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Research Paper

Integrated disaster management and smart insurance using cloud and internet of things

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Abstract

Over a period of decades there are lot of frequent disruptions due to natural, man-made and technological disasters which are seriously effecting the society, environment and economy. Hence it is vital that an effective integrated disaster management must be defined by integrating various types of disasters for being equipped in real time to face disasters in an extremely short span of time. In this paper a framework for disaster management is defined based on cloud and internet of things. A disaster management use case is developed based on the defined framework by integrating natural and manmade disasters. Natural disaster events are integrated to derive the probable insurance claims based on historical data and for the insurance agencies to be equipped in the event of disaster. Manmade disaster events will alert the end users when disaster events are about to occur. Here heterogeneous devices and data are firmly integrated to monitor various disaster events at one stop.

Keywords: *Cloud Computing, Disaster Management, Internet of Things, Smart Insurance*

1. Introduction

With the advancement and utilization of technology by humans without cautious precautions are leading to rapid environmental changes which are causing various manmade and natural disasters. Disasters like earthquakes, tsunami, tornados or any manmade disasters will usually occur with a very a minimum warning and hence it is very difficult to stop a disaster that is about to occur [1]. Over last 20 years the impact of disasters is very high where 4.4 billion people were effected, 1.3 million people were killed, there is $2 trillion economic loss worldwide and the predicted economic loss by 2030 will be $431 billion [2]. As per the study of center of research on the epidemiology of disasters (CRED), 337 disasters related to natural hazards and 192 disasters related to technological hazards are reported worldwide by year 2013 [3]. Out of the reported disasters, floods and storms remain the most frequent occurring disasters leading to most of the deaths [3]. Since natural disasters cannot be avoided or stopped, a better governance and sustainable development should be planned to protect the economies and people when the disaster is about to occur rather than to blame as an act of god [4]. In the case of manmade disasters, there are numerous issues like urban flooding, gas explosions, fire risks, inefficient waste management leading to various diseases that are occurring in developing countries. The urban flooding caused by plastic clogging in drainage systems have disrupted the normal life in most of the cities in India during heavy downpours [5] and the GAIL gas pipeline disaster in the state of Andhra Pradesh, India have led to 22 deaths with few people being injured [6]. Hence it is essential to address the natural and manmade disaster events using cloud and internet of things by defining an effective disaster management with smart insurance, so that the economies can be equipped to face unforeseen disasters in real-time to minimize the loss of lives and damage.

The reminder of the paper is organized as follows. Section 2 presents the literature survey for disaster management and in Section 3 a framework for integrated disaster management with smart insurance is defined. Based on the defined framework as use case with process flow is defined in Section 4. Section 5 presents the discussions and results of use case implementation and conclusion is drawn in Section 6.

2. Literature survey

It is vital that an efficient disaster management must be defined by integrating various types of natural and manmade disasters with the swift changes in technologies and increased urbanization across the world. Economies must be prepared to face disasters in a very short span of time and should enable efficient recovery options with insurance mechanisms. In [7] architectural considerations of internet of things for disaster management are explained with a summary of potential obstacles and challenges in topics like IoT and WSNs (Wireless Sensor Networks). The state of art scenarios to handle disastrous events, IoT supported protocols and market ready deployable products are illustrated in [8]. A stack based reference model for internet of things based on disaster management is defined to classify various protocols. An overview of cost effective market solutions such as Brinco, BRCK, Grillo, Citizen flood detection network, flood beacon, myshake and lighting detection systems with a classification of disaster management systems comprising of service-oriented disaster management, natural disaster management, manmade disaster management and post disaster management are demonstrated to realize an effective disaster management [8]. In [9] IoT based proposals were defined for post disaster management using D2D (device to device) communication and traditional cellular network where D2D communication will be initiated if cellular network is not available. A prototype has been developed in [10] for disaster management using IoT based interconnected network and for smart city monitoring. A systematic methodology is devised to process disaster management where the modules located at different locations will connect automatically using Wi-Fi to its nearest vicinity module when a disaster event occurs and then all the information is collected by sensors for relaying to the station over the chain network that has been formed [10]. In [11] the people flow analysis and air pollution monitoring is introduced. Later authors have introduced situation awareness system to illustrate the evacuation and safe routing in the event of hazards. Emergency fire management system is illustrated based on web of objects framework in [12] and it focused on fire emergencies in urban areas.

The above-mentioned research efforts majorly focused on illustrating various disaster management systems using internet of things and explained various disaster management solutions available in market based on various protocols. But the proposed systems are independent of each disaster event and no mechanism is defined to derive the probable cost estimates based on the severity and type of disaster. Hence it is vital that a unified and integrated disaster management application must be defined based on natural and manmade disasters to get real-time alerts in the event of disaster and to perform historical data analysis based on past disaster events to derive probable insurance claims. This paper proposes a framework based on cloud and internet of things for disaster management. Based on the defined framework an integrated disaster management application with smart insurance is developed where the users will get real time alerts if the disaster events are of manmade and for natural disasters the probable insurance claims are derived for insurance agencies to be equipped in the event of disaster.

3. Cloud framework for disaster management

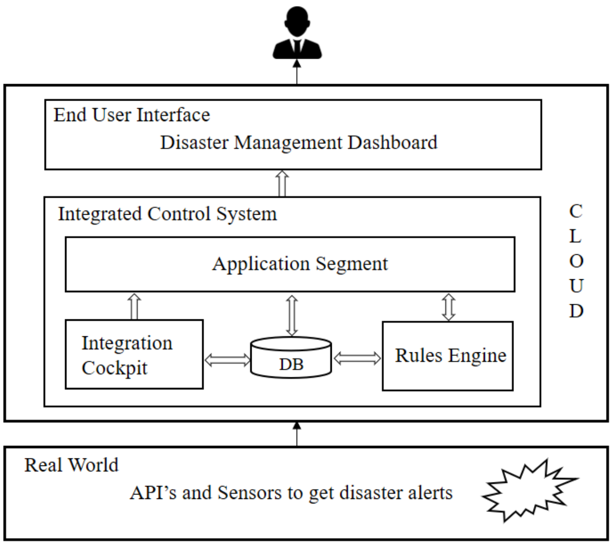

Fig.1. Cloud Framework for Disaster Management

The framework proposed in fig. 1 is based on cloud and internet of things where it provides flexibility to develop an integrated disaster management with smart insurance to get real time alerts in the event of disaster and the probable insurance claims can be derived based on the type and severity of disaster. In case of natural disaster events, flexibility to perform an historical data analysis is enabled for disaster response team to be equipped in the event of disaster based on the past learnings. In the event of manmade disasters, real-time alerts are triggered to end users for evacuation. The framework is comprised of two levels – Integrated Control System and End user interface which are reusable across diverse applications to get real time data. Integrated Control System has four sections – Application segment, Integration cockpit, database segment and rules engine. The devices that are installed in real world are registered in integration cockpit to get real time data in the event of manmade disasters and the API's of UGCS [13], Pitney Bowes [14] can be used to get near real time data in the event of natural disasters. The database segment stores the near real time and real time data that comes from API's and various devices installed in real world. The data in the database segment is further consumed in end user interface after a refined business logic is applied in application segment. The rules engine validates the data based on predefined conditions to derive severity and type of disaster along with probable insurance claims. End user interface is deployed with integrated disaster management dashboard where various natural and manmade disasters are integrated at one stop to get real time and near real time alerts in the event of disaster.

4. Implementation

In this section, a use case for integrated disaster management is presented based on the defined framework. A control flow for disaster management is demonstrated based on the developed use case to validate the functioning of integrated disaster management launchpad.

4.1. Use case design for disaster management

Disaster management use case is developed as shown in fig. 2 to efficiently integrate heterogeneous devices installed in real world to get real time alerts and to derive natural disasters data through API's in near real time. Here both manmade and natural disaster events are available at one stop for the disaster response team to be equipped in the event when the disaster is about to occur.

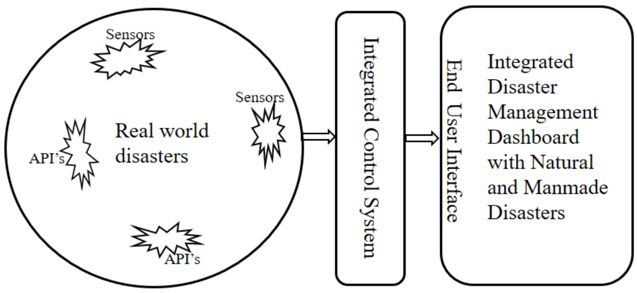

Fig.2. Use case for Integrated Disaster Management

Process flow for integrated disaster management launchpad is devised as shown in fig. 3. Here disasters are classified into two categories – natural disasters and manmade disasters.

Natural Disasters: Data sets of earthquake, tsunami and tornados [15], [16], [17] are considered for natural disaster events to check the severity of the disasters in near real time based on which the disaster response team will be equipped for the disasters that might occur in future. A mechanism is also enabled for the use case to update the natural disaster data at regular intervals based on the available API's. Based on the data updated in database segment, a refined business logic in applied in application segment using the validation rules in rules engine to derive the severity of the disaster based on the event type. The below considerations are derived for each disaster event, to realize the severity of the disaster and probable insurance claims.

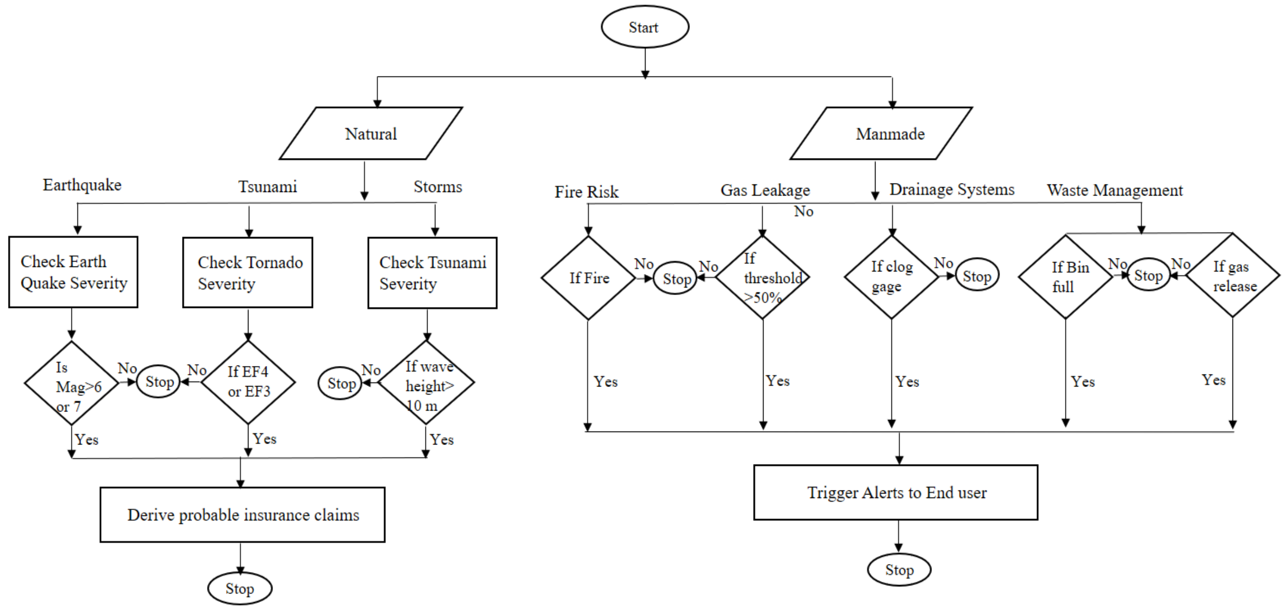

Fig. 3. Control Flow for Integrated Disaster Management

- **Earthquakes:** In the event of disaster the date, time, latitude, longitude, magnitude, magnitude type is recorded. If the earth quake magnitude is high the probable insurance claims and damage are derived, for the insurance agencies and disaster response team to be equipped in the event of disaster.
- **Tsunami:** In the event of disaster the date, time, latitude, longitude, distance from source, arrival time, disaster travel time, water height is updated. Based on the disaster travel time and water height the severity of the disaster is derived. If the severity exceeds the defined threshold the probable insurance claims are triggered to insurance agencies and alerts are send to disaster response team.
- **Tornados:** In the event of tornado the date, time, latitude, longitude, length and width of the tornado, tornado scale describing the strength of the tornado is considered. Based on the tornado scale, the severity of the disaster is derived and the probable insurance claims are triggered to insurance agencies and disaster response team.

Manmade Disasters: Fire risk, house hold gas pipeline leakages, urban drainage clogs due to plastic and waste management are frequent manmade disasters that are addressed as part of the process flow defined in figure 3. In the event of fire an automatic alert is triggered from flame sensors to proactively reduce the disaster risk and damage. The liquefied petroleum gas sensors installed along with the house hold gas pipelines are used to monitor the gas leakages and alerts are sent if there is an event of leakage. The ultrasonic sensors installed in drainage systems across different locations will help to monitor the drainage clogs and when the drainage clog reaches the defined threshold an alert will be sent to disaster management launchpad. The waste management is tracked in two stages – a) Bin weight: Based on the bin weight alerts were send to the end users to empty the bins and when it exceeds the defined threshold weight, the bins were emptied. Here load cell is used to measure the bin weight b) Gases released from the waste: At times, there are gases released from the waste though the bin is not full which causes diseases to humans. The gas sensors installed in the garbage bins across different locations will trigger alerts to end users if gases like ammonia, H2S are released that causes bad odor in surroundings. In [18] a similar concept has been demonstrated for waste management based on the ultrasonic range to check the bin level and gas sensors are used to check if any harmful gases are released.

4.2. Hardware Components

Currently there is wide focus on internet of things across the globe and to implement various solutions based on internet of things there are various plug and play devices available in marketplace. To implement integrated disaster management use case, Raspberry PI 3 module is used. It is a low cost high performance device that provides flexibility to integrate various sensors with ease to get real time data. The main features of Raspberry PI 3 are easy to integrate capabilities, Broadcom 900 MHz Quad core 64-bit CPU, adequate RAM and it is known for its less software glitches with high performance [19]. Ultrasonic sensors, gas sensors, flame sensors and load cell are used to monitor various manmade disasters and to reduce the risk of disaster events. These sensors are tightly coupled with Raspberry PI 3 to get real time data and to alert the end users based on the defined thresholds.

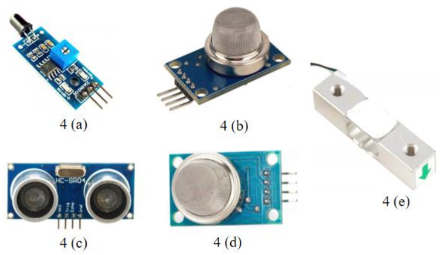

Fig. 4. Sensors for Manmade Disaster Management

The Flame sensor ZX-FLMS-01 shown in figure 4 (a) is a ready to use module that uses a photo diode to detect flame [20] and it triggers alerts to end users in the event of fire. The MQ-6 liquefied petroleum gas (LPG) sensor shown in figure 4 (b) is used to detect house hold gas pipeline leakages and trigger alerts to end users to take proactive action for reducing the level of disaster. The MQ-6 gas sensor has the capability to detect gas concentration anywhere from 200 to 10000 ppm with high sensitivity and fast response [21]. The ultrasonic sensor HC-SR-04 shown in figure 4 (c) is used to detect the drainage clogs based on the water level in drainage and if a threshold level is reached in drainage due to clogs an alert will be triggered to end users. The HC-SR-04 module is a compact in size and ease to use sensor to evaluate the distance of the target by interpreting the echoes from ultrasonic sound waves [22]. The DGS-H2S 968-036 H2S sensor [23] and FC-22-I air quality sensor [24] can be used to detect the harmful gases in the bin for waste management. These sensors send alerts to end users for emptying the bins when the defined maximum threshold reached. For the use case, only FC-22-I air quality sensor shown in figure 4 (d) is used to monitor odor in the bin. CZL-601 load cell shown in figure 4 (e) is used to measure the bin weight where analog signals are received from the load cell and when the bin reaches the defined threshold it alerts the end users [25].The flame sensor, liquefied petroleum gas sensor, ultrasonic sensor, H2S sensor and load cell are integrated with Raspberry PI as shown in fig. 5. The sensor data is updated in cloud platform to further consume in integrated disaster management dashboard and to get real-time alerts based on the defined calibration and threshold.

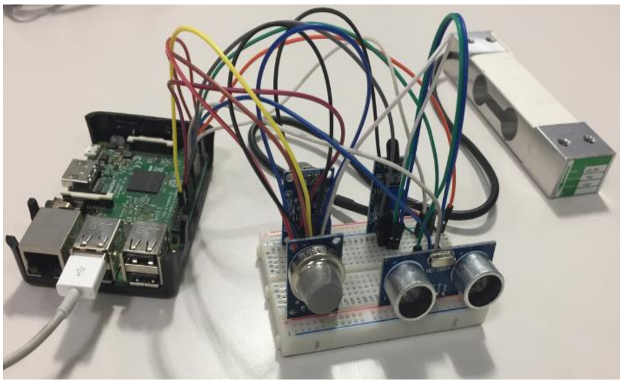

Fig. 5. Sensors for Manmade Disaster Management

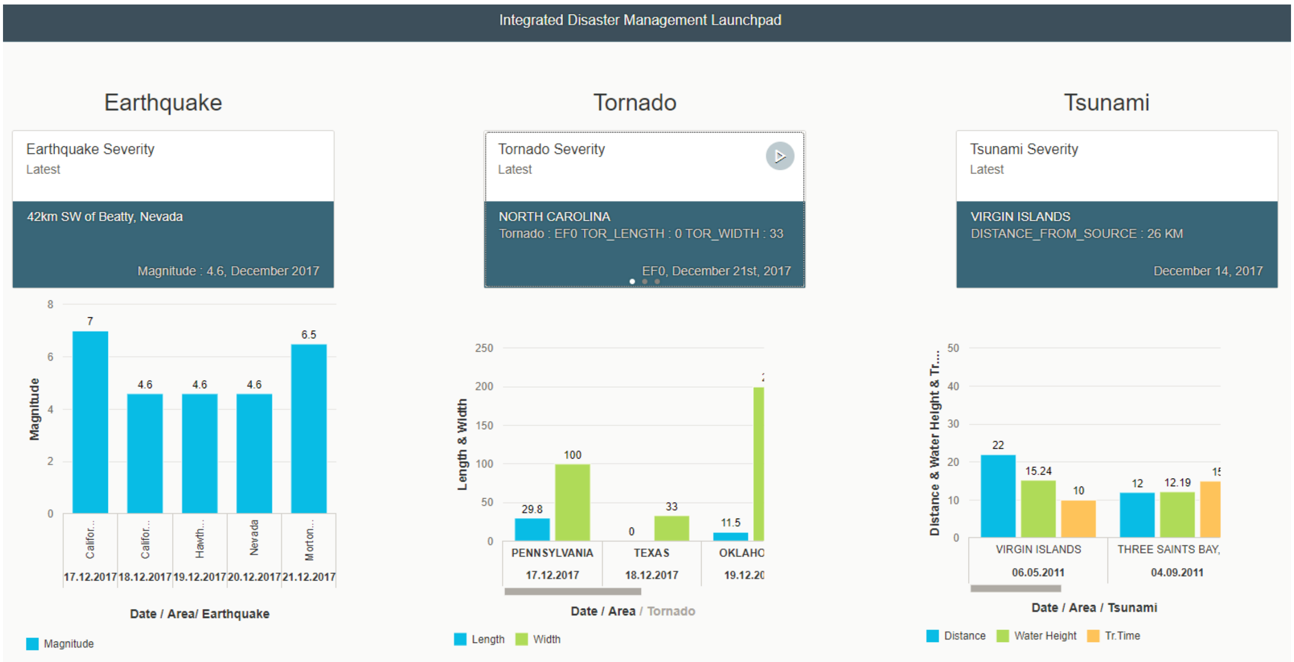

Fig. 6. Integrated Disaster Management Launchpad

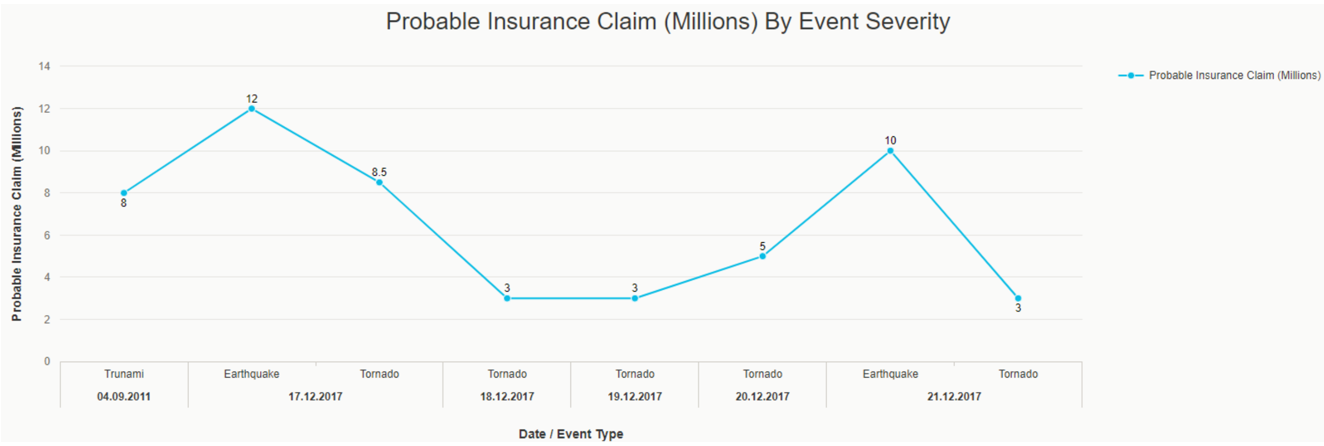

Fig. 7. Probable Insurance Claims based on Disaster event type and Severity

4.3. Software components

It is important that the end users or the disaster response team should have the flexibility to monitor the disaster management launchpad any time anywhere and the solution for this is cloud platform. To implement the disaster management use case, SAP cloud platform trail version is used which is an open platform as a service (PaaS) that provides in-memory capabilities and platform services [26]. The SAP cloud platform offers various capabilities like advanced analytics, data storage, secured integration services, machine learning, intuitive user experience and easy to deploy internet of things services. For implementing the use case the internet of things services, user experience services, HANA database of SAP cloud platform are used. Raspberry PI 3, flame sensor, gas sensor, load cell and ultrasonic sensor are registered using internet of things services and the real-time data from these sensors is stored in HANA database that combines online analytical processing (OLAP) and online transactional processing (OLPT) into a single in-memory database [27]. Here the data is transmitted from the sensors to cloud using representation state transfer (REST) which uses HTTP protocol [28]. The disaster management application development and rules validation of rules engine are done using Web IDE - web based integrated development tool that simplifies the end to end development process [29].

5. Results and Discussions

This section presents the integrated disaster management use case results where tests were carried out based on the defined algorithm to monitor the natural and manmade disasters events.

Natural Disasters: Fig. 6 represents the natural disaster events that are integrated in disaster management launchpad. The launchpad is deployed in SAP trail cloud platform to access it from anytime anywhere. Here earthquakes, tsunami and tornado disaster events are visualized in near real time as shown in fig. 6 and the probable insurance claims are derived based on the severity and type of disaster event as shown in fig. 7.

- **Earthquakes:** Earthquake event feeds are updated in disaster management launchpad in near real time as shown in fig. 6. The most recent major disaster events are represented to understand the trends of earthquake events based on latitude, longitude, magnitude, date and time of the disaster. Here the location of the disaster is identified based on the latitude and longitude. The severity of disaster is updated from rules engine based on the depth and magnitude of the disaster to derive the probable insurance claims based on location and date as shown in fig. 7. The insurance claim is estimated if the magnitude threshold of the disaster is greater than six.
- **Tsunami:** Tsunami event feeds are updated in disaster management launchpad as shown in fig. 6. The most recent tsunami events are shown to understand the trends of tsunami based on date, time, latitude, longitude, distance from source, water height and travel time of tsunami. Based on the water height and travel time of tsunami the probable insurance is updated as shown in fig. 7. Here water height of 12 meters and travel time of 10 minutes is defined as threshold to derive the insurance claim based on date, time and location.
- **Tornados:** The feeds of tornados are updated in launchpad as shown in fig. 6. The recent tornados are indicated to understand the tornado trends based on date, time, latitude, longitude, tornado length, tornado width and tornado scale. The tornado length is derived as minimal of tenths of miles and tornado width is recorded in feet. Enhanced fujita (EF) scale is used to represent the strength of tornado based on the amount and type of damage caused by the tornado from EF0 to EF5 where EF0 represents least damage and EF5 indicates incredible damage with 261 – 318 miles per hour. The probable insurance claim of a tornado is derived based on the severity measured in EF scale as shown in fig. 7.

Manmade Disasters: Manmade disasters are represented as shown in fig. 8 and these disaster events feed real time data based on the sensors installed in real world. Few events that might lead to manmade disasters with recent urbanization are fire risk, house hold gas pipeline leakages, clogs in drainage system, inefficient waste management. Here tests were carried out in three cycles to visualize the data that is triggered from sensors.

- **Fire risk:** The ZX-FLMS-01 flame sensor installed in real world sends alerts to end users at regular intervals and when the sensor detects a flame with the defined threshold, it triggers alerts to end users as shown in fig. 8.

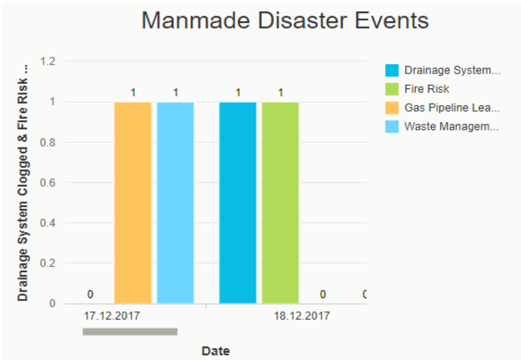

Fig. 8. Manmade Disasters

Here tests were carried out based on data generated by sensor in real time and the sensor triggers value 1 in the event of fire.

- **Clogs in Drainage System:** The ultrasonic sensor HC-SR-04 is used to detect the clogs in drainage system in real time. The sensor values are captured at regular intervals based on the ultrasonic sound waves. In the event when the drainage is full or blocked based on the defined threshold an alert is triggered in disaster management launchpad as shown in fig. 8.
- **Gas Pipeline Leakages:** The MQ-6 liquefied petroleum gas sensor is used to detect the gas leakages in real time. Here the sensor values are captured in real time at regular intervals. In the event of gas leakage an alert is triggered in disaster management launchpad as shown in fig. 8.
- **Waste Management:** The waste management is effectively managed based on the bin waste and odor of gases released from the bin. The FC-22-I air quality sensor is used to identify the odor of bin at regular intervals. The sensor values are transmitted to cloud platform at a frequency of five minutes. In the event of harmful gases an event is triggered to dashboard as shown in fig. 9. CZL-601 load cell is used to measure the weight of bins at a regular frequency. The values from the load cell are updated in database at regular intervals to indicate the bin weights. Fig. 9 illustrates the bin weights based on date that will enable end users to act when the bins are about to be full.

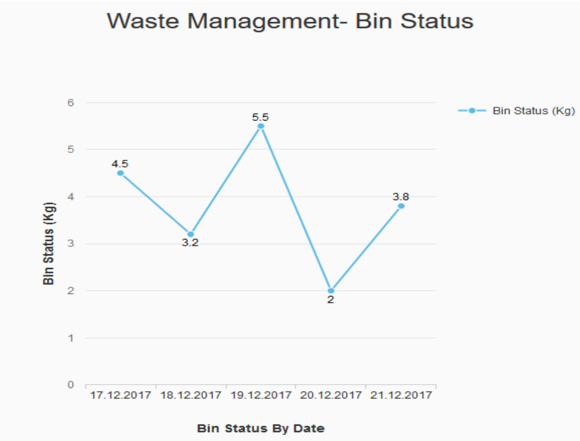

Fig.9. Waste Management – Bin Status

6 Conclusion

In this paper an integrated disaster management is established based on natural and manmade disasters. For natural disasters like earthquakes, tsunami and storms, data is fetched in near real time for the end users to be equipped in the event of disaster. Based on the severity and type of disaster the probable insurance claims are derived for the insurance agencies to be equipped in the event of disaster. For manmade disasters like fire risks, house hold gas pipeline leakages, clogs in drainages and inefficient waste management, real time data is updated from the sensors installed in real world and alerts are triggered to end users when the defined maximum threshold is reached. The use case is successfully tested in several cycles based on the data transmitted from various sensors installed in real world. The defined framework and use case can be reused or extended for smart city monitoring, industry specific applications, infrastructure sector with few customizations.

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