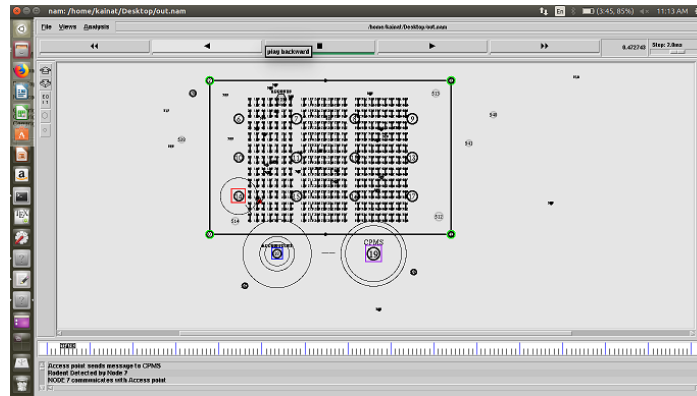


Fig. 6.2

An active pest marked in Red is detected at sensor unit 14. Sensor Unit communicates with access points to transmit the presence of Pest to the CPMS, Fig. 6.2.

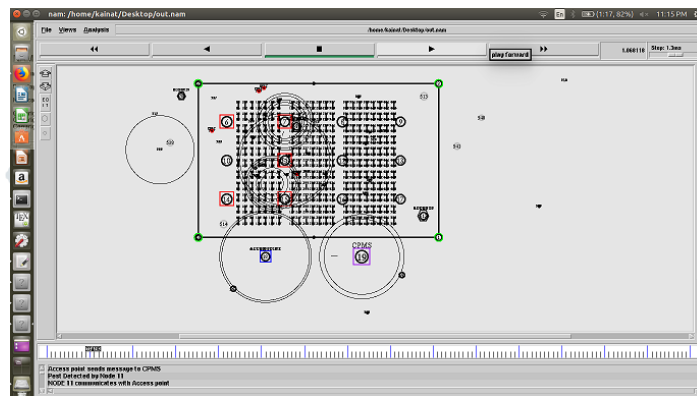


Fig. 6.3

Pest and Rodents are detected at SU 6, 7, 11,14,15. Sensor Units detecting the pest are Red , Communicates with Access points to transmits the presence of Pest to the CPMS, Fig. 6.3.

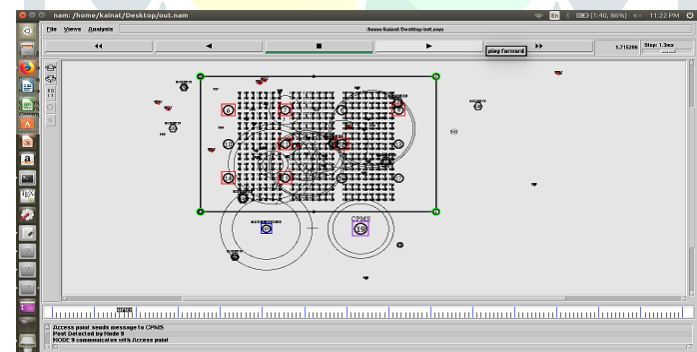


Fig. 6.4

Pest and Rodent are detected at Sensor Units 6, 7, 9, 11, 12, 14 and 15. Sensor Units detecting the pest are Red , Communicates with Access points to transmits his presence of Pest to the CPMS, Fig. 6.4.

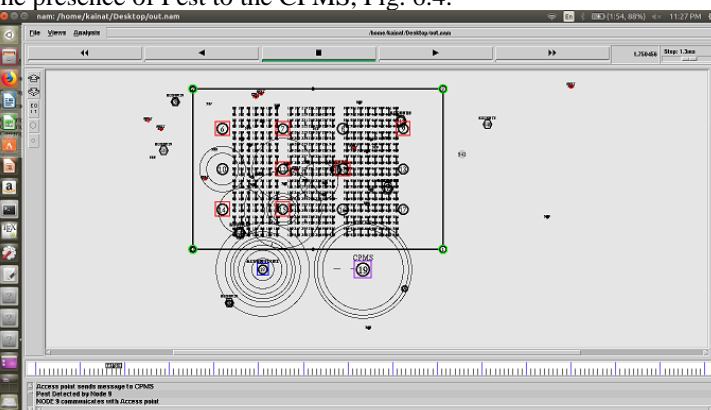


Fig. 6.5

Pest from outside are attracted towards the Warehouse. Sensor Unit 6, 7, 9, 11, 12, 14 and 15 detects the presence of Pests and Rodent , communication with access point, Fig. 6.5.

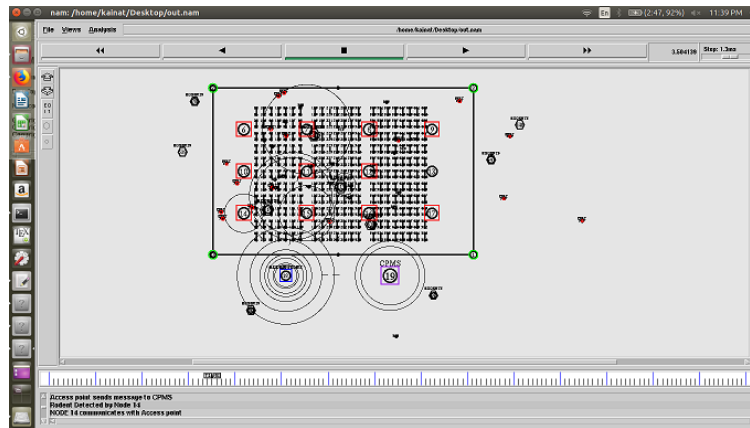


Fig 6.6

Pest detected at Sensor Unit 6, 8, 9, 10, 14 and 15. Rodents detected at Sensor Unit 7, 11,12, 14 and 16. Communication Between Sensor Units and access points are visible. Access points sends further message to CPMS, Fig. 6.6.

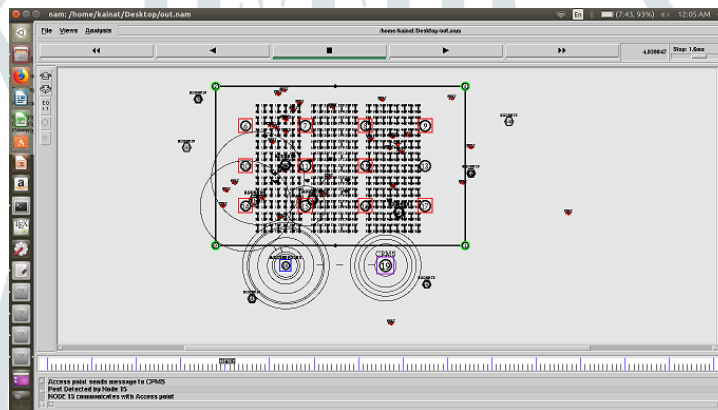


Fig.6.7

Maximum Pest Detected at Sensor Unit 7. Also, SU 14 detects both Rodent and Pest at the same time. Communication Between Sensor Units and access points are visible, Fig. 6.7.

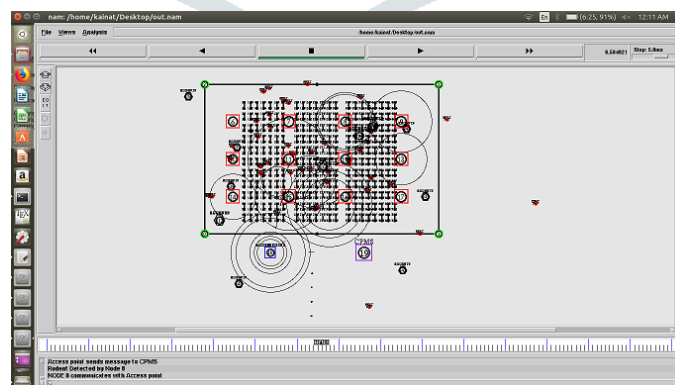


Fig. 6.8

Maximum pest and rodent entered the warehouse, Communication Between Sensor Units and access points are visible, Fig. 6.8.

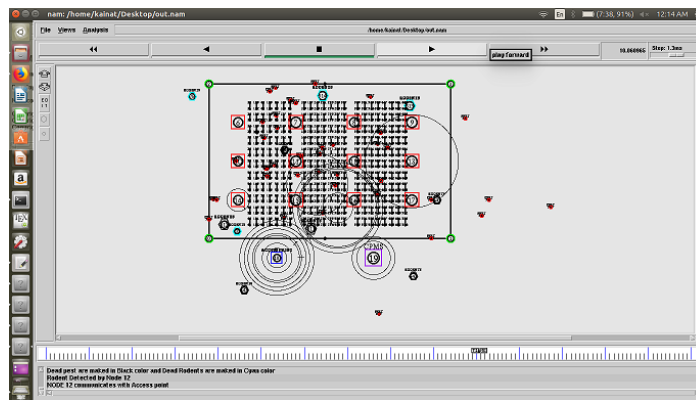


Fig. 6.9

Few Pest and rodent died after completing their life cycle. Dead pests are marked in black and Dead rodents are marked in Cyan, Fig. 6.9.

VII. CONCLUSION

After Comparing and analysing all the existing methods for pest detection, WSNs found to be the most effective, economical, environment friendly and accurate as it provides the data in real time.

A warehouse has been monitored for the presence of pest with CO₂ Sensor, Sound Sensor, Optical Dust Sensor, Odour Sensor, RH and Temperature sensor and PIR sensors. Sensors are deployed as shown in the block diagram for monitoring pests and rodents. The information got by these sensors are used for management of these pests to control the population of pest and insect growth. The sensors together gives the best results for instant identification of pests by categorizing them in their specific genera. Faster the identification of pests, faster is the remedy taken. Thus the pest control in warehouses is implemented.

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