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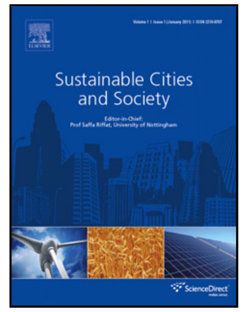

An Integrated Fire Detection System using IoT and Image Processing Technique for Smart Cities

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An Integrated Fire Detection System using IoT and Image Processing Technique for Smart Cities

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HIGHLIGHTS

- The novelty of the proposed work is to detect fire with higher accuracy, early prediction, real-time monitoring, and validation using UAVs and cross-validation of true prediction of fire event using IoT and image processing techniques
- The proposed system further improves the true detection of forest fire from the existing 95 to 98 percent.
- This is the first kind of study that use UAVs and integrate them with the existing system to improve real-time monitoring and detection of a fire event.
- Simulation results have shown promising outcomes in terms of fire detection with high accuracy and the same may be utilized for smart cities.
- As the proposed system can generate an early alert and warning message in case of fire, it may be emerged as an essential application for smart cities.
- The proposed solution may also be extended for addressing the need for many more disaster management activities in smart cities.

ABSTRACT

In the current scenario, the concept of Smart Cities is one of the emerging and challenging research areas. The cities are surrounded by forests, agricultural land, or open areas, where fire incidence can occur threatening human life and causing many resources to become extinct. This article aims to design an early fire detection system to get rid of fire events using the concept of senor network and UAV's technology. The architecture proposal is based on sensors for monitoring environmental parameters and to process the information through sensors and IoT application. The proposed fire detection system is the combination of wireless sensor technologies, UAVs, and cloud computing. Some image processing techniques are also integrated into the proposed fire detection system to identify the fire event with better accuracy and used as an integrated solution. To improve the true detection rate, rules are also designed. The simulation results of the proposed fire detection system are compared with several existing methods. It is observed that the proposed system has a higher fire detection rate to improve the true detection of forest fire from 95 to 98 percent.

Keywords: Smart Cities, Wireless Sensor Network(WSN), Sensor Deployment, Internet of Things (IoT), Forest Fires, Image Processing, Unmanned Aerial Vehicles (UAVs).

1. INTRODUCTION

Nowadays, the concept of smart cities is getting wide attention in the research community. This article is an attempt for making the cities safer from the disaster like forest fires. The major contribution towards this attempt is to develop a forest fire detection system using wireless sensor networks (WSN) and Unmanned Aerial Vehicles (UAV's) based on Internet of Things (IoT) and image processing. The environmental parameters are measured in real-time using IoT devices and the information is processed for the detection of events. The detected event is further validated using image processing techniques. The main objective of smart cities is to provide a better urban environment for living based on the concept of information and communication technology (ICT), IoT, WSN, and other related computing technologies. Moreover, the regular operations of cities such as transportation, monitoring, resource scheduling, etc. can be managed and monitored through IT-enabled infrastructure. It is also assumed that smart cities improve the living standard of human beings while utilizing the resources effectively (Islam et al., 2017). In the present time, many countries run the smart city pilot project that relies on the conversion of cities into smart cities through smart technology for improving the environment and everyday living. Smart technology utilizes ICT, IoT and the power of data for developing smart applications (Cerchecci et al., 2018). A smart city can manage its resources and infrastructure efficiently for making the day-to-day living more comfortable. In smart cities, all information is captured in real-time and this information is used for continuous monitoring as well as an adaptation of learning parameters (Hanif et al., 2018). The smart city consists of sensor networks and IoT based applications such as smart building, pollution detection, smart water system, intelligent traffic, health monitoring, public surveillance, smart grid monitoring, and many others (Wan et al., 2018).

In the ecosystem, a forest can be acted as a shelter for living beings like wild animals, birds, squirrels, beavers, etc. Approximately, thirty-five percent of the land is covered with forest. The forest can be extended using plantation and other natural processes. But, a forest fire is a natural process affecting the forest ecosystem thereby leading to deforestation. It is observed that increased temperature and sometimes humans can be responsible for this. So, the monitoring of the forest is one of the challenging tasks as it requires a lot of time and resources. Forest fire is also a threat to smart city, environment, economy, infrastructure, wildlife, and human life across all over the world. Recently in India, forest fires incidents have dramatically increased ("Forest Fires Surge 30% In 2016," 2016; Jenner, 2016). A survey reveals that the number of incidents of forest fires is 15937 in 2015, while in 2016, it reached to 24,817. Hence within one year, the rate of increment of fires has increased up to 55%. It is revealed that nearly 17502 acres of land is affected in Himachal and Uttarakhand states due to fires in 2016. Its consequences are the loss of human life and wildlife, affecting the natural ecosystem and also leading to the degradation of soil fertilization. Forest fires also affect ground microorganisms, nutrients and in some cases, fire causes the death of inhabitants in the fire-affected zone. The main reasons for forest fires can be listed as a fire source, environmental element, and combustible material, etc. To protect the environment, natural resources, and wildlife, some forest fire prevention mechanisms have been reported in the literature (Celik, 2010; Celik et al., 2009). A wildland fire significantly differs from fires conquer in urban and agricultural areas and several factors can be responsible for forest fires. One of the main factors responsible for wildland fire is intentional or accidental human intervention. Global warming is another reason for forest fires due to the increased temperature. To protect forests from fires, it is recommended that some continuous and comprehensive approaches can be adopted to spread awareness among people and instant response in the case of fire. A forest fire detection system can satisfy several fundamental requirements which are summarized in Table 1.

Table 1: System requirements for Forest Fire Detection System

Requirements	Specification	Reason
Quick processing (Töreyin et al., 2006)	Early Detection	Detecting fires at a very early stage and alerting management system
24x7 Monitoring, Cost-effective, Less human interference (Celik, 2010); (Celik et al., 2009)	Day/Night Detection	System should capable enough of operating automatically anytime in day/night
Maximum Coverage (Lloret et al., 2009); (Yuan et al., 2017a)	Range of Detection	Covering larger areas by using less number of sensors, hence reducing energy consumptions

Cost-effective (Qiu et al., 2012)	Notification	Alert message through Mails and SMS anywhere in globe
Portable (Tsetsos et al., 2012)	Energy Utility	Less energy consumption, increasing the longevity of the system

The basic diagram of the fire detection system through the sensor is presented in Fig. 1. The input image is a primary source for the identification of forest fire. The system processes the input image and forwards an alert message whenever there is an incident of fire. The basic requirement for this system based on image processing consists of multiple sensors, communication channels, an image processing algorithm and a mechanism to send an alert and warning message. The sensor nodes are connected to a communication system that supplies images to the processing unit. The processing unit contains an algorithm which identifies flames and smoke or both by implementing RGB and YCbCr color models and generates warning message for any detected fire event. It also ensures that an uninterrupted power supply should be provided.

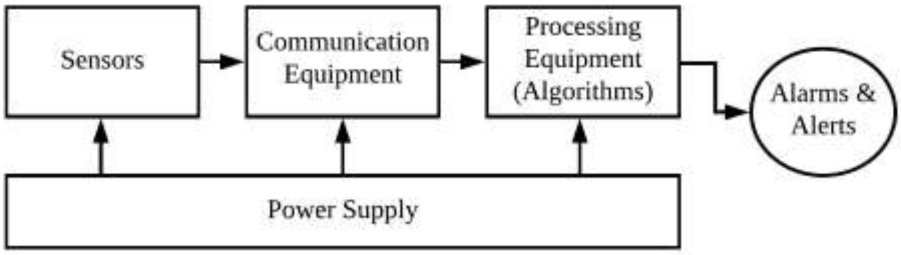


Figure 1: Block Diagram of the Fire Detection System

1.1 Fire Detection based on WSNs and IoT for Smart Cities

In recent times, the wireless sensor network is one of the most prominent techniques for forest fire detection around smart cities. Sensors provide real-time data from the fire zone and also observe the neighboring physical parameters. WSNs offers a scalable network for connecting multiple devices and can add several different sensors to collect information regarding various parameters. Sensors can be deployed in different locations and there is no requirement to build towers (Habibzadeh et al., 2017). Due to technological advancement, sensor devices are capable to detect and broadcast the information through IoT applications for real-time analysis. The IoT based sensor network collaboratively can detect and forecast forest fire more effectively in comparison to the traditional satellite-based approach. The monitoring of fire through satellite imaging is a popular technique but their long scan time and low resolution can restrict the effectiveness of the satellite-based fire detection method. Moreover, the satellite-based system cannot predict the forest fire before the spreading of fire. Fig. 2, represents the deployment of the sensor and the transmission of information. In a wireless sensor network, large numbers of sensors are densely deployed in the forest area. Sensor nodes collect the sensed data like temperature, humidity, smoke, etc., and send the information collected from this data to their relative cluster node, which further sends the data to cluster head forming a network (Du et al., 2019). The on field-deployed sensor nodes communicates with each other utilizing RF (radio-frequency) links. The gateway node is deployed for enabling a connection among Wireless Sensor Networks and the rest of the world through cloud. The gateway node is responsible for mobile communications (GPRS) and it enables a remote user to access or monitor the real-time field data.

Figure 2: Sensor Deployment and Information Transmission

Sensors equipped devices are scattered at different locations according to the area of interest that can be houses, buildings, or any intelligent control system in a smart city and even for remote mountains and forests. These sensor nodes are composed of a radio communication channel that enables the sensor to transmit data from one place to the control room via a communication channel. These sensor nodes transmit data securely towards the gateway in repeating data relays. The gateway sends this information to a server or cloud. The IoT enabled cloud platform stores the data and analyses it for decision making. After analyzing the data, a fire warning and alert message can be generated. The scenario of fire events has been investigated from various perspectives along with different research trends like IoT, Future Internet technologies (Csáji et al., 2017).

1.2 Contribution of Work

In this context, the perspective of this article is towards the deployment of sensor networks and IoT. The purpose is to implement a system for the prevention of cities from disasters that may occur surrounding a smart city. The sensing, storage, and computation in real-time are provided to several users, controllers, service providers, and others as a service. The objective of this article is to propose an architectural design for the detection of fire events across smart cities. The silent features of the proposed fire detection architecture are mentioned below.

- To develop a system for forest fire detection utilizing Wireless Sensor Networks, Internet of Things, and Image processing techniques.
- To collect real-time information for various environmental parameters like temperature, humidity, light intensity, and smoke through IoT devices.
- To validate the occurrence of fire events using image processing based technique.
- To generate an early alert and warning message in case of fire.

Additionally, the architecture accomplishes a strong interaction of system and sensors through the application for analyzing, filtering, and aggregating the sensed information for decision making. The architecture gives a uniform solution for the detection of a fire event in the early stage using sensors and IoT. The motive of this work is to develop an early fire detection system for determining the exact locations of fire in forests. The proposed model consists of RGB and YCbCr color space models to determine the fire region. The experimental results obtained for the true detection rate are compared with the other existing techniques. The proposed model provides significantly improved performance outperforming the existing state-of-the-art methods in terms of true detection rate.
The rest of the manuscript is organized as follows: Section 2 provides the related works on smart cities using WSNs and IoT. Section 3 discusses the proposed fire detection model and its components. Section 4 presents the working of the proposed model in terms of its operations. The experimental results are discussed in section 5 followed by the conclusion of the entire article in section 6.

2. LITERATURE SURVEY

This section presents the recent works reported in the direction of smart cities and the prevention of fires. The extensive literature survey executed in this article is divided into four categories i.e. deployment of WSNs and IoT for Smart Cities, application of fire detection, fire detection using image processing and fire detection using UAVs.

2.1 Related Works on deployment of WSNs and IoT for Smart Cities

In the last decade, the evolution of IoT has transformed the definition of the Internet. IoT enables things and users to be connected anywhere at any time. These connected things creates a huge volume of data that brings the concept of big data. The collected data from the smart devices need efficient storage and it's processing in real-time. Cloud computing allows the processing of resources remotely at a very reasonable cost. The fog and edge computing are the extension of cloud computing architecture where the computation and storage are carried out near the edge devices(Bibri, 2018). (Zahmatkesh et al., 2020) presents an overview of the technologies that consider the use of fog computing for sustainable smart cities. Authors have discussed the challenges and potential of fog systems for various application domains in smart cities. (Al-Turjman et al., 2019) presented the overview of the evolving IoT and WSNs techniques for the application of smart parking. They have emphasized mainly on various design issues and discussed the importance of data reliability, privacy and security.(Luna et al., 2018) provides the solution for efficient deployment of WSNs with better network lifetime for smart cities. The collected information from the sensors required regular monitoring and storage. The sensor collects data periodically and stores it on the cloud for processing. The amount of data is very huge and it is important to process each of the sensed information. (Silva et al., 2018) proposed an experimental architecture for big data analytics to meet the requirements of real-time processing. (Zamanifar et al., 2020)proposed an efficient communication protocol which provides a solution for less power consumption during the process of communication. As discussed, the problem of WSNs operation such as hardware constraints and the limited available energy because of the node's electronic operation and processing performance is of main concern. There also exist some other issues such as scaling of several devices in a network and selecting efficient topology for the implementation (Liu et al., 2017). In the beginning, the deployment of WSNs follows star topology with limited sensor nodes, which is now replaced by the mesh network forming from hundreds of sensor nodes. There are several types of researches have been addressed in the past for the detection of fire, by implementing different approaches. The reducing cost of sensor devices allows the deployment of several sensor devices to embed them in an area of interest for monitoring environmental parameters and for making Internet of Things or Everything. Wireless sensor networks can easily collect the information of temperature, humidity, smoke, light intensity, etc. and monitors them for any abnormality (Aloqaily et al., 2019; Malche et al., 2019). The application based on sensor networks provides timely information which leads to further decision making for safety and comfort (Du et al., 2019). The monitoring systems for smart cities have greatly improved the living by providing high means of comfort and safety. The comfort and safety of smart cities have also raised many research challenges for sensing, collection and safety. (Khan et al., 2014)have presented a framework for addressing the issues of data services for smart city citizens.The small size of sensor devices leads to the limited capability for storage, computation and communication. Most of the sensor devices are battery-powered which results in limited energy for operation. Additionally, certain application-specific sensor devices that require high-resolution parameters with maximum accuracy are also limited (Habibzadeh et al., 2017). Therefore, designing WSNs based sensing system for smart cities is a challenge, considering what nodes are efficient and deployment strategy to cover the desired target area with minimum energy utility. In order to overcome these challenges, various researchers presented their results in several directions. Unfortunately there exists no such system that presents clear strategies for designing and preserving monitoring system for smart cities. The node deployment and sensing management are the two major problems for designing and preserving monitoring system for smart cities which have been studied for general-purpose WSNs (Jin et al., 2014; Peixoto et al., 2017). The authors (Jalali et al., 2015; Theodoridis et al., 2013) proposed an intelligent system utilizing the embedded system and RFID technology and help users for checking the availability and current scenario through the internet. In the last few years the sensor networks have been used for the detection of fire (Filipponi et al., 2010). (Baroffio et al., 2015) proposed architecture for the event detection using WSNs that uses image detection. (Daely et al., 2017; Vlacheas et al., 2013), authors have introduced intelligent systems for management and smart street lights based on wireless sensor networks and the Internet of Things. The authors (Singh et al.,2014; Ullah et al., 2017) proposed a routing technique for extending the services with better detection and enlarge network lifetime. (Sadhukhan, 2017) proposed a smart parking system for smart cities that utilizes wireless technologies and their applications for acquiring the information in real-time. The collected information is transmitted to the monitoring station through gateways for processing. (Vilajosana and Dohler, 2015)presented a solution for the smart traffic management system based on video analytics that monitors the traffic using a sensor network. (Ma et al., 2016), the authors presented a smart system based on the sensor network. An algorithm is proposed for the accurate detection of an event and the sampling technique reduces the consumption of energy. (Difallah et al., 2013), present a smart sensor-based system that detects the event at an early stage. Most of the solution that has been proposed does not consider the utilization of either sensor network or RFID by deploying the sensors efficiently in the target area. The optimal placement of sensor nodes for coverage is a challenge for the emerging Internet of Things. (Lloret et al., 2009), presented an approach focusing on maximum coverage with little attention towards the communication among sensors. (Alkhatib, 2016), authors presented an algorithm that focuses on optimizing sensor location for maximizing the overall coverage. The approach presented by (Marta et al., 2009), considers virtual force methods for the deployment of sensors. By addressing optimal techniques for connecting deployed sensors through optimal placement, the energy consumption can be reduced through layout optimization (Liu et al., 2017). The system presents a heuristic solution utilizing multi-objective optimization for the placement of the nodes (Xu et al., 2010). The problem of node placement is presented as a non-linear problem that adds one node at a single time to network in an efficient way (Hammoudeh et al., 2017). (Fernández-Berni et al., 2012), authors proposed the placement of static sensor nodes optimally across the network for navigating the area utilizing rage measurements to locate itself. (Sarwar et al., 2019) presents an approach based on IoT and fuzzy interference system for the fire warning application. Their system is capable of sensing the true incidences of fire by calculating the maximum likelihood of the occurrence of fire and thereby sending a direct alert to the user smart phone. (Hsu et al., 2019), provides the use of smart sensors from the prevention of fire. The confirmation of the event of fire is enabled through the Internet protocol cameras which allows the personal to deal with the incident.

2.2 Related Works towards the application of Fire Detection

Forest fires are a big threat to wildlife, ecological, and infrastructure. There are many evidences reported on forest fires in the past. Forest fires can be examined as a consequential issue that can affect the ecological and economical destructions of wildlife and human lives. There are several techniques reported in the literature for forest fire detection (Celik, 2010; Ko et al., 2010; Töreyin et al., 2006). The conventional forest fire detection methods require mechanical systems and humans for monitoring the forests (Xuan Truong et al., 2012). The fire detection systems can be categorized as fire watchtowers, wireless sensor networks, and satellite monitoring (Franke et al., 2012). One of the oldest and traditional methods to detect fires is watchtowers. In this technique, humans observe the entire forest area. Whenever the incidence of fire is seen, it is reported and necessary action can be taken. But, it is not the optimum method to detect fires due to certain reasons such as operator fatigue, area locations, wider area, lack of 24x7 support and slowest processing. In the WSN based fire detection system, sensor devices are deployed for measuring real-time data in the area of interest (Kosucu et al., 2009). The recent advances in the field of sensor networks are motivated through the capabilities of wireless sensor networks to gather the information from the environment and communicate to the existing infrastructure of internet described in (Akyildiz et al., 2002; Hammoudeh et al., 2017; Heinzelman et al., 2004). To make energy-efficient communication in such networks, hardware components at low power and system architecture are the foremost requirements. The major requirements for various applications in WSNs are the long lifetime and the limited capability of the sensor nodes for storing energy. These two requirements lead to the issue of less consumption of power in any operation of the sensor network. Several hardware components meet the low power requirements and general-purpose architecture of sensor network are developed in a project (Alkhatib, 2016). The two objectives of consumption of low power and less processing are accomplished by taking into consideration the high tolerance towards latency and less sampling rates in a sensor network. (Marta et al., 2009) have developed a technique that uses devices of small sizes having the capability of optical communication called motes instead of the techniques of sensor nodes that are based on radio communication. Some of the newly designed low powered protocols of communication in a sensor network are presented in (Abdullah et al.,2014; Kong et al., 2014; Kumar et al.,2016). From the past few years because of the capabilities of sensor networks, the design of ultra-low-power sensor networks has been gaining attention from various researchers. WSNs are capable of collecting the information even from the areas where humans can't reach. The sensor node just required to be deployed once; afterward, they work on their own for the collection and serving the data for the reason of deployment (Liu, 2015). A sensor network contains deployment of various sensor nodes over a geographical area of interest for monitoring different parameters such as temperature, humidity, pressure, gases and other various events. A sensor node is a small device that has three main components sensing unit, processing unit and storage (Luo et al., 2012). The two major issues in designing protocols for the sensor networks are low power consumption and maximizing the lifetime of the network. The lifetime of the network can be maximized by optimally assigning a state of sensors for energy-efficient sensor state planning. In an example for the application of area surveillance, the set of sensors is turned ON that covers the monitored area completely while the other subset of sensors are turned OFF. In general, any of the sensor nodes can be turned ON/OFF or can be turned as a cluster head and different levels of power consumption can be attained from each of these different states (Izadi et al., 2015). The coverage is typically known as how efficiently a network covers and monitors an area of interest. Generally using WSNs efficiently we can monitor an area of any size, continuously track a target and gather as much of the required information. Coverage in a sensor network generally covers every single point in the interested area and every point comes in a sensing range of at least one sensor node (Kong et al., 2014). The deployment of a sensor node can be classified as intense or scatter deployment. An intense deployment comparatively has a higher number of sensor nodes in a similar area of interest while the scatter deployment may have fewer sensor nodes. The sensors are deployed intensely for the reason of not skipping any event and for the task where the number of sensors is important to cover a particular area. Scatter deployment becomes necessary where the cost of sensors makes the intense deployment a difficult task and where it is required to cover the maximum area with less number of sensor nodes (Rakavi et al., 2015). The problem of coverage in WSNs is generally originated because of three major reasons. The first reason is less number of sensors for covering the complete AOI, the second reason is the random deployment of sensor nodes and the third reason is the limited range of sensing of sensor nodes. The power supply of the sensor nodes for their operation is limited and therefore, some of these sensor nodes may die which further causes the insufficient sensor nodes to cover the complete AOI. The sensing radius of each sensor node is limited that generally causes the problem of coverage. The same problem can be sorted out by simply using sensors with a high sensing range, but the problem in using such sensors is their high cost. The biggest advantage of WSNs is the deployment of sensor nodes randomly. The random deployment of sensor nodes can be achieved through an airdrop, which enables the deployment of sensor nodes even in the unreachable field. The problem associated with random deployment is that sometimes sensor nodes are deployed very close to each other, though the other sensors are comparatively far. In both of these scenarios the problem of coverage comes. For the first case where the sensor nodes are deployed closer to each other, the capabilities of sensing are not properly utilized and also the maximum coverage cannot be achieved. For the second case where the sensor nodes are far from each other, the communication among them suffers and consumes high energy which further in later stage leads to blind spots. This problem is further improved by the planned deployment of sensor nodes and hence the coverage is improved by carefully deploying the sensor nodes in AOI (Rout et al.,2016). The work of sensor nodes is to collect the information from surrounding and send the collected information to the base station. At the base station level, the collected information is processed for meaningful patterns. But, coverage and energy are the key issues with this approach.

2.3 Related Works on Fire Detection using Image Processing

Another method to detect forest fires is to monitor the entire forest through satellites. In this process, several images are captured at different time slots and further, these images are processed for the identification of fire incidents. But, the captured images are low-resolution images and sometimes, it is difficult to retrieve useful information from low-resolution images. It is also noticed that weather conditions can also impact the accuracy level of satellite imaging (Premal et al.,2015). (Surit et al.,2011) developed a detection model based on R, G and B colors. Smoke detection through IR smoke detectors is one of the popular forest fire detection techniques. This method is based on the sampling of particles, temperature and air quality. This system works with the smoke particles. If smoke particles are available in air, then sensor nodes sense these particles and invoke an alarming system. While, (Töreyin et al., 2006)used the Gaussian mixture model in RGB color space. (Celik et al.,2009)presented a YUV color space in which fire regions are described as derivative of Luminance i.e. Y. Further, fire regions are confirmed using information from chrominance i.e. U and V. In continuation of their work, (Celik, 2010)adopted the HSI model for separating the fire pixels. This process considers the concept of brightness and darkness for separating the pixels. Further, it is noticed that segmentation is done based on the HSI color approach. The pixels with lower intensities and saturation are eliminated to avoid false alarm rate. (Ko et al., 2010) designed several rules based on normalized RGB to avoid illumination effects in an image. The image analysis is done through three axis i.e. rg, gb and rb. The entire region is divided into three-axis and the area enclosed in between axis is denoted as area of interest for fire pixels. The pixels that belong to the area of interest are classified as fire pixels. (Truong et al., 2012) designed a color model for separating fire pixels and normal pixels using the YCbCr color model. The proposed approach can effectively segment the flame region except the centre of the flame. Moreover, fire pixels differ based on color information. (Vipin, 2012), presented an approach based on RGB and YCbCrcolor models to segment the fire region form images. The authors claimed that the proposed approach works effectively in normal conditions, however, results are unreliable in diverse environmental conditions. (Premal et al., 2015) developed YCbCr based approach for fire pixel segmentation using statistical features of the image. In this study, seven hundred fifty images are considered to evaluate the performance of the proposed approach. The simulation results of the proposed approach are compared with existing image classification techniques. It is stated that the proposed approach improves the true alarm rate. A uniform image partitioning method reported to process images in a parallel manner (Wu et al., 2006). An ORNAM model developed for enhancing the quality of the reconstructed image and also for reducing the number of homogenous blocks (Zheng et al., 2018). This model is capable to achieve higher efficiency for grey images. A feature extraction method called EWLDA is developed to determine global as well as local information from images (Zhang et al., 2016). An improved model for the accurate detection of motion is presented in (Tang et al., 2016). This model successfully overcomes the external interferences problem and also enhances the efficiency of detection. To process the large scale images, a general-purpose auto-tuning method reported in (Wang et al.,2016). This approach executes the tasks in parallel order and provides efficient results. (Jiang et al., 2017) adopted an RGB-D sensor to address the problem of automatic detection. The depth and RGB information are used for the detection process. The simulation results stated that the proposed approach achieves quality of results. (Zanotta et al., 2015) presented an image detection technique based on the concept of different time slots. In this technique, expectation maximization algorithm is used for estimation of parameters. This approach is suitable for stabilized situations but not for dynamic environment. (Yuan et al., 2017a) presented an automatic detection system based on image processing for forest fires. This algorithm utilizes brightness and motion features to confirm the fire regions. Further, histogram approach is used for segmentation task. Authors claimed that integration of these features can improve the capabilities of forest fire detection system. (Qiu et al., 2012)developed an algorithm based on HIS and RGB color models for the detection of fire. The proposed approach is computationally efficient but false alarm rate increases with moving objects. (Tsetsos et al., 2012)designed an algorithm to prevent the forest fire disaster. This algorithm is based on properties of smoke and fire. It is seen that proposed algorithm efficiently detects fire, but smoke particles can intensify the false alarm rate. Table 2, presents the pros and cons of color models with parameters.

Table 2: Advantages and Disadvantages of Color model and their parameters

Color Model	Advantages	Disadvantages
RGB (Red, Green, Blue)	RGB is considered as the basic color model in the majority of the applications as there are fewer requirements for	The specific color determination in RGB is very difficult. RGB is a hardware-dependent system and it

	transformation to display the information on the screen. RGB is also reflected as the computational practical system	reveals the use of CRTs. RGB is not suitable for the specification of objects and color recognition.
HIS(Hue, Saturation, Intensity)	In the HSI model, the colors can easily be defined by human perception, unlike RGB. The model is robust earlier of non-uniform illumination	The angular nature of the model results in the instability of Hue. This model is having non-removal singularities.
YCbCr(Y is for Luminance, Cb and Cr is for Chrominance blue difference and red difference)	This model is efficient for the compression of the image. Luminance can be utilized individually for storage in high resolution whereas the chrominance values can be adjusted to enhance the performance.	The color in display depends on the primary RGB which displayed the signal originally. The range of color is limited in color TV images.

2.4 Related Works on Fire Detection using UAV's

Traditional methods for monitoring of fires were suited for surveying plain areas. However, most of the fires occur in remote locations with a harsh environment that can cover the area of any size with the flow of wind. The modern satellite systems have got high efficiency, accuracy and accurate automatic operations. These satellite systems in combination with the traditional monitoring methods could attain a high level of accuracy, but it is not reliable and susceptible towards poor signals of satellites (Bisio et al.,2007). Some other new technologies such as remote sensing have shown significant advantages in monitoring large areas. The high spatial resolution images are very efficient and satisfactory for monitoring events (Hua et al.,2017; Tasselli et al., 2010; Xiao-rui et al., 2005)compared to earlier unsafe monitoring techniques. The capabilities of InSAR provide day/night monitoring with all weather conditions and therefore it is considered as the significant technology for area surveying and mapping. The monitoring of fire events requires continuous observation and the evaluation based on the time axis which is limited in InSAR as it provides monitoring for the corresponding time. Therefore the monitoring of fire events through satellite systems is not reliable for continuous monitoring in terms of precision, time, cost, and scale (Gupta et al., 2013). Moreover, the quality of some images in dense fog, cloudy and rainy conditions may lead to the generation of false alarms. Compared to all previous monitoring methods the UAVs presents fast acquisition of data, reliable operation for short visit period, and simple operations. UAVs can operate at low altitude and provides images rapidly during their operational time (Christensen, 2015). As the continuous operation and efficient data acquisition the UAVs technology is advantageous over traditional monitoring methods and remote sensing-based techniques (Thiel et al., 2016). Table 3, presents the comparison of UAV based monitoring with other traditional methods.

Table 3:UAV Technology in comparison with other traditional methods

S.N.	**Techniques for Monitoring**	**Data Processing**	**Processing Information**	**Scanning Time**	**Scanning Condition**	**Cost**
1	GPS	Fast	Line and Point	Shorter	Any Weather	High
2	Satellite Imaging	Slow	Space, Line and Point	Shorter	Weather Dependent	Lower
3	InSAR	Fast	Space, Line and Point	Shorter	Any Weather	Lower
4	UAVs	Faster	Space, Line and Point	Short	Weather Dependent	Low

The advantages of UAVs like their timely response and quick acquisition of data can be seen in various studies of different UAV sensor platforms (Padró et al., 2019). The other previous methods for confirmation and monitoring of an event are limited with time constraints and safety aspects which results in incomplete processing information for the evaluation and monitoring of events. The studies show that the UAVs can monitor the area more effectively in a range of about 100000 m^2(Sartinas et al., 2019). The UAVs can effectively monitor the area and confirms the event at a large or small scale. On the comparison of UAV with other monitoring techniques, it is less expensive and at the same time provides wide applicability. Particularly, a large number of UAVs can be deployed for monitoring of an area due to cost-effectiveness. The UAVs equipped with digital cameras are utilized to provide the basic surface model and regular images (Yuan et al., 2017a). The UAVs equipped with multiple lens cameras provide the texture information of the mapped area. The UAVs equipped with less expensive cameras may be considered as the most convenient strategy for monitoring smart cities and mapping an effective area. This method of area mapping can overcome drawbacks of the low spatial resolution of satellite imaging (Yuan et al., (2017b). UAVs also provide the 3D visual effect and avoids the large amount of ground station work. The studies present that the UAVs can achieve high accuracy imaging at the centimetre level. Presently, UAVs with digital cameras are widely used for monitoring areas.

3. PROPOSED ARCHITECTURE

The major challenge for any fire detection system is the confirmation phase, which is necessary to decrease the number of false alarms. The proposed system is designed by considering the challenge of fire confirmation through collected images of the affected region. Fig. 3, presents a general overview of the smart city environment and shows the schematic diagram of the data collection process in a smart city. It demonstrates the application domains of WSNs and IoT in smart cities. IoT provides a platform for the development of applications that can collect the information from connected devices and offer services to authorities, users, and industries. The proposed sensor network and IoT based system is for the application of fire detection around cities. The city's service efficiency based on smart devices highly depends on the collection of data which is followed by its manipulation and final decision generation. Generally, the efficiency of smart city services is enhanced through real-time processing and inter-communication among smart devices with IoT which makes the city smarter. The observation data is collected through devices and it is transferred to the cloud through a gateway.

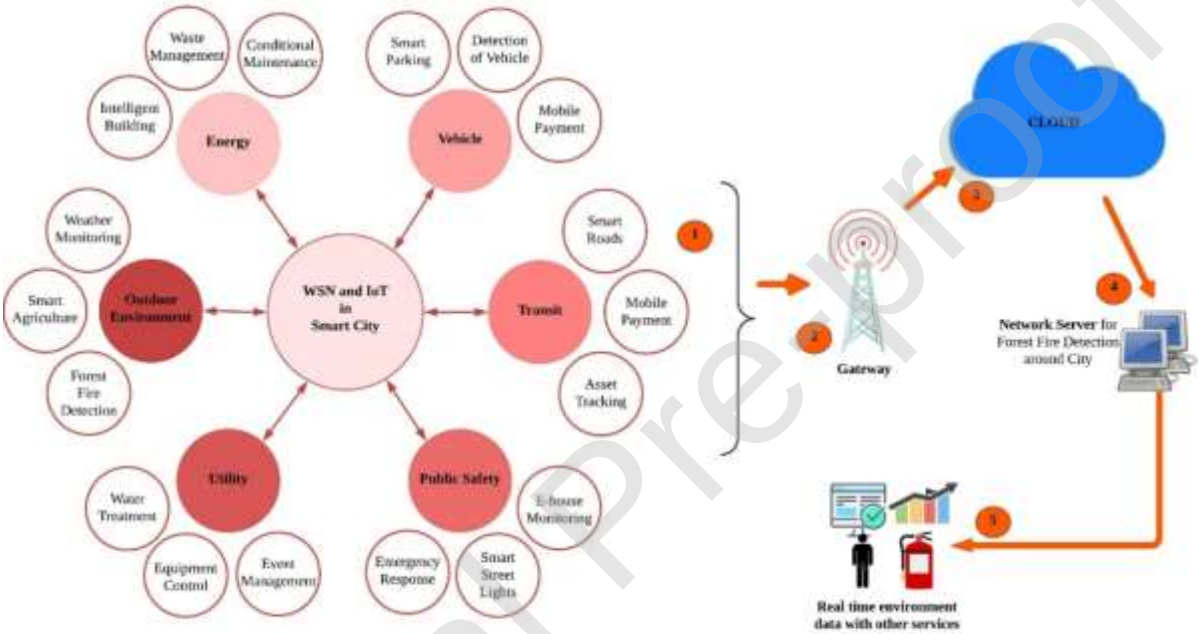


Figure 3: Wireless Sensor Network and Internet of Things assisted Smart City

The cloud can act as a platform to store the data in real-time and provides its analysis for monitoring and decision making. This data is accessed by several users and controllers through a network server and provides services from the real-time environment data. The system is designed considering the efficiencies of WSNs and IoT for smart cities. The working of the proposed architecture for the detection of fire event in a city is presented in Fig. 4. It is the combination of wireless sensor networks and IoT devices for detecting and monitoring fire events. Generally, a smart city is surrounded by an area that may be a forest area, agriculture field, or any terrain. The proposed architecture plays an important role in protecting cities from natural or manmade disasters. The working principle of the proposed system is categorized into five parts i.e. Sensor deployment, Satellite Network, ThingSpeakIoT Cloud, UAV Network, and Control Station.

3.1 Sensor Deployment (Part A)

The first part refers to the random deployment of sensor nodes in an area of interest around the city. The sensor nodes are deployed in the field area for the collection of environmental parameters. The information of various environmental parameters like temperature, humidity, smoke and intensity of light are collected in real-time. The sensor nodes communicate among each other using radio frequency links and transfers the data to sink node. The sink node collects the sensed data and transfers it in the cloud platform through GSM (GPRS) for real time analysis. The sensors are programmed for providing real time environment data in every 2 to 5 minutes range. The specification of each sensor node is discussed in Section 4.

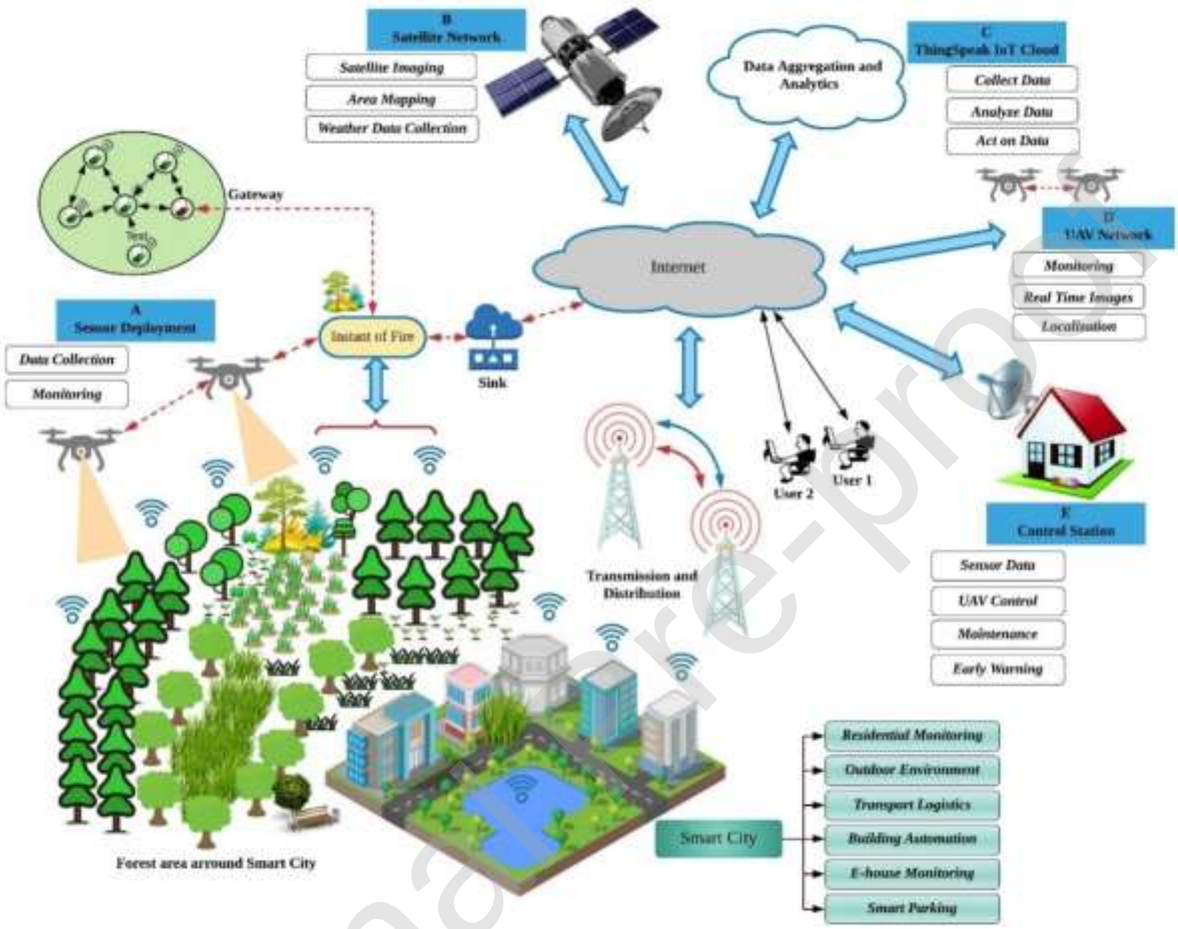


Figure 4: Vision of an integrated system for detection of fire event in Smart City

3.2 Satellite Network (Part B)

In Part B,the satellite system for scanning of area. Satellite based monitoring is a popular method for the detection of fire but the long scan duration and low resolution of satellites restrict the effectiveness of the satellite based fire detection method. Moreover, the satellite based system cannot predict the forest fire before the fire event grows wild. The satellite system are utilized to map the area for future direction and this part is also responsible to collect information regarding other important variables like weather, wind direction, etc. The area scanning through satellite provides the accurate dimensions of the area of interest. The satellite based images are utilized for effective area mapping and deploying drone network for real time monitoring. The satellite system gathers the latitude and longitude of the target area and transfers the data to the control station for area tracking. Based on the latitude and longitude information from the satellite system the area is mapped for scanning.

3.3 ThingSpeakIoT Cloud (Part C)

Part Cis IoT based cloud platform for data analytics. The live streams of data coming from sensors stored in this platform for data aggregation, visualization and its analyses. The collected data from the ground is transmitted privately to cloud where the data is analysed and visualized using MATLAB. This platform creates an instant visualization of live stream data and triggers an alert when required. The results of real time analysis through ThingSpeak cloud platform in the form of table and graphs are presented in section 5.

3.4 UAV Network (Part D)

Once the event is detected, the proposed system then extended to provide the real time images of the affected zone which is carried out in Part D.The UAV helps to localize the event and provides the image data to the control station where image processing algorithm is applied for the confirmation of a fire event in real time. The process of scanning begins with the request from server for the monitoring mission. The mapping software is utilized for planning of mission where the check points along with their coordinates are defined. The trajectories are thus formed on the mapped area for the drone to fly as per the mission and further this information is broadcasted with the updated parameters to the ground station. The drone deploy provides the high resolution images of the target area. The sensed information is transferred to the ground station for processing in real time. The occurrence of an event initiates the process of location identification for tracking and confirmation of an event.

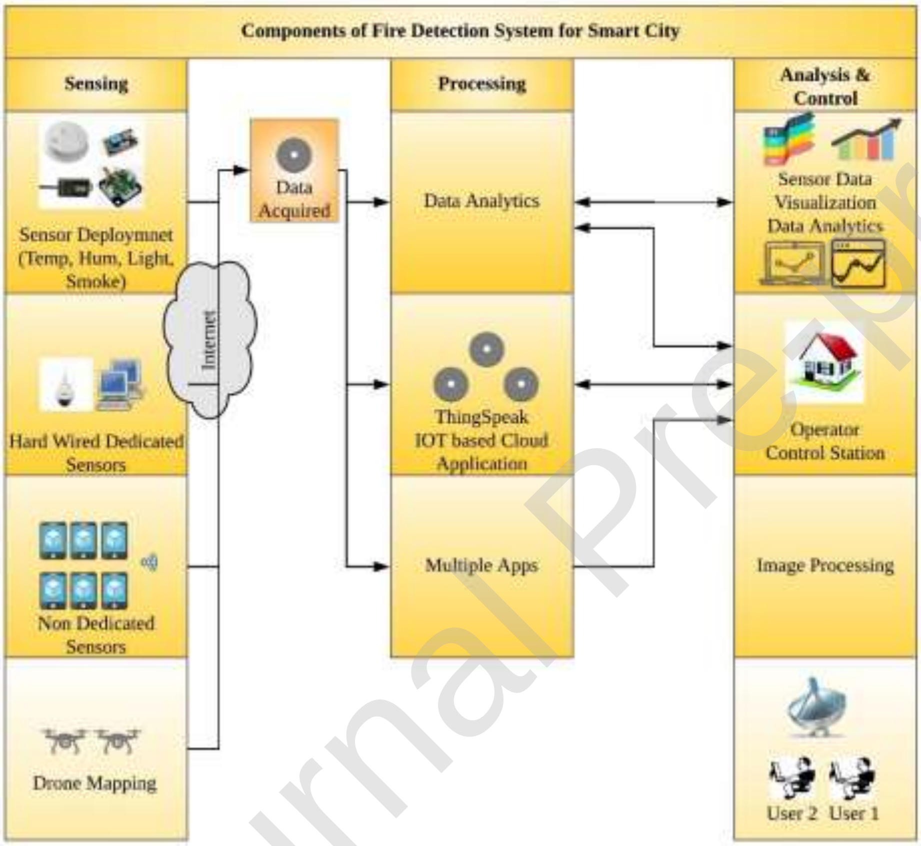


Figure 5: Components of Fire Detection System for Smart Cities

3.5 Control Station (Part E)

Part E is the control station which is responsible for processing of the sensor data, control and maintaining network and validating the occurrence of a fire event through image processing technique. The collected images are analysed in control station for the detection of event. The control station sends an early warning, when occurrence of fire is confirmed.The basic components of proposed architecture are sensing, processing and analyzing. Fig. 5, presents the basic components of proposed fire detection system. In initial phase, the temperature, humidity, light and smoke sensors are deployed in outdoor environment randomly to collect the information regarding environmental parameters. Each sensor node communicates directly to the sink node. The sink node is responsible for communicating the collected information to the ThingSpeak cloud for storing and processing purpose. The collected data is stored on cloud platform for analyzing purpose and various application specific tasks are also performed. The work of sensing stage of proposed system is to deploy the sensor nodes and also monitor the environmental parameters which are responsible for the occurrence of fire. The collected information is stored at ThinkSpeak cloud in every 2 to 5 minutes for regular monitoring and analysis. The processing stage collects the data from sensor and analyze it for the detection of abnormality and take the decision based on data analysis. The data available on the cloud can easliy be accessed by remote users. The regular monitoring of the data enables the user to detect the adversaries and the occurrence of an event at its early stage.The third component is analyzing which confirms the event by applying image processing technique on the real time data provided by UAVs. The data stored in cloud can easily be accessed by remote location through as many as users and controllers. The control station can manage and control the devices for better communication. The proposed fire detection system works with color images that are collected through UAV. Remote station takes the images as input. The image detection algorithms are applied to detect the fire regions. The work of control station is to receive information; analyse the collected information and invoke the alarm. The alert message is sent to management team for firefighting and planning strategies for the future directions.

4. SENSING AND OPERATION OF MONITORING

The proposed integrated system for detection and monitoring of fire through Wireless Sensor Networks and the Internet of Things is shown in Fig. 6. The system works in five different stages which are mentioned as Part 1 to Part 5. The major contributions of the working stages of the proposed system are the deployment of sensors, analysis of data in ThingSpeak cloud and confirmation of the event through image processing.

4.1 Flow of Information

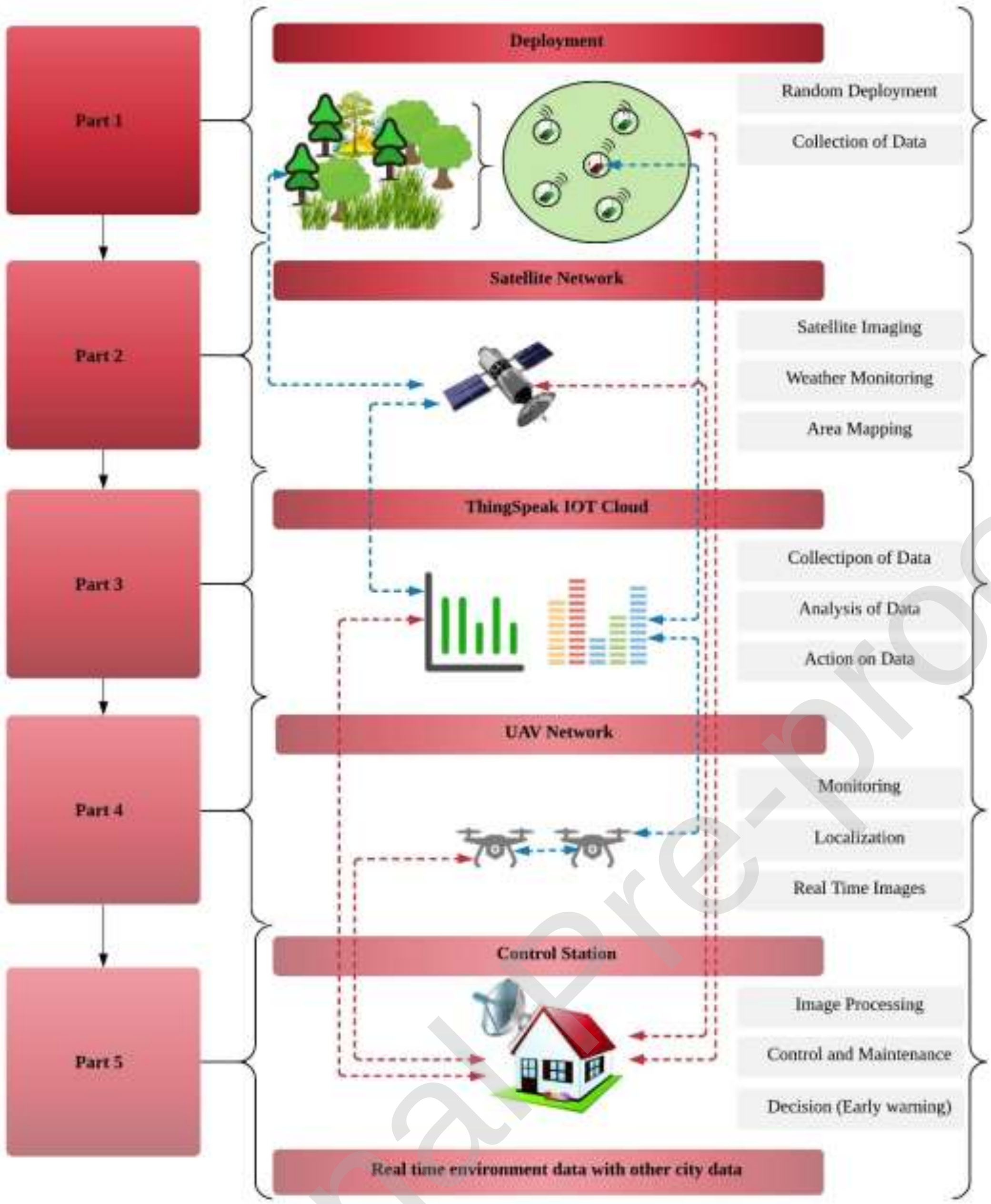


Figure 6: Advanced concept of detection and monitoring of an event through WSNs and IoT

Fig. 7, presents the flow chart of the WSNs and IoT operation for monitoring and tracking of an event. The process of detection begins with the deployment of sensor nodes. The condition for the maximum coverage with the least number of sensors is then checked. If, the objective is satisfied then, the shortest path for the transmission of data to the sink node is planned to achieve higher energy efficiency. The data is transmitted to the base station from the sink node and the ThingSpeak Cloud is used for storage of data within every two to five minutes. The cloud-based application reads and analyses the real-time data and runs the MATLAB analysis for event detection. For any abnormality in the sensed information, a message is transferred to the control station along with the GPS coordinates of the node which triggers it. The control station maps the target area for capturing real-time images of the affected zone through checkpoints marked with the GPS coordinates.

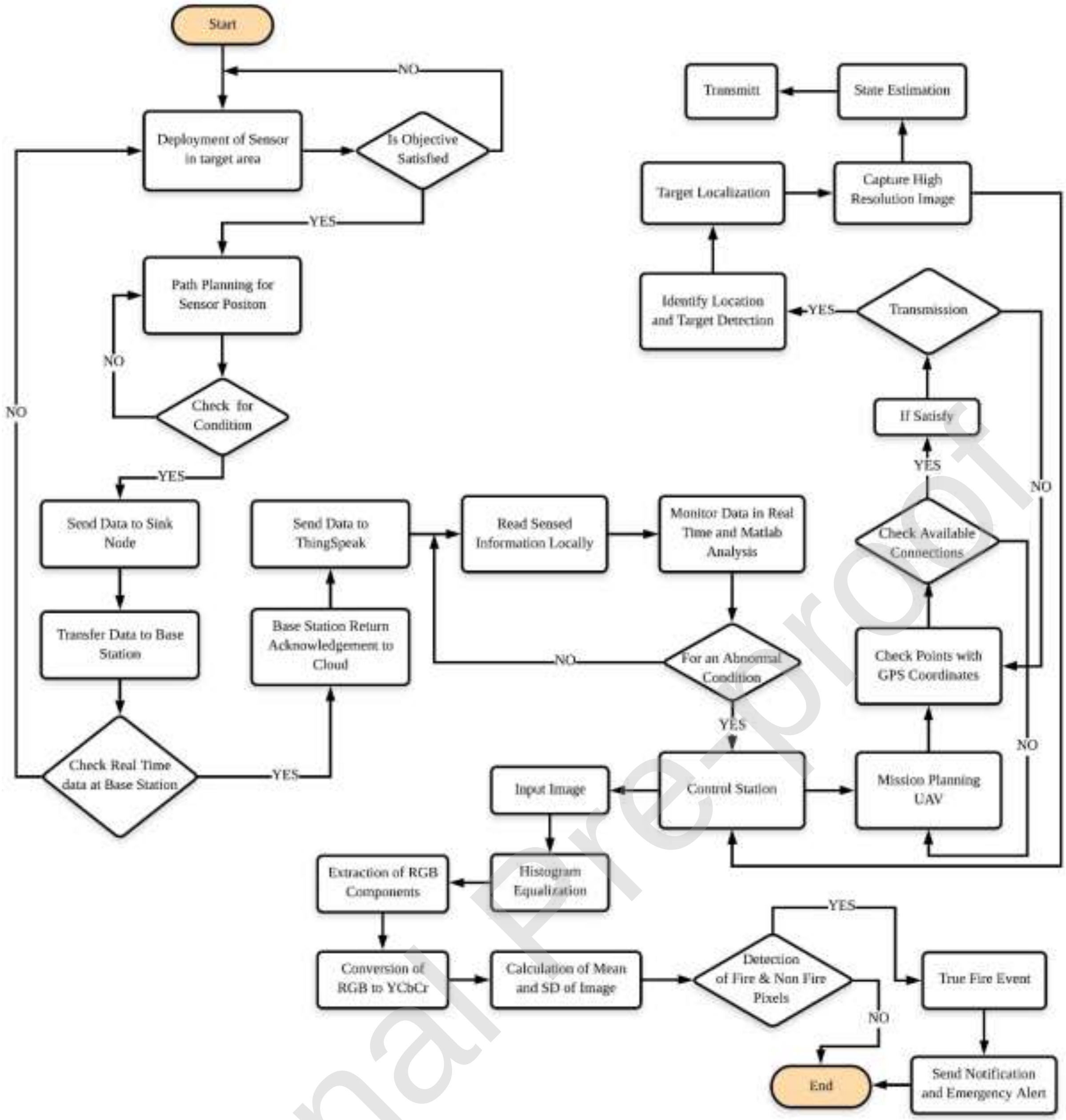


Figure 7: Flow chart of the proposed event detection system for Smart Cities

The localization of the affected zone is carried and the real-time images are transferred to the control station. The image processing algorithm is implemented to every input image. The steps for the confirmation of a fire event through image processing are discussed. The first step is to generate the histogram equalization of image. Further, to enhance the contrast of the image, the intensity of the image is adjusted. For the proposed algorithm, it is considered that fire images contain a high value of the red component. So, a threshold function is designed to extract the red component of fire color images. Another thing that can be considered in this work is the ratio of red, blue and green components. Hence, the proposed fire detection system is based on color detection and mapping of these color components. Initially, an image is loaded for color detection and mapped with the extracted edge.The color detection system identifies the properties of RGB pixels and presents an image in its output with the selected area of fire color detection. In the second step, RGB components are extracted from the enhanced image and RGB image is converted to YCbCr for the detection of fire pixels. The next step is to compute the mean and standard deviation of images for confirmation of fire and non-fire color pixels. When, no fire region is detected in the image, the algorithm jumps to the next sample of images to evaluate fire pixels. If a fire is detected, then a set of rules are applied to the sample images, and based on these rules fire alert is triggered for decision making.

4.2 Deployment of Sensor Nodes

Fig. 8, shows the various sensors which are deployed for the detection of fire in the area of interest by the collection of information regarding various environmental parameters. Light sensors (a) detect light density but do not record images. The most common light density sensors are Photodiodes (LDR Light Dependent Resistors) and photo resistors (LDR Light Dependent Resistors). Photo diode can convert light into either current or voltage. Photo resistor is a resistor whose resistance decreases with increasing the light intensity.


(a)


(b)


(c)


(d)

Figure 8: (a, b, c) are the sensor nodes for light, temperature, humidity, smoke and (d) is the coordinator node

HTS-220(b) sensor which is a basic, low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air and spits out a digital signal on the data pin (no analog input pins needed). It is very simple to use but requires careful timing to grab the data. MQ2 (c) is a smoke sensor that is capable of detecting the concentrations of combustible gas in the air and outputs its reading as an analog voltage. The sensor can measure concentrations of flammable gas of 300 to 10,000 ppm. The sensor can operate at temperatures from -20 to 50°C and consumes less than 150 mA at 5 V. All the data collected by the **sensor** nodes are forwarded to a **sink (Coordinator)** node (d). Therefore, the placement of the sink node has a great impact on the energy consumption and lifetime of WSNs. In Wireless Sensor Networks (WSN) the energy consumption and lifetime of sensors are an important issue. The data collected by the respective cluster nodes will be transmitted to the elected cluster heads. The cluster heads then will send all collected data to the Sink Node or Base Station. The data received by the base station will be sent to the data processing centre. This is why the Sink Node is called the gateway between the sensor nodes and the data processing centre.

4.3 Analysis of Data

Internet of Things is an intercommunication of smart devices, vehicles, smart homes, hospitals, buildings and many other smart things that are embedded with sensors, actuators and connectivity which enables these things to collect and exchange information. In this system, ThingSpeak based cloud platform is used for the collection of data and its analysis. ThingSpeak is a cloud-based application platform that is designed to facilitate meaningful connections among smart things and people. The sensed information is stored in ThingSpeak at real-time and the control station monitors every event.

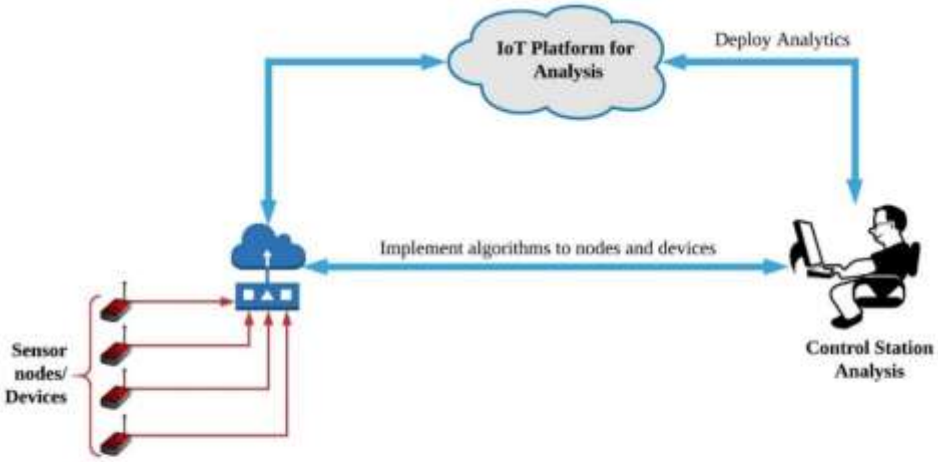


Figure 9: Working of ThingSpeak Cloud

Fig. 9, presents the working of IoT based cloud platform. ThingSpeak is an IoT based application that collects the measured data from sensors and visualizes that data instantly. It provides an instant act on the data when the measured data or instant reaches a threshold.

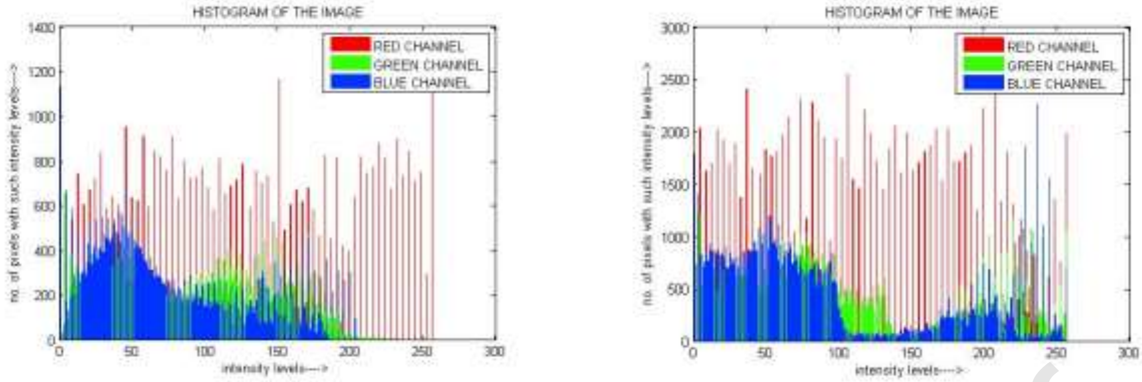
4.4 Confirmation of Fire Event

The detected abnormality in the sensed data through the analysis of data in ThingSpeak application triggers the UAV for capturing the real-time images of the region. The UAV maps and localizes the target area through the GPS coordinates which is available in the control station. The proposed image processing algorithm is implemented at control station on the input images for the confirmation of fire. The first step is to construct the histogram equalization which redistributes the image intensity. The received input image is tested for equalization by converting it to HSI image of higher intensity while conserving the Hue and Saturation components of the original image. The equalization is applied and tested for four sample images of fire to improve the image intensity as illustrated in Fig. 10, (a) is the set of original images of fire event and (b) Improved image intensity after the equalization process.

(a) (b)

Figure 10:(a) Sample image before Histogram Equalization (b) After equalization process

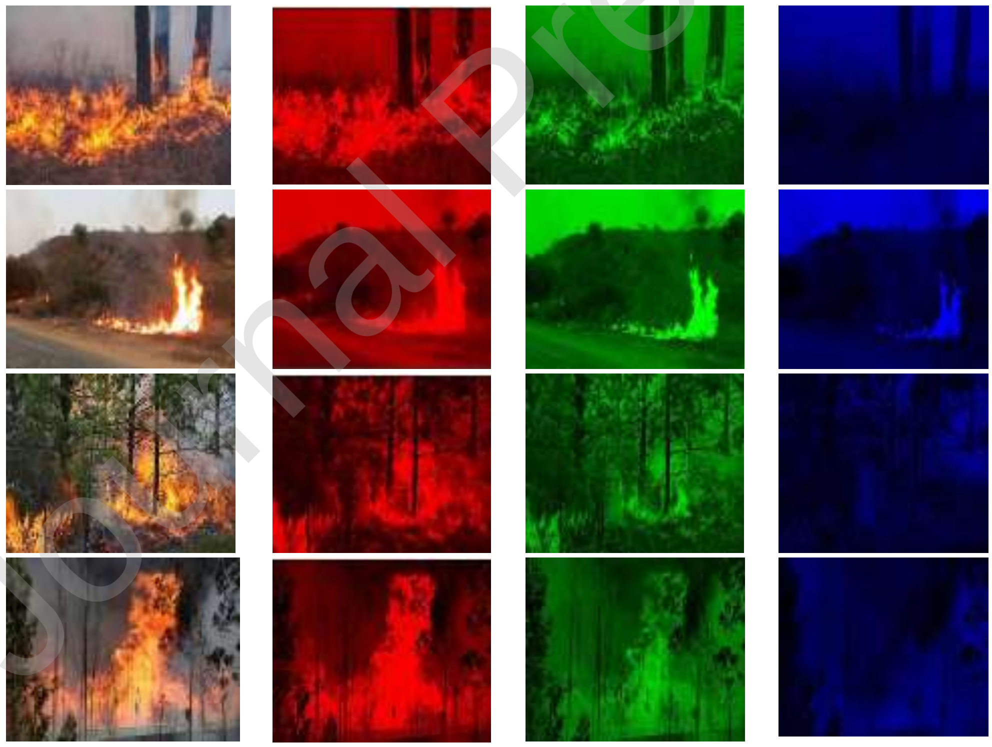
It is noticed that histogram equalization cannot improve the R, G and B components of an image individually. Fig. 10, shows the histogram results before and after histogram equalization on an image using R, G and B. Four sample images are taken to determine intensity levels and the number of pixels. The histograms of these images are reported in Fig. 11(a and b) depicting the histogram of two original sample images. It shows frequency distributions of the original image using histogram equalization.



(a) (b)

Figure 11(a, b): Number of Pixels with Intensity Levels of Sample Image 1, Image 2

Additionally, the input RGB matrix of the image is transformed to HSI format and then the equalization is applied on intensity matrix for improving the image quality. Further, the updated matrix of HSI (Hue, Saturation and intensity) is transformed back to RGB matrix while keeping the HSI matrix constant. In the proposed method, YCbCr model is applied because it separates the image luminance information from chrominance efficiently than any other color model. The fire color during its highest temperature state is yellowish-white at the centre which varies from red to yellow for other regions except for its centre. The fire region is segmented based on certain rules designed and implemented for the extraction of fire pixels. Rule 1 is applied to segment the fire region and Rule 2 is applied to segment the centre region.The final image is generated by satisfying rule 1 and rule 2. A true fire image is obtained using these two rules. Rule 3 is applied for matching the threshold of the fire region.



(a) (b) (c) (d)

Figure 12: (a) Images after histogram equalization, (b, c &d) Extraction of red, green & blue component

The aforementioned rules efficiently segment the true fire region and capable of arranging the fire pixels which vary from yellow to red with changing temperature. The color plane of any color image is defined by RGB components. Every color plane is quantized into discrete levels having 256 quantization levels i.e. 8 bit per color plane. At RGB, the black color is represented using (0, 0, 0) whereas white color is represented as (255, 255, 255). Fig. 12(b, c and d), shows the extracted RGB components of an input image. The RGB model is applied to extract the green, blue and red components of an image. The intensity value of R channel is higher in comparison to the intensity of G channel for any fire region in an image. Similarly, the intensity value of G channel is higher in comparison with the intensity of B channel. To confirm the same, some sample images are taken which are illustrated in Fig. 10. Further, the RGB model is applied to extract the R, G and B components. Fig. 12(b-d) illustrates the R, G, and B components of the original image. It is observed that figure 12(b) have more red component as compared to Fig. 12(c). Fig. 13(a), presents the real sample images of fire and 13(b) demonstrates the corresponding fire region extracted using a manual approach. The mean values of the segmented fire region are computed using the original set of images. Table 4, presents the calculated mean value of fire images. It can be concluded that the intensity of R is higher than G and the intensity value of G is higher in comparison to B. Therefore, a pixel at any spatial location (a, b)can be described as fire pixel, if it is satisfied equation 1. Equation 1, reveals that for any image$X$, if the mean intensity value of R is higher than G and$B$, then the pixel at any spatial location (a, b)can be a fire pixel.

$$X_1(a, b) = \begin{Bmatrix} 1, if\ R(a, b) > G(a, b) > B(a, b) \\ 0, else \end{Bmatrix} \quad (1)$$

Table 4: Mean values of***R***, G and B components of the manually segmented fire regions of Fig. 6

Number of Images	R_{mean}	G_{mean}	B_{mean}
1	252	240	154
2	249	218	145
3	251	235	152
4	242	211	136


(a) (b)

Figure 13: (a) Input RGB image, (b) Manual extraction of fire region

For the classification of the fire region, several rules are implemented based on RGB. The RGB approach cannot extract red component if the image has a high intensity level. Further, it is not possible to separate pixels from intensity and chrominance. The chrominance is an important factor for modelling the color of fire, whereas intensity can represent the fire color pixels. So, it is not possible through RGB approach to extract fire pixels from the estimation of chrominance and intensity of the original image alone. Hence, in this work, the YCbCrcolor space model is applied for the classification of fire color pixels. When the fire region is manually computed, some fire pixels can be left. So, to extract fire pixels more accurately, a new parameter is developed. This parameter is summarized in equation 2. For the ease discrimination of intensity and chrominance the image is transformed from RGB to YCbCrcolor space model.

$$X_2(a,b) = \begin{cases} 1, if\ (R(a,b) > 190) \cap (G(a,b) > 100) \cap (B(a,b) < 140) \\ 0, else \end{cases} \quad (2)$$

Fig. 14, presents the extraction of Y, Cb and Cr component from the input RGB image. The images are converted into YCbCrcolor space model to determine intensity and chrominance. This transformation can be done using equation 3. In turn, YCbCr conversion matrix is produced and the range of colors is varied in between 0 to 255.

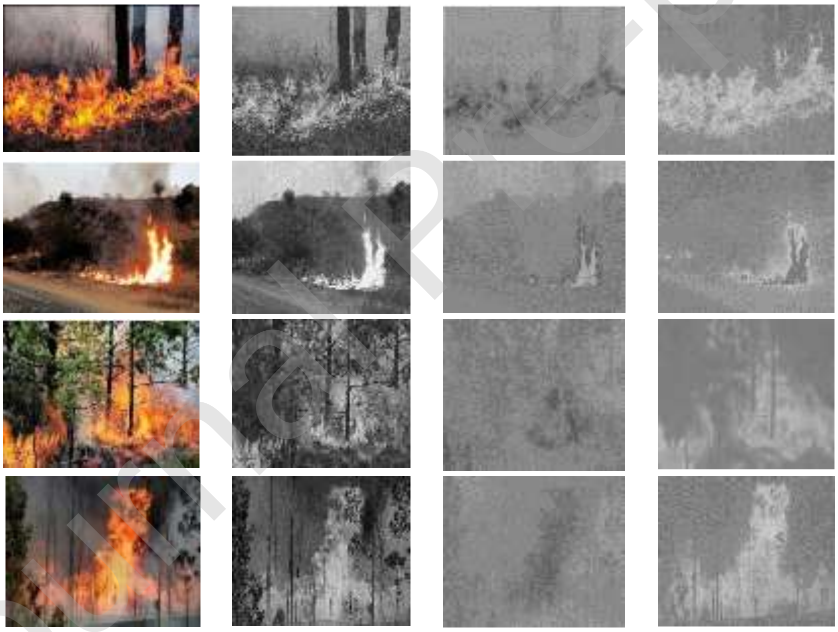
$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.256 & 0.504 & 0.098 \\ -0.148 & -0.292 & 0.441 \\ 0.441 & -0.369 & -0.071 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} \quad (3)$$

In above equation, Y, Cb and Cr represent luminance, chrominance blue and chrominance red components. The range of luminance Y is 16-235, whereas the range of Cb and Cr is 16-240. These ranges are used to compute mean values of three components i.e. Y, Cb and Cr. The mean values for Y, Cb and Cr are computed using equations 4-6.

$$\mathrm{Y_{mean}} = \frac{1}{\mathrm{M \times N}} \sum_{x=1}^{M} \sum_{y=1}^{N} \mathrm{Y(x,y)} \quad (4)$$

$$\mathrm{Cb_{mean}} = \frac{1}{\mathrm{M \times N}} \sum_{x=1}^{M} \sum_{y=1}^{N} \mathrm{Cb(x,y)} \quad (5)$$

$$\mathrm{Cr_{mean}} = \frac{1}{\mathrm{M \times N}} \sum_{x=1}^{M} \sum_{y=1}^{N} \mathrm{Cr((x,y)} \quad (6)$$



(a) (b) (c) (d)

Figure 14: (a) Input RGB image, (b, c and d) Extraction of Y, Cb and Cr component from the input image

At each location (x, y), the value of pixels for Y, Cb and Cr components are defined as Y(x, y), Cb(x, y) and Cr(x, y), where (x, y) describes the spatial location of pixels and $M \times N$ is the total number of pixels in an input image. The standard deviation of an image can be determined using equation 7. In this work, the standard deviation of Cr plane is used. The mean values of the fire region of planes Y, Cb, Cr are represented in Table 5.

$$\mathrm{Cr_{std}} = \sqrt{\frac{1}{\mathrm{M \times N}} \sum_{x=1}^{M} \sum_{y=1}^{N} (\mathrm{Cr(x,y)} - \mathrm{Cr_{mean}})^2} \quad (7)$$

Table 5: Mean values of Y, Cb, Cr Plane

Sample Image	Mean Y	Mean Cb	Mean Cr
1	132	109	158
2	190	78	150
3	155	67	155
4	165	70	165

To identify fire pixels more accurately, three rules are designed and these rules are tested on different sample images. These rules are defined as below.

Rule 1: This rule is designed for the segmentation of flame region using table 5. Equation 8 is used for the segmentation process which is described below.

$$R_1(a,b) = \begin{Bmatrix} 1, if\ Y(a,b) \geq Cb(a,b) \\ 0, \quad else \end{Bmatrix} \& \begin{Bmatrix} 1, if\ Cr(a,b) \geq Cb(a,b) \\ 0, \quad else \end{Bmatrix} \tag{8}$$

Rule 2: It is implemented for the segmentation of centre pixels. In a fire image, the region of flame is the brightest region and the mean value of channels Y, Cb, Cr contains valuable information. It is noticed from Fig. 14 that the value of Y component is higher than that of mean value of Y component of the fire image whereas the value of Cb component is lesser than its mean Cb component of the image. Additionally, the value of Cr component is higher than the mean of Cr component in an overall image. Rule 2 can be designed on the above mentioned concept and described as.

$$R_2(a,b) = \begin{Bmatrix} 1, if\ (Y(a,b) \geq Ymean(a,b)) \cap (Cb(a,b) \leq Cbmean(a,b)) \cap (Cr(a,b) \geq Crmean(a,b)) \\ 0, else \end{Bmatrix} \tag{9}$$

Rule 3: Through Fig. 14(c-d), it is noticed that there is a significant difference between the components of Cb and Cr fire pixels. In a fire image, Cb component has low intensity value, whereas Cr component having higher intensity. Hence, a rule is formulated on the above mentioned fact to detect fire pixels.

$$R_3(a,b) = \begin{Bmatrix} 1, if\ |Cb(a-b) - Cr(a-b)| \geq Td \\ 0, else \end{Bmatrix} \tag{10}$$

In equation 10, Td is evaluated using ROC curve. This ROC is generated by evaluating different values of Td over 50 sample color images. Rule 1 and 2 are applied to defined (Td) over fire sample images. Results are measured in terms of positive alarm rate and negative alarm rate.

5. RESULT AND ANALYSIS

This section presents the system setup that consists both hardware and software and experimental analysis of the system. The general architecture of the fire detection system is presented in Fig. 4.

5.1 Sensor Nodes

Sensor devices are the peripherals which acts as a link among the devices and the external world. The sensor node collects the environmental parameters and transmits the collected data to the processing unit for its analysis. In this work HTS-220 has been used for gathering relative humidity and ambient temperature, MQ2 and TL sensor has been used for the detection of smoke, and measuring light intensity. The 2G/3G gateway module is used to receive and transmit the collected data to the internet using 802.15.4 standard. The hardware setup of the deployed sensor and gateway modules is presented in Fig. 8.

- **A. HTS-220:** This sensor is capable of sensing relative humidity and ambient temperature. It enables a user to design a temperature or environmental specific application with minimum cost and efforts. The sensor provides a 14 bit resolution digital output.
- **B. MQ2 Sensor:** This sensor works on the principle of ionization. This sensor node consists a sensing element which senses the smoke generated from heat. With the change in air, sensing element ionizes which changes the sensor's resistance and thus the sensor output varies. The detection range of this

module for CO_2 is from 350 to 1000 ppm and for CO it ranges between 20 to 2000 ppm. The smoke sensor is capable of operating at a temperature range between -20ºC to 70ºC.

C. **TL Sensor:** This sensor module is capable of measuring the intensity of light for monitoring environment. It provides a 16 bit resolution digital output and light range between 3 to 64k lux. The TL sensor is capable of operating at a temperature range between -25ºC to 80ºC.

D. **2G/3G Gateway Module:** It comprised of Fibocom G510 model which is IoT enabled 2G/3G/GSM/GPRS module. This module acts as an interface between the sensor data and application. It provides a GSM based solution for collecting and transmitting the sensed information using IEEE 802.15.4 standard to internet.

5.2 ThingSpeak for IoT and Drone Mapping

The data analytics is carried out using ThingSpeak cloud platform. ThingSpeak is an open source IoT platform service from MathWorks. This platform allows user to collect, analyse and visualize real time data in cloud and act accordingly. This platform presents data visualizations instantly based on the live data streams. The online analysis of the live data and processing of data are performed by executing MATLAB code in ThingSpeakIoT platform. It provides the capabilities of accessing data both online and offline and presents the remote visualization of sensor data in real time. Drone deploy is the platform utilized for the mapping of drones which offers both the web and app based platforms. The drone deploy provides the high resolution images and videos of the target area to the ground station. The collected images are analysed in ground station by implementing image processing algorithm for the detection of fire event.

5.3 Experimental Analysis

The operational stages of the system are divided into three phases which are deployment phase, analysis of data and confirmation of an event. The sensor nodes are deployed for collecting data of environmental parameters such as humidity, temperature, intensity of light and smoke from an area of interest. The real time data analytics is carried out using ThingSpeak Cloud. The data is monitored continuously and for any adversaries in data, user executes MATLAB code in ThingSpeak for the confirmation of event.

A. Sensor Interface with Gateway Module

The sensor nodes for the real time collection of data from environment are deployed in the outdoor field. These nodes senses relative humidity, ambient temperature, light intensity and smoke parameters regularly. The sensor nodes communicate with each other and transmit the data to gateway module. Gateway module uses Fibocom G510 model which is a kind of microcomputer and provides a GSM based solution for collecting and transmitting data. The sensed data from various sensors are collected using gateway module and transmitted to internet. The gateway module updates the cloud system with live instances of field data in every 2 to 5 minutes. This module provides the advantage of low power consumption and its operating voltage is typically around 4 volt. This module can be powered through power bank and acts as a gateway or interface that links the collected data with the internet. The gateway module collect the data in real time and store it to the ThingSpeakIoT platform.

B. ThingSpeakIoT Analysis

The analysis of the real time data is carried out in ThingSpeak platform where each of the sample data is processed for the detection of any adversary. A sample of the observed data is presented in Table 6 and its MATLAB analysis is shown in Fig. 15. The third phase of the system is confirmation of an event based on image processing technique. For the reliable and efficient transmission using a WSN, the energy consumed for the transmission must be as less as possible.

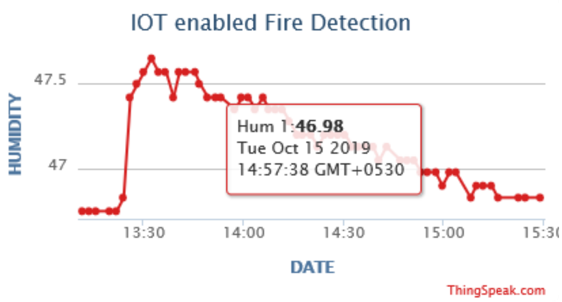
Table 6: Sample of observed data set from sensor nodes in ThingSpeak Cloud

Time created at (Instances)	Entry	Smoke 1	Temp 2	Light 1	Smoke 4	Hum 1	Hum 2
2019-10-15 12:15:23 +0530	601	465	21.02	153	245	43.45	50.2
2019-10-15 12:20:00 +0530	602	584	21.07	165.21	234	44.23	51.47
2019-10-15 12:24:41 +0530	603	589	21.7	192.3	274	45.63	54.31
2019-10-15 12:27:10 +0530	604	592	21.8	180	265	47.2	50.03
2019-10-15 12:31:30 +0530	605	590	21.23	186.3	284	46.32	50.27

2019-10-15 12:34:20 +0530	606	560	21.03	167.2	247	44.8	52.6
2019-10-15 12:38:03 +0530	607	570	21.7	191	246	47.61	54.24
2019-10-15 12:41:28 +0530	608	554	21.7	175.2	269	49.3	55.2

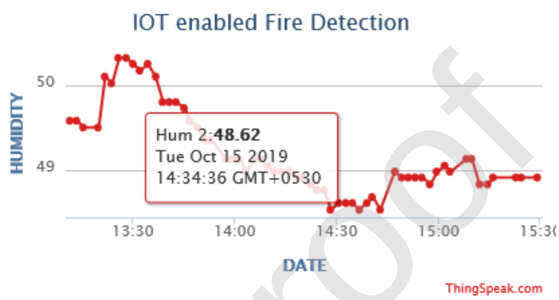
Table 6, presents the sensed information from the sensors of the environment. The collected data is stored in cloud in every 2 to 5 minutes. The column 1 shows the different instances with the date and time for the arrival of data in cloud. For every instance of time various values of temperature, humidity, smoke and light intensity is measured and stored in the cloud for analysis.

Field 1 Chart



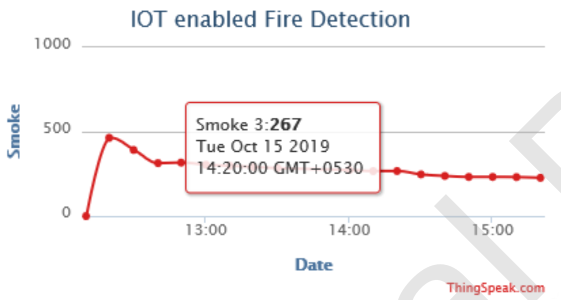
(a)

Field 2 Chart



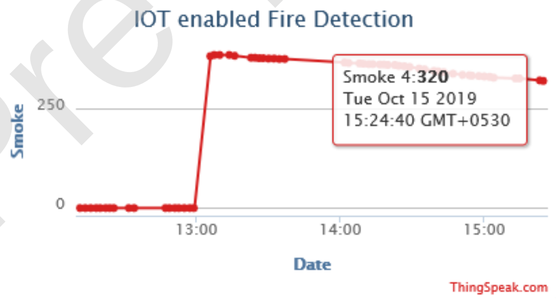
(b)

Field 3 Chart



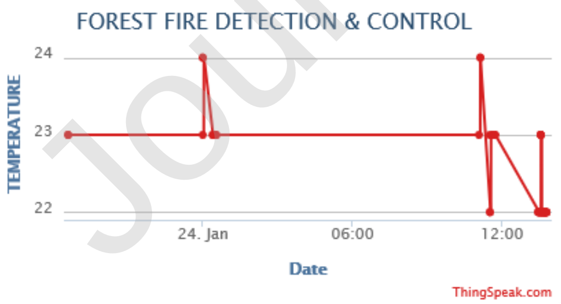
(c)

Field 4 Chart



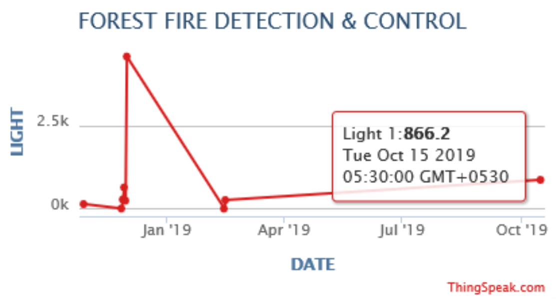
(d)

Field 5 Chart



(e)

Field 6 Chart



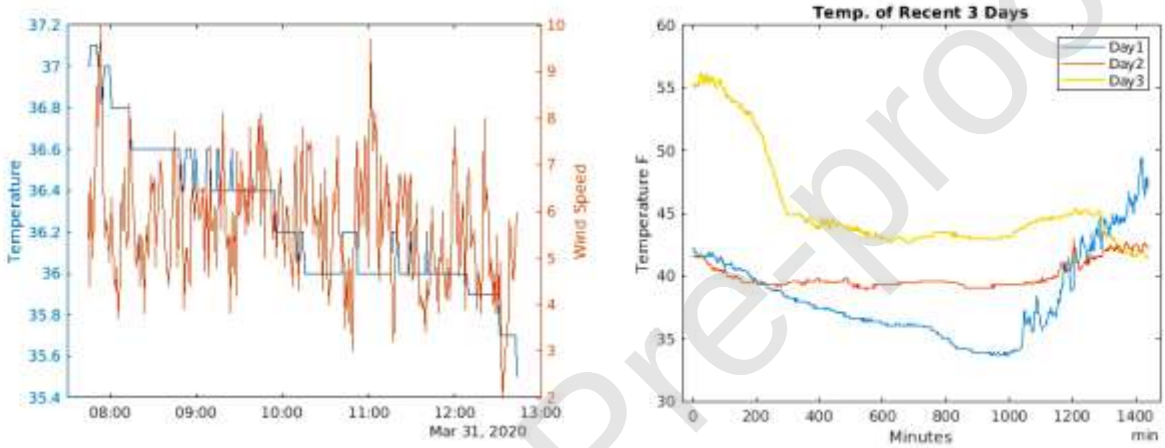
(f)

Figure 15: (a-f) Real time analysis of the observed data in ThingSpeak Cloud application for smoke, temperature, light and humidity from different fields

Fig. 15, shows the graphical representation of the cloud data. The results obtained in ThingSpeak Cloud for different fields set as (a and b) Humidity, (c and d) Smoke, (e and f) for Temperature and Light. The data observed in real-time by accessing the ThingSpeak cloud application. The application provides a reliable output and clear representation of the collected information. From Fig. 15, it can be verified and analysed that all the sensor values are updated on ThingSpeak. It allows users to display different sensor parameters in graphical format by setting its various field sets. Fig. 15 shows these variations in parameters like temperature, light, humidity, and smoke respectively. It senses on a near real-time basis as there is a few seconds delay for data getting updated on ThingSpeak.

C. Data Analysis at Ground Station

There are several graphs which incorporated in this section, generated using ThingSpeak IoT platform. The Thingspeak provides regular monitoring of sensed field data. The field data in the form of temperature, humidity, light and smoke are regularly monitored through deployed sensors. The sensed information is stored in the ThingSpeak platform for the analysis. The sample of stored sensed data is presented in Table 6. For any adversary, the system sends an alert of the detected event along with the coordinates through email to the users. The system runs MATLAB analysis and checks the current temperature and speed of the wind. The system also runs a program for comparing the temperature values for the recent three days.



(a) (b)

Figure 16: (a) Read temperature and wind speed data (b) Comparison of temperature values of three days

Fig. 16, presents the visualization of the data for the predicted event, where (a) presents the temperature and wind speed data and (b) recent three days temperature variations. The data is collected by deploying sensors in JUIT Wakhnaghat, located in Shimla, Himachal Pradesh. The data is collected once in every two/five minutes.

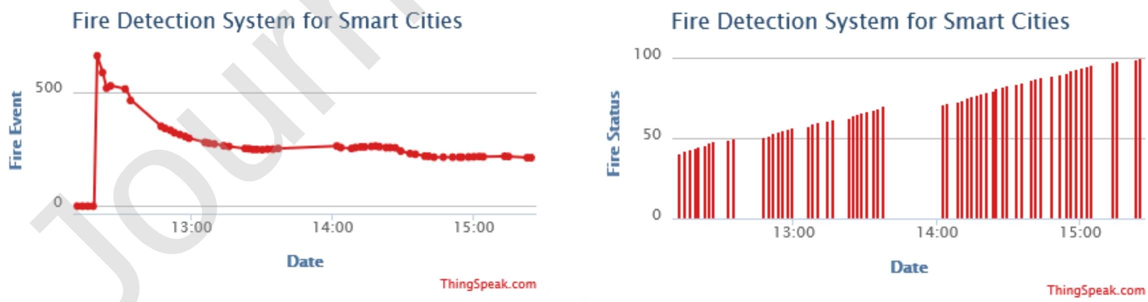


Figure 17: Plots depicting fire event and intensity level obtained using ThingSpeak

The detected event is monitored using ThingSpeak platform. Fig. 17, presents the graph obtained using ThingSpeak. The values exceed threshold, i.e, 500 indicates that the sensor transmits data is close to a fire event, and regularly monitors the intensity of the fire. The spike in the plot indicates the increase and decrease in the value of fire event that may vary depending on the distance between fire and sensor placed. The next phase is the confirmation of a fire event based on image processing carried out using UAVs operation. The drone deploys and a logic is utilized for target area mapping and collection of images. The occurrence of fire event initiates the process of location identification in order to track and confirm the event. Fig. 18 (a), presents the screenshot of the target area and (b) target area mapping which is obtained using DroneDeploy.

(a) (b)

Figure 18: (a) Map screenshot of the target area using DroneDeploy (b) Area mapping for UAV operation

The DroneDeploy localizes the target area and broadcasts the present state of the event to the ground station. The operation of DroneDeploy is to collect the images of the region and transmits it to the ground station for analysis. The ground station collects the information from the DroneDeploy in real time for monitoring. The captured images are analyzed in the ground station for the detection of an event. The performance of the proposed detection system is tested using real world fire and non-fire images and analyzed with some existing approaches (Qiu et al., 2012; Töreyin et al., 2006; Tsetsos et al., 2012). (Celik et al., 2009) used RGB color space model and developed some rules to identify fire region. In continuation of their work, (Celik, 2010) also designed a system for the identification of fire color pixels using RGB values. (Vipin, 2012) developed a system for the verification of fire color pixels using YCbCr color space model. The proposed detection system is the combination of YCbCr color model and RGB values.

Table 7: Performance analysis of proposed system for true detection and false detection

Techniques	RGB (Celik et al., 2009)	RGB(Celik, 2010)	YCbCr(Vipin, 2012)	RGB and YCbCr(Premal et al., 2015)	**This Approach**
Parameters Used	-	-	Mean	Histogram and Mean	Mean and Standard Deviation
True Detection	90	89	93	94	96
False Detection	66	58	30	19	10

A similar approach for the detection of an event is reported in (Lloret et al., 2009). Their approach can detect the event of fire at its early stage but lacks in terms of confirmation of event. There are other approaches for the confirmation of fire event based on image processing reported in (Celik et al., 2009; Premal et al., 2015; Vipin, 2012). The performance of the proposed detection system is tested on two set of images taken from internet. Both of sets contain 100 images individually. A set of one hundred RGB fire images of different sizes ranges from 267×178 pixels to 3000×2000 pixels and of various formats (bmp, jpeg and png) has been created. Similarly, a set of non-fire images has been created that consists of fire like images. The created dataset is composed of free images available from internet and the images which are taken by the researchers and firefighters during experimentation and real fire scenes. The images were preferred for representing different fire contexts of heterogeneous environment such as forests, agricultural land, terrains and also for different luminous characteristics such as cloudy, night, sunny. Fig. 10, presents some of sample images from dataset. Table 7, summarizes the performance analysis of proposed system for true detection and false detection rate. It is analyzed that our proposed system obtains higher true detection rate and lesser false detection rate. Further, in this study three rules are designed to classify the fire region accurately. The results of rules 1 and 2 are mentioned in Fig. 19 (a and b). It is revealed that these rules are capable to determine the fire region. If, fire is identified using either rule 1 or rule 2, then the outcome is indicative of the fire-affected region.

Figure 19(a): Segmentation of flame region implementing Rule 1

Figure 19(b): Segmentation of centre region implementing Rule 2

Fig. 19(a) and 19(b) is the recognition of fire by implementing two rules. Rule 1 is used for segmenting the fire region and Rule 2 is used for segmenting centre region of fire from the original images refer to Fig. 19 (a and b). At last the image obtained which satisfies rule 1 and rule 2 both results as the true image of fire. Rule 3 is implemented to confirm the existence of fire using rules 1 and 2. The final outcome of rule 3 is mentioned in Fig.20. Fig. 20 (a and c) represents the original image and Fig. 20 (b and d) represents the corresponding image obtained through rule 3. Hence, it can be stated that these rules are efficient and capable to determine whether a region is affected through fire or not.

(a)

(b)

(c)

(d)

Figure 20:(a and c) two sample images, (b and d) Detection of fire using Rule 3

Fig. 20, shows the effectiveness of the system in terms of detection of fire. For the analysis, the algorithm is tested for hundreds of fire images and the output shows the accurate detection of fire in an image. The results of the proposed detection system are evaluated on two sets of fire images. The simulation results are measured in terms of true detection rate and false detection rate and compared with existing fire detection approaches. It is observed that the proposed detection system can predict fire images with a higher true detection rate as compared to other existing approaches. Hence, it can be concluded that a combination of the YcbCr color model and RGB values improves the true detection rate outcomes.The obtained results are compared with some existing techniques for two conditions. The first condition is the performance evaluation of the system in same cloud platform and other is performance evaluation in different cloud system. The average response time, standard deviation, true and false detection rate are the metrics that have been measured and used for the evaluation of the overall performance of the system. The performance evaluation in terms of true detection and false detection rate is presented in Table 7.

Table 8: Measured standard deviation and response time for same cloud and different cloud platform

Cloud Platforms	**Performance Metrics**			
	Standard Deviation (ms)		**Average Response Time (ms)**	
	Without Load	With load (512 Kbps)	Without Load	With load (512 Kbps)
Same Cloud	7.56	12.45	24.56	40.28
Different Cloud	9.88	16.54	58.24	68.34

Table 9: Performance evaluation for standard deviation and response time in same cloud and different cloud platform

Cloud Platforms	**Approaches**	**Performance Metrics**			
		Standard Deviation (ms)		**Average Response Time (ms)**	
		Without Load	With load (512 Kbps)	Without Load	With load (512 Kbps)
Same Cloud	IoT Atlas	8.12	13.87	30.57	48.26
	M2M	12.9	21.25	52.35	78.51
	GSMA	10.92	17.88	46.24	66.47
	Proposed	7.56	12.45	24.56	40.28
Different Cloud	IoT Atlas	11.24	18.62	68.35	85.42
	M2M	15.27	25.64	122.32	175.63
	GSMA	13.21	22.31	92.54	120.36
	Proposed	9.88	16.54	58.24	68.34

The measured average response time and standard deviation with and without load (512 Kbps) for same and different cloud platform is presented in Table 8. The standard deviation without load is calculated as 7.56 milliseconds and with load is calculated as 12.45 milliseconds. The response time is measured as 24.56 milliseconds without load and 40.28 milliseconds with load. Table 9, representsperformance evaluation for standard deviation and response time in same cloud and different cloud platform. These obtained evaluations has been compared with other existing approaches one machine to machine (M2M)(Vilajosana and Dohler, 2015), global system for mobile communication (GSMA)(Sadhukhan, 2017) and IoT Atlas (Khan et al., 2014).It is observed that the proposed system presents better response time, standard deviation and optimized for fire detection application.

6. DISCUSSION AND CONCLUSION

The fire around smart cities or forest fires are serious concerns across many countries. Researchers or experts across the globe agree that for the prevention of these disasters the foremost requirement is to invest in efficient technologies. This paper presents a WSN and IoT based platform for the detection of fires at an early stage. Wireless sensor network has been successfully implemented using sensenut hardware platform. The sensor nodes are deployed in an outdoor environment for collecting and analysis of real-time data. Data collected through the sensor nodes are stored on the cloud for analysis. Several plots have been designed using the

ThingSpeak cloud application for smoke, temperature, humidity & light intensity. The system is capable of sensing various environmental parameters and efficient in the detection of an event, by analyzing real-time data. In this work, a fire detection system is designed based on the cloud platform and IoT devices. The design is efficient and provides a moderate and cost-effective method for collecting and monitoring real-time data globally. The proposed system integrates the image processing technique for the detection of a fire event. Several rules are also designed to detect the fire event more accurately.

The performance of the system was tested with image sequence consist of a fire/non-fire and fire detection and non-detection of the image at its output. This gives verification for the system's ability to detect fire at its initial stage. This allows related authorities to battle fire without delay and minimizing damages caused by fire. Besides, the system enables the monitoring of an event at any time, provides an effective solution to reduce the chances for the occurrence of fire.In addition to the basic functionality of WSNs and IOT, the objectives that were achieved demonstrates as below:

i. Forests fire detection system based on WSNs, IoT and image processing is presented. The experiments conducted demonstrates accurate detection and rare false alarms.
ii. Data is collected in real-time by deploying senor nodes, and collected data is analyzed in the IoT platform for the detection of an event.
iii. The confirmation of an event is carried through the image processing technique and hence the occurrence of fire is validated.
iv. The system is capable of sending an early warning alert of the detected event along with coordinates in the form of emails to users.

The proposed system is not suitable for smoke detection as the smoke is an indication of fire at its initial stage. Thus, the performance of this system can further be improved by adding smoke detection. In the future, the proposed system will be tested to detect the hidden fires due to dense fog, etc.

Conflict of Interest

On behalf of all authors, I further declare that, this manuscript has no conflict of interest.

Thank you very much for your consideration

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