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Fog Computing Architecture for Indoor Disaster Management

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ABSTRACTS

Most people spend their time indoors. Indoors have a higher complexity than outdoors. Moreover, today's building structures are increasingly sophisticated and complex, which can create problems when a disaster occurs in the room. Fire is one of the disasters that often occurs in a building. For that, we need disaster management that can minimize the risk of casualties. Disaster management with cloud computing has been extensively investigated in other studies. Traditional ways of centralizing data in the cloud are almost scalable as they cannot cater to many latency-critical IoT applications, and this results in too high network traffic when the number of objects and services increased. It will be especially problematic when in a disaster that requires a quick response. The Fog infrastructure is the beginning of the answer to such problems. This research started with an analysis of literature and hot topics related to fog computing and indoor disasters, which later became the basis for creating a fog computing-based architecture for indoor disasters. In this research, fog computing is used as the backbone in disaster management architecture in buildings. MQTT is used as a messaging protocol with the advantages of simplicity and speed. This research proposes a disaster architecture for indoor disasters, mainly fire disasters.

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1. INTRODUCTION

Most people spent their time in daily life indoors, either consume their time in the office, campus, shopping Centre, airport, and home. Other studies also establish the average time of people spent their time indoors is around 90% for different contingents and time (Klepeis *et al.,* 2001). Meanwhile, the advanced construction of the building nowadays is enormous, and it has a complex structure. The advance of building constructions possibly increases the complication for managing the urban disaster, which is fire. The concentrated human population in urban society has increased the potential for destruction, such as natural or human-made disasters. Based on the statistics from 31 countries reported by the International Association of Fire and Rescue Services, in 2013, 2.5 fires are breaking out on average every minute and the total number of fires, deaths is more than 217. 000 worldwide.

Moreover, crowd behaviors of human beings, which are common occurrences in confined spaces, can have a significant impact on emergency evacuation. Destructive crowd behaviors such as pushing and trampling caused by congestion may block evacuees and induce serious fatalities and injuries, sometimes even more severe than losses caused by fire (Desmet *et al.,* 2013).

Hence, people who are not acquainted with it may have difficulty to navigate through the building. This kind of emergency situation requires people to do rapid evacuation inside the building. In emergency scenarios the fast conduction of victims to exit and the precise monitoring of the rescuers position are both important to reducing deaths and injuries. Location positioning systems can be used to automatically gather the positioning of rescuers and victims (Bastos *et al.,* 2015). The lack of real-time, coordinated responses, driven by integrated decision making facilities based on information collected by first-respondents acting on a crisis site, is a critical challenge in emergency management (Palmieri *et al.,* 2016).

Disaster management is a sort of integration and coordination of actions required preserving, improving and preparing the capability to respond to disasters or natural disasters caused by humans. Disaster management involves various tools and is also an initiative various area, of various parties. A co-operation and coordination structure is necessary to include multiple partners and players in disaster management.

Adoption of new techniques can reduce the chances of losing human lives as well as harm to large scale infrastructures due to both human-made and natural disasters. IoT, which enables interconnection among devices with diverse performance, is a solution for disaster management. Employing intelligence applications and data analytics, IoT-enabled tragedy management methods used for warning about the mishap. Since the impact of any tragedy is tremendous, the IoT-enabled disaster management system can be implemented to obtain possible rescue operations and the victim (Ray *et al.,* 2017).

Localization expedite the healing procedure and helps in disaster control that is effective. Among the issues of disasters is obtaining information what's their place from the location and whether they're secure or not. Localization will help in these situations by providing them with aid in situations like the consumer and offering the location of the people. Likewise in the event of a flame or some other calamity within a environment, the user places can be obtained by the rescue group Throughout the system that may be used for functioning at the place (Zafari *et al.*, 2019) (see Fig. 1).

Emergency Navigation Systems	
System type	Period
Human experience driven system	1970s - 1990s
Static WSN based system	1995 - present
Mixed WSN based system	2006 - present
WSN & Cloud based system	2007 - present
Cloud based system & mobile phones	2011 - present

Fig. 1. Emergency Navigation Systems (Bi & Gelenbe, 2019)

Since hazard sensors have gradually become the norm for public buildings, various wireless sensor network-based algorithms have proposed to provide dynamic evacuation plans in a real-time fashion. Because of Constraints in Battery Life Capacity and processing Capacity of a wireless sensor System, these algorithms are typically made in an efficient Fashion. The rapid development of cloud computing technology in the last decade has made much research carried out by leveraging the enormous computing power of cloud servers to design more sophisticated and accurate algorithms to guide disaster evacuation. Due to the high processing capacity, storage that is big degree, and interoperability, cloud computing systems has the capability and has come to be a tech. In comparison WSN-based counterparts emergency response methods are flexible because of the removal of the time to Establish a WSN along with the maintenance, for example battery changes (Gelenbe & Bi, 2014).

Cloud Computing is utilized to store and process the enormous amounts of information created by increasing IoT devices. However, transmission delay difficulty occurs in the cloud computing system environment because the huge quantities of data is saved in the cloud servers that are remote. (Khan *et al.*, 2015) introduces a way for context aware route planning through coupling of a multi-purpose cloud-based method structure using a complex IndoorGML data model, and it's an impending OGC standard for representing and exchanging semantics, geometry, and topology advice of in-door 3D construction models.

Additional due to the immense dependence on connectivity along with regular power supply of Cloud Computing, the use of cloud services could be problematic throughout the occurrence of crises at which both energy and communication networks will crack down. Efficient and easy usage of Cloud infrastructure, particularly during the disaster, is still among the key challenges although Cloud computing delivers a better solution for disaster simulation and modeling. (Ujjwal *et al.*, 2019) have shown that cloud-based solutions are somewhat more cost effective for running disaster forecast models compared to the on-premise systems.

Fog Computing Attracts the Cloud computing Paradigm into the boundary of this network. Fog Computing is a distributed computing architecture, in which devices at the edge of the network are ubiquitously connected to offer storage services, communication, and flexible computation (Anawar *et al.*, 2018). Due to the Closeness to End-users in Comparison with the cloud data centers, Fog Computing offers several advantages such as immediate notification services for Realtime Software, Grade of service assurance and Also low latency, location awareness (Kotb *et al.*, 2019).

The Center Feature of this fog computing structure is that it provides data and compute analytics services more instantly and near the physiological apparatus which make this data, i.e. in the edge of this system, and so bypassing the wider Internet (Mahmood, 2018).

The emergence of this Internet of Things (IoT) has forced cloud computing to be united with fog computing, in order to prevent latency. Evacuation wayfinding systems must not make use of the calculating capacity of the cloud and also apparatus but other individual devices in the vicinity to offer services (see Fig. 2).

Edge computing and haze computing are very promising to support future wayfinding evacuation systems, because they not only utilize the computing power of portable and cloud devices, but also other individual devices in the vicinity to offer services (Bi & Gelenbe, 2019).

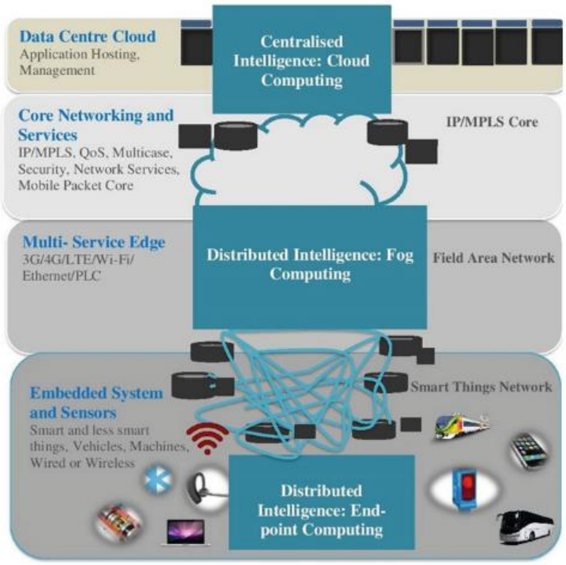

Fig. 2. Fog Computer Architecture (Zhu *et al.*, 2013)

2. RELATED WORK

While exterior navigation is well recognized and accessible just about all weather conditions, indoor navigation nevertheless remains a technological discipline with no effective integrated solutions Due to the increasing complexity of internal spaces and dynamic shift in certain specific partitions in large indoor locations, indoor navigation has become more important as it is helpful to aid individuals find their destination or evacuate from dangerous places. Disasters could be either artificial or natural, and in the two situations, among the most significant elements in reducing loss of life is the time. The Global Positioning System (GPS) can be used in the instance of outside navigation and is founded on satellite navigation by providing reliable location information on the consumer. Once an evacuation occurs in confined spaces process can be more challenging since the motion and alternatives of evacuees are restricted from the surrounding atmosphere. Emergency evacuation methods have experienced a few phases: in the original human systems to the cloud-based wayfinding systems, which are still in their infancy wayfinding systems, to the currently booming in wireless sensor network-based (Bi & Gelenbe, 2019).

Disaster management system and accident detection may face challenges concerning latency and bandwidth awarded the centralized nature of the cloud service. An emerging concept that can help address these problems is fog computing that provides the promise of latency assistance, scalability and Greater resilience (Dar *et al.*, 2019). The primary notion of fog computing would be to utilize the processing and storage resources at the edge of the network by deploying solutions on advantage devices that are open to decrease latency.

The enhancement of complexity for indoor structures may cause many issues regarding to the evacuation system in case is indoor disaster. Buildings are turning into a significant topic of recent disasters leading to huge quantities of casualty and damage costs for both the public and crisis managers. Greater urbanization and sophistication of modern structures subtract emergency response processes and decision making particularly in indoor crisis scenarios where a lot of the data remains unrevealed to crisis managers before inputting the scenes exposing danger to individuals' lives as well as resources.

Additionally, unfamiliarity with all the indoor surroundings, restricted visualization because of smoke, and dropped and obstructed regions all raise the problem of crisis response and rescue in addition to undesirable drifting and doubt routing in indoor environments (Tashakkori *et al.*, 2015). (Nikoohemat *et al.*, 2020) are implementing a complete workflow, allowing the development of 3D models from the building point cloud and the extraction from these models of fine seed indoor networks to enable comprehensive emergency management route planning and navigation of the different types of agents. The method removes structural elements such as walls, tiles, ceilings and openings and reconstructs their volumetric forms.

Indoor emergency response plays an important role in disaster management, especially for a fire in a building, which must consider the evacuation of people in an environment that is indoor that is dynamic. A process of cooperation and coordination is necessary to include various actors and stakeholders in the handling of disasters. Disaster Management is the organization and alignment of all appropriate measures for creating, sustaining and strengthening preparation for, defending from, adapting to and recovering from human-led disasters. The topic is a multidisciplinary field of research Where ICT, in particular the Internet of Things, has a significant impact on the sensing and dynamic calculations of responses which increase or prevent the worst effects of disasters (Bi and Gelenbe, 2019). One of the significant problems for indoor emergency management is that the current indoor spatial structures do not fulfil emergency response criteria (Tashakkori, 2017). The indoor search and rescue challenge can, therefore, not be easily used for decision taking in this area.

One among the most important factors in indoor emergency response operations is awareness, which Is created only after Assessing all information that is available (Dilo & Zlatanova, 2011). The Great Deal of Multi-Domain Sensory Data generated by increasingly advanced sensor networks that increase the burden of Crisis Navigation Methods requiring time-critical response to the collection of information. Interpretation and transmission Traditional WSN-based emergency response systems, including functionality-identical detectors, have trouble providing optimum evacuation in a timely manner in the presence of all time-varying hazards due to this limitation of processing space, battery power and speed of communication (Gelenbe & Bi, 2014).

Fog computing has been widely researched in various fields, for example, the health sector, smart city, commercial industry, and other areas (Hernández-Nieves *et al.*, 2020). The work discussed in (Al-Khafajiy *et al.*, 2019) focusses on the development of a smart healthcare monitoring device that can remotely track the elderly. The technology mentioned in this paper is aimed at monitoring the physiological data of a person in order to identify particular conditions that could help to improve early intervention practices. The accuracy and analysis of sensory data acquired while transmitting disorder detection to a suitable career are achieving this. Meanwhile (Yan and Su, 2016) has introduced an infrastructure to enhance current smart meter data storage and processing. The smart home, the building etc. is the user layer in this case.

The Fog layer consists of intelligent meters serving as Fog nodes. They act as a particular data node that is considered a master node with modules that store the file name and storage location metadata. Include also modules which duplicate and divide the collected data and then distribute it at fixed intervals to data nodes. Using the MQTT protocol, (Mekki *et al.*, 2019) propose a remotely controlled IPS. MQTT is an internet-of-things (IoT) data exchange protocol widely found in the TCP / IP architecture. Because of low bandwidth and the use by limited-resources devices, it is more suitable than other protocols, such as HTTP. (dela Cruz *et al.*, 2016) has developed and designed the corresponding specification for wireless mesh network points using accessible hardware. Apps have been introduced, such as message caching. The network, especially the MQTT messaging, has also been tested for reliability.

3. METHODOLOGY

We adopt the research methodology scheme described in Fig. 3 following the indications in (Kitchenham, 2004).

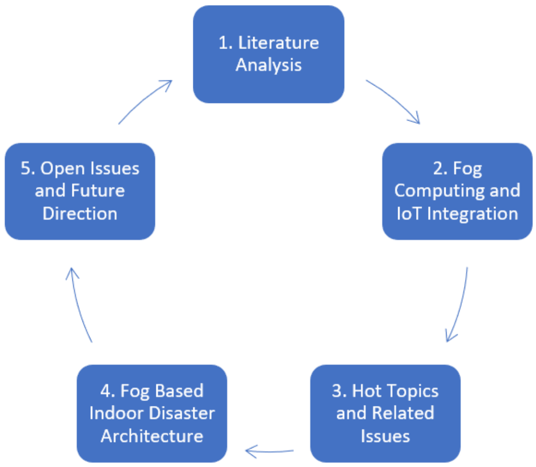

Fig. 3. The Research Methodology

First, we provide a temporal interpretation of the literature in order to demonstrate the temporal conduct of research and the common interest in the Fog computing paradigm qualitatively. Secondly, we address in greater depth the Fog Computing model, which illustrates the need to incorporate them into IoT. Third, we examine the model of Fog Computing and the implementation scenarios together to assess the hot topics and associated research concerns. Fourth, we propose indoor disaster Architecture based on Fog Computing. Ultimately, we build on open issues and possible guidance about Fog Computing in the area of indoor disasters.

4. RESULTS AND DISCUSSION

The NIST (National Institute of Standards and Technology) Fog Computing Model defines fog computing as a vertically model which enables distributed applications and services to be deployed, ensures low latency, reliable operation and eliminates the need for persistent cloud connectivity (Battistoni *et al.*, 2019). In Fig. 4, we can see how the fog computing layer is structured.

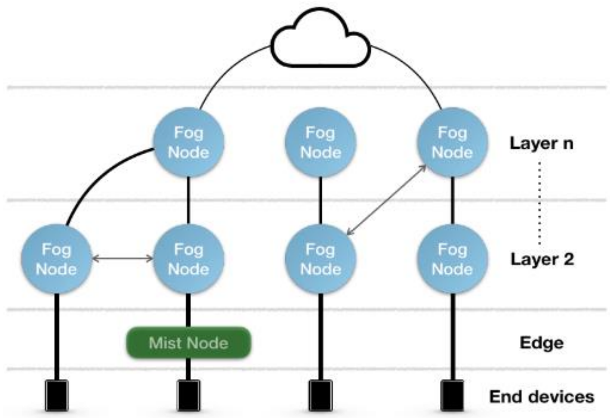

Fig. 4. Fog Computing Architecture (Battistoni *et al.*, 2019).

From Fig. 4, we can see that the data sources originating from end devices are collected and processed by fog computing. If necessary, it will be passed to cloud computing. The number of layers of fog computing can be more than one. With regard to efficiency and storage capacities, the Fog computing processing and storage modules called Fog nodes are heterogeneous.

The CISCO sets the standard terms for each level and outlines each level and level interaction and functionality, including the IoT reference model (Cha *et al.*, 2018). The model of reference consists of seven levels. Each level does not limit or limit the size of the respective component. For example, Table 1 identifies CISCO 's proposed reference IoT model and related levels.

Table 1. CICCO's Internet of Things Reference Model.

Layer	Name	Detailed Role
1	Physical Devices & Controllers	The "Things" in IoT
2	Connectivity	Communication, Processing Units
3	Fog Computing	Data Element Analysis, Transformation
4	Data Accumulation	Storage
5	Data Abstraction	Aggregation, Access
6	Application	Reporting, Analytics, Control
7	Collaboration & Processes	Involving People, Business Processes

According to (Xu *et al.*, 2016), The Fog node serves the following purposes:

- Behaves as actual broker for MQTT clients,
- Serves as a platform for performing analytics at the Fog node.
- Have to connect with the server to store the end-host broker and complete delayed review. The fact should be noted that an external Fog node communication is used in a distributed broker environment, for example, to link to another Fog node.

Messaging protocol is one of the important things in IoT solutions. With regard to the question of which IoT solutions have the messages protocol used, the results from this analysis have shown that the most used and adopted protocols are MQTT and HTTP (Dizdarević *et al.*, 2019). MQTT and HTTP REST are currently more mature and robust IoT standards than other protocols. With several IoT developers in its IoT, fog or cloud deployments, MQTT and HTTP, are the protocols of convenience. The Publish / Subscribe concept is used in this protocol. Contrary to HTTP using the request/response concept.

Pubsub (publish and subscribe) is an event-driven server that allows messages to be sent to the client when necessary. The Contact Center is at MQTT Broker, which sends all messages, including the distribution channel. All customers, including the subject in the messages, who send a message to the broker. The subject is included in the broker's routing information. Clients who want to receive messages may subscribe to a given topic, and the broker sends to the correct client all of the messages corresponding to the pattern of the subject. This method does not necessarily mean that clients need to know each other, but may easily interact using themes.

MQTT is a lightweight coordination protocol for MQ Transportation. A broker can be connected to multiple customers or nodes in the MQTT network. The clients advertise certain data under a specific subject as a message. Any other user who would like to receive these data subscribes to the related topic. The exchange of all data by the broker takes place.

Speaking solutions of this type are flexible because they need to be kept out of the ties between device producers and data consumers. In this indoor disaster architecture, each building is assumed to have smoke sensors and fire sensors, which will send data about fire events to MQTT Broker Server for later data processing as we can see in Fig. 5.

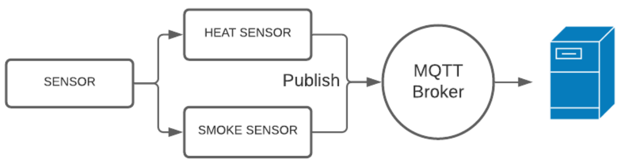

Fig. 5. MQTT Publisher-Broker Architecture

In Fig. 6, we can see that a disaster management system, which includes a fire brigade, police and medical service, acts as a MQTT subscriber. A disaster management system will get data or a warning from MQTT Broker regarding the danger of a fire that occurs in a building. MQTT has been developed to address the complexities of linking the increasingly physical world of sensors and actuators with a platform for information processing.

Reactions times, output, less battery use and lower bandwidth are key design criteria in the mobile environment. The MQTT protocol provides an advanced IoT data control management and collection system. Each control packet helps to reduce the data transmitted across the Network for a smaller footprint and better battery life, and each bit of the packet.

The MQTT broker is the main mediator between publishers and subscribers. This ensures that subscribers and publishers share messages through the broker node (see Fig. 7).

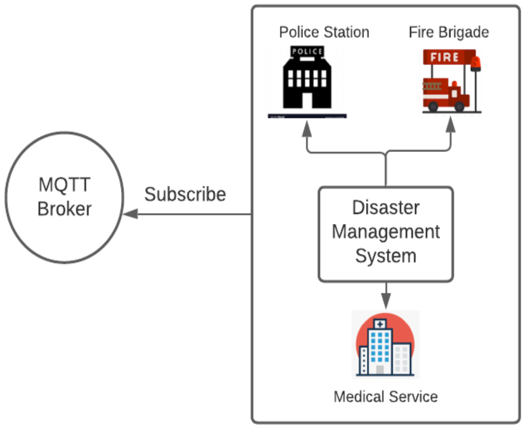

Fig. 6. MQTT Subscriber-Broker Architecture

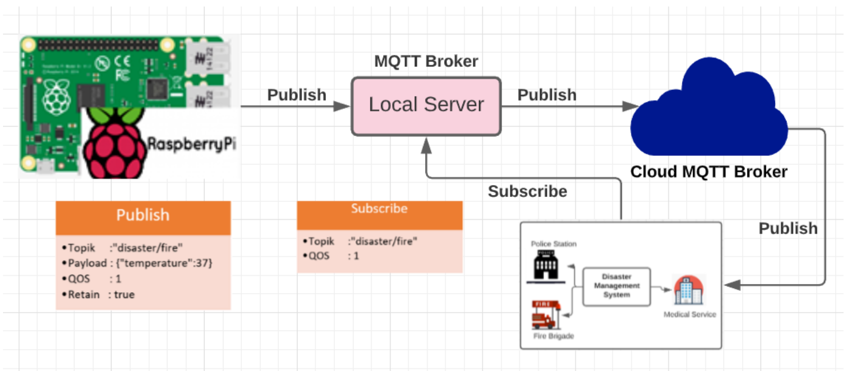

Fig. 7. MQTT Connection of the IoT, Fog and the Cloud

As in Fig. 7, a Raspberry Pi is a MQTT client that is completely compatible with the Mosquitto broker by installing the library of the MQTT Paho. At the other hand, the broker refers to the higher abstraction layer of a fog machine node with more significant processing and storage capabilities. Raspberry Pi is connected to the temperature, smoke and fire sensors and releases data on the sensors to a broker fog node in the proposed intelligent scenario. In this case, the local server with the installed Mosquitto library has a position for the broker, a simple personal computer outside the shelf. The information from local server/MQTT broker then transmitted to the cloud released to the local broker. Here, the MQTT fog broker is used to connect all data to another cloud-based instance MQTT Broker. Related work so far has more commonly considered MQTT from the IoT device layer to fog nodes. can be found in (Dizdarević *et al.*, 2019).

5. CONCLUSION

Most people spend indoor time. The interior is more complicated than the exterior. In addition, today's building structures are becoming sophisticated and complex, so that disasters in the room can lead to problems. Fire is one of the catastrophes in a building that often happens. They ought to handle accidents to reduce the likelihood of casualties. The Internet of Things is a current technological trend. Via the Internet of Things, various developments exist. In various studies, disaster management using the Internet of Things and cloud computing was widely discussed. Though, there are many issues with crisis recovery where the time and resources required are important, relies on cloud computing. Of this function is Fog Computing. Fog computing is used in this work as the foundation of the buildings' emergency response system. MQTT acts as a communication protocol with flexibility and speed advantages. This study proposes an indoor disaster architecture, mainly fire. This research is expected to be the basis for further research by utilizing all the advantages offered by fog computing in the context of handling a disaster. Along with advances in artificial intelligence and deep learning technology, it is very open to research that can integrate fog computing with artificial intelligence and deep learning in supporting the indoor disaster management process.

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