To Propose a New Model for Emergency Systems based on Cloud Computing and Wireless Sensor Networks

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***Abstract*—Wireless Sensor Networks (WSN) is one of the major techniques that widely employed for emergency evacuation. By utilizing internet connection, wireless networks, cell phones and other communication technologies, the quality of evacuation can be improved. WSN allows a target monitoring, a hazard sensing, and data collecting and transferring to navigate the evacuees during hazards. This research aims to address congestion issues during the evacuation. It tries to balances the load of the evacuees among the different available paths of a confined area (i.e. building, campus, zoo, etc.). Our approach is based on WSN. It is intended to be adaptive, able to function in real time, and avoid congestion in calculating the evacuation paths.**

***Keywords*—WSN, evacuation; indoor emergency systems; congestion aware evacuation**

I. Introduction

With the increased complexity and augmentation of modern buildings around us, the evacuation process has become harder during emergent situations due to the occurrence of disasters such as earthquakes, fire, building collapse, etc. [21]. Recently, several implementations of WSN have been appeared and renovated the development of this world such as smart infrastructure development, smart cities, intelligent controlling systems, etc. [22]. Evacuation is a process applied as a response of sudden emergency cases to navigate occupants in an orderly, quickly and safe manner. Evacuation is a critical component of emergency response, in which evacuees must be guided accurately, quickly and safely to optimal routes to leave the hazard zone with no casualties.

In fact, the main performance factors in most emergency evacuation approaches are survival rates and evacuation time. It aims to transfer and guide people, during the hazard from the affected area toward exits or safe areas. For various emergency incidents including fires, terrorism, natural disasters and congestions, the most critical performance indicators of the evacuation approach are: 1) survival rates, and 2) the evacuation time. The concentration of populations in modern urban areas is increasing over years, which requires efficient emergency planning and preparedness systems to safeguard national security and economy. Congestion occurs when evacuees are rushed and directed towards exits without considering the capacity of selected paths compared to other less-congested available (yet safe) paths. In most cases, congestion cannot be predicted since it occurs in real-time and affects the reaction of the evacuees.

Accordingly, this research proposes an Adapted Congestion-aware Evacuation System (ACES) based on Wireless Sensor Network and Clouds which minimizes cognition by providing a load-balanced evacuation guiding scheme in a confined area. It calculates paths in real time to guide evacuees to their closet exit. It also considers the distance to the hazard and the capacity of exit in calculating the evacuation path. Thus, the safety of evacuees and evacuation time are expected to be improved. We attempt to provide a dynamic model that considers network maximum flow and bottleneck during the disaster through dynamic monitoring of building components. This involves to suggest an intelligent routing approach to guide people and to achieve load balancing at the safe paths, gateways, and exits. Therefore, the congestions zones will be determined and excluded from the available safe paths.

Indoor environments can be keep tracked to provide QoS for the people inside public offices. Monitoring private and public buildings can be achieved through the deployment of WSNs that can sense different conditions like lights and heats to control and detect the presence of any hazard [4]. The significance of the presence of EMS refers to the growing complexity of buildings and the increasing number of people. Thus, a new type of management systems is needed to control and secure these buildings [2].

Decisions during emergency situations should be made in real time and with immediate response. Many resources are allocated in coordinating different interesting perspectives and challenges to handle technical issues belonging to evacuation process [1]. The serious problem regards the lack of awareness of the evacuees about the direction of safe routes to follow them in an optimal evacuation time. This problem increases with the hazards that move from place to another such as fire, floods, and smoke [3]. Critical performance of the evacuation process can be measures through considering several metrics such as survival rate, human behavior, safety metric, Evacuation time, degree of damage, safe escape routes, and mobility and communication.

II. BACKGROUND

A. WSN and wireless technology

Wireless Sensor Networks (WSNs) contain a set of small wireless end points distributed in a quite large topographical area that capable to exchange sensed information about physical events by monitoring the conditions in a specific region in environment. WSNs compromise large number of wireless sensors that transmit information to the Base Station (BS) also called sink. WSN is complex in nature. A sensor nodes contains several components: memory, sensor, processor, battery, peripherals, and RF transceiver [32].

The advent of WSNs was initiated for the first time in military applications, while they have become common in meanwhile extended to many other applications such as transportation, healthcare, and environmental studies [33]. Based on another source, WSNs was driven first by battlefield surveillance for military investigation [34]. WSNs are employed in numerous industrial and academic applications, as well as business environments [31]. One of the most significant technologies in this century is WSNs that enables distributed connected sensor nodes to transmit and receive data automatically [34]. A novel line of research is the Emergency navigation through indoor environments that enable engineers to deploy wireless sensor networks (WSN). A lot of advantages make from WSN a coherent solution for indoor EMS such as low cost, easy of deployment, wireless connection link, and the ability to handle node failures [27].

A set of significant terms mostly used in the field of WSNs are listed below.

- Sense function refers to the process of converting physical events like sound, heat, motion, and light into other signals (e.g. electrical signals) that can be maintained by another apparatus.
- Sensor nodes are the basics units in WSN, which is built in with a memory, power supply, processor, and wireless modem.
- Network topology is a connected graph that represents the sensor nodes as nodes and the communication links as edges.
- Routing is the process of defining the optimal path to route from the source to the destination.
- Resources are the main components of WSNs that include sensors, processors, node energy, communication links, and storage capacity.
- Data storage (memory) is the capacity of WSN to support run time system that might be localized at the generating nodes, distributed in balance across network nodes, or linked over different end points [34].

B. Characteristic and Constraints of WSN

WSNs are easy and simple to deploy, they need low cost for deployment and can be fine enough of monitoring [35]. The sensed data carried out by the nodes contain the location or coordinate of a node that can be gained by Global Poisoning System (GPS). However, GPS is no longer work inside buildings, therapy the predefining of location for each node is a very tedious task. The lifetime of deployment is one of the main challenges faced during the deployment of WSNs for monitoring real world objects. Therefore, the neediness for effective topology control protocols and power management increases since the deployment of nodes requires prolonging their lifetime and putting some of selective nodes in sleep mode [33]. The resources should be efficiently utilized especially for routing and data communications to prolong the deployment time of the applications of WSNs [30].

Many challenges are faced by the development of WSNs such as ability to face harsh environment, ability to cover a wide and dangerous area, Ability to overcome node failures, self-configuration, and mobility of node [26]. The replacement of batteries of the sensor nodes is incontrollable task so the WSNs need to operate within a limited energy resource. Consequently, the failure occurring in some node caused by low energy may prone the overall network [32]. The movements of the sensor nodes within the network is influenced by the characteristics of the corresponding actors and the conditions in the physical environment [26]. Examples of these challenges are limited of storage and computation, node size, minimum data rate, unreliable sensor node, data redundancy, security issue, and application domains [28].

C. Applications of WSN

The applications of WSNs provide many opportunities to examine the possibility of employing them in decision making systems by studying the impact of the information sensed by sensor nodes on the allocation of resources [34]. The applications of WSNs are Environmental application, military and surveillance application, agriculture application, commercial application, home intelligence application, health care application, and traffic control application. First, environmental monitoring is comprised of a set of sensor nodes that are used for monitoring a group of environmental conditions, situations, and parameters like hazard monitoring and habitat monitoring [27].

Second, the application of WSNs in military field originated to early stages of the development of WSN and deploying it into surveillance process. Nowadays, many applications of WSNs emerge as integral parts of military intelligence systems like remote sensing, intelligent guiding, and battlefield monitoring [29]. Third, the deployment of WSN in industrial and manufactural field can be utilized for monitoring the conditions of the manufacturing equipment and the manufacturing and production processes [31]. WSN is a promising topic that can be used in intelligent homes to provide an intelligent and suitable environment for people [33].

D. Cloud Computing

Cloud computing is a new era for the provision of shared access to the computing resources such as infrastructures, platforms, services, and applications. Cloud computing model allows users to access convenient services and to request their intended services on demand (pay as you go) from a shared pool of resources of computing such as storage applications, servers, networks, and other infrastructures. The users can obtain a rapid quality of service provided with minimum price and effort required for purchase, management, and maintenance [34]. The applications of cloud computing are growing in these days for different implementations of distributed computing systems. Further, the use of cloud platforms for data processing and storage also increases with the needs [34].

Cloud computing model is categorized into three classes: *Infrastructure as a Service (IaaS), Software as a Service (SaaS), and Platform as a Service (PaaS).* In *Infrastructure as a Service (IaaS)* model, the basic capacities of storage, computing, and processing can be provided to the clients. A shared pool of infrastructure resources is accessible to handle large amount of data and heavy workload. For example, data center, storage systems, network equipment, and servers are provided by Amazon as a type of IaaS [34]. In *Software as a Service (SaaS)* model, the services are provided by cloud server to the clients those demand services. Many end users can be serve by one instance of cloud service to run on many client systems. There is no required license or investment of the servers at the end user side. For example, Google services are categorized as services under SaaS model [34]. In *Platform as a Service (PaaS)* model, the service provider can offer development environment such as software that is included by higher level of application to run servicers. Therefore, the clients can establish and run their own applications on the provided infrastructure such as application servers and OS. For example, Google App Engine can be considered as an instance of PaaS [34].

Cloud computing model can be deployed in different four modes: public mode, private mode, community mode, and hybrid mode. In *public mode*, cloud components are owned and operated by a third party who manages the share of the same infrastructure and pool of resources among clients. Some considerations are restricted in this mode such as availability of services, limited configuration, and security protection [34]. In *private mode*, the cloud infrastructure is managed by third parties regardless their locations, but operated by a single organization. The main goal of deploying such that mode is to set up a private cloud within an organization for optimizing resources utilization and for securing data with less transmission costs from private in house infrastructure to public global infrastructure [34].

In *hybrid mode*, a combination of private and public cloud modes is realized. The flexibility of the resources usage can increase with the employment of a third party by service providers to provide partial or full services [34]. In *community cloud*, set of organizations are joint to construct the cloud infrastructure by creating a shared policy of the use of available resources. One of the organizations or a third-party vendor (service provider) can be recognized as a host of the cloud infrastructure [34].

The servers in the cloud models are either virtual or physical machines. Furthermore, powerful servers and large data centers are used in cloud applications and hosted by Web service providers and Web application providers. The access to cloud application is straightly possible through a standard browser and internet connection [34].

The essential characteristics of cloud computing are summarized as follows [34]:

- On-demand services: the clients can request to access cloud resources by automatically fulfillment of cloud service request with no reasonable interaction.
- Resistance of demand: the use of resources is not restricted by a specific time or a formal agreement; but rather whenever the clients wants to use the resources they can automatically request them; and whenever they finish they can release them.
- Abstraction: the clients cannot see the resources, know where the resources are existed, know the place where the data is retrieved or stored; they can only use them in abstraction manner.
- Network access: using a secure internet connection, the clients can access cloud application via laptop, mobile phone, or PDA.
- Service management: multitenancy environment allows multiple clients to access and use computing resources pooled and shared in cloud environment. the usage of resources can be measured by metering capabilities of the cloud infrastructure.
- Resource pool: a pool of resources permits a dynamic on-demand assignment of resources for each client.

E. The integration of WSN with Cloud

The combination between WSNs and cloud computing emerges an easy task of sensing real time data and processing it on the fly. Therefore, an advantage of a service of sensing and processing data over internet can be obtained. For example, new forms of services appear like Sensing as a Service (SaaS) and Sensor Event as a Service (SEaaS). These new types of services make the sensor data accessible by cloud clients in addition to cloud infrastructure and increasing the number of cloud applications and services [34].

III. RELATED WORK

The implementation of WSNs in emergency situations has shown effective solutions, like studies presented here, to save people and physical infrastructure. The dynamicity is featured by the changes of the appearances of graph’s elements (nodes, weights, and arcs) over time. Dynamic approaches are constructed on varying weights on arcs that represent the estimated transmission time corresponding to the evacuation before the arrival of fire hazard. Therefore, the sensors should dynamically work to produce a graph that represents the safe transitions and evacuation routes into fixed weights computed by shortest path algorithm. The safety evacuation paths are defined based on a shortest path algorithm within a central manner represented by dynamic model changed over time.

Many researches have paid attention to the evacuation process in emergency systems such as a fire emergency evacuation system [25] (a dynamic centralized model which expands the concept safety in the dynamic graph navigation situation) and [24] (a dynamic distributed approach). The **centralized** computation of the shortest path can generate improved accuracy, and hence the base station resources can be utilized more. The speed of alert system relies on the time taken to route data (routing protocol) in WSN [25]. On the other hand, a **distributed** algorithm that can guide and evacuate people to safer places though exits considering the motion of people and danger with time dependent based on the distribution of evacuates and safe navigation assistance [24].

In this section, we review a set of recent related works to WSNs, cloud computing, and congestion-aware approaches with respect to emergency systems. Each reviewed work will be discussed and detailed to show the main contribution, as well as to compare between different works in terms of robustness and limitations.

A. *Wireless Sensor Network for emergency systems*

An intelligent method dependent to Internet of Things (IoT) and WSN was proposed in [21] to design a responsive system for fire emergency with minimum resources. The proposed system was based on WSNs that can intelligently define the presence of a problem (fire or building collapse) in bidirectional ways and guide people to exits considering the location and time constraints. The authors used guiding lights to inform and bypass the people to the evacuation paths and locations, cooperated with the government's central disaster prevention system. It can minimize the losses through determination of the exact place of disaster occurrence inside one building, and hence the prevention of misperception caused by confusing lights. More beneficial thing is assisting firefighters with faster response and quicker assessment of the fire location based on centralized emergency management.

An algorithm based on WSN for indoor emergence guidance was proposed in [23] to monitor real time environment, to detect any emergent event, and to faster guide the trapped people to safer places. The regular security systems are only capable to send alarms without any guide to the safe paths. Three phases were involved in the proposed algorithm: deploying (setting all possible paths and exit gates), monitoring (ordinal state and detecting risks), and emergency state (guiding the people to the safe paths and closed exit gates). The author of the paper concluded that the use of a suitable number of sinks (base stations) in the most appropriate positions based on the given building architecture should be in 3d dimensions.

An early warning system based on WSNs for earthquake prediction was introduced in [22] resulted from investigating the implementation of Information and Communication Technology (ICT) infrastructures to manage disasters like earthquake. Variation in water level, unstable behavior of animals, and radon gas emission are some prediction ways of the earthquakes. Therefore, the incorporation of WSNs in predicting earthquake can merge disaster management and earthquake warning system through (Global Positioning System) GPS that can track the motion of animals, sensors to monitor ground water pressure, and checking temperature and pressure of radon gas emission. Furthermore, the neediness of transmitting information to all devices in one region to alert people lead to evacuate the citizens, their homes, infrastructure, offices, etc. to safer areas will reduce the heavy losses.

A novel algorithm based on Maximum Connected Load-balancing Cover Tree (MCLCT) was developed in [15]. The proposed algorithm in the paper was formulated like maximum cover tree problem to enable the base station to cover all of nodes in WSNs, as well as to achieve dynamic sensing. The authors allow the nodes to share the load in sensing and transmission through MCLCT to distribute the consumption of energy. Every node senses the network and sends information to the base station, which is considered as the root of the maximum connected tree. The process of determination of the routing path considered the transmission distance, the load, and the residual energy among all of nodes. The results of the experiment showed that the proposed algorithm is efficient and overcomes other approaches since it can improve the connectivity, efficiency, and prolong network lifetime for longer time. The studies [21] [23] and [23] are only those studies belonging to the use of WSNs in emergency system regardless the consideration of the congestion and load balancing issues.

B. *Integrated WSN with Cloud Computing for emergency systems*

A cloud enabled emergency navigation algorithm was developed in [12] to efficiently achieve evacuation based on changed conditions such as hazard source location and the distribution of evacuees and occupancy rate. The novel algorithm includes two layers; user and cloud layers. When a disaster happens, evacuees take snapshots of the hazard using their phones and then upload them on the cloud server to identify their locations. A set of servers dedicated for image processing were employed to define landmarks of the photos and map them with those stored on server to address the region of hazards. Paths were found by a WSN that based on the Dijkstra's shortest path algorithm (considering time dependent metric instead of distance dependent metric) based also on estimating the spreading of hazard and the initial distribution of civilians. Results show that the developed system has an enhanced survival rates.

The integration of WSN and Mobile Cloud Computing (MCC) has been presented in [14] to take the advantage of data collection and data storage of cloud and due to the received attention of the interests by academic and industry. The proposed sensory approach aimed to transmit data between mobile devices in a secure, reliable, and fast data processing framework. Further, the proposed model can predict and monitor future pattern of data traffic over sensors, as well as it can improve the security of obtained data from cloud. The analytical model of experiment proved the effectiveness of the proposed approach in data traffic filtering, data encryption, data compression, and data prediction. The capacity of cloud in processing large data and other capabilities were exploited through clouds for better performance of WSNs in terms of lifetime, security, and storage requirements, as well as cloud processing and cloud storage overhead.

SIGMA project [19] aimed to exploit distributed, scalable, efficient, and united services of cloud technologies for processing data collected from heterogenous WSN sources to control and monitor environmental risks (e.g. manage water risks) based on an established distributed risk management system. Particularly, the paper discussed how SIGMA works as a process of data collecting, data storing, risk sensing, and thus data processing. Further, it allows to simplify the processes of sensing, collecting, formatting, storing, and processing data in cloud systems. In conclusion, a system prototype was discussed in the paper for data collected from water sensors and sent to cloud for business intelligence processing and storage.

A design, development, and integration of an extensible architecture was developed in [20] for cloud WSNs sensor data platform called Open.Sen.se. A set of web based services (interoperable application layer) were set up in smart environment. Therefore, an energy efficient approach was proposed with low power for increased lifetime of the sensor nodes. The alarm system can use tweets or emails to notify users for exceeding values of interesting events data. Open.Sen.se server can process, store, and analyze collected data from sensor nodes through Application Programming Interface (API). Intelligence at several layers of the architecture was embedded to meet various requirements and scenarios and to avoid loss of data and network disruption. Based on the evaluation results, any user has any mobile device supported with internet access can access sensor data anywhere. The studies presented [12] [14] [19] [20] are only those studies belonging to the integration of WSNs and cloud services in emergency system.

C. Congestion- Aware emergency approaches

An investigation of smart building evacuation was proposed in [3], considering routing diverse types of evacuees with Cognitive Packet Networks (CPNs). Three routing algorithms were used: distance-aware CPN algorithm, Dijkstra's shortest path algorithm and time-aware CPN algorithm. The congestion is minimized using an adaptive congestion aware algorithm, which has the capacity of predicting future congestion based on present state to avoid directing evacuees to hazards. Results showed that for 30 evacuees, CPN with time and distance metrics approach has reached an optimal performance like that of the Dijkstra's algorithm.

Another quality of service purposed algorithm to dynamically manage and group crowded areas after hazards was proposed in [4]. The purposed approach directs various types of evacuees based on their needs with considering a movable or changeable hazard over time, such as a fire. In such algorithm, evacuees were grouped dynamically depending on hazards around them and their physical condition. Consequently, the proposed algorithm can collect spatial information about the distribution and location of hazards to prune hazardous zones from the available directed paths and to handle different characteristics of evacuees such as mobility, resistance level, and age. The results of the performance of the proposed dynamic grouping algorithm proved its ability to provide quality of service and achieve larger number of survival rate.

An emergency navigation algorithm called WSN-based Safe, Ordered and Speedy (SOS) was presented in [5] to reduce the evacuation time and losses among evacuees. Authors used the modeling and scheduling of network flow for emergency navigation problem to decrease the evacuation time. Using this approach, each evacuee is guided to the best schedule of emergency navigation via sensor nodes located on the scheduled paths, considering the state of hazardous areas and the physical location of people. The total evacuation time is minimized using the navigation algorithm starting from guiding people to reaching the safe exits. Two capacity conditions were considered: linear capacity (the number of hops is linear) and uniform capacity (the equal division of the capacity between sensor nodes). The results of the experiment indicated of the low overload, efficiency, scalability, and the superior performance of SOS algorithm with respect to the average evacuation time.

Another research concerning the congestion level in the evacuation process was conducted in [31]. It proposes a WSN-based indoor congestion aware navigation algorithm focusing on reducing direction oscillations and interactions among evacuees. In such algorithm, the moving speed concept was considered to assess the level of congestion for precise estimation of the evacuation time and evaluation of the congestion degree for accurate estimation of the evacuation time. Three performance metrics were considered: 1) evacuation time. 2) time of oscillations. 3) communication cost. Hence, the results showed the improved performance of the algorithm better than the state of the art work with respect to the evacuation time and oscillations.

An indoor distributed flow-based guiding approach was proposed in [7] to evacuate people to safe exits from dangerous zones using a WSN. The purpose of this approach was to construct paths with low congestion to reduce both the congestion time and escape time (communication overhead and computational cost) inside buildings. The moving speed and traffic flow of people was estimated for each path using the traffic flow theory to discover the density versus less congested paths and then balance the load of both paths and exits. The results showed that the performance of the approach is efficient enough to achieve load balance at exits and reduce the congestion time. However, the proposed approach cannot evacuate people to exits considering the capacity of all exits that might result in congestion.

Another indoor adaptive guiding protocol for crowd evacuation process was proposed in [8] with deploying a WSN. The purpose of such protocol is to guide people and balance the load between multiple navigation routes to avoid congestion of such routes and decreasing the evacuation time. The main considered factors are the congestion degree of paths, exits width, distance to exits and hazardous areas. In this protocol, a potential value that based on the crowd density, exits width and distance to exits was assigned to each location to avoid the movement of objects to the source of hazard. The proposed protocol can provide less congestion and less evacuation time since it considered more realistic measures in real time environment. Thus, it achieved high survival rate and low guiding time in both emergency and nonemergency environments.

An efficient method for managing crowds in Arafat area of Makkah called Wireless Sensor and Actuator Networks (WSAN) rings communication overlay was proposed in [9], which is combined of WSN and RFID technology. It can assist in monitoring the targeted region, controlling the crowd and supporting the evacuation process from the overcrowded area. The proposed approach could be complementary to other approaches considering real time management with the aid of WSN and RFID. It concerned with huge size and short term of crowds, therapy the costs associated with building monitoring stations is relatively high. The proposed optimal monitoring and evacuation system has considered many challenges of managing crowd to be undertook.

An adaptive emergency protocol based on greedy approach and dynamic computing was proposed in [10] to navigate people in high-rise buildings. In the study, all the accesses of each floor inside the building were considered to define the safe evacuation paths with load-balancing. The proposed algorithm can route evacuates with minimum cost of safe path selection. Three scenarios were conducted and repeated three times to make a comparison between different subgraphs with different distribution of people. Results proved the efficiency of such system, where the discovered evacuation paths drive all evacuees outdoor with minimum costs for various addressed risk scenarios with similar average length of paths.

Another WSN an analytical model for distributed emergency guiding algorithm with a load-balancing framework was proposed in [11], which was designed to decrease the evacuation time. This work differs from other similar ones in considering the length and capacity of corridors along with the capacity of exits and the distribution and concurrent movement of people to estimate the evacuation time and determine the escape routes. This in turn can reduce the congestion at exits and in corridors and decrease the evacuation time. The proposed model considers the concurrent movement of people and reselect the directing paths to predict the evacuation time for each sensor to get the nearest exit path.

A summary of literature review is shown in Table 1.

IV. Motivation

Wireless sensor network WSN consists of multiple nodes that have limited resources (e.g. battery power) and processing, so we can’t use the same node all the time for routing. WSN nodes (mobile devices) are connected in ad-hoc fashion and the architecture is either centralized or distributed. Sensors nodes are used to collect data that encoded and transmitted through communications channels until reaching the base station to be saved there for use and analysis. In this research, cloud computing can be used for scalable and powerful storage and processing of huge data delivered by multiple wireless sensors.

We consider several purposes of this research to investigate the exiting approaches in the area, to address the congestion problem, to design and analyze the proposed approach. The proposed model, WSN-Cloud-integrated, will be analyzed in terms of minimizing congestion, minimizing total evacuation time, maximizing load-balancing, and maximizing evacuees’ safety. We have proposed an improved architecture which integrates wireless sensor networks running on mobile devices with cloud computing.

A. Architecture

Every sensor node senses data, base station collects sensed data from all sensor nodes and then collected data is sent to

Table 1: a summary of literature review

Category	Source	Strengths	limitations
Wireless Sensor Network for emergency systems	[15]	Maximum coverage	Energy consumption
	[21]	Minimize losses	Specific to fire
	[22]	Early warning	Specific to earthquake
	[23]	Faster guide to safe places	Does not evacuate people to the outside
Integrated WSN and cloud for emergency systems	[12]	Enhance survival rate	Requires snapshot of the location
	[14]	Improved security and performance	Encryption and compression overhead
	[19]	Scalable and efficient services	Specific to water risks
	[20]	Energy efficient approach	Specific only for users of twitter or Facebook
Congestion-Aware emergency approaches	[3]	Minimized congestion with CPN	Only considers distance and time metrics
	[4]	Dynamic grouping of different ages of evacuees	Does not consider the mobility of hazard
	[5]	Linear capacity and uniform capacity of paths	low overload, efficiency, and scalability
	[31]	Moving speed and congestion	Only focus on reducing direction oscillations
	[7]	Moving speed, traffic flow, and density	Cannot consider the capacity of all exit paths
	[8]	Less congestion and less evacuation time	Realistic measures need extensive computations
	[9]	Crowd management and control	Dependent to RFID with medium capacity

	[10]	Minimum cost and load balancing for high-rise building	Dependent to greedy algorithm that might failure at any time
	[11]	Movement of people and load balancing	Extensive cost to re-compute the altitudes for each sensor

cloud directly or in multi-hop manner through other nodes. In this context, we use Cognitive Packet Network (CPN) model to send Cognitive Packets (CP) for network monitoring and discovering new routes. In the architecture of CPN, each node carries a regular Random Neural Networks (RNN) including neurons for neighbor nodes. Therefore, each node should maintain its own routing table that reserves a fixed number of routes.

CPN conveys three types of packets: Smart Packet (SP), Acknowledgement (ACK) and Dumb Packet (DP). SP is used for routing discovery and information collection. All packets can either randomly discover paths not measured or select the next hop with maximum activation neuron value. Once the target destination is reached by SP, the collected information are involved into an ACK and sent to the source node through the inverse path in the direction of the source node. The routing table of the source node will be updated when ACK arrives at that node, which then performs Reinforcement Learning (RL) to train a random neural network. DP carries the payloads that always select the top path of the routing table.

Since the environment of emergency evacuation is highly dynamic, SP can be used for route discovery to search of existing paths and gather information. Moreover, DP is used to send real information of any disaster to the base station. ACK backs to the source node carrying out the gathered information and updating the activation neurons degree for every navigated node. DP always follows the top path (best path) in the routing table (listed in descending order) for faster data collecting, information processing and evacuation time reducing.

Figure 1 shows the integration of WSN and clouds. It shows end users those have mobile devices equipped with a sensing service inside buildings. Thus, these mobile nodes are linked to the base station that directly communicates with clouds to utilize highly efficient scalable resources.

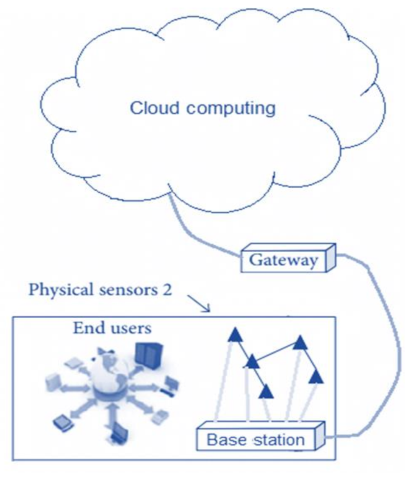

Figure 1: The integration of WSN and cloud services

B. Proposed model

In the proposed model, the nodes are divided into two types Classical Nodes (CNs) and Master Nodes (MNs). CNs are mobile nodes with limited capacity of resources (e.g. people that have smartphones). MNs are fixed-location nodes with greater capacity of resources. MNs act as routers most times. In addition, CNs are divided into three classes: Class A (nodes located at exits), Class B (nodes located at corridors), and Class C (nodes located at offices). Consequently, there are two types of exits: Main-Exit (ME) and Sub-Exit (SE). MEs are the head exits of the whole building. SEs are the internal exits inside the building such as doors, stairs, and elevators. Exit nodes are fixed-location nodes neither classical nodes nor master nodes. There two sinks in this model: base station regarding the transmission of sensed data, and the main exits regarding the route of evacuees with the minimum time, maximum survives, and load balancing (least congestion). All nodes are treated as source nodes and the main exits are considered as destination nodes. The backbone edges represent the augmented paths whereas the nodes denote the physical locations of the fixed installed sensors.

Figure 2 shows a simple architecture of the proposed model considering less congestion, load balancing, and less evacuation time factors. Hence, the proposed model is distinguished from the earlier approaches since it considers the source of hazard to dynamically update the information of the topology of the network during hazard. In addition, it is organized based on equi-distance among fixed-location nodes called master nodes MNs that are employed to balance the work across nodes and minimize the utilization of resources at mobile nodes called classical nodes. In this architecture, there are 11 master fixed-location nodes, 29 classical mobile nodes, and 5 exits.

To apply the concept of CPN applied by WSNs with adjusted Dijkstra algorithm incorporated with cloud computing for emergency evacuation, some assumptions must be fulfilled: a predefined graph of the location detailed with the main exit node capacity and the length of edges. At regular basis, all nodes send sensed data to the base station, which collects and sends information to the cloud, then clouds analyze these data and resend result to the sink. After that, the base station resends result to all nodes. The role of cloud is to find the nearest, safest, and fastest exit node for each mobile node depending on the adjusted Dijkstra algorithm proposed in this work. Once a danger is detected based on the analysis carried out by clouds, the cloud uses the knowledge about current topology of network and finds the best paths for each node using Dijkstra algorithm considering least congestion, load balancing, and minimized evacuation time and then it sends the possible paths to the base station that resend data to all nodes.

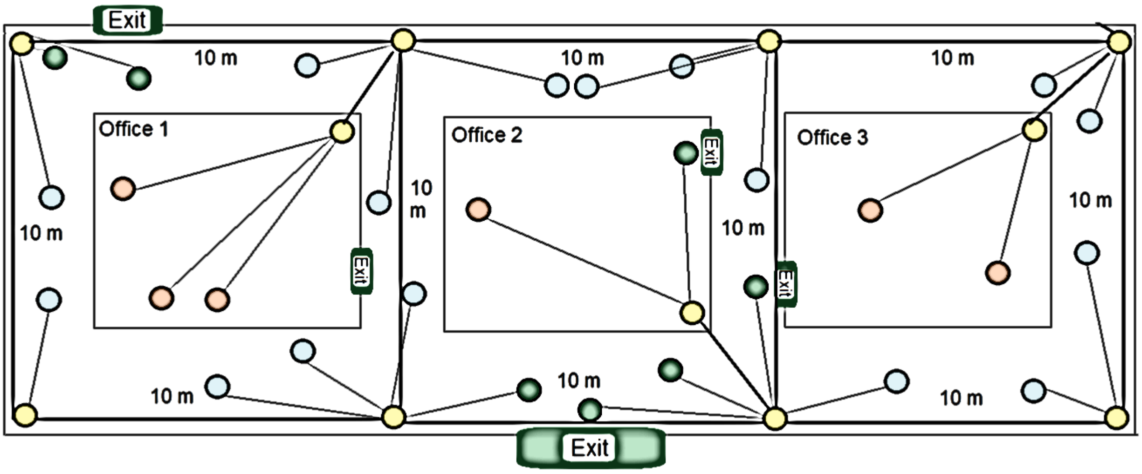

Figure 2: a simple architecture of the proposed model

For each SP, the lifetime (number of hops can be traversed before discarding) is assigned to be maximum. In this case, the maximum number of hops will be the total number of MNs in the network plus one. MNs can communicate with its neighbors, CNs, to exchange the information about the detected hazard. The proposed load-balancing and congestion-aware algorithm assumes that the MNs (sensors installed near MEs) can sense and record the number of arrivals that potential to be congested. Thus, MEs' congestion is dependent to the total number of arrivals and departures and the present state of exit node. We assume that if the capacity of a main exit node minus the average departure rate multiplied by the average arrival rate is larger than the estimated number of evacuees, then congestion will occur.

By employing the adjusted Dijkstra algorithm at cloud, it is possible to determine the shortest distance or lowest cost between a start (classical) node and any other node in a graph. The idea of the algorithm is to continuously calculate the shortest distance beginning from a starting point (classical node), and to exclude longer distances and paths guiding to the source/s of hazard when making an update. Based on Dijkstra algorithm, all CNs with distance are initialized to infinite and the destination to MEs to 0 for the first time. Thus, the next step includes an assigning of the distances to CNs (starting nodes) as temporary and MEs as permanent and setting them as active. To calculate the distances of all CNs, we can sum up the distances between CNs, MNs, SEs (if any), and MEs along with the path to the exits. Based on the calculation results, it might be several results per the number of main exits. Subsequently, if there are two MEs, then there will be two different values of distances. If such a calculated distance of a CN is smaller than the other, the distance form that node to its associated exit is updated and set as the optimal path. After that, each updated value of distance per CNs are set to permanent. This process is repeated until no CNs with temporary state. The adjusted algorithm of Dijkstra algorithm is shown in Pseudo code 1. To predict the potential amount of congestion at each ME during the evacuation process we employ pseudo code 2 which is concerned to find it.

Pseudo code 1: Adjusted Dijkstra algorithm

Input data: a predefined graph of nodes, distances between nodes, and the capacity of each main exit

Output: a List of Optimal/shortest Paths (LOP) from each classical node to one of the main exits

```
For π(0) ∈ N do the following
    If π(0) is a main exit node then
        Set distance = 0
        Set distance type = "permanent"
        Set a main exit node as active
    Else
        Set distance = "infinite"
        Set distance type = "temporary"
    End if
End for
For E(π(0), π(m.e)) do the following
    Find total distance to all main exit nodes
        For each calculated distance
            If di < di+1 then
                Update distance to smaller one
                Update distance type to "permanent"
            End if
        End for
End for
Return LOP
```

Where π(i): represents source node, π(m.e): represents destination node, Ee(π(i): π(m.e)) represents an effective length calculated by Dijkstra, Eedge: calculates the time cost, Vspeed:

represents the average speed of certain type of evacuees, Ene: represents the estimated number of evacuees estimated to arrive a main exit, C: represents the capacity of the main exit node, $\bar{\lambda}$: represents the average arrival rate, $\bar{\mu}$: represents the average departure rate, Ctotal: represents the potential total number of evacuees causing congestion at a main exit, and Ttotal: represents the estimated time needed to a node to reach a main exit node.

Pseudo code 2: concerned to predict the potential congestion.

Input: A safe route π from every node π to a main exit node

Output: The potential number of evacuees causing a congestion by nodes moving over π

```
Set Ctotal = 0        // number of evacuees causing congestion
Set Ttotal = 0        // total travel time of π
For e(π(i), π(m.e)) ∈ path π do the following
        Eedge ← Ee(π(i), π(m.e)) / Vspeed
                if (C − μ̄) * λ̄ > Ene then
                        Ctotal ← Ctotal + 1
                        Ttotal ← Ttotal + Eedge
                end if
        Ctotal ← Ctotoal + Ttotal
end for
Return Ctotal
```

Based on above algorithm if the congestion is more likely to be, Ctotal is incremented by adding the time delay triggered by the congestion. Thus, to satisfy QoS of normal evacuees measured by the time function, it should follow the lowest time needed to reach an exit traversing a path predicted as follows:

$$P_t \sum_{i=1}^{n-1} \{ \frac{E_e\left(\pi(i), \pi(m.e)\right)}{V_{speed}} \tag{1}$$

Time needed to evacuate each node is predicted as follows:

$$T\left(\pi(i), \pi(m.e)\right) = \frac{E_e\left(\pi(i), \pi(m.e)\right)}{V_{speed}} + t(\pi(i)) \tag{2}$$

The congestion at exits is predicted as follows:

$$C_t \sum_{i=1}^{n-1} \{ \frac{E_e\left(\pi(i), \pi(m.e)\right)}{V_{speed}} + (C - \bar{\mu}) * \bar{\lambda} \} \tag{3}$$

Per the proposed system, two routing algorithms are employed: CPN-based algorithm and an adjusted Dijkstra's algorithm. Because the basic Dijkstra's algorithm inclines to group evacuees and guide them to the nearest exit and can lead to congestion, it does not consider the degree of congestion of a main exit and can attain the optimum but with little residence rates and serious fatalities in densely-populated environments. Conversely, CPN-based algorithm cannot grasp the exact performance of Dijkstra's algorithm in high density in terms of survival rates. Indeed, the proposed CPN-based algorithm that considers time metric can achieve better performance with the aid of an adjusted Dijkstra's algorithm that is aware of the safety and congestion of an exit.

In this paper, we use Adaptive Congestion-aware Distributed (ACD) approach for evacuation emergency system using wireless sensor networks and cloud computing. Certainly, ACD considers the risks and hazards in guiding the evacuees far away from the possible hazardous areas to decrease the overall time. Moreover, considering the developed an adjusted Dijkstra's algorithm with time metric can customize all exits for each evacuee using ACD algorithm.

The original Dijkstra's shortest path algorithm have often commonly used to find shortest paths, therapy it has been familiarized in emergency navigation systems operated on WSNs. In contrast, a set of issues (i.e. direction oscillation, communication latency, signal interference, and high energy utilisation) might arise these emergency response systems referred to Dijkstra's algorithm that visits each sensor node in the network. However, we can avoid all these issues in our proposed algorithm by considering time metric in Dijkstra's algorithm that is totally performed on the clouds. In specific, the proposed adjusted Dijkstra's algorithm is the same as the standard Dijkstra's shortest path algorithm but with one difference that we substitute the distance metric with a time metric.

Evacuees can change their classes; a portable node of Class A might move to Class B during a hazard due its mobility. The process of changing an evacuee from Class A to Class B, from Class B to Class C, from Class B to class A, or from Class C to Class B. Pseudo code 3 illustrates how each node can move from one place to another and changing the corresponding classes.

Pseudo code 3: A change from one class to another of evacuees

Input: a set of evacuees with different classes lists

Output: Updated Class Lists

```
When an evacuee becomes a neighbor to one of master nodes
in a specific area, it obtains Class id of this master node
        if distance (ei, mi) <= a threshold then
                e id ∈ Class mi gain the Class id of this
                master node
        end if
        return UPL return updated class lists
```

V. DICUSSION

In this paper, the architecture of CPN is a bit adapted to discourse the requirements of emergency evacuation response. These requirements contain two types of wireless sensor nodes (CN's and MN's) used for sensing and for information transmission. Classical Nodes (CNs) sense the existence of hazards and evacuees in their locality too. All wireless sensor nodes communicate with the corresponding (nearest) MNs neighbor to send them the results of information they sensed.

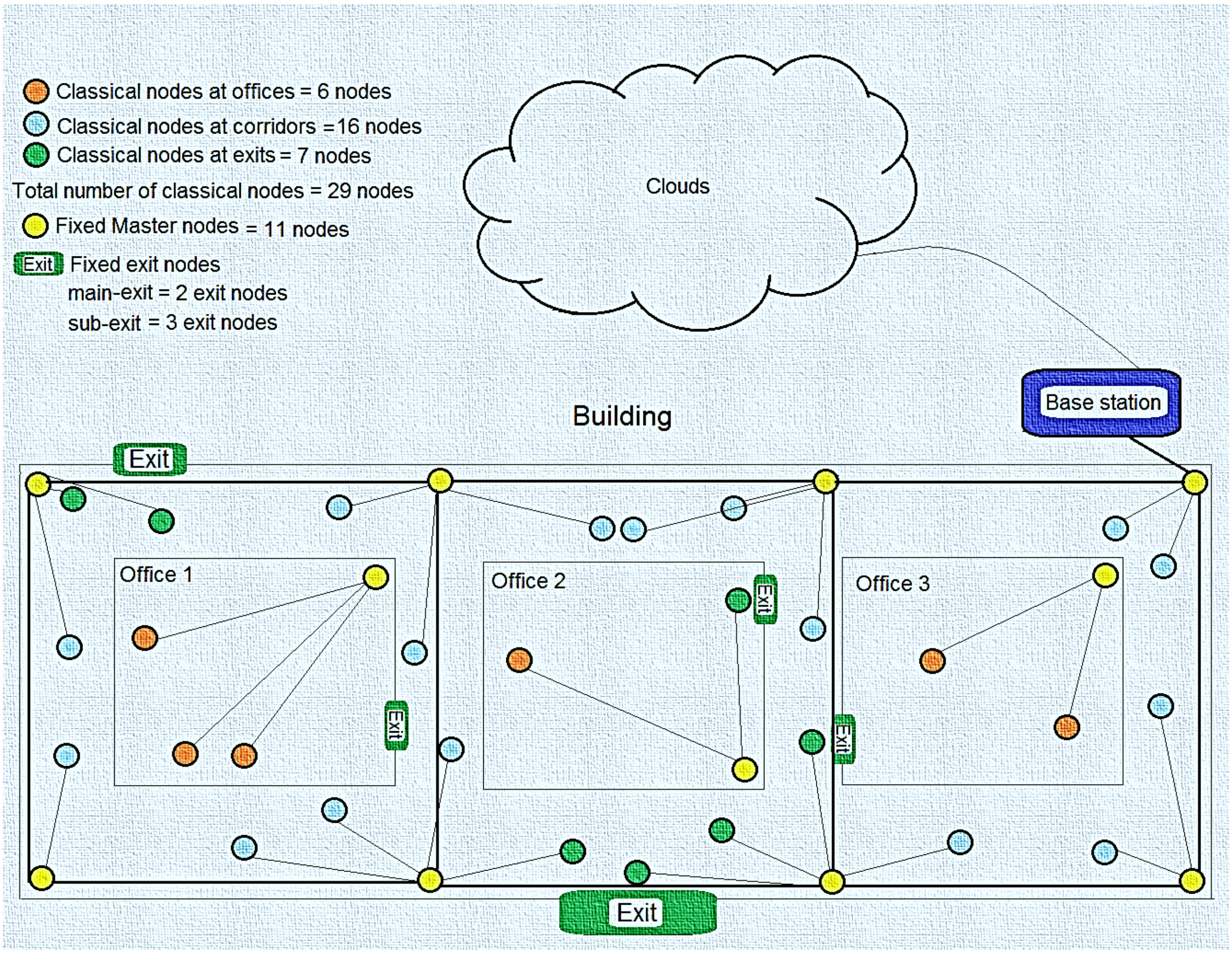

Figure 3: proposed architecture of WSN and cloud for emergency system

Master Nodes (MNs) act as routers and transmitters in wireless CPN. Based on Figure 3, there will be a MN in each office and corridor inside building. In normal situations, MN, which is placed in a fixed location (i.e. on ceiling), acts as a CPN node that sends packets. This network topology should be known to the designer EMS early. Each CN is assigned to the closest MN based on the distance threshold specified by the user to provide guidance to evacuees with the best exit. In the middle of two MNs, there may be more deployed CNs, and there is at least one deployed CN between any pair of MNs for better coverage of monitoring the surrounding area.

Further, every MN recognizes the status of the path to its MNs and CNs neighbors and paths to exits, so it periodically sends SPs moving from MN to its CNs. Furthermore, every sent SP could collect information about paths and exits during its movement to MNs that in turn collect the information of the state of all neighboring CNs. Based up on, MNs select the optimum exit to route information using CPN algorithm. Therefore, MNs send the potential paths to the base station and then they can be analyzed at cloud side to direct evacuees to a safe exit based on their own locations with minimum time and less congestion.

Full path information including the movement deepness value, available exits, congested places, and blocked paths are sent to all evacuees. Evacuees follow the newest updated path and exit to traverse, providing the number of nodes (e.g. sub-exit nodes) before arriving the main-exit.

VI. EVALUATION

Obviously, two quality of service metrics are held in EMS to find the optimum path to exit for all evacuees. These metrics are Time Metric (TM) and Safety Metric (SM). TM is straight forward since it pursues a close near evacuation exit used to support evacuees far away along their paths from the main exit nodes (i.e. Class A evacuees) in the EMS. TM denoted by $T\left(\pi(i), \pi(m.e)\right)$ selects exit paths that minimize the evacuation time. SM or the survival rate will be used for the all classes of evacuees to maximize the survival rate with the presence of congestion or hazard. SM is simply denoted by the total number of departures over the arrivals for each selected, effective, and shortest path.

There is a total of 45 nodes on the graph, including the 2 main exits, 3 sub-exits, 29 classical nodes, and 11 fixed-location master nodes. At each node, we assume that a MN has been placed with CNs placed between each pair of MNs. The spaced horizontal lines linking the nodes are the graph edges representing the possible paths in the building, and on each edge, there will be at least one CN.

In Figure 3, there are 29 classical nodes and then should be evacuated to one of the two exits and each mobile node far away from the exit with specific distance. Let the capacity of the main exit within 10 seconds is 15 and the capacity of the second exit is 5. Considering equation (1) and (2), the time taken to go through the path form each classical node is computed to one of exits considering the speed of node, the source of hazard, and the time needed to evacuate everyone. Now, suppose we have a node in one of the three offices and its distance from the local MN is 3 meters. Supposing that the main exit has a congestion over 15 at some moment, and this node needs to be evacuated to an exit without congestion, and the node is guided to the main exit based on adjusted Dijkstra algorithm, then the node will be directed to the second exit dynamically.

This responsive and adaptive approach allows far away nodes to go through fewer distances and consequently less evacuation time. In this research, cloud computing can be used to process huge data delivered by base station (that collect information from all wireless sensor nodes) to utilize the power and scalability of cloud's processing and storage. Therefore, we have presented a congestion-aware algorithm based on the proposed architecture that is built on the integration of WSNs with cloud computing.

VII. CONCLUSION

This research aims to address congestion issues during the evacuation. It tries to balances the load of the evacuees among the different available paths of a confined area (i.e. building, campus, zoo, etc.). Our approach is based on WSN. It is intended to be adaptive, able to function in real time, and avoid congestion in calculating the evacuation paths. In specific, the proposed adjusted Dijkstra's algorithm is the same as the standard Dijkstra's shortest path algorithm but with one difference that we substitute the distance metric with a time metric. By employing the adjusted Dijkstra algorithm at cloud, it is possible to determine the shortest distance or lowest cost between a start (classical) node and any other node in a graph. Future work will be an implementation of the three algorithms proposed in this research using network simulation to analyze the model in terms of minimizing congestion, minimizing total evacuation time, maximizing load-balancing, and maximizing evacuees' safety.

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