Fire evacuation situation recognition and evacuation route search scheme of 5G-based mobile system

Mahnsuk Yoon
Future Mobile Communication Research Center
GERI(Gumi Electronics & Information Technology Research Institute)
Gumi, Korea
yms@geri.re.kr

Jaemin Lee
Future Mobile Communication Research Center
GERI(Gumi Electronics & Information Technology Research Institute)
Gumi, Korea
ljm0128@geri.re.kr

Hyunjoo Lee
Future Mobile Communication Research Center
GERI(Gumi Electronics & Information Technology Research Institute)
Gumi, Korea
mft.master@geri.re.kr

Gilhwan Lim
Research Institute
Daon Co., Ltd.
Gumi, Korea
ghlim@idaon.or.kr

Hyunchul Choi
Research Institute
Daon Co., Ltd.
Gumi, Korea
daon@idaon.co.kr

Kyucheol Cho
School of Computer Secience and Engineering, Software Education Center
Kyungpook National University
Daegu, Korea
k5435n@knu.ac.kr

***Abstract*— This paper introduces a comprehensive system and associated technologies designed to facilitate fire evacuation and minimize the risk of secondary accidents such as battery explosions in mobile systems utilizing 5G communication technologies. As the use of mobile systems like kiosks and vacuum cleaners becomes widespread in multi-use facilities, the potential risks associated with their large-capacity batteries, especially during fire emergencies, have become a significant concern. In densely populated environments, if these mobile systems are effectively utilized, they can guide evacuation routes during a fire, significantly reducing human and property damage. The proposed approach uses a multi-sensor-based fire detector that leverages 5G communication technology for real-time fire detection. Upon detection of a fire, the system determines the degree of spread of substances harmful to humans and, in conjunction with the mobile system, guides individuals along evacuation routes to safe areas. This technique operates through the integration of fire detectors, a fire situation awareness server, and the mobile system using 5G communication technology. The proposed technology operates in such a way that, leveraging building and fire map data, the mobile system situated in the area receives the optimal path to the emergency exit from the fire situation awareness server, and guides the evacuation route accordingly. The performance of the proposed technology, with respect to its collaborative operation through fire detection sensors, has been validated in a simulation environment assuming a fire incident.**

Keywords—Fire Detection and Evacuation, Multi-Sensor Based Systems, 5G Communication Technology

I. INTRODUCTION

Evacuation during fire emergencies is critically important, and substantial research has been undertaken to find the safest and quickest routes for evacuation. The focus of these studies is predominantly on fire detection technologies and algorithms for identifying evacuation paths during fires[1][2]. Recently, mobile systems are being utilized in multi-user facilities for delivering services such as delivery, kiosk services, cleaning, etc., aimed at enhancing customer convenience. However, these systems can be exposed to dangers such as battery explosions during fires, necessitating the need for solutions and technologies that can help during disasters like fires in system development. Mobile systems are embedded with wireless communication technologies like 5G, which can be used for real-time information reception from disaster control servers, thereby enabling disaster situation awareness. Furthermore, these mobile systems can be utilized to guide nearby people along safe evacuation routes. This paper presents an integrated service that uses multi-sensors for fire detection and sensors that can collect harmful gases, a situation awareness server that determines the presence of a fire, and a mobile system that guides real-time evacuation routes[3][4][5]. Given the increasing deployment and use of these mobile systems, we propose a novel framework that leverages these systems not just for everyday services but also for emergency evacuation during fires. The system can alert nearby individuals of the danger and provide a real-time evacuation route that considers the dynamically changing fire conditions. The mobile system leverages machine learning algorithms to dynamically determine the fastest and safest path to the nearest exit, considering the current location of the fire and the building layout. Moreover, the system includes sensors for smoke and carbon dioxide detection and a machine learning model trained to detect fire using real-time sensor data. The model can quickly and accurately determine the presence of a fire, allowing the mobile system to commence evacuation procedures without delay. The proposed framework also includes a cloud-based disaster management server. In the event of a fire, the mobile system sends real-time sensor data to the server. The server uses this data, along with data from other sources in the building, to track the progress of the fire, predict its future movements, and plan evacuation routes accordingly. The server communicates these routes to the mobile system, which then guides nearby people to safety. The main contributions of this paper include an innovative approach for utilizing mobile systems in fire situations and a comprehensive framework for real-time fire detection and evacuation planning. The experimental results highlight the effectiveness of our approach, offering promising implications for the design of future fire safety systems in multi-use facilities.

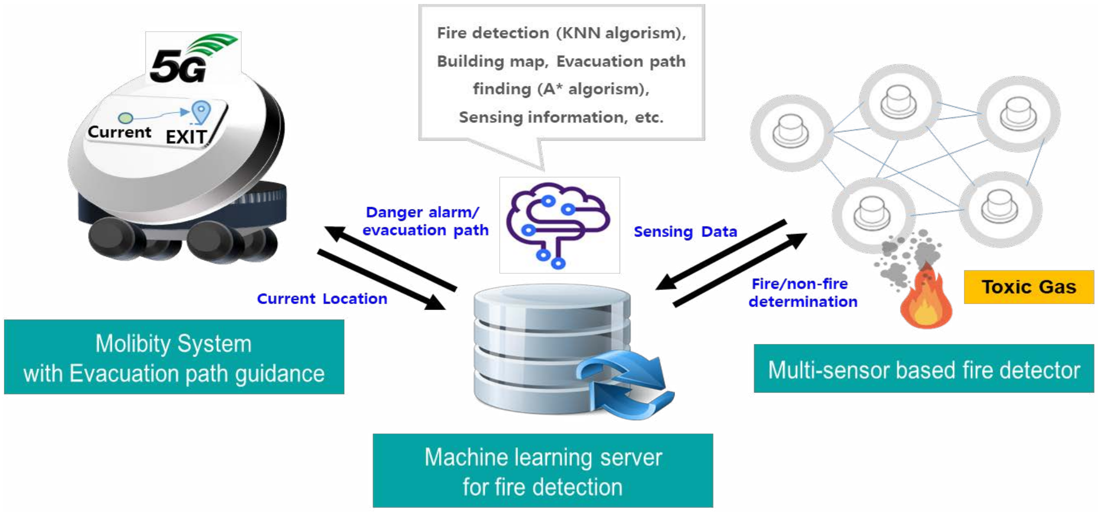

Fig. 1. System configuration diagram of the proposed scheme

II. Proposed Scheme

This study introduces an innovative method leveraging 5G communication technology to execute fire detection in unpredictable environments. The system configuration of our proposed method consists of (1) a fire detection system, (2) a machine learning server for fire detection, and (3) a mobile system solution as shown in Fig. 1. At the core of this approach is the deployment of a multi-sensor system that scrupulously monitors an array of variables such as carbon monoxide, temperature, smoke, VOCs, gas, and humidity. These variables serve dual purposes: identifying the presence of a fire and evaluating the feasibility of potential evacuation routes. Humidity is particularly monitored to enhance the accuracy of non-fire alarms, preventing the misfiring of sensors in high humidity conditions when there is no fire.

CO	VOC	SMK	GAS	TEMP	HUM	FIRE
140	466	515.1	501	49.85	4.26	1
140	464	517.1	499	49.85	4.26	1
140	464	517.5	502	49.85	4.26	1
139	457	513.5	499	49.85	4.26	1
133	454	516.8	500	49.85	4.26	1
132	444	519.8	500	49.85	4.26	1
137	434	526.5	501	49.85	4.26	1
138	431	522.4	499	49.85	4.26	1
142	423	540.7	500	49.85	4.26	1
133	416	549.7	501	49.85	4.26	1
150	405	552.2	502	49.85	4.26	1
0	238	62.4	448	34.06	31.11	0
0	240	60.1	449	34.06	31.11	0
0	240	60.6	446	34.06	32.58	0
0	240	60.9	448	34.06	32.58	0
0	238	59.2	448	34.06	32.09	0
0	240	58.7	448	34.06	32.09	0
0	240	56.5	446	34.06	28.18	0
0	240	54.4	448	34.06	28.18	0
0	242	55.3	447	34.06	30.62	0
0	245	57.5	449	34.06	30.62	0
0	243	55.4	447	34.06	33.55	0

Fig. 2. Dataset configuration for Fire and danger detection

Fig. 2 presents information from a dataset collected from multi-fire detection sensors under actual fire conditions and normal circumstances, forming the basis for discerning fire and non-fire situations. In the proposed technique, criteria such as carbon monoxide, temperature, smoke, and VOCs determine the viability of evacuation routes. In this paper, these criteria have been categorized into three stages based on data collected during a fire, and the collected data's three units during normal and fire situations have been set to 1 and 2. The K-Nearest Neighbors (KNN) algorithm, utilized in the proposed method, distinguishes fire signs through machine learning using the captured dataset. This algorithm is trained to pinpoint fire signs using the aforementioned set of variables. Extending its utility, this data aids in assigning weights to potential evacuation paths. Indicators such as smoke, heat, VOCs, and gas are classified into three levels of intensity: mild, moderate, and high, and expressed as mild, medium, and strong, respectively, providing an understanding of the hazard levels. The proposed scheme employed in this paper primarily performs routine roles such as delivery, guidance, kiosk services, and cleaning in the mobile system, running the proposed fire evacuation guide program as a background process. Upon the detection of a fire, the system promptly switches its operation, prioritizing the fire evacuation guide program. The machine learning server sends alerts to the mobile system upon the detection of a fire, initiating the guidance for the evacuation route, thereby ensuring a swift and safe evacuation for both the mobile system and surrounding individuals. We apply the A* algorithm to derive the evacuation route, a dynamic path that is ceaselessly refined based on risk monitoring informed by real-time fire detection and harmful gas leakage data. In the face of a fire, the mobile system diligently adheres to the guided evacuation route, showcasing or broadcasting real-time path updates. Table 1 schematically shows the algorithms operating for each system in the proposed technology. Table 1 schematically shows the algorithms operating for each system in the proposed technology. The proposed technology provides a solution that can efficiently detect and respond to fire through organic linkage between Machine Learning server, fire detector, and mobile system.

To ensure our system evolves and improves over time, we have incorporated a feedback mechanism. This mechanism adapts the system based on real-time inputs, enhancing the accuracy and efficiency of both fire detection and evacuation route selection. This continual self-improvement guarantees improved reliability and safety across diverse fire scenarios.

TABLE I. OPERATION ALGORITHM FOR EACH SYSTEM OF THE PROPOSED SCHEME

Machine learning server for fire detection :
1. Collect sensor data from Fire Detectors (CO, VOC, smoke, temperature, humidity, GAS); 2. Process data with KNN algorithm for fire presence estimation; - If fire presence estimation > Threshold, declare fire; - Store hazardous space information; 3. If fire declared, initiate evacuation route search using A* algorithm, hazardous space information, and building map data; - Based on map data, identify the optimal evacuation path avoiding hazardous spaces; - Continuously update the evacuation route based on real-time hazard updates and dynamic conditions of the building; 4. If fire declared, send alerts and evacuation guidance, including optimal evacuation path, to Mobile System;4. If fire declared, send alerts and evacuation guidance to Mobile System;
Fire Detector :
1. Continuously monitor environmental variables (CO, VOC, smoke, temperature, humidity, GAS); 2. Periodically monitor environmental variables (CO, VOC, smoke, temperature, humidity, GAS) based on the set monitoring schedule; - If any sensor value exceeds its respective threshold during a monitoring cycle, send data to Fire Detection Server;
Mobile System :
1. On receiving an alert from Fire Detection Server, switch to Fire Evacuation Guide program; 2. Display or broadcast the evacuation path provided by Fire Detection Server; - Continuously update display or broadcast based on real-time path updates from the server; 3: Follow the evacuation path;

III. IMPLEMENTATION

To validate our proposed technique, we executed real fire scenarios to accumulate relevant sensing data. This data was then utilized as a dataset for the KNN algorithm-based machine learning server, which was trained to detect fire occurrences. The accuracy of the system was measured through the performance of this trained server. Furthermore, we also verified the data transmitted to the mobile system when a fire was detected. The performance of the KNN algorithm yielded a result of 98.33% accuracy. From the heatmap measured during actual fire incidents, we confirmed the direct correlation with fire to be as follows: VOC at 89%, GAS at 85%, temperature at 64%, carbon monoxide at 58%, smoke at 50%, and humidity at -74%, as shown in Fig. 2. Also, during a fire event, an alarm was successfully transmitted from the fire detection server to the mobile system via the connected program. Moreover, we verified that the simulation code providing location guidance for the route in the solution to be utilized in the mobile system functioned correctly, as shown in Fig. 4.

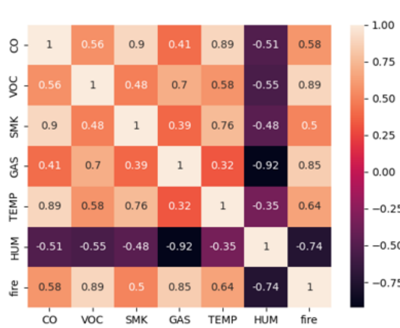

Fig. 3. Heatmap of KNN Algorithm

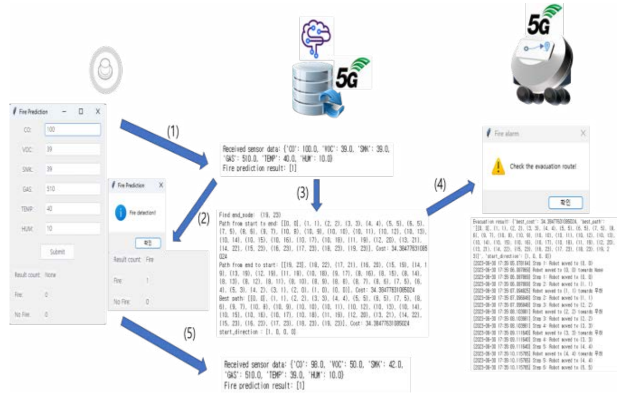

Fig. 4. Operation results for program implementation of the proposed scheme

IV. CONCLUSION

This paper presented an integrated system to facilitate fire evacuation and reduce the risk of secondary accidents by utilizing 5G communication technology, especially in relation to large-capacity batteries of mobile systems in multi-use facilities. With the increasing ubiquity of mobile systems such as kiosks and vacuum cleaners, it is important to manage the potential risks associated with batteries, especially in fire emergencies. Our approach showed that these mobile systems can be effectively used to guide evacuation routes based on accurate fire awareness in the event of a fire. Through a multi-sensor fire detector and real-time fire detection function through 5G communication technology, it responds quickly in the event of a fire, evaluates the spread of harmful substances, and guides safe evacuation routes. Future research plans to continuously improve this technology to further improve fire detection and evacuation functions by analyzing the accuracy of fire detection and the spread of harmful gases in various environments.

ACKNOWLEDGEMENT

This work was supported by National IT Industry Promotion Agency (NIPA) grant funded by the Korea government(MSIT) (D0738-23-1001, The project of foundation and operation of metaverse hub in northeast region of South Korea)

REFERENCES

[1] S. Lee, T. Kim, S. Hong, J. Kim and J. Kim, “A Study on Fire Evacuation Guidance System using Indoor Spatial Information from Beacon”, Journal of Korean Institute of Building Information Modeling, Vol. 6, No. 3, pp. 15-23, 2016.

[2] H. Kim, “A Study of Evacuation Route Guidance System using Location-based Information”, Journal of Korea Academia-Industrial Cooperation Society, Vol. 18, No. 9, pp. 18-23, 2017.

[3] Cha, J.H. “A study on improving the standard related to fire alarm malfunction in security system.” Asiapacific Journal of Multimedia Services Convergent with Art, Humanities, and Sociology, Vol. 6, 2016, 6, No. 12, pp 675-682

[4] Choi, K.C. “Technical recommendation to reduce false fire alarm of automatic fire detection system”, Dongwon University, KFI

[5] G. S. Son.; S. H. So “A Study on Fire Alarm Test of IoT Multi-Fire Detector combined Smoke/CO and Smoke/Temperature Sensors”, Vol. 17, No. 2, pp. 236-244

[6] Pradeep K. G, Rahul R, Ravindharan N, “Early Forest Fire Detection Using Machine Learning Algorithms”, International Journal of New Technology and Research, Vol. 7, 2021, 01-05.