IoT–Fog Enabled Framework for Forest Fire Management System

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***Abstract*—The Forest fires are one of the most critical catastrophes which has been initiated mostly by global warming. Due to environmental pollution, nature can make this threat even worse by destroying themselves and mankind. Forest management and wild life department are handling many problems such as rehabilitating wild animals, migration of animals to residential regions. The strength of the trees has drastically decreased which lead to unhealthy forest environment. It has been analyzed from the yearly survey that 85% losses in forest calamities are due to wild fire. In recent years, few works have been carried out on forest management using wireless sensor networks. However, forest management with the help of wireless sensor networks are still having issues in the quality of data, delay in arrival. Currently there is big wave of IoT and Edge computing deployed in lot of smart city applications for processing the data closer to devise for quick action rather than cloud. Also issue of bandwidth, latency and delay in processing data is avoided with Edge/Fog computing in IoT. So, with this as basis, we propose an IoT- Fog based Forest Fire Monitoring system. The proposed IoT – Fog based framework for forest fire management system is used for monitoring and alerting to safeguard the trees and wild life. The detailed architecture been explained in the paper.**

Keywords – IoT, Fog, Forest Fire

I. INTRODUCTION

Forest fires are seasonal environmental event in our country often listed during the high temperature season. As per the forest survey of India-2019, 37059 fires were identified in the year 2018. This was collected using Moderate Resolution Imaging Spectro-radiometer (MODIS) data. Each and every year very huge area of forest are badly influenced by fires of different intensity. Based on the reference taken from forest survey, India, occasional fires happened is 54.40%, recurrent fires are 7.49% and 2.405% of forest areas were prone to high level fire and remaining 35.71% of regions were safe without any fire. On an average, half of the forest area in India is inclined by forest fire. As noted in the Forest Survey of India survey [1], "In the year 2019 about 21.40% of forest cover in India is prone to fires, with forests in the north-eastern region and central India being the most vulnerable".

The forest fire creates environmental hazard not only to the woodlands but also to all biological nature in the surroundings. Basic reasons for forest fires are lightning, outrageous blistering and dry climate, serious dry spell, and human ignorance [2]. Forest fires frequently start unnoticed and spread rapidly, causing great harm and guaranteeing numerous human lives each year in numerous nations. Basic reasons for forest fires are lightning, outrageous blistering and dry climate, serious dry spell, and human ignorance.

There are several steps already taken by the government to monitor the forest remotely with the deployment of WSN. Non replaceable batteries are used by different types of sensor nodes in the remote environment. Power saving is very important for remote based application like forest management. Several energy saving protocols has been adopted for the communication in the WSN. But still there are few challenges that are open to the researchers to optimize the energy utilization and durability of data trade off.

Because of global warming, there is a peak rise in forest fire which require periodic monitoring and surveillance of forest fire in vulnerable areas. Wireless Sensor networks [3-4] can be efficiently be used for this purpose. In 2014, Arse´nioet et. al. proposed an e-SENSE framework with three layered approach to monitor the remote sensing in the forest environment with enhanced GUI and middleware support. Another framework, in WSN which adds one more layer supports for solving security issues in remote data communication in forest environment. This work also provides supports for long term forest monitoring with numerous parameters, such as: cost benefitable framework, enabling for group of sensors deployment, quality of service, durability of sensors.

Low Power Wide Area Network (LPWAN) is an emerging field which provides coverage of wide area with less power consumption and low bandwidth. A lot of LPWAN techniques such as LoRA [5], RPMA, NB-IoT, Sig-Fog, etc have grown. These techniques have been adopted for WSN which has been used to monitor the remote area applications by implementing sensor nodes. The idea of continuous monitoring has been achieved with the help of implementing the potential technologies such as Wireless Sensor Networks (WSN), Internet of Things (IoT), Big Data, Edge/Fog Computing, Cloud Computing in remote forest surveillance regions. With a reference to general IoT framework, a collection of physical sensor nodes is connected to the network and all these nodes are having the capability to communicate with each other.

A proper tradeoff has to be achieved between the IoT sensor nodes communication and its energy efficiency.

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Various IoT architectures were discussed in [6] pertaining to all application fields. Researchers have found still challenges in WSN framework related to balance the load in the communication media. The proposed IoT framework for forest fire management utilizes Fog/Edge layer that serves for balancing the entire work load and acts as spontaneous gateways in IoT enabled system. The remaining part of this paper is organized as follows. section 2 describes the related frameworks for forest fire management and IoT frameworks. Section 3 lists the motivation of research and the proposed IoT-Fog based architecture for Forest fire management system is explained in detail. Conclusion and future work in this domain is stated in the section 4.

II. Literature Review

A. Wireless Sensor Networks in Forest Fire Management

There are plenty of research work carried out employing wireless sensor network communication model [7] for the data transfer in remote area. Considering the forest fire management system, different type of sensor nodes senses the environmental data and forward to the central node. To accomplish this communication protocol, the author has used different modes of communication such as Link Search Mode (LSM), Test/Reset Mode (TRM, Automatic Monitoring Mode (AMM, Fire Alarm Mode (FAM), Under request Monitoring Mode (UMM, Data Dump Mode (DDM). All the sensor data are sent to central control node. This will create overhead in the communication channel.

Priority based communication scheme [8] has been implemented among the sensor network area. All the deployed sensing nodes communicate directly to the base station. Dynamic paths have been identified by considering different parameters such as energy, fire, weather index code. Dijkstra's algorithm is used for routing purpose. The author has developed a system of four components WSN, middle ware, Application based on web platform and a fire alerting subsystem.

Josu´e Toledo-Castro et al, developed an IoT integrated system [9] which monitors the real time environmental variables mainly on polluting gases such as CO and CO2 (air polluting parameters). The system will monitor and give notifications on detecting extreme environmental situations. They have incorporated security algorithms such as block cipher and an advanced authentication method for communicating these data from the sensor nodes. Web and mobile services have been added as an advantage for enriching the architecture.

Chaczko et al. implies the role of wireless sensor network in forest fire monitoring system by implementing two different types of sensor nodes that are deployed in the sensor network area such as temperature and humidity. The smoke detector is also employed in the network area to give critical event notifications. The network is fully connected mesh network to communicate the information in order to achieve loss less communication [10]. Because of the mesh design no critical data can be lost during communication.

B. IoT/Fog Influence in Forest Fire Management

In this work [11], the author gives a survey about distributed architectures that enables for connecting IoT to cloud. This helps to implement IoT for analytics purpose in critical application scenarios. Whenever a Fog /Edge node comes in to the distributed architecture, range of their communication is important. An overview of FECIoT technology, challenges are listed and finally the author provided with an architecture as a solution how to incorporate FECIoT for remote / mission critical applications.

In another work related to Fog computing, Fog initialized architecture [12] intend to cope up with continuous streaming data from the remote unmanned areas. In this architecture, first the sensor nodes send the data to Edge layer where IoT gateway is located. It forwards the data to Fog layer. These Fog nodes are capable of storing the data, messaging and real time processing of data. Finally, the needed data is forwarded to cloud layer for storage or computing.

In [13], a protocol for routing is implemented to maximize the energy efficiency. Nodes are chosen for routing purpose based on the energy level. Node that is going to die early has been chosen as a neighbor to relay the packet. This will save the energy of other power full nodes. Maximize Unsafe Path (MUP) Routing using IPv6 is a modification that enhances the RPL protocol. MUP has been implemented in three stages namely managing the neighbor nodes, routing the packets through neighbors and detection of critical events.

Harkiran Kaur et al presented an efficient IoT framework supported by Fog and Cloud technologies in [14] for predicting the forest fire. The authors developed a layered framework which consists of six functionalities. Data perception, Fog computing and Fog gateway are grouped as one part. Fire prediction, Cloud storage, Management layers are clubbed together. Vulnerability index metric is computed at fog layer. Prediction of the vulnerability index in done at Fire prediction layer using Artificial Neural Network.

III. IoT – Fog Based Forest Fire Architecture

The research work been discussed earlier purely focused on employing wireless sensor network for forest fire monitoring which focused on data transfer, priority-based communication, remotely monitoring the parameters for forest fire. In regards to IoT, Fog enabled frame work for Forest Fire management proposed. Also there has been work where Fog nodes collect data from sensor node and perform real time processing. Then the analyzed data sent to Cloud for storage. Also work has been focused on routing protocol implemented for maximizing the energy efficiency where RPL routing protocol used. Lastly an IoT framework with Fog and cloud proposed with six functionalities where Data perception, Fog computing and Fog gateway are grouped as one part and Fire prediction, Cloud storage, Management layers are clubbed together.

But in none of IoT framework, there has been data properly aggregated and distributed towards real time

streaming analytics of environment data for prediction before the fire catches based on historical data region wise using machine learning or deep learning model. Also, no proper usage of Cloud computing and big data analysis incorporated.

So, with all these as basis, we here have proposed an IoT-Fog based Framework for Forest Fire monitoring where real time data captured by gateway region wise in forest communicated to Fog where streaming data analytics done using Machine or Deep learning model for real time prediction before forest fire. Cloud for performing Big data analysis where further statistical analysis done on vulnerability region of forest fire, climatic condition and season wise. In addition, messaging, alert notification and many more incorporated based on forest fire predicted

Our framework is aimed at creating a solution for the issues in current forest monitor systems. As per general WSN framework, group of sensor nodes are available to interact with the surrounding environment by sensing humidity, temperature, soil moisture, etc. The proposed IoT-Fog enabled framework for forest fire management system is planned to monitor the forest environmental scenarios, which in turn will helps us to control the fire factors precisely and timely manner. The overall system framework is presented in the Fig 1. The IoT-Fog Enabled FFM system is having the five subsystems of specific functionalities. "IoT Sensor Layer" is the one where deployment of Smart IoT sensor nodes for sensing different environmental parameters of the forest is done. Environmental sensors for monitoring temperature, humidity, wind, rainfall have been deployed in this perception layer which is 6lowpan based. These sensors collect their environmental data and forward to the 6lowpan aggregator using 6lowpan communication. "Aggregator Layer" will collect all the data from the 6lowpan nodes/sensors and aggregate it based on the need. 6lowpan aggregator nodes are placed in between the IoT Sensor and Fog layer. Data from aggregator would be communicated to "Fog/Edge node" which support 6lowpan/RF/4G/5G communication where the metrics to predict the forest fire such as Fuel Moisture Code (FMC), Duff Moisture Code (DMC), Drought Code (DC), Initial Spread Index (ISI), Build Up Index (BUI) and Fire Weather Index (FWI) are computed by employing Machine learning or deep learning techniques for predicting the forest fire based on model trained in cloud. The intelligence is deployed in Fog/Edge node which can be supervised, semi supervised or Reinforcement learning for quick control action. The predicted and analysed results from Fog layer sent to Central Server Layer which is Cloud. "The Cloud Server Layer" (CSL) is responsible for performing statistical analysis of data analysed and perform big data analysis using 'Big data tools and techniques like statistical analysis of vulnerability region based on seasonal, climatic conditions. This layer also supports messaging, mobile notifications, storing data sources and sending fire alerts by prediction system. The prediction system is built in CSL which helps to give notifications for the humans in and around by means of alerting system.

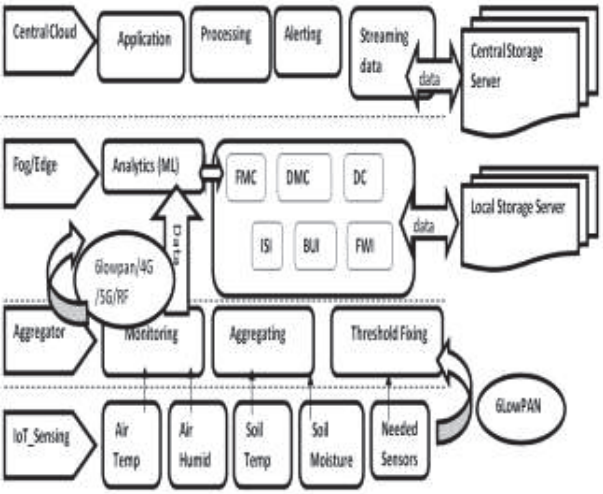

Fig. 1. IoT – Fog Architecture for FFM

IV. Conclusion

Though there are a lot of frameworks available for forest fire management systems with WSN as specified in the literature survey, there are some lack of things like load balancing, routing, computing power, etc. In the proposed IoT – Fog supervised framework for Forest Fire Management, the load of the computing and analyzing data operations are balanced and split across Fog, aggregator and central cloud layer. A large number of wireless low powered heterogeneous sensor nodes are deployed in forest area. Data sensed from those sensors are continuously monitored by aggregator nodes separately. There are a lot of advantages of Fog computing such as low bandwidth and latency communication, heterogeneous data computation, which induces to do computing of forest related metrics. At last, Cloud layer helps to manage all fire related notifications, alerting to the forest office and people in the surrounding. In future, there is need to work on optimized energy efficient routing protocol of IoT sensor node for communicating to aggregator and gateway. Also need to work on optimized placement of Fog node in environment for efficient usage of Fog node for performing higher level of analytics for forest fire monitoring.

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