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ABSTRACT

Smart buildings technology is becoming ever more important due to increasing demand in the market. One of the main issues of concern is the integration of different products made by different manufacturers designed for different functions in an environment with frequent changes. Therefore, in this paper a model is presented to deal with this issue and help manage the decision making processes in a smart building environment as well as support the relationships between manufacturers and customers. Also, this model should help manage conflicts between different customers' requirements. The model is designed to accommodate future expansion in functions, properties, and services.

Keywords

Decision Making System (DMS), Smart Buildings.

INTRODUCTION

The increasing demand for smart buildings, especially in Asia and the Middle East, has created a new business area for technology. Among the main reasons for this growing demand are the potential of saving resources and minimizing operational cost. Also, the new technical capabilities in smart buildings have added new ideas in building security and emergency procedures. Moreover, adding or removing services in smart buildings is generally much faster and easier than in conventional buildings, and many luxury features have become achievable through this technology (Johnson 2007).

On the other hand, as these features have increased the market demand for smart buildings, they at the same time have made the smart buildings environment more complicated:

- A wide range of requirements, as smart buildings are designed for different purposes, such as hotels, shopping malls, and hospitals.
- Many different products and functions, such as IP (internet protocol) telephony, IP TV, and access control.
- Similar products offered by different vendors or manufacturers using different techniques.
- Frequent changes in requirements and dynamic environments requiring complex and fast decision-making.
- The need and capability of adapting new products.
  (Luxenberg 2007; Batty 1997; Nussaum and Miesenberger 2004)

Therefore, to manage a smart building environment, taking into consideration the above issues, there is a need for a specific type of decision-making technology that can deal with the issues without compromising the features that make smart buildings desirable. The goal of this paper is to identify the nature of decision needs in a smart building environment by building a model to represent and structure the issues identified above. In addition, this model will provide a framework for the relation between manufacturers and customers of this type of environment by showing how different requirements may be satisfied and potential conflicts may be resolved.

In this paper, we start out by describing the environment of smart buildings, and explaining their functions and capabilities, followed by describing our proposed model. Finally, we give an example to validate our model based on various business requirements. In the next two sections of this paper, the smart building environment is explained based on published literature, and we discuss the different perspectives of decision-making technologies. In the following section, the proposed model is presented to help solve the current problems in smart building environments, and applied to specific example. Finally, we summarize the paper and discuss the future outlook in the conclusion section.

SMART BUILDINGS: REQUIREMENTS AND CAPABILITIES

Nussbaum and Miesenberger (2004) define a smart building as “a building, usually a new one that is equipped with special structured wiring to enable occupants to remotely control or program an array of automated home electronic devices by entering a single command. For example, a homeowner on vacation can use a touchtone phone to arm a building security system, control temperature gauges, switch appliances on or off, control lighting, program a home theater or entertainment system, and perform many other tasks”. However, the essential characteristic of smart buildings is that their design and construction require the integration of complex new technologies into the fabric of the building (Luxenberg 2007). In this paper, a smart building is defined to be any building that integrates various technologies in order to improve the services provided by the building facilities or to minimize the cost of its operation.

In fact, the integration of complex engineering services into buildings is not a recent innovation. The earliest example of central heating systems can be found in buildings dating back to the Roman Empire. However, the beginning of modern smart buildings, as dealt with in this paper, was perhaps in the 1980s, when the emergence of smart buildings was uniquely associated with the big bang in the financial services sectors. Users needed buildings that could facilitate their growing use of information technologies to deliver their core businesses. We may distinguish two generations for smart buildings, where the first generation started in the early 1980s. Electronic technologies were installed in buildings, typically to control the delivery of engineering services, with very little knowledge about how best to satisfy user needs or to create adaptive and responsive internal environments. This approach was largely technology driven, and experience of using these systems led to the questioning of the appropriateness of the various technologies for different types of users, and for meeting the requirements of an increasingly diverse range of functions. The second generation placed greater emphasis on adaptability and the management of space, providing a more user-oriented approach to the installation of information and control systems (Luxenberg 2007).

Batty (1997) expects that by the year 2050, everything around us will be controlled by some form of computer, and already, we are seeing a massive convergence of computer and communication technologies through various forms of media. One of the most challenging issues in smart building environments is the need for integrating the newer technologies into a process of monitoring and control, which are essentially politically determined. State-of-the-art technologies are being accommodated in a context where the industry structure and the rules and procedures are, at best, still at an "infant" stage of development (Nussaum and Miesenberger 2004).

To date, the academic literature on smart buildings is very sparse. This may be due to the interest in smart buildings so far having been more in the realm of practitioners, rather than academics; however, we can define smart buildings as modern buildings designed to use the latest technology in order to accommodate the requirements of the owners. Thus, based on the current available technologies, the following functions and capabilities may be available in a smart building environment:

- IP telephony and IP TV: These offer all functions that are available in the traditional telephony systems in addition to new features, such as utilizing the Internet, which means that there is no need for a separate, dedicated infrastructure for these services (Johnson 2007).
- Access control: This manages admission to the buildings and other resources and is performed at two levels. The first level of access control is authenticating the user, which requires checking the identity of the user or client machine attempting to gain access. The second level is granting the authenticated user access to specific resources based on company policies and the permission level assigned to the user or user group.
- Utilities metering in smart building: This allows readings to be taken remotely.
- Car parking: New car parking systems are manageable by computer.
- Advertisement system: Advertisement screens can be used for different additional purposes, such as signs for directions, announcement, and alerts.
- Surveillance system: New functions are available, such as motion detections, and counting people.
- Fire alarm system: New systems have the capability to alert other systems and indicate the effected locations.

(Turpin2007)

DECISION MAKING SYSTEMS IN ORGANIZATIONS

Through the last decades, different decision making systems have been developed. These systems can be categorized into different categories; the following are some of them:

- Decision Support Systems (DSS): The concepts involved in DSS were first articulated in the early ’70s, and DSS can be defined as “interactive computer based systems, which help decision makers utilize data and models to solve unstructured problems” (Sprague 1980).
- Expert Systems (ES): These are systems that comprise at least a knowledge base, an inference engine, an explanation module, and a user interface in order to mimic expert decision making (Yoon et al. 1995).
- Executive Information Systems (EIS): These are “flexible tools that provide broad and deep information support and analytic capability, for a wide range of executive decisions. They are designed to make the information contained in the lower-level systems in the organization available in a form that is easy to access, easy to use, and germane to decision making” (Vandenbosch 1997).
- Directive Decision Devices (DDD): DDS differ from other decision making systems as they employ computer programs to make decisions without human intervention, rather than support humans to make the decisions. These are used effectively in making lower and mid level decisions, and are not applicable for executive level decision making (Blue et al. 2006).

We prefer to name this last category *Decision Making Systems* (DMS) rather than Directive Decision Devices. The reason being consistency with the other categories’ designations and better compatibility with the nature of these systems as the main purpose of these systems is to replace human decision making.

Blue et al. (2006) subcategorized DMS into four groups, as follows: 1) *Executory* systems designed to execute a decision function entirely without any human intervention or contribution. Included in the domain of decision functions for which a computer program is sufficient would be those where a decision choice is to be determined by taking recourse to a decision table or something similar, as well as, where a neat algorithmic resolution is both available and appropriate. 2) *Compensatory* systems are targeted at decision areas where (a) the likelihood of a proper (rational, if not optimal) choice is dependent on the technical skills or sensibilities of the decision-making agent, and (b) there is some reason to suspect that no human functionary adequately equipped with such skills or sensibilities is available. 3) *Interdictive* systems have a preventative mission. When an interdictive program is in place, local management decisions or directives would not actually be implemented unless or until they have been corroborated by the computer as innocent of any predictably perilous prospects or procedural improprieties. 4) *Cooptive* systems are designed to seize the initiative and implement an appropriate course of action (contingency planning script) if the human manager has not already done so prior to some point in time.

In fact, all four subcategories are needed in smart building environments, and using such systems will help in framing the relationships among stakeholder parties. For example, an understanding of these subcategories will help the customer in expressing and structuring requirements, and it will give the constructor an overview of what to consider in various construction stages. Also, understanding these subcategories will help salesmen in marketing and presenting their products. In the following, we will show how each subcategory can be used in a smart building environment:

- Executory systems can be used to execute well-defined scenarios that do not need human intervention. Some of the daily routines in smart building environments require straight-forward decisions and can be executed through computer programs without human interference. Examples may be deciding to which floor a hotel guest should have access, and deciding which elevator should be sent to which floor.
- Compensatory systems may be used for monitoring readings of devices and carrying out the right actions when some threshold is reached. In fact, new technologies allow DMS to monitor such devices as generators, and take required actions as necessary.
- Interdictive systems are needed in this environment because the large number of decisions needed may result in conflicts between responsive actions. This subcategory of DMS will prohibit low priority decisions from overriding higher priority decision. For example, in case of an acute emergency, the DMS will give priority to emergency actions, and prevent other activities from interfering.

- Cooptive systems are also needed in smart building environments to protect it from human and machine mistakes. This may include such simple things as preventing damage from leaking pipes or utility abuse. Another example where such systems may be used is intervening when unauthorized people gain access to critical places at unexpected times, and thus prevent potential sabotage or other harmful activities.

THE PROPOSED MODEL

The approach taken with the suggested model is to deal with the smart building environment as an object-oriented environment (OOE). We will apply object-oriented concepts. Smart building environment consists of services, functions, and customer requirements; while OOE consists of classes, which have properties and methods, and objects which belong to one of the defined classes (Kadar et al. 1998).

In creating this model, each service will be considered as a class. Thereby, each service will have its own properties and methods/functions. For example, IP Telephony is a class with properties such as *ID*, *location*, *status* (on, off, hold), *call type* (local, national, international), and with methods such as *send recorded message, change phone status*, *change call type* (see Figure 1). This structure will allow the system to adapt any new property, method, and even service. Also, the system will have the capability to cover all customers' requirements and even cover possible future changes. The second step in constructing the model is translating customer requirements into scenarios. These scenarios will be created in an IF THEN format. For example, a customer requires that in case of motion detected in the server room between 12:00AM and 07:00AM, the system should call security. The scenario will be created as in Figure 2. Finally, the priority between scenarios should be tuned in order to avoid conflict during execution time. This can be done by assigning a priority number to each scenario, and the system can decide which scenario will have priority in case of conflict (see Figure 3).

Class Name: IP Phone
Properties: ID Location Status (On, Off, Hold) Long Distance Calls (None, Local..) In use
Methods: Call (Tel Number) Send-Recorded-MSG(Tel,MSGID) Change-Status (Status) Change-Call-Type(Type)

Figure 1. IP Phone Class

```
Scenario name: xxx
Priority: 01
IF camera1.motion_detection = TRUE
AND time >= 12:00 AM
AND time < 7:00 AM
 THEN phone1. send-recorded-msg(Tel,MSGID)
```

Figure 2. Scenario Example

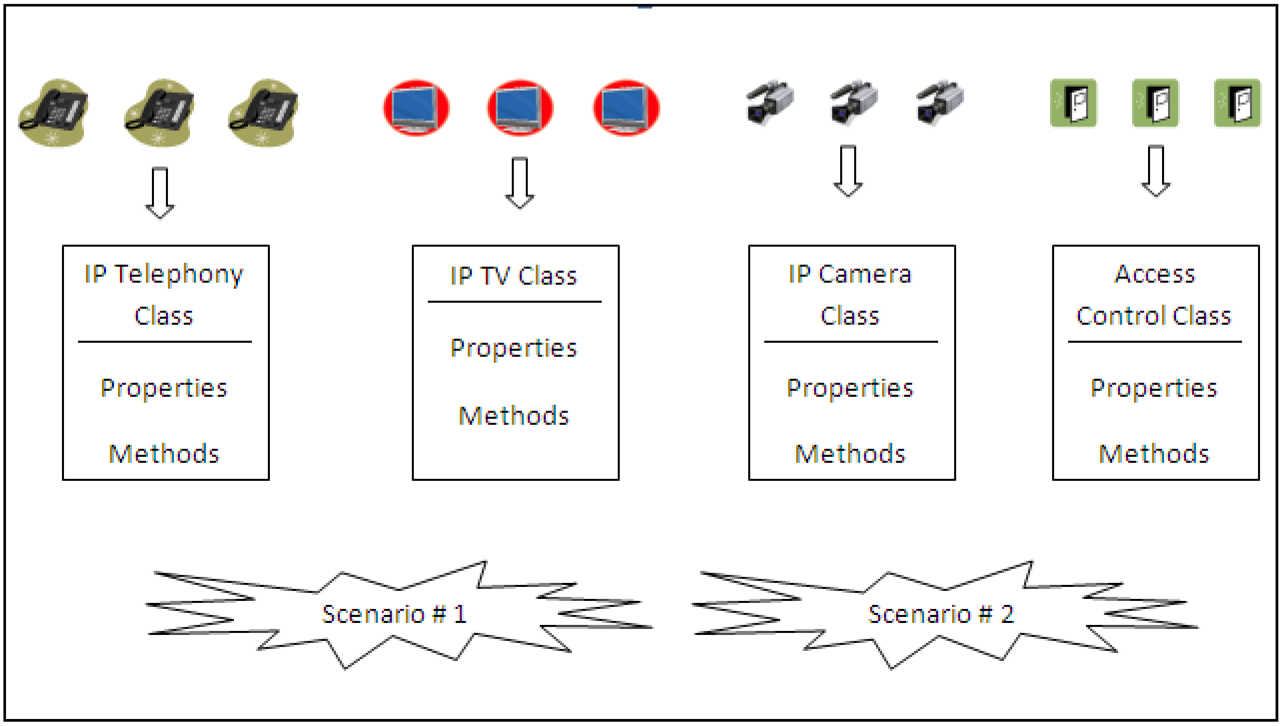

Figure 3. Decision Making Model

To explain this model, we will look at a hypothetical case as an example. In smart building environments, it is important to have a procedure for evacuation, but it is more important to give the right directions during execution of this procedure. For example, having fixed "Exit" signs that direct people to the emergency exits is not efficient in huge buildings because the problem that caused the emergency may be in the exit itself; so directing people to that exit may cause a disaster. Also, the exit may become so crowded, so that it is better to direct people to another exit. Therefore, it is important to have a DMS, which can give instant directions. In this case, the DMS will receive an emergency alert from the fire alarm system indicating the location(s), emergency type, and emergency level. Based on these, the DMS will make the appropriate decision(s) according to the given procedures and instructions, and immediately order the other systems to execute the action(s). These actions may include the following: 1) Assign advertisement screens and TVs in the related locations to switch to emergency mode and give directions. 2) Order the access control system to unlock all gates in these location(s). 3) Send recorded messages and text messages to concerned person(s). 4) If any camera noticed too many people in the surrounding area of any exit, the system will direct people to a different exit. 5) At the end of the evacuation process, the surveillance system may indicate to the DMS if there is any human still in the locations that should be evacuated, and the DMS will call the person in charge to inform him/her or show this information on the advertisement screen.

CONTRIBUTION AND CONCLUSION

In this paper, we have focused on a new area of decision-making. This area is the smart building environment, which has become very important because of increasing market demand. We have represented this environment, and shown the need for decision making systems. Also, we have identified a main concern in this environment, which is having different products, made by different manufacturers, to do different functions, and working in an environment with frequent changes. Today, customers in the smart buildings environment are suffering from systems incompatibility. They have to expend much effort on determining which system can communicate with which, and how to integrate the various technologies.

We presented a model designed to help in solving this issue and managing the environment and the process of decision making. Also, this model is designed to help in avoiding conflicts, which may arise between different requirements. In addition, this model has the capability to accommodate possible future expansion in functions, properties, and services. Moreover, this model may help manufacturers of smart building products by presenting a view on the future of smart buildings from different angle.

To validate this model and enhance or improve it, a field study may be conducted in the future.

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