Original Article

Data Governance Conceptual Model for IoT (DGCMIoT) in Flood Management: the Malaysia Perspective

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Abstract

Internet of Things (IoT) is seen as a promising technology that can effectively collect data through varieties of devices and sensors that are placed at every imaginable places. The analyses of the data can be used in many ways such as weather prediction and flood mitigation. The value of the data collected and used depends on how well it collected, managed and governed. Following that this paper aimed at presenting an overview of the uses of IoT in the risk reduction and mitigation of flood condition in Malaysia by doing a rigorous review on the relevant research papers. Then, a case for a good data governance for IoT-based data in the Malaysian context is made based on the desirable characteristic of: availability, usability, integrity and security of the collected data. Finally, a conceptual model mapped against the basic IoT three-layered architecture and examines the role of the system's user, compliance, processes and tools is proposed. The conceptual model also considered several models reportedly used in other countries and strengthens by findings gathered through field study. The model can be used to further develop guide to improve decision making and transparency in managing flood disaster.

Keywords: Internet of Things (IoT), Flood, Information Management, Governance, Technology.

1. INTRODUCTION

The worsening climate change has manifested in increase recurrence and worsening natural calamities such as flood, tsunami, and earthquake. In the case of Malaysia, the calamities take the forms of monsoon flood, flash flood and related landslides. The obvious flood factor is the amount of rainfall, the period of time, where the rain falls, and when did it fell. Added to the severity is the condition of the drainage system and human activities that may have raged the flood site.

Technological advancement in Internet (Internet of Things or simply the IoT) has afforded us better means to monitor, predict, manage and control the flood condition. Although heavy rainfall cannot be avoided, the use of technology may be able to support preparation and reduce the impact of the disaster. As with any technology and data collected, an important aspect that be addressed is how can the technology and data be optimally govern?

This paper aimed at exploring and gaining insight on the advancement of IoT and its role in flood risk reduction. Alongside, it wishes to draw attention to issue of data collected via the IoT system. This pertains to the uses and potential abuses of the data collected. Following that, a model that reflects good governance over the IoT data collected will be proposed.

The remainder of the paper is organized as follows. Section 2 provides the background on uses of IoT technologies by flood agencies in Malaysia. Also, a review of the IoT technology framework and architecture is shared. In section 3, the application of IoT in disaster management in general and flood management in Malaysia are elaborated. Section 4 presents the use case of the Integrated Flood Detection and Notification System Based on IoT adopted by the Department of Irrigation and Drainage (DID) of Malaysia. In section 5, the need of a data governance framework due to the proliferation of the use of the data for flood management is highlighted. A novel Data Governance Conceptual Model for IoT (DGCMIoT) for Flood Management is proposed in Section 6 before the work presented in this paper is concluded.

2. Background

A flood early warning system which combines prediction algorithms against data from hydrological, meteorological, and geological IoT sources can potentially reduce damages by sending mobile warning to prevent traffic from entering an imminent flood site and allowing evacuation to safely take place before disaster strikes. These data are collected using devices such as sensors placed in the river to collect river levels, and satellites that produce images of the land. The use of the IoT technology, which connects thousands of sensors, services, and other internet-enabled devices [1], has proven to have mitigated the impact of floods on life and property in Kemaman, Terengganu, East Coast of Peninsular Malaysia in 2014 [19].

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Figure 1. 'Stick gaugle' installation, maintenance of Hydrology station and Radar Level Sensor System (RLS) were done at at Sungai Mas Ladang Tebak Padang Kubu, Kemaman [20]

IoT is an indispensable component of the future Internet [4], and an extension of the Internet to the physical entities that can only support low-power computations [6]. IoT can be seen as a global infrastructure for the information society, enabling advanced services by interconnecting things based on existing and evolving interoperable information and communication technologies (ICT) [7]. The convergence of advanced Machine-to-Machine (M2M) communication, autonomic networking, data mining, and decision-making, security and privacy protection, and cloud computing with advanced sensing and actuation are enabling a large range of IoT applications such as healthcare smart homes/buildings social networks, smart cities, smart vehicles, power grid management, infrastructure system, and disaster management response system [2][7]. The information interchange over the network of physical devices has brought the biggest changes and improvements in disaster management including floods. Information about the disaster was gathered by collecting data from one device to another device such as the level of river water, which was recorded by using CCTV and the data was sent to the main system.

3. IoT for Disaster Management

The application of IoT in disaster management can be demonstrated through the various types of systems developed for disaster management such as real-time patient-monitoring systems, CodeBlue, RF-based, and IEEE's Big Data New Initiative which allow real-time data via sensors, networking, and internet [3] [7]. IoT is proven to have the capability in providing more significant, scalable, portable, and energy-efficient [3].

The key application areas in achieving the abovementioned capabilities include (1) Disaster risk minimization and prevention: Monitoring disaster possibilities through satellite communication and geographic information system (GIS), designing early

warning systems, and use of social media for awareness creation. (2) Emergency response: Real-time communication for timely relief and response measures. (3) Disaster recovery: Online missing person search and fund management systems. The success of IoT in these areas makes IoTs implementation a high demand in the sector's prudence in developed countries to facilitate the management process. This is evident in the studies conducted by most researchers related to technology in disaster management [1][3][7]. The Responding Agencies (RA) require timely information for an effective decision-making process. The disseminated information enables effective extraction of heterogeneous data which will lead to effective decision-making [11]. For instance, the information retrieved from IoT based system will assist in the identification of disaster-affected areas and thus channel out the required resources to the critical area in order to prevent losses in the contiguous area [19]. Therefore, timely information sharing and speedy action can be achieved with the utilization of IoT [9][10].

4. Integrated Flood Detection and Notification System Based on IoT in Malaysia

The early warning system is crucial in alerting the signs of disaster. The warning is beneficial and important in ensuring the safety of the residents impacted by the disaster by providing them ample time to get ready before the flood happens. The warning system relies on the data provided by the forecasting system. Inputs for flood forecasting systems in Malaysia typically include data from river level and river flow, rainfall, and tide. These data are owned and managed by selected agencies as stated in Directive 20, which includes the Department of Irrigation and Drainage (DID) and Meteorological Department (NSC, 1998).

IoT has potential role to play in disaster management, such as in handling flood. Sensors can be used to detect water levels and monitor weather conditions in real time, helping to provide early warning of potential flooding. IoT can also be used to monitor and manage infrastructure during and after floods, helping to prevent further damage. Integrated flood detection and notification system based on IoT has been adopted by the Department of Irrigation and Drainage (DID) of Malaysia. The system will notify the agency through Short Messaging System (SMS) and this helps the agency monitor the flood situation based on the river level data which has been sent. The system uses river level sensors that are placed in several main rivers such as Sungai Air Putih to estimate the depth of the river by incorporating IoT as an essential tool. The IoT mechanism works by sending the information about the river level to a local machine through a GSM network on a mobile phone. The received information on the local machine can be obtained by any smartphone which has been registered earlier. The same implementation of IoT in flood monitoring can also be seen in the experiment conducted by [9] where cooperative flood monitoring and early detection service can be implemented using IoT, Global System for Mobile Communication (GSM), and SMS.

5. The Need for an IoT Data Governance Framework for Flood Management

With the proliferation of IoT in flood management expected in the coming years, it is expected that a humungous amount of sensor data would be elicited and transferred over the vast network. Defining an IoT data governance framework is crucial as it serves the purpose of accountability of the data being transferred across multi-devices Governance is related to accountability, transparency and effective decision-making process. The role of IoT governance is to ensure transparency for each of the decision made based on the signal received from the IoT devices.

A suitable governance framework is needed for IoT as it is a complex domain compared to Information Technology (IT) governance. The existing IT governance may have tackled the issue of the scale of usage, heterogeneity, and degree of technological autonomy. As IoT is a recent technological advance, a new set of rules or regulations concerning IoT implementation in flood management is critical Several issues that need to be managed relating to IoT governance are the privacy issues, accountability of information, and the correct and ethical use of IoT technologies.

A basic IoT architecture consists of three different layers; namely the perception that deals with data or information, the network layer that does the data routing and transmission, and the application layer that receives, integrates, and stores the information [16]. It can be inferred from the three layers of the basic IoT architecture that data or information is the core element of an IoT implementation.

Implementing IoT in flood management requires data to be collected from sensors placed in the rivers or monitoring stations. The data is sent to the communication systems using a specific network, which is then stored and passed to applications that

function as information sharing. The data can be presented on websites or certain applications that has being built by selected agencies in identifying vital information to mitigate incoming disasters.

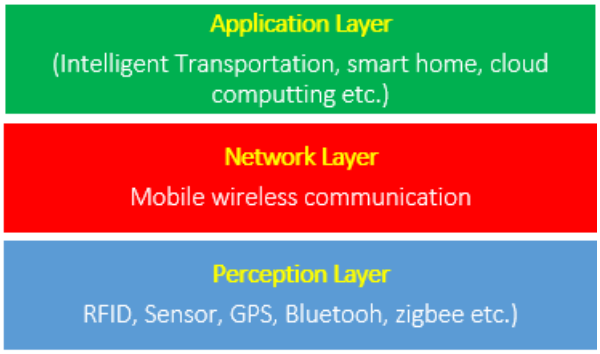

Figure 2. A basic IoT architecture [16]

Before the use of IoT, data is transferred with the consent of the owner through specific acknowledgment of the data owner. As data from IoT can easily be transferred using sensors through networks, there is no control on when and how the information should be passed. In the case of flood management, the sensors belong to certain agencies such as the Department of Irrigation and Drainage. These sensors are being placed in the river to track and capture levels and to predict incoming floods in case of any increase in the river level.

Although these sensors are being placed by the department, there is no specific ownership of the data. The level monitoring devices and the collected information can be passed and shared with another system that requires the information to manage the flood, especially in providing early warning to the public and other stakeholders.

There has been a suggestion that data owners should have the right to opt out, delete or mask their information from systems in the IoT. However, in the case of flood management, it will be impossible or even infeasible for an agency to control all the data generated by their sensors or systems. Data generated in flood management is supposed to be shared with other agencies in helping those agencies make the right decisions in a timely manner with the goal to minimize the flood impact.

IoT technology is considered an autonomous system that may replace human activities. The use of IoT in flood management is almost autonomous, where the data being collected from the sensors are sent to the application for the stakeholders to receive and view the important information.

The information presented to relevant agencies is crucial as they need it to assess the flood situation and make the right decisions. However, when the system becomes autonomous, there is a challenge for the stakeholders involved to identify when and how these systems should be deployed and who is responsible and accountable for the information being passed using the IoT, either the raw data or the data being presented to the disaster agencies.

If the devices or systems for flood management are being hacked or fail, there must be a mechanism to identify the entity accountable for the information. A complete IoT governance must include the element of ethical use. Technologies used by humans need to promote no harm. Data gathered by the sensors or monitoring devices need to be used by the selected agencies in flood management and should not be misused or abused by anyone that wants to harm the public. The harm can be in the form of providing false information to the public or manipulating the data gathered from the sensors for the flood management activities.

6. Proposed Data Governance Conceptual Model for IoT (DGCMIoT) for Flood Management

In this paper, a conceptual model for IoT Data Governance is proposed. The IoT Data Governance model is tailored for the application domain of flood management. In the context of this paper, data governance is defined as the process of managing

the availability, usability, integrity and security of the IoT sensor data collected and owned by the government or semi-government organizations for flood detection and mitigation, based on internal data standards and policies that also control data usage. Effective data governance ensures that data is consistent and trustworthy to drive effective decision making in flood analytics and management.

The proposed Data Governance Conceptual Model for IoT (DGCMIoT) for flood management consists of a set of tools, standards, policies and procedures for governing data, as well as implementation and enforcement procedures to be carried out by those responsible for the data management, which may include but not limited to the data management and analysis committee members and data stewards, who oversee data sets to keep them in order, as well as the flood management committee members responsible for disaster decision making process.

The proposed Data Governance Conceptual Model for IoT (DGCMIoT) for flood management consists of the following four components, namely the tools, processes, compliance and end-user / stakeholders.

Starting from the bottom layer, tools are software or hardware which facilitate for collection, integration, ingestion, processing and management of IoT data for quality, availability, usability, integrity and security. The purpose of the tool is to assist in the data part including data collection, data analysis and data information dissemination.

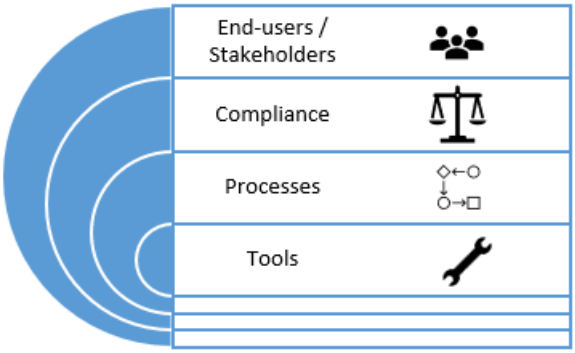

Figure 3. Iterative Interaction between the four main components of the proposed Data Governance Conceptual Model for IoT (DGCMIoT)

Processes are sets of standard operating procedures that define the “what”, “who”, “where”, “when” and “how” for data collection, data transmission, data decoding, data normalization and cleansing, data storage, data query, data visualization and reporting, and data analysis. The effectiveness of the processes is determined by the compliance checkpoints handled by committee members who regularly assess, monitor and audit the standards and policies, and keep them up-to-date based on feedbacks of the stakeholders. The process is crucial in flood management whereby the right decision making is required in each of the process. The transparency is required in the decision-making process whereby the input and output from the process need to be shared with the right stakeholders. Finally, the end-users or stakeholders (1) define the goals and expected benefits of flood analytics and management; (2) measure the level of goals achieved and derived benefits; (3) formulate the scorecard of the flood analytics process based on a set of metrics; (4) regularly provide feedback on the effectiveness of flood analytics based on IoT data. The stakeholders need to be informed on the process involved. All the involved stakeholders are accountable for what they are supposed to do in each of the process.

7. Conclusion

Successful flood management needs to be integrated with technology, as evident with the current use of IoT. Evident in real use cases, performing analytics and decision-making based on IoT data helps in reducing the damages that may impact humans and properties. In this regard, a good IoT data governance framework is important to ensure that the data collected are correctly managed and utilized. This paper proposed a novel IoT data governance conceptual framework to serve this purpose. With the proposed framework, future research works on flood management that utilizes IoT will help to advance the society and the nation that is facing disaster. In summary, the aim of this study is to provide an overview of the flood management in Malaysian

and how a good IoT data governance framework can help to solve challenges of flood management systems. The role of governance is crucial regardless of how advance is the system. The data and the processes need to be governed to ensure an effective decision-making process takes place, the stakeholders are accountable for the decision done and also to promote transparency.

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