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Cloud asset for urban flood control

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ABSTRACT

The performance of physical assets has become a major determinant success factor for urban flood control. However, managing these assets is always challenging as there are a huge number of diverse assets involved, which are distributed throughout the city, and owned by different agencies. Aiming at improving the management efficiency of these assets, and ensuring their performance, this paper proposes the concept of cloud asset based on cloud computing, mobile agent, and various smart devices. Through hardware integration and software encapsulation, cloud asset could sense its real-time status, adapt to varied working scenarios, be controlled remotely, and shared among agencies. It enables accurate real-time control of every asset, and thus improves the management efficiency and effectiveness. This paper first presents the concept of cloud asset with its technical architecture, and then analyses the software agent model for cloud asset, which is the key enabler to realize UPnP (Universal Plug and Play) management of assets, and provides mobility and intelligence for them. After that, the framework of cloud asset-enabled workflow management is built, in which cloud asset could be easily found and dynamically invoked by different workflows. Finally, a demonstrative case is provided to verify the effectiveness of cloud asset.

1. Introduction

Urban flood control has attracted more and more attention in recent years since flood is becoming the most frequent and greatest natural disaster for urban areas, and usually causes severe impacts. Over 233 out of the 633 largest cities in the world are threatened by flood, affecting about 663 million inhabitants [1]. In China, during 2008 to 2010, at least 62% cities had encountered urban flood, and 137 cities were flooded for more than three times. According to the Flood Control and Draught Relief Headquarters of China, over 234 cities had been suffered from flood in 2013. The situation will become even worse in the future with the worldwide excessive urbanization and climate change [2]. To mitigate future flood damages in urban area, various measures have been taken out, such as river training, storm water diversion, flood forecasting, real-time warning, and emergency management.

However, the effectiveness of these measures is always impeded by the poor performance of diverse physical assets involved, such as dams, sewers, pipes, pumps, hoisters, and sandbags, which will then threaten the success of urban flood control [2]. In order to ensure the performance of these assets throughout the whole process of urban flood control, effective management of them is urgently needed. Currently, some attempts have also been made. For example, Malano et al. [3] identified the roles asset management program (AMP) plays for irrigation and drainage infrastructure, and analyzed its investment requirements. Park and Kim [4] developed a data warehouse based decision support system for the management of sewer infrastructure. To monitor the condition of water pipeline and networks, Davis et al. [5] made a detailed analysis for the possible techniques, and Lau and Dwight [6] proposed a fuzzy-based decision support model. Nevertheless, as most of them are only focusing on a sub-set of assets in urban flood control and covering parts of their lifecycles, many problems remain unsolved, including how to get real-time data from different assets, make remote control of them, and optimize the usage throughout their whole lifecycles.

Information technology provides an opportunity to solve these problems, and has been proved to be effective in many other fields. For example, radio frequency identification (RFID) could help asset managers to make asset tracking and monitoring. It has already been widely used in hospitals to improve the asset management efficiency and reduce the cost [7]. As the enabling technology to collect real-world information, wireless sensor network (WSN) has also been widely used in asset management [8]. In addition, agent technology, which could make the management process

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much more intelligent and flexible, is also widely adopted, such as in the management of transformers in smart grids [9]. However, compared with these practices, the management of physical assets in urban flood control is immensely more complex. It evolves tremendous large amount of diverse physical assets that are physically distributed in very large areas, located in extreme environment, and owned by different agencies [3]. Major challenges still exist that impede the adoption of these technologies to improve the effectiveness and efficiency of physical asset management in urban flood control.

Firstly, how to make asset smart so that it could work automatically and be controlled remotely? In urban flood control, monitoring the working status of various physical assets and the environmental information around them is of great importance. However, the dispersion of assets and their extreme working environment makes it impossible to make on-site control for them, thus is a challenge to collect real-time data from them. Besides, during the process of urban flood control, many assets are mobile that would move from one place to another, which further increases the difficulty of managing them. Moreover, the poor connectivity of network posts another difficulty to manage assets remotely as it cannot be always guaranteed in emergency during urban flood.

Secondly, how to realize UPnP management for all the diverse assets? In urban flood control, physical assets are usually differed from properties, functions, and interfaces. Even for the semantic same assets, such as pumps from different manufactures, may varied from the implementation point of view. Professional knowledge is usually required when managing these assets, which is fault-prone and inefficient. UPnP is an agile, efficient and platform independent concept for the management of devices, and could greatly improve the management efficiency and flexibility of these assets. However, due to the diversity of APIs for different assets, it is a challenge to develop an information infrastructure for the UPnP management of assets. In addition, the differences on assets executing platforms also impede the development of integrated asset management solution, and hinder the deployment of information systems.

Thirdly, how to improve the flexibility of asset management so that assets could easily adapt to the dynamic and diverse working scenarios? In urban flood control, the exact working scenarios of assets are usually dynamic and unpredictable. It will benefit a lot if assets could be easily raised and adopted in a new working scenario according to the real-time situations. However, the management of assets is always separated with the process of urban flood control, and information of them is isolated in different agencies with different formats and security levels. It will be a great obstruction to realize flexible utilization. Moreover, the absence of effective asset sharing mechanism further increases the difficulty, and impedes the global optimal decision making during the process of urban flood control.

Aiming at addressing the above challenges, this paper proposes the concept of "cloud asset" for urban flood control. Through equipping with various information technologies, cloud asset could: (1) Automatically collect real-time data from the physical world during its whole lifecycle; (2) Be monitored and controlled remotely in an UPnP manner; (3) Be flexible and intelligent to adapt to various working scenarios; And (4) be easily invoked and shared through the cloud by all the authorized agencies.

In the rest of this paper, relevant literatures will be reviewed first, and then Section 3 will introduce the concept of cloud asset and its technical architecture. In Section 4, the mobile agent model of cloud asset will be discussed in details, and Section 5 will describe the mechanism of how a cloud asset is invoked and used by diverse workflows. A case of cloud asset with its executing process will be presented in Section 6. After that, Section 7 will conclude the whole paper and discuss the future works.

2. Literature review

In this research, the relevant literatures can be categorized into three aspects: urban flood control, smart object, and cloud computing and mobile agent.

2.1. Urban flood control

Generally, the whole process of urban flood control can be divided into four stages [10], they are flood planning and designing, flood event (includes flood warning and flood forecasting), flood response, and evaluation after flood. A variety set of measures have been taken for these four stages, including both structural and non-structural measures [11]. Structural measures refer to engineering works that make physical changes on urban landscapes to mitigate the risks of flood, such as canalization and detention basins. Non-structural measures stand for those preventive methods. For example, flood forecasting and warning, disaster management, flood proofing, and the method proposed in this paper, all belong to non-structural measures.

Plenty of research and practices have been done on non-structural measures by using various information technologies. Al-Sabhan et al. [12] have built an information system to provide real-time flood forecasting. By using GIS and WWW, environmental data could be accessed and processed online in near real time. Price and Vojinovic [13] have introduced the concept of digital city based on GIS to provide urban flood disaster management. Basha et al. [14] have developed a framework for predictive model-driven control, and applied it in the flood prediction. Besides, various decision support systems have also been built to support the different stages of urban flood control [15–17].

Despite abundant research on the non-structural measures has been done, virtually scare research has been conducted from the aspect of physical asset management, needless to say the research on how to use information technologies to facilitate the asset management process in urban flood control.

2.2. Smart object

The concept of smart object has been introduced over 20 years with the development of information technologies [18,19]. It refers to any object that can be uniquely identified, be aware of its status and the environment around it, communicate with others, make decisions, and take actions automatically [20]. Smart object serves as the building block of Internet of Things (IoT), and has been widely accepted and adopted in many areas, such as supply chain management, healthcare, smart homes, and product management [21,22].

With the development of emerging technologies, smart object has also been further studied and developed in various aspects. López et al. [20] proposed the general framework of smart object system, so that it can be seamlessly integrated with various technologies and be implemented feasibly and flexibly in different applications. Considering the real-world context of smart object and the changing network structure, Siegemund [23] developed a communication platform for smart object. Menegatti et al. [24] presented a robotic system for the discovery, detection and localization of smart objects. Furthermore, the concept of smart object has also been extended to support the specific requirements of diverse fields, and many new concepts have been proposed, such as smart device [25] and self-serving asset [26].

However, to our best knowledge, currently, scare research of smart object has been conducted in the context of urban flood control. Efforts are still needed on how to build smart object