1.3. From BIM to BEMS, covering the Design- and Operational-Phase Interoperability Gap

C. Valmaseda FUNDACIÓN CARTIF, SPAIN

P. Yebra FUNDACIÓN CARTIF, SPAIN

D.V. Rovas DEPARTMENT OF PRODUCTION ENGINEERING AND MANAGEMENT, TU OF CRETE, GREECE

E. Kosmatopoulos DEPARTMENT OF PRODUCTION ENGINEERING AND MANAGEMENT, TU OF CRETE, GREECE

Abstract

This paper deals with the FP7 EU project "Building as a Service" (BaaS). The BaaS project is a research initiative which aims at providing a generic solution for delivering standardization and interoperability concepts for building data and open middleware platform covering the Design- and Operational-Phase In-teroperability Gap in the application domain of "non-residential buildings." There are two important phases in the building life-cycle: the design phase and the operational phase. Development and integration of ICT tech-nologies can help best coordinate the building design and operation phases. Overcoming interoperability gaps between both phases so as providing a way of integration to use existing and future tools and services would help to enhance building operations and controls. Better design, standardization and interoperability can con-tribute themselves to the goals of improving energy efficiency. Interoperable components working as services at the building level, will lead naturally to the concept of the Building as a Service ecosystem. This paper aims at analyzing some of the BaaS project topics: (1) building data management and interoperability: data warehouse to collect, organize, store and aggregate static and dynamic data from various in- and out-of-building sources; an IFC-based BIM will act as a central repository for all static building data, and a data warehouse will be used for dynamic data, both schemes mapped using a unique vocabulary. (2) Integration of building energy management Services using Open Service Middleware Platform technologies. A service middleware platform to abstract the building physical devices, support high level services on the cloud and facili-tate secure two-way communication between the physical and ICT layers (building) with high level services (cloud).

1 Introduction

The discussion on energy-efficiency in the building sector has become ubiquitous, as has become the ef-fort of achieving improved operational performance along with a lower lead time from building design to commissioning, and the development of tools to support facility management and operation. The de-velopment and integration of ICT technologies can help best coordinate building design and operation and thus contribute to achieving energy performance objectives. Still despite significant advances there exist no tools that are capable of streamlining the whole process and achieving in a systematic and well-defined way design objectives.

There are two important phases in the building life-cycle: the design phase (along with subsequent retrofitting phases) in which design decisions signif-icantly affect subsequent performance; followed by the operation phase where the Building Energy Management System (BEMS) ensures a parsimoni-ous and effective use of the available resources. Achieving energy efficiency requires mitigation of both design-phase and operational-phase inefficien-cies.

In the design phase, issues of collaboration and in-formation interchange are crucial (Shen, 2010) for the successful orchestration of the different teams (including architects, engineers, contractors, owners, site planners etc.) and for achieving many, – often conflicting, – requirements and constraints imposed by the different teams involved. In current practice, during the initial phases of design, different tools are utilized with little or no connect between them (Van-lande, 2010), (Singh, 2010): ineffective communica-tion (of files and documents) and lack of standardi-zation between the various teams involved along with incomplete information incur significant delays to the design and construction phase, and design er-rors are easily introduced (and overlooked) that re-quire retroactive actions

In the operation phase, designing the building monitoring system and also incorporating decision strategies is a laborious task requiring expert knowledge. Buildings viewed from a systemic view-point are becoming increasingly complex: they have a wealth of energy systems that have to operate har-moniously together; they have to respond to signals from the grid; the atypical availability of energy through Renewable Energy Sources (RES) has to be effectively utilized; and graceful degradation of per-formance has to happen in case one or more of the building subsystems fails or goes offline. More to that, changes on the building components (through refurbishing, installation of new systems and/or sen-sors etc.) and characteristics (degradation of perfor-mance) during the operational life-time of the build-ing present formidable problems in reconfiguring and updating the BEMS. And last but not least, building users largely stay out of the loop and their actions inside the building can have detrimental effect on energy efficiency and building performance.

The fact that the BEMS is configured once during the initial installation along with possible reconfigu-rations during subsequent retrofitting phases repre-sents a very static (and limited) view. Even more, the separation and discontinuity between design- and operation-phases seems unnatural. The availability of BIM description during the initial phases is essential for effective information interchange; but in the operational life-time of the building this description can be updated and can evolve dynamically, to de-scribe and reflect actual changes in the building.

This paper deals with the FP7 EU project "Build-ing as a Service" (BaaS) < http://www.baas-project.eu >. The BaaS project is a research initiative which aims at providing a generic solution for deliv-ering standardization and interoperability concepts for building data and open middleware platform covering the Design- and Operational-Phase In-teroperability Gap.

2 Building Data: interoperability and standarization.

Current building environmental and energy man-agement systems are focused on building control and automation. As long as building energy management systems (BEMS) succeed in maintaining set envi-ronmental conditions (e.g. temperature, relative hu-midity), the client has shown little interest in access-ing/analyzing the environmental and energy data being utilized by the BEMS and associated data log-ging meter equipment (Maile, 2007). Monitoring and targeting (M&T) software tools attempt to address this situation when a client/facility manager requires this data. This tools 'communicate' with a variety of data streams from stand alone and/or multiple building management systems and data loggers usually in the form of ASSCII and/or CSV text files (Keller, 2008). This has resulted in ad-hoc fragment-ed systems development of building environmental & energy management systems.

All designs of M&T systems are reactive to exist-ing installed BEMS infrastructure. Also, clients are not encouraged to retrofit such systems to effect bet-ter energy management because of the prohibitive costs of these systems. The limitations of current en-vironmental & energy management systems lie in their infrastructure (cost restrictions) and in the unre-liability and inaccessibility of the environmental and energy related data across a fragmented BMS infra-structure. The emerging EU directives relating to energy (EU EPBD and the EU Directive on Emis-sions Trading) now places demands on building owners to rate the energy performance of their build-ings. This creates demand for integrated and reliable building environmental and energy data.

2.1 Building Automation Systems

Building Automation Systems (BAS) have made tremendous strides in recent years toward embracing connectivity and interoperability standards. These efforts have given building owners more freedom to choose among manufacturers for both products and service support. Even greater benefits await an or-ganization whose BAS is seamlessly merged with its information technology architecture. The synergy created by sharing infrastructure and data reduces operating costs and creates new service opportuni-ties.

Building automation system manufacturers have accelerated the rate of open protocol device devel-opment to BACnet® (www.bacnet.org) or Lon-Mark® (www.lonmark.org) interoperability, or both. In the new world of convergence, systems that claim to provide interoperability and conform to industry standards also must provide connectivity to a variety of equipment that integrates seamlessly into the net-work. Neither BACnet nor LonMark alone provide a complete answer for the vision of total enterprise information compatibility. A better solution is to apply the new standards for interoperability, such as XML-based communications applications, in order to achieve all of the benefits that each protocol offers individually. In general, systems that require in-teroperability on a broad basis will be best served if they support multiple protocols.

eXtensible Markup Language (XML) is the uni-versal language of Internet data exchange, and can be called across platforms and operating systems re-gardless of programming language and offers an op-portunity to use web-services. The Web Services model provides information to diverse requestors of information. This opens the floodgates for a new class of information-rich applications to be delivered anywhere, anytime across a network that is in place and inexpensive.

With true convergence, stakeholders are empow-ered to obtain more information on a by-request ba-sis and in a manner that is more easily understood by any technology system within the building or by the stakeholders. This integration level opens opportuni-ties for stakeholders that were not technically or economically feasible in the past.

2.2 Building Information Model and DataWarehouse

Building Information Modeling (BIM) presents a vi-able solution for information inter-change by estab-lishing, through accepted standards, a common lan-guage to describe architectural, structural and energy concepts in the building. It can therefore help estab-lish a stronger (and more direct link) between various stakeholders. The Industry Foundation Classes (IFC) (currently ISO/PAS 16739 and with the new version IFC2x4 destined to become ISO/IS 16739) provides consistent frameworks, of sufficient granularity, capable of describing all pertinent details (www.buildingsmart-tech.org).

Often, the failure of the operation and performance of buildings is a result of insufficiently integrated representation for building products, process and control resulting in an inappropriately defined build-ing performance criteria (Wong, 2005) and because an information loss regarding the intended building operation strategy as the building progresses through the building lifecycle (NIBS, 2011).

3 Building energy services integration: open middleware platform.

IT systems for Building Management (BMS) control and monitor the building's mechanical, electrical and energy equipment (e.g. HVAC, lighting, power). Their functionality might include links to Facility Management Systems (Schach, 2004), Enterprise Management Software (Malatras, 2008), and offer web services (Malatras, 2008), (Wang, 2002), (Wang, 2007), (Jang, 2008). BMS are usually com-plemented by fire, and security systems. They con-sist of an interface layer to the usually Ethernet-based network backbone using management layer protocols like BACnet, OPC, SOAP, etc. (Malatras, 2008), (Wang, 2002), (Jang, 2008), to communicate with gateways connected to the field level network protocols (BACnet, LON, EIB/KNX, EnOcean, ZigBee).

The Building Management IT systems require to access and to utilize heterogeneous resources of dif-ferent devices, subsystems and external resources. The systems often need to process, filter and route emerging data in a scalable manner, given the other challenges, such as volatility of network and mas-siveness of volume of data.

3.1 Service Oriented Architecture concept for System Integration

Service Oriented Architecture (SOA) is a core con-cept for middleware platforms in order to organize IT resources and data collectively, to enable integra-tion between different technologies and to allow for standardized data interaction (Bell, 2008), (Valipour, 2009). SOA focuses on interoperable, robust, reusa-ble, and composable services that abstract the appli-cation functionality and data of each technology (Fowler, 2002).

Two important aspects of implementing a success-ful SOA are Web Services and their ontology (data models).

While Web Services (Malatras, 2008), (Wang, 2002), (Wang, 2007), (Jang, 2008) are partially inte-grated in Building Management Systems, there is currently not yet a consistent Service Oriented Ar-chitecture approach available for building control systems (Malatras, 2008).

The middleware solutions are often tailored for individual applications. There are also some solutions that adopt "programming abstractions" that have been successfully used for many years in distributed computing.

Since the emergence of Web Services and their wide area of applications, the SOA- and Web-Service-based technologies are also utilized to de-velop middleware solutions for various areas.

The SOA-based middleware solutions allow to re-duce the complexity and to offer high-level service-specific interfaces to access the data. While the cur-rent middleware solutions introduce flexible and loosely coupled methods, there are issues such as in-teroperability, efficiency, scalability and aggregation of service and the emerging data from Internet Con-nected Objects that require further research and de-velopment.

3.2 Connectivity to Building information Model

The BIM encompasses building geometry, spatial re-lationships, material specifications, properties of building services components, etc. However, current BIM's capabilities are limited regarding their man-agement and control functions or their performance analysis of buildings. On the other side, features of Service–Oriented computing, such as standard pro-tocols, loosely coupled components; ontology-enabled dynamic discovery and composition of SOA seem to be capable to address these deficits of soft-ware systems in the building construction and build-ing controls domain. The potential gains of applying SOA techniques have not really been discovered.

4 BAAS solution

The BaaS approach is considering three layers archi-tecture: the data layer which is used to collect, store and aggregate all static and dynamic data regarding the building; the middleware layer to abstract the building and its subsystems and allows transparent two-way communication between the physical and the ICT layers; and the service layer where high-level services could be provided. A "separation of concerns" approach is adopted to help manage the complexity and provide a generic and widely appli-cable solution.

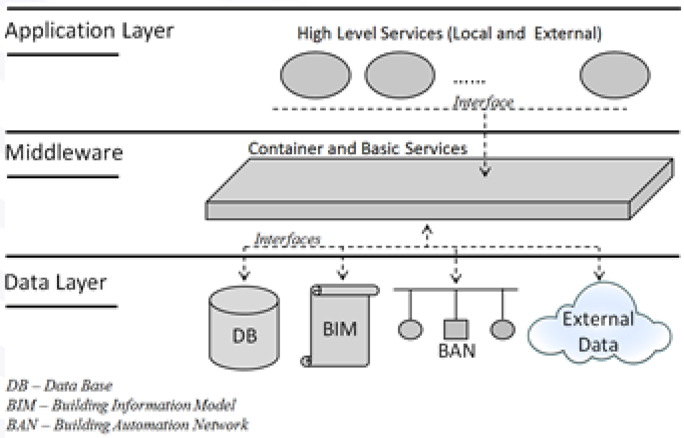

Figure 1. Components and global architecture in BaaS.

In that sense the BaaS system is not just a Build-ing Energy Management System but rather a next-generation holistic interactive multi-player extensible enterprise building management system capable of providing access-to and integrating most aspects of building operation in a harmonious and effective manner.

In addition, special care will be taken that the BaaS platform ensures secure interaction between all stakeholders and enables privacy protection where appropriate.

4.1 Data Management Layer

At the data layer, the use of Building Information Modeling (BIM) using the open soon-to-be-standard IFC (Liebich, 2010) will be used as a central reposi-tory for all building-related information. The upcom-ing IFC2x4 specification has new and consistent definitions for building systems, services and controls that we intend to fully utilize.

A "BaaS view" of the data model will be created with all pertinent to our system information and ap-propriate interfaces will be created for interacting with the BIM. In addition to static data, all dynamic-data (i.e. ones obtained through sensor measurements) are to be stored and aggregated in a "data warehouse" (Ahmed, 2010) that will be automatically generated from the BIM sensor information descriptions, and will be able to obtain data through the middleware layer of the building, and will make them available to the high-level services in almost real-time.

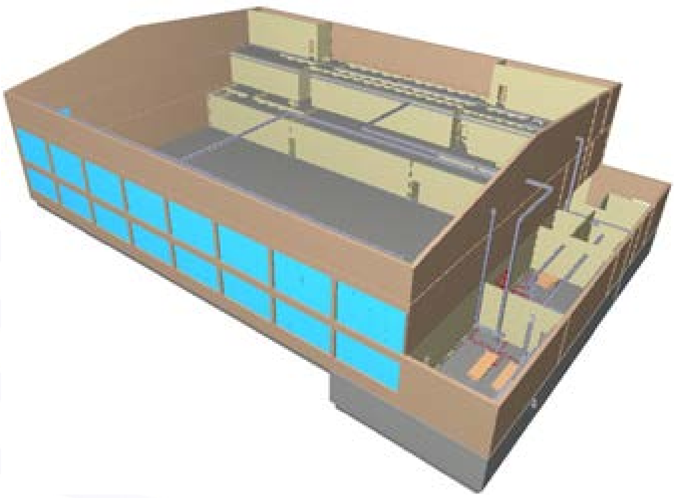

Figure 2. Building Information Model.

BaaS will develop a standardized central BIM that acts as a 'one-stop-shop' for acquisition & stor-age of data from standard and non-standard sensor networks and provision of that data to upstream data warehouses that aggregate the data to support best practice facilities management. The BIM will be de-veloped using standard engineering definitions of sensors (e.g. temperature), energy components (valves, pumps etc) and energy systems (Air han-dling units, heat pumps etc.) as stipulated by recog-nized professional engineering institutions such as CIBSE (www.cibse.org) and ASHRAE (www.ashrae.org). The BIM will be developed using an industry data standard data model (Industry Foundation Classes – IFC). The IFC data model will have to facilitate interoperability with multiple data warehouses.

The use of an extended BIM to describe building-related information and to generate all components aspires to deploy a generic widely-applicable tool to a wide range of building typologies.

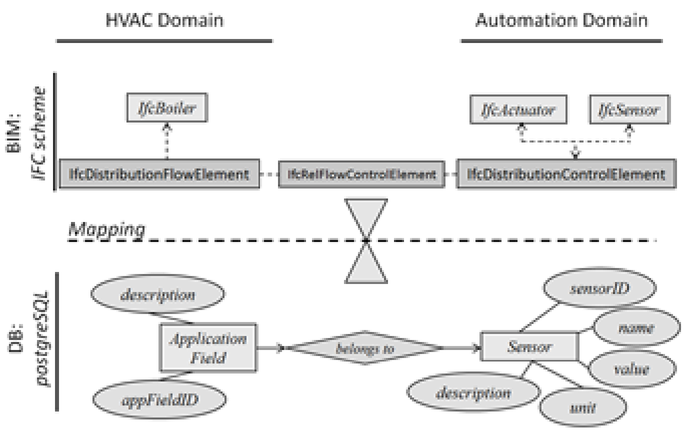

Figure 3. Mapping data schemes between both, BIM and data-base.

BaaS project proposes the development and test-ing of an integrated data management technology platform capable of capturing both energy and envi-ronmental data by utilizing sensor networks and an integrated database management system that struc-tures this data to support the management activities that underpin building energy and environmental management.

BaaS addresses the problem of inconsistently and incompletely stored and managed building perfor-mance data by establishing an integrated Data Warehouse Platform. The project will develop a Data Warehouse to support facilities management relating to environmental & energy performance activities in the first instance. This will involve formal data mining and analysis of the data contained in the BIM and the creation of multiple representations and views of the data to support activities that include Inspection & Maintenance, and Control and Config-uration of building management systems.

4.2 Middleware Layer

The middleware layer will be a set of services to provide transparent two-way communication be-tween the building and the high-level services. It acts as a building gateway (BGW) in the individual buildings which abstracts from the BMS particulari-ties and provides a generic and well-defined inter-face for the communication platform to interact with those BEMS which implement standards building automation protocols.

This project will progress beyond the state of the art with respect to the way how a communication platform can interface with the individual BEMS of different buildings: this project introduces a building gateway (BGW) in the individual buildings which abstracts from the BMS particularities and provides a generic and well-defined interface for the commu-nication platform to interact with a wide range of BEMS, for sending configuration settings to the BGW, and for propagating commands from the plat-form through the BGW to individual BEMS as well as passing data from BEMS (e.g. sensor data such as in-building temperatures) through the BGW to the communication platform. Additionally, more dy-namic ways of interaction between the communica-tion platform and the BGW such as the aforemen-tioned Web Services will be considered for applicability and extended if needed to carry data relevant for BEMS.

The BaaS project will focus on identifying the best gateway service and building service architecture to allow best tools for building control ICT system in-tegration and interoperability with different systems. Integrating tools will be developed that support easy of communication and open interfaces. This project proposes the development of ontology-based service composition framework for integration of internal and external ICT-systems hosted in an open cloud-based environment. BIM should be extended to in-clude function requirements and service specifica-tions targeting for a holistic Building Energy Man-agement and Control including a Performance Moni-toring system.

An important point for creating the data models and shared middleware platform is privacy and secu-rity, it is clear that any new technology has to look at privacy and security for having an impact. First ideas of privacy-preserving energy management systems and suitable data aggregation were developed recently (Bohli, 2010).

4.3 Application Layer

The service layer will provide building character-istics (as available from the BIM), and measurements (as available from the DW) for high-level services which, for instance, could intelligently perform building management operation. During normal op-eration the middleware platform will abstract build-ing devices, the data warehouse will be the central data repository.

5 Expected result

Based on the concise analysis presented above, BaaS attempts to fill a number of methodological, techno-logical and practical gaps for the development of a vertically integrated building energy management solution for integration of multiple trusted and un-trusted cloud-enabled services; this solution will have to be able to support:

- *Data management in charge of aggregating static and dynamic data from building (BIM, Data Warehouse and BEMS) and external sources in a harmonized way, and make them available in near real time,*
- *Communication interfaces between the communi-cation platform, external ICT systems (e.g. weather services on the Internet) and the building systems in a secure manner (Building Gateway).*
- *Current IFC scheme and extension about proper-ties regarding building dynamics, mapping the data schemes between both, the data warehouse and the BIM,*
- *Implementation of high-level services (models, simulations and algorithms) for energy saving and operation optimization.*

6 Conclusion

In summary, the crucial points for interoperability are harmonized data models, interactive communication protocols and architectures respecting privacy and security and accompanied with a certain level of open standardization.

Hereby vertical standardization of data represen-tation to enable communication between standard data models within each associated industry will greatly benefit the market for integration of diverse systems.

The reliance on BIM for building description en-sure that the system will be generic and usable to the whole building lifecycle enabling information from previous phases like design and retrofitting phases to operational phases.

Overall better interoperability and standardiza-tion, and integration of the high level services will make the BaaS system a generic ICT-driven enabler of energy efficiency.

7 Acknowledgments

The authors would like to acknowledge financial support by the European Commission under the 7th Framework Programme, call FP7-ICT-2011-6: ICT Systems for Energy Efficiency, "BAAS" Project, Contract No.: 288409. DVR would like to thank Mr. Katsigarakis for fruitful discussions that led to the culmination of some of the ideas presented in this paper.

8 References

1. Ahmed, A., Ploennigs, J., Menzel, K. , and Cahill, B., "Multi-dimensional building performance data management for continuous commissioning," Advanced Engineering Infor-matics, vol. 24, pp. 466-475, 2010.
2. Bell, M.: Service-Oriented Modeling: Service Analysis, Design, and Architecture. Wiley & Sons. 2008,
3. Fowler, M: Patterns of Enterprise Application Architecture, Addison-Wesley Longman, 2002
4. Jang, W.; Healy, W. M.; Skibniewski, M. J.: Wireless sensor networks as part of a web-based building environmental monitoring system, Automation in Construction, Vol. 17, No. 6, Pages 729-736, August 2008
5. Jens-Matthias Bohli, Osman Ugus, Christoph Sorge: A Privacy Model for Smart Metering, In Proceedings of the First IEEE International Workshop on Smart Grid Communications (in conjunction with IEEE ICC 2010), 2010.
6. Kastner, W.; Neugschwandtner, G.; Soucek, S.; Newman, H. M.: Communication Systems for Building Automation and Control, Proc. of the IEEE, Vol. 93, Nr. 6, pp. 1178-1203, 2005.
7. Liebich, T. (2010) Unveiling IFC2x4 - The next generation of openBIM.
8. Maile, T., M. Fischer, and V. Bazjanac, Building Energy Per-formance Simulation Tools-a Life-Cycle and Interoperable Perspective. Center for Integrated Facility Engineering (CIFE) Working Paper, 2007. 107.
9. Malatras, A.; Asgari, A.; Baugé, T. & Irons, M.: A service-oriented architecture for building services integration. Jour-nal of Facilities Management, Emerald Group Publishing Limited, vol. 6, no. 2, pp. 132-151, 2008.
10. NIBS, The National Institute of Building Sciences, “Whole Building Design Guide”, Washington D.C., 2011; http://www.wbdg.org/project/doc_comp.php (last visited January 2011).
11. Schach, R.; Kabitzsch, K.; Höschele, V.; Otto, J.: Integriertes Facility Management. expert Verlag, Renningen (ISBN 3-8169-2467-0), 2004.
12. Shen, W., et al., Systems integration and collaboration in archi-tecture, engineering, construction, and facilities manage-ment: A review. Advanced Engineering Informatics, 2010. 24(2): p. 196-207.

13. Singh, V., N. Gu, and X. Wang, A theoretical framework of a BIM-based multi-disciplinary collaboration platform. Au-tomation in Construction, 2010.

14. Valipour H.M., Zafari B.A., Maleki K.N., Daneshpour N.: A Brief Survey of Software Architecture Concepts and Ser-vice Oriented Architecture, in Proceedings of 2nd IEEE In-ternational Conference on Computer Science and Infor-mation Technology, ICCSIT'09, pp 34-38, Aug 2009, China.

15. Vanlande, R., C. Nicolle, and C. Cruz, IFC and building lifecy-cle management. Automation in Construction, 2008. 18(1): p. 70-78.

16. Wang, S. & Xie, J.: Integrating Building Management System and facilities management on the Internet. Automation in construction, Elsevier, vol. 11, no. 6, pp. 707-715, 2002.

17. Wang, S.; Xu, Z.; Cao, J.; Zhang, J.: A middleware for web service-enabled integration and interoperation of intelligent building systems. Automation in Construction, vol. 16, no. 1, pp. 112 - 121, 2007.

18. Wong, JKW and Li, H. and Wang, SW., “Intelligent building research: a review”, Automation in Construction, 14(1) 143-159, 2005.