Wireless Sensor Network for Disaster Management

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Abstract—**Wireless Sensor Networks (WSNs) is an emerging technology with a wide range of applications. Depending upon the applications, different wireless technologies are used for making WSNs such as ZigBee etc. WSNs have a number of advantages like no cabling required etc. The major drawback of WSNs is that they are application oriented which can be overcome by the concept of virtualization.**

***Index Terms*—ADC, FFD, RFD, ICT, IEEE, IoT, VSN, WSN, ZC, ZR, ZED**

I. INTRODUCTION

A wireless sensor network is a collection of sensor nodes organized into a cooperative network. These sensor networks are spatially distributed to monitor the physical and environmental conditions such as temperature, pressure, sound, motion, vibration etc [3].

The architecture of Wireless Sensor Network is shown below:

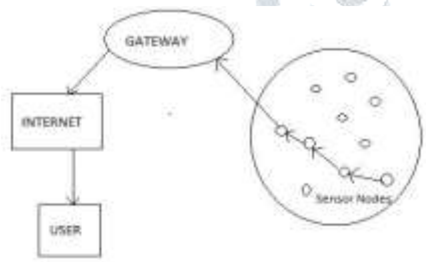

Figure 1: Architecture of Wireless Sensor Network

Sensors collect data from the environment and pass it to the base station, which in turn pass the data to the remote user via internet.

II. SENSOR NODE

A sensor node consists of a sensing unit, a processing unit, a transmission unit and a power unit [3].

Data collected from environment is in analog form which is then converted into digital form by analog- to-digital converter (ADC). The digital data is then processed and stored in processor's memory. When needed the data in transferred to the base station by low-power radios. The sensor node is generally battery operated.

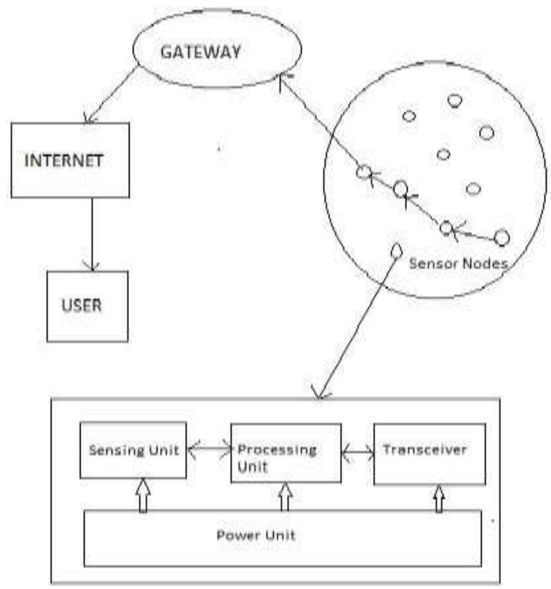

Figure 2: Components of Sensor Node

III. WIRELESS TECHNOLOGIES

As the applications of WSNs are increasing different WSN standards have been developed to enhance network efficiency [2]. These are:

a) Bluetooth
b) Wi-Fi
c) ZigBee

Table 1: Comparison of Wi-Fi, Bluetooth and ZigBee wireless technologies

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Features	Wi-Fi IEEE 802.11	Bluetooth IEEE 802.15.1	ZigBee IEEE 802.15.4
Application	Wireless LAN	Cable replaceme nt	Control and monitor
Frequency bands	2.4GHz	2.4GHz	2.4GHz,868MHz,915 MHz
Battery life(days)	up to 5	up to 7	100-7000
Nodes per network	30	7	65000
Bandwidth	2-100Mbps	1Mbps	20-250Kbps
Range(meters)	up to 100	up to 10	75 and more
Topology	Tree	Tree	Star,Mesh,Cluster tree
Standby current	20mA	200µA	3µA
Memory	100KB	100KB	32-60KB

Of course, selection of a particular standard depends on certain factors such as target application requirements, network size, network environment and network duration.

IV. ZigBee Technology

ZigBee is the most popularly deployed wireless technology because ZigBee is low-cost, low–speed, low-power protocol that allows operability between systems. It is based on IEEE 802.15.4 protocol. Its main application is home/industry automation and monitoring systems.

A. ZigBee Device Types

ZigBee Devices are of two types: full-function device (FFD) and reduced-function device (RFD). ***FFD*** perform all the tasks defined by ZigBee standard. It can form any type of network (star, mesh and cluster tree). ***RFD*** has limited functions. It can only connect to an FFD. With respect to these functionalities, ZigBee devices are classified as Coordinator, Router and End Devices.

1) ZigBee Coordinator (ZC)

It is an FFD. There is only one coordinator in a network. It is responsible for starting the network and its overall management. Other functions of ZC includes: (i) address allocation (ii) granting permission to nodes to join or leave (iii) transfer application packets (iv) keep list of neighbor tables. An FFD must always be powered ON.

2) ZigBee Router (ZR)

It is also an FFD. It can be one or more depending upon size of network and network topology. It is not required in Star topology. It performs all the functions of coordinator except network establishment. Like ZC constant power supply is provided to ZR.

Out of the above mentioned three topologies, Mesh topology is mostly preferred because it allows multi-hop communication [5]. Topology of a ZigBee network may change as node moves from one point to another. Topology affects the correctness and accuracy of sensor readings, ease of network implementation and network security.

3) ZigBee End Devices (ZEDs)

They are RFDs. They are located at the extremities of the network. Their main task is sending & receiving of data packets. When they are not transmitting/receiving data, they go to sleep mode. This saves power.

B. ZigBee Network Topologies

Three network topologies are specified for ZigBee network: Star, Tree and Mesh [4]. These topologies are explained below:

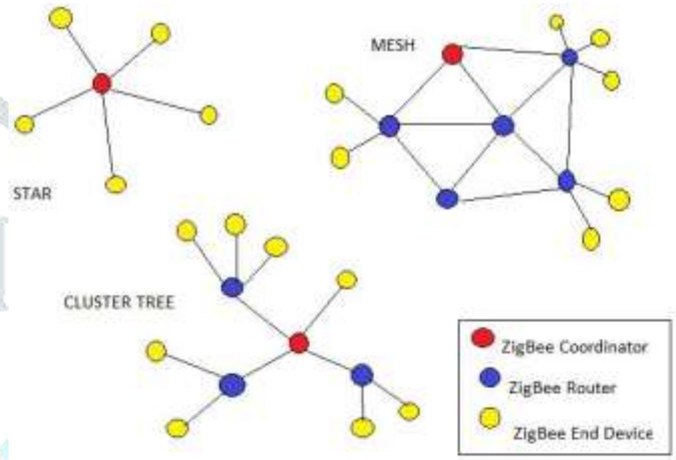

Figure 3: ZigBee network topologies: Star, Mesh, Cluster Tree

1) Star Topology

There is a coordinator and several end devices. There is no router. These end devices can communicate with each other through coordinator. Since all transmission and reception go through the coordinator, this increase burden on the coordinator and may cause network congestion. The main advantage of this topology is its simplicity.

2) Tree Topology

In this topology, coordinator is connected to router and end devices. Router is used to extend the network so a router may connect to several other routers and/or end devices. Like in star topology, there are no alternative paths to destinations in this topology, so if a parent node fails, its children cannot communicate with other nodes in the network.

3) Mesh Topology

In this topology, coordinator is the head. There are several routers to extend the network and also to provide multiple hops from source to destination. It is also known as peer-to-peer multi-hop network. Here, alternative paths are available to reach destination if in case regular paths fail. For this reason we say mesh is a self-healing network.

C. ZigBee Applications

ZigBee find applications in a variety of a variety of personal area networked systems [2] such as:

1) Home Automation: ZigBee can be used to remotely control home doors and lightings.

2) Commercial Building Automation: With ZigBee all the smoke detectors in a building can be remotely monitored and managed from a central location.

3) Smart Energy: ZigBee enables reading of water, gas and electrical meters remotely.

4) Health Care: ZigBee enables remote monitoring of patients in hospitals and health care centers.

5) Industrial Process Monitoring and Control: With ZigBee industrial processes are now being controlled and monitored wirelessly.

6) Remote Control for Consumer Electronics: Most remote controllers for consumer electronics now uses radio frequency (RF) with the help of ZigBee technology.

7) Telecommunication Applications: ZigBee devices are embedded in smart phones, thus enabling communication with other ZigBee enabled devices.

D. Challenges for Wireless Sensor Network

Despite their countless practical applications, wireless sensor network faces numerous formidable challenges [2]:

1) *Energy Limitation: Wireless sensor nodes are powered with batteries and replacing batteries in the field is often not practicable.*

2) *Self-Management:* WSNs are usually deployed in remote and harsh environmental conditions, often without any infrastructural support for repair and maintenance. Therefore, the need to build a self-managed WSN network becomes a necessity.

3) *Connectivity Challenge:* If the distance between sensor nodes and base station increases, transmission power increases and signal strength decreases. Therefore, for energy and connectivity efficiency large distances should be split into several shorter distances and multi-hop communication should be used.

4) *Decentralized Management:* Another challenge to WSN is that topology management and routing functions are not centralized.

5) *Privacy and Security:* It is a well known fact that WSNs are located at remote, unattended and hostile environments, and information collected by sensor nodes is sensitive so privacy and security is a big challenge.

V. THE CONCEPT OF VIRTUALIZATION

Though WSN nodes have the capability of interacting with the environment for collection of information, perform computations and then communicating that information to the base station where the information is then used to predict occurrence of disaster and any natural or man-made calamity; but there is one major drawback associated with WSNs and that is WSNs are domain-specific and application-oriented. They are designed for a particular task and cannot be reused in any other application. Using the concept of ***Virtualization***, multiple applications may run simultaneously on single WSN infrastructure [1]. It actually creates abstraction of actual physical computing resources into logical units. Thus efficient utilization of WSN deployments can be made.

A. Classification of WSN Virtualization

WSN virtualization can be broadly classified into two categories namely, node-level virtualization and network-level virtualization.

B. Node-Level Virtualization

In node-level virtualization multiple applications run their tasks simultaneously on a single sensor node. There are two ways to achieve node-level virtualization namely, sequential execution and simultaneous execution [1].

1) Sequential Execution: As the name might suggest, in sequential execution different tasks are executed sequentially i.e. one at a time. Obviously, this is time consuming, other applications will have to wait in queue.

2) Simultaneous Execution: In this approach, different tasks run concurrently on time-division basis with rapid switching from one task to another, thus it appears as if all the tasks are executed simultaneously. The obvious advantage of this approach is that application tasks that take less time to execute will not be blocked by longer running application tasks. The disadvantage is that its implementation is comparatively complicated.

C. Network-Level Virtualization

In network-level virtualization, virtual sensor networks (VSNs) are formed. A VSN consists of a subset of WSN nodes that is dedicated to a particular application. Remaining WSN nodes may be used for other applications. There are two ways to achieve network-level virtualization namely, multiple VSNs over single WSN and single VSN over multiple WSNs [1].

1) Multiple VSNs over Single WSN: In this approach, multiple VSNs are created over the same underlying WSN infrastructure as shown below:

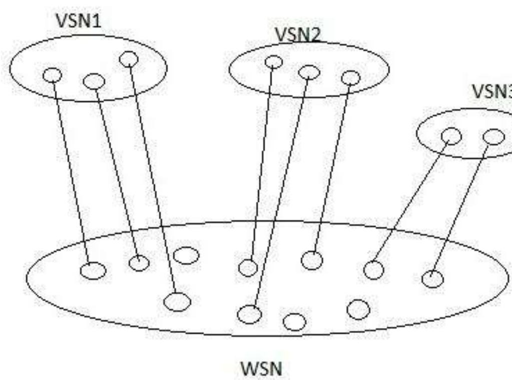

Figure 5: Multiple VSNs over Single WSN

2) Single VSN over Multiple WSNs: In this approach, a VSN is composed of nodes from different WSNs as is shown in figure below:

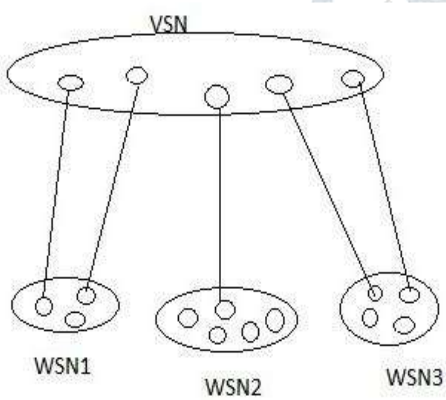

Figure 6: Single VSN over Multiple WSNs

VI. WSN FOR DISASTER MANAGEMENT

The use of WSNs is no longer limited to environment monitoring; in fact they are used in disaster early-warning systems. Architecture of wireless sensor network for disaster detection [10] is given below:

Figure above shows a WSN consisting of clusters of sensor nodes. Each cluster is surrounded by four ad hoc relay stations (ARS). The function of ARS is to monitor the movement of sensor nodes from one cluster to another cluster. In each cluster there is a head node called cluster head which is directly connected with sink node. Sink node is responsible for maintaining a communication path between cluster head and base station. Base station transfers disaster related information to emergency response center. Emergency response center dispatch rescue team to the site of disaster. Through satellite communication disaster related information is also sent to the nearby hospital for providing first-aid and ambulance service at the site of disaster.

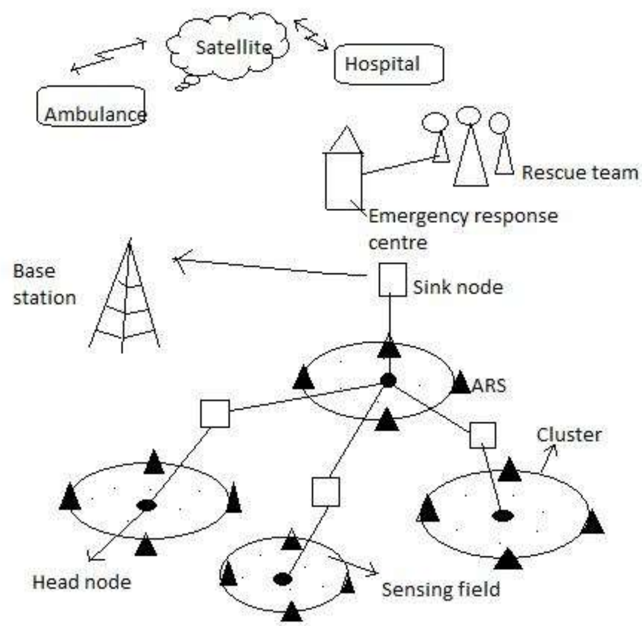

Figure 7: Wireless sensor network architecture for disaster detection

A. *ICT for Disaster Management*

Information and Communication Technology (ICT) is changing every aspect of human life [7]. It enhances the quality and effectiveness of trade, manufacturing, services, other aspects of human life such as education, research, culture, entertainment, communication, national security, etc. IT pays crucial role in disaster management to decrease damage and save the life of people. The advanced techniques of information technology such as remote sensing, satellite communication, GIS, etc. can help in planning and implementation of disaster management.

- *Internet* provides a useful platform for disaster mitigation communications
- *Geographic information technology* tools like Geographic Information Systems (GIS) and Remote sensing (RS) support all aspects of disaster management:

- Hazard Mapping
- Threat Maps
- Disaster Management
- Records Management

- An advance *system of forecasting, monitoring and issuing early warnings* plays the most significant part in determining whether a natural hazard will assume disastrous proportions or not

- *Satellite radio* can play a key role during both the disaster warning and disaster recovery phases. Satellite radio can also be of help when the transmission towers of the normal radio channels are damaged in a disaster.

B. IoT-based Proposal

An IoT-based solution is proposed to effectively maintain communication even after disasters. In this context, it is proposed to incorporate a disaster mode in all the mobile phones. Whenever traditional cellular network is out of service, mobile phone will automatically switch to disaster mode and start D2D communications. This will allow sending disaster messages or placing voice calls to the concerned people. The entire process is done using a pre-installed application that is triggered once the necessity for D2D communication is decided, i.e. when traditional cellular network goes out of service for a certain interval of time called beacon interval. When any device recognizes restoration of traditional network, ad hoc D2D network ceases to work and all the allocated resources will be released to normal condition.

During D2D communications, an ad hoc network is formed in which some of the devices act as relay or gateway agent. These relay agents connect the affected area with the rest of the world using Wi-Fi or satellite link. These relay agents are chosen on the basis of following cost functions:

- Device residual energy

- Computational power

- Signal-to-Noise Ratio (SNR) i.e. Interference from surrounding devices

- Bandwidth availability

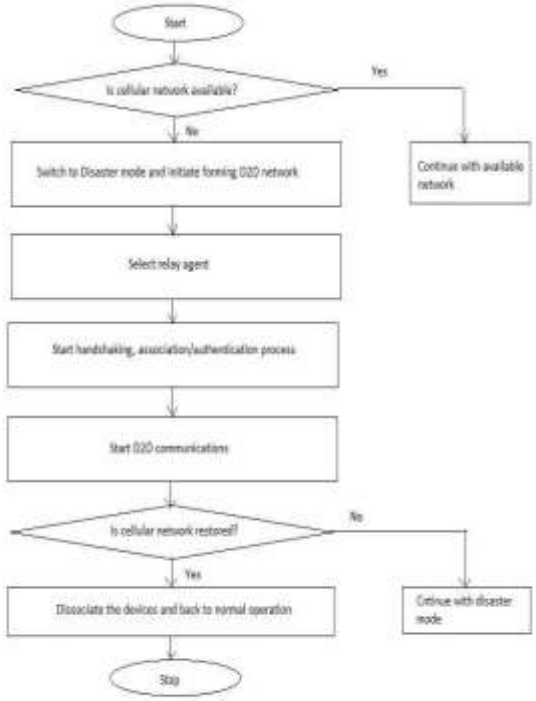

Figure 8: Flowchart for ad hoc network formation

VII. Conclusions and Future scope

WSNs can be applicable for thousands of potential applications like disaster management. As a result of its attractive features, ZigBee is the preferred technology for wireless sensor networks. Virtualization is a technique for efficient utilization of WSNs which enables capturing multiple events using the same WSN infrastructure. ICT is an effective way of mitigating the impact of future disasters. IoT is a promising technology for post-disaster management.

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