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IoT-based Intelligent for Fire Emergency Response Systems

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Abstract

Modern buildings around the world have become complex and augmented. Given the structural characteristics of modern buildings, quick evacuation using emergency exits or evacuee guidance markers during blackouts due to fire, building collapse, earthquakes, or aging of buildings need to be possible.

This paper suggests an Internet of Things(IoT)-based intelligent fire emergency response system that can control directional guidance intelligently according to the time and location of a disaster and the design of an integrated control system using wireless sensor networks to address the problems with existing fire emergency response systems in times of fire or building collapse.

Keywords: *Detour Evacuation System, Wireless Sensor Network, Internet of Things, Fire Detection, Integrated Control System*

1. Introduction

Taking more than 20 minutes to evacuate from a fire, which is one of the most frequent disasters, greatly reduces survivability [1, 9, 12]. Uniform evacuation guidance such as exit lights are inadequate for guiding evacuees during a fire, which can create poisonous gases, or when buildings are collapsing [2-3, 8]. Because existing emergency exit guides do not consider the location of the fire and merely direct people to the nearest exit, this may create significant secondary casualties if a fire has occurred at the exit and the evacuees are guided towards it. This paper suggests an IoT-based intelligent fire emergency response system with decentralized control that can intelligently guide evacuees based on the location and time of a fire to minimize the loss of human life.

2. Relevant Research

2.1 Detection Sensors

Sensors such as smoke detectors, flame detectors, heat detectors, vibration sensors, ultrasonic sensors, pressure sensors, proximity sensors, and location control sensors convert and output the recognition of fire, information on the progression of a fire and poisonous gas, and the vibrational state of the building into an electric signal [4, 13].

2.2 Wireless Sensor Network (WSN)

The network is composed of dispersed sensor nodes that measure the physical and environmental conditions such as the temperature and pressure, gateways that collect information from the nodes wirelessly and relay the information to the central server,

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and user interface software for storing, managing, analyzing, and utilizing the collected information [4-5]. As shown in Figure 1, ZigBee is generally used for wireless communication between sensor nodes. The observed data are relayed to the gateway through flooding.

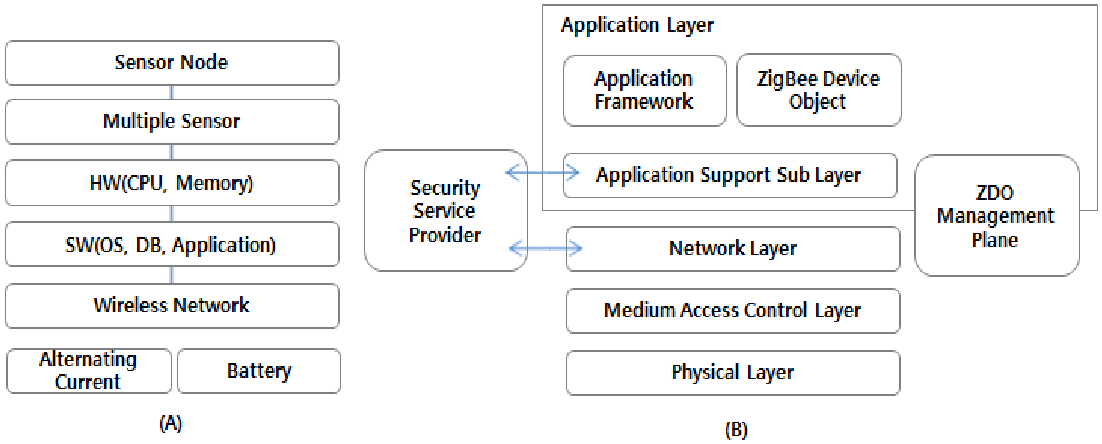

Figure 1. Sensor Network (a) and ZigBee Protocol Stack (b)

2.3 Egress Capacity

Egress capacity for approved components of means of egress shall be based on the capacity factors shown in Table 1[1].

Table 1. Capacity Factors

Area	Stairways		Level Components Ramps	
	in.	cm	in.	cm
Board and care	0.40	1.00	0.20	0.50
Health care, sprinklered	0.30	0.80	0.20	0.50
Health care, nonsprinklered	0.60	1.50	0.50	1.30
High hazard contents	0.70	1.80	0.40	1.00
All others	0.30	0.80	0.20	0.50

3. System Design

High-rise buildings have become complex and enlarged. Hence, the system needs to facilitate quick and safe evacuation out of the building exits during blackouts due to natural disasters such as fire, building collapse, or an earthquake when vision has been impeded (*e.g.*, by smoke) [7]. All evacuees within a building should be alerted and guided to an optimal evacuation point remote from the point of the disaster through pop-up notices based on analysis of the data received by detection sensors during disasters such as a fire [10-11].

3.1 System Composition

The proposed intelligent fire emergency response system is designed to improve the evacuation safety and reliability shown in Figure 2. Human cognitive characteristics and intelligent evacuation equipment concepts were utilized for the development of an effective detour evacuation system that alters the evacuation directions according to the situation and location of the fire.

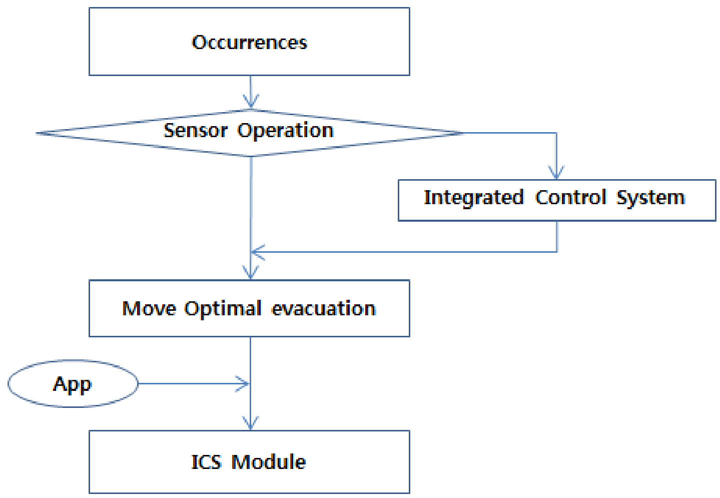

Figure 2. Fire Judge Module

- Figure 3 shows an intelligent optimal evacuation route where the processor controls the direction of the guidance lights based on various detectors and the evacuation guidance design.
- The fire emergency response system designs the path to evacuation locations through various detours depending on situational conditions such as fire, visibility, and the number of evacuees.
- Guide lights toward the optimal evacuation locations are lit during disasters through cooperation between the disaster prevention system of the relevant building and the government's central disaster prevention system; bidirectional data are integrated when fire or smoke is detected.
- The system environment composition modules are designed to comprise an Ember EM250 chipset, sensor modules, a CDD controller, a communication module, a power module, a CSD controller, an LED display, and buzzers

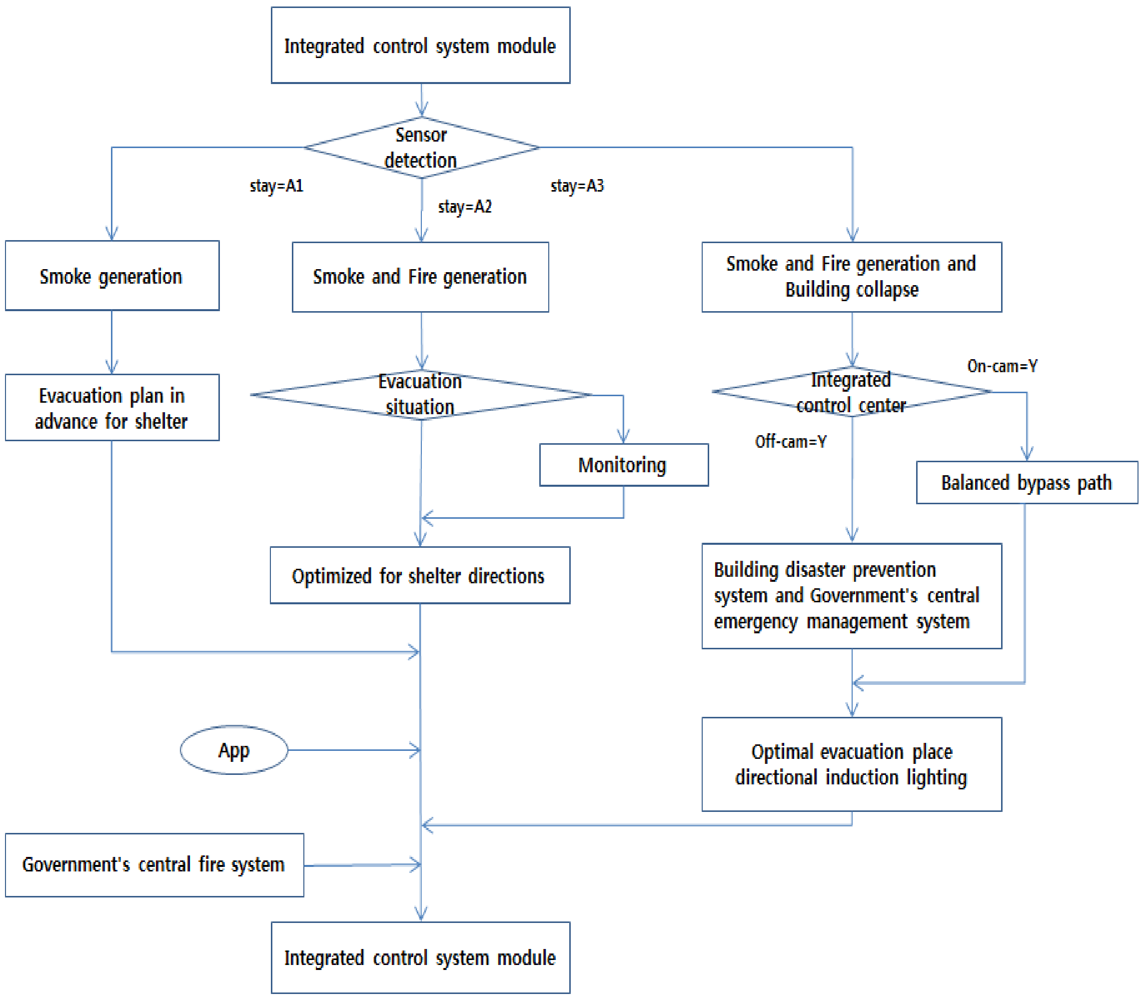

Figure 3. Evacuation Simulation Flowchart

3.2 Emergency Lights

The emergency lights are powered by cable wiring and batteries and contain detectors for smoke, flame, and heat. They are configured as bidirectional indicators that communicate via the WSN shown in Figure 4.

Figure 4. Emergency Lights

3.3 Design of Integrated Control System Module

Lights create a connection between the information shown in Figure 5. Figure 6 shows the system, where information is detected by the various sensors of the emergency lights and analyzed through the controller. The information is collected and relayed to the operating server, which receives information on the analyzed evacuation path and messages the smartphones of the evacuees located on the relevant floor.

To calculate the speed of the pizza S for the building [6] shown in Table 2.

$$S = k - ak\frac{1}{d^2\pi} \quad (1)$$

S : According to each person's interval speed(m/s)
k : Due to the constant sex
a : Constant(0.266)
d : The closest person separation distance(m)

Table 2. For Pizza's Speed (1)

Area	Older(max)		Newer(max)	
	Time(S)	person	Time(S)	person
1st floor	1.05	10	1.06	10
7th floor lower	1.15	10	1.23	10
7th floor upper	0.7	10	0.72	10

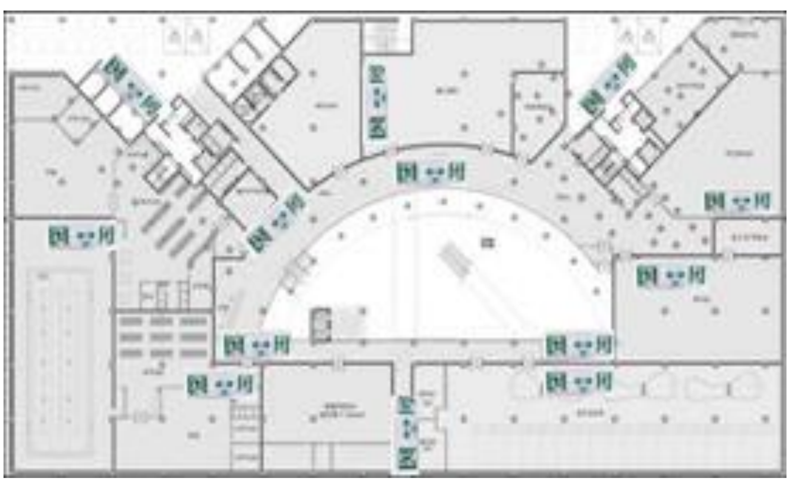

Figure 5. Lights Create a Connection between the information

The system provides approximate location information of the evacuees connected to the integrated control system of each floor, dispersed detour evacuation path information, the location of ignition based on the first detection of fire, and the location of the fire and information on evacuees. The integrated control center and central disaster prevention system work together based on the prearranged evacuation plans of the building on fire.

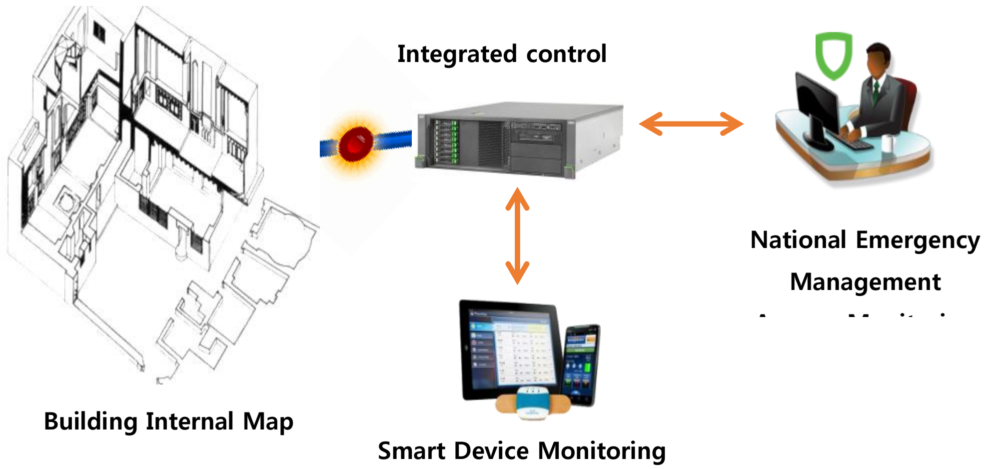

Figure 6. System Configuration

3.4 Smartphone Application Development

Figure 7 shows a smartphone app developed to alert evacuees of the building to a fire and allow evacuees who could not escape by following the emergency lights and whose visibility is obstructed by smoke to check their location and the evacuation path. The app provides the building blueprints and evacuation map necessary for evacuation (a) to 2G phones as text information and (b) to 3G phones as text information and in the form of an App. The information allows the approximate location of an evacuee to be assessed for a quick rescue based on the information on the time and location of the ignition, progression of the fire, direction of the evacuation route, and connection with the integrated control center through the App.

Figure 7. Integrated Controller Received the Smartphone Screen, (a) is 2G Phone, (b) is 3G Phone

4. Conclusion

The proposed IoT-based intelligent fire emergency response system can reduce casualties by determining the point of occurrence of a disaster in a building to prevent directional confusion of the emergency lights and inappropriate evacuation guidance. The intelligent emergency evacuation system can also aid firefighting because it allows for a quick assessment of the exact location of the fire by integrating the intelligent and automated evacuation system with the central national emergency management agency. It reduces casualties and the time required for evacuation by guiding evacuees into dispersed detours that bypass the location of the fire.

Future studies will focus on expanding the applicability of this system to not only building disasters, but also various fields such as ocean vessels and evacuation within buildings, disaster safety through Web or mobile application services, and preventive actions for optimal disaster recovery.

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