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AN e-SERVICE DELIVERY PLATFORM FOR BUILDING INDOOR ENVIRONMENT AND ENERGY PERFORMANCE ASSESSMENT

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ABSTRACT

The volume of data relating to the built environment is expected to markedly increase as low cost, wireless monitoring devices proliferate. It is anticipated that the technology will provide facilities managers with new tools for cost-effective energy use reduction. To address this opportunity, several projects worldwide are developing data platforms possessing integrated analytics corresponding to distinct energy-related services (hereinafter referred to as 'e-services'). This paper summarises the first year activity of a Korean project addressing the delivery of new information services relating to the energy and environmental performance of buildings. An e-service delivery platform based on pervasive sensors and the Hadoop 'big data' platform has been developed. The hardware and software components are designed to meet technical requirements for a range of energy and environment services for which the essential features are low cost devices and open communication protocols. The form of the hardware and software systems is herein described and results from deployments in Korea and the UK reported.

KEYWORDS

Big data platform, pervasive sensing, e-service delivery, low cost, energy management

INTRODUCTION

In the context of the emerging 'Internet of Things' (IoT) market, an IoT-enabled data management system has been developed comprising new monitoring and data processing components. The former, termed BuildAX, was developed by the Energy System Research Unit and Culture Lab at the Universities of Strathclyde and Newcastle within EPSRC project EP/I000739/1 (Clarke *et al*. 2014). The latter, termed EnTrak (Kim and Clarke 2004), supports the delivery of discrete building performance information sets addressing issues such as indoor discomfort, poor air

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quality, operational energy reporting, equipment conditions monitoring, upgrade quality assurance and the like. The BuildAx low cost, open, device encapsulates 6 sensors recording temperature, relative humidity, illumination, people presence, window/door actuation and battery state, with data communicated wirelessly to a local logger/router for onward transmission to EnTrak (Clarke and Hand 2015).

While low cost pervasive sensing technologies allow effective performance assessment and accurate predictive control to enhance energy and environment performance of the built environment building estates, they give rise to large data sets which requires more computational resource. To address this need, the Hadoop big data platform (Hadoop ref) has been adopted. This paper presents the configuration of the e-service delivery system and its field deployment for testing and demonstration.

e-SERVICE DELIVERY SYSTEM

Figure 1 illustrates the components and data transmission routes of the e-Service delivery system. Extensive data are involved in e-services to create valuable information for energy users at various decision-making levels. A large portion of these data are available from existing monitoring systems, utilities, meteorological stations and public databases. The novel approach in this study is to add high resolution information on indoor environment conditions using pervasive sensing technology. The data collected from all sources and the results of applying processing rules to these data are encapsulated within the Hadoop platform..

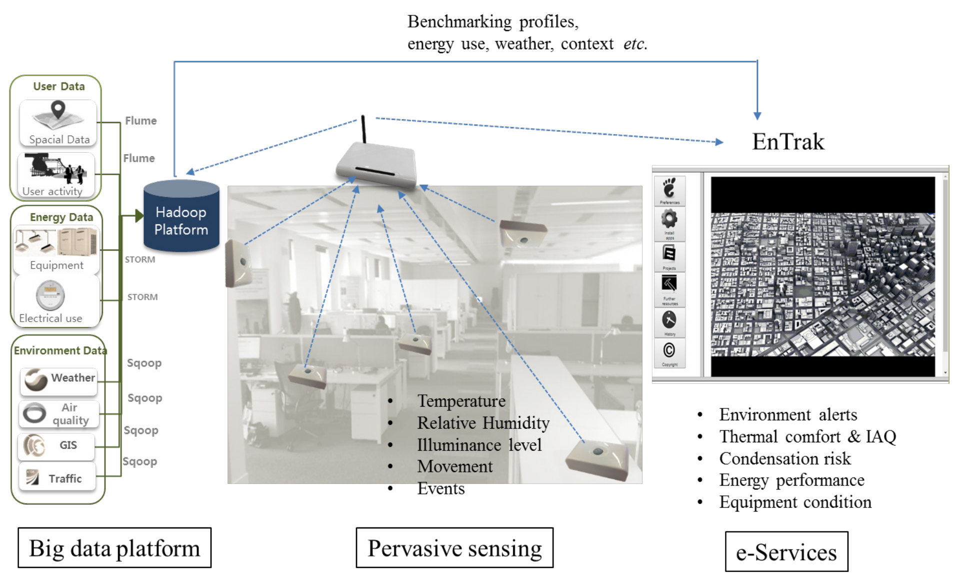


***Figure 1**: e-Service delivery system.*

The scale of data transmission, storage and retrieval in this infrastructure is beyond the capability of conventional building energy management systems (BEMS). As depicted in Figure 2, the Hadoop platform comprises three clusters: data mashup, analytic application and publishing.

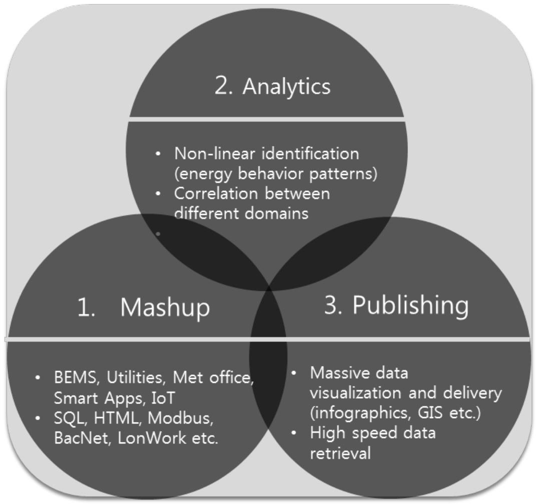


Figure 2: *Role of Hadoop-based big data cluster for e-service delivery.*

1) The data mashup cluster - this manages multi-channel data import with heterogeneous data format conversion. One of components within the cluster, SQOOP, transfers bulk data between Hadoop and structured databases in BEMS, weather stations, and utilities.

2) The analytic cluster - this provides analysis engines for non-linear identification of energy use patterns and correlation between different data domains some of which have never been examined with conventional regression studies in the building energy field (e.g. HVAC energy consumption and traffic condition). It is expected that the pattern detecting model will provide energy managers with new insight and ability for more accurate prediction of energy demand compared with cause-effect model approaches.

3) The publish cluster - this supports data visualisation through third party tools. Usually tools such as 3D infographics, GIS and so on require high volume of input data. This cluster handles data transformation and delivery from extensive data sources to such visualization tools.

Figure 3 gives an example of a prospective e-service for benchmarking the energy use patterns of air conditioning systems in terms of 4 impacting factors: occupancy, spatial, regional and climatic. In this study, impacting factors were defined to identify determinants correlated with electricity consumption of air conditioning systems. Various data items are involved and categorized in one of 4 factors. Some data items have never been examined in conventional energy models. For example, road condition, outdoor air quality data, commercial events around the targeted building/space will be examined as one of the regional factors. One of objectives of this project for coming years is to establish extensive data connectivity for energy use prediction model. Critical challenge is to get on-line access to data sources available to public.

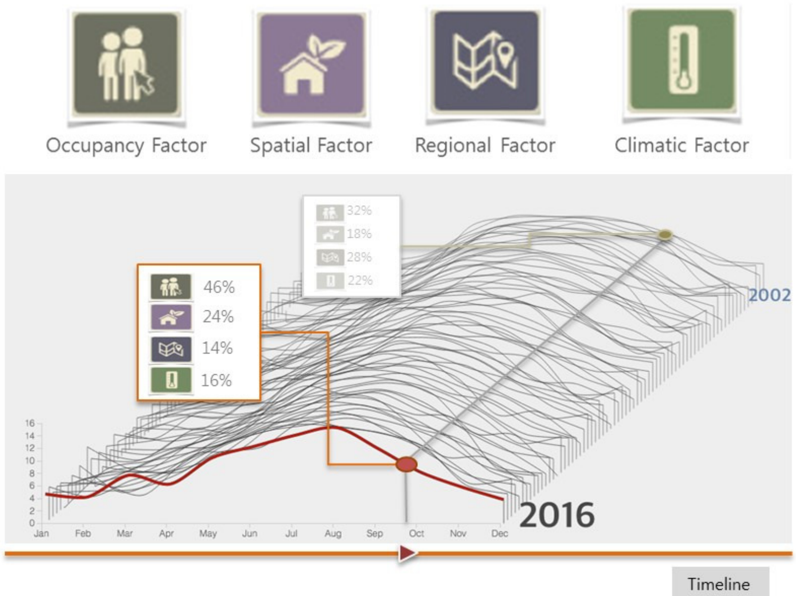


Figure 3: *Longitudinal benchmarking of energy consumption patterns depending on energy impacting factors.*

FIELD DEPLOYMENT

The e-Service delivery system was deployed at test sites in Korea and the UK representing different climate contexts and culture-related energy use patterns. An e-service for indoor environment conditions assessment was deployed in which data is acquired from pervasive sensors distributed throughout the targeted space. The sensors are installed throughout the working areas of occupants – all while being as unobtrusive as possible.

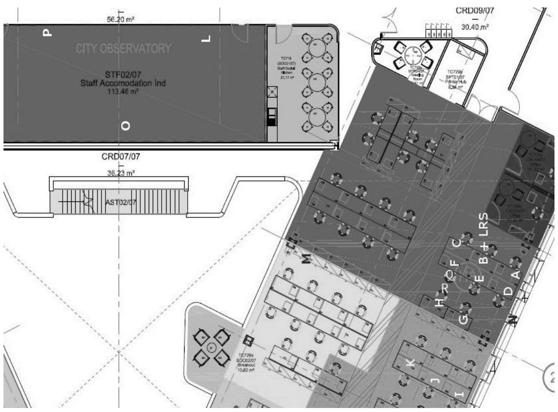
One deployment was within the Technology and Innovation Centre at the University of Strathclyde; Figure 4 shows sensor locations. Offices within this building were experiencing environmental problems relating to glare and overheating.

Such high resolution data from the distributed wireless monitoring devices provide the facility manager with identification of problematic locations and their temporal patterns. As can be seen in Figure 5, temperature profiles of various locations in the office space can be displayed to facility managers (and potentially occupants) on demand. Such data can help to identify problematic areas and, through automated analysis, suggest remedial actions.

On the other hand, monitored data are transferred to the Hadoop platform for data mashup and analytics after integration with data collected from other sources (e.g. smart utility meters). The aim of the second year of the project is to deploy analytic models for the prediction of energy use patterns.

a) Outlook of the site building at University of Strathclyde.

b) Internal scene of the office at ETRI.



d)

c) Location of sensors marked with alphabet A to P.

d) A BuildAx placed at a position.

Figure 4*: Field deployment of pervasive sensors in offices at the University of Strathclyde, UK and ETRI, Korea*

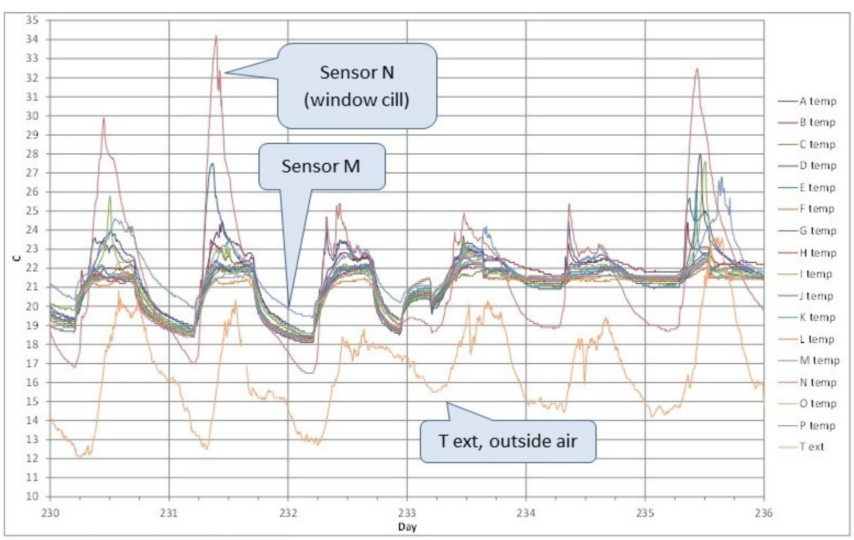


Figure 5*: Temperature profiles during a warm period from all sensing points.*

DISCUSSION

Low cost, pervasive sensing devices and extensive data resources can provide facility managers with opportunities for effective performance assessment and accurate predictive control of energy systems. However, there are still non-trivial barriers to implementing innovative e-Services in practice. Institutional communication security policy does not yet allow direct communication between private network devices (here a BuildAx router), and external network servers (here EnTrak connected to a Hadoop platform). Even if data connectivity can be established, too much data traffic may give rise to high cost for data communication. To justify low cost and powerful analysis engine-assisted energy management systems, it is necessary to design a data transfer and analysis job allocation strategy depending on the nature of e-Service. The next step in the present project is to specify analytic models and data transferring architecture.

CONCLUSION

It is anticipated that the proposed e-service delivery system will facilitate more effective performance assessment and accurate control for energy management. Facility managers could make strategic and operational decisions on the basis of large volumes of data collected from extensive sources. Through the course of the project, the viability of the proposed e-service delivery system is being evaluated by comparison with conventional building energy management systems, which require significant monitoring infrastructure and on-site system maintenance.

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