University-Based Smart Cities: from collective intelligence to smart crowd-conscience

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ABSTRACT

Quality of life, economic, knowledge and human capitals ‘development are the main challenges of the new wave of smart cities. Hybrid strategies of cost leadership and innovation need to be aligned mostly by highly deliberate university creative services. Physical, intellectual and social capitals are loosely coupled to better understanding of the urban fabric and norms of behavior. It requires the creation of applications enabling data collection and processing, web-based collaboration, and "real-time" mining of the collective intelligence of citizens. The Internet of Things (IoT) has been viewed as a promising technology with great potential for addressing many societal challenges, filling the gap in terms of citizen's sensitivity measurement. At the physical level of its ecosystem, buildings are responsible for about 40% of energy consumption in cities and more than 40% of greenhouse gas emissions. With recent products available today, energy consumption in buildings could be cut by up to 70 percent, but it requires an integrated and collective adaptive framework to show how buildings are operated, maintained and controlled with the support of IoT-based innovation and solutions. The number of new IoT protocols and applications has grown exponentially in recent years. However, IoT for smart cities needs accessible open data and open systems, so that industries and universities can develop new services and applications. The main aim is to develop energy efficient frameworks to improve energy efficiency by using innovative integrated IoT techniques. These techniques could integrate technologies from context-aware computing, context-dependent user expectation and profile and occupants' actions and behaviors. This paper tend to present in what extent a case of university-based smart city would invest in IoT as both strategy and process in order to enhance efficiency, innovative education and attractiveness for its current and future citizens.

KEYWORDS: University-based Smart cities, data collection, real-time processing, collective intelligence, IoT-based innovation, energy efficiency, context-awareness.

1. INTRODUCTION

The daily time for people in cities is spent spatially in home, work or even while driving between by car. People of contemporary cities are in search of both performance and comfort in these places. The more sustainable the city, the more it will be attractive and self-adaptive to its ecosystem. The city's innovative capacity is important for its ability to adapt and renew itself in response to new and future challenges. However, the resilience of a city not just depends on its capacity to produce innovations. A city's "make-ability" to respond to new challenges requires the ability to adapt itself, which does not necessarily require the implementation of innovation. Adaptive capacity is in part determined by the physical boundaries of the system. However, systems are in general more able to respond to new conditions if the system's components are more varied and the control of the system is executed at the lowest level [1]. This implies that resilient cities should have: Innovative capacity, a dense and varied social fabric, decentralized control and physical infrastructures that allow future adaptation. In short, the city should be more and more smarter and need to master its "metabolism" with a holistic and coherent transition strategy.

Quality of life, economic, knowledge and human capitals ‘development are the main challenges of the new wave of smart cities. Hybrid strategies of cost leadership and innovation need to be aligned mostly by highly deliberate university creative services. Physical, intellectual and social capitals are loosely coupled to better understanding of the urban fabric and norms of behavior. It requires the creation of applications enabling data collection and processing, web-based collaboration, and "real-time" mining of the collective intelligence of citizens. The Internet of Things (IoT) has been viewed as a promising technology with great potential for addressing many societal challenges, filling the gap in terms of citizen's sensitivity measurement. At the physical level of its ecosystem, buildings are responsible for about 40% of energy consumption in cities and more than 40% of greenhouse gas emissions. With recent products available today, energy consumption in buildings could be cut by up to 70 percent, but it requires an integrated and

collective adaptive framework to show how buildings are operated, maintained and controlled with the support of IoT-based innovation and solutions. The number of new IoT protocols and applications has grown exponentially in recent years.
The first purpose of this paper is to examine in what extent a case of university-based smart city would invest in IoT as both strategy and process in order to enhance efficiency, innovative education and attractiveness for its current and future citizens. The second purpose is to ask: what conditions are necessary for decision makers to realize a hybrid strategic alignment between the business model of the smart city, its organization and its operational tasks of teaching and educating its future citizens.
We outlay first a framework of the University-based Smart city (UBSC) as an emblematic new form of smart cities. Then we present an application of IoT inside a smart grid applied for smart buildings as a miniature innovative matrix of smart city that try to combine two strategies and to mobilize it as a tool of highly interactive curriculum of education inside and between its different schools and departments.

2. UNIVERSITY-BASED SMART CITY

The smart city is a new form of city management concept based on advanced hardware infrastructures, data and knowledge of city and citizens, to improve the competence of a city. It highlights the importance of Information and Communication Technologies (ICTs). According to [2], a smart city can be defined along six dimensions: smart economy, smart mobility, smart environment, smart people, smart living and smart government. Each dimension includes some factors that can further describe the idea of them. For example, under the dimension of smart mobility, it comprises (inter-) national accessibility, availability of ICT infrastructure, and sustainable, innovative and safe transport systems. The smart city originates from the concept of “Smarter Planet” which was put forward by IBM in November 2008 (Smarter Planet, IBM, 2008).

2.1. What is a smart city?

The smart city is not just a linearly scaled version of the smart home where all of our personal devices and domestic appliance are networked, automated, and good communicators. It is fundamentally about infrastructural and civic applications — the kind of things that constitute the techno-political ordering of society — and it is about the data and control those applications generate. To be sure, not all “smart cities” are implemented in the same way; we see three main types:

a) Those that are retrofitted and renovated with upgrades that transition current cities from dumb to smart. In these cases, “the smart city is assembled piecemeal, integrated awkwardly into existing configurations of urban governance and the built environment” [3]. Typically the underlying motivations are political economic, the result of an increasingly entrepreneurial form of urban governance that seeks to make the city into a center of (regionally or globally) competitive economic growth and activity [4]. Getting smart is the handy panacea for overcoming austerity, managing the urban system, and becoming an attractive place for capital to flow into — all by using “networked infrastructures to improve economic and political efficiency and enable social, cultural and urban development”[5]. Hence, smart initiatives promise to provide city leaders with the means necessary for achieving their entrepreneurial ends.
b) Those submitted to the ‘shock therapy’ method — or, what we might call smart shock — wherein a city undergoes a quick, large-scale integration of ‘smart’ ideals, technologies, and policies into an existing landscape. There are not as yet any cities that have experienced a full shock, but rather there are examples where the smart city transition has occurred to a greater degree and at a more rapid pace than the typical retrofits. Perhaps the best example is the Intelligent Operations Center built in 2010 by IBM for the city of Rio de Janeiro, which “draws together data streams from thirty agencies, including traffic and public transport, municipal and utility services, emergency services, weather feeds, and information sent in by employees and the public via phone, Internet and radio, into a single data analytics center”.
c) The idealistic models for the smart city are the built from scratch projects that are being constructed where nothing existed before. A canonical case is New Songdo in South Korea, which serves as a global test-bed [7] and urban laboratory [8] for implementing large-scale smart systems in the wild. At a cost of approximately US$40 billion, Songdo’s corporate and government backers hope to make it the world’s first fully smart city.

As we focus our study on this last type, we assume that smart cities must align their "design" strategies gradually while they run for the competitive course of self-marketing in terms of innovative organization and attractive policies of their capital human level. We believe that those built from scratch will succeed rapidly in shaping a more balanced, coherent and efficient core that matches with the big economic, social and environmental challenges that face the 21 century city. We assume also that those built from a highly interactive intellectual body (e.g. innovative universities) will be the perfect object of such development especially for emergent countries.

2.2. University-based Smart cities as a laboratory of urban metabolism

In some research works, concepts of smart cities and creative cities are interrelated. In particular, in studies that aim to build the concept of « smart cities » on the leverage of the « triple helix model» [9]where the smart city is apprehended from its capacity to make from its territory a place of innovation and creation of knowledge. The smart city is defined as a « network of organized knowledge production » [11]around ICT's and the knowledge economy. We talk then about "creative cities" (Landry, 2000), "intelligent cities» (Komninos, 2008), "smart cities" (Hollands, 2008) or even "selection environments" [10]to describe the "one best way" to combine innovation, smart citizens and well-being and healthy environments.

As an urban planning and governance movement, a lot of effort is expended on pushing and pulling "smartness" — the major corporate players work hard to push smartness as an ideal and to pull city leaders and investors into the smartness orbit. These corporations did not just stumble upon an existing market for which they could fill the needs. They, rather, have worked hard to create this market and to shape it in certain ways.
The economic catching up of the University-based cities relies partially on the offer development and the quality of higher education and the link between the university and businesses. If its political decisions makers support actively the start-ups and encourage the cooperation between business and academia worlds, they still have some unrealistic expectations on the potential of universities in revitalizing the local economy. The "intellectual" city with a big university, without a good and permeable interface with the local economic sphere, can't be necessarily a smart city (Van Winden, Van Den Berg, Pol, 2007).

The shift in political language — wherein the social contract is replaced by the corporate contract — is subtle, but critical for understanding the politics smuggled into the technocratic agenda of smart cities (cf., Sadowski and Selinger, 2014). This explains why the six principles they propose are all based on admonishing "city leaders" for not valorizing (enough) the products and services offered by the ICT sector. Like savvy businessmen, the authors recognize the asymmetry of public-private partnerships in an era of neoliberalism. When top managers at firms earn many multiples of top civil servants, the latter readily allow the private sphere to reshape the public sphere in its own image. Corporations can afford a phalanx of economists, designers, attorneys, and public relations specialists, all skilled in presenting one possible future for the city as a technocratic unique best way. Indeed, other than the corporate model, "there exist no large-scale alternative smart city models, partly because most cities have generally embraced a pro-business and entrepreneurial governance model of urban development"[4]

Consequently, only innovative universities built from scratch can apply to access to the "club" of smart cities from its biggest door. Their occupants (students, faculty, businesses like start up and spin-off…) also can be the perfect population that interact in real time and contribute with a great interest in the "adventure" of making their city more smart, attractive and reflexive. Almost all political effort is centralized in the hand of the administration of the university, as a smart city leaders, regarding their holistic approach of managing all administrative, students and academic affairs. Therefore, the university-based smart city (UBSC) can invest its efforts in the six previous dimensions characterizing smart cities (economy, mobility, environment, people, living and government) via a smart designed network of interaction systems with its multiple and interdependent stakeholders.

2.3. University-based Smart cities from "span to spectrum" of control

The hypothesis underlying the concept of smart city is to create a decentralized collective smartness. The goal is to provide computing services that help people and businesses to translate their behavior into collective interests: fellowship and mastering of fluid costs, change of mobility forms, collective sharing rather than individual appropriation of limited resources, collective services built from the individual contributions. The application of information technology in Smart Cities can produce various benefits:

- Reducing resource consumption, notably energy and water, hence contributing to reductions in CO2 emissions [NYC, 2007].
- Improving the utilization of existing infrastructure capacity, hence improving quality of life and reducing the need for traditional construction projects [Stockholm, 2006].
- Making new services available to citizens and commuters, such as real-time guidance on how best to exploit multiple transportation modalities.
- Improving commercial enterprises through the publication of real-time data on the operation of city services [1].
- Revealing how demands for energy, water and transportation peak at a city scale so that city managers can collaborate to smooth these peaks and to improve resilience [Peterborough, 2011].

The corporate and governmental actors behind the smart city ideal have distorted debate in two ways. First, focusing on the narrow goals of promoting transparency and efficiency (in short performance), they have obscured the revolutionary changes in law enforcement's intensity, scope, and punitive impact portended by pervasive surveillance systems that are easily embedded into a regime of ambient law. Second, they offer a doubly crabbed view of the politics and ethics of digitizing space via the IoT: as a post hoc constraint imposed on technical systems, primarily to encourage "privacy," in the individualistic sense of the right to control the collection of information about oneself.

By applying a hermeneutics of suspicion, a more complete — and troubling — social theory of the smart city emerges. Even at the least intrusive end of the spectrum of control enabled by the IoT, there is far more at stake than the nebulous set of concerns about perception and reputation traditionally encapsulated in the umbrella term "privacy." And at the far end of control, the stakes are very high. The IoT is not simply a chance to watch people, to produce and reproduce certain patterns of interaction (Bogard, 1996), or to replace people with robotic agents once data about them has been so pervasively recorded that it can be downloaded into an automaton to simulate their actions, but also an opportunity to serve and take care of people.

Rather than applying the new generation of ICT's into the business, government and civil society of the city, by installing sensors in the objects in a complicated system (e.g. a grid network), to monitor its status, and connect all the sensors as an IoT's which meanwhile connects to an internet, they should contribute to manage successfully their activities, status of living and production in a finer way without forgetting their comfort. The smart city is not only the application of new information technology, but also the participation of the citizens in the various activities of the city with the intelligence of humans.
Smart city leaders need, for sure, to walk along the transition of the open innovation and the open data. They need to integrate IoT's in order to develop new services likely capable of enhancing the capacity of cooperation with all kind of users (public/private, citizen/business, different generations, etc...). These new forms of participative innovation could cover beyond technological aspects (fablabs, 3D printers, etc.) some other social ones (real time home distant surveillance, socialization, numerical violence and harassment, etc.) that allowed to accompany recurring patterns of territorial development (the ecological conversion and the numerical revolution (Veltz, 2012)) in service of reducing a potential numeric "tragedy" of the smart city.

However, Innovation in UBSC face has two main challenges: First, within the system, in what extent can we master how to intervene in the operation of certain services in the city through flows of information coupled with analysis in dynamic and semi-automotive way?
The second problem is between the users of a system. A ubiquitous system might be oriented at multiple users for sequence interaction or simultaneous interaction. So we should consider how to make all users feel pleasant during the whole process of interaction, and assign resources to users reasonably.

Technologies as IoT's in general and smart grids in particular tend to optimize, thanks to ICT's, existent networks 'management and to consider its transformation by incorporating a dynamic demand management, which is historically absent in networks built as a natural monopoly. Interpretatively, we can distinguish tree levels of smart grids: First, electric network function-centric. Second, its extension to take into consideration Home Automation services grafted on smart sensors. Third, more extended, smart grids are considered as a possible matrix of smart cities: We go beyond internal services of homes to consider urban services via smart buildings as a smart actor of the city.

In both ends of the continuum, from performance to comfort, is it possible for UBSC to succeed in a hybrid design of the two objectives by the mean of smart grids tool? Can UBSC leaders and decision makers implement their vision by achieving a strategic alignment between their "business model", organization and operational practices? In what extent their dynamic system can adjust "automatically" whatever anomalies that can occur at the tree levels?

3. METHODOLOGY

Our choice of the UBSC model is motivated by many reasons: First, only this kind of cities in Morocco could be considered a smart city built from scratch. Second, in the context of emergent countries, it almost impossible to pretend that the administrative sphere (and governance) of the smart city could be smart, which is more appropriate when the administrative dimension and the academic one are loosely coupled. Third, all occupants of the city are structurally involved in the educative and academic agenda of it even for businesses that apply to be integrated in its ecosystem.
From the outset, International University of Rabat (UIR) has developed a highly attractive model of innovative teaching which has soon gained renown for its professionalism and rigour both at the national and international levels. UIR is the first university to have been set up as part of a partnership between the State and the private sector in the field of higher education. This partnership allows UIR to work towards the attainment of its objectives: excellence in education, research and active participation in the socio-economic development of the Kingdom and the region, at large. Its managers 'strategic efforts, combined with continued commitment on the part of its academic partners, allow it to offer Moroccan and foreign students high level schemes of studies which are in some cases rewarded by two degrees.
Educational materials intended to educate students on issues related to renewable energy, particularly the materials and techniques used in this area. This pedagogical cube has panes on which are deposited photovoltaic panels which allow the passage of light through a mesh of cells, making it possible to transform the solar energy into electrical energy.The UIR continues to innovate by setting up a photovoltaic power station, called "solar farm" with an area of 2,500 m2 that can produce a power of about 320 kWp thereby supplying electric power to several buildings of the campus of the UIR. The overall investment cost is about MAD 8 million.
All those technical platforms are used from all components of the UIR campus: its five engineering schools (Automotive, Aerospace, Informatics and logistics, Renewable energy, Architecture), business and law schools and its international faculty of dentistry. The UIR curriculum is oriented toward its vision to make the campus smarter and almost all students projects are focused on the innovative side and participatory and competitive contributions of each department.

UIR is very dynamic university in the field of applied research. Indeed, in less than two years, it was able to deposit more than 14 patents. The International University of Rabat has an international vocation and puts its openness onto the world at the heart of its training and research missions. University team is a multidisciplinary research group with experience in designing and building adaptive architecture and algorithms in ubiquitous and pervasive computing domains. They have been supported by many grants. Their research interests include Energy-efficiency and smart city based on novel control strategies, ubiquitous and pervasive computing, computer networks and communications and IoT-based technologies. The main mission of UIR is to educate both undergraduate and graduate students and to develop innovative applied research in different areas related with Information and communication technologies that benefit the technological and economic growth and development of Morocco.

In the next section, we will first surveyed exiting work from literature that is related to control approaches and solutions for energy efficiency in university-based smart buildings. Most important metrics are then presented by putting more emphasize on efficiency and comfort metrics and their relationships with building physical properties, equipment control, outdoor environment, and occupant behavior. We will then introduce the necessity of an integrated and holistic approach that combine energy consumption and occupant comfort. To show the usefulness of this solution, a CO_2-based state feedback control scenario for ventilation system modeling and control is presented and deployed in real test lab in UIR University.

4. IoT-BASED TECHNIQUES FOR SMART BUILDING

The Smart cities are regarded as the new generation of electric power systems, combining the development of Information Technology, distributed systems and Artificial Intelligence and Internet of things for more features on the real-time monitoring and processing the huge amount of data and managing energy consumption. Smart Cities are also composed of smart information and communication technologies sub-system that enable it to disseminate necessary information in a timely manner to be able to process it and take proper control and management actions. However smart buildings as a part of city, could be then seen as complex systems composed of different heterogeneous parts or entities (e.g., occupants, computers, robots, agents, sensors, actuator, hardware, software) that interact collectively in complex and largely unpredictable manner. These complex systems should incorporate mechanisms that allow entities interact and perform actions favoring the emergence of global desired behavior. Systems having these features and capabilities are called Socio-technical Collective Adaptive Systems [18, 19, and 20]. In this type of systems, decision-making should be made locally by each entity in a distributed manner and entities might join or leave without disturbing the collective, i.e., the entities should self-organize and continue performing their goals. Furthermore, the system should include decentralized control mechanisms to allow entities with different and conflicting goals to operate at different temporal and spatial scales. In fact, the system could react to the environment changes and buildings occupants' preference with the main aim is to make their life more comfortable according to their locations, current time and situation.Engineering these adaptive complex systems require maintaining a strong focus on context-dependent user expectation, profile, and behavior. This could be done by including the occupants' actions and behaviors in context tacking into account the complex interlinked elements, situations, processes, and their dynamics. In this chapter, we put more emphasis on the influence of occupants' activities, complex building's systems on energy saving by reviewing existing control approaches and solutions for energy efficiency in complex real buildings.

4.1 Energy Efficiency Metrics in Buildings

There are mainly two main categories of metrics to measure energy efficient buildings (see Figure 1): improving the building performance by taking into account all energy sources and the carbon dioxide emission factors, and reaching the occupant comfort while minimizing negative environmental impacts and ensuring building safety. These metrics need to be considered for developing holistic frameworks for minimizing energy consumption while improving occupant comfort.

Performance metrics are required to evaluate the energy efficiency in buildings. There are two main important metrics, the first metric is the ability to improve the efficiency of energy by reducing and managing energy demands and the second one is the control of building systems by managing in real time energy expenditure. Currently, the efficiency of energy sources tends to provide long-term benefits by lowering base load (e.g. Electricity, Natural Gas, and Fuel Oil) and peak demand. Beside the use of a passive energy sources there is a need for additional generation and transmission assets to achieve "zero-energy", using renewable energy sources (e.g. solar, wind). This could lead to more efficiency in reducing energy consumption and cost savings. Furthermore, high performance of a building will be only achieved if there are various control strategies implemented in buildings to enhance the management of energy use. This includes, the control of Heating, Ventilation and Air-Conditioning (HVAC) systems, lighting and power appliances in buildings. Indeed, several control strategies were developed for managing the operation of all types of building equipment as presented in the previous section. For example, cyber-enabled BEMS meant to increase energy utilization efficiency by decision-making control methodology using agent-based systems for electrical, heating, and cooling energy zones with combined heat and power system optimizations [21].

Comfort metrics can be categorized into three main metrics: *thermal comfort*, *visual comfort*, and *indoor air quality comfort*. *Thermal comfort* is an important metric for indoor environment quality and also one of the main sources of energy consumption in buildings. Maintaining occupants' thermal comfort means conserving the performance of thermal parameters (temperature, mean radiant sources, air flow velocity, and humidity) within an acceptable range. This means that the thermal comfort depends firstly on heating, ventilation air conditioning management services and the insulation of buildings. Thermal comfort evolution methodologies use respectively two keys calculation: the analytic theory by the ISO 7730 [22], and the extended Standard Prediction Mean Value (adaptive PMV) [23] model for non-air conditioned buildings. The adaptive PVM modeluses adaptive factors that affect the sense of thermal comfort, which is calculated using physical measurements for warm and cool conditions. Many research works combine numerical local weather forecasting and MPC (Model Predictive Control) to enhance building energy usage and indoor thermal comfort. In other words, thesestatic and adaptive thermal approaches are mainly used to assess thermal comfort in buildings.

Visual Comfort depends primarily on lighting conditions of a building (luminance, illuminance).Maintaining visual comfort means ensuring that people have enough light to perform their activities, i.e., the light has the right quality and balance, and people have good views. Several occupant behavior models utilize predictions of visual comfort suchus DGP-based shading control [24], which uses the concept of daylight by taking into account different assessment modes, such as sky conditions, blinds setting and sensors positions, to predict the short-time-step development of indoor illuminance. In [25] a manual lighting and blind control algorithm was developed to predict electric lighting usage based on probabilistic behavioral patterns, which have all been observed in actual office buildings. In fact, an extended DGP control method- the Adaptive Zone [26] - was proposed to add occupant's preferences, where the occupant has the right to change the view direction to avoid the discomfort in workspace. However, ensuring acceptable level of visual comfort involves management of lightning and directly affects the energy consumption of the building.

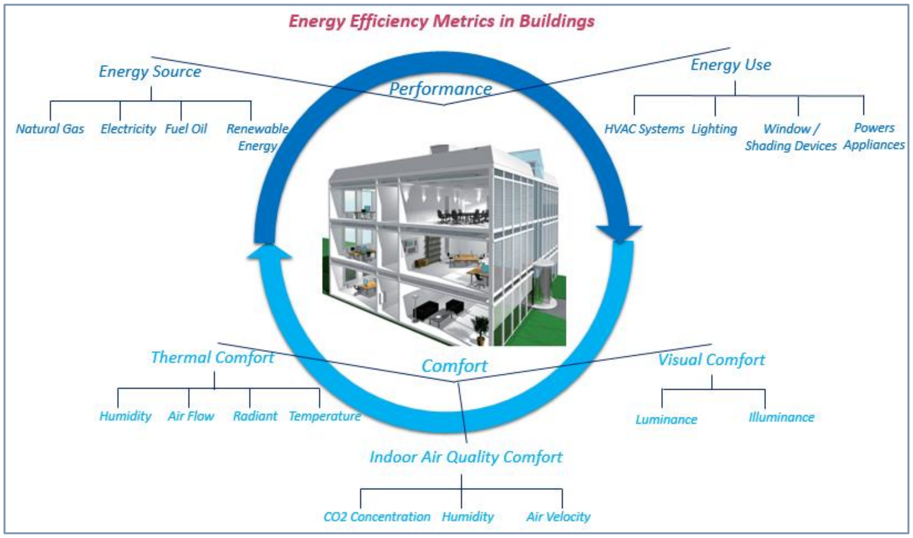

Figure 1: Energy efficiency metrics for buildings

Indoor air quality is a significant concern in maintaining occupant comfort in buildings. More precisely, the air quality of the indoor environment can profoundly affect the health, comfort, and productivity of building occupants. It is important to evaluate the air qualityaccording to the level of CO_2 concentration, and identify if the air is clean, fresh and circulated effectively (i.e. verify air velocity distribution within and between rooms in building).The building sector currently contributes approximately one-third of energy-related CO2 emissions worldwide, it is economically possible to achieve a 30% reduction by reducing CO2 emissions [27]. Currently, the CO_2 emissions depend not only on the energy consumption in systems (i.e. heating, cooling and hot water), but also on the building envelope, the occupant behavior and the type of energy sources used [28]. Some studies have shown that the carbon dioxide concentration is considered as a relevant key according to occupants' perception of indoor air quality. For example, relationships between the percentage of user discomfort with indoor air quality and calculated levels of CO_2 concentration are proposed in [29, 30]. Recently, in an experimental study [31], authors show that the level of occupancy affects negatively the indoor air quality using the concentration of carbon dioxide as an evaluated index. On the other hand, several studies stated that perceiving indoor air quality is related to an intelligent maintenance of HVAC systems (i.e. adopting active systems such as HVAC fans and ducts in control approaches). In [32], a multi-objective optimization with gradient-based method is implemented to yield optimal indoor-air condition in order to insure thermal comfort and indoor-air quality while maintaining efficient energy usage.

4.2 Intelligent Control in university-based smart city: IoT-based approach

The aim of our work is to improve energy efficiencyby usingIntelligent Control with IoT techniques for integrating the building behaviour with EnergyPlus and the HVAC control system together with an occupant behavior simulator. We first focused on ventilation system modeling and introduced an intelligent control approach that relies on a state feedback technique to regulate the indoor air quality with the aim was to maintain indoor CO_2 concentration with an optimal ventilation rate while reducing energy consumption. The ventilation system was analyzed, modeled, and simulated using BCVTB as shown in Figure 2 and then deployed in a real Test-Lab in the International University of Rabat (UIR). The obtained results showed that the CO_2-based state feedback control with integrated IoT techniques leads to better comfort with improved energy efficiency as compared to the traditional and fixed controls.

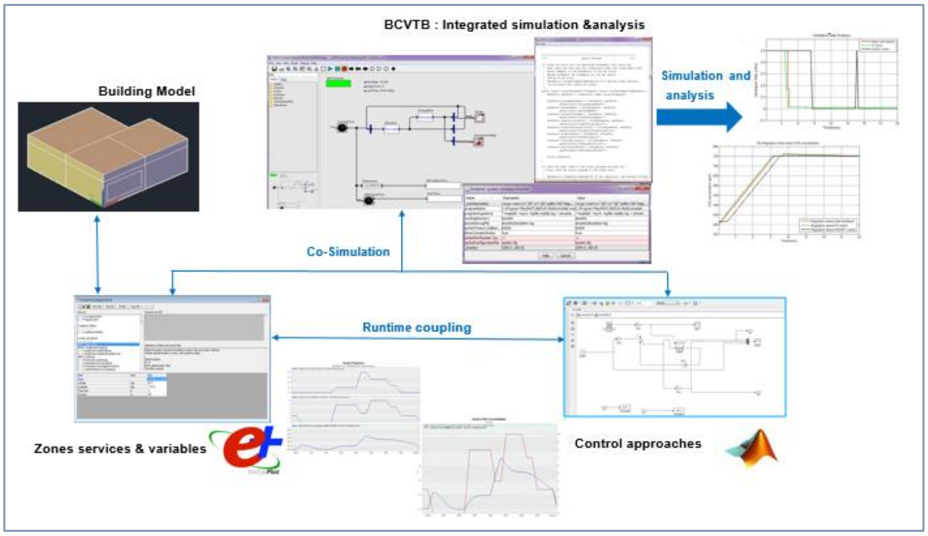

Figure 2: The integrated simulation and analysis of the state feedback technique

4.2.2 HVAC System Control

The ventilation system operates at buildings level for improving air quality by providing fresher air from outside. In order to get indoor fresh air, occupants may open doors or windows. However, in many situations, such as cold or hot periods, many people inside, there are no windows; ventilation systems that automatically act on behalf of occupants are required. The controller of the ventilation system insures this task by automatically adjusting fresh air as much as needed based on outdoor temperature and occupants preferences. It is like a valve that automatically allows or shuts off fresh air as needed based on outdoor temperatures and indoor CO_2 concentration.

Most commercial ventilation system controllers include two types of indoor metrics: odors generated by occupants and gas generated by equipment. For example, if the occupancy is very low, CO_2 generated from occupants is very low and no need for ventilation, however, in many situations (e.g., classrooms, conference rooms) there is a higher need for ventilation. Therefore, a ventilation controller that adapts to all situations is required. Adapting the ventilation rates based on occupancy level could save energy to be consumed since it is not necessary to operate the heating/cool systems as much outside air get inside.

In our study, we mainly focus on the relationship between CO_2 concentration and ventilation operation. We propose a CO_2-based model to ensure occupant comfort and energy saving. Specifically, we seek to establish a control strategy to calculate the airflow needed for maintaining indoor CO_2 concentration at an acceptable level.

The most proposed technique for using indoor carbon dioxide levels to determinate building ventilation rates is referred to perfect mixture model [33]. It describes the coupling procedure and exchange area between the outside and inside the building. This model is based on a mass balance of CO_2 in the building and can be expressed as follows:

$$V\frac{dC_i(t)}{dt} = Q(C_i(t) - C_e(t)) + qN(t) \quad (1)$$

The relevant quantities describing the volume input and output flow rates, as well as CO_2 concentrations, are as follows: $C_i(t)$ is the indoor CO_2concentration in ppm at time, $C_e(t)$ is the outdoor CO_2concentration in ppm at time, Q is the ventilation rate in (m^3/s), q is the CO_2rate per person in (L/s), V is the volume of the building in m^3, and t is time second. In fact, the comfortable value of CO2concentration varies from 600 ppm to 1000 ppm, and 750 ppm is set as a realistic set point for a good indoor air quality .However, this differential equation has a highly nonlinear dynamics due to a multiplication between the airflow and inner concentration. The difficulty of the synthesis of this law of order lies in the coupling between the fresh airflow and air quality. Indeed, the concentration dynamics coupled with several variable parameters are making control more complex.

To solve this problem, we proposed to linearize it by defining Q and Ci as follows:

$$Q = Q_0 + \partial Q$$
$$C_i = C_{i0} + \partial C_i$$

Where Q_0 is a constant initial rate, ∂Q is the change necessary to achieve the desired concentration, C_{i0} is the initial concentration of C_i, and ∂C_i is the change of concentration following the application of ∂Q. Therefore, eq (1) becomes:

$$\frac{d(C_{i0}+\partial C_i)}{dt}=\frac{Q}{V}C_e-\frac{Q}{V}(C_{i0}+\partial C_i)+\frac{q}{V}N \tag{2}$$

Thus, eq. 2 can be written as follows:

$$\frac{d(\partial C_i)}{dt}=\frac{Q}{V}(C_e-C_{i0})-\frac{Q_0}{V}\partial C_i+\frac{q}{V}N \tag{3}$$

The state model can be described as follows:

$$\begin{cases}\dot{X}=Ax+Bu+b\\ Y=Cx\end{cases} \tag{4}$$

Where the parameters are described as follows:

$$A=\left[-\frac{Q_0}{V}\right], B=\left[\frac{C_e-C_{i0}}{V}\right], b=\left[\frac{qN}{V}\right], C=1$$

The proposed CO_2-based control is implemented by a state feedback technique in Matlab Simulink (see Figure 3), which depends on sensed inputs data such as occupant number, and outdoor CO_2 concentration and the maximum ventilation rate accepted. We have also developed the On/Off and the PI control strategies for comparison purpose. The goal of this study is to keep CO_2 levels to less than CO_2 set point (i.e. an average of 750 ppm during the day), while reducing the energy consumption. A ventilation rate at 0.0083 l/s/person is typically adopted, and the occupant's number is generated which are sensed and calculated from the CO2 sensor.

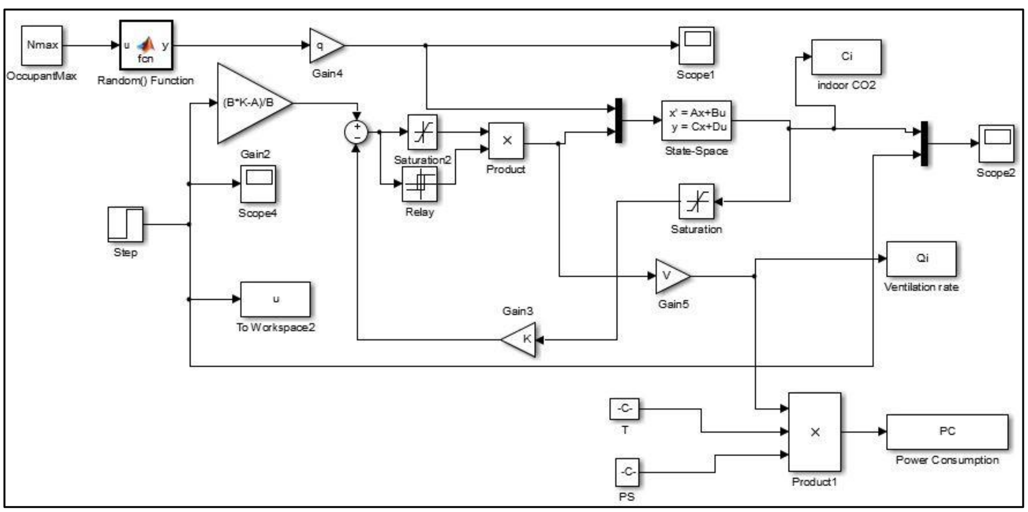

Figure 3: The State feedback control under Simulink

4.3 IoT-based techniques for monitoring and data acquisition

The amount of energy wasted in buildings is incredibly big. Thus, the need of monitoring and controlling the energy consumption has become really high. This report states the work that has been done in this direction using different sensors and techniques in both getting the data returned by the sensors, storing it and later acting on it.

The energy consumption within buildings has a direct relation with the occupancy. For instance, if a room is unoccupied there will be to need to turn neither the lights nor the air conditioning on. Also, once the occupants free the room, they may leave the lights or the air conditioning on out of inattention which will certainly introduce a significant energy loss.

This work deals with the problems mentioned above through creating a small energy autonomous case with different sensors to end up having a context-aware, eventually intelligent environment that takes decisions based on the current context.

Component			Description
CASANET Node	**Sensing devices**	*PIR motion sensor*	A passive infrared sensor (0 or 1) is an electronic sensor that detect person presence.
		LM35 temperature sensor	The LM35 allow us to return the current value of the temperature in a specific environment.
		MG811 CO2 sensor	The MG811v allow us to sense motion. In our case, it is used to detect whether a room is occupied or not.
	LED light		This LED is used for our control methods , turned on when a motion is detected and off otherwise. Adjusted by user via an android application.
	Processing unit	Arduino Uno	The Arduino board is one of the main components that we have, it allows all the sensor to work and send their values.
	Sending unit	NRF24 Module	The nRF24 is used for radio communication between Arduino sending the data and the Raspberry receiving them for preprocessing.
	Power		9V battery for powering the system
Server side	**Pre-Processing unit**	Raspberry	the raspberry pi is used to receive the data coming from the Arduino board and display them on the platform.
	Receiving unit	NRF24 Module	

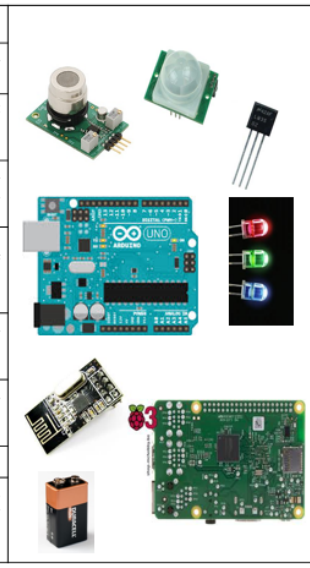

Figure 4: The IoT component for sensing and data acquisition

The current system that we proposed consists of many IoT sensors as presented in Figure 4, such as PIR (motion sensor), LM35 (temperature sensor), and MG811 (gas sensor). All the sensors gather and send data that is then processed by an Arduino micro-controller and stored using RRDtool. As a previous work, those readings were not stored, they were only displayed using a mobile application where the user gets to choose the building and then the room to visualize the ambient temperature, the occupancy, CO_2 concentration and turn on or off the lights. Currently, a work has been done to allow sending the data to a server and store it.

A constitutive model has been developed to regulate the level of CO_2in building resulting from high occupancy. The model was experimentally verified in one class room in university. It was found that the model accurately regulate the ventilation rate and improve a good air quality by keeping CO_2between 400 ppm and 600 ppm with variable number of occupants. The prototype was developed and carried out on a 24-hour time scale and the simulation step for the ventilation system is set as 15 minutes for easy visualization of results. In order to get the number of occupants as depicted in Figure 5 below, we measured within one day and we injected in the state-feedback control for ventilation regulation and CO_2 comfort.

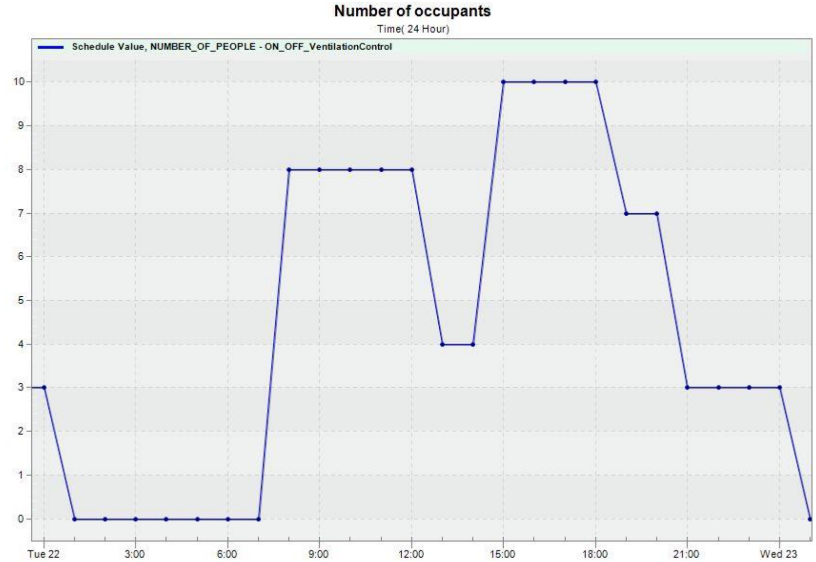

Figure 5: The number of occupants simulated within 24 hours

We developed and ON/OFF control for comparison purpose, the goal of this comparison is to control within one day a hybrid ventilation system to keep the CO_2 concentration at the comfortable set point and to optimize ventilation rate while reducing energy consumption. The regulation of the CO_2 concentration using the two control strategies is illustrated in Figure 6. It can be observed that CO_2-based state feedback control methods are able to maintain the CO_2 concentration in the comfortable zone. However, the On/Off control exceeds the set point in some time periods which turns On the fan with the maximum power. However Figure 7 shows the ventilation rates obtained by CO_2-based state feedback control strategy which he results indicate that the total ventilation rate is reduced after applying the CO_2-based state feedback technique, and offers an optimal ventilation rate. Thus, the power consumption is decreased as shown in Figure 7.

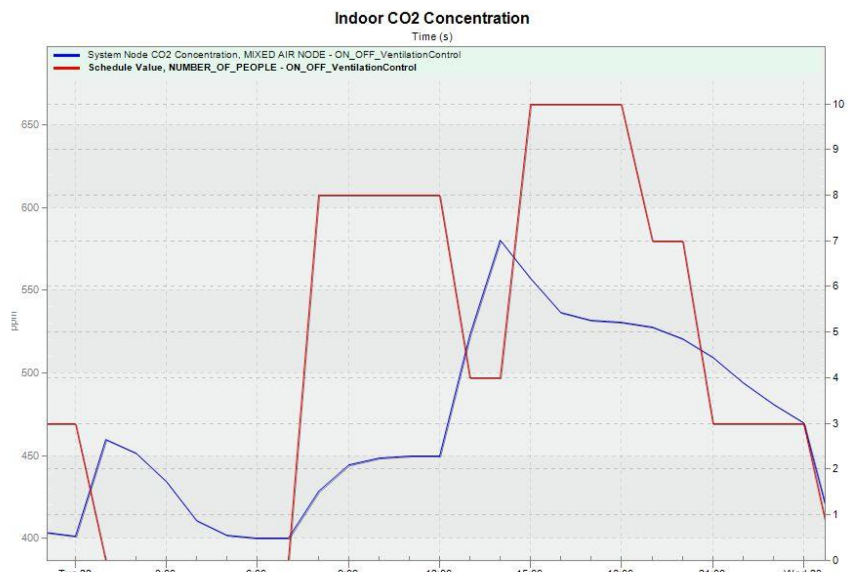

Figure 6: The indoor CO2 concentration of the two control strategies

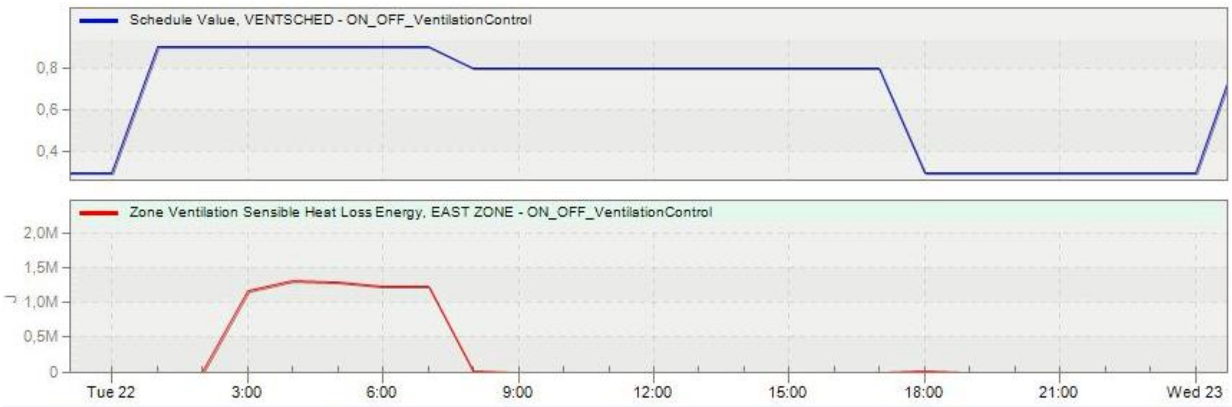

Figure 7: The ventilation rate and the overall loss energy

Overall, this work found that implementing intelligent strategies based on IoT-based technologies in buildings will saved considerable energy in comparison to traditional and prefixed approaches while providing a comfortable environment for occupants. In this paper, we propose a state feedback based control approach that use indoor/outdoor CO2 concentration and deployed it in real test scenario in UIR. Experiments have been conducted and obtained results show the efficiency of the proposed solution.

The UIR tend to involve all different schools in its holistic approach of building a smart city based on its own academic needs and fields of research and experiments. While engineers contribute in the innovation of technical aspects (solar and renewable energy), business students tackle other topics and issues related to smart building and cities (e.g.: sustainable development, social entrepreneurship and so on…).

5. CONCLUSION

The IoT-based innovation framework presented here, provides a number of steps to overcome the "black box" approach that current urban environmental assessment studies suffer from. This comprehensive framework can provide a vast matrix of information encompassing the complexity that revolves around smart cities. However, there are limitations inherent to data and accounting approaches and therefore to all of the steps presented here. In addition, in the use of this wealth of context-specific data and indicators, it is recommended that extreme caution be used as they provide a multitude of slightly different angles to view the metabolism of a city that only when assembled can be used to describe the complex, dynamic, heterogeneous, interconnected and ever-changing character of a city. It should also be noted that more elaborate identification of drivers is possible through more complex statistical analyses such as multivariate analysis and principal component analysis.

To conclude, this comprehensive UBSC framework creates a solid basis for better understanding cities and their metabolism. Comparing the temporal evolution of spatialized Input and output analysis and IoT's metabolic flows, helps to construct a complex understanding of cities as the articulation of local and global environmental, social and economic challenges. Upon this solid basis it is ultimately possible to create a theoretical model that describes urban systems and urban dynamics within a set of non-linear equations. In turn, this complex UBSC model could serve to forecast different scenarios of environmental effects based on different policies, socio-economic and territorial organization inputs. It also serves as an important tool for the sustainable design and management of new and existing cities. Meanwhile, "flexibility" which could be defined as "the use of the users' critical intelligence and commitment in an environmental-technical, aesthetic and political or socio-political way for the design of environmental-technical and spatial processes" can be achieved through the participation of users in the design, the construction and even the management of the built environment or parts of it. While managing itself ecosystem that express, not only a "sympathy" toward our needs (comfort) and constraints (performance) but also a kind of "empathy" toward our behavior, we contribute to design collectively a smart "crowd-conscience" of the city that involve a holistic view of its mainly metabolic active citizenship.

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