Internet of Things technology for fire monitoring system

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ABSTRACT- *IoT is one of the dominant position all over the world in technological development. It is another information industry following computer, Internet and mobile communication. In Internet of Things technology the fire-fighting, fire monitoring and safety management system are an important applications. It discusses IoT system framework for fire-fighting, planning, and monitoring. It gives development points for providing research and development of IoT in fire-fighting, monitoring and safety management field. Intelligent fire monitoring systems need a key of accurate and effective firefighting software design. This paper also discusses about the requirements of user and key main issues of wireless sensor network hardware and software for monitoring fire. It discusses in elaborate the function of each module and implementation of that module in a detailed way. It also discusses application features of IoT technology and Wireless Sensor Network technology for according to fire-fighting requirements.*

Keywords: Fire-fighting and safety management system, Fire security, Internet of Things, fire monitoring, smart city, fire safety, Wireless Sensor Network.

I. INTRODUCTION

Prevention of fire and fire risk level control difficulty are increased day by day. Fire-fighting and monitoring situations are very serious today. Public security keep on insisting in increase of technology in firefighting and monitoring. They give special attention to improve the science and technology in resisting fire disasters. They are concerned about the application of new technology such as IoT and wireless sensor network in fire-fighting and monitoring field. IoT is very suitable for fire-fighting with wide scope along with wireless sensor network (WSN). IoT has high degree of intelligence for maintaining many product categories, quantities, complex fire danger factors and large range of equipments for fire monitoring and fighting. IoT has high scalability and high resource sharing capabilities for handling various complex business information. IoT combined with WSN plays an important role in the fire alarm, fire control facility monitoring and fire equipment management. IoT technology is combined with fire fighting for hazard source monitoring, fire monitoring, fire-fighting rescue, fire early warning, prevention and early disposal. It is used effectively to enhance the fire brigade fire frightening and emergency rescue capabilities.

Fires accidents are becoming more series because of bigger building density and higher urban buildings. Accidental fires caused 6% of all unnatural deaths in India. Exploding cooking gas cylinders and stoves accounted for nearly one-sixth of all deaths from accidental fires between 2010 and 2014, with a total of 19,491 deaths. Electrical short circuits killed 7,743 people over the same period. Fire accidents kill 54 people daily in India[1] and direct property losses are unknown. In order to protect the people and secure the properties from fire, it is necessary to design good real time high reliable fire monitoring system.

There are lot of disadvantages in the available fire detection, monitoring and alarm system. The few disadvantages are small surveillance capacity, simple human computer interface system, poor reliable in detection, slow response time and non flexible network interface system. The traditional fire monitoring system has false negative responses and false positive responses are high in number. The rate of occurrence of malfunctions in these system are large and the time delay in detection is very serious. It is necessary to design a system to overcome these problem and satisfy the application user requirements.

The wireless system performance and price are not good compared with the wired system. Even though the advantages of wireless have many. Some of them are fast speed of installation, small damages to the buildings, wireless sensor cost drops down, application places are wider and less power consumption. The wireless system are simple, flexible network structure, low cost and short delay. It could meet all the requirements of user. The forecasting ability, warning of fire and improvement in the reliability are also the advantages of the wireless fire alarm system.

The rest of the paper is organized as follows. Section 2 presents the related work analysis. Section 3 presents requirements of new fire fighting system. Section 4 presents the design requirements of IoT system frame work for fire monitoring. In section 5 implementation of the IoT function for fire monitoring in WSN is presented. Section 6 presents function realization and finally conclusion is discussed.

II RELATED WORK

Zanella, N. Bui et al (2) discussed about the Internet of Things for smart cities. S. C. Folea and G. Mois (3) are

discussed about the low-power wireless sensor for online ambient monitoring. P. Changhai et al (4) analyzed the design and application of a VOC monitoring system based on a ZigBee wireless sensor network. S. D. T. Kelly et al(5) discussed the towards implementation of IoT for environmental condition monitoring in homes. N. K. Suryadevara et al(6) analyzed the system for wellness determination of elderly. S. Helal et al (7) analyzed about the Gator tech smart house as a programmable pervasive space. L. C. De Silva (8) discussed about the state of the art of smart homes. N. K. Suryadevara (9) discussed about the WSN based smart sensors and actuator for power management in intelligent buildings. J. Byun et al (10) analyzed about an intelligent self-adjusting sensor for smart home services based on ZigBee communications.

S.R.Vijayalakshmi and S.Muruganand [11] discussed about the real time monitoring of wireless fire detection node. M. Morin at.el [12] analyzed about the computer-supported visualization of rescue operations. Xue-gui Wan at.el [13] analyzed about the novel conceptual fire hazard ranking distribution system based on multisensory Technology. Konstantinous at.el [14] dealt about an automated fire detection and alerting application based on satellite and wireless communications. Fatih Erden at.el [15] discussed about the wavelet based flickering flame detector using differential PIR sensors. S. R. Vijayalakshmi and S. Muruganand [16] were discussed about the challenges in integrating Wireless Sensor Network and Internet of Things for Environmental Monitoring. Son. B [17] was discussed about a design and implementation of forest-fires surveillance system based on wireless sensor networks for south Korea mountains. Yunus Emre Aslan et al.[18] were analyzed about a framework for use of wireless sensor networks in forest fire detection and monitoring. Qiang Liu et al.[19] were analyzed about the green data center with IoT sensing and cloud-assisted smart temperature controlling system. Kruger. C.P. and Hancke, G.P. [20] were analyzed about the implementing the Internet of Things vision in industrial wireless sensor networks.

Jun and Yuan [21] discussed about the internet of things, and WSN. They designed a low power consumption wireless sensor network node. Andrej Kos et al. [22] presented an IoT platform designed to support a number of usage scenarios with special emphasis on e-Health use cases. Jie Li et al. [23] presented a coding scheme called separate coding for collecting all data continuously in wireless sensor networks with a mobile base station. Mir Sajjad Hussain Talpur et al. [24] designed a healthcare monitoring system depends on the use of internet of things (IoT) technologies.

III REQUIREMENTS OF NEW FIRE FIGHTING SYSTEM

The new modern fire monitoring system is based on wireless sensor network in combination with Internet of Things. Because of modern advanced technology, the system minimize the losses due to fire. Sensors detects the fire condition and transfers the data to the system. Fire brigade and building owners can do the interactions with the system. All the data from the sensor nodes located in the buildings are provided to the users. The historical data reference from building data base server provides final useful response mechanisms. The users can communicate with the system through different ways to monitor and control the environment and get more information about it. The wireless fire fighting or monitoring system consists of the following units as shown in figure 1.

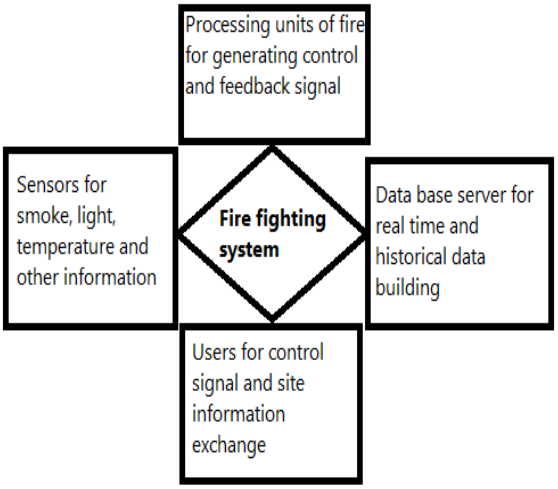

Figure 1. Fire monitoring system requirements

They are sensor for data collection, data base server building for data storage, human-computer interface for data exchange and micro controller for data processing. The system includes the process of finding fire and fire treatment mechanisms. This includes fire prevention and elimination of fire from the buildings. Wireless sensor network is communicated with the base station or computer system through RS232 serial port. The fire department or house owner or any attention need public persons will get information through PC Ethernet port. The communication is possible with the other locations in the building through web access parameters by this Ethernet port. GSM interface with short messages and WIFI interface for WIFI camera video transmission.

IV DESIGN REQUIREMENTS OF IOT SYSTEM FRAME WORK FOR FIRE MONITORING

IoT is a network of linking things through sensors and communication equipment, linking things among themselves and finally linking between people and

things. In IoT technology, RFID (Radio Frequency Identification), wireless sensor network, pervasive computing, cloud computing, real time monitoring and other technologies are integrated to realize intelligent real time monitoring, management and control of fire. The fire monitoring IoT system frame is planned in accordance with the requirement of fire prevention and control, firefighting, emergency rescue and so on. It is planned to the technical characteristics of IoT and the need of fire monitoring. As shown in Table 1, the IoT system frame for fire monitoring adopts layered structure. This structure includes sensing layer, transport layer, service layer and application layer.

Sensing layer

This layer is mainly used for complete collection of object and environment information. For collecting real time information about various objects using sensors, video, RFID and other technologies involved in fire fighting safety management. Intelligent equipment, sensors and RFID are useful for collecting information such as people, events, environments, materials, fire-fighting products, fire-fighting facilities and fire-fighting equipment. The collected information is communicated layer by layer, so sensing and control of fire event can be realized in real time.

Table 1. IOT System frame work for fire monitoring

Application layer	Service layer	Transport layer	Sensing layer
Fire fighting product identification system	Data mining	Mobile communication	Fire fighting product
Fire fighting facility monitoring system	Hetero-genious integration	Police special network	Fire fighting facility
Hazard source monitoring and warning system		Field bus	Firefighting equipment
Firefighting equipment and materials monitoring system	Visualize service	LAN	Personnel, Event, Process, Environment, Material Perceptions
Family, social units, fire brigade, government, intermediaries, manufacturers, service provides	Data storage	Internet	
Fire fighting and rescue scene management and control system	Interface	Wireless network	

Transport layer

It is used to realize the transmission of sensor information to different networks. The proper transmission and access methods are selected depends on different situation such as Internet, LAN, mobile network and police special network etc. It ensures the proper information transmission and achieve data exchange between different objects and platforms.

Service layer

This layer is mainly used for data storage, integration and interface of heterogeneous networks, data mining and visualization of services for different information resources. It supports reliable platform for service management. It ensures the establishment of fire-fighting safety application. It manages network equipment, converting information, integrating business information and device information.

Application layer

This layer is used for sharing information, integration of user, intelligent analysis and process control for firefighting IoT. It provides application services for service providers, manufacturers, intermediates, government institutions, fire brigade, social units and family. Finally it supports fire-fighting and monitoring business work.

The IoT firefighting application service includes five systems. They are 1. Fire-fighting product identification system, 2. Fire-fighting facility monitoring system, 3. Hazard source monitoring and warning systems, 4. Fire-fighting equipment and material monitoring system and 5. Emergency field management and control system.

i. Fire-fighting product identification system

It includes fire-fighting product identification codes, resolution and management. The system is designed to do the following works. They are 1. Fire-fighting product supervision, 2. Management of the products, 3. Improving firefighting product quality 4. Establishing fire-fighting product market order 5. Preventing production and circulation of fraud imitation fire-fighting products and so on. It also includes technical support for maintenance of fire-fighting products, quality tracking, performance evaluation and management of fire-fighting equipment.

ii. Fire-fighting facility monitoring system

It includes the following division of works. They are 1.Fire-fighting facility state perception, 2. Fire disaster early warning, 3. Household fire alarm, 4. Remote network transmission, 5. Video surveillance access and transmission, 6. Remote monitoring information platform of fire-fighting facilities, 7. Fire-fighting facility availability assessment and diagnostic analysis, 8. Fire-fighting facility maintenance and inspection information management, 9. Fire control supervision, 10. Emergency field information services and so on. The system can ensure the following operations. They are 1. The function of fire-fighting facilities, 2. Extending firefighting supervision vision, 3. To improve the operation of fire-fighting facilities, 4. The timely discover and eliminate fire hazards, 5. To strengthen emergency

field information support, 6. To provide technical support for fire disaster early warning, 7. For early prevention and early disposal and so on.

iii. Hazard source monitoring and warning system

It includes the following functions. They are 1. Hazard source status monitoring, 2. Hazard source environmental monitoring, 3. Safety hazard inspection and monitoring, 4. Hazard source logistics trajectory control, 5. Hazard source warning judgment, 6. Project construction site hazard source monitoring, 7. Hazard source emergency treatment plan, 8. Emergency response linkage platform and so on. The system can predict hazard source potential risks, and can prevent fires, explosions, toxic leaks and other serious accidents caused by hazard source, and providing solid foundation for timely and effective emergency rescue after occurrence of accidents.

iv. Fire-fighting equipment and material monitoring system

It includes intelligent deployment and monitoring of fire-fighting equipment, intelligent management of firefighting equipment emergency repository, fire-fighting equipment deployment and monitoring, fire-fighting equipment data analysis, national fire-fighting equipment support system and so on. The system can improve information, intelligence and automation level of firefighting equipment and materials management, and can enhance co-ordination management ability and resource integration sharing of fire-fighting equipment and materials, accelerating fire-fighting equipment management modernization construction, and further can enhance the core fighting force of public security fire brigade.

v. The emergency field management and control system

It includes on-site monitoring of environmental parameters, fire-fighters personnel positioning and sensing, fire vehicle dynamic monitoring, on-site fire-fighting equipment and material supervision, on-site fire spread trend forecasting, fire-fighting force situation management, emergency evacuation personnel location perception and so on. The system can improve the emergency field information sharing of fire brigade, disaster judgment, emergency field situation control, police dispatch, command and decision-making as well as other capabilities, and can provide information and technology support for creating modern public security fire fighting strong army.

Table 2. The fire-fighting safety management IoT technology system

Fire fighting safety management IoT technology System		
Fire fighting product identification	Fire fighting facility management	Hazard source monitoring and warning
Fire fighting product identification source technology	House hold fire alarm	Emergency treatment, status monitoring
	fire alarm linkage platform and detection	
Fire fighting product identification management technology	Facility status perception	Early warning, Environmental monitoring
	Nonelectric appliance and electric appliances automatic fire facility status perception	
Fire fighting product identification resolution technology	Fire early warning technology	Video monitoring, logistics track
	Gas leakage, Electric appliance fault detection fire	
	Public facility status perception	
	water source monitoring	
	Fire fighting and rescue	
	on-site fire spread, video monitoring and information	

Fire-fighting safety management IoT is an important part of application layer in fire-fighting IoT as shown in table 2. This system includes fire-fighting product identification, fire-fighting facility management and hazard source monitoring and warming. The fire-fighting safety management IoT technology requirements are as follows.

a. Fire-fighting facility state perception

Fire-fighting facility includes fire automatic alarm systems, fire-fighting linkage control system and large amount of non-electric fire-fighting facilities such as fire doors, fire hydrants, fire extinguishers, fire hose, and escape equipment and so on. The fire-fighting facility state perception methods can be improved, and the firefighting monitoring range can be expanded through applying new technology for sensing.

b. Video monitoring information access and transfer technology

The fire-fighting control room audio and video remote monitoring platform should be established, thereby realizing video and audio remote monitoring on personnel in real time, and strengthening fire-fighting departments.

c. Fire-fighting facility inspection maintenance information management

Fire-fighting facility inspection maintenance information management platform should be established for standardizing failure acceptance, maintenance management, inspection check and other information flow, thereby promoting to improve management level and work efficiency of fire-fighting facility maintenance enterprise.

d. Fire-fighting safety inspection process tracking technology

RFID technology is utilized for dynamic perception and process tracking on fire-fighting inspection thereby timely discovering inspection missing phenomenon and strengthening the supervision and management efforts of fire-fighting.

e. Emergency field information supporting technology

For information support technology, fire-fighting safety management IoT provides detailed and accurate status of building fire fighting facility, fire burning time, the fire trend development process, dynamic information for emergency actions and effective disposal after the fire-fighting rescue forces arrive. The fire site video surveillance system is used for the fire-fighting rescue forces timely, accurately and intuitively grasp the fire site situation and conduct disaster pre-judgment and analysis on the way to the site, thereby effectively enhancing the fire-fighting and rescue operational effectiveness.

V Implementation of the IoT function for fire monitoring in WSN

The wireless sensor network fire monitoring system is mainly for the control of entire system related with fire monitoring operation. The system is developed to perform the following operations.

1. The node will read the building parameters from the fire wireless sensor network.
2. It operates the fire alarm of the building.
3. It process the collected data and finds abnormal by the algorithm related.
4. It displays the read data and results measured by the node.
5. Based on results and measurements the system makes the appropriate response mechanisms.
6. It works and correlates with fire brigade department, administrators, house owners.
7. The system interacts simultaneously with different types of users.
8. The measurement data received by the computer system from sensor node also periodically saved in the database server in the building.

The software system is divided in to four different modules as said above. Again the system is divided as shown in figure 2.

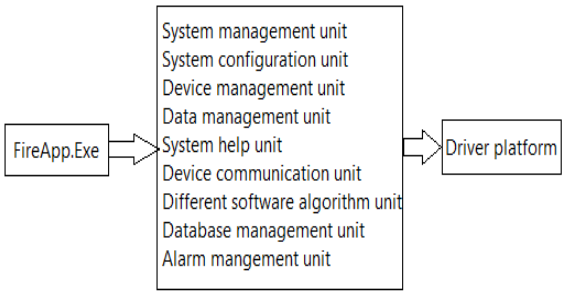

Figure 2. Fire monitoring system software design

1. System management unit

This unit performs the function such as user validation, system logs, user login verification, management of user passwords, users can update login passwords and records system operation log. The table 3 shows the users relevant authority provision. Fire fighters, administrators and house owners input the password and then enters into the relevant authority software interface and operate only those units.

Table 3. Authority provision

Users	Access authority
Fire fighters	Can use system management, alarm management, data management, database management, fire unit control, historical data query
Administrators	Can use any function of fire fighting system software
House owners	Lowest access authority. Can use alarm management, building data display

2. System configuration unit

This unit provides communication configuration for serial interface, fire unit parameters settings, database configuration settings, equipment addition, wireless sensor network parameters settings and computer time reading setting etc. The default configuration sets the system alarm unit and automatic fire extinguishing units. New equipment is installed on the drive and added in the control unit. The equipment is successfully installed and sets the related equipment data. The same is followed for database as well as WIFI.

3. Device management unit

This unit implements all functions of the control part of device such as maintenance of device, remote control of device, information about the fire and so on. Maintenance of device includes function such as system time synchronization, self inspection and online upgradation. System time synchronization update automatically or through manual control to setup time frequency correction. The automatic bench mark time is the master computer time. Self inspection helps for system maintenance. Sensor nodes monitor the

environmental parameters through different sensors. These environmental parameters submitted to the base station or computer system in the form of data package. After processing at computer system, the node failure and their position are declared by the computer system. Online upgradation makes system adjustment, software version updating, driver updating and software adjustment according to the environment updating. Remote control of device includes fire unit control through virtual instrument interface and images through WIFI camera. Different user have different control interface in accordance with control devices. New user interface control is generated automatically when new equipment is joined. Information about the fire includes alarm display and showing the data of the building.

4. Data management unit

This unit provides interaction between house owners with the building database server. House owners are able to get all data storage function including operation of data deposit into data base or files. The storage of data, retrieval of data and display of data from the database. The measured data and results about the building along with number of configured sensors details are stored into the database. The raw data is processed by the algorithm based on sampling, current value and value repetition. They are stored in the specified directory in the form of text file so that user can export data to analyze and easily do the experimentation. User or administrator will decide whether to save the data or not and how long the data in database based on system parameters set value. The software can save data with disk partition capacity. Database export import function is supported for long time running of software disk space of hard drive.

5. System help unit

The unit provides user manual for material developers, configuration assistant, software version and so on.

6. Device communication unit

This unit is responsible for communication between RS232, USB, TCP/IP, CAN etc and software. It test the connection status of equipment and instrument, It updates the driver at proper time.

7. Different Software algorithm unit

This unit is the core of the system includes various algorithm to detect fire and alarm fire warning. The algorithm such as threshold algorithm, comparison algorithm, fuzzy logic algorithm, Dempster-Shaffer Theory based algorithm are used to detect the fire.

8. Database Management unit

This unit is responsible for building the database server to manage, database updates, database input, decision support, database read and so on.

9. Alarm Management unit

This unit is responsible for generating different variety of alarm system control for the event of fire or early warning prompt and so on

VI FUNCTION REALIZATION

There are mainly three parts of core functions.

1. Analyzing the data from database for the various parameters of fire sensors, appropriate algorithm for its storage, processing and judgment of fire.
2. Fire actions according to plans made for dealing with unusual situations.
3. Provides the user interface functions.

System software is divided in the 3 layers. The first layer is data analysis layer. This is responsible for the data base via serial port to transform into parameters data such as temperature, humidity and image. It is used to maintain classification table for easy transporting query. The second layer is business layer. It is the core of the program. It is used to process the obtained data using different variety of algorithms and based on results the arranged plan is implemented. The third layer is user interface interaction layer. It is used for maintenance of user interface and displays sensor information for fire status monitoring. User can view the data of temperature, humidity, atmospheric pressure, light and three dimensional acceleration information related to fire monitoring. The data curve is analyzed based on historical data. User know the monitoring node based on received signal strength indicator. For WIFI system the background record is used to monitor image in the real time. This system provides remote web accessibility. User can visit and view the information in real time about fire fighting system through internet. Figure 3 shows the PC interface for sensor fire node information.

Fuzzy logic Algorithm

The characteristics of fuzzy logic algorithm is based on information fusion. This analyzes and synthesizes multi sensors or multi sources of data under certain criteria to complete data processing for decision making and task estimating. The algorithm fuse fire parameters of multi sensors for determining fire occur or not according to different kinds of fire parameters. This method overcome the limitation of using single sensor. This algorithm effectively improves the reliability and reduces the rate of false findings. The algorithm of multi parameter on the fire source localization and different analyze can be done from different fire fighting nodes quickly and accurately decide fire sources according to fuzzy methods and track the trends of fire. The faulty node is found based on received signal strength indication method. Different fire alarm signals for

different fire fighting scheme. Sometimes it may report the smoke or other fire sensitive signal level. So that routes are not blocked to ensure timely and effective management of event. Fire plan is based on GIS information management. It supports building structure, fire data and variety of plans when fire event happens. After the occurrence of danger, the system gives the reference scenario to the fire department, so that they could make decision rapidly using command and control. The system also gives the reference to escape route plans. It gives real time adjustments based on the state of fire so that user get maximum of the guidance of rescue and reduce losses.

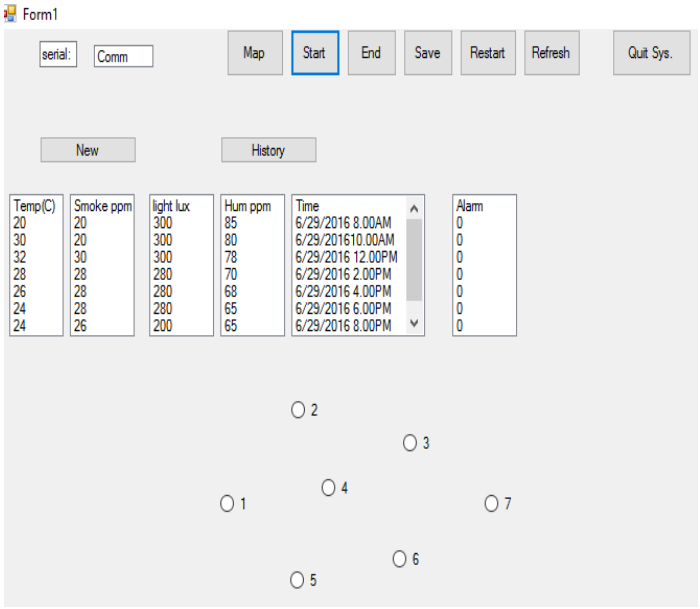

Figure 3. PC interface for sensor fire node information

VII CONCLUSION

Firefighting IoT standard system construction can be accelerated, and nationwide IoT platform can be constructed by actively carrying out system integration and information sharing of fire-fighting remote monitoring system. The IoT technology improves the fire-fighting safety management work from traditional fire-fighting to modern fire-fighting. It promote army construction development, full efforts to maintain fire-fighting safety. It can effectively protect people's lives and property safety.

This paper discusses about the design concept and construction of fire fighting IoT model and the steps to be followed to do fire-fighting safety management IoT design. The development of wireless sensors networks with the integration of Internet of Things arise challenges in fire-fighting fields. This new approach gives a reliable solution that can permit to detect fires risks, in order to avoid severe damage of this disaster, when it happens. Application of IoT in fire monitoring is an excellent solution for smart city creation. The system has to be implemented for the success of fire IoT concept. The methods to be followed for fire-fighting IoT, fire monitoring IoT and fire- hazard management IoT are discussed. The layers needed to construct fire IoT are analyzed. Software system for fire monitoring is introduced. This software system is divided into several parts to build set of software system framework. This paper proposes a new fire monitoring system software platform and development proposition. The system is user friendly, precise, stable in operation, multifunctional and concise. Cloud computing and video interface are further modification required in this system.

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