Wireless Sensor Networks and their Application

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TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

Environment degradation around the world has motivated many researchers to deal with an important yet endangering aspect of rural and forest fires. Forests are conceived as one of the most significant and essential resources on earth. Based on the inadequacies of conventional forest fire monitoring on real time detection, the wireless sensor network technique for forest fire detection was introduced. In this paper, we have proposed a framework for forest fire detection and monitoring as an application area of wireless sensor networks. Our systems gather temperature from every points of forest and transmit it to control center speedily. Our framework includes proposals for the wireless sensor network architecture and communication protocols to detect the fire threats quickly. It also conceives the consumption of energy by the sensor nodes and the physical conditions that may hinder the activity of the network. When it consumes energy from nature then it provides fast reaction to forest fires. This framework can provide fast reaction to forest fires together with efficient energy consumption. In this paper we have presented an algorithm for controlling forest fire and a sleep-awake cycle to increase lifetime of sensor network.

CHAPTER 1

INTRODUCTION

Accurate and low-cost sensor localization is a critical requirement for the deployment of wireless sensor networks in a wide variety of applications. Low-power wireless sensors may be many hops away from any other sensors with a priori location information.
In cooperative localization, sensors work together in a peer-to-peer manner to make measurements and then form a map of the network. Various application requirements (such as scalability, energy efficiency, and accuracy) will influence the design of sensor localization systems. In this article, we describe measurement-based statistical models useful to describe time-of-arrival (TOA), angle-of-arrival (AOA), and received-signal-strength (RSS) measurements in wireless sensor networks. Wideband and ultra-wideband (UWB) measurements , and RF and acoustic media are also discussed. Using the models, we show how to calculate a Cramér-Rao bound (CRB) on the location estimation precision possible for a given set of measurements. This is a useful tool to help system designers and researchers select measurement technologies and evaluate localization algorithms. We also briefly survey a large and growing body of sensor localization algorithms. This article is intended to emphasize the basic statistical signal processing background necessary to understand the state-of-the-art and to make progress in the new and largely open areas of sensor network localization research.

Wireless Sensor Networks

A **wireless sensor network (WSN)** (sometimes called a **wireless sensor and actor network[1](WSAN)**[1]) are spatially distributed autonomous sensors to *monitor* physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling *control* of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on.

The WSN is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. A sensor node might vary in size from that of a shoebox down to the size of a grain of dust, although functioning "motes" of genuine microscopic dimensions have yet to be created. The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding.[2][3]

In computer science and telecommunications, wireless sensor networks are an active research area with numerous workshops and conferences arranged each year, for exampleIPSN, SenSys, and EWSN.

Applications of WSN

Area monitoring

Area monitoring is a common application of WSNs. In area monitoring, the WSN is deployed over a region where some phenomenon is to be monitored. A military example is the use of sensors detect enemy intrusion; a civilian example is the geo-fencing of gas or oil pipelines.

Health care monitoring

The medical applications can be of two types: wearable and implanted. Wearable devices are used on the body surface of a human or just at close proximity of the user. The implantable medical devices are those that are inserted inside human body. There are many other applications too e.g. body position measurement and location of the person, overall monitoring of ill patients in hospitals and at homes. Body-area networks can collect information about an individual's health, fitness, and energy expenditure

Environmental/Earth sensing

There are many applications in monitoring environmental parameters,[5] examples of which are given below. They share the extra challenges of harsh environments and reduced power supply.

Air pollution monitoring

Wireless sensor networks have been deployed in several cities to monitor the concentration of dangerous gases for citizens. These can take advantage of the ad hoc wireless links rather than wired installations, which also make them more mobile for testing readings in different areas.

Forest fire detection

A network of Sensor Nodes can be installed in a forest to detect when a fire has started. The nodes can be equipped with sensors to measure temperature, humidity and gases which are produced by fire in the trees or vegetation. The early detection is crucial for a successful action of the firefighters; thanks to Wireless Sensor Networks, the fire brigade will be able to know when a fire is started and how it is spreading.

Landslide detection

A landslide detection system makes use of a wireless sensor network to detect the slight movements of soil and changes in various parameters that may occur before or during a landslide. Through the data gathered it may be possible to know the occurrence of landslides long before it actually happens.

Water quality monitoring

Water quality monitoring involves analyzing water properties in dams, rivers, lakes & oceans, as well as underground water reserves. The use of many wireless distributed sensors enables the creation of a more accurate map of the water status, and allows the permanent deployment of monitoring stations in locations of difficult access, without the need of manual data retrieval.[6]

Natural disaster prevention

Wireless sensor networks can effectively act to prevent the consequences of natural disasters, like floods. Wireless nodes have successfully been deployed in rivers where changes of the water levels have to be monitored in real time.

Chemical agent detection

The U.S. Department of Homeland Security has sponsored the integration of chemical agent sensor systems into city infrastructures as part of its counterterrorism efforts. In addition, DHS is supporting the development of crowd sourced sensing systems that will draw upon chemical agent detectors embedded in mobile phones.[7]

Industrial monitoring

Machine health monitoring

Wireless sensor networks have been developed for machinery condition-based maintenance (CBM) as they offer significant cost savings and enable new functionality.[8]

Wireless sensors can be placed in locations difficult or impossible to reach with a wired system, such as rotating machinery and untethered vehicles.

Data logging

Wireless sensor networks are also used for the collection of data for monitoring of environmental information, this can be as simple as the monitoring of the temperature in a fridge to the level of water in overflow tanks in nuclear power plants. The statistical information can then be used to show how systems have been working. The advantage of WSNs over conventional loggers is the "live" data feed that is possible.

Water/Waste water monitoring

Monitoring the quality and level of water includes many activities such as checking the quality of underground or surface water and ensuring a country’s water infrastructure for the benefit of both human and animal.It may be used to protect the wastage of water.

Structural Health Monitoring

Wireless sensor networks can be used to monitor the condition of civil infrastructure and related geo-physical processes close to real time, and over long periods through data logging, using appropriately interfaced sensors.

Entertainment Industry

Music Technology

Wireless sensor networks are also used in music technology, for example to sense live performers, and transmit the sensor data to a central computer which then plays back sound or visuals in sync with the music. One example of such an application are the Audiocubes, smart objects which form a star network and which can sense each other's location, orientation and relative distance, as well as distance to the user of the network (i.e. the performer).

Advantages

1. It avoids a lot of wiring
2. It can accommodate new devices at any time

3. It's flexible to go through physical partitions
4. It can be accessed through a centralized monitor

Disadvantages

1. It's easy for hackers to hack it as we can't control propagation of waves
2. Comparatively low speed of communication
3. Gets distracted by various elements like Blue-tooth

GPS

The **Global Positioning System** (**GPS**) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the earth where there is an unobstructed line of sight to four or more GPS satellites.[1]The system provides critical capabilities to military, civil, and commercial users around the world. The United States government created the system, maintains it, and makes it freely accessible to anyone with a GPS receiver.

The US began the GPS project in 1973 to overcome the limitations of previous navigation systems,[2] integrating ideas from several predecessors, including a number of classified engineering design studies from the 1960s. The U.S. Department of Defense (DoD) developed the system, which originally used 24 satellites. It became fully operational in 1995. Bradford Parkinson, Roger L. Easton, and Ivan A. Getting are credited with inventing it.

Advances in technology and new demands on the existing system have now led to efforts to modernize the GPS system and implement the next generation of GPS Block IIIA satellites and Next Generation Operational Control System (OCX).[3]Announcements from Vice President Al Gore and the White House in 1998 initiated these changes. In 2000, the U.S. Congressauthorized the modernization effort, GPS III.

In addition to GPS, other systems are in use or under development. The Russian Global Navigation Satellite System (GLONASS) was developed contemporaneously with GPS, but suffered from incomplete coverage of the globe until the mid-2000s.[4] There are also the planned European Union Galileo positioning system, India's Indian Regional Navigation Satellite System, and the ChineseBeiDou Navigation Satellite System.

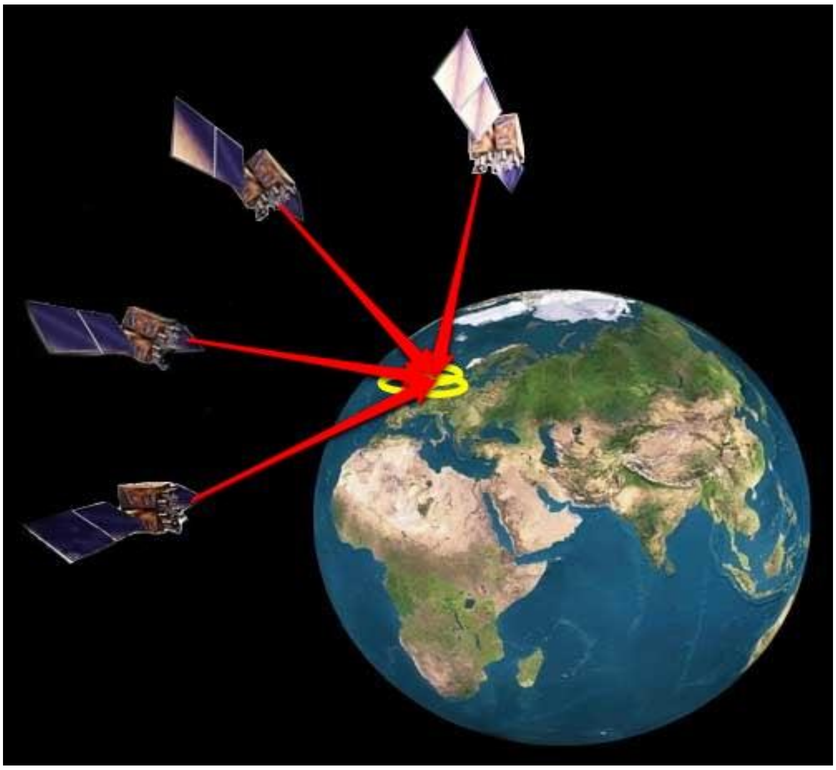
Working Of GPS

The GPS satellites transmit signals to a GPS receiver. These receivers passively receive satellite signals; they do not transmit and require an unobstructed view of the sky, so they can only be used effectively outdoors. Early receivers did not perform well within forested areas or near tall buildings but later receiver designs such as SiRFStarIII, MTK etc have overcome this and improved performance and sensitivity markedly. GPS operations depend on a very accurate time reference, which is provided by atomic clocks on board the satellites.

Each GPS satellite transmits data that indicates its location and the current time. All GPS satellites synchronize operations so that these repeating signals are transmitted at the same instant. The signals, moving at the speed of light, arrive at a GPS receiver at slightly different times because some satellites are further away than others. The distance to the GPS satellites can be determined by estimating the amount of time it takes for their signals to reach the receiver. When the receiver estimates the distance to at least four GPS satellites, it can calculate its position in three dimensions.

There are at least 24 operational GPS satellites at all times plus a number of spares. The satellites, operated by the US DoD, orbit with a period of 12 hours (two orbits per day) at a height of about 11,500 miles traveling at 9,000mph (3.9km/s or 14,000kph). Ground stations are used to precisely track each satellite's orbit.

Here is an interesting comparison. The GPS signals are transmitted at a power equivalent to a 50 watt domestic light bulb. Those signal have to pass through space and our atmosphere before reaching your satnav after a journey of 11,500 miles. Compare that with a TV signal, transmitted from a large tower 10 - 20 miles away at most, at a power level of 5-10,000 watts. And compare the size of your TV's roof mounted antenna with that of your GPS, often hidden inside the case itself. A wonder then that it works as well as it does and when the occasional hiccup occurs you will at least understand the reasons why.

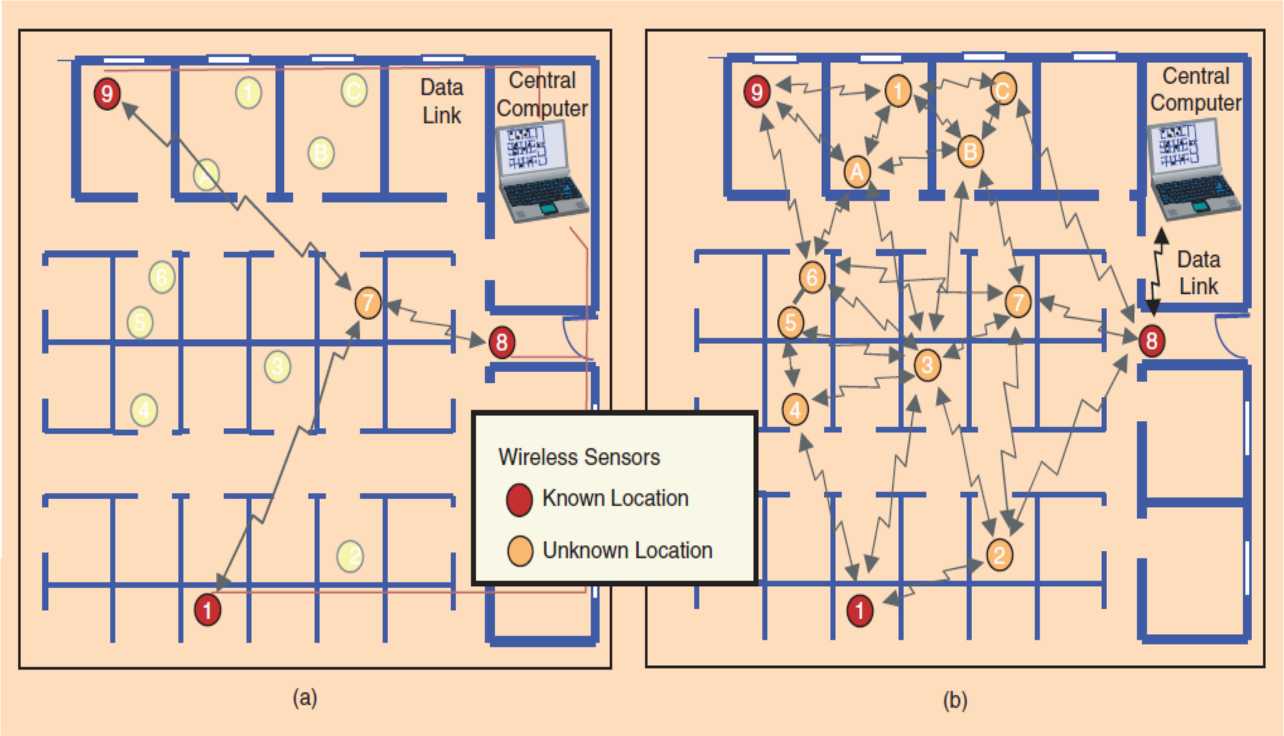


RANDOM DEPLOYMENT

Traditional localization techniques are not well suited for these requirements. Including a global positioning system (GPS) receiver on each device is cost and energy prohibitive for many applications, not sufficiently robust to jamming for military applications, and limited to outdoor applications. Local positioning systems (LPS) rely on high-capability base stations being deployed in each coverage area, an expensive burden for most low-configuration wireless sensor networks.

Instead, we consider the problem in which some small number *m* of sensors, called reference nodes, obtain their coordinates (either via GPS or from a system administrator during startup) and the rest, *n* unknown-location nodes, must determine their own coordinates. If sensors were capable of high-power transmission, they would be able to make measurements to multiple reference nodes. Positioning techniques presented in other articles in this special issue, for cellular mobile station (MS) location or location in wireless local area networks (WLANs), could be applied. However, low-capability, energy-conserving devices will not include a power amplifier, will lack the energy necessary for long-range communication, and may be limited by regulatory constraints on transmit power.

Thus, wireless sensor networks, and thus localization techniques, will be multihop (a.k.a. “**cooperative” localization**”). Such localization systems are an extension of techniques used in or proposed for WLAN and cellular MS location, as described elsewhere in this issue. We still allow unknown-location devices to make measurements with known-location references, but in cooperative localization, we additionally allow unknown-location devices to make measurements with other unknown-location devices. The additional information gained from these measurements between pairs of unknown-location devices enhances the accuracy and robustness of the localization system. In the considerable literature, such systems have alternatively been described as “cooperative,” “relative,” “distributed,” “GPS-free,” “ multihop " or “network” localization; “self-localization;” “adhoc” or “sensor” positioning; or “network calibration.”



(a)

(b)

FOREST FIRE

The forests are believed as one of the most significant and indispensable resource, moreover as the protector of the earth's ecological balance. Forests fire or wild fire, are unrestrained fires occurring in forest and cause substantial damage to natural and human resources. The main causes of forest fire are extreme heat generated by collision of trees, lightning and some human uncontrolled behaviour .It bums the infrastructure and may result in high wild animal's death. The damage caused by fire is dangerous for natural resources therefore early detection and repression of fire is essential. The most vital issue in a forest fire detection system is instantaneous response to minimize the disaster. A good forest fire detection system must have constant monitoring of the forest area .At present, traditional forest fire prevention systems are watching towers, aerial surveillance, long distance video detection and satellite monitoring etc. However, they do not achieve timely detection because of long period of monitoring and low resolution. Hence, there is a need for scalable solution that can provide real-time wild fire detection with high accuracy. A solution using wireless sensor networks make a framework for constructing near real time forest fire detection systems. In the wireless sensor network, a mass of integrated micro sensor nodes are deployed in the forest, nodes can be deployed manually or randomly. Next, they collect the targeted environment information and then transfered it to the user by wireless channel. WSN has property of self-configuration; which means there is no need to organize it manually. Sensor nodes are low cost in nature and therefore in forest fire, it will have less damage as compare to other techniques. In the forest, sensor nodes can be spread by helicopter or manually. Currently, sensor nodes can sense a variety of phenomena including relative humidity, temperature, and smoke which all are helpful for fire detection systems.

RELATED WORK

During the last decade, quite extensive research work has been performed
on wireless sensor networks, their protocols and algorithms, and their applications
Although these studies are not targeting specifically fire detection application, the approaches proposed are adaptable to various applications, including _re detection and monitoring. In our work, we adapt some of these existing methods (like clustering) and integrate various approaches in the literature to come up with a WSN design specifically targeting energy-efficient and effective forest fire detection.

For fire detection application of wireless sensor networks, specifically, there has been a considerable amount of work carried out as well. In one study, Doolin and Sitar [12] provide experiments through controlled fires in San Francisco area. Their system is composed of ten sensor nodes with GPS capability. The sensor nodes are deployed with ranges up to one kilometre and they sense and forward temperature, humidity and barometric pressure values to a base station. The system was implemented and real-world observations were gathered from the field. However, because of the long distances between sensor nodes, the data arriving to the sink is not valuable enough to detect a fire quickly and forecast the spread direction of the fire. Also, with the growth of fire and burning out some of the sensor nodes, the sensor network could fail in delivering the data from all sensor nodes to the base station.

Lloret et al[19] use a wireless local area network (WLAN) together with sensor-node technology for fire detection. The system they propose mixes multi-sensor nodes with IP-based cameras in a wireless mesh network setting in order to detect and verify a fire. When a fire is detected by a wireless multi-sensor node, the alarm generated by the node is propagated through the wireless network to a central server on which a software application runs for selecting the closest wireless camera(s). Then, real time images from the zone are streamed to the sink. Combining sensory data with images is the most important contribution of this study.

In all the studies discussed above ([12, 19]), the sensor nodes are deployed to have quite large distances between each other and the sensory data gathered at a centre is supported with visual data obtained with cameras. Our proposed system, however, considers a denser deployment strategy where the distances between neighbouring sensor nodes are quite short. In this way, we are aiming to detect forest fires in a much faster way and send the related information to a centre as quickly as possible.

Son et al. [13] propose a forest _re surveillance system in South Korea in which a dynamic minimum cost path forwarding protocol is applied. After gathering data, a sink node makes several calculations regarding the relative humidity, precipitation and solar radiation, and produces a forest fire risk level. Different from this study, we propose to do in-network processing in cluster-head nodes rather than doing calculations only at a sink node. In this way, in our system, a sink node gathers filtered and processed data, not just raw data. Additionally, [13] applies a minimum cost path forwarding method that causes some sensor nodes (especially the ones that are closer to the sink) to consume their energy much faster than the others. Our system, on the other hand, applies a low and fair energy consumption strategy by use of appropriate intra- and inter-cluster communication protocols which take the remaining energy levels of sensor nodes into account.

Yu and Wang [14] present a method which applies neural network techniques for in-network data processing in environmental sensing applications of wireless sensor networks. Several data fusion algorithms are presented in their study. Maximum, minimum and average values of temperature and humidity data are calculated by the cluster-heads. Data are propagated to the sink only if a certain threshold is exceeded. The main focus of this study is data aggregation methods, hence energy consumption and forecast capability issues are not discussed.

Ngai et al. [17] provide a general reliability-centric framework for event reporting in wireless sensor networks which can also be used in forest fire detection systems. They consider the accuracy, importance and freshness of the reported data in environmental event detection systems. They present a data aggregation algorithm for filtering important data and a delay-aware data transmission protocol for rapidly carrying the data to the sink node.

Wenning et al. [16] propose a proactive routing method for wireless sensor networks to be used in disaster detection. The protocol is developed to be aware of a node's destruction threat and it can adapt the routes in case of a sensor node's death. The method can also adapt the routing state based on a possible failure threat indicated by a sensed phenomenon.

The studies described above ([13, 14, 17, 16]) consider and handle a single aspect of environmental monitoring and forest fire detection. In our proposed system, on the other hand, we deal with multiple parameters and trade-offs. We consider and aim both energy-efficiency and early-detection. We also incorporate environmental conditions, obstacles and features in our protocols.

There has been also a significant amount of work performed for clustering in wireless sensor networks [31, 29, 30, 32, 33, 34, 35, 36]. These works, however, consider mostly how clusters are formed and maintained for various applications. They are not focusing on use of clusters for fire detection application. Therefore, their focus and scope are much different than the cluster communication protocols we are proposing in this report. Moreover, in this report we are not concentrating on how clusters are formed, but on how clustered hierarchy is utilized in a most efficient and effective man.

PROPOSED FIRE DETECTION FRAMEWORK

Intention of our study is to propose an inclusive framework that views the two basic goals of fire detection one is low energy consumption and the other is early detection of fire.

Our proposed framework requires the design of three primary parts: a sensor deployment scheme, network architecture and an intra-cluster communication protocol. Concerning sensor deployment, examine how the nodes should be deployed in forest. In this section, we have specified clustered network architecture. After that, the communication scheme that is applied between the ordinary sensor nodes and the cluster heads are described.

DEPLOYMENT OF SENSORS

The sensor node deployment scheme can affect the design and performance of all aspects of the system. In a deployment scheme, There are two major decisions to make:

- What should be the average distance between neighbouring sensor nodes?

- What should be the deployment pattern or distribution (random or a regular pattern)?

The requirement for low and balanced energy consumption, early detection, desire to achieve low channel contention, properly covering the region, the terrain and other parameters of the forest should be considered in making those decisions.

The average deployment distance between neighbouring sensor nodes is an important parameter that affects the performance of a wireless sensor network deployed for fire detection. The time to detect a temperature increase at a node due to a fire is related with the distance of the node to the fire ignition location. Therefore, in order to reduce the expected fire detection time, the average distance between neighbouring sensor nodes should be reduced. But this may contradict with the goal of reducing collisions which is expected to happen more when a network becomes denser. Hence, there is a trade-off between reducing the fire detection time and collision probability.

In our suggested framework, the goals of the sensor node deployment stage are the followings:

- The distances between sensor nodes should be equal and therefore, the sensor nodes consume almost the same amount of energy.

- The deployment strategy of sensor nodes should try to derogate the possibility of collisions of data packets.

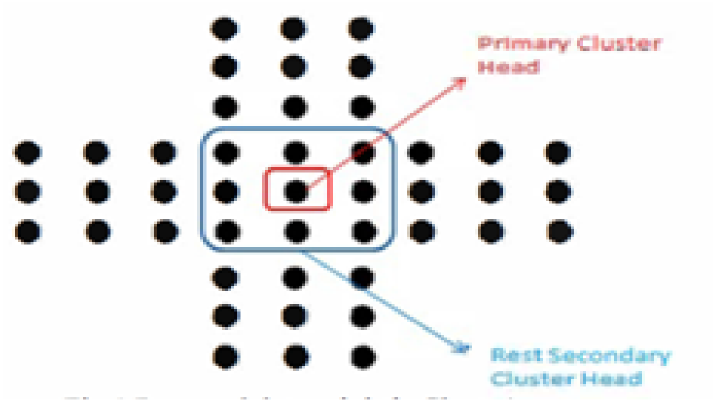
- To detect the forest fire rapidly, the sensor nodes should efficiently cover the entire forest with minimum number of nodes

NETWORK TOPOLOGY DESIGN

The logical topology of the network should be planned to conceive the goals of a fire detection system. For deployment of network, the primary focus of the network architecture depends upon several physical and environmental circumstances. Most of the time, when there is no fire and the chance of fire is pretty low, the monitoring system should reduce the message overhead during the network and the data should be transferred to the sink with minimum cost which also reduces energy consumption of sensor node. On the other hand, while considering the energy restrictions, the objective of detecting fire as early as possible should not be compromised.

In our deployment, we have deployed 8 secondary cluster head adjacent to single primary cluster head in a 3x3 matrix and 36 total sensor nodes are placed around this topology. Nine sensor nodes are arranged in each direction in a 3x3 square matrix.

Proposed deterministic Cluster

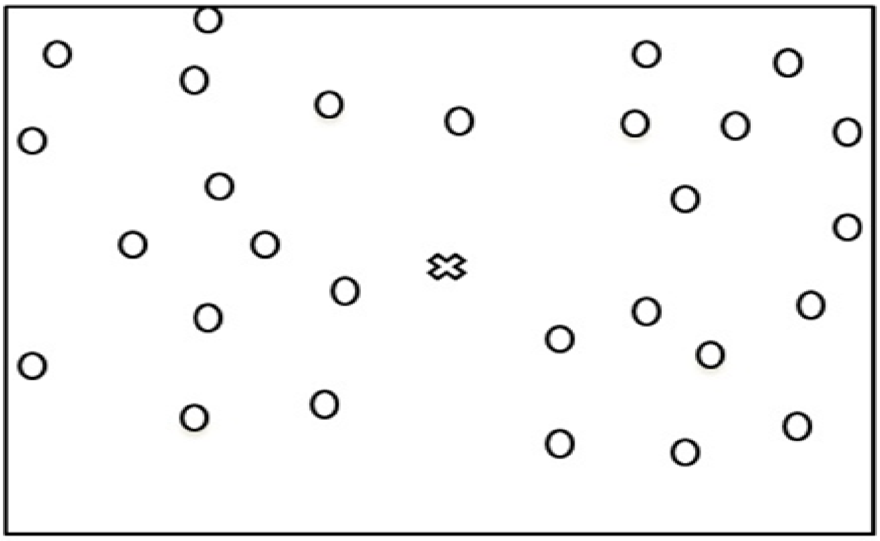


Assumptions of the topology are as follows: -

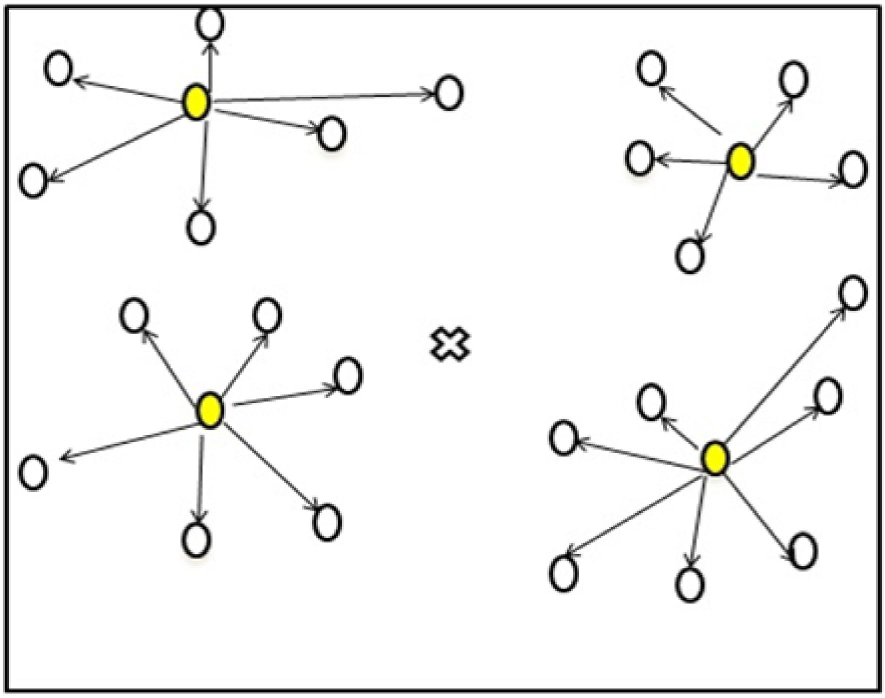
- Event will occur at only one node at a time.
- Nodes can receive and transmit data to and from the neighbouring nodes only.
- Primary cluster head has the authority to send data to any of the node deployed in this topology.
- The range of nodes is set in such a way that even neighbouring diagonal is not allowed to transmit and accept data from one another.
- Secondary cluster heads are used to disseminate the load equally among the boundary nodes.

WORKING OF CLUSTER HEADS

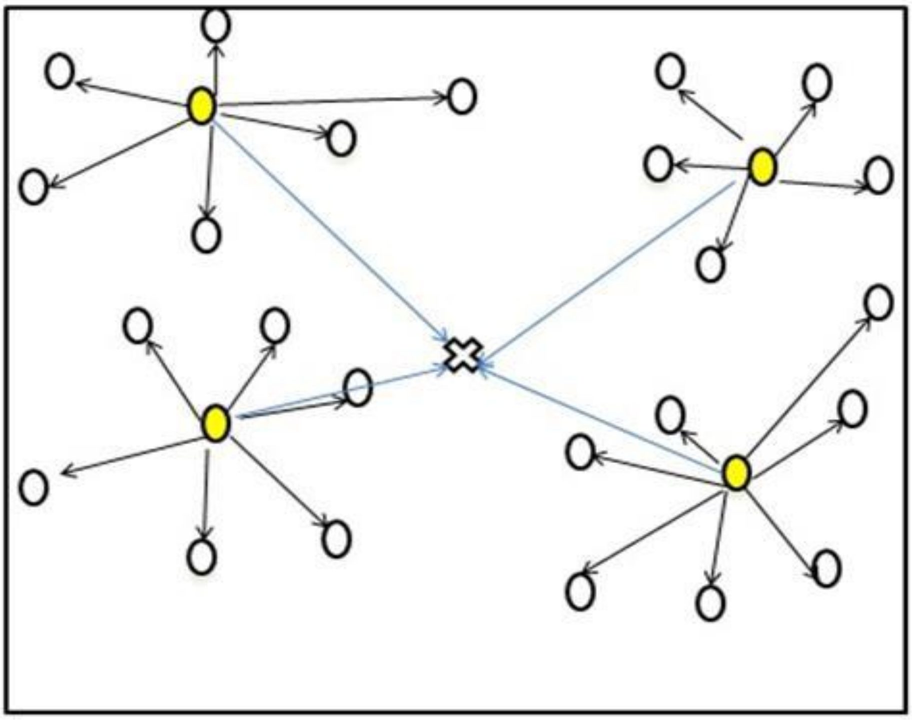
The given figure shows the randomly deployed sensor network in the network. The circle represents the deployed sensor node and the cross at the middle of the network represents the sink node.



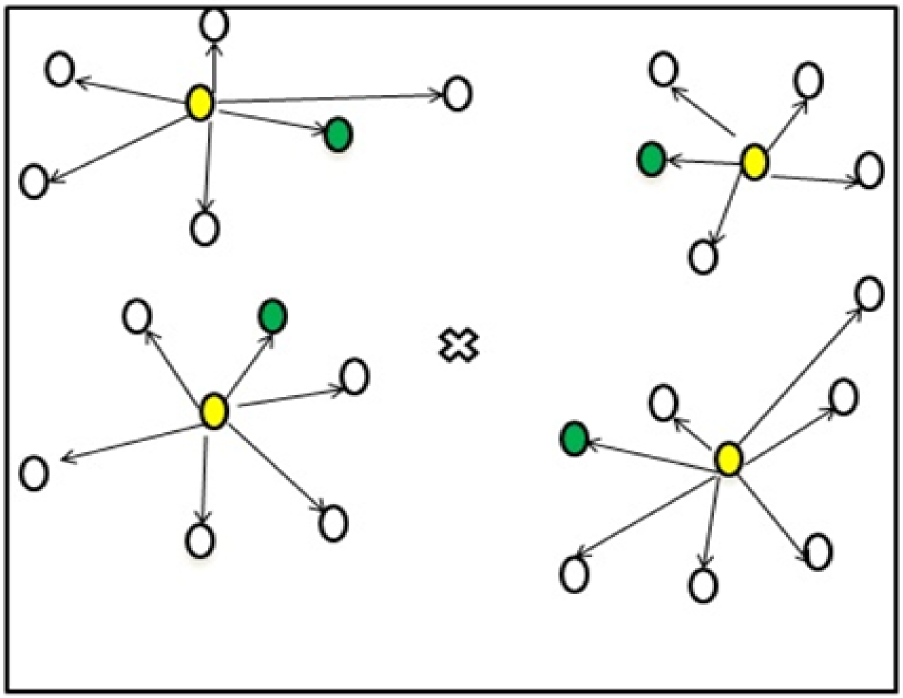
Deployed Sensor Node in the Network



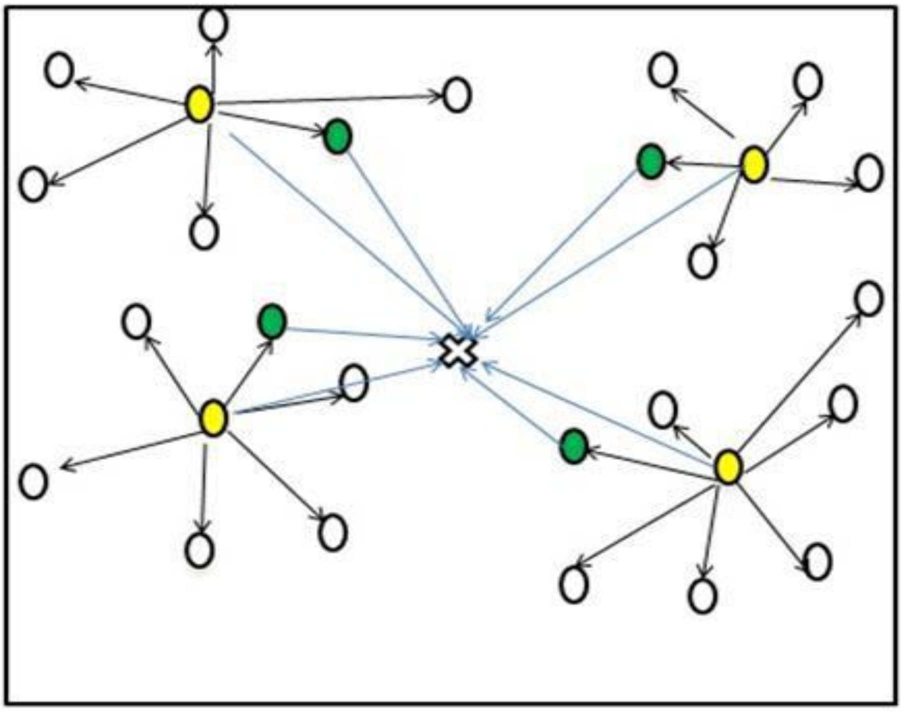
Nodes joining their respective cluster heads



Cluster Head Sending Sense data to Base Station



Cluster Head Selecting Cooperative Node



Final data Transmission to the Base station

FEATURES OF FIRE DETECTION DESIGN

We first identify the following as some of the important design goals and features that a wireless sensor network should have in order to be able to successfully monitor a forest and detect fires.

- *Energy efficiency*: Sensor nodes are powered with batteries, therefore a wireless sensor network deployed for fire detection should consume energy very efficiently. Energy consumption should also be balanced fairly among nodes. Usually the deployment area is very large and thousand of sensor nodes may be needed, and therefore replacing batteries may be too costly, impractical or even not possible.

- *Early Detection and Accurate Localization*: It is important to detect a forest fire as early as possible and to estimate the fire location with high accuracy. A forest fire usually grows exponentially and it is crucial that the fire should be detected and interfered in about six minutes to prevent the fire from spreading to a large area .Accurately estimating the fire position is important to send the fire fighting personnel to the correct spot in the shortest possible amount of time.

- *Forecast Capability*: Being able to forecast the spread direction and speed is important for planning fire fighting, being proactive in mobilizing resources, and warning the surrounding area. Accurate forecasting requires accurate and fresh sensory data to arrive at the decision and control centre from all points of the forest, especially from and around the region where the fire has occurred (i.e., critical zones).

- *Adapting to Harsh Environments*: A sensor network for forest fire detection will operate usually in harsh environments and therefore should be able to deal with and adapt to harsh conditions. It should be able to recover from node damages, link errors, high temperature, humidity, pressure,etc.

Our aim in this work is to consider the above goals as much as we can in designing a wireless sensor network for fire detection. Besides these goals, there may be some other crucial requirements for a WSN designed for fire detection, such as providing security, coping with vandalism, incorporating self-healing mechanisms, being able to self-organize, etc.

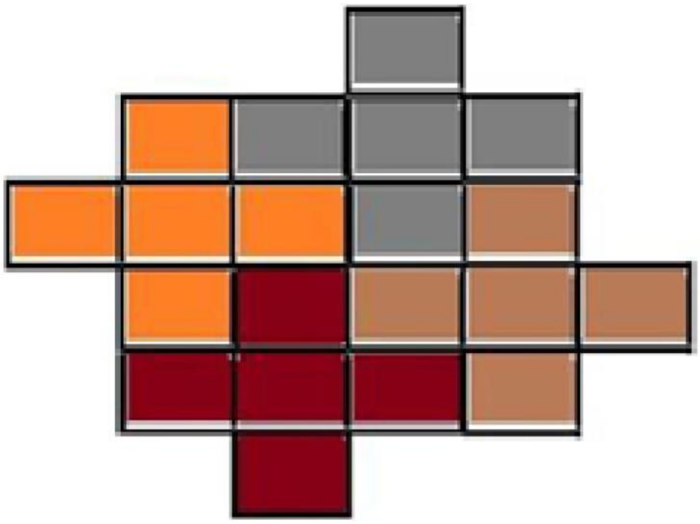
BENEFITS OF FIRE DETECTION

Data fusion: Data fusion is a well-known method in which messages are aggregated to build a single cluster which leads to fewer messages overhead in the network. Forest fire detection application is very suitable for data fusion.
In our topology, each node of a column sends a message to the next node of its respective row if it finds its surrounding temperature above the threshold. In the next column, if they also find their surrounding temperature greater than threshold, combine their data in the data packet and they received it from the preceding node & then transmit it to the next node. Just like that, data fusion goes on.

Balanced energy consumption: This is a very critical goal to be achieved in WSN applications. Especially, in environmental monitoring applications where the messages are gathered at one control centre, the sensor nodes that are closer to the sink node will consume more energy since more packets are forwarded through them comparing to the nodes that are far away from the sink. In our application, sensor nodes send regular information messages to the secondary cluster head which have regular power supplied to them. The secondary cluster head then transmit the data to the main cluster head. Hence, energy consumption is balanced in the nodes close to base station.

Less messaging overhead: Providing only the necessary and required data to the centre not only prevents unnecessary traffic throughout the network, but also simplifies the data processing at the centre by eliminating unnecessary data. In our design, the nodes send data to the Base Station only when they find their nearby temperature more than threshold otherwise they do not transmit any data. So, only helpful data is passed to Base station.

Simple to expand: The entire topology is very easy to expand. It can be viewed as a unit cell and the whole area can be enclosed by combining these unit cells to construct an absolute lattice.



ALGORITHM

STEPS OF ALGORITHM

- Initially all nodes are in "WAKE" state.

- After receiving the first SYNC signal from the base station, all nodes run a timer of 60 minutes (let us call it TimerO) & then go into the "SLEEP" state.

- After 60 min., they come in "WAKE" state & another timer of 100 ms runs on them, let us call it Timer 1.

- Each node then senses its surrounding temperature.

- If the leftmost node of each row doesn't find it above threshold temperature, it just goes into the "SLEEP" state. If it finds it above the threshold value, it sends the "Danger Packet" to next node of that row only & then goes to "SLEEP" state.

- The second node of that row waits for a fixed interval to receive a packet from the preceding node. If it receives the packet then the two cases arise:
    a. If its own surrounding temperature is above the threshold, in this case it modifies the received packet & sends it to next node.
    b. If its surrounding temperature is below the threshold it then just sends the packet it received to next hop without adding its own contents.

- Then the second column nodes also go to "SLEEP" state.

- Now if it doesn't receive a packet from its preceding node in the fixed interval, then again two cases arise:
    a. If its surrounding temperature is above threshold, then it generates a Danger Packet, sends it to next node & goes into the "SLEEP" state.
    b. If its surrounding temperature is below the threshold value, then it just goes to "SLEEP" state without sending a packet.

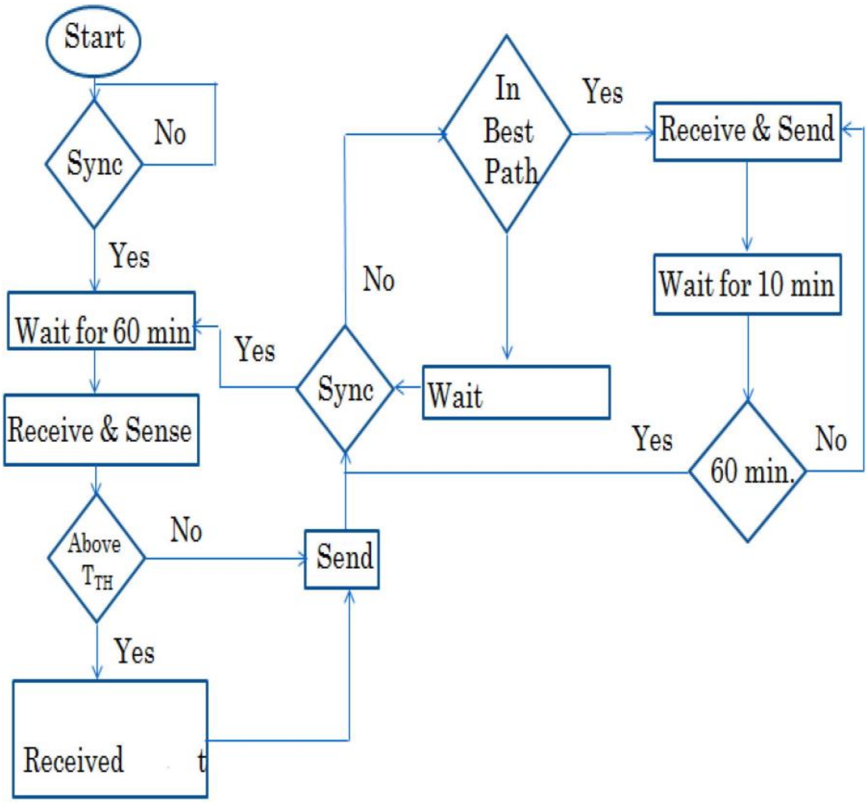
- The same process takes place in next column nodes.

- 10. After Timer 1 fires, all nodes come in "WAKE" state & wait for signal from Base Station.

- If they receive a Sync Signal they again go to the "SLEEP" state for 60 min. & the same process takes place as described above.

- If they receive an Alert Signal, then they wait for the Best Path signal from the Base Station. The Base Station calculates the best path (considering two factors, Battery Level and Distance).

- The Base Station broadcasts the Best path by encoding it in a packet.
- Each node receives the packet & decodes it to check whether it is in the path or not.
- The nodes which are not in the path run TimerO of 60 min. & go to "SLEEP" state.
- The nodes which come in the path then check whether they are the first node of the path. The first node only has to send the data, the rest nodes just have to make sure that the packet generated by the first node is received by the Base Station.
- The first node then senses the temperature around it & sends it to next node. The other nodes wait till they receive a packet. When they received it then they just send it to next hop. In this way, the data is sent to the Base Station.
- After sending the data, these nodes go to "SLEEP" state for the next 10 min., then again they come in "WAKE" state & the same cycle goes till TimerO fires. Actually, it happens when the nodes in the path have gone through the "Receive & Send Cycle" for six times.
- Then all the nodes again wait for a signal from the Base Station. The Base Station checks whether the surrounding temperature of the node where the event occurred is still above than the threshold or it has been controlled by some means. If it has been controlled, then it broadcasts the Sync Signal & the same cycles goes as described above. If it is still above than the threshold, it again calculates the Best path (which can be different now) & broadcasts it & the cycle described above goes.



Algorithm for Base Station

- The Base Station is always in the "WAKE" state.

- Initially, the Base Station broadcasts the SYNC signal.

- The Base Station runs a timer of 60 minutes, let us call it TimerO.

- When a TimerO fires, the Base Station will run another timer of 1 second, let us call it Timerl.

- Now, if the Base Station does not receive any Danger Packet from any node of any field till the Timer 1 fires it again broadcasts the SYNC signal & the same cycles goes on.

- If the Base Station receives any Danger Packet, then it will find out in which field the event has been occurred, then it will check which one of the node has detected the event.

- The Base Station will calculate the best path (considering two factors, Distance & Battery Level. The Algorithm for finding the best path is discussed in detail in another section).

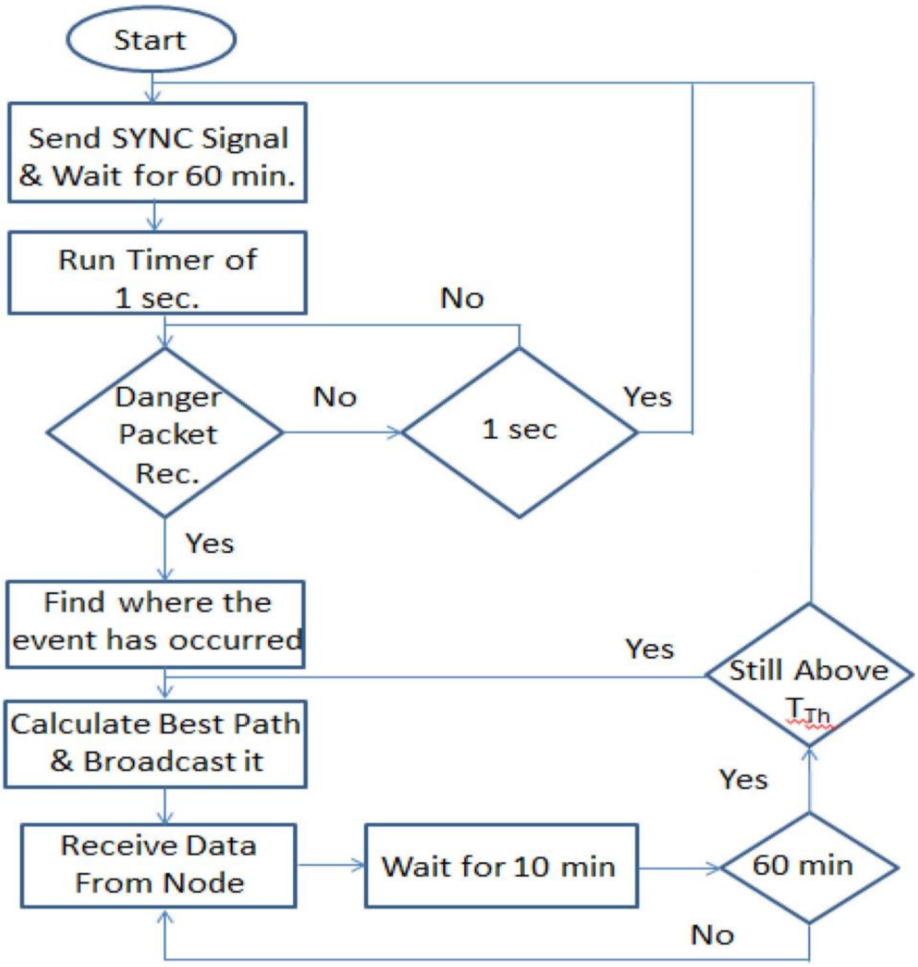
- It will broadcast the best path by encoding it into a packet & it will receive packets from the node which detects the event.

- After receiving this packet for six times, it analyzes the last packet it received from the node.

- It checks whether the surrounding temperature of that node is still above than the threshold temperature or not.

- If it is still above the threshold, the Base Station again calculates the best path & broadcasts it & the same cycle goes on as described above.

- If it is below than the threshold, the Base Station then broadcasts the SYNC signal & the same cycle goes on as described above


Start
Send SYNC Signal & Wait for 60 min.
Run Timer of 1 sec.
No
Danger Packet Rec.
No
1 sec
Yes
Yes
Find where the event has occurred
Yes
Still Above T_{Th}
Calculate Best Path & Broadcast it
Yes
Receive Data From Node
Wait for 10 min
60 min
No

ENERGY CONSUPTION CALCULATION

In the proposed system the transmitting node are two or more and there is only one receiving node which is sink. In other there are three possibility whether the SISO(single input single output) or MISO(multiple input single input). To calculate the per node energy consumption it is required to involve all the circuit and signal processing block involving in the wireless communication link. Some blocks which involve in the communication are avoided in this calculation such as source coding pulse shaping and digital modulation blocks this can be the extension for the future work. It has been also assumed that the wireless system is encoded thus no error correction block has been considered while calculation the energy consumption.

During the calculation of per bit energy consumption during the transmission from the cluster head and the cooperative node to the base station. The energy consumption in clustering and local communication that is the communication within a cluster is neglected because energy consumption in the long haul communication that is the communication from cluster head to the base station is quiet large then the local communication and clustering

Considering the square law path loss model which can be given by:

Pout = Eb* Rb*(4*pi*d)^2*Ml*Mf/Gt*Gr*(lambda)^2

Where Eb represents the per bit energy at the receiver for given BER, Rb is the bit rate, d represents the transmission distance Gt representing the transmitting antenna gain and Gr representing the receiver antenna gain Ml representing the link margin which compensates the hardware process variation noise and interference and
Nf is equal to noise level of receiver circuitry:
= Nr/No

Nr Represents power spectral density of total noise at the receiver and N0 is single sided power spectral density of thermal noise. The value of N0 = -171 dbm⁄Hz at 27 ℃ (Room Temperature).

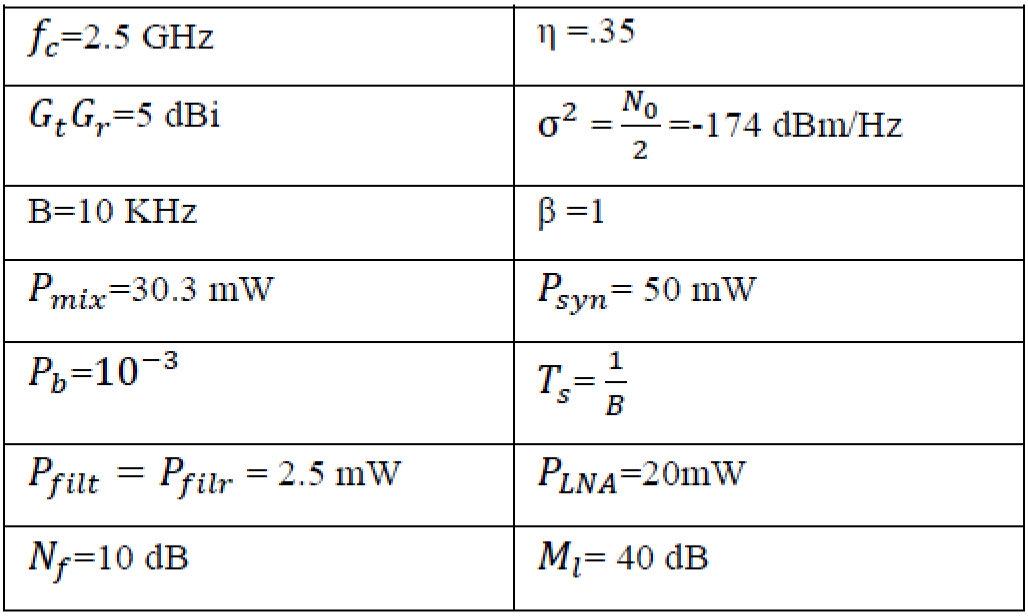
Consider a signal transmitted through free space to a receiver located at a distance d from the transmitter. Assume there are no obstructions between the transmitter and the receiver and that the signal propagates along a straight line between the two. The channel model associated with the model is called line of sight and the corresponding received signal is called LOS signal.

Pt=Pr*(4*pi*d)^2/Gl*(lambda)^2

Where

Gl = The product of transmit and receive field radiation patterns in the LOS direction
Pt= Transmitted Power
Pr = Received Power

System Parameter



f_c=2.5 GHz	η =.35
$G_t G_r$=5 dBi	$\sigma^2 = \frac{N_0}{2}$=-174 dBm/Hz
B=10 KHz	β =1
P_{mix}=30.3 mW	P_{syn}= 50 mW
P_b=10^{-3}	$T_s = \frac{1}{B}$
$P_{filt} = P_{filr}$ = 2.5 mW	P_{LNA}=20mW
N_f=10 dB	M_l= 40 dB

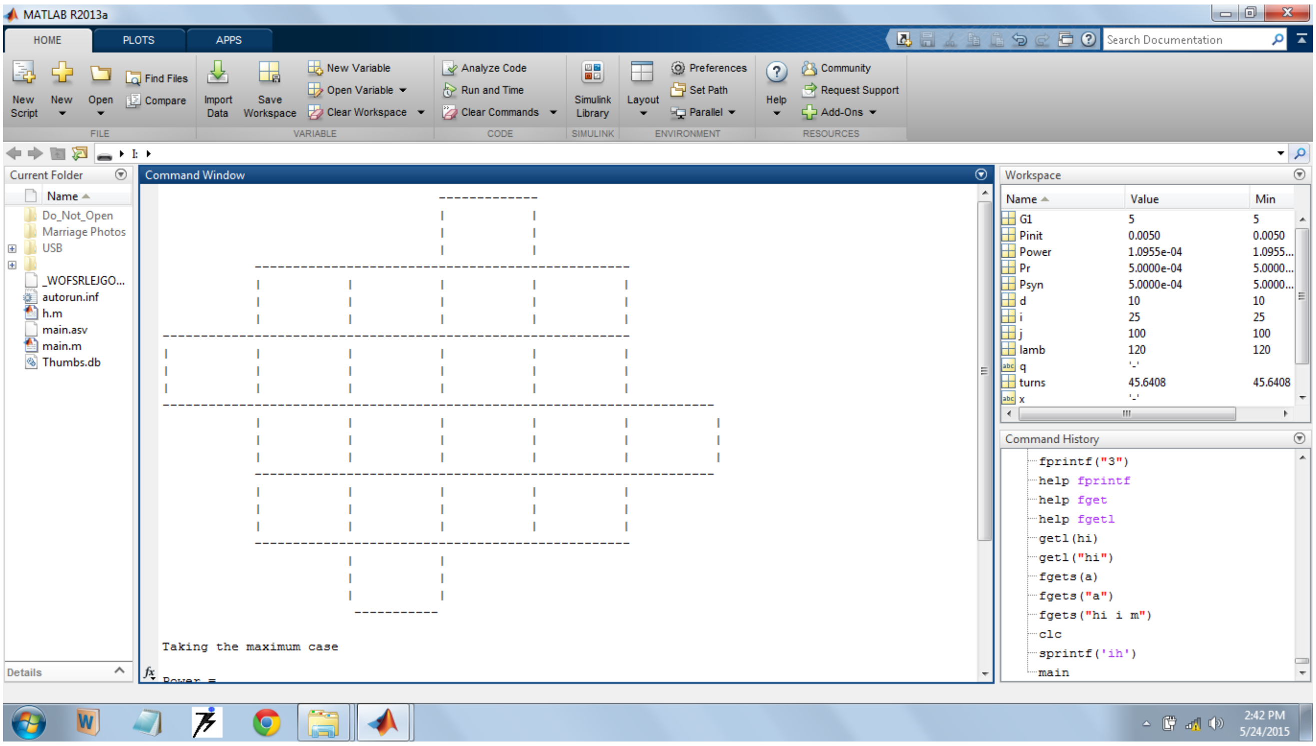
These are the Assumptions that we have considered in our energy calculation for Fire Detection System

MATLAB CODE FOR ENERGY CALCULATION

```
clc;
clear all;
close all;
% t=0:0.00001:0.05;
% y=cos(1000*t).*cos(3000*t);
% plot(t,y);
x=['-'];
y=[' '];
q=['-'];
i=0;
j=0;
z=0;
for i=0:1:25
    for j=0:1:100
        if (i==4  || i == 20)
            if(j>=12 && j<61)
                fprintf(x);
            else
                fprintf(y);
            end
        elseif ( i==8)
            if(j>=0 && j<61)
                fprintf(x);
            else
                fprintf(y);
            end
        elseif ( i==12 )
            if(j>=0 && j<72)
                fprintf(x);
            else
                fprintf(y);
            end
        elseif ( i==16 )
            if(j>=12 && j<72)
                fprintf(x);
```

```
    else
        fprintf(y);
    end



elseif ((i>=4 && i<=7) || (i>=17 && i<=19))
        if (j==12 || j==24 || j==36 ||j==48 || j==60)
            fprintf('|');
        else
            fprintf(y);
        end

elseif ((i>0 && i<=3))
        if (j==36 ||j==48 )
            fprintf('|');
        else
            fprintf(y);
        end
elseif ((i>8 && i<=11))
        if (j==0 || j==12 || j==24 || j==36 ||j==48 || j==60 )
            fprintf('|');
        else
            fprintf(y);
        end
elseif ((i>=13 && i<=15))
        if (j==12 || j==24 || j==36 ||j==48 || j==60 || j==72 )
            fprintf('|');
        else
            fprintf(y);
        end
elseif ((i>20 && i<=23))
        if (j==24 ||j==36 )
            fprintf('|');
        else
            fprintf(y);
        end
```

```
        elseif(i==0)
            if (j>=36 && j<= 48 )
                fprintf(x);
            else
                fprintf(y);
            end
        elseif(i==24)
            if (j>=25 && j<= 35 )
                fprintf(x);
            else
                fprintf(y);
            end

     end
     end
    fprintf('\n');
end

Pinit = .05;
d = 10;
Psyn = .0005;
lamb = 120;
Pr = .0005;
G1 = 5;
turns = 0;
Power = (Pr*(4*3.14*d)^2)/(G1*lamb*lamb);
turns = Pinit/Power;
fprintf(“Taking the maximum case");
fprintf(power);
fprintf("number of rounds each unit will work");
fprintf(turns);
```



```
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                         -----------

Taking the maximum case

Power =
```
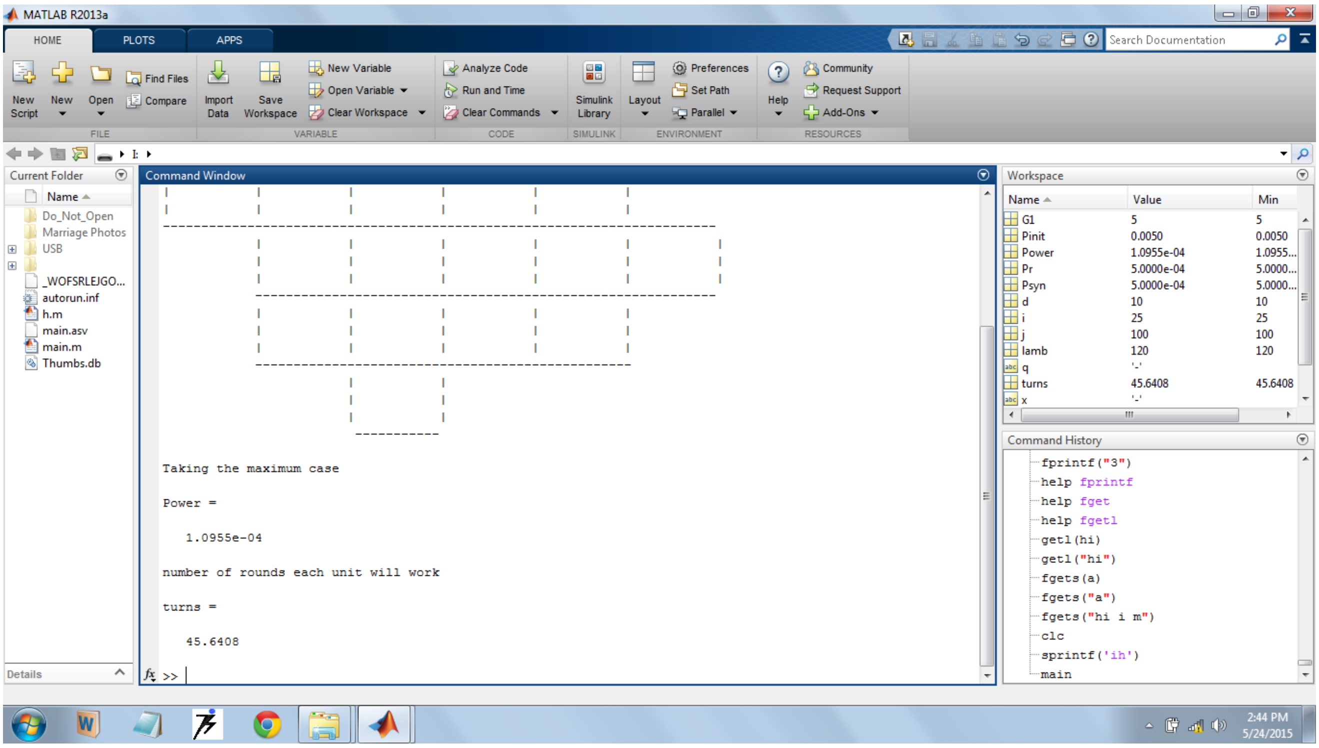

Name	Value	Min
G1	5	5
Pinit	0.0050	0.0050
Power	1.0955e-04	1.0955...
Pr	5.0000e-04	5.0000...
Psyn	5.0000e-04	5.0000...
d	10	10
i	25	25
j	100	100
lamb	120	120
q	'-'	
turns	45.6408	45.6408
x	'-'	

```
fprintf("3")
help fprintf
help fget
help fgetl
getl(hi)
getl("hi")
fgets(a)
fgets("a")
fgets("hi i m")
clc
sprintf('ih')
main
```

SQUARE GRID



```
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                        |           |
                        |           |
                         -----------

Taking the maximum case

Power =

   1.0955e-04

number of rounds each unit will work

turns =

   45.6408

>> 
```
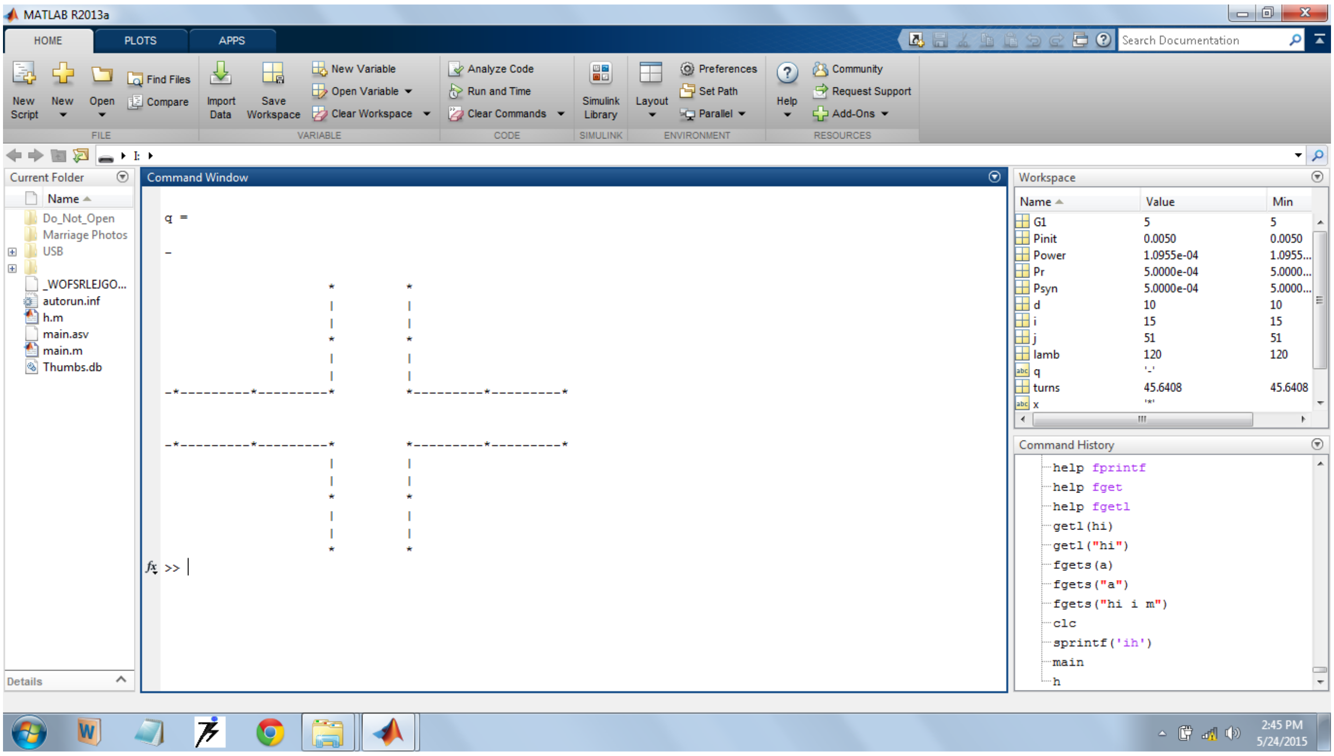

Name	Value	Min
G1	5	5
Pinit	0.0050	0.0050
Power	1.0955e-04	1.0955...
Pr	5.0000e-04	5.0000...
Psyn	5.0000e-04	5.0000...
d	10	10
i	25	25
j	100	100
lamb	120	120
q	'-'	
turns	45.6408	45.6408
x	'-'	

```
fprintf("3")
help fprintf
help fget
help fgetl
getl(hi)
getl("hi")
fgets(a)
fgets("a")
fgets("hi i m")
clc
sprintf('ih')
main
```

ENERGY CALCULATIONS



Do_Not_Open
Marriage Photos
USB
_WOFSRLEJGO...
autorun.inf
h.m
main.asv
main.m
Thumbs.db

```
q =

-

                     *         *
                     |         |
                     |         |
                     *         *
                     |         |
                     |         |
-*---------*---------*         *---------*---------*


-*---------*---------*         *---------*---------*
                     |         |
                     |         |
                     *         *
                     |         |
                     |         |
                     *         *
>> 
```

Name	Value	Min
G1	5	5
Pinit	0.0050	0.0050
Power	1.0955e-04	1.0955...
Pr	5.0000e-04	5.0000...
Psyn	5.0000e-04	5.0000...
d	10	10
i	15	15
j	51	51
lamb	120	120
q	'-'	
turns	45.6408	45.6408
x	'*'	

```
help fprintf
help fget
help fgetl
getl(hi)
getl("hi")
fgets(a)
fgets("a")
fgets("hi i m")
clc
sprintf('ih')
main
h
```

SINGLE UNIT

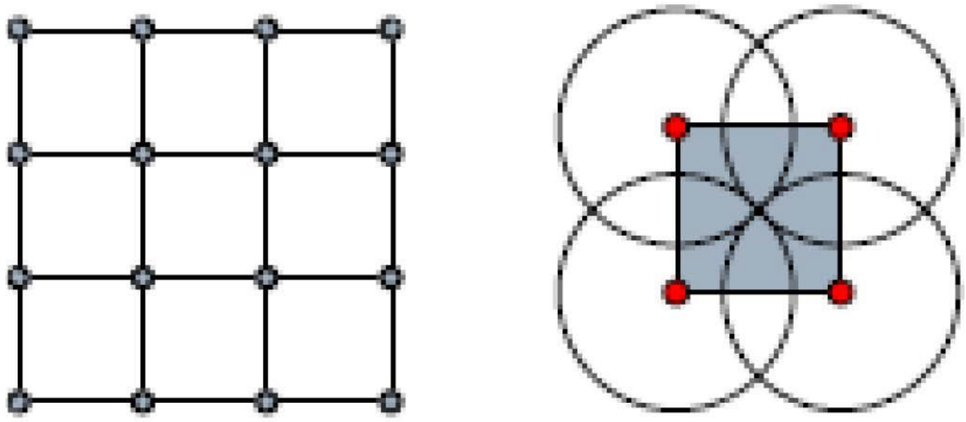
RESULT

SQUARE VS HEXAGONAL

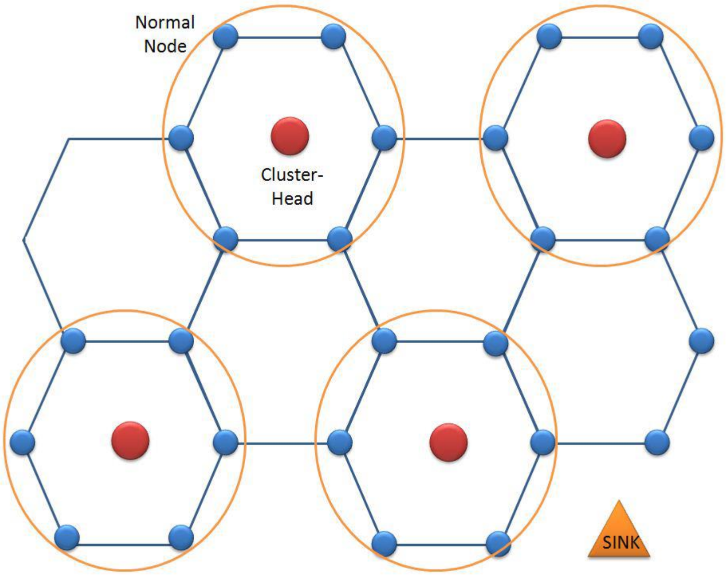
In the proposed framework, less number of nodes will be required for square grid as compare to hexagonal. Less overlapping is occurred in square grid as compare to hexagonal and therefore it performs better than the hexagonal.

For comparing hexagonal and square grid, we have taken area verses number of nodes. In this graph we can see the difference between numbers of node in both cases. For a small region the difference is minor however for a large area there is huge difference between numbers of nodes in both cases.

Hence, it proves that square grid is much better than hexagonal grid.



SQUARE GRID



HEXAGONAL GRID

CONCLUSION

The objective is to propose a comprehensive analysis that covers all parts of the life cycle of a wireless sensor network particularly for forest fire detection and monitoring. Apart from early detection of forest fire, we also have an attempt to construct a framework that considers the low energy capacity of the sensor nodes. Beginning from the wireless sensor node deployment, various design decisions are assessed considering the system goals. Furthermore, our framework presents significant data to the base station during the occurrence of fire explosion which will help fixing the forecast procedure of forest fire. Sensor nodes deployed in a hieratical fashion and a data aggregation method is applied for making fewer messages overhead during transmission.

Furthermore, since the nodes that is closer to the sink need to forward messages more frequently and consume more energy. Communication protocols preserve the goal of balanced energy consumption and it provides each node sends about the same amount of messages at each period.

FUTURE WORK

After finding out the energy consumed by the system to transfer the detection from affected area to Cluster Head, in future we will find out the energy required to transfer the information from Cluster Head to the Base Station(sink).

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