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Information Gathering of Earthquake Disasters by Mobile Crowd Sourcing in Smart Cities

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***Abstract*—Natural disasters such as earthquakes have always threatened and victimized the lives of humans and other creatures. After each earthquake, the environmental conditions change and various information is required to carry out the rescue operation. A major part of this information cannot be obtained from the knowledge that had already existed about the disaster area. However, the disaster management organizations as well as rescue teams need comprehensive information in the shortest possible time to be able to operate. Given the progress of Internet of Things and ubiquity of smartphones, it is possible to obtain this comprehensive information in the shortest time through crowd sourcing. In this article, the requirement analysis of the earthquake information gathering system has been performed. The requirements are generally classified into 4 groups including victims, facilities and livelihood, security and health, and maps. Afterwards, a layered architecture is designed for the earthquake information gathering system, which includes 4 layers including sensing, fog, cloud and application. The scenario-based approach validates that the proposed architecture satisfies the identified requirements. Finally, as selfish users could corrupt the whole information of crowd sourcing systems, a simulation reveals that the system is able to detect and eliminate these users.**

Keywords—Disaster Management, Data acquisition, Mobile Crowd Sourcing, Requirement analysis, Architecture, Smart city

I. INTRODUCTION

Every year, we witness natural disasters such as earthquakes, floods, storms, volcanoes, and tsunamis around the world. These disasters, depending on their severity, can cause irreparable damages and harms and the loss of lives. After the disaster, disaster management organizations or volunteer teams have common objectives: aiding the injured, minimizing the damages, and effective management of resources [1].

Disaster management includes four phases of prevention, preparedness, response and recovery [2,3]. In the response phase, the rescue and relief teams need proper planning and decision-making to perform the necessary actions. To carry out a good planning and subsequently to make the right decisions, accurate information is needed in the shortest time after the disaster. The collection of accurate information from the environment is a challenge, because a significant part of the information gathering platform is destroyed by the disaster.

Today, mobile phones have become smart applicable devices with sensing, processing, and communication capabilities. These features have provided the opportunity for users to be able to sense and generate information. Given the ubiquity of smartphones among the people, the crowd sensing (sourcing) paradigm [4] has been proposed for participation of people in gathering different types of information [5]. In crowd sourcing, the required information is extracted from the environment by participation of people [4]. Users can send sensed information to the cloud server [6], where the information provided by many users is aggregated and disseminated to the organizations requiring it [7]. In this regards, many types of information can be gathered from the disaster area using crowd sourcing paradigm as well as available technologies in smartphones [8].

In the context of earthquakes, the conduction of the rescue operation requires diverse information, most of which cannot be obtained from the knowledge we previously had from the disaster area. For example, due to debris falling, many changes happen in urban routes such as streets and alleys. Other required information, such as location of the injured people, must be precisely acquired after the disaster [9]. This diverse information can be obtained in the shortest time with the lowest cost using crowd sourcing. Previously, user comments in Twitter and Facebook have been exploited to extract information from a disaster area [10]. Furthermore, the emergency call and image sending system has been presented that enables users to request for help or send informative images of the disaster area [11]. According to our best knowledge, the full potential of crowd sourcing has not been exploited in designing a comprehensive information gathering system of the earthquake area. In this regard, this paper proposes the architecture of an information gathering system of the earthquake area using crowd sourcing. To this end, at first requirement analysis is conducted by the help of Red Crescent Society experts. It proposes four main categories of necessary information that should be gathered including information regarding victims, facilities and livelihood, security and health, and maps. Afterwards, the proposed system is designed using the multi-layer pattern. The proposed architecture has four layers including sensing, fog, cloud and application. Finally, the proposed architecture is evaluated using the scenario-based approach and a simulation. Evaluation results validates that the proposed architecture satisfies the intended information gathering functionality, while it is able to detect selfish users and prevent data destruction by them.

After this introduction, section 2 describes the requirement analysis of the information gathering system. Section 3 presents the proposed architecture in detail and section 4 deals with its evaluation. Finally, section 5 concludes the paper.

II. REQUIREMENTS

In the world, Red Cross and Red Crescent societies are known as a rescue and relief force who are responsible for responding to disasters such as earthquakes. Iran is an earthquake-prone country and has experienced many severe earthquakes in the past, such as the 2017 Kermanshah earthquake with 7.3 magnitude. Several experts of the Iran's Red Crescent Society have been interviewed to investigate the information required by the rescue forces in the earthquake region. The interviews resulted in the requirement analysis of the earthquake information gathering system. In general, the information required from an earthquake area can be classified into four groups, as follows:

- *Victims:*

This category includes the information about the bodies and wounded and missing people, as well as domestic and wild animals in need of assistance. Unfortunately, after each earthquake, many people inhabited the disaster area might be killed, wounded or missed. In the system, these people are considered in the categories of body, wounded and missing, respectively. Naturally, the nature of the area is home to a variety of animal species, including domestic and wild animals. With the incidence of an earthquake in the area, special search and rescue teams must be specified to these animals. The presence of animal carcasses in the area causes the outbreak of some diseases that may threaten the health of all residents.

- *Facilities and livelihood:*

This category includes the servicing status of preliminary facilities such as water, electricity and gas, as well as first aids required such as tents and blankets. After the occurrence of a severe earthquake, the houses where people had inhabited may be destroyed or no longer usable. In this case, the supply of shelter for the disaster survivors is a top priority. Supply of tents and blankets is the first action that should be done. These people also need preliminary facilities such as water, electricity and gas, the supply of which is important.

- *Security and health:*

This category includes the medicines needed for patients, the risks of gas leakage and fire and protection of properties. The people in the disaster area may require certain medicines. For example, a person who suffers from a headache or gastrointestinal illness might need medication to treat or relieve his/her pain. Supplying this medicinal need is also a part of the rescue teams' responsibility. Also, with the change of physical conditions of the disaster area, new risks such as gas leakage and fires threaten the area and people. Therefore, it is necessary to identify the places prone to these dangers and act quickly to eliminate the risks. In such abnormal conditions, there is also the threat of thieves. Therefore, security teams must have an active presence in the insecure areas to protect the properties.

- *Map:*

The physical conditions of the area may change in the event of a disaster. For example, after an earthquake, there is a possibility of the destruction of bridges and passageways, as well as appearance of cracks in the ground. Therefore, previous maps are not valid anymore. In this case, the provision of a new map from the area is of great importance. In such conditions, the roadmaps are vital for the start and continuation of rescue and relief operations.

III. PROPOSED ARCHITECTURE

Architecture is a structure that describes the elements of the system as well as the way of their interaction. The well-known layered structure is a type of module-based patterns in which, each layer contains one or more modules that provide specific services. The proposed architecture of the information gathering system from the disaster area is layered and consists of 4 layers including sensing, fog, cloud and application. As the architecture is based on crowd sourcing, the fog and cloud layers correspond to the local and global layers of crowd sourcing systems, respectively. In the following, these layers are described in detail.

- **Sensing layer:** All information that should be collected based on the requirement analysis are acquired by this layer. It should be noted that some of this information is obtained directly through sensors and the remaining part is manually entered by the user. In general, we have three hardware/software components in this layer that include:

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- *GPS*: This sensor is used to specify the precise coordinates of the intended location; Determination of the exact location of images and other information elements is important in crowd sourcing. Therefore, the GPS coordinate tag is inserted to each acquired information element. With the help of this geotagged information, different information maps can be plotted by crowd sourcing.
- *Camera*: Images usually contain much information and can be used to identify the incidents and events and to extract diverse information types. Today, image processing and machine vision have made much progress and computers are capable of performing highly sophisticated and intelligent processing on images. Besides, the images can be reviewed by humans, and information can be extracted by them. In this regard, the camera of mobile phones is considered as an important sensor in collecting information from the environment.
- *IGUI (Information Gathering User Interface):* Human is the key player in crowd sourcing and can provide high-level information that cannot be easily measured by sensors. In this regard, user interfaces are the main part of the sensing layer for collecting high-level information. Multiple user interfaces have been designed to collect the required information. By asking 20 predetermined multiple-choice questions, the required information that cannot be directly measured by sensors is collected. Figure 1 shows a schema of the questions asked for the map category. In this regard, specific questions are considered for each of the proposed requirements, and the answer of people is recorded and sent to the higher layer for local analysis. Multiple-choice questions have the options of “perfect”, “good”, “attention-required”, and “critical” situations. In addition, a comment section is considered at the end of each question for further user comments. In the crowd sourcing system, these comments can be manually or automatically processed. In the manual scheme, the volunteer people to participate in the crowd sourcing system review the comments and extract high-level and important information from them. Besides, the database of comments is a rich source for data mining and knowledge extraction, which are done by another module.

❖ **Fog layer:** The hardware near the sensing location (e.g. mobile phones or local gateways) forms the fog layer. The information collected by sensors and IGUI is provided to this layer. The layer includes 2 modules:

- *Local Analysis (LA):* The local analysis module is responsible for pre-processing the gathered data as well as noise removal. In this module, the information and comments entered by the user are locally analyzed, and then, the keywords are extracted. Afterward, the text subject is identified. For easy reasoning of user comments, they can be asked to annotate the comments by hashtags (#) according to the type of the information requirement analysis. Performing these local processes by users' smartphones will allow a large volume of computations to be perform in a distributed way; therefore, the overall load of the above layer is highly reduced.
- *Sampling Frequency Management (SFM):* The information obtained by sensors and IGUI is not static and change over time and location. Therefore, this information needs to be kept up to date. The SFM module specifies the time period that this information should be re-acquired. This time period depends on the type of information, and the sampling frequency is adjusted based on it.

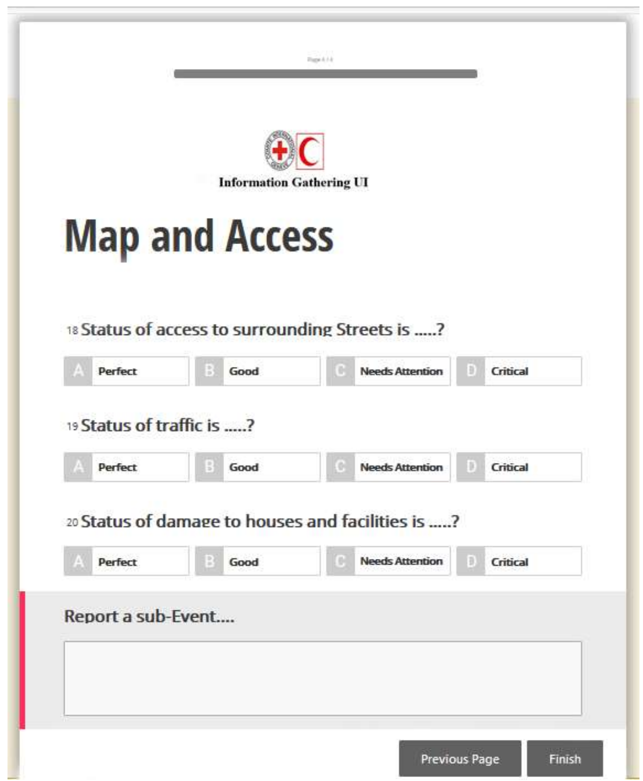

Figure 1. The interface of acquiring information required for the “map” category

❖ **Cloud layer:** The information locally analyzed in the fog layer is sent to the cloud for aggregation. This layer contains the following three modules:

- *Storage:* The cloud, as a massive storage, stores the information processed in the fog layer. The archive of this information over time is a rich source for performing high-level processes such as data mining.

- *Aggregation:* The information gathered by sensors and IGUI needs to be integrated and become consistent. The most important task of the cloud layer is to perform the aggregation operation. In this module, the response provided by the majority of users for each question is selected as the aggregated answer in the desired period.
- *Reputation Management (RM):* Since in each crowd sourcing system a number of individuals and entities might play negative roles, and corrupt the information generated by the system, there is a module to validate the individuals and entities. With the help of reputation management module, malicious individuals can be detected and data generated by them can be deleted.
  At first the system uses a probabilistic scheme to detect outliers. In fact, a data element that is far from the mean of the data provided by all users is regarded as outlier. Next, the individuals whose outlier rate is more than 40 percent are regarded as malicious users. Finally, a sophisticated scheme for scoring other users is utilized. Scoring allows the system to identify users with higher scores to be contacted (if necessary) for participating in emergency actions [5]. The proposed scoring mechanism uses dynamic parameters, which are directly derived from the user's past behavior including "user useful participation" and "information completeness". This mechanism will be provided in our next paper, as it has much details.

❖ **Application layer:** This layer contains applications and disaster response services. The information dissemination mechanism has also been anticipated in it for system-independent applications. In this regard, the Context Aware Information Dissemination component provides the relevant organizations with the information and maps generated by the bottom layer. Figure 2 shows the proposed layered architecture for the crowd-sourcing-based information acquisition system.

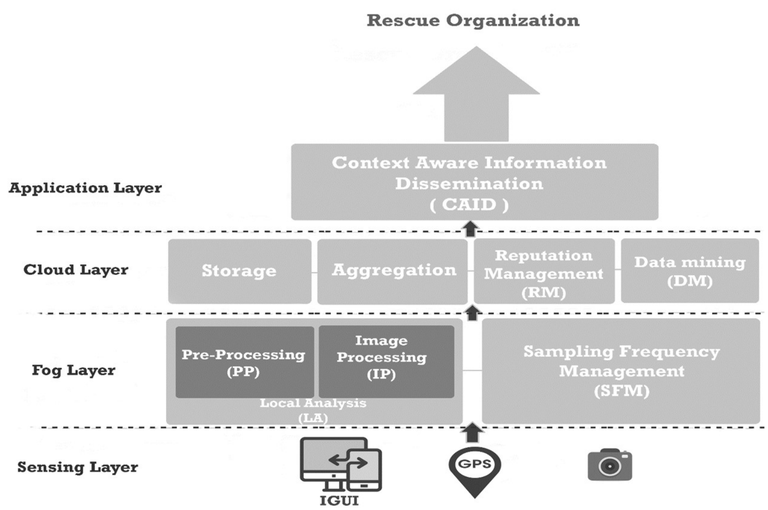

Figure 2: Proposed Architecture for Information gathering system

IV. Evaluation

Scenario-based method is the most important approach of evaluating software architectures [12]. In this method, one or more scenarios that accurately reflect the requirements of the system are provided. Then, it is checked whether the designed system is able to accurately satisfy the scenario or not. In this regard, the following scenario is considered.

A late autumn night, when most people are asleep, a sudden and bitter news is broadcasted: The Iranian Seismological Center has recorded a 7.3 magnitude earthquake in west of Iran! After receiving this news, various rescue teams are dispatched to the site in the shortest possible time. Unfortunately, the lack of information makes the relief process difficult. The face of the city is quite different from what it used to be. Parts of the city are in complete blackout and other facilities such as water and gas are cut off. Some people are confused and some others are looking for their loved ones in the rubble. In the meantime, a text message containing the installation link of the information gathering application is sent to all mobile phones available in the disaster area, asking people to help with information gathering by installing the application.

The information gathering can be carried out in this application in two ways:

- Answering multiple-choice questions or writing an observation.
- Taking photos from the subject and tagging the exact location using the GPS sensor.

In this regard, each person by answering the questions determines whether he/she is seeing an injured or incarcerated person or a body nearby. If the answer is yes, he/she takes a picture from the subject and sends it. By answering another question, volunteers inform the disaster management center of the availability of services such as water and electricity in different parts of the city. By taking pictures from the structures and roads and sending them, participants greatly help in awareness about open and closed roads and bridges, as well as the status of important buildings such as medical and service centers.

The task of gathering information does not end with the start of the rescue operation, and the information needs to be updated. The parameters of the disaster area are constantly changing. For example, with the attendance and operation of rescue teams, the fires in buildings are controlled and the facilities such as water and electricity are re-provided.

After preprocessing on the smartphone, all of this data is transferred to the server for storage and aggregation, and various information maps are prepared, accordingly. With this dynamic and accurate output, the disaster management center will be able to make the best decisions in the shortest possible time. Figure 3 illustrates how the proposed architecture is able to satisfy the scenario.

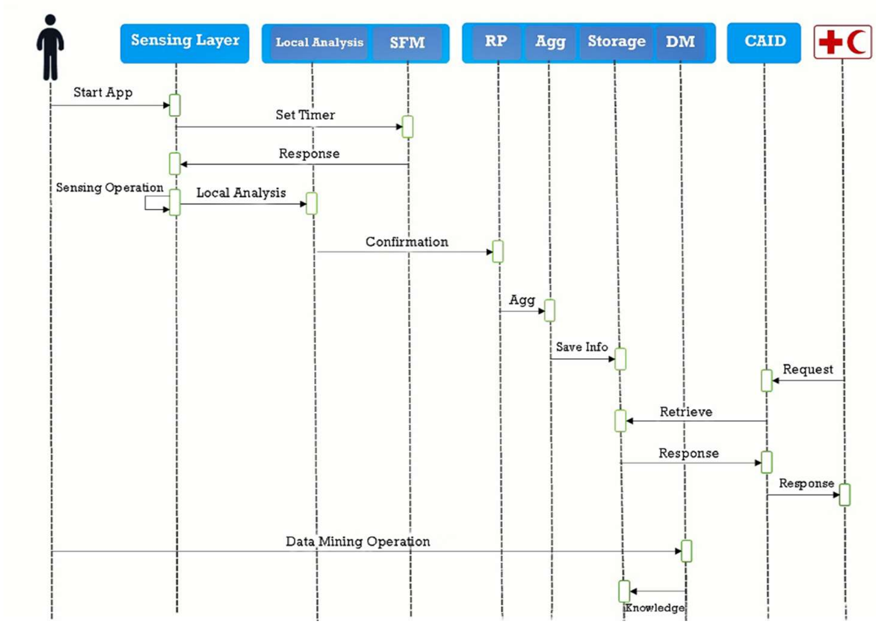

Figure3. Sequence diagram of the information gathering scenario

The main challenge of deploying crowd sourcing systems is the participation of malicious users who can corrupt the whole data. Therefore, recognizing these users is essential for crowd sourcing systems. The reputation management component is firstly responsible for detecting malicious users. To evaluate the effectiveness of the proposed scheme, two selfish users are simulated. The first user provides the first option for all questions and the second user enters the last option for all questions. After simulation, the average ratio of outlier data elements entered by these users is calculated as 0.52; hence both of them are correctly detected as malicious users since their outlier ratio is more than 0.4. It should be noted that we conservatively use a high threshold for outlier ratio to emphasize the dynamicity of the information from both aspects of time and location.

V. CONCLUSION

In this paper, requirement analysis of the disaster information gathering system has been investigated and the requirements has been classified in four categories including victims, facilities and livelihood, security and health, and map. Afterwards, the architecture of the system has been designed using the multi-layer pattern. It consists of four layer including sensing, fog, cloud and application. Finally, the proposed architecture has been validated using the scenario-based approach. In summary, the proposed crowd sourcing system (by using the proposed sensing layer, which includes multiple-choice questions as well as camera and GPS sensors) can provide the rescue organizations with comprehensive and vital information from the earthquake area. Therefore, the rescue operation could be performed with a better efficiency as well as optimal allocation of resources.

This research assumes that the cellular communication is available in the disaster area. It is anticipated that in future satellite-based Internet will be available all around the world;

hence, it could alternatively be used if cellular communication infrastructure was failed due to the disaster.

Finally, it should be noted that the reputation management, aggregation and data mining modules have been described briefly. In fact, they have much detail that cannot be presented here and will be published in another paper. Moreover, as users provide images and texts within the proposed crowd sourcing system, processing these images and texts in order to acquire the required information from the disaster area is regarded as future directions of this research.

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