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Detecting the Boundary Area of Gas Diffusion in Wireless Sensor Networks

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Abstract: - **Petrochemical plants convert natural resources such as crude oil, natural gas, ores and minerals into products for a wide range of applications. They produce many important building blocks for industrial processes, including ethylene, propylene, butadiene, and aromatics. Detecting and visualizing the dangerous area of leaking toxic gases is important for large-scale petrochemical plants. There are many kinds of toxic gases in petrochemical plants, e.g., sulfuretted hydrogen (H2S), hydrogen chloride (HCl), and sulfur dioxide (SO2). Once these toxic gases leak, they can cause an explosion that results in serious economic loss. The existing system uses planarization algorithm to planarize a WSN and based on the planarized network, the boundary area of gas diffusion is calculated to delimitate the dangerous area. However, when all of the nodes are in the working state at the same area, the probability of the interference, collision, and congestion in the network will increase during the process of transmitting data. Moreover, multiple nodes covering an interested area will result in the emergence of redundant information. In order to avoid this ant colony optimization algorithm with adhoc on demand multicast distance vector routing protocol is used to find the amount of gas diffusion and dangerous area. Also, this protocol will send the alert message to controller of the monitoring area. The simulations are done performed using network simulator the parameter such as node density, probability of gas diffusion, throughput, energy consumed and packetloss is analyzed.**

Index Terms— **Leakage detection, continuous object detection,wireless sensor networks.**

I. INTRODUCTION

A Wireless sensor network can be defined as a network of devices that can communicate the information gathered from a monitored field through wireless links. The WSN is built with nodes that are used to observe the surroundings like temperature, humidity, pressure, position, vibration, sound etc. These nodes can be used in various real-time applications to perform various tasks like smart detecting, a discovery of neighbor node, data processing and storage, data collection, target tracking, monitor and controlling, synchronization, node localization, and effective routing between the base station and nodes. WSN monitoring provides continuous and near real-time data acquisition and autonomous data acquisition (no supervisionis required); increased frequency of monitoring compared with manual inspection; improved data accessibility, data management,and data use compared with non-networked systems as all data can be collected and processed centrally; the ability to combine data from a wide variety of sensors; intelligent analysis of data to "predict and prevent" events using intelligent algorithms; the ability to turn data into information about the status of important structures, infrastructure and machinery;and, a global data view that allows trending information to be determined where degradation is happening slowly over a relatively long period of time. In WSN detecting and visualizing the dangerous area of leaking toxic gases is important for large-scale petrochemical plants.There are many kinds of toxic gases in petrochemical plants,e.g., sulfuretted hydrogen (H2S), hydrogen chloride (HCl), and sulfur dioxide (SO2). Once these toxic gases leak, they can cause an explosion that results in serious economic loss.For example, if the SINOPEC Maoming Petrochemical Company stops producing for one day, the economic loss is almost 10,000,000 RMB 1. Explosions also seriously threaten the lives and safety of local citizens who are living around the leakage [1] Independent two hundred sensor nodes are randomly deployed in a 600_600m2 area to detect toxic gases, and scattered concentration reports are provided by these nodes. The continuous and invisible boundary which encloses a dangerous area is difficult to be detected. Fig.1,describe about the system diagram of gas leakage boundary area detection in WSN.First the network is deployed with H2S, HCL, SO2 gas sensor. Neighbor information is transmitted between each sensor nodes. The gas diffusion level is detected using ACO. After that boundary of gas diffusion area is calculated and the emergency message is transferred using enhanced ACO based AOMDV. After that the performance is evaluated

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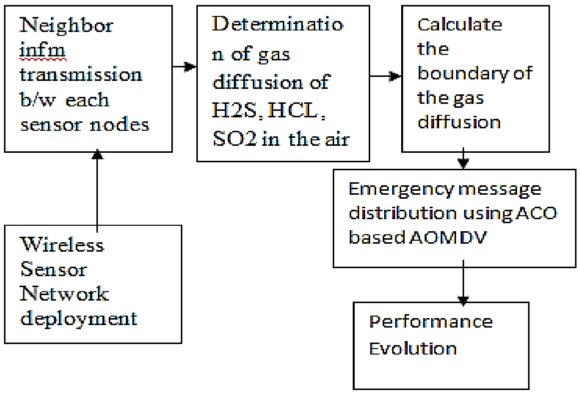

Fig.1 System Diagram Of Gas Leakage Boundary Area

and compared with existing technologies.The existing system uses planarization algorithm to planarize a WSN and based on the planarized network, the boundary area of gas diffusion is calculated to delimitate the dangerous area. However, when all of the nodes are in the working state at the same area, the probability of the interference, collision, and congestion in the network will increase during the process of transmitting data. Moreover, multiple nodes covering an interested area will result in the emergence of redundant information. In order to avoid this ant colony optimization algorithm with adhoc on demand multicast distance vector routing protocol is used to find the amount of gas diffusion and dangerous area. Also this protocol will send the alert message to controller of the monitoring area. Networked monitoring is necessary to cover the continuous area of toxic gas diffusion, and the continuous area is referred to as the dangerous area in this work. Wireless Sensor Networks (WSNs) [4], [5], [6] can be used to achieve the networking and concentration sensing [7]. Such networks use spatially distributed autonomous sensors to monitor physical or environmental condition. This study shows how a WSN detects and visualizes the dangerous area. The detection and visualization of the dangerous area provide for the visual management of gas diffusion.The scientific contributions of this paper are listed asfollows:

1) A detection scheme is proposed to detect the dangerous area of leaking toxic gases. This scheme utilizes Ant Colony Optimization (ACO) with Adhoc On Demand Multicast Distance Vector (AODMV)routing protocol ,which is helpful to is used to find the amount of gas diffusion and dangerous area.Also this protocol will send the alert message to controller of the monitoring area.

2) The impact of aco and aomdv is clearly shown by comparing the accuracy in detecting a dangerous area.

3) The calculated size of a dangerous area varies depending on the different node failure percentages.

The sections are organized as follows. Section II describes the related work on the gas boundary detection. Section III introduces the network model and planarization. Section IV provides the detection scheme to detect the dangerous area of leaking toxic gases. Section V provides the evaluation results and the corresponding analyses. Section VI discusses more related work about planarized graphs and system model parameters

in regards to the area detection. Finally, Section VII concludes this paper.

II. RELATED WORK

Many methods have been proposed to detect continuous objects with WSNs [8].Ji et al. proposed the concept of boundary nodes and used such nodes to detect the 1-hop neighboring objects [9] in their algorithm Dynamic Cluster Structure for Object Detection and Tracking (DCSODT). The boundary nodes were divided into several clusters to reduce the communication cost. The Cluster Heads (CHs) sent the locally-estimated boundary information to a sink node. Hussan et al. [10] used collaborative boundary detection to track continuous objects. This type of detection located the boundary nodes through the local communication between the sensor nodes in order to reduce the communication cost.There were a series of improvements made in the detection accuracy. Luan et al. proposed a Ring-based Continuous Object Tracking (RCOT) scheme [11], which used sensor nodes as a ring to detect objects and calculate the boundary of gas diffusion to improve the accuracy of detection. This scheme improved the accuracy of the target detection using ring-based continuous detection. Park et al. used a 2-tier network structure to improve the detection accuracy [12], [13]. First, a sparse network was used to detect objects. Then, this sparse network was transformed into a dense network to improve the accuracy in the calculation of the boundary locations. There has also been some research on the special application of detecting the boundary of continuous objects. Charim et al.proposed a distributed approach to detect gas diffusion in large industrial spaces [14]. In this approach, many sensor nodes were deployed around a specified area and these sensor nodes reported the sensed information to a data center.The above-mentioned approaches only used scattered concentration reports from distributed sensor nodes.Because of the gradient change in the gas concentration in a gas boundary detection application, detecting a boundary area is more useful than detecting the edge of a boundary. In this kind of area detection, scattered concentration reports are not sufficient. Networked detection is necessary: the nodes of a WSN are connected to each other to detect a boundary area and this boundary area is bounded by some connected sensor nodes. Shu et al. recently proposed a detection algorithm to detect the boundary area of gas diffusion called DeGas [15].The

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Vol 4, Issue 12, December 2017

above-mentioned research did not consider realistic situations.For example, in a real WSN, node failure is a common problem. The failure nodes heavily affect data reading, data submission, and the connectivity of the network. Ding et al.developed a detection algorithm to detect continuous objects in the network with failure nodes [16].Based on the above review, it is necessary to develop a networked detection system for toxic gas detection applications.This system detects a boundary area instead of the edge of the boundary. The node failure needs to be taken into consideration since it is common in a real WSN.This research is an extension of the work done by Shu [15];the dangerous area of the leaking toxic gases was detected and visualized by a detection algorithm and the size of the dangerous area was calculated. The dangerous area consists of the inner area and the outer boundary area of the gas diffusion.

III. SYSTEM MODEL

A. Network Model

A sensor networks are used to monitoring network for the toxic gases, where S = {s1, s2, …….. , sn}, where n is the number of sensor nodes, si denotes the senor node with ID = i. The communication radius is R for each sensor node.The nodes are deployed at randomly with an area 1500 x 1500. Here 60 nodes are deployed to detect toxic gases, and there are no failure nodes.This network is formed to monitoring the environment about gas diffusion in air. All of these nodes are active and connected with each other to construct a monitoring network.Because the communication between two nodes depends on the distance between these two nodes,it is possible that one node is able to communicate with more than one other nodes. Here three sensors are considered which are sulphur dioxide, hydrogen sulphide and hydrogen chloride sensor with the colors orange, brown and blue respectively.Initially these three gases node broadcasts its information to its 1-hop neighbours.

B. Gas Diffusion Model

The diffusion of a certain kind of gas was modeled as an increscent circle, and the center of the circle was the source of the gas leak. The influence of the environmental factors, such as wind, airflow, and air pressure, on gas diffusion was not taken into consideration. In this diffusion model, there were nobvious distinctions between the 2 different gases; these gases had different rates of diffusion, ability to cause explosions,and levels of threat to the environmental and public health.However, in this study, the target of the toxic gas detection was only the dangerous area of the gas diffusion.The connectivity of the network that was used in detecting the gas diffusion required the deployment of a sufficient number of sensor nodes.

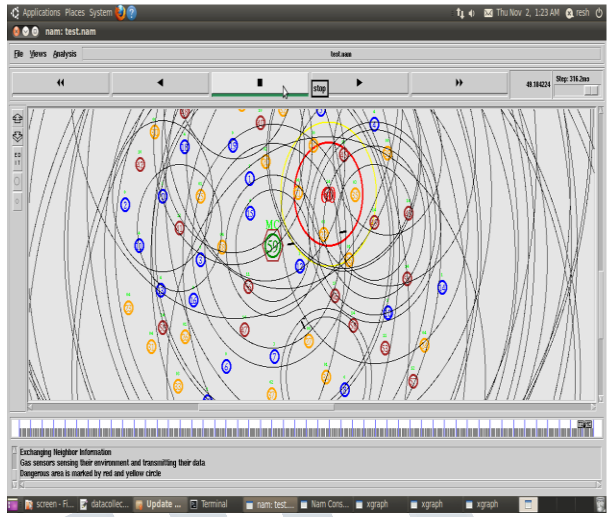

Fig.2 Dangerous Area Of Gas Diffusion With Boundary

Fig.2 shows that dangerous area of gas diffusion model.The gas sensor sensing their environment and transmitting their data to the control unit. The dangerous area is detected and marked as yellow and red circle. The yellow and red circle surrounded area is very dangerous.The red circle is the inner boundary area which is considered to be as dangerous. All of the outer boundary nodes are connected to each other to construct the inner boundary loop The yellow circle is the outer boundary area and it receives a information from 1-hop neighbour nodes.If atleast 1 of its1-hop neighbor nodes has detected toxic gases,it is an outer boundary node.All of the outer boundary nodes are connected to each other to construct the outer boundary loop.

C.Algorithm:

DANGEROUSGAS DETECTION ALGORITHM

Step 1 : Initialization
Notations:
N = Total number of nodes
X_i= x-coordinate of the ith Node
Y_i= y- coordinate of the ith Node
Step 2: Calculation of neighbor list
1. Begin
2. For i= 1 : N Then
3. Dist() calculate distance
4. End
5. If dist < Range of Node
6. N_x = N
7. Where, N_x R is adding node in neighbor set
8. End
9. End
Step 3: Broadcast the Route Request messages.
Notations:

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Vol 4, Issue 12, December 2017

N = Set of neighbor nodes
T initial = 0; initial time
1. Begin
2. For i = 1 : N Then
3. Start clock
4. For j = 1 : N
5. Broadcast(); Node j
6. Node i //Node i send route request message to Node j
7. End
8. End
Step 4: Route Reply Algorithm
Notations: N_R = Nodes which received Route Request
1. Begin
2. For i = 1 : N_R
3. For j = 1 : N
4. If N_j == destination
5. #any Node has route to destination
6. Reply()
7. End
8. End
9. End
10. Stop time

Route Reply

Notations: T_R = Set of time values taken to receive Reply
G= Gas Diffusion value of sensor nodes such as HCl, H_2S, So_2
1. Begin
2. For i = 1 :T_R and check the sensed value
3. If T_R > Threshold
4. Forward the data
5. If r>25 then Marked as Dangerous area
6. End
7. End

IV. GAS LEAKAGE DETECTION SCHEME

The steps for detecting and calculating the dangerous area of leaking toxic gases are listed as follows

- Network deployment
- Neighbor Information transmission between nodes
- Environment monitoring using gas sensor (H2S,HCL,SO2)
- Prioritize based data transmission using ACO based AOMDV algorithm
- Performance evaluation

Network Deployment

A sensor networks are used to monitoring network for the toxic gases, where S = {s1, s2, …….. , sn}, where n is the number of sensor nodes, si denotes the senor node with ID = i. The communication radius is R for each sensor node. Each sensor node broadcasts its own information to its 1-hop neighbors. Here three gases are considered such as sulfuretted hydrogen (H2S), hydrogen chloride (HCl) and sulfur dioxide (SO2). All of these nodes are active and connected with each other to construct a monitoring network. Because the communication between two nodes depends on the distance between these two nodes, it is possible that one node is able to communicate with more than one other nodes, which makes the topology of the network be not planar.

Neighbour Information transmission between nodes

Each sensor node broadcasts its information to its 1-hop neighbors. The broadcast information includes the node ID, node coordinates, and a status. The broadcast information includes the node ID, node coordinates, and a status indicator to indicate whether a node detects toxic gases. Therefore the neighbor nodes should exchange any gas detection emergency messages and pass it to monitoring center.

Environment monitoring using gas sensor (H2S, HCL, SO2)

The gas sensor detectors such as H2S, So2 and HCl are used to monitoring the environment. Hydrogen sulfide is a colorless, flammable, extremely hazardous gas with a “rotten egg” smell. It occurs naturally in crude petroleum and natural gas, and can be produced by the breakdown of organic matter and human/ animal wastes (e.g., sewage). It is heavier than air and can collect in low-lying and enclosed, poorly ventilated areas such as basements, manholes, sewer lines and underground telephone/electrical vaults. If gas is present, the space should be ventilated. If the gas cannot be removed, use appropriate respiratory protection and any other necessary personal protective equipment (PPE), rescue and communication equipment. Atmospheres containing high concentrations (greater than 100 ppm) are considered immediately dangerous to life and health (IDLH) and a self contained breathing apparatus (SCBA) is required.

- **Low concentrations** – irritation of eyes, nose, throat, or respiratory system; effects can be delayed.
- **Moderate concentrations** – more severe eye and respiratory effects, headache, dizziness, nausea, coughing, vomiting and difficulty breathing.
- **High concentrations** – shock, convulsions, unable to breathe, coma, death; effects can be extremely rapid (within a few breaths).

Hydrogen Chloride is a colorless to slight yellow corrosive gas with a pungent irritating odor. Although not considered a combustible gas, it may react or form combustible compounds when contact is made with alcohol and hydrogen cyanide or with aluminum-titanium alloys. Dissolving Hydrogen Chloride in water will yield a strong highly corrosive acid. It is for this reason that HCl is a strong irritant to the eyes, nose, and upper respiratory tract. Levels of 35 ppm can cause irritation to the throat even after a very short period of time.

Table.I HCL Level and Human condition

Hydrogen Chloride Level in PPM	Resulting Conditions on Humans
.25	Odor threshold.
5	Permissible Exposure Limit (PEL).
35	Irritation to the eyes, nose, throat even after a short period of time.
50	Immediately Dangerous to Life and Health (IDLH).
1,300-2,000	Death in 2-3 minutes.

Sulfur dioxide (SO2) is a colorless, extremely toxic gas with a strong odor. Common applications of sulfur dioxide include sulfuric acid production, pulp and paper mills, chemical processing, food and beverage, coking operations and petroleum refineries. Since coal and petroleum often contain sulfur compounds, their combustion will generate SO2 unless the sulfur compounds are removed before the fuel is burned.

Table.II SO2Level and Human condition

Sulfur Oxide Level in PPM	Resulting Conditions on Humans
.3-1	Sulfur Dioxide initially detected by taste.
5	Permissible Exposure Level (OSHA).
3	Odor becomes easily detected.
6-12	Irritation of the nose and throat.
20	Irritation of the eyes.
50-100	Maximum exposure for a 30 minute period.
400-500	Dangerous concentration can cause edema of the lungs and glottis and death from prolonged exposure.

Prioritize based data transmission using ACO based AOMDV algorithm

If there is any gas level will be detected from the above step as dangerous level means the gas detectors will send the emergency message to monitoring center. Which gas level will be dangerous that data will be send first using priority based data transmission. The gas diffusion level is optimized and transferred by ACO based AOMDV protocol. The diffusion of a certain kind of gas was modeled as an increscent circle, and the center of the circle was the source of the gas leak. The influence of the environmental factors, such as wind, airflow, and air pressure, on gas diffusion was not taken into consideration. In this diffusion model, there were no obvious distinctions between the 2 different gases; these gases had different rates of diffusion, ability to cause explosions, and levels of threat to the environmental and public health. However, in this study, the target of the toxic gas detection was only the dangerous area of the gas diffusion. The connectivity of the network that was used in detecting the gas diffusion required the deployment of a sufficient number of sensor nodes. In this network, the nodes were fully connected with each other to detect the dangerous area of the gas diffusion. When a source node S wants to find a route to a destination node D, it checks in the Routing table whether the route to the Destination is already available. If there is no previous route to the destination then the Source broadcasts a RREQ packet to the neigh boring nodes. when a RREQ packet arrives at an intermediate node, RREQ is scanned; if the destination address of the RREQ is same as address of intermediate node then the intermediate node acts as destination node to send route reply else it rebroad cast the RREQ The destination node or any other node that has a valid route to the destination now replies to the RREQ.. The K-level shortest path algorithm is used to discover the entire shortest path among the disjoint links. The stored routes in the routing table are sorted based on the shortest communication cost.

V.PERFORMANCE EVALUTION

A.Simulation Set-up

NS2 was used to conduct the simulation. The nodes are deployed at randomly with an area 1500 x 1500. Here 60 nodes are deployed to detect toxic gases, and there are no failure nodes.This network is formed to monitoring the environment about gas diffusion in air. These assumptions were used in this simulation: the gas diffusion was an ideal circle, the radius was changed from 60 m to 90 m (the pace was 5 m),and the leakage source of the gas was located in the center of the circle.

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 4, Issue 12, December 2017

B. Dangerous Area Detection and Node Failure

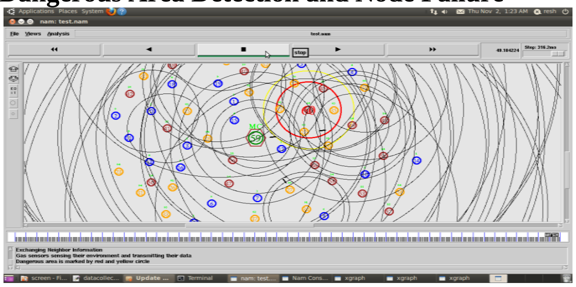

Fig.3 Dangerous Area Detection and Node Failure

In a real monitoring scenario, the failure of the monitoring nodes is a common problem due to the nodes' energy and performance issues. .The dangerous area is detected and marked as yellow and red circle. The yellow and red circle surrounded area is very dangerous.The red circle is the inner boundary area which is considered to be as dangerous. All of the outer boundary nodes are connected to each other to construct the inner boundary loop The yellow circle is the outer boundary area and it receives a information from 1-hop neighbour nodes.If atleast 1 of its1-hop neighbor nodes has detected toxic gases,it is an outer boundary node.All of the outer boundary nodes are connected to each other to construct the outer boundary loop.

Table.III Values of Simulation Parameter

Parameters	Values
Network Size	1500 x 1500
Number of nodes	10,20,30,40,50,60
Gas radius	40m,50m,60m
Node transmission radius	40m

C. Performance Evaluation

A performance comparison of the scheme for detecting the dangerous area was conducted for 3 cases:i)Delay ii)Node vs Dangerous area iii) Radius of gas diffusion vs Dangerous Area

i)Delay

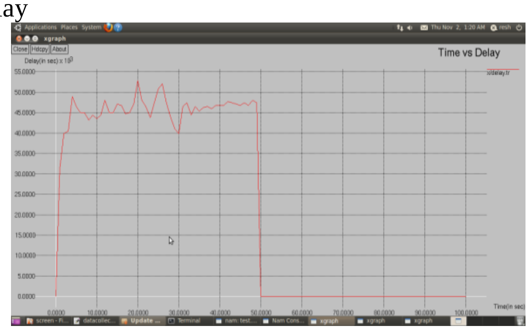

Fig.4 Delay

Delay graph compares the time and the delay in the Wireless Sensor Networks. This delay graph in the Wireless Sensor Networks consists of x-axis and y-axis. The x-axis in the Wireless Sensor Networks represents the time in seconds and y-axis in the Wireless Sensor Networks represents the delay in seconds. Delay represents the time taken for data transmission to reach the monitoring centre in the Wireless Sensor Networks. The delay has to be plotted as a xy graph in the Wireless Sensor Networks. The time is to be measured as in seconds and also the delay is to be measured in seconds in the Wireless Sensor Network

ii) Radius versus Dangerous area

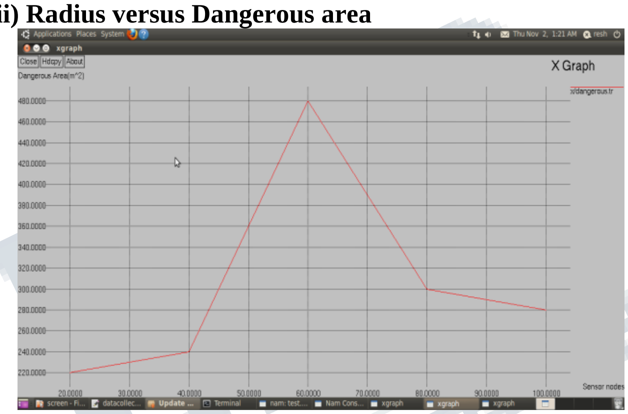

Fig.5 Radius versus Dangerous area

Fig 5 shows that radius versus dangerous area in the Wireless Senso Networks. This graph compares the time and the delay in the Wireless Sensor Networks. This X graph in the Wireless Sensor Networks consists of x-axis and y-axis. The x-axis in the Wireless Sensor Networks represents the radius and y-axis in the Wireless Sensor Networks represents the dangerous area. The dangerous area is represented as radius in the Wireless Sensor Networks. This graph shows that the increases of radius will increases the dangerous area of monitoring network in the Wireless Sensor Networks

iii) Sensor nodes versus dangerous area

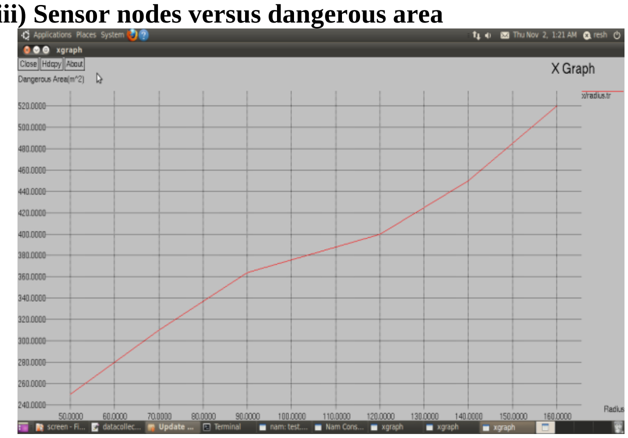

Fig.6 Sensor nodes versus dangerous area

Fig 6 shows that sensor nodes versus dangerous area in the Wireless Sensor Networks. This X graph in the Wireless Sensor Networks consists of x-axis and y-axis. The x-axis in the Wireless Sensor Networks represents the sensor nodes and y-axis in the Wireless Sensor Networks represents the dangerous area. The sensor nodes here we are considering is 60 to 100 nodes in this Wireless Sensor Networks. The dangerous area is plotted with respect to number of sensor nodes in the Wireless Sensor Networks.

VI CONCLUSION

Continuous target real-time detection has attracted significant attention in the Wireless Sensor Networks. Toxic gas is a kind of continuous object and it is invisible. Its boundary is very hard to be accurately detected. The dangerous area consists of the inner area and outer boundary area of the leaking gases in the Wireless Sensor Networks. In proposed Ant Colony Optimization with adhoc on demand multicast distance vector routing protocol is used to detect the leakage area of gas in WSN. The simulations are done performed using network simulator the parameter such as node density, probability of gas diffusion, throughput, and energy consumed and packet loss is analyzed. The future work of this study will be implementation of the system and checking its efficiency in practical use and make it use practically in the real time systems in the Wireless Sensor Networks.

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