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Wireless Sensor Networks for Disaster Management

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Abstract- **World is a happening ground for the disasters almost daily. These incidents of mass destruction irrespective of the whether natural calamities or man-made catastrophes cause a huge loss of money, property and lives due to non-planning on the part of the governments and the management agencies. Therefore steps are required to be taken towards the prevention of these situations by pre determining the causes of these disasters and providing quick rescue measures once the disaster occurs. Wireless Ad hoc sensor networks are playing a vital role in wireless data transmission infrastructure and can be very helpful in these situations. Wireless sensor networks utilize the technologies which can cause an alert for the immediate rescue operation to begin, whenever this disaster is struck. Through this paper our aim is to review technological solutions for managing disaster using wireless sensor networks (WSN) via disaster detection and alerting system, and search and rescue operations. We have first discussed the basic architecture of WSNs that can be helpful in disaster management and the wireless sensor network models that can be employed for the different disaster situations. Finally, we propose how these networks can be effective in Indian scenario which lags behind the developed world in basic infrastructure amenities.**

Keywords: Wireless Sensor Networks, cluster, Sink Node, GRNN, Intelligent Drought Decision System.

I. INTRODUCTION

Global climate change is increasing the occurrence of extreme climate phenomenon with increasing severity, both in terms of human casualty as well as economic losses. Authorities need to be better equipped to face these global truths. An efficient disaster detection and alerting system could reduce the loss of life and properties. In the event of disaster, another important issue is a good search and rescue system with high level of precision, timeliness and safety for both the victims and the rescuers. Recently, Wireless Sensor Networks (WSNs) have become mature enough to go beyond being simple fine-grained continuous monitoring platforms and become one of the enabling technologies for disaster early-warning systems.

Event detection functionality of WSNs can be of great help and importance for (near) real-time detection of, for example, meteorological natural hazards and wild and residential fires.

Figure1 shows a wireless sensor network, where each cluster in network architecture consists of four ad-hoc relay stations [1]. The sensor nodes within each cluster are surrounded by ARS and in middle the head node is responsible for communicating with all the nodes within the sensor field. Each cluster with in a network is directly interfaced with Sink node that is responsible for maintaining communication path between head nodes within each cluster towards base station. The base station uses UMTS based or Wimax based communication system that is responsible to transfer disaster affected information from cluster based network architecture towards emergency response Centre [2].

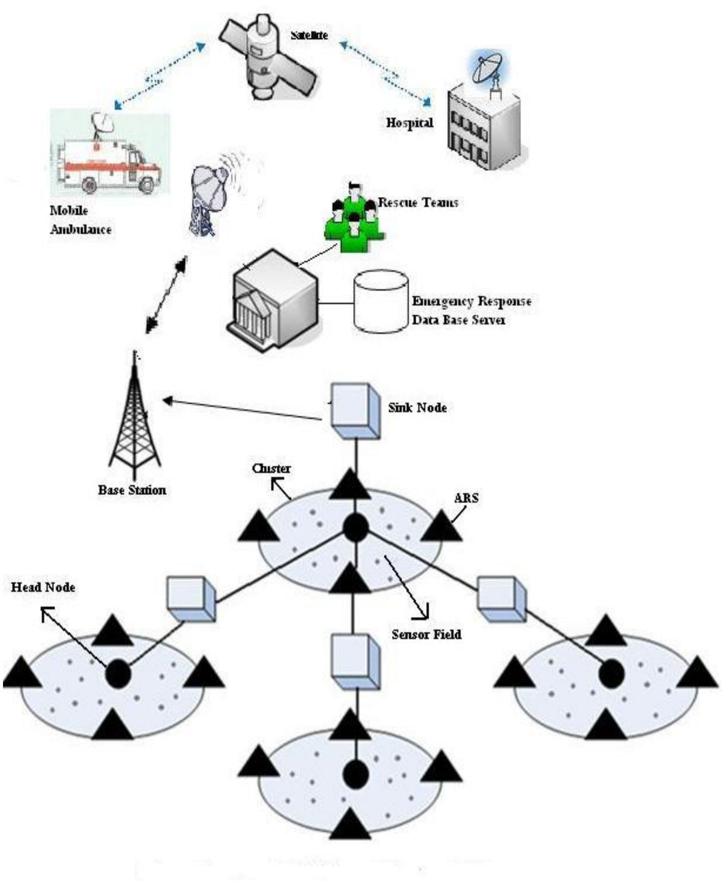

Fig.1.Wireless Sensor Network Architecture for disaster survivor detection

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The Emergency response authority at the emergency operations centre dispatch Emergency rescue teams towards the point of need with in a limited time span for mission critical applications. The Emergency response data base centre further route this information via satellite broadcast Antenna towards Satellite Station.

The Satellite communication infrastructure is responsible for transferring the disaster related information towards Mobile Ambulance and Hospital which will be responsible to provide urgent Medical needs including medical first aid services using this Telemedicine based infrastructure [3].

II. DIFFERENT WSN ARCHITECTURES

A. Wireless Sensor Network for Flood and Water Level Monitoring System

Each year floods cause loss of thousands of lives and billions worth of property in India. Last year, major loss of human lives, cattle as well as billions worth of establishments was reported in the floods in Bihar and West Bengal. Each year both Ganga and Yamuna break their boundaries and cause numerous losses. Although all these losses cannot be eradicated fully but the losses to lives and property can be reduced to barest minimum level, if the protective measures can be taken before the disaster has struck in the form of flash floods. This can be made possible with the help of communication technology employed on top of wireless sensor networks. The system development involves the various phases and of course, all phases are equally important. Starting with the first phase of data collection, level one is to deal with the physical deployment of sensing devices in the riverbanks and implementation of an effective localization scheme depending on the situation and environment. The flow path of the river, past records of water flow and future prediction of the route of the river, influence the placements of the wireless sensors. These sensors form clusters to communicate with the local base stations. The local base stations are powerful enough to communicate with one another directly using wireless communications.

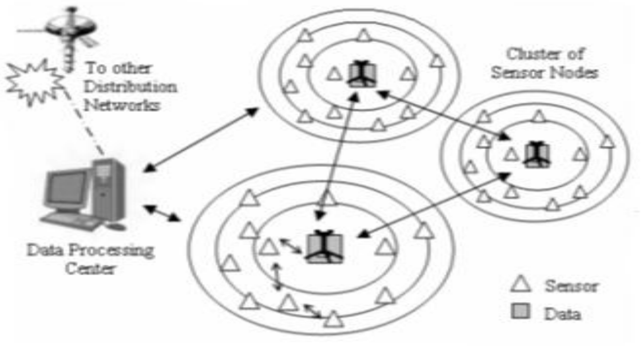

Fig.2 Data collection and aggregation in wireless sensor network

The data sent from the sensors are aggregated in the local base stations to provide as inputs to the data processing centers. Fig.2 shows a pictorial view of the deployment of sensor nodes and data aggregation [5].

Level two deals with the setup of local base stations as well as with data communication at district level. Level three could be involved with the central monitoring system at the headquarters to process acquired data. Data analysis then takes place either at headquarter or at outside research centers that particularly do high-risk flood analysis. Fig.3 shows various phases used for monitoring system.

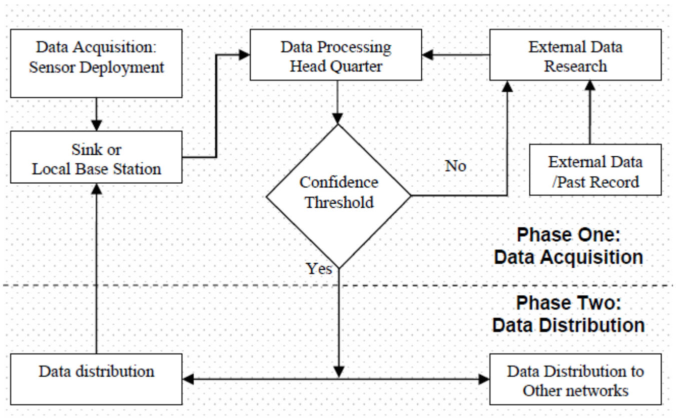

Fig.3 Smart System aided with Wireless Sensor Network

B. Wireless Sensor Network for Forest Fire Detection

Forest house millions of rare species of animals, birds and insects. Forest fires cause not only the loss of their shelters but also cause huge loss to flora and fauna. Forest fires are common in the middle ranges of Himalayan region of India due to

Lightening , excessive heat or carelessness on the part of local natives. There has been numerous occasions when the forest fires broke out due to the negligence of the natives in Uttarakhand, Chhattisgarh, and north-eastern states. Last year, southern Australia bore the brunt of ravaging forest fires, but the losses to the human lives were minimized on account of adequate evacuation steps taken well in time. Although it is almost impossible to put off raging fires, but the calamity can be averted provided the information about the site of the fire can be immediately sent to the nearest control centre and adequate measures be taken to control it, before it engulfs everything. A large number of sensor nodes are densely deployed in the forest. These sensor nodes are organized into clusters so that each node has a corresponding cluster header. Sensor nodes can measure environment temperature, relative humidity and smoke. They are also assumed to know their location information by equipment's such as Global

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Positioning System GPS. Every sensor node sends measurement data, as well as the location information, to the corresponding cluster head. The cluster header calculates the weather index using a neural network method and sends the weather index to the manager node via sink. The sink is connected to a manager node via a wired network. A few wind sensor nodes are manually deployed over the forest and connected to the sink via wired networks to detect wind speed [6].

The manager node provides two types of information to users:
(1) Emergency report for abnormal event (e.g. smoke or extremely high temperature is detected); (2) real-time forest fire danger rate for each cluster based on the weather indexes from the cluster header and other forest fire factors.

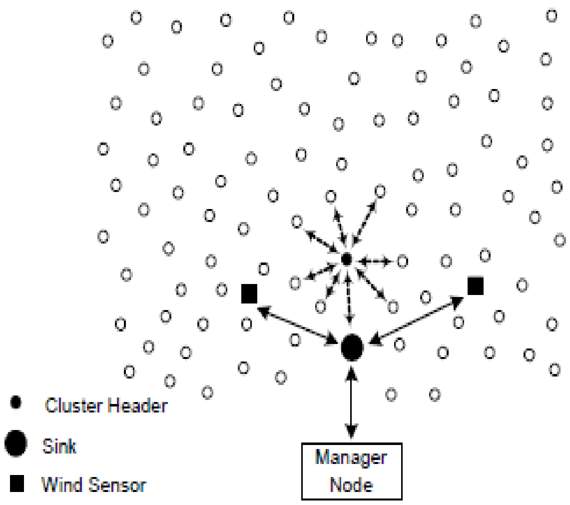

Fig.4 A wireless sensor network for real-time forest fire detection

C. Wireless Sensor Network for Earthquake Sensing

Mass destruction of human lives and property happens when earthquake strikes. The most ferocious earthquake that happened in India was on 26th January, 2001 that rattled not only India, but the other neighbouring countries like Pakistan, Afghanistan and Iran also couldn't escape its fury. Lakhs lost lives, limbs and cattle and loss to the property was unaccountable. Though loss to the property cannot be ruled out, but many precious human lives can be saved by timely action. System architecture for our approach has been shown in Fig.5 each sensor detects earthquake event every sampling period based on seismic frequency spectrum. To handle the earthquake dynamics such as highly dynamical magnitude and variable source location, each sensor maintains separate statistical models of frequency spectrum for different scales of seismic signal energy received by sensor [7].

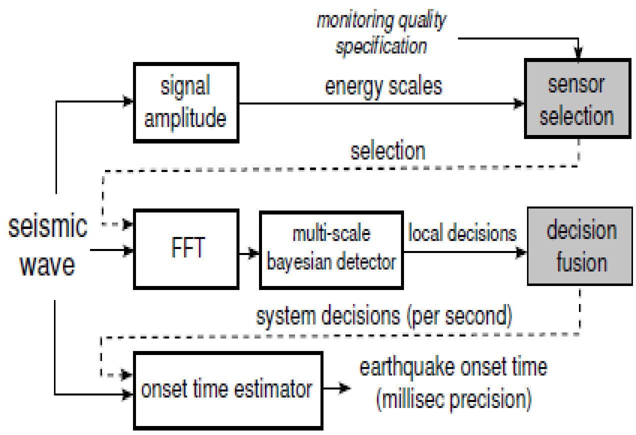

Fig.5 System Architecture White blocks are the components at a sensor; shadowed blocks are the components at the base station; solid line represents data flow; dotted line represents control flow

Various studies indicate that the frequency-based detector has better detection performance when the sensor receives higher signal energy [8]. Therefore, it is suggested that, the base station first selects a minimal subset of informative sensors based on the signal energies received by sensors while satisfying system sensing quality requirements. The selected sensors then compute seismic frequency spectrum using Fast Fourier Transform (FFT) and make local detection decisions which are then transmitted to
the base station for fusion. In addition to the detection of earthquake occurrences, node-level earthquake onset time is critical for localizing earthquake source. In this approach, the base station first identifies an individual earthquake and estimates a coarse onset time [9].

D. Wireless Sensor Network for Tsunami Detection

The wounds are still fresh onto the hearts of all those survivors who lost their near and dear ones in 2004 Tsunami which ravaged the complete east coast of India. It is estimated that tens of thousands of people died in that event only in India and lakhs in other countries of Asia.

Even recently, almost 32 countries throughout the world were put on alert, when an earthquake of 8.9 measure on Richter Scale struck in Indian Ocean. Thanks to the effective monitoring system, an alert was sounded and more coastal areas were evacuated. Though Tsunami is not a common sight in India when compared with Japan, Indonesia, Vietnam and Thailand, yet it is wiser to be alert rather than repenting after the tragedy. A system for tsunami detection and mitigation using a wireless ad hoc sensor network defines three types of nodes: *sensor*, *commander*, and *barrier*. A relatively large number of sensor nodes collect underwater pressure readings across a coastal area. This data is reported to commander nodes which analyses the pressure data and predict which, if any, barriers need to fire. Although it is impossible to completely stop a tsunami, we propose using a number of barriers which may be engaged to lessen the impact of the wave. Fig.6 illustrates the architecture of a prototype system that can be implemented as live-model up to a level of perfection and satisfaction. Fig.6 depicts a sensor network consisting of 80 underwater sensors (Sensor1-Sensor80) that are connected to two commander nodes which are in turn connected to four barriers (Barrier1-Barrier4).

An algorithm as suggested by K. Casey, A. Lim, and G. Dozier et.al. has been implemented [10] which uses a general regression neural network (GRNN) [11] as prescribed by D. Specht, to predict the path of the wave. The GRNN analyzes the pressure data from sensor nodes and predicts which barriers should fire to most effectively impede the tsunami. It also uses a real-time response mechanism for diffusion. This protocol is inspired by RAP [12] predicted by C. Lu, B. Blum, T. Abdelzaher, J. Stankovic, and T. He but does not require location information.

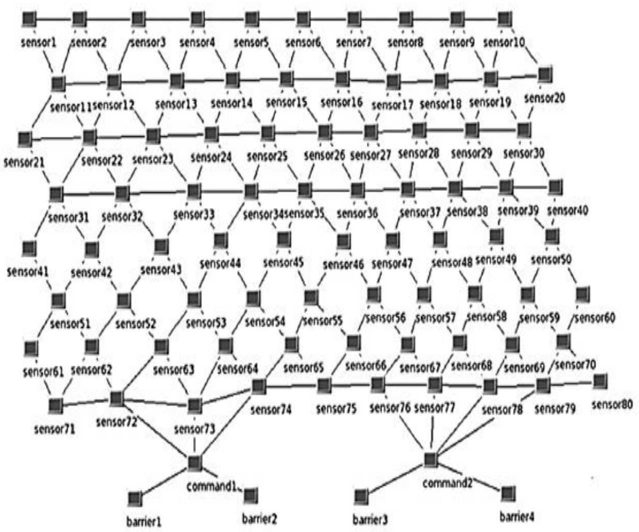

Fig.6 Tsunami detection and response system architecture

E. Wireless Sensor Network model for Drought Forecast

More irrigation techniques have almost got over the problem of drought, but like many other developing and under-privileged countries, India too is dependent on rain gods for the seasonal rains to meet their requirements of water for irrigation purposes. A mechanism has been suggested by Hsu-yang kung, jing-shiuan hua and chaur-tzuhn chen to forecast the drought by the means of wireless sensor networks. The suggested model is based on an intelligent system called Drought Forecast and Alert System (DFAS), which is a 4-tier system framework composed of Mobile Users (MUs)[13], Ecology Monitoring Sensors (EMSs), Integrated Service Server (ISS), and Intelligent Drought Decision System (ID2S). DFAS combines the wireless sensor networks, embedded multimedia communications and neural network decision technologies to effectively achieve the forecast and alert of the drought. DFAS analyzes the drought level of the coming 7th day via the proposed drought forecast model derived from the Back-Propagation Network algorithm.

The drought inference factors are 30 day accommodated rainfall, daily mean temperature, and the soil moisture to improve the accuracy of forecasting drought [14]. These inference factors are detected, collected and transmitted in real-time via the Mote sensors and mobile networks. Once a region with possible drought hazard is identified, DFAS sends altering messages to users' appliances. System implementation results reveal that DFAS provide the drought specialists and users with complete environment sensing data and images. DFAS makes it possible for the relevant personnel to take preventive measures, e.g., the adjustment of agricultural water, for a reduced loss.

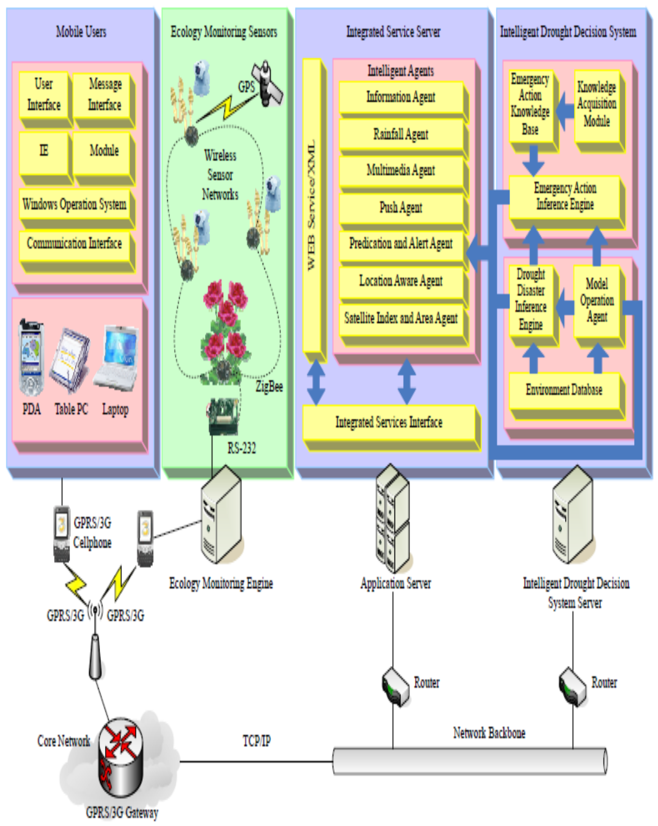

Fig.7 Drought forecast and alert system and network architecture

III. SAHANA: OVERVIEW OF A DISASTER MANAGEMENT SYSTEM

Sahana is a Free and Open Source Software (FOSS) application that aims to be a comprehensive solution for information management in relief operations, recovery and rehabilitation**.** The Sahana project has proved without a doubt the viability of FOSS solutions for humanitarian applications. More significantly, a disaster typically requires the coordination of multiple clients; hence Sahana has also provided a platform for inter-organizational data sharing during a disaster. There is much left to be for the technical development of FOSS as much sought disaster management software as the primary functional requirement is the need to deal with heterogeneity of data types (text, semi structured, Web HTML and XML, GIS, tabular and DBMS), and secondary functional requirement is to develop standards and protocols for data sharing [15]. Policies for data security and privacy during the different phases of a disaster have to be developed to provide robust performance and finally be able to provide additional capabilities as the communications infrastructure is restored. Real time response may be needed for some modules such as mobile messaging and situation control.

IV. CONCLUSION

Wireless sensor networks (WSNs) have attracted significant attention over the past few years. As technology emerges over the decades, WSN has come to the spotlight for its unattained potential and significance. We observe that these wireless sensor network architectures serves us a lot in predetermining the causes of the natural as well as man-made disasters and providing rescue and preventive measures if somehow any area is struck by these disasters. Hence these structures help in protecting many precious human as well as animal lives that would have been destined to perish from the effects caused by these disasters.

WSNs not only contributes in saving human lives but also plays an important role in conserving our unique flora and fauna consisting of many plants and biological micro-organisms, which are important for the survival of humans, by alerting us from the dangers of forest fires. Finally we conclude by stressing on the need to survey the state of the research and classified the different schemes. We developed taxonomy of relevant attributes and categorized the different schemes according to the objectives, the desired cluster properties and clustering process. We highlighted the effect of the network model on the pursued approaches and summarized a number of schemes, stating their strength and limitations. These technologies have produced very effective results, once put to use in the deploy these wireless sensor networks for mission critical applications. In this paper, we developed countries like USA, Germany, France and England but in India there is still a lot to be done in this field as all these protective networks need huge investments and manpower for these dreams to become reality in India.

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