Development of Internet of Thing (IoT) Technology for flood Prediction and Early Warning System (EWS)

Nur-adib Maspo, Aizul Nahar Harun, Masafumi Goto, Mohd Nasrun Mohd Nawi, Nuzul Azam Haron

Abstract: ***Flood is the most significant disaster happened in almost every part of the world. When the event occurred, it causes great losses in economic and human life. Implementation of the advancement of ICT brings significant contribution to reduce the impact of flood toward the people and properties. This paper attempts to investigate the capability of internet of things (IoT) technology in reducing the impact of natural disaster specifically in flood disaster scenario. First, the concept of Internet of Things (IoT), key technologies and its architecture are discussed. Second, related research work on IoT in disaster context will be discussed. Third, further discussion on the propose Internet of Things (IoT) architecture and key components in the development of flood prediction and early warning system. The smart sensors will be placed at river basin for real-time data collection on flood related parameter such as rainfall, river flaw, water level, temperature, wind direction and so on. The data will be transmitted to data centre via wireless communication technology which will be processed and measured on the cloud service, then the alert information will be sent users via smart phone. Thus, early warning message is received by the people in terms of location, time and other parameters relate to flood.***

Keywords: Flood prediction, flood disaster, early warning system, Internet of Things (IoT), wireless sensor network.

I. INTRODUCTION

Recently, many countries in the world are experiencing different types of natural disaster such as earthquake, tsunami, flood, landslide, drought, storm and so on. When disaster occurs, it brings great damage such as property, infrastructure, environment and lives loss. Disaster can be defined as an unexpected event, when it happened, people are not able to control.

Alexander (1993) defines disaster as “a sudden, calamitous event that seriously disrupts the functioning of a community or society and causes human, material, and economic or environmental losses that exceed the community’s or society’s ability to cope using its own resources”. In general, disaster is caused by natural disaster or human-made disaster. In this paper, natural disaster is the main focused, it defines as disastrous outcome of natural phenomena or a mix of phenomena bringing about damage, death toll or contribution to a moderately huge scale and some interruption to human activities(Goel 2006). According to Mohamed Shaluf and Ahmadun (2006), floods account for 40 percent of the natural hazards affecting the Asia and Pacific regions where more than 83 percent of the total reported disasters in Asia alone in last decade were due to floods.

Conventional flood early warning system is practical in some cases, however, implementing state-of-the-art technology such as IoT for flood prediction and early warning system is crucial for real-time data acquisition from the field, data processing, measuring and disseminate warning information to people who are likely to be affected by flood before an event strikes. Although IoT technologies cannot stop the occurrence of disaster but it very well may be exceptionally valuable apparatus for conveyance catastrophe readiness and counteractive action data, for example, disaster‘s prediction and early warning systems.On top of that, information delivery is the main factor to support disaster preparedness and prevention. Thus, there is a need to ensure that information delivery within the function of system development must be concise, right to the point, useable and in timely manner.

In particular, very few studies have been made on IoT application in specific to flood disaster are available. As such no investigation has been made on the evaluation of IoT technology and its application specifically in flood disaster context. Therefore, the aim of this work is to analyst the current IoT technology and its application in flood disaster and propose a suitable solution to reduce the impact of flood. For this reason, the various studies on IoT technology and its application in disaster application domain were investigated in order to identify the current IoT technology and its application in natural disaster context.

The objective of this study is to propose the development of Internet of Things (IoT) based for flood prediction and

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early warning system by investigating Internet of Things (IoT) capability in disaster management application domain. The finding of this study will contribute to the advancement of IoT application development in reducing the impact flood disaster to the people and properties.

II. INTERNET OF THINGS (IoT)

The advancement of Information and Communication Technology (ICT) started from the advent of computer in 1970s and World Wide Web (www) in 1990s then emerging of mobile devices which able to connect to the internet together with the advancement of standard communication network wire or wireless technology then the idea of connecting objects to the internet was proposed and lead to the era of Internet of Things(IoT) (Soumyalatha ; Dubey, Luo et al. 2015; Perera, Liu et al. 2015). The concept of IoT was introduced in 1999 by Kevin Ashton in the Auto-ID laboratory. In 2003, Radio Frequency Identification(RFID) was introduced and it is known as the pre-requisite of IoT. The first invention was to keep track of items from the production plant to the shelf for supply chain management.

In 2005, International Telecommunication Union (ITU) addressed the concept of IoT in the report which issued on the World Summit on Information Society(WSIS) that everything would able to connect to each other at any place and in any time through the technologies like the radio frequency identification technology (RFID), wireless sensor networks technology(WSN) and others (Chen and Jin 2012). It is also mentioned that IoT vision is added to the world of information and communication technologies: from anytime, anyplace connectivity for anyone to anytime, anyplace connectivity for anything (Tan and Wang 2010). Hence, anything can be any device or any object connects to the network at anytime and anyplace.

Atzori, Iera et al. (2010) describe the meaning of IoT as "a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols". As the number of objects are increasing and connected seamlessly, The European Commission has predicted that, there will be 50 to 100 billion devices connected to the Internet by 2020(Sundmaeker, Guillemin et al. 2010).

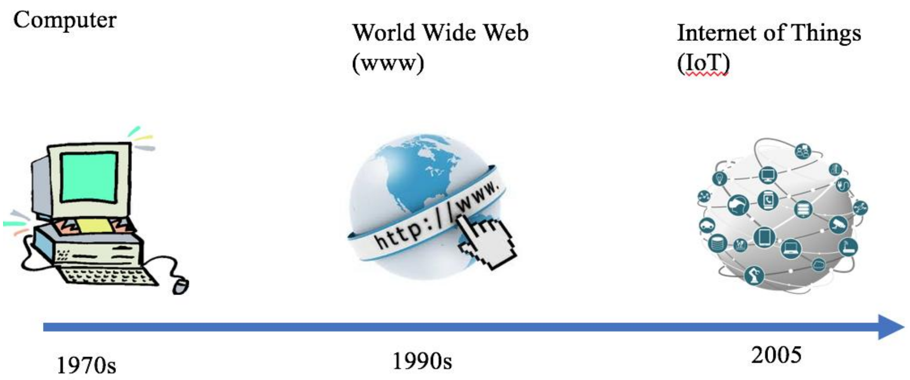

Fig. 1 The evolution of IoT

In general, IoT enable things or objects to be connected and communicate to each other by using technology such as RFID and WSN, each thing or object must have a unique identification based on standard communication protocol in order to build interconnected network. The connection can be established at anyplace anytime and anywhere using all kind of networks and services. IoT is also a paradigm which allows the integration of physical and cyber system, machine to machine (M2M), human to machine, human to human, machine to human, machine to infrastructure and machine to environment.

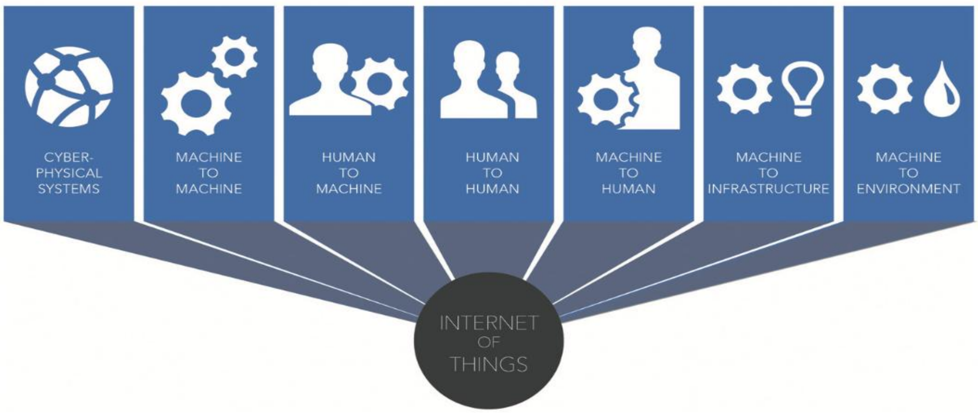

Fig. 2 IoT integration (Vermesan and Friess 2016)

Recently, there are many studies on IoT in different application domains such as IoT for industry like transportation and logistics (Hribernik, Warden et al. 2010; Sun 2012; Karakostas 2013; Tao, Zuo et al. 2014), health care application domain (Doukas and Maglogiannis 2012; Jara, Zamora-Izquierdo et al. 2013; Amendola, Lodato et al. 2014; Catarinucci, De Donno et al. 2015), agriculture application domain (TongKe 2013; Dlodlo and Kalezhi 2015; Jayaraman, Palmer et al. 2015; Ojha, Misra et al. 2015), environmental monitoring (Kelly, Suryadevara et al. 2013; Lazarescu 2013; Fang, Da Xu et al. 2014; Harun and Bichard 2015; Shan, Wang et al. 2017; Zhu, Tian et al. 2017) however, there are few studies focused on disaster management application domain. This paper is going to discuss on the IoT application in flood disaster management scenario.

In case of disaster, different types of sensors are used to sense phenomena and collect data where human are not capable to perform. For flood disaster, information on hydrology such as rainfall, water level, flow discharge and other components such as wind and temperature, etc. are required to be collected, processed and measured to generate a meaningful information which will be used for flood prediction and disseminate early warning information. With IoT enable devices like sensors, information can be quickly acquired, analysed and communicate in real-time.

The Internet of Things (IoT) is also one of the major technological trends being used for natural monitoring and human made resources to provide early prediction which able to detect an emergency incidents like flood, gas, fire and leakage of water that caused hazard to social and human life (Gangopadhyay and Mondal 2016). However, the implementation of IoT required interconnected network among the key technologies and IoT architecture is the fundamental knowledge for the development of application based on IoT. The following sections will be discussed about the IoT key technologies and its architecture.

Key Technology of IoT

IoT by the name is internet-connected things including objects or devices. Under the IoT concept, the object such as mobile phones,computers, RFID tags or sensors which can be identified by a unique address, are capable to dynamically connect the network, work together and participate productively to accomplish the shared objective(Christin, Reinhardt et al. 2009). However, each object is performed specific task and functional differently.

- Radio Frequency Identification (RFID) is that the idea of exploitation radio signals to automatically sight associate object for storing and remotely retrieving data. Generally, RFID carries with it tags, tags reader, antenna, information management software and database.Data transmitted by radio waves through sender and receiver.
- Wireless Sensor networks (WSNs) are the technology that is mix of reasonable and low power group of sensors and microcontrollers that might offer ubiquitous computing (Poslad 2011) to discover the environmental diversity, and log a bit of gathered data to centralized remote server wirelessly (Gangopadhyay and Mondal 2016). In natural disaster scenarios, WSNs is an essential device in providing effective early warning system (Grado-Caffaro, Grado-Caffaro et al. 2011) by deploying WSNs to gather environmental parameters in long period such as temperature data, moisture, rainfall etc. we will be able to analyst environmental phenomena such as climate change, whether forecasting and able to predict the occurrence of disaster events.
- Cloud computing is another service that we have to consider in IoT application, it is a great solution that capable to manage, analyse and process the Big data. It then can be further enhance to generate information and provide basis for decision-making (Khan, Anjum et al. 2013).
- Smart-phone technology, with the rapid growing in social networking and the advancement of smart phone, there is the emergence of a new sensing paradigm which community people are contributing information towards urban management. This is called participatory sensing or crowd sourcing that is set to play a major role in Government-citizen interaction (Jin, Gubbi et al. 2014).
- Wireless communication technology is a key component of IoT which can be considered as a backbone of the system. Wireless communication technologies are comprised of WiFi, Bluetooth and ZigBee. Each wireless technology carrying different features in terms of power consumption, distance in data transmission and bandwidth. For example, ZigBee is meant to deal with the unique needs of low-power, affordable wireless sensor, and control networks. It has been developed to address the requirements of the communication of data with a simple structure like the data from the sensors, while Wi-Fi may be a variety of low-power wireless communication employed by many electronic devices such as smart phones, systems, laptops, etc.
- A weather station is a device that using different types of sensors such as sensors to measure rainfall, wind speed and direction, humidity, temperature and more to capture data related to the weather and environment. The real-time data updated every minute, 24 hours a day without human intervention(MMD 2017).
- Camera is another component of IoT used to capture image of surrounding environmental changes before and during disaster events.

IoTArchitecture

Initially, the accepted IoT architecture consisted of three layers which are perception later, network layer and application layer(Said and Masud 2013; Tsai, Lai et al. 2014). However, based on the complexity of the network and managing big data, the IoT architecture should be open based on the requirement of application development. Uckelmann, D., et al. (2011) suggested that future IoT architecture should be based on developments to an outstanding standardised open architecture and requires a more holistic architecture. These include layering of standards, arrangement of extension systems, specification and separation of data models and interfaces which initially in a neutral abstract aspect (e.g., using UML), then with arrangement of definite transport bindings (e.g., web services) and schema bindings (e.g., XML).

According to International Telecommunication Union(ITU), there are five layers of IoT architecture, the first layer is the sensing layer, second is the access layer, third is network layer, forth is the middleware layer and the top layer is the application layer. The access layer and middleware layers are added to the five layer and each layer performs different tasks.

However, IoT architecture is also broadly classified into four layers (Soumyalatha ; Tan and Wang 2010; Wu, Lu et al. 2010; Khan, Khan et al. 2012; Zhang and Yu 2013).

In this paper, the development of flood prediction and early warning system will be implemented based on the four layers of IoT architecture which consist of Perception Layer, Network Layer, Middleware Layer and Application Layer. As the functionality of the Access Layer within the five-layer architecture is functional similarly with the Network Layer that is to transmit messages between the objects and systems,and to manage the communications within the IoT environment (Tsai, Lai et al. 2014). Therefore, the author would like to merge Access Layer into Network Layer as explained in the following figure.

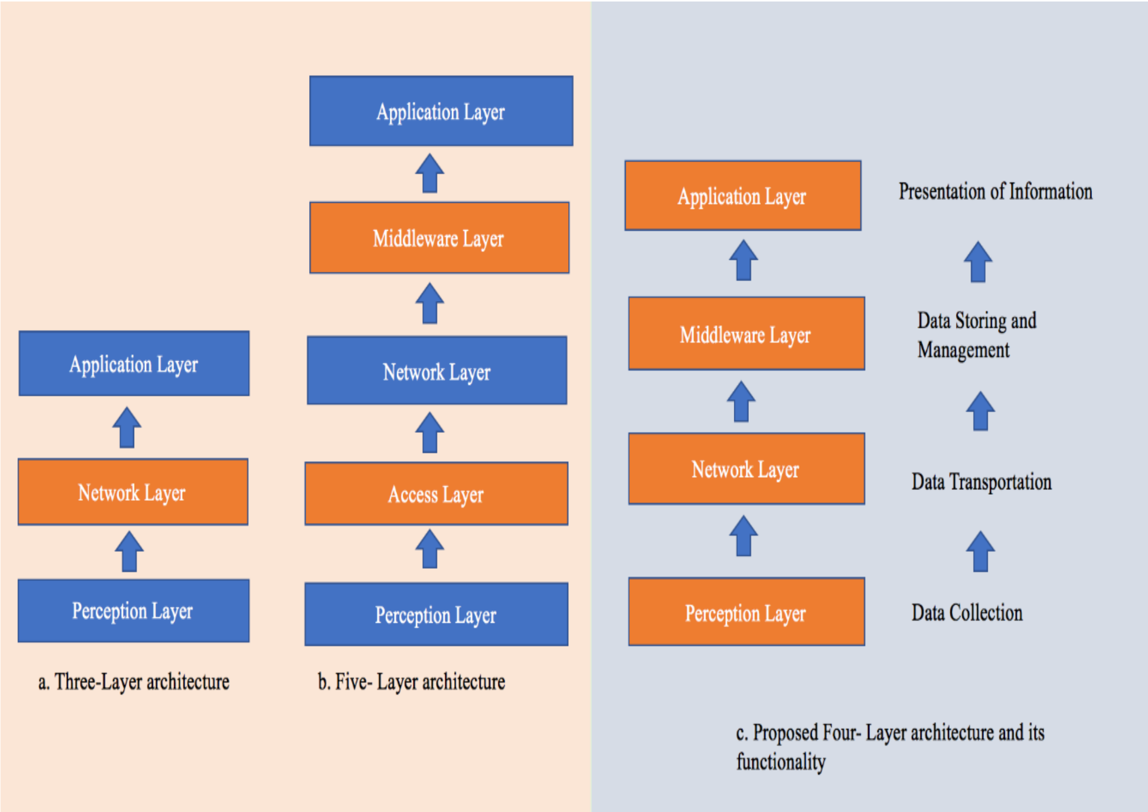

Fig. 3 Three-layer architecture, five-layer architecture and the selected four-layer architecture

- Perception Layer: The perception layer is also known as sensing layer. Physical objects and sensor devices are the main technology in the layer. Different type of sensors is used to collect different types of data such as temperature, humidity, vibration, rainfall etc. The collected information is then transmitted to the network layer for further information process.
- Network Layer (Access Layer): The network layer is also known as transmission layer. It transfers the data from sensor devices to the information processing scheme in a secure manner. There are standard communication technologies that used for data transmission like wired or wireless technology such as 3G, GPRS, GSM, Wifi, Bluetooth, infrared, ZigBee, etc. depending upon the sensor devices and the application purpose.
- Middleware Layer: This layer is incharge of the service management and has a connection to the database. It receives the data from Network layer and stores it in the database and processes data and ubiquitous computation and automatically takes based results decision.
- Application Layer: This later provide information for user to access based on data processed and analysed in middleware layer.

III. IoT IN DESASTER MANAGEMENT CONTEXT

Previous studies have been conducted for the system development based on IoT for different types of disaster monitoring, disaster prevention and disaster response. The following table has summarized the previous researches on IoT in disaster management context. Each study proposed different IoT components and architecture based on application requirement and environmental specification.

Among the 13 articles related to IoT in disaster management context, there are only 4 articles which specifically developed the system in the case of flood disaster scenario.

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However, there are limitations in terms of the validation was done in the close environment which is not being tested in the real field. Hence, the result may not be reliable when implementing in the real situation. Data error is another concern which resulting in false alarm and alert information was not sent out when water level reached at warning level.

Another system was only designed and developed the system for flood management team for decision making, however, the flooding warning information was not send to community people right after the flood disaster has been detected while the other one focused on flood warning information disseminates in social media such as twitter.

Table. 1 Summary table of IoT architecture and key components of related work

Authors	Architecture	Components	Application/Disaster types
Dersingh (2016)	- Sensor Layer: Rain gauge, Ultrasonic and Camera to collect environmental data. - Network Layer: GSM/3G to transmit data. - Data center: Web server application and data base application used for data processing and measurement. - Application Layer: Web application and Mobile Application used for information presentation.	- Sensors - GSM/ 3G cellular network - Smart phone - PC	Developed flood warning system: web application provides user with flood information and mobile application gives push notification to users within the area that effected by flood. By using ultrasonic sensors, the author encounter data error approximately 2% when the water level reached warning level but there was no information sent out.
Deak, Curran et al. (2013)	- Perception Layer - Transmission and communication Layer: - Application Layer: runs data processing algorithms and services dependent on application requirements	- WSN and Device Free Passive Localization(DFPL) - WiFi - PC, Mobile phone.	Developed a system to detect human movement in disaster situation. DFPL is embedded in WSN to keep track of the presence of people in the monitored environment. Data will be stored in data base server and it can synchronize into the cloud.
Zeng (2014)	- Perception layer - Transmission and communication layer: - Application layer: runs data processing algorithms and services dependent on application requirements	- Weather station network. - Hydrological station network - Rain guage - GPRS/GSM, Ultra-short wave(UHF/VHF), Satellite. - PC	Developed a platform to monitor and give the early warning, the system called mountain torrent disaster prevention system which collect rainfall data, gaging and images of river basin and transmit data to country's flood prevention command center. This system was developed for flood disaster management team.
Fang, Da Xu et al. (2014)	- Perception Layer: real time data collection - Network Layer: data and information transmission, interconnected system and platform. - Middleware Layer: Management of data, software/tools, model/platform Application Layer: Storing, organizing, processing, sharing environmental data.	- Sensors, RS platform, Situ-instrument - Sensors area network(SAN), 2G, 3G, Wifi, Zigbee - Service Oriented Architecture(SOA)	Provided a prototype of Integrated Information System (IIS) such as IoT, cloud computing, Goniometric (RS, GIS, GPS) and e-Science for environmental monitoring and management. The case study on climate change and ecological response were conducted at Xinjiang, China.

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Niu, Zhu et al. (2012)	- Sensor Layer: collect real time information - Network Layer: Perform data transmission. - Cloud computing platform: receive data from the sensors, process and manage complex data - Presentation Layer: Information representation of monitoring and early warning.	- WSN, RFID - wireless fidelity(WIFI), ZigBee - PC	IoT Application for disaster monitoring and early warning system in metal mine
Perumal, Sulaiman et al. (2015)	- Sensor Layer: collect water level data - Network Layer: used to transmit data. - Middleware Layer: cloud server used to store and analyze data of water level - Application Layer: Display data in web-based dashboard	- ultrasonic, water sensor - Wifi - Web-based dashboard	Proposed an IoT based water monitoring system that measures water level in real-time. When water reached warning level, information will be feed in social media like twitter in real time.
Gangopadhyay and Mondal (2016)	- Sensor Layer: collect data - Network Layer: communicate between microcontroller and cloud - Cloud platform: uploading and storing the data are - Application Layer: Display weather information and alert notification	- wireless sensor module (IEEE802.15.4/Zigbee) - Arduino microcontroller - android app	Proposed a unique prototype of wireless real-time weather monitoring station that uploads weather data received from the group of sensors to cloud database from a distant location which may be observed from anyplace.
Shi-yong, Fei et al. (2012)	- Perception Layer: using WSNs as data collection node - Network Layer: using Zigbee as data transmission, GPRS and GSM networks used to transmit data from gateway to the base station - Middleware Layer: data management center - Application Layer: presentation of information monitoring.	- Wireless Sensor Networks(WSNs) - Zigbee, GSM, GRPS - Cloud computing - Tablet, PC, smartphone.	Developed a real-time and online geological disaster monitoring system such as landslides, debris-flow, earthquake in China

Giorgetti, Lucchi et al. (2016)	- Perception Layer: perform data collections by different types of sensors - - Network Layer: perform data transmission - - Middleware Layer: data processing and management by using My SQL server - -Application Layer: Presentation of information through website	- WSNs - Weather statuin - GPRS, EEE802.15.4 - PC -	In this paper, the author discussed on the design of new network protocol for sensor nodes in order to ensure energy efficiency and reliable communications in harsh environments, and proposed a wireless sensor network (WSN) which designed for land- slides monitoring and risk management.In their proposal, the data captured by sensors are delivered through the network to a remote unit for online analysis and alerting.
Hernández-Nolasco, Ovando et al. (2016)	- Perception Layer: to sense water level data. - Network Layer: to transmit data for displaying warning alert in smart phone. - Application Lsayer: Display warning information when water level reached certain level.	- Sensors - Wifi - PC, smartphone	Developed a system to measure water level in river basin by using sensor. However, the testing was done in the control environment which the experimental was conducted in a water container. Sensors detect the level of water, when the water rise at certain level, the alert signal will be sent to smart phone.
Lin and Liaw (2015)	- Perception Layer: Use radiation sensing node to collect data. - Network Layer: transmitted data to remote monitoring and control server. - Middleware Layer: Database management and used information exchange web service (IEWS) for system interface between WSNs clients and disaster information presentation at Application Layer Application Layer: disaster information delivery.	- WSNs - Wifi, GPRS, 3G - web service (IEWS) - Smart phone	The author has developed an IOT-based intelligent disaster information integrated platform (IDIIP) for disaster information management to support the disaster monitoring and emergency-response coordination. The author selected radiation-monitoring scenario as a case study to prove the concept of the IDIIP.
Liaw and Lin (2013)	- Perception Layer: perform data sensing and management. - Network Layer: used wireless communication network for data transmission. - Middleware Layer: used IEWS for system interface and exchange different type of information. - Application Layer: Mobile application platform for data representation, control and event notification.	- WSNs - WiFi, Zigbee - Information Exchange Web Service(IEWS) - Mobile device -	Developed a framework of internet of civil infrastructure (IoCT) to collect, process and store data which is useful for managing crisis situation and information for disaster management and emergency response.

Alphonsa and Ravi (2016)	- Perception Layer: to sense physical environmental condition. - Network Layer: used Zigbee to transmit data. - Application Layer: warning signal sends to the public when the vibration of P wave occurs.	- Sensors - Zigbee - Smartphone - GSM for non-smartphone user -	Proposed an IoT earthquake early warning system. The sensors are placed in the surface of the earth to detect the P wave before the arrival of S wave which is stronger and caused more damage than P wave.

IV. RECOMMENDATION

Previous studies have been implemented IoT application for different types of disasters such as landslides, flood and earthquake. However, researchers have proposed different components and architecture for different application development based on the system requirement. Additionally, the finding shows that the trend of IoT application in disaster application domain is for monitoring and providing alert for the early warning purpose. Data processing and analysis should be included as a part of the system as a whole, for instance the analysis of flood prediction before giving alert to the people. On the separated note for the proposed IoT technology in this study, wireless sensor networks (WSNs), camera, mobile phone and weather station are selected as the main components used to collect related parameters such as WSNs collect water level and water flow data. Weather station collects temperature, wind speed and direction. Cameras capture images of surrounding environmental information while mobile phone is used for information sharing by community people. Wifi and Zigbee are used in Network Layer to transfer the collected data to Middleware Layer for data processing and analysing. Middleware Layer received data then performs data management such as process the collected data and analyse the flood occurrence in the cloud service, then the useful information such as the flood extend, scale of the flood, time and location will be presented as the flood map that will be displayed in Application Layer for user to access and make use of information through smartphone. Push notification will be send to users in case of emergency event occurs.

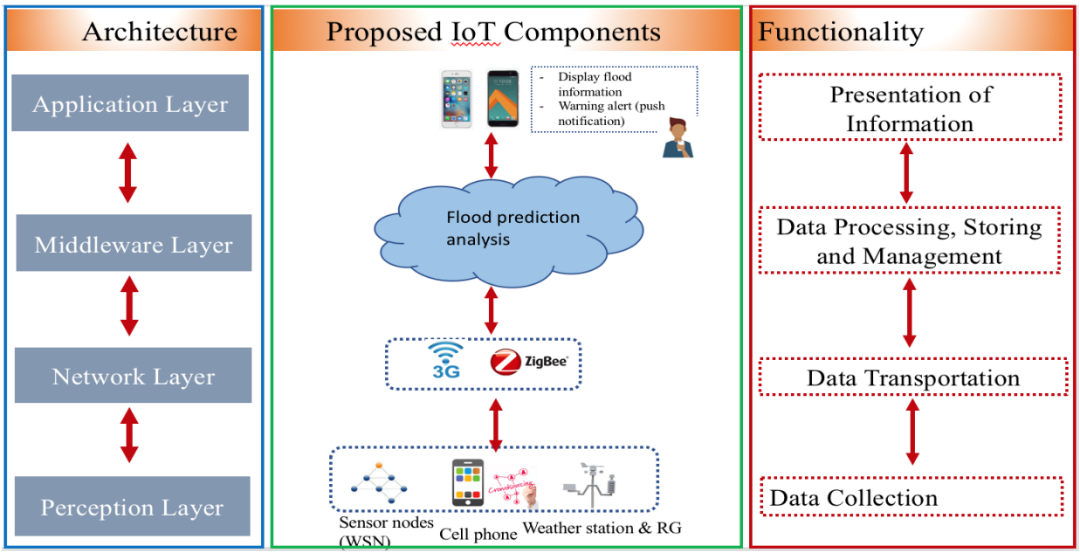

Fig. 4 Proposed IoT components and architecture

Thus, the compound of sensors and their autonomous coordination with well manage in data processing, analysis and display the useful information to be understandable by community people would help to predict the occurrence of flood disaster and send the early warning to people to take appropriate and effective actions before disaster occurs.

V. CONCLUTION

The development of IoT application for disaster management especially in prediction for early detection and warning are the key steps to avoidgreat losses in disaster events, with the powerful sensing ability of physical environmentby deploying WSNs or other types of sensors able to collect environmental datathat human are not able to access, it also provides real-time monitoring over the environment. With the combination of collected data and embedded intelligent technology within the architecture, IoT is the countless technology that could provide information for flood prediction and disseminate early warning information effectively. As a result, IoT will be widespread technology in implementing disaster prevention system such as flood, landslides, earthquake and other kinds of disaster monitoring governing the concept of cost efficiency and information dissemination effectively.

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