APPLICATION OF CLOUD COMPUTING AND INTERNET OF THINGS FOR INFRASTRUCTURE PROJECTS: A REVIEW OF LITERATURE

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ABSTRACT

This paper is an attempt to explore the available literature pertaining to Cloud Computing and Internet of Things (IoT). Cloud Computing and Internet of Things (IoT) are the novel technologies which can enhance the co-ordination, collaboration and communication of mega infrastructure project. The architecture, engineering and construction (AEC) industry requires proper collaboration among the various project stakeholders, which can be improved only by making the communication more efficient. Cloud Computing and Internet of Things (IoT) will provide platform to collaborate project stakeholders of infrastructure project. The objectives of this study are to provide and implement Cloud-IoT paradigm in order to enhance the probability of successful project completion. Cloud- IoT paradigm will help project stakeholders in continuous monitoring and tracing of various construction activities, safety management and inventory management. This paradigm will also helpful in mitigating various risks associated with project. These technologies were recognized as the engine to drive the transformation and upgrading of building and construction industry.

KEYWORDS: Cloud, Cloud Computing, Internet of Things (IoT), Building Information Modelling (BIM)

INTRODUCTION

Cloud computing and Internet of Things (IoT) are two very different technologies that are both already part of our life. Their adoption and use is expected to be more and more pervasive, making them important components of the Future Internet. A novel paradigm where Cloud and IoT are merged together is foreseen as disruptive and as an enabler of a large number of application scenarios. The essential aspects of Cloud computing have been reported in the definition provided by the National Institute of Standard and Technologies (NIST): “Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.” The architecture of Cloud can be split into four layers: datacenter (hardware), infrastructure, platform, and application. Each of them can be seen as a service for the layer above and as a consumer for the layer below. In practice, Cloud services can be grouped in three main categories: (a) Software as a Service (SaaS), (b) Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). Usually, a cloud model is composed of five essential characteristics (i.e., on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service) and four deployment models i.e., private cloud, community cloud, public cloud, and hybrid cloud. While IoT refers to “a world-wide network of interconnected objects uniquely address- able, based on standard communication protocols” whose point of convergence is the Internet. The basic idea behind it is the pervasive presence around people of things, able to measure, infer, understand, and even modify the environment.

The requirements imposed by AEC (Architecture/Engineering/Construction) projects with regard to data storage and execution, on-demand data sharing and complexity on building simulations have led to utilizing novel computing techniques. Internet of Things (IoT) and cloud computing provide opportunities to solve these problems. The benefits of cloud computing and IoT technologies for construction industry have been detailed, including automatic and real-time data collection, remote control, resources and safety management, visibility and traceability of construction processes.

CLOUD-BASED IOT APPLICATIONS

Xu et al. (2018)[1] propose an integrated cloud-based Internet of Things (IoT) platform through exploiting the concept of cloud asset. They propose Construction Information Management Service Sharing (CIMSS) for adopting IoT technologies in prefabricated construction, which entails the sharing of the IoT infrastructure and information management services through the pay-per use mode among all the companies involved in prefabricated construction.

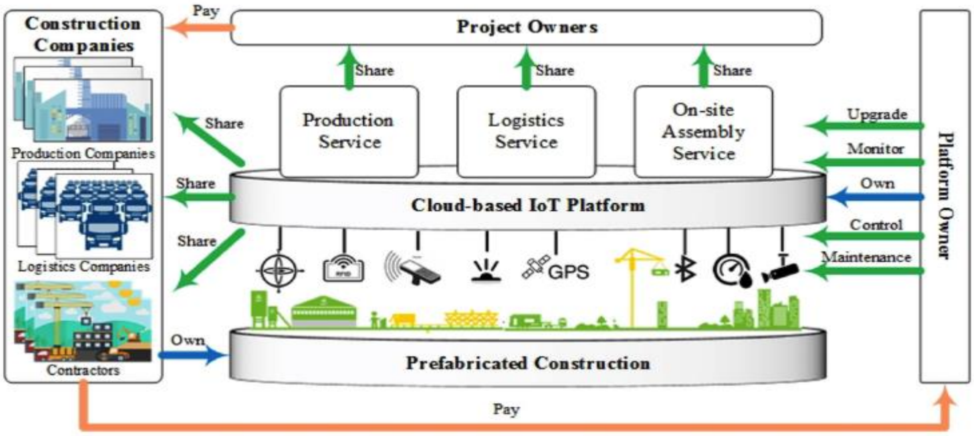

Fig. 1 Working principle of CIMSS

Source: Xu et al. (2018)

Zhong et al. (2017)[2] introduces a multi-dimensional Internet of Things (IoT)-enabled BIM platform (MITBIMP) to achieve real-time visibility and traceability in prefabricated construction. Design considerations of a RFID Gateway Operating System, visibility and traceability tools, Data Source Interoperability Services, and decision support services are specified for developing the MITBIMP.

Li et al. (2018)[3] propose an Internet of Things-enabled BIM platform for on-site assembly service (OAS) in prefabricated construction. IoT-enabled platform can provide various decision support tools and services to different stakeholders, for improving the efficiency and effectiveness of daily operations, decision-making, collaboration, and supervision throughout on-site assembly processes of prefabricated construction.

CLOUD-ENABLED BIM

Park et al. (2016)[4] present a framework for safety monitoring system as a cloud-based real time on-site application. The system integrates Bluetooth low-energy (BLE)-based location detection technology, building information model (BIM)-based hazard identification, and a cloud-based communication platform. Potential unsafe areas are defined automatically or manually in a BIM model. Real-time worker locations are acquired to detect incidents where workers are exposed to predefined risks. Then, the safety monitoring results are instantly communicated over the cloud for effective safety management.

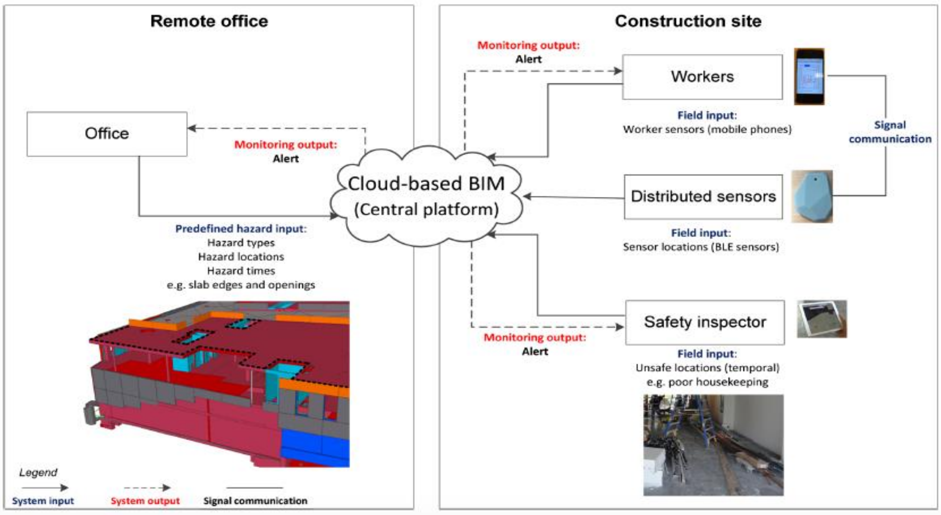

Fig. 2 Framework for the cloud-enabled safety monitoring system
Source: Park et al. (2016)

Das et al. (2014)[5] present a distributed cloud-based BIM framework that was designed to support collaboration among project participants and information sharing. Much information and communication in the AEC industry are verbal or documented on paper, which are lost sometimes as the lifecycle of a facility progresses. The proposed BIM-Cloud framework allows these information and interactions to be captured and associated with building components in an integrated model in the cloud environment.

Zhang et al. (2014)[6] present a framework of distributed BIM service on a private cloud platform in order to solve the problems of distributed BIM data sharing and management in construction projects. By this framework, multi-stage participants store relevant data on their own servers, which are virtually integrated through a CC (cloud computing) platform to form a logically complete BIM. It supports participants to establish, manage and transfer consistent BIM data efficiently with ensuring of data privacy. To achieve this BIM service, a BIM integration and service platform (BIMISP) based on IFC (Industry Foundation Classes) and CC was developed.

Du et al. (2014)[7] propose a free cloud based BIM performance benchmarking application called building information modeling cloud score (BIMCS) to automatically collect BIM performance data from a wide range of BIM users nationwide. It utilizes the software as a service (SaaS) model of cloud computing to make the collection, aggregation, and presentation of benchmarking data autonomous and interactive. Based on the big data collected from the BIMCS database, an overall view of the industry status quo of BIM utilization may be obtained, and ultimately, a protocol for BIM performance can be developed on the basis of a better knowledge discovery process.

Petri et al. (2017)[8] present how multi-site construction projects can be coordinated by the use of federated clouds where the interacting parties are represented by AEC industry organisations. They show how coordination can support (a) data sharing and interoperability using a multi-vendor Cloud environment and (b) process interoperability based on various stakeholders involved in the AEC project lifecycle.

Alreshidi et al. (2015)[9] develop specifications for a cloud-based BIM governance platform (GovernBIM). They use findings from wide consultation in combination with software engineering approaches using business process model notation (BPMN) and unified modeling language (UML) to define the platform’s requirements and specifications. This platform also aims to provide a computerized solution for overall BIM governance solution to facilitate team collaboration and mange generated BIM data during a project’s lifecycle.

Chong et al. (2014)[10] develops a Decision-making Tool to review and identify the appropriate cloud computing applications in the built environment. This tool will assist parties to select appropriate application.

Mathews et al. (2015)[11] examine the effectiveness of cloud-based BIM for real-time delivery of information to support progress monitoring and management of the construction of a reinforced concrete (RC) structure.

Chen et al. (2015)[12] explores a new computing paradigm called collaborative mobile-cloud computing (CMCC) and proposes a CMCC framework for conducting intelligent civil infrastructure condition inspection. Through software design, this framework synthesizes advanced mobile and cloud computing technologies with three innovative features: (1) context-enabled image collection, (2) interactive imaging and processing, and (3) real-time on-demand image analysis and condition analytics.

Li and Deng (2017)[13] propose 4PL (Fourth Party Logistics) informational integration platform, which integrates existing logistics service model, the Cloud Computing, BIM, GIS and other technology. They also propose the organic integration of Cloud-BIM and logistics technology to provide technical support for the establishment of the 4PLplatform, and specifically analysis the main applications of logistics Cloud-BIM in each stage of building materials supply.

CLOUD-ENABLED RFID

Fang et al. (2016)[14] propose a building information modeling (BIM) and cloud-enabled radio-frequency identification (RFID) localization system. The proposed RFID localization solution is able to localize construction workers and provide real time visualization on various devices through a cloud server for remote monitoring. The system is designed and developed to maximize its accuracy, reliability, and scalability when applied in an indoor construction environment.

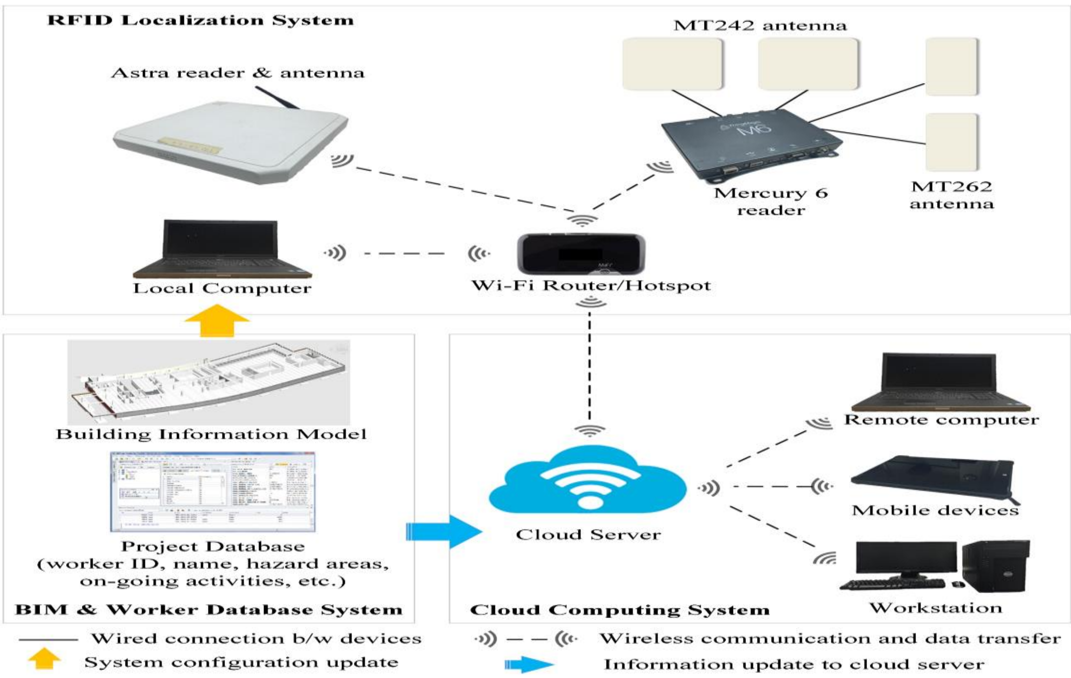

Fig. 3 Framework of the BIM and cloud-enabled RFID localization system

Source: Fang et al. (2016)

Ko et al. (2016)[15] proposes a cost-effective materials management and tracking system based on a cloud-computing service integrated with RFID for automated tracking with ubiquitous access.

COLLABORATIVE ENVIRONMENT

Zhang et al. (2017)[16] proposes a multi-server information-sharing approach on a private cloud after analyzing the requirements for cross-party collaboration to address the aforementioned issues and prepare for massive data handling in the near future. This approach adopts a global controller to track the location, ownership and privacy of the data, which are stored in different servers that are controlled by different parties.

Afolabi et al. (2018)[17] assess the linkages and leakages in a cloud-based computing collaboration among construction stakeholders. The result of the study revealed that construction stakeholders rarely utilize cloud-based technologies for their construction processes. The study classified the leakages that exist in the use of cloud-based technologies as Security based factors, Cloud-based infrastructure factors and Cloud-based benefits deficiency based factors. The study revealed that the linkages in the use of cloud-based technologies include knowledge sharing, remote access of back-office activities and engendering collaboration among construction stakeholders.

CLOUD-IOT FOR TRANSPORTATION

Wang (2010)[18] introduces the first Internet-based solution for transportation modeling software, named "Mint" (i.e., Modeling on Internet). Mint is a web-based, hosted scalable platform for transportation modeling that provides governments and consulting firms with software-as-a-service (SaaS) benefits.

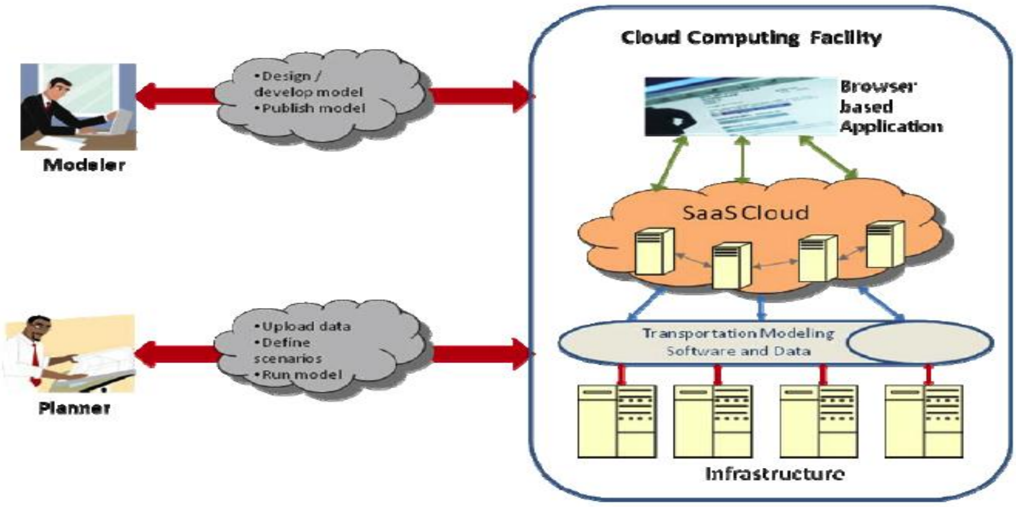

Fig. 4 System architecture of "Cloud Computing" based Internet Solution for Transportation Modeling

Source: Wang (2010)

Gong et al. (2017)[19] [20] investigated a novel cyber-physical infrastructure framework that can effectively and efficiently transform existing transportation hubs into smart facilities that are capable of providing better location-aware services (e.g. finding terminals, improving travel experience, obtaining security alerts) to the traveling public, especially for the underserved populations including those with visual impairment, Autism spectrum disorder (ASD), or simply those with navigation challenges. They propose the integration of a number of IoT elements, including video analytics, Bluetooth beacons, mobile computing, and facility semantic models, to provide reliable indoor navigation services, yet requiring minimum infrastructure changes.

CONCLUSIONS

Reviewing the available literature it has been observed that most previous works have focused on using cloud and IoT technologies to solve specific problems in construction separately, or manage the operations in a single phase of the whole construction process. Adequate literature is available on both cloud computing and IoT separately. But adequate literature is not available on integrated Cloud-IoT model. There have been few works on establishing the integrated management platform, from platform design, development, to field verification. There is also less collaborative environment among project stakeholders in traditional cloud and IoT model, which leads to information inconsistency and communication bottlenecks, which may cause errors, interruptions, and delays during the construction. Beside this, the aspects of security and privacy were not given much concern in traditional models. Considering these gaps, the present study aims at exploring the possibility of developing an integrated Cloud-IoT model for infrastructure projects.

REFERENCES

[1] Xu, G., Li, M., Chen, C. and Wei, Y. (2018). “Cloud asset-enabled integrated IoT platform for lean prefabricated construction”, *Automation in Construction,* Vol. 93, pp 123-134.

[2] Zhong, R.Y., Peng, Y., Xue, F., Fang, J., Zou, W., Luo, H., Ng, S.T., Lu, W., Shen, G.Q.P. and Huang, G.Q. (2017). “Prefabricated construction enabled by the Internet-of-Things”, *Automation in Construction,* Vol. 76, pp 59-70.

[3] Li, C.Z., Xue, F., Li, X., Hong, J. and Shen, G.Q. (2018). “An Internet of Things-enabled BIM platform for on-site assembly services in prefabricated construction”, *Automation in Construction,* Vol. 89, pp 146-161.

[4] Park, J., Kim, K. and Cho, Y.K. (2016). “Framework of Automated Construction-Safety Monitoring Using Cloud-Enabled BIM and BLE Mobile Tracking Sensors”, *Journal of Construction Engineering and Management,* Vol. 143(2), pp 1-11.

[5] Das, M., Cheng, J. and Kumar, S.S. (2014). “BIMCloud: A Distributed Cloud-based Social BIM Framework for Project Collaboration”, *Computing in Civil and Building Engineering*, pp 41-48.

[6] Zhang, J.P., Liu, Q., Yu, F.Q., Hu, Z.Z. and Zhao (2014). “A Framework of Cloud-computing-based BIM Service for Building Lifecycle”, *Computing In Civil And Building Engineering,* pp 1514-1521.

[7] Du, J., Liu, R. and Issa, R.R. (2014). “BIM Cloud Score: Benchmarking BIM Performance”, *Journal of Construction Engineering and Management,* Vol. 140(11), pp 1-13.

[8] Petri, I., Beach, T., Rana, O.F. and Rezgui, Y. (2017). “Coordinating multi-site construction projects using federated clouds”, *Automation in Construction,* Vol. 83, pp 273-284.

[9] Alreshidi, E., Mourshed, M., and Rezgui Y. (2015). “Cloud-Based BIM Governance Platform Requirements and Specifications: Software Engineering Approach Using BPMN and UML”, *Journal of Computing in Civil Engineering***,** Vol. 30(4), pp 1-23.

[10] Chong, H. Y., Wong, J. S., and Wang, X. (2014). “An explanatory case study on cloud computing applications in the built environment”, *Automation in Construction,* Vol. 44, pp 152-162.

[11] Matthews, J., Love, P.E.D., Heinemann, S., Chanler, R., Rumsey, C. and Olatunj, O. (2015). “Real time progress management: Re-engineering processes for cloud-based BIM in construction”, *Automation in Construction,* Vol. 58, pp 38-47.

[12] Chen, Z., Chen, J., Shen, F. and Lee, Y. (2015). “Collaborative Mobile-Cloud Computing for Civil Infrastructure Condition Inspection”, *Journal of Computing in Civil Engineering,* Vol. 29(5), pp 1-13.

[13] Li, Y. and Deng, Y. (2017). “Research on the Application of the Building Materials 4PL Model Based on the Logistics Cloud-BIM”, *ICCREM 2017: Project Management and Construction Technology,* pp 250-261.

[14] Fang, Y., Cho, Y.K., Zhang, S. and Perez, E. (2016). “Case Study of BIM and Cloud–Enabled Real-Time RFID Indoor Localization for Construction Management Applications”, *Journal of Construction Engineering and Management,* Vol. 142(7), pp 1-12.

[15] Ko, H. S., Azambuja, M. and Lee, H.F. (2016). “Cloud-based Materials Tracking System Prototype Integrated with RadioFrequency Identification Tagging Technology”, *Automation in Construction,* Vol. 63, pp 144-154.

[16] Zhang, J., Liu, Q., Hu, Z., Lin, J. and Yu, F. (2017). “A multi-server information-sharing environment for cross-party collaboration on a private cloud”, *Automation in Construction,* Vol. 81, pp 180-195.

[17] Afolabi, A., Amusan, L., Owolabi, D., Ojelabi, R., Joshua, O. and Olayeni, P.T. (2018). "Assessment of the Linkages and Leakages in a Cloud-Based Computing Collaboration among Construction Stakeholders", *Construction Research Congress*, pp 673-683.

[18] Wang, M. (2010). "A New Way of Transportation Modeling – "Cloud Computing" Based Internet Solution for Transportation Modeling", *ICCTP 2010: Integrated Transportation Systems*, pp 1086-1096.

[19] Gong, G., Feeley, C., Tang, H., Olmschenk, G., Nair, V., Zhou, Z., Yu, Y., Yamamoto, K. and Zhu, Z. (2017). "Building Smart Transportation Hubs with Internet of Things to Improve Services to People with Disabilities", *Computing in Civil Engineering*, pp 458-462.

[20] Gong, G., Feeley, C., Tang, H., Olmschenk, G., Nair, V., Zhou, Z., Yu, Y., Yamamoto, K. and Zhu, Z. (2017). "Building Smart and Accessible Transportation Hubs with Internet of Things, Big Data Analytics, and Affective Computing", International Conference on Sustainable Infrastructure, pp 126-138.