A Model For Integrating Sensor's And RFID In A Vast Landscape Area For Disaster Monitoring

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Abstract: Vast landscapes are prone to different types of disasters in our environment which need to be monitored. Sensors play a vital role in environmental monitoring where its main function in a mission such as environmental monitoring is to collect information from the monitoring field. Monitoring in our environment against any type of disaster is crucial, due to the uniqueness of disaster monitoring applications; there features are different from other sensor application which may affect the performance of the sensor network. Wider landscape coverage is one of the important feature. In this research, a model was developed to find the optimal number of sensors required to cover a particular area at the monitoring field with a certain constant cost of network design and area to be covered. A mathematical solution based on linear programming to ascertain optimal number of sensors is used, number of simulation has been carried out to verify the proposed model using Matlab. The result shows a maximum coverage of the landscape area and lifespan of network was increased with a good connectivity.

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1. Introduction

Natural disaster, metrologically originated such as floods, cyclones, drought and tornadoes, or geologically originated such as landslides, earthquake and volcanoes or environmentally originated such as air pollution, forest fire and water pollution, have a devastatting effect on human life, environment and economy. Certainly, different types of natural disaster have been known to hit hard such as the floods that causes severe difficulties in Malaysia which lead to death (Kia et al., 2012), 2010 - 2011 Pakistan and Australia water flood, 2010 sludge flow in Hungary, 2011 Landslides in Brazil (Awange, 2012). "The greatest exploiter for all of us is floods today, droughts tomorrow, and earthquake some times and all of these multiply our trauma of deprivation, pains of poverty and hunger. These disasters take away not only our crops, shelters, lives of our families, friends cattle's, but also destroy our hopes and dreams of the future. Is there any event comparable to these which causes so much human sufferings and injustice?" (Jayaraman et al., 1997).
Disaster management have become a global issue and concern, measures to examine its probability of occurrence, consequences, understanding the total processes of it cause, effect and to identify a preventive measure with the implementation of a good rescue strategies show the needs for a good and robust monitoring system, vast area coverage and long lifetime monitoring that can be used to monitor the environment.

Coverage preservation is one of the important features of WSN (Liu et al., 2012), the total area been covered in a sensor network by sensors is very important which can be a major problem in the network design, while a vast landscape coverage in disaster monitoring is required, it may require a high number of sensors ranging from hundreds, thousands or hundreds of thousands (Chang et al., 2011), for instance maximum coverage may be required by some applications in which large amount of sensors are needed to completely cover the monitoring field (Miyazaki et al., 2011). It is important to consider the cost of each and every single node as to justify the total cost of the network due to the high number of sensors usage in monitoring fields such as disaster monitoring that needs to cover a wide landscape. The cost of the sensor node have to be kept low for the feasibility of sensor network. The low cost will enable the deployment of many of them at the required area to construct a network with a good connectivity (Ramesh, 2012), (Burgess et al., 2010).

Wireless sensor network current applications require sensors to stay alive for a long period of time. Sensors have a finite lifetime since it is unfeasible or impracticable when deployed to replace or recharge the batteries of a sensor when their energy is fully consumed (Weng et al., 2013), (Akyildiz et al., 2002). Due to the large number of sensors deployed unattained in the monitoring field, communication among them is based on message broadcasting. Broadcasting configuration and location is being done periodically with the sensing information, which is one of the major factors that drains the sensor batteries. In fact, most of energy being consumed is related to the communication (Aslan et al., 2012a). In such situations, reducing the energy consumption of WSN to keep it alive by implementing strategies for energy saving such as energy efficient algorithms and battery technology to allow the sensor to live for a long time is very important.

Disaster monitoring application have their own features which are all connected to each other, this features are facing a serious challenges in the monitoring field, even though there make it different from other sensor network applications, vast area of the disaster prone region lead to a wider coverage requirement and constant cost of deploying the sensors at a higher number in disaster prone areas (Ramesh, 2012), (Burgess et al., 2010)

2. Background

Sensor networks have changed the way organizations and individuals coordinate activities and exchange their information. Recently we are witnessing a change in which there are utilized or involved in control and observation of the physical world, the availability of this communication devices enable the densely deployment of the sensors in a distributed manner in a network for a wide variety of application such as biological, health, agriculture, military, earth and environmental monitoring to monitor their condition (Cerpa et al., 2001). One of the emerging technologies of sensor networks application is environmental monitoring, where disaster monitoring and management is an aspect of this application.

Disaster monitoring has been studied through different applications and one of its early applications is ocean monitoring through underwater sensors (Dhyanesh and Raghavan, 2004). Another popular research in this field is earthquake monitoring where Cayirci and Coplu(Cayirci, 2006) showed that using a sensor network to gather information from the environment could reduce the side effects of earthquake in Turkey (1999) dramatically. Fire and gas detections are another popular environmental monitoring applications among researchers (Qandour et al., 2012), (Zeng et al., 2011). Water and air pollution monitoring are othere examples on environmental monitoring applications which have been practiced using WSN (Liu, 2012), (Sempere-Payá and Santonja-Climent, 2011). The main feature of environmental monitoring for disaster management is a long term low activity network which in a specific time (disaster) needs to work at its highest throughput for message and information delivery.

Long term monitoring of a vast landscape area needs cheap, low energy usage devices, which are reliable at the disaster time for message delivery and speed. Wireless Sensor Network (WSN) has been proposed for disaster monitoring by many researchers where various works from hardware architecture design (Liu, 2012), (Propst et al., 2012), (Soleymani et al., 2013), (Chizari et al, 2013) to network design (Sempere-Payá and Santonja-Climent, 2011) have been done on WSN. However, the environments are of large amount of sensors in a landscape environment for long term monitoring may not be practical and economical. Radio Frequency Identification (RFID) devices have been proposed for disaster monitoring due to their very low energy usage and low cost. Nevertheless, RFID devices are not a complete alternative for sensors in WSN. Thus, a two tired network combing RFID devices and sensors could be both cheap for implementation, reliable and fast for message delivery at the time of disaster (Hao et al., 2011). While for both WSN and RFID devices there are many works on disaster monitoring, the integrated RFID-WSN architecture has not been developed for environmental monitoring in disaster management.

In this research the focus is on environmental disaster monitoring. Disaster monitoring application have their own features which are all connected to each other (Muhammad, 2013), this features are facing a serious challenges in the monitoring field, even though the features makes it to be different from other sensor network applications, vast area which lead to a wider coverage of the monitoring field and constant cost of deployment at disaster prone areas (Ramesh, 2012), (Burgess et al., 2010).

Combining two different device with different characteristic to achieve a certain goal is very important such as reducing the cost to achieve wide landscape coverage, increasing the coverage, reducing the number of hops in the network, the device should work alongside with each other as in (Cho et al., 2007), many advantages are mentioned for this type of network such as reducing cost, increasing portability, increasing scalability and reducing number of hops in the network (Mason, 2006). The applications monitoring that needs to monitor each and every point of the region for early detection at all time, therefore long lifetime of the network is necessary (Weng et al., 2013), sensor nodes have a finite lifetime when deployed in a disaster monitoring field it is difficult to recharge or replace it batteries when the energy is fully consumed (Aslan et al., 2012a).

3. Features of Disaster Monitoring Application

The features of disaster monitoring application are interconnected with one another as shown in figure 1 below.

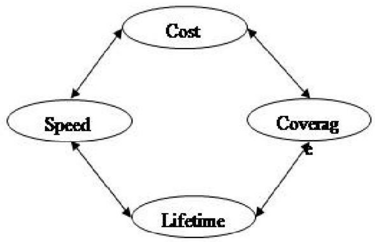

Figure 1: Features of Disaster Monitoring Applications

Cost Efficiency:- Cost of purchasing each an every sensor node is important when it comes to covering a large monitoring region, justifying the total cost of the network due to the high number of sensors to be deployed in the monitoring fields such as disaster monitoring to cover a vast landscape, lead to the need of a way of bringing the cost of each sensor to be low (Ramesh, 2012).

Coverage:- Coverage preservation is one of the important features of WSN (Liu et al., 2012), the total area been covered in a sensor network by sensors is very important which can be a major problem in the network, studies carried out such as (Chang et al., 2011) and (Miyazaki et al., 2011) for disaster prevention in different application show the need of coverage in the monitoring field, which may lead to the need of high numbers of sensors to be deployed for the disaster monitoring to have adequate coverage of the region (Burgess et al., 2010).

Energy Efficiency:-Wireless sensor network for disaster monitoring application have constraint such as limited energy for the network to stay alive for a long period of time (Aslan et al., 2012b), sensors have a finite lifetime since it is unfeasible or impossible when deployed to recharge or replace their batteries when their energy is fully consumed (Weng et al., 2013), (Burgess et al., 2010).

4. Problem Formulation

The problem formulation, however, considers some parameters that are common between the sensors and the monitoring field such as sensing range, area to be covered, and the number of sensors to be deployed etc. After all, the mathematical formulation is implemented using MATLAB 7.8.0 for an optimal deployment scheme .The experiment is conducted and runs several time with different scenarios to measure the optimal coverage of the field.

Defining the Constants in the Problem

There are two types of devices in this problem: Sensors and RFIDs. Each has a sensing range and a cost for purchase as follow:

1. c_s The cost for buying one sensor.
2. c_r The cost for buying one RFID.
3. C The overall budget that project has.
4. s_s The sensing range of one sensor.
5. s_r The sensing range of one RFID.
6. $a_s = \pi * s_s^2$ The covered area by one sensor.
7. $a_r = \pi * s_r^2$ The covered area by one RFID.
8. $Z = A + \Delta A$ The area that must be covered.
9. n_s Number of sensors which must be calculated.
10. n_r Number of RFIDs which must be calculated

In order to have proper values for problem definition, these constraints must be satisfied:

11. $C_s > C_r$ One sensor is more expensive than a RFID.
12 . $S_s > S_r$ The sensing range of a sensor is more than a RFID.
13. $a_s/c_s < a_r/c_r$ The ratio of covered area to cost for a sensor is lower than a RFID. It means it is more cost effective to use RFIDs than sensors.

To find the proper values for C, Z, C_s, C_r, S_s and S_r, we use following variables.

If S_s , S_r and C_r are all given while C_s is not, then using Eq.13, we can find the proper value for C_s :

Eq. 13 →
$$\frac{a_s}{c_s} < \frac{a_r}{c_r}$$
$$\frac{\pi S_s^2}{c_s} < \frac{\pi S_r^2}{c_r}$$
$$\frac{S_s^2}{c_s} < \frac{S_r^2}{c_r}$$
$$c_r s_s^2 < c_s s_r^2$$

Then we make C_s subject of the formula

$$\frac{c_r s_s^2}{s_r^2} < c_s = c_s > \frac{c_r s_s^2}{s_r^2}$$

If S_s , S_r and C_s are all given while C_r is not, then we still use Eq.13, to find the proper value for C_r :

Eq. 13 →
$$\frac{a_s}{c_s} < \frac{a_r}{c_r}$$
$$\frac{\pi S_s^2}{c_s} < \frac{\pi S_r^2}{c_r}$$
$$\frac{S_s^2}{c_s} < \frac{S_r^2}{c_r}$$
$$c_r s_s^2 < c_s s_r^2$$
$$c_r < \frac{c_r s_s^2}{s_s^2}$$

If we are not giving the cost of sensor (C_s)is not given we use $c_s > \frac{c_r s_s^2}{s_r^2}$ to find its value

While

If we are not giving the cost of RFID (C_r)is not given we use $c_r < \frac{c_r s_r^2}{s_s^2}$ to find its value

Given Z as a constant value, then we find the proper value for C which will be as follow:

First:

a) If we are to use all sensors to cover the monitoring area Z, what number of sensors did we need to deploy:

$n_s a_s \geq Z$

$n_s \geq \frac{Z}{a_s} \rightarrow n_s \geq \frac{Z}{\pi s_s^2}$

n_s is equal to the value greater than n_s

b) The cost (C_1) of network for having only sensors is $C_1 = n_s * C_s$

Second:

a) If we are to use all RFID's to cover the monitoring area Z, what number of RFID's did we need to deploy:

$n_r a_r \geq Z$

$n_r \geq \frac{Z}{a_r} \rightarrow n_r \geq \frac{Z}{\pi s_r^2}$

n_r is equal to the value greater than n_r

b) The cost (C_2) of network for having only RFID's is

$C_2 = n_r * C_r$

Thus

$C_1 > C > C_2$

To ensure that it is not possible to just use all sensors in the network and the money is enough to cover the deployment area with all RFIDs.

Problem Formulation

Maximize n_s:

$$C_s n_s + C_r n_r \leq C \qquad \rightarrow \text{Eq. 14}$$

$$S_s^2 \pi n_s + S_r^2 \pi n_r \geq Z \qquad \rightarrow \text{Eq. 15}$$

$$n_s \geq 0$$

$$n_r \geq 0$$

Since we want to maximize n_s, then we simply use Eq. 14 as show below

→Eq. 14

$$C_s n_s + C_r n_r \leq C$$

$$n_s \leq \frac{C - c_r n_r}{c_s} \rightarrow n_s = \frac{C - c_r n_r}{c_s}$$

To find the value of n_r, we substitute the simplified value of n_s in Eq. 14 into Eq. 15

→Eq. 15

$$S_s^2 \pi n_s + S_r^2 \pi n_r \geq Z$$

$$S_s^2 \pi \left(\frac{C - c_r n_r}{c_s}\right) + S_r^2 \pi n_r \geq Z$$

$$S_s^2 \pi (C - c_r n_r) + S_r^2 \pi n_r C_s \geq ZC_s$$

$$S_s^2 \pi C - S_s^2 \pi c_r n_r + S_r^2 \pi n_r C_s \geq ZC_s$$

$$S_s^2 \pi C + n_r (S_r^2 \pi C_s - S_s^2 \pi c_r) \geq ZC_s$$

$$n_r (S_r^2 \pi C_s - S_s^2 \pi c_r) \geq ZC_s - S_s^2 \pi C$$

$$n_r \geq \frac{ZCs - S_s^2 \pi C}{S_r^2 \pi C_s - S_s^2 \pi c_r}$$

To find the value of n_s and n_r we use the following Eq. below

$$n_s = \frac{C - c_r n_r}{c_s} \qquad \rightarrow \text{Eq. 16}$$

$$n_r \geq \frac{ZCs - S_s^2 \pi C}{S_r^2 \pi C_s - S_s^2 \pi c_r} \qquad \rightarrow \text{Eq. 17}$$

Note that we must find the value of n_r first before finding the value of n_s.

5. SIMULATION SETUP

Sensors and RFID's are used in our simulation in three different scenarios using the same dimension of the monitoring field, the model (algorithm) was used to determine the number of Sensors and RFID's to cover the monitoring region by considering as much Sensor the budget can afford and complement with RFID's to ensure full coverage with a low cost (budget) of the network design, firstly we considered only sensors to be deployed, secondly only RFID's are considered, while thirdly sensors and RFID's are integrated together, we then observed the coverage of the region, by considering the fixed budget of network design.

The simulation setup in this research is as follows.

- Dimension of the area covered 1000 by 1000 M^2
- Node placement strategy is random
- Sensor communication range 500M
- Sensor Coverage 250M
- RFID communication range 200M
- RFID Coverage 100M
- Assumed budget $ 2920
- Assumed Cost of Sensor $ 200
- Assumed Cost of RFID $ 30

Different simulation topology where chosen by the algorithm which placed the sensor nodes in monitoring region at random.

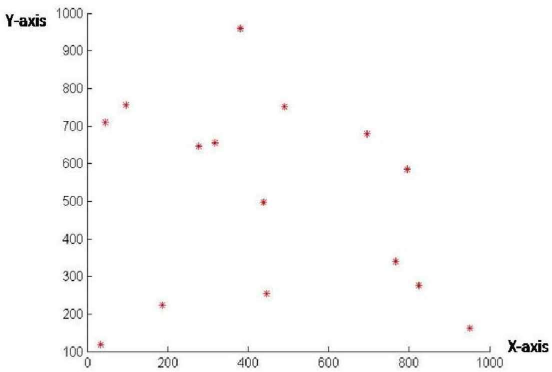

Figure II: Deployment of Sensors Only

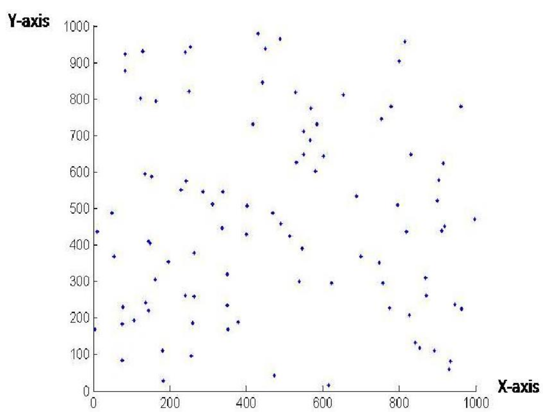

Figure III: Deployment of RFID'S Only

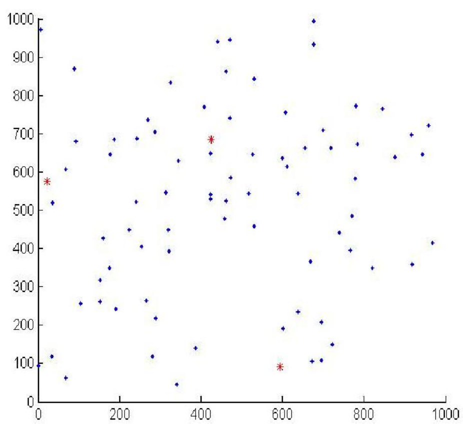

Figure IV: Deployment of Sensors and RFID's

Discussion

The simulation was run several times and disaster monitoring application features such as coverage and budget (cost) are considered, in figure I in which only 15 sensors are deployed, shows that the monitoring field that requires 20 sensors is not adequately covered by the sensors deployed due to the allocated budget cannot provide the required number of sensors. In Figure II the RFID's have fully covered the region based on the budget, but we observed that there is multiple hops while sending or receiving data due to short communication range of the RFID which may lead to high energy consumption, in Figure III where Sensors and RFID's are integrate together, the monitoring field is covered with optimal number of sensors and energy consumption is reduced due to combination of the two different devices, sensors have wider communication range than RFID, multiple number of hop that is required in the case of second scenario of only RFID will reduce due to the integration of the Sensors in the field.

Conclusion

The problem formulated using sensor and RFID covered the maximum landscape in the monitoring field with a constant cost, which cannot be used to deploy all sensors, and if we use all RFID in the network more energy will be consumed due to high number of hops in the network. The model shows that with the integration of two devices a certain area can be adequately covered with a constant cost. In the future studies more elements will be considered in the model. This study will help environmental designers to have more cost effective plan for monitoring a large landscape environment in pre-disaster situations.

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