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Chapter 4: Designing scalable IT frameworks using cloud connectors to achieve seamless integration between learning platforms and energy management systems

4.1 Introduction

This chapter provides a theoretical contribution to designing scalable IT frameworks for the integration of "interaction-based" informal learning environments for engineering education and cloud-based energy management systems developed within the scope of a project. The presented framework is based on a "loose coupling at all levels" design paradigm. This design paradigm aims to overcome the complexity overheads of tightly coupled fixed topologies while bringing to the domain of target systems the base features of heterarchical resilience that are seen within the living systems of the natural world.

The studied initiating example of this class of systems is educational services within a resource-aware scenario of a smart city with heterogeneous components of both the learning and energy domains operating within cloud-based settings. Specifically, the study investigates the relation between the educational function on one hand and the energy usage function on the other. This allows educational administrators to adjust the educational process in a way that aligns the usage of energy resources with the specific educational targets pursued. Positively, it provisionally motivates tenants in educational buildings to adopt more sustainable educational practices in their temporary living quarters. This behavior change should be the main concern of sustainability-oriented initiatives focusing on energy-related habits in educational frameworks that are developed in this setting, including e-learning services.

4.1.1. Overview of the Document Structure

We start this document with a short overview of what we understand as learning platforms and energy management systems, what type of functionality they provide, and what kind of features they could provide if more advanced integration between IT systems were to take place. We also provide a brief review of related work in the field of Smart Learning Environments. The second section outlines the energy management problem with a focus on University Campuses. We describe the Campus Aggregate Model, and how it allows building the energy management problem as a market problem, how specific campus management constraints are addressed, and then summarises the policy changes supporting the new high-accuracy campus model. The proposed platform development framework and reference architecture, which aims to support both short term and longer term integration of Open Source Learning Platforms and Campus Energy Management Systems is described in Section 3.

Fig 4 . 1 : Integrated Framework for Smart Learning & Campus Energy Systems

This framework aims to support sustainable, scalable, robust, and lower cost solutions by making use of automatic and off-the-shelf tools, multiple but confined data storages, and generic interfaces that can be adapted to the specifics of each IT system.

Proposed mechanisms for the introduction of security and privacy protection and early experiments and test work in support of the platform's development is discussed in Section 4. Finally, some conclusions are outlined.

4.2. Understanding Cloud Connectors

While a variety of EAI application tools and an SOA can be utilized to integrate management agents and energy management/forecasting servers with Learning Management Systems (LMS), it is common to use enterprise-grade EAI applications and SOAs to realize that integration. On the other hand, we propose to use distributed cloud connector appliances as the basic integration building blocks. In a nutshell, message handling agents using web services are integrated with different corporate web servers through cloud connector appliances. Additionally, we describe the default style of their deployment that leverages content delivery networks to relieve the traffic intensity of student-teacher collaboration in LMS. This paper focuses on the integration of management agents with LMS in public-private CSCU. Preventive management is achieved by utilizing PAEP to provide student-side agent-based calculation facilities based on collected data, e.g., student-side demand response and solar power forecasting. Contraction actions are affected by the external energy market and the building's integration with the campus energy system. We also discuss PAEP and the student-side collaborative design for CSCU and PV-based campus ECO2 powerhouse overpairing.

First, we describe cloud connectors as a way to realize the high-performance integration of remote applications. We put them into perspective with other tools. Then we elaborate on the message handling agent-based integration of combination technology in e-learning education and cloud-based several agents with LMS, and the mechanisms embedded in the public-private cloud service deployment of public-private CSCU. It should be fairly accepted that ACCES's intrinsic property of deeply distributed collaboration actions among participants. Web-based e-learning (which may progressively upgrade to cloud-based form) is a nearly universal user technology that is frequently utilized to provide a modern interface for users to achieve learning goals. Still, LMSs are components of content delivery networks that, in most cases, realistically enforce information security. Due to the enormous length and the huge variance in quantity over professional education, educational software development and deployment business is marked by the learning content. It is increasingly common to solve this security problem using the add-on of message handling agents with a programmatic interface of this add-on.

4.2.1. Definition and Purpose

The use of IoT in smart environments that house educational settings results in leveraging the intelligent awareness, comfort, and energy sustainability benefits. Avoiding disconnected silo-like systems and creating an IT architecture is a must. In this research study, we focus on scaling and managing educational settings' IT framework that integrates learning platforms with energy management systems. Learning platforms referred to in this study are IoT-based educational technology platforms that are focused on enabling personalized smart environments for intelligent awareness, personal comfort, and learning support activities, particularly in educational spaces. Current definitions of learning platforms point to Information Communication Technology services that are independent of the underlying infrastructure that is part of or supports educational activities.

A learning platform can be viewed as an integrated set of capacities for data gathering, data analysis, monitoring, and control and response that produces information to manage behavior in the direction of creating smart environments that serve intelligent awareness, comfort, and effective learning support activities. There is no one technology that universally enables smartness, as no single technology could afford to support all the functions and services necessary to respond to user requirements for performance, security, safety, comfort, governance, accessibility, and aesthetics. The function of a learning platform depends heavily on the quality of its technology components and the competencies that are developed, implemented, and maintained. Energy management systems are present in countless buildings and are made up of several subsystems. Dozens of proprietary Building Automation Systems products, many networking protocols, and hundreds of unique control sequences drive these subsystems.

4.2.2. Types of Cloud Connectors

As already stated before, cloud connectors are crucial components of any cloud broker, as they are the ones that create federated cloud applications. A cloud connector service is a specialized type of cloud service providing a network service that facilitates consumer usage of one or more cloud service provider offerings. The core functions of the cloud connector include creating and maintaining virtual machines or network cloud services, establishing virtual networks, leading to a fully connected infrastructure between dispersed data centers and platform architectures, creating point-to-point and multipoint communication basics for SaaS and PaaS. These connectors provide clear interfaces for the creation, modification, and application of PaaS or IaaS services, including cloud storage. IT professionals are in need of a reliable mechanism to search for and use connectors supporting these IaaS offerings functionalities. Specialized cloud connector search catalogs exist, but visibility in the vast web has to be improved to guarantee that the target audience takes advantage of this downstream value segmentation. The proposed functional connector classification, the rule of thumb for future proposals in this trend, includes business collaboration connectors, cloud access and integration connectors, data and sensor connectors, data storage, processing, and data transport connectors, infrastructure services connectors, lab companion connectors, research analytic connectors, and specialized services connectors. Scientists and engineers should have an available central registry to search for the existing connectors that might address the inherent complexities and the IT requirements to run parallel workloads or thousands of processes hundreds to thousands of times faster, easier, and more affordably at risk-rewarded prices.

4.2.3. Benefits of Using Cloud Connectors

The design of scalable and reliable connectors allows interaction with large data volumes stored in cloud-based LMS and EMS solutions. Most details of this solution are defined in the cloud environment. There is no necessity for the development of additional hardware as is necessary in usual on-premises based LMS systems. Moving the service via the platform allows for a reduction in the costs of resource maintenance for the internal IT department as part of the budget. These requirements are in line with the integration of e-learning tools and Energy Management Systems (EMSs). A traditional method to integrate IT systems is to write custom code. This is, however, labor-intensive and increases the risk of discrepancies between the systems. Another way to approach the problem is to use middleware, which has built-in adapters.

The use of cloud connectors promises to deliver similar benefits, such as application integration, communication between cloud and on-premises services, and performance enhancement. Cloud connectors serve as a tool to deliver scalable, flexible, and accessible service, which would be difficult and time-consuming to develop and maintain. In particular, cloud connectors make LMS-EMS integration feasible and affordable for smaller institutions. The cloud and its data storage are managed by the vendor. Users can purchase and download their cloud-based media, access the e-courses available 24/7, paying for consumed resources, and create their classes and take the e-courses to administer their classes. The design of scalable and reliable connectors allows interaction with large data volumes stored in cloud-based LMS and EMS solutions. Most details of this solution are defined in the cloud environment.

4.3. Learning Platforms Overview

We start this section with an overview of recent learning platforms that were launched by well-known organizations. This knowledge is essential for the design of the learninggrounded intelligence that is crucial in intelligent demand-side management systems. The platforms employ a range of technologies including mobile devices, adaptive sampling algorithms, data visualization techniques, video snippet clarification algorithms, question routing, and applications for the support of personalized learning.

Today, personal computers and the Internet have made it possible to disseminate much wider the knowledge created by experts who spend centuries acquiring it. There are triggers in recent online platforms developed to maximize interaction among students, a successful approach in traditional education. Consider the example of students in a seminar who receive each week the lesson notes as well as old exams from several courses. When one question is asked by the instructor, all are available to provide the answer!

4.3.1. Key Features of Learning Platforms

Learning platforms are generic platforms that support courses but do not supply the courses themselves. The courses can be on subjects within one particular academic discipline or else concern issues that cross faculties. Learning platforms normally contain features like an announcements bulletin board, communication tools, access to resources, course lists, content and evaluation tools, collaboration tools, and instructor tools. Included are such teaching functions as document presentation of each kind (text, audio, video, image, etc.), interactive learning with real-time tracking, communication, and remote interaction with authentic learning. Included too are other essential components like access control, internet safety measures, systems to manage teaching, organization and maintenance, student assessment for all teaching approaches, personalization, videoconferencing, and problem-solving sessions with remote access to software used in the discipline.

Available resources include both content and services. Content is deliverable with metadata and format. Content could go beyond the offering of access to library collections as structured material. Content agents function as course guides to diverse subject domains by providing access to dynamically generated and interactive teaching guides, without restrictions due to geographical, financial, or time limitations. Content agents can provide additional motivational incentives for the students. Content agents have to provide the environment to distribute teaching areas. Content agents are part of participants' browsers. They provide direct services for the development of teaching and learning environments and are efficiently managed, monitored, controlled, navigated, and evaluated. Their concepts undergo implementation, improvement, use, and reuse. Each participant in a distributed teaching area has a personal agent. Their attribute functions must carry out teaching jobs with the awareness of the participants in the system. Their goal is to integrate the students' work settings into a distributed teaching area, ensuring that the students can act alone in the attainment of expected interdisciplinary and multidisciplinary abilities.

4.3.2. Current Trends in E-Learning

Introduction of the chapter: 'Designing Scalable IT Frameworks for Integration of Learning Platforms and Energy Management Systems'. The chapter is devoted to the current trends and state of modern e-learning systems. An original role of e-learning is emphasized – education support by e-learning for future engineers and system designers. Modern society develops rapidly and leads to more and more problems in different life domains because these problems demand sophisticated intelligent systems to analyze and solve them. Therefore, such specialists are necessary. Where architecture and management (including energy management) of e-learning are important tasks. Nowadays, e-learning has become a multidisciplinary area and incorporates educational, training, and retraining modules in different fields. Among almost 90 different e-learning platforms, each of them has its own specific purpose in distribution, content organization, and communication methods. Obviously, e-learning systems vary in their goals, content, and tools which they use. Here we consider a new scope of e-learning: education in architectures of IT approaches which system designers must use to organize mutual work of e-learning and energy management systems aimed at creating an environment in which the required specialists can be prepared.

4.3.3. Challenges in Integration

There are and will be a plethora of learning platforms and a wide range of commercial and academic ESB-based learning ecosystem solutions to accompany them. The Enterprise Service Bus (ESB) performs this and other tasks employed by scalable IT, including message transformation, intelligent bus routing, plug-and-play services, and standards-based messaging. ESB is a mechanism for ensuring data integration in a highly distributed, modular, and complex architecture. This is especially important as developers create applications that acquire data from a variety of increasingly rapid sources. The ESB should be designed to effectively manage the complexity and tremendous benefit of allowing one service to "react" directly with data distributed at many events. The Enterprise Service Bus is therefore a fundamentally enabling mechanism for value chains, as it enables services in the chain to interface in a manner that often cannot be known when services are created for ESB. It is, by its very name, a bus with a collection of functions that every one of its attached applications is capable of.

The nature of rapid data and the growing frequency of even larger data applications make it important to design a synergy ESB/CEP that provides practical-specific value. Often, new value chains and independent R&D activities cannot bear the costs associated with frequent large data processing. Furthermore, not all platforms for technologies that have a high entry cost are of a scale changed between rich, thin, pull-oriented services and capabilities against repeated analyses. Consequently, the combined event processing capabilities that are at the heart of the ESB can fall victim to the open-source development curse. Even when the technology is available, the value at risk of rapid data generated from small deployments of a technology that could demonstrate and develop needs to be considered. ESB's rapid, open-source developments, services provided by emerging research markets, and solutions sold by small niche market providers can minimize the cost of realizing these opportunities while retaining the quality of both good. This is the problem the paper aims to solve.

4.4. Energy Management Systems Overview

Energy management is often perceived as an engineering discipline traditionally focused on energy conservation and energy cost, requiring precise knowledge about the thrifty effect of the measures implemented. This point is not a surprise, as the major initial goals of energy management systems were to help organizations in the field of energy procurement and banking, portfolio management, along with energy accounting, as well as to keep up with the complex legal requirements. Until now, a great number of different energy management programs and systems have been created and developed to support the workers responsible for energy management in their everyday problems. Those applications, such as Computer-Aided Facility Management, Building Automation Systems, Energy Information Management Systems, Facility Management Information Systems, Facility Operations Management Systems, Operations Management Systems, and Project Management Systems, have a diversified impact within organizations and can offer a variety of functions. This has really helped different groups of workers to reach their particular energy goals by monitoring energy use, analyzing energy trends, detecting unanticipated increases, and reducing peak demands, fixing the causes of the positive or negative energy trends, etc., all in their areas of responsibility.

The development of Energy Information Management Systems was supported by considerable progress in the fields of telecommunications, information and communication technology, data management, and artificial intelligence. These technical capabilities gave manufacturers of computer software the ability to design Energy Information Management Systems services by filling them with more and more advanced and diversified functions, capable of simple data visualization and understanding. A deep analysis of the initial goals of Energy Information Management

Systems, which were to support enterprises with efficient energy management activities, helps to reveal how important it is to consider how economic and environmental issues have also turned out to be very important in determining business targets. Therefore, achieving an enterprise's efficiency in the field of energy, supporting energy-saving investments, assessing the reduction of energy costs and the risks associated with energy procurement, evaluating the best investment methods, and avoiding environmental fines are indispensable topics to carry out an Energy Intelligence Management System.

4.4.1. Components of Energy Management Systems

Energy management systems consist of several key components, the internal innovative structure of which depends on the downward vertical supply chain present in the cycle service of TEO-IT: service demand—TU-TE. Terminal equipment is an integral part of the overall energy sensor system. It is designed to collect data, energy-saving, and operational and technological control tasks with the installation or service of various software. The key differentiator and innovative object in our approach is the use and development of a special part of business process technology with an extended task service life.

The consumption of energy, the organization of its control tasks, and the managerial preventive system are problem-solving processes where energy consumption in a particular group of services or trade protocols can be identified and controlled over a particular range of operating modes. Results on creating white matter in these regions of technology make it possible to use LE to better meet the service requirements of each of these classes of energy-dependent servers.

4.4.2. Importance of Energy Efficiency

Higher education institutions, together with schools, are among the largest consumers of electricity per unit of area. In the traditional educational system, in addition to services provided to students, services to teachers and to research students, fixed laboratory requirements, and numerous hours of operation are included. Due to the strict legal requirements regarding the control systems of all the previously listed energy consumers, and given the diversity of the buildings and, above all, their different purposes, large buildings such as schools and universities present energy consumption challenges. It should be noted that most of the educational buildings managed in Portugal have been around for decades or even a century, very often with growth that does not fit the current legislation or the real needs of the users. Energy efficiency is considered a new source of energy that can increase the economy of organizations and society. It is an important environmental issue as well as being a significant dimension of sustainability.

Climate change issues, increased sensitivity to environmental performance in the context of social responsibility, and the need to reduce extraction and generation of energy appear inevitably linked to corporations and the management of resources invested in the built environment. The theme of energy performance in the built environment and energy management requires a cross-cutting approach to understand the problem in an integrated way and to seek optimizing solutions both at the level of management, architectural design, and at the component level. Consider becoming a more actionable index, simple for the high-level manager to understand, compare, and evaluate. The energy consumption at a certain time influences the price and energy security of electricity. The existence of instantaneous demand, quantified on an hourly basis, is responsible for the deviation of the price of electricity from spot markets. The markets are highly influenced by the variation of energy prices that are more sensitive to demand support until the sources are remunerated. These aspects contribute to the surplus of electricity with low value, reducing the overall efficiency of the electricity system; consumers pay for the standby capacity and for the non-recoverable resources that require adjustments to the structure of the transmission and distribution networks. These system inefficiency characteristics are recognized as contributing to the widespread variations in electricity prices that accelerate climate change. It invests in initiatives that enhance the system, improve the comfort of people, better control energy consumption, and thus reduce electricity bills.

4.4.3. Integration Challenges

There are a number of factors inhibiting successful integration of learning platforms and EMS, including the legacy and service-oriented architecture of IT systems involved, variety, complexity, and lack of standards in data, services, and physical environments. Most EMSs are traditionally developed as monolithic, reducing the overall scalability of deployed systems with heavy costs for their maintenance and upgrade. This often leads to a necessity for the development of a new learning management system or data aggregator application to integrate the virtual with the physical learning environments. On the other hand, all LMSs and platforms typically have their own user management processes and legacy authentication mechanisms. The LMS business processes are often as complex as those in large LOB applications. So, the loggerheads of integrating the LMS and EM processes bring down new opportunities for companies in thought leadership, revenue growth, enhanced branding, and sustainability. The question of how to make a seamless low-energy integration of the applications to process the educational and management data appears to be interesting and difficult.

Currently, there are some challenges in applying existing frameworks and methodologies to the accurate definition and realization of integration based on the commonly used standards in both SOA and data domains, for real use cases and discussions. On the other hand, in order to escape the ad-hoc nature along with the project-oriented considerations and achieve a one-step guide for enabling the development lifecycle, it is essential to open the research area of scalable service-oriented frameworks with regard to both teaching and management information. First of all, the standardization and conceptual description of the electric microgrid components are not mature enough, and the emergence of Internet of Things solutions does not create the necessary data model consensus. Indeed, the support for mature, robust, and efficient engines capable of handling and managing complex scenarios is missing in most popular learning, teaching, and administrative systems.

4.5. Framework Design Principles

This section explains in detail the proposed PIM and the associated P-mode. This section provides specific examples for the integration of Energy Management Services. The architecture and the related components are specified to show the core concepts used in proposing the framework for the integration of e-learning platforms and Energy Management Services.

Proposed Platform Integration Model

We came up with the following Platform Integration Model for the integration of Learning and Energy Management Platform. The approach takes into consideration important aspects such as scalability, adaptability, modularity, and flexibility as important principles for the e-learning platform and energy management systems.

In this section, we present a methodology that outlines the building blocks that will provide our guide towards understanding the functional and non-functional requirements crucial in the design of the integration of the Learning Platforms. This section will address system description and specification, conceptual modeling of the system, functional analysis, and related use case diagrams. The integration of the theoretical content and the real-world applications will constitute the basis for novel architectures, involving learning platforms' services and knowledge management services based on business process models developed in Semantic Web Ontologies and from frameworks.

4.5.1. Scalability Considerations

There are significant differences in the sizes of educational institutions. In terms of modern educational technologies, such as open education resources and learning platforms, the most significant aspects are related to the number of teachers and students, and the number of courses provided. The second major aspect is the load on the platform and other educational services as a result of the number of students and teachers at any given moment. In terms of energy management, the energy management system has to deal with the part of the institution's buildings and with the physical infrastructure that is behind the operations of the learning platform, communications, and data storage. Both of these services can operate independently by principles of aggregation or can be connected in case the number of students is small. This can be accomplished using a single server for all software services and network equipment for traffic aggregation, which is a reversible process. The juncture point details are currently untested. Evidence suggests a large institution may use the capabilities provided by an energy management system and the providers of its learning platforms, while other institutions may outsource them to better focus on their main professional activities.

Special attention should be paid to the possible application of the proposed method for scalable operation of both the learning platform and the energy management system. Dynamic reorganizations, stratification, and heterogeneous aggregation by services, by student clusters, and by course clusters, depending on traffic aggregation or student flows due to education restrictions could be necessary for a larger number of students. Further research, development, and deployment of the multiservice cluster infrastructure with port and link sharing become important. Many learning platform solutions use equipment to provide such functionality, but their major functionality is for virtual LANs and their use for different types of traffic—data, control, and voice—is problematic. In our case, the use of multimedia capabilities is limited by the specifics of the educational process. Since the data path is predefined by the student and course clusters, the function can be moved to other devices that are involved in the process and support logic aggregation by IP or MAC addresses and different types of traffic synchronization. This requires no alteration in the software management of the controller; therefore, it does not present any significant problems, although the development of new portable code is required and implies the usage of certain proprietary technologies in the equipment.

4.5.2. Security and Compliance

The vast amounts of data that can be gathered when collecting information on consumer behavior can be used to deliver tailored services that translate into savings for both consumers and service providers. The storage and processing of this data are typically administered and managed by third-party entities that may be located in jurisdictions that offer no jurisdictional guarantees for this data. Furthermore, the processing of consumer data for business intelligence purposes is subject to standard guidelines. Providing for the secure transmission and storage of data and implementing a process for data scrubbing are common practices.

Security in the electricity demand management sector goes beyond the simple concern for the protection of sensitive data. Security issues are connected with data analysis integrity and at later stages of data analytics. Subsequent considerations during data analytic procedures can be condensed within the idea of ensuring results transparency: regulators or agents can check why certain rules are in place to ensure no discriminatory or, worse, anticompetitive practices are implemented. It seems interesting that policymakers are concerned with the anticompetitive practices of regulated parties. However, antitrust authorities did design specific recommendations for this sector. Another aspect in the scope of security during data mining is the robustness of a research project. A data node could intentionally collaborate to contaminate the results by injecting wrong data or modifying values of data entries. Nonetheless, the ability to detect this event when it has disrupted a decisional process is only a secondary interest. Ideally, modules to detect and exclude spurious events and entries close to the origin node during processed data should be preferred.

4.5.3. User Experience Design

The IT framework described in this study addresses developers and integrators who need to understand how LMSs and BEMSs can be interoperable. However, the complexity and diversity of IT products that can be built upon the proposed approach can hide the integration of two domains that are not so heavily addressed by common IT projects. Indeed, the main stakeholders influenced by the developed platform are students and teachers of an educational institute. In this section, we present how the implementation of the proposed IT framework should be done to offer a potentially user-friendly experience to the stakeholders of educational institutes and energy and facilities management services providers.

As a pedagogical tool, the LMS is designed primarily for the students, who work for most of the lessons or subjects and occasionally for the teachers who are the course managers. In general, the connection with the BMS can be overlooked by the teachers who handle their courses. At the beginning of the course, the LMS is constituted by several course formations containing lesson materials that students should assume to learn, as well as the upload of the related lessons and quizzes whose purpose is to check the learning of the students. For instance, it is highly recommended that the formation is aligned with the planning of the course. The BMS provides the space occupation analytics and the control for devices and equipment that influence energy consumption. In some sophisticated BMS, a complex economic simulation concerning bills due can be created in advance for internal space occupation. Preferred energy sources can be used to cover the energy demand: PV production, battery storage, or local natural gas engine cogeneration system. Beyond these basic features, the BMS may also have relative sensors in classrooms or some weather prediction tools, among others. After functioning, the BMS handles the actual resources also depending on the external unexpected elements. Due to the collateral discomfort generated by the alienation of the teachers with the course as it is planned at the beginning of the academic course, it is challenging to anticipate the analogous efficient handling of the unexpected elements responsible for changes in the BMS.

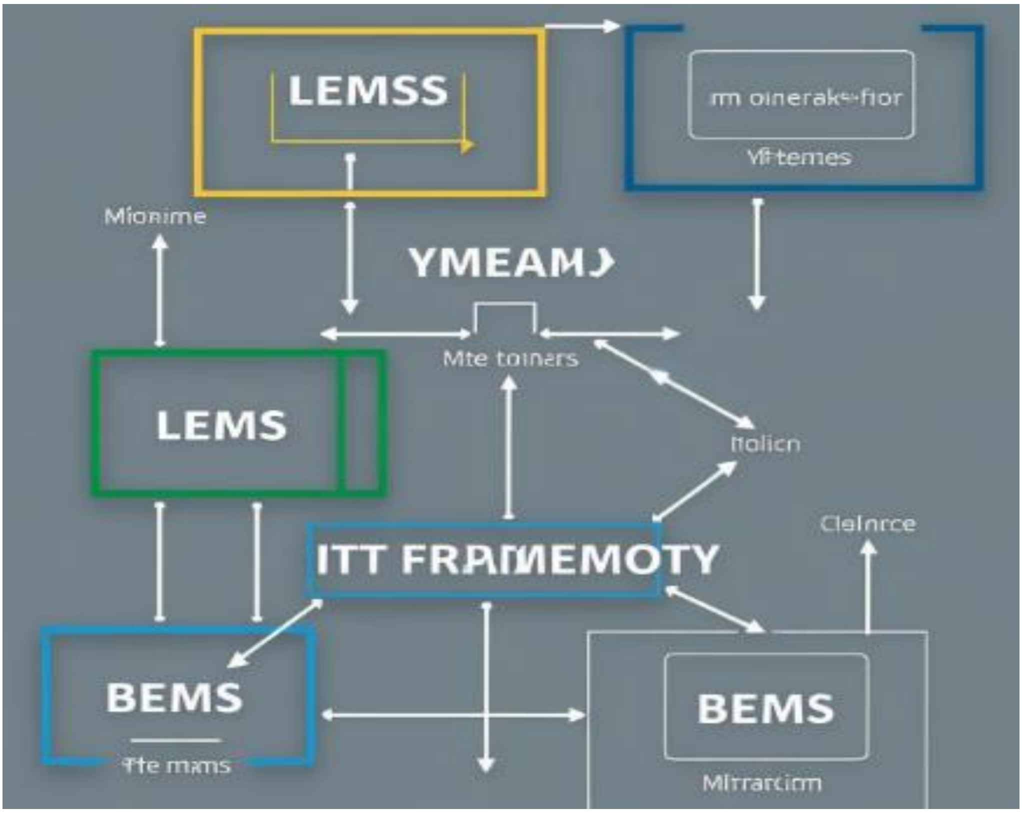

Fig 4 . 2 : Professional Integration Flow: LMS - IT Framework - BEMS

4.6. Integration Strategies

The development of seamless integration between LMS and EMS requires an IT framework that is based on a modular and scalable approach, forming an interoperability layer between both systems. In this way, independent improvement of the internals is allowed, and it also provides backward compatibility while the EMS is implemented or improved. This layer also shields the LMS from internal EMS details, which may need to change in the future. The energy-related data collected by the EMS solution needed by the discussion layer generally needs to be supplemented with actual data received by the EMS once classes are operating, as opposed to data delivered by temporal forecasting for scheduling. Additionally, it is likely that this data should be enriched with tags that describe which device table it is gathered from. During scheduling, and even forecasting, there is no need for the EMS to select this tag. However, during a class, if the data source is an actual control group, error-free tag selection is critical for correct operation. Ease in generating reliable data for two modes of operation is also critical not only for the plug-and-play but also for a neighboring IoT.

Now we have keys to the discussion and data flow layer of our interoperability layer. However, it might be clearer if learned knowledge was available to users via the LMS, as in other web-based, not necessarily energy-related services. This means LMS should, when possible, use EMS devices as sources of knowledge once they are turned on, for example.

4.6.1. API-Based Integration

Since the early days of commercial software services, application programming interfaces (APIs) and the process of applications that link or facilitate using two or more software services to facilitate shared data and usage have been important. APIs allow platforms to connect with each other in real time, such that real-time events within one platform can lead to actions in another platform, and updates in one can be reflected in another. The RESTful API software architectural style is increasingly popular because of its simplicity and the variety of resources and methods that it represents. This allows IT professionals to invoke the functionalities of RESTful web services, which are structured in a way that can be addressed by various methods, such as HTTP GET and HTTP POST, providing support to employ integration strategies to combine, migrate, and manage different platforms. Invocation is an essential IT management issue for API-based linkage, providing interface capabilities for IT infrastructures.

Many well-established online platforms have been addressed as being "API-based". For instance, the widely used online database has a comprehensive roadmap of the API because they have many tools for companies that want to use these pre-established knowledge resources. Understanding the APIs is under active research because of the lack of common knowledge or study. Regulatory research and high-level policy issues must resolve open technical questions or guidelines, deciding how APIs should be used. These questions include concerns about how platforms apply their terms of service, the costs of embedding a service, the permitted scope of services, sandbox development practices, the staff expertise required to execute a platform embedding strategy, preferred development styles, programming languages, legal constraints on use and access, etc.

4.6.2. Middleware Solutions

Middleware solutions are the cores of the whole framework. They deal with the disjunction between different software on different platforms in the network. When integrating many Heterogeneous Learning Platforms and Heterogeneous Energy Management Systems, middleware plays a significant role. The working mechanism and the performance of middleware have been studied and proved that middleware is suitable for architecture design of the integration of learning platforms and systems, and practical-enough for further development.

For the redesigned learning platforms and energy management systems, enclosed systems were built by making targeted-selectable plugins, such as hardware drivers, business logic, redundant computation business logic, and business logic of getting or delivering collaborative data. In order to support the re-architectured learning platforms and energy management systems, a time share collaborative server was provided. It deals with the situation of ambiguous computing performance between work and spare time. It saves energy effectively by shutting down redundant infrastructures. It also manages LEGO building blocks for future quick-building of learning platforms and energy management systems. The working mechanisms and experiment results show that the proposed server is both effective and efficient enough. Furthermore, the server can support the future re-architecture of learning platforms and energy management systems with an emphatically more effective and general-purpose way.

4.6.3. Real-Time Data Synchronization

Real-time data synchronization capabilities allow for close tracking and reaction to these changes and bring the possibilities for active predictive as well as correlative control and management services that would not be possible without them. To be exploited in learning and teaching, these capabilities have to be expanded to include the integration of campus-critical non-E-learning IT deployments, in coping with campus overloads or campus-needed load shedding. These exert a unique and challenging problem to IT frameworks which have to ensure the healthy operation of the systems stressed beyond the normal operation point and which have to ensure that a priority can be given to different curricular E-class activities with known contribution to campus-wide general objectives.

An adapted cascaded system of IT platforms consisting of a scalable services infrastructure of the E-learning platform, an event-driven data synchronization module, an operations research pattern model engine, and the energy management system is tested in order to determine the value and stress points of the real-time data synchronization capabilities. The system provided excellent access time to operational building status data. The event-driven data synchronization, deployed on a campus for transmission of data from an object digital twin to the scalable IT platform block including the simulated and real E-learning platform and the expert module at the server presented sub-second increments in the determining student request from the servers provided the heatmap.

4.7. Technical Challenges

We have analyzed the relevant relationships from both technical and contextual aspects. Each relationship has its particular purpose, which originates from specific needs, requirements, and technological principles. This initial architectural model should be improved based on the future development of learning platforms, building management systems, and smart grid technologies. In this section, we discussed some technical challenges for each relationship and the overall framework.

The creation, adoption, or termination of such complex relationships is very error-prone in the real world. Technical challenges exist due to the diverse deployment models and the heterogeneous nature of both systems. In addition, system architects have to address the limitations of existing standards and specifications in order to make these systems loosely coupled yet interoperable with minimal implementation complexity. Such challenges include the publication and discovery of services, policies, and events, system integration strategies, communication security and privacy, domain knowledge representation, and error tolerance. Although learning-managed domains and GPNs have been proposed, much debate has been, and will continue to be, focused on the precise technological choices and features needed in order to best benefit the needs of different customer preferences.

4.7.1. Latency Issues

Today's business IT infrastructure is enabling innovative uses of data, systems and internet of things (Botlagunta, 2024; Kumar et al., 2025a; Kumar et al., 2025b). The challenge is to ensure that businesses have scalable and versatile ways to access information as well as deploy and manage service and process data across networks. The key to successful web-based information distribution and visualization infrastructure is the development of frameworks that can support efficient services and applications. Given the present technological status, key concerns for scalable localization are sending data rapidly, providing scalable computing support, and data visualization. Real-time data updating is provided. In the related electrical energy markets, decision makers can then value decision support for electricity going up, mostly when current programs including but not confined to smart growth and real time value. As the information age gleans a glut of usable power, we are creating and connecting more sophisticated energy storage and expansion systems for a more efficient electricity market. Monitoring, processing and navigating great amounts of data from energy management systems provide improved grid security and asset control. But once information is delivered and requested on a daily basis, who asks the energy-consuming question? The present consumer dashboard model does not fit those business users who need real-time information.

4.7.2. Data Privacy Concerns

Given that learners divulge sensitive information during instructional activities, integrating learning data with energy data in LPS+EES increases the scope of privacy concerns. A context-aware, energy-aware adaptive security framework is presented that provides data security, resilience, and safeguards. The system is based on adaptive security, which uses the context-aware policy and geofencing model, providing a developed technique in physical security.

The resilience part enhances the environment safeguards. The architecture is proposed for a smart home, establishing a necessary adaptive security dimension. As future work, the architectures may be further modified to establish data management for LPS+EES.

The presented LPS+EES data management context-aware, energy-aware security framework utilizes a tailored security sub-model that limits potential threats to the different security contexts presented. The framework is proposed to address identified data-driven energy management system security threats and proposes efficient prevention and mitigation architectures that enable context-aware energy use adaptable to LPS+EES. Privacy awareness and protection techniques can be considered in the context-aware prevention part to enhance the proposed privacy-preserving security architecture.

4.7.3. Interoperability Problems

Achieving interoperability between the software components of a typical campus IT infrastructure usually involves breaking up a proprietary application solution into programmatically controlled Lego-like pieces. In practice, it is often a nearly impossible feat. The typical philosophy involves the definition of a set of standards for the communication between pieces that is agnostic with respect to the specific software modules and systems utilized. Then the implementation of the standards is taken by vendors so that different components of the overall system can be purchased on a best-of-breed basis. This typically works well for some categories of software like enterprise resource systems such as finance, HR, or student management, and for basic infrastructure services such as security mechanisms and applications. The usual approach to interoperability then consists of putting in place a set of connectors from the different applications' software components to the central systems.

However, a different situation occurs between educational tools on one hand and the energy, environmental sensors and actuators, and building management tools, which are the basis for the Campus IoT, on the other hand. The reason why this is so is not as much technical as it is economic—that users look for a different kind of design decisions for capable learning technology products and are willing to use a different set of management tools when using them. At that point in time, users shun simple best-of-breed strategies in favor of generic enough solutions that are based on a cohesive logic and a single service provider. In our case, the educational market forces educational tool providers or university IT managers to become de facto one-stop shops even while the market forces de facto one-stop shops known for the efficiency and effectiveness of their approach must either change their maladapted business models or are effectively excluded by the market.

4.8. Future Trends in IT Frameworks

In this paper, four organizations' case studies were used, implementing solutions in production environments. However, a given IT framework is intended for multiple contexts concurrently. Thus, some solutions may need to be adapted or discarded in the future. In this section, the main lessons learned from the IT framework validation in real operating conditions are summarized, and the possible impacts of future developments are analyzed. The results presented can be valuably used to introduce novelties in the IT frameworks and to help organizations optimize their existing interconnections.

The developed IT framework has been validated and fine-tuned with a considerable amount of diverse information sources, adaptation services, and their defined control algorithms and mechanisms under real operating conditions in various learning platforms. The results obtained from the four considered smart organizations clearly demonstrate that the introduced integration IT framework allows scalability and interoperability, enhancing the energy management of the smart organizations based on dynamic, adaptive, and highly scalable, configurable, intelligent building dimensions, all reaching clear and consistent benefits through the explored IT framework.

4.8.1. Artificial Intelligence in Integration

Integration domain refers to a smart integration of learning platforms and energy management systems that leads to satisfying the needs of learning with an optimal consumption of energy resources. The integration domain involves a continuous recalibration of the energy management system based on the lessons recorded successively in an enterprise resource planning system. The core point of view of integration is the continuous improvement of the interaction between the learning platforms and the energy management systems. In integration, the efficiency of the integration of the building management systems with learning platforms is crucial. Only a larger involvement of the learning platforms in the quality of services may lead to additional benefits that result from intelligent integration of artificial intelligence.

AI is employed to extract and verify lessons or to identify energy-saving improvements underneath the surface (Nampalli & Adusupalli, 2024; Kumar et al., 2025a; Kumar et al., 2025b). Only by correctly identifying behavioral outcomes of the occupants of the building may the learning platform use such inputs for optimizing its output and energy consumption. AI connects the learning through the integrated building systems directly with the energy management system. The planned and implemented improvement of the system's performance is the very proof of sustainable development in the BMS projects. Balancing between providing comfort to the tenants and the assigned scaffolding measures lies in the behavior of living beings. Educational buildings may be viewed as complex living platforms that require not only the intelligent synthesis of intelligent building systems but also the education industry to adapt the technology of education to support wider aspects of human intelligence and ways of mental development.

4.8.2. Blockchain for Security

Use of blockchain as part of the integrated IoT and IT framework can further provide a foundation for the cybersecurity of the school energy systems, ensuring secure data sharing across multiple systems. This can be done by not only offering a procedure for secure and private data sharing but also building the bedrock that can ensure cybersecurity by design into the operations of the pilots. These security mechanisms could provide CISOs of large school districts with a streamlined approach to spend school funds meant for CAPEX and OPEX for cybersecurity improvement, not limited to administrative computer systems but also addressing in a coordinated manner OT systems, which are increasingly opening up the school district to operational data that can be used both for operational improvement and as a recruited IoT system by threat actors.

Distributed ledgers provide methodologies that guarantee a secure, distributed, and immutable set of records known as an append-only ledger. This has made blockchain and distributed ledger technologies appealing in the effort to build secure systems that coordinate tasks across vast sets of entities. Numerous features can be enhanced, a significant one for consideration being smart contracts, which enable a summary set of rules to be defined that allow entities operating at a distance from each other to execute a contract without the need for the client to rely on centralized entities. These fall into several categories and offer varying levels of added security to the IT infrastructure and the underlying distributed energy system.

Fig 4 . 3 : Blockchain in School Energy Systems: Cybersecurity & Cost Benefits

4.8.3. The Role of IoT

The so-called Internet of Things (IoT) has often been portrayed as a harbinger of a future and brave new world, as well as at times increasing abstraction and alienation from the physical world. The IoT, which has been defined as many networked smart devices, or at least enough of them to make a big difference, is mainly connected through wireless links and uses a number of Internet technologies to enable self-configuration of devices, intelligent collaboration with other devices, and communication with backend services that in turn provide ubiquitous access to services through the Internet. In the ambition to connect everything through the Internet, IoT networks and applications will represent a major share of the overall traffic in the global Internet.

In recent years, there has been a particular emphasis on industry-specific IoT applications that cater to the Industrial Internet of Things (IIoT), also promoted under the concept of Industry 4.0. There is great potential in applying IIoT solutions because they can provide real-time information about the physical world around us, which can then be used to make more rational decisions. These implications in certain areas are profound and include, for instance, supply chain logistics and manufacturing, where Industry 4.0 has concentrated, but are thought to be relevant also for more general domains such as consumer electronics interacting with environmental, energy management, and building automation, and much of the integration of the ICT systems that impact the physical world.

4.9. Conclusion

We may conclude that large-scale and open learning that is designed for a large population of learners faces a similar challenge to cities when it comes to energy management: the systems in use were never originally designed to be physically integrated in a smart way. While the pressure for more accommodating energy management solution makes that concept herald a great leap forward, co-creating a similarly scalable smart integration for learning platforms is taking pace across learning innovation projects. This work concludes that the underpinning IT framework ought to be designed modular to integrate and adapt in flexible ways to effectively accommodate potentially fluctuating complexities and their level of integration ambition in transboundary learning innovation projects in particular. These organizations are interconnected in view of their highly interdependent processes and pursue broadly similar concepts to realize learning scenarios at scale. The conclusion is that their IT frameworks should not only adapt to their internal complexities but also to the assumed level of inter-organizational smartness exploitation using energy management scenarios as a proxy.

The default approach to the co-creation of the Smart Cities indicates a large scale–or regional–approach. Physical accommodations on a neighbourhood level might deal with a local momentum but usually with a limited momentum. An innovation team with administrative power faces the challenge that not all buildings are currently used the same way and will not all be renovated or updated at once. Novel energy management systems should fit seamlessly in post-modern as well as modern and in classical buildings. Additionally, citizens should be empowered–at least encouraged–to live and work in an energy efficient manner. In speaking terms, smart cities are supposed to combine data-driven and human-centeredness. Data-driven propositions are fairly appropriate for building configurations, predictions, and buildings–systems integration. On the other hand, human-centered user-engagement, user-monitoring, and user-feedback still has to be automated. The concept of smart integration of voice-responsive household robots for the modern house is already answered by the concept of indoor-pollution keeping, cleaning, and energy service domain integration with clusters for indoor climate, energy, and activity modalities in the feedback loop of the quality-driven or-parallel in-shop nested-polyhedra implementation of smart dialogue management.

4.9.1. Summary and Final Thoughts

This paper highlights the technical challenges and design aspects in combining learning management systems with building energy management systems as web-based scalable applications. Our presented IT framework introduces a scalable and distributed service composition solution based on SOA. Our case-based evaluation of the framework based on e-learning content processing and building energy management demonstrates the practical feasibility and scalability of the proposed IT approach in real-world settings. Economic, as well as environmental, implications of the integrated solution are detailed. Building facilities, because of their manageable space and complexity, have implications for more scalable and novel information technology solutions. Including IT master pattern control in combination with distributed service composition and service-oriented architecture frameworks and implementation models are relevant for those IT professionals involved in IT and facilities management.

We conclude that scalable and manageable services require standardized integration interfaces. For the integration area of physical IT, we propose the re-investigation and cross-education effort of the similarly named term 'Enterprise Service Bus' – one a hardware and software bus used between different, distributed service architecture-based systems in one master pattern, the other an actual bus driven by a driver that is executing one master pattern, also as a service-oriented architecture based on a master pattern. The argument and its practical impairments result from the growing prominence of distributed service-oriented IT patterns like the example solutions of learning platforms and energy management presented previously. Scalable, manageable service integration and service creation, and especially service deployment, require the performance of a scalable, manageable, distributed service-based computing infrastructure.

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