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A Novel Semantic IoT based Model using dynamically Managed Wireless Network for Disaster Management (MWNDM)

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***Abstract*— Severity of natural calamity are unpredictable in nature. During disaster like earthquake, flood, communication establishments get affected including the power supply. Establishing normalcy in communication takes unpredictable amount of time which sometime creates a great difficulty for search and rescue operation. We some time refer to these time periods as Golden Hour since initiation of rescue operation with proper co-ordination may save lots of life in the wee hours. Disaster generally affects the established communication infrastructure in a severe manner. To perform the rescue operation in a well coordinate manner we may rely on wireless network or ad hock network. Quick tracking of living object or human being is of the highest priority as that may save a life. So immediate and authenticated communication is very much required in locating the distressed. Unmanned arial vehicle (UAV)s with some processing power may be used in the network for generating message after detection of living object or human being. In this paper we are proposing a reliable network for the affected area by using long range wireless area network (LoRa WAN) which will help the Search and Rescue (SAR) team to manage and control the operation in an effective as well as affordable manner. Certain positive attitude of the proposed model ensures lifesaving during rescue.**

Keywords*— *disaster, rescue, Internet of Things, IoT, wireless sensor network, Long Range (LoRa), Search and Rescue (SAR)

I. INTRODUCTION

Disaster is a natural or man-made incident, due to whom damages of infrastructure, loss of life becomes very common. It is a part of our life. Although we have developed early detection system to prevent the after-disaster effect but still it creates a havoc sometimes even after warning system has worked successfully like in case of tsunami worldwide (2004), cyclonic storm Amphan at India etc. Below mention graph clearly showing the increasing trend of natural disaster throughout the world for the last more than 100 years. Only certain natural disasters are considered here. It reached the maximum around 2004 as the devastating Tsunami was there.

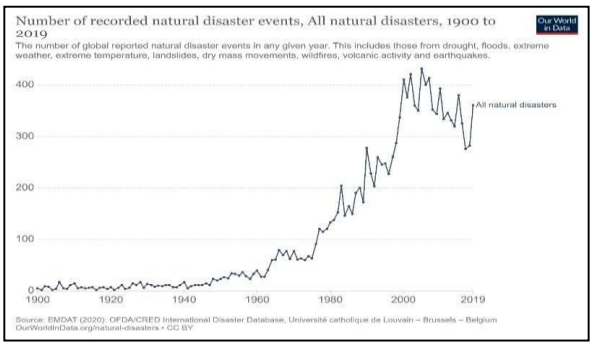

Fig. 1. Natural disaster all around the world from 1900-2019.

To protect maximum life just after the disaster along with superior manual expertise, we need a strong technological support which will make the entire operation quick & efficient one. Internet of things in that situation will work like a blessing for us.

I. a Internet of Things (IoT):

The Internet of Things (IoT) presents itself as the next future of internet [2]. Any object can be connected to the internet, based on its association with IoT. The strength of IoT fraternity can be measured from the fact that billions of IoT devices are available and numbers are increasing rapidly. IoT devices may communicate [8,13,14] with each other and may take some decision based on that. Various combination of IoT devices along with particular wireless sensor network now a days has become a trend in handling complex problem. Various permutation and combination of these are producing tremendous result. Sophisticated real life-based different IoT applications ranging from healthcare to smart city, smart office culture to smart agriculture are there [16].

I. b IoT devices & it's network:

The strong point behind the day-by-day improvement of IoT based industry is the communication of information. At the appropriate time availability of significant information can play with havoc impact specially in handling of disaster situation [15]. Advent of wireless sensor network (WSN) has impacted the IoT deployment in a strong manner. WSN ensures the intercommunication [5,6] among the IoT devices during the crucial hour of certain task which not only helps in high co-ordination but also helps in quick and pertinent decision making. Although computational capability, energy capacity, bandwidth etc. of sensor nodes, are some of the challenges for WSN. There are various wireless technologies available based on range like ZigBee [7], Low -Power Wireless Personal Area Network (6LoWPAN) etc. for short range and Long Range (LoRa), Sigfox, UNB, weightless, LTE-M, etc. for long, medium range. Short range generally covers 10-100 meters. Here we are going with long range like LoRa [3].

Low Power Wireless Area Network (LPWAN) operates in wireless bands that are licensed and unlicensed. Following properties of LPWAN's are desirable for Internet of Things (IoT) based networks:

- Easy to implement and add devices to the network
- Low power consumption
- Low cost for set up and maintenance.

- Secure [9]
- Extended coverage

We assume LoRa can be a perfect fit for Disastermanagement where data is collected, processed and communicated to different parts of the network along with a support of long range. Once authenticated data is received bythe Search and Rescue (SAR) team by the self-controlled network component, immediate action can be done.

This paper performs an integration of Long Range (LoRa) along with Unmanned Aerial Vehicle (UAV) to manage the post disaster activities through a proposed model. The rest of the paper is organized as follows: A brief discussion about Long Range (LoRa) and Wireless Network and LoRaWAN in terms of Internet of Things (IoT) devices are mentioned in section **II**. Section **III** presents the proposed model for disaster management and Section **IV** contains the discussion on the working principles of the proposed model. Section **V** concludes the paper with future scope.

II. Overview of Long Range (LoRa) and LoRaWAN in terms of IoT devices:

LoRa is a network technology for Internet of Things (IoT) [10]. It consumes less power and covers a wide area.

II. a Basic LoRa properties:

We are familiar with Wide Area Network (WAN) technologies like the cellular 4G and 5G networks which allows high speed data transmission over long distances but, cellular WAN consumes lot of power. Under such conditions a wireless network is required that consumes low power but also covers a wide distance larger than other networks such as Wi-Fi. Thus, as a solution Long Range (LoRa) was introduced.

Long Range (LoRa) is a proprietary radio modulation technology owned by Semtech and deals with only the Physical layer. Long Range (LoRa) uses a proprietary Chirp Spread Spectrum modulation technology that makes long range transmission along with low power consumption possible over the unlicensed ISM band. Long Range (LoRa) technology has been licensed to several vendors who produce Long Range (LoRa) devices by Semtech [11,12].

LoRaWAN follows some set of rules and a specific system architecture. It deals with MAC layer and application layer of the Long Range (LoRa) protocol stack. Long Range (LoRa) Alliance, a non-profit association of over 500 companies which are responsible for the development and promotion of the LoRaWAN open standards.

As mentioned earlier Long Range (LoRa) operates in unlicensed ISM band in sub-Giga Hertz frequency, which means that no license is required to transmit data via Long Range (LoRa) technology. In different continent different frequency band is there like in India it is 865-867 MHz

A LoRaWAN network consists of Long-Range nodes and gateways. Long Range (LoRa) nodes are devices with the Long Range (LoRa) radio modulation capability along with sensors and microcontrollers.

II. b Single hop Star topology vs Multi hop Mesh:

A single hop LoRaWAN cannot achieve high data rate as well as long distance transmission at the same time. As the Long Range (LoRa) technology allows customization of its physical layer parameters, such as bandwidth, spreading factor, coding rate and transmission power, the Long Range (LoRa) physical layer settings that yields fastest data transmission rate can be used but it reduces coverage. As a solution a for reduced coverage a multi hop [1] communication can be used which requires a routing protocol that can discover and maintain data forwarding paths. This multi-hop LoRaWAN network forms a wireless mesh network [4] which ensures multiple paths for guaranteed communication.

Features like large area coverage, low power consumption, security (end to end AES128 encryption, mutual authentication, integrity protection and confidentiality), mobility (maintaining communication with devices in motion without strain on power consumption), high capacity (millions of messages transmitted per base station) and last but not the least its low cost makes Long Range (LoRa) technology more convenient than others.

III. Proposed Model:

Objective of the model is to detect living object or human being just after the disaster at the disaster faced region and to pass the information to the concerned authority in a minimum amount time but effectively. In the model we are proposing a set of Internet of Things (IoT) devices with a wireless network protocol named Long Range (LoRa). They will perform in a collaborative manner. Unmanned Aerial Vehicles (UAVs) as the end points will be connected in a mesh network. End point devices will carry a processing unit like raspberry pi. This small single board computer will help in processing every image locally. This will reduce the load of the entire network and the response time becomes firster. A coordinator device (also a UAV) will be a part of these mesh network. The coordinator will receive information from the network and convey information to the gateway in an intelligent manner. The gateway will share the information to the router and to the Search and Rescue (SAR) team. Based on the location information, search and Rescue (SAR) team decides their next course of action. Router then pass the location information to the dedicated cloud or web server for further analysis. In table1 we have mentioned the necessary components along with their functionalities.

Following diagram (Figure 2) shows the pictorial representation of all the component and their interconnection.

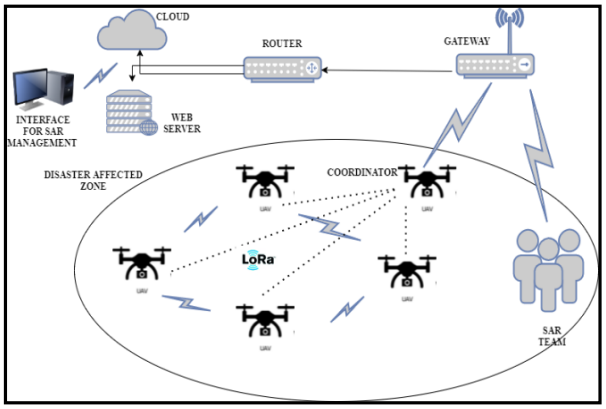

Fig. 2. IoT based Proposed Model with LoRa network for Disaster Management

Table 1: Proposed Model Components

Component	Function
1. Cloud / web server	Will share all the minute-to-minute rescue activity details
2. Router	Will pass information to the cloud/ web server
3. Gateway	Will pass information to the router and to the search & rescue (SAR) team
4. UAVs along with Internet of Things (IoT) components	Will detect the living object or human being and communicate with each other's
5. Infrastructure of Long Range (LoRa) based Wireless sensor network.	Will perform the effective communication with a wide range support

When we are working with IoT we have to keep in mind the pros and cons of using these devices with respect to Security. We shouldn't fall prey to cyber-attack while using these devices during SAR or other similar emergencies. [17]

IV. Model Discussion (Working Principles):

At the initial stage, the end-points UAVs will try to capture the images from the disaster area and immediately process that for living object or human being detection. If any positive responses are generated then immediately information is conveyed to the other networked devices in the mesh network otherwise it will continue the scan process. When any position information (of living object) is generated, it is conveyed to the coordinator device via network. The near most other end points also start concentrating on the same position from different angle. They also follow the same procedure of tracking. On detecting some positive response from the network, information is also conveyed to the coordinator. Once coordinator receives any response from network, it checks the count i.e., how many endpoints have confirmed the response. If multiple responses from same position are there, then it conveys the information to the gateway in the network. The gateway then passes the location information not only to the router in the network but also send message to the search and rescue (SAR) team for speedy rescue operation. Router then passes the information to the cloud or to the web server for further dynamic analysis. The end point based IoT devices captures and analyses every information locally which reduces the load of the network. The long-range wireless network (LoRa) uses a mesh network topology to ensure intercommunication among the IoT devices. With the help of intercommunication end point devices positions themselves.

The entire procedure with the help of a flow chart is mentioned below using Figure 3.

Effectiveness:

Following effectiveness can be observed in the proposed novel model:

- Effective wireless communication due to long range support of Long Range (LoRa) protocol.
- MESH topology supports dis connectivity of certain node at any instance.
  Multi hop communication in the Long Range (LoRa) network widens the communication range of node.
- Coordinator ensures guaranteed communication to authority.
- Flexible adjustments of Unmanned Aerial Vehicles (UAV) position help in quick tracking of distressed object.
- Multiple responses from different Unmanned Aerial Vehicles (UAV) about same object helps to switch to other objects quickly.

Unmanned Aerial Vehicles (UAV)s will capture the image of affected area and process that locally so that transmission of huge data can be averted. This will also help the entire system to take decision in faster manner.

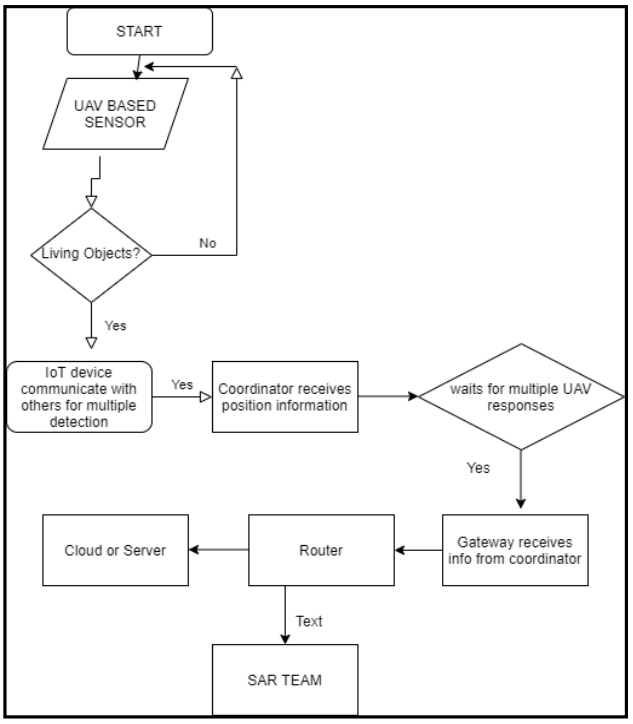

Fig. 3. Flow Chart of proposed Model's Working Principle

V Conclusion:

This is an era when transition is going on in the mobile communication sector. Transition is happening from 4G to 5G. Along with the advent of fast data communication, Internet of Things (IoT) is becoming stronger day by day. We are trying to utilize here the duo combination for disaster management.

Post disaster rescue operation with the blending of technology and manual effort will become sophisticated and efficient one. This life saving task requires a support of dynamic management based on correct guided information. A lot of infrastructural disruption in the environment is quite common in any kind of disaster, where the support of Internet of Things (IoT) can fulfill that. Our proposed model has shown a tremendous scope of dynamic decision-making ability of the search & rescue team as the end nodes can communicate among themselves via Long Range (LoRa) network. The support of long-range wireless sensor network has given the flexibility to cover a wide area. The mesh topology also boasts immense support for the undesirable disconnection situations. In this paper we are motivated to make a self-controlled, dynamic decision-making system which will indeed help the Search and rescue (SAR) team to save life just after the disaster in a quick manner as well as in a controlled reliable environment. It explains the working principles, Internet of Things (IoT) infrastructure and focuses on the reliability of the entire communication after disaster.

REFERENCES

The template will number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]—do not use “Ref. [3]” or “reference [3]” except at the beginning of a sentence: “Reference [3] was the first ...”

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