Conceptual Model and Simulation Results for Section-Based Digital Habitat Ecosystem Architecture in Built Environments

Kamatchi Pillai

Abstract— Digital Ecosystem (DE) is the Information and Communication Technology (ICT) system, which includes both an open and loosely coupled network of self-organising ICT nodes and links. The advancement of the DE technology, an emerging research area, promises new approaches for controlling, monitoring, and managing the use and reuse of resources in built-up environments. However, the use of the DE technology is currently most widely utilised in business enterprise networks, and many research and development challenges exist and must be addressed before this technology can be scaled to and applied in built environments. The main objective in this research is therefore to investigate and build a Digital Habitat Ecosystem Architecture (DHEA) that can integrate all the existing smart devices available in the home environment. Furthermore, it will monitor and control the use of the vital resources (water, electricity) in built up environments. The specific objective of this proposed research is to address the shortcomings of the wireless communication networks and to standardize the devices into a common platform. This paper aims to outline the significance of the DHEA, and the core DHEA devices. Emphasis will be on the discussion of the Element and Section-based models of a proposed DHEA model. Conceptual model and simulation results will be presented with simple examples such as a lighting system model in Simulink.

Index Terms— Conceptual Model, Digital Ecosystem, Digital Habitat Ecosystem, Sensor Networks, Simulation, Simulink , Web-based Architecture, Wireless Communication.

I. INTRODUCTION

DE is a computer based system that can evolve with changing technology and the demands of the application. It can even combine the application, the environment becoming interchangeable from it. Modern computers are now connected to each other using a variety of wired and wireless communication systems [1]. These features have led to the concept of DE, i.e. digital computer systems that can evolve with time to meet the changing application needs. Initially, a DE concept was developed for the enterprise networking of European business activities and was referred to as the Digital Business Ecosystem (DBE) [1]. A DBE was defined as the digital environment that can be used for the advancement of business enterprises, especially for small to medium enterprises [2,], [[4]. It supported the transactions between the buyer and seller existing in a business network.

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The DE application can act as a “Client-Server Virtual Machine” which can be activated by either the local client or the remote server [2]. It integrates core technologies such as multimedia, web services, mobile communication, wireless technologies and smart systems. DHE is being proposed as a self-organizing, pro-active, collaborative ICT-based system providing services for monitoring the usage of resources in built environments and applying control schemes to maximize their utilization. The use of multimedia content and wireless communication technologies will be an integral part of the DHE.

Taking this DE concept into consideration, the proposed research study aims to develop a model that can monitor and control the usage of vital resources used in the built environments [2]. Furthermore, it will analyze the current technologies used in the home environment and evaluate its challenges based on communication with smart systems. The main objective of this paper is to introduce the DHEA that will monitor and control the utilization of vital resources, such as water and electricity in built environments for sustainable living. The specific aims of this research study are to:

- Study the existing integrated water and electricity management system.
- Investigate the current ICT technologies vis-a-vis their suitability to develop DHE architectures.
- Design the architectures to analyze the data communication and networking challenges.
- Develop the high level model to validate the designed architecture using simulation tool such as Matlab (Simulink), Opnet.
- Propose a pathway for developing open-architecture DHEs.

The DHE will automatically detect various Digital Species (DS) connected to the network and acquire information regarding the functionality of the connected species.

II. ELEMENT-BASED ARCHITECTURE FOR DHE

The information available within the network will be integrated within a central communication device, which will be responsible for controlling the utilisation and reusing of

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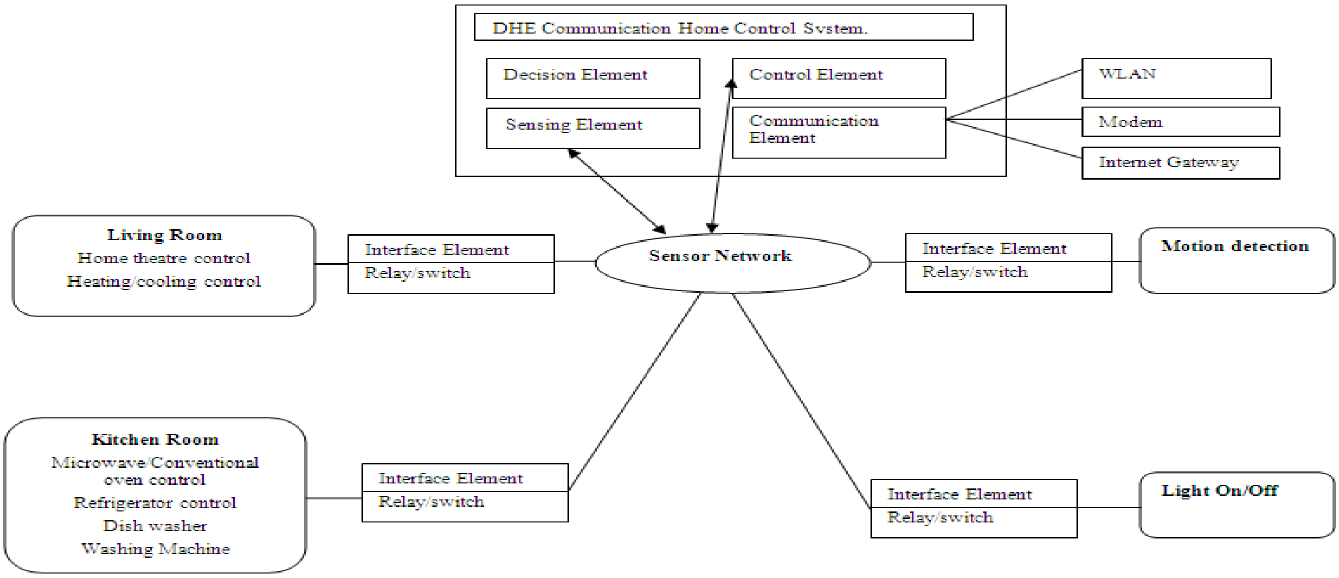

Figure 1: Element-based Architecture for the Built-up Environment

vital resources from a single source. Multicast messaging allows the dispatcher to send a single copy to the data stream, which will then be replicated and forwarded to consumers that have previously signalled their interest **Error! Reference source not found.**.Therefore, instead of sending thousands of copies, the dispatcher sends a single copy directed by routers on the network to consumers that have indicated their interest in the message.

Figure 1 show the complete device set up used in the built-up environment. DHE communication home control system consists of: Decision Element, Sensing Element, Contol Element, Interface Element and Central Communication Network.

III. Simulink Model and Conceptual Model for Indoor and Outdoor Lighting System

Lighting system operates based on the brightness sensor and the motion sensor. If there is a motion in the room and the brightness is low, requiring illumination, then Lighting sub-system turns on the Lamps in that particular room. Lighting subsystem is modeled with the vision of energy-efficient consumption concept. There are two sensors devices in the kitchen such as to identify motion and brightness. The motion sensor is used to detect whether there is any motion in the selected location e.g. kitchen. The brightness sensor is used to detect the light due to sun and daylight.

Figure 2 is the Simulink model for lighting system, in this model; it clearly shows the different zone; location and the light devices. The declarations of all the devices have been mentioned as common standards such as DHE-Location-Device format. Here the strandarize code refers the the common code for all devices to identify the device location, device type for the normal end users. By using this genric standardized format , the end user can easily communicate through the set guidelines.

This method is made to facilitate the processes and tasks very easy.As explained in the earlier publication [12, 13], the model has been designed with Matlab SIMULINK. The input devices are marked as RED, and they have integrated devices such as motion sensor, brightness detector for five different locations such as the kitchen, living room, bathroom, bedroom and laundry. All these devices connected to the Central communication Network (CCN) are marked as CYAN and have been monitored and controlled according to the action placed, and then the output is received according to the action. The output devices are in MAGENTA. The output device gets activated according to the various operation held based on the input devices and generates output according to the signals/information received from the CCN based on the end user's need and perception.

Table1 shows the clear abbreviation of devices, it explains the complete lighting system generic standardized format with the input and output devices and its location. This table comprises the indoor and outdoor lighting system.Lighting system activates based on the motion and brightness. The latter is used to ensure that the lights are not kept on when there is sufficient sun-light inside the house. Figure 3 shows the operation principle of Lighting sub-system for indoors while Figure 4 details the outdoor lighting subsystem. The number of the rooms and peripheral areas utilized are intended to be explanatory and are by-no-means limiting on the developed system. They can be adapted for different houses and environments. There are two signals to go from rooms to CCN, motion sensor output and the brightness output. Considering these two signals, the lighting is operated automatically as follows; if there is a motion in the room and the brightness is low, requiring illumination, then Lighting sub-system turns on the Lamps in that particular room. This decision is sent via an output signal called Lamp control signal. Each room is handled separately to increase efficiency.

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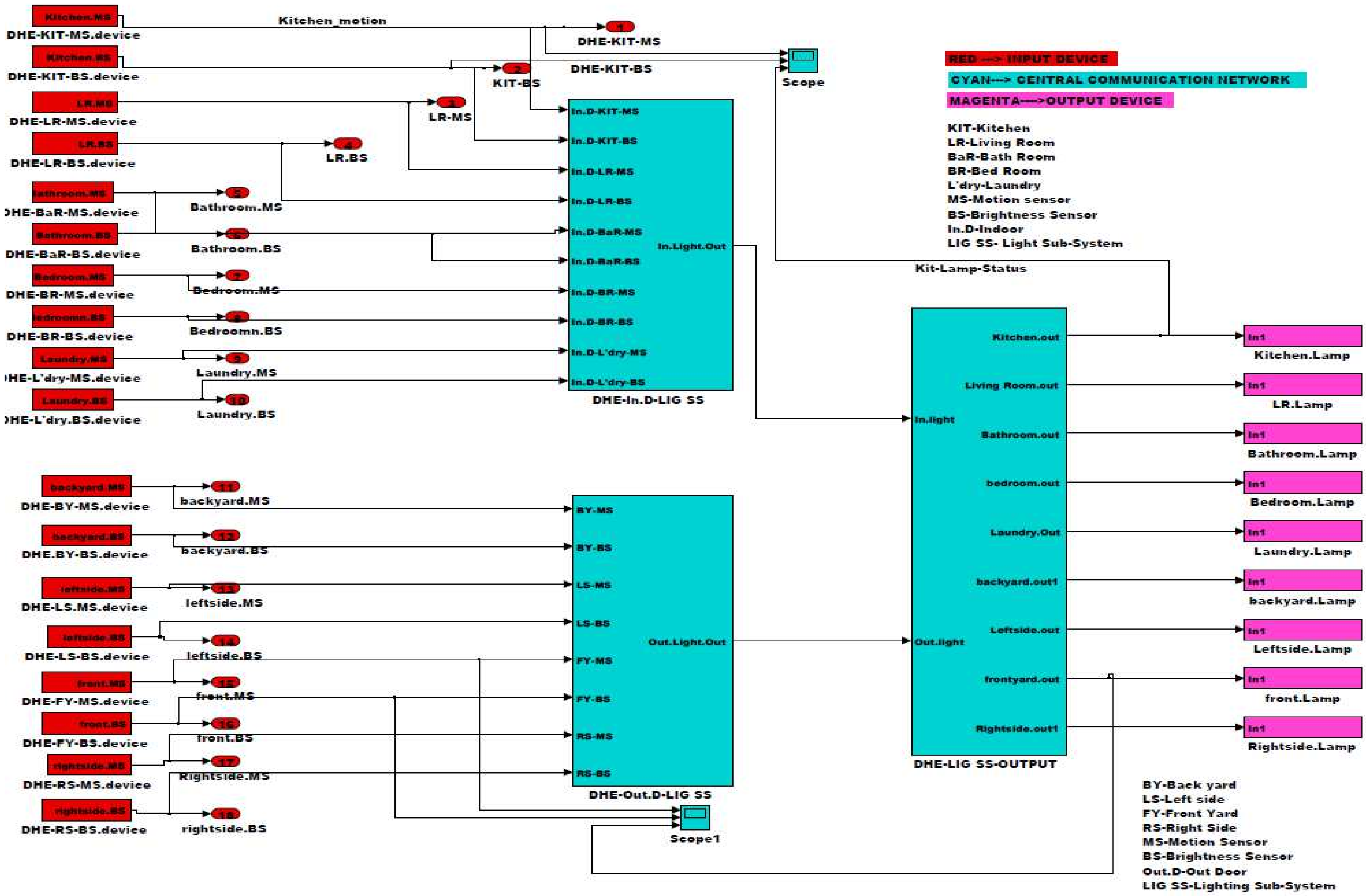

Figure 2: Simulink Model for the DHE-Smart Home Lighting System

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Table 1. Complete DHE-Smart home lighting system devices

Device Number	Devices	Device Type	Location	Standardization Code for InPut Device	Standardization Code in CCN for Indoor Lighting system	Standardization Code for output Device	Other abbreviations
1	KIT.MS	Motion sensor	Kitchen	DHE.KIT-MS.device	In.D.KIT.MS	Kitchen.Lamp	Scope- To check the output of lamp status
2	KIT.BS	Brightness sensor	Kitchen	DHE.KIT-BS.device	In.D.KIT.BS		
3	LR.MS	Motion sensor	Living Room	DHE.LR-MS.device	In.D.LR.MS	LR.Lamp	
4	LR.BS	Brightness sensor	Living Room	DHE.LR-BS.device	In.D.LR.BS		
5	BaR.MS	Motion sensor	Bathroom	DHE.BaR-MS.device	In.D.BaR.MS	Bathroom.Lamp	DHE-In.D-LIG SS- Digital Habitat ecosystem Indoor Lighting subsystem
6	BaR.BS	Brightness sensor	Bathroom	DHE.BaR-BS.device	In.D.BaR.BS		
7	BR.MS	Motion sensor	Bedroom	DHE.BR-MS.device	In.D.BR.MS	Bedroom.Lamp	
8	BR.BS	Brightness sensor	Bedroom	DHE.BR-BS.device	In.D.BR.BS		
9	L'dry.MS	Motion sensor	Laundry	DHE.L'dry-MS.device	In.D.L'dry.MS	Laundry.Lamp	DHE-Out.D-LIG SS- Digital Habitat ecosystem Outdoor Lighting subsystem
10	L'dry.BS	Brightness sensor	Laundry	DHE.L'dry-BS.device	In.D.L'dry.BS		
11	Backyard.MS	Motion sensor	Backyard	DHE.BY-MS.device	BY.MS	Backyard.Lamp	
12	Backyard.BS	Brightness sensor	Backyard	DHE.BY-BS.device	BY.BS		DHE-LIG SS- Digital Habitat ecosystem Outdoor Lighting subsystem
13	Leftside.MS	Motion sensor	Leftside	DHE.LS-MS.device	LS.MS	Leftside.Lamp	
14	Leftside.BS	Brightness sensor	Leftside	DHE.LS-BS.device	LS.BS		
15	Rightside.MS	Motion sensor	Rightside	DHE.RS-MS.device	RS.MS	Rightside.Lamp	
16	Rightside.BS	Brightness sensor	Rightside	DHE.RS-BS.device	RS.BS		
17	Frontyard.MS	Motion sensor	Frontyard	DHE.FY-MS.device	FY.MS	Frontyard.Lamp	
18	Frontyard.BS	Brightness sensor	Frontyard	DHE.FY-BS.device	FY.BS		

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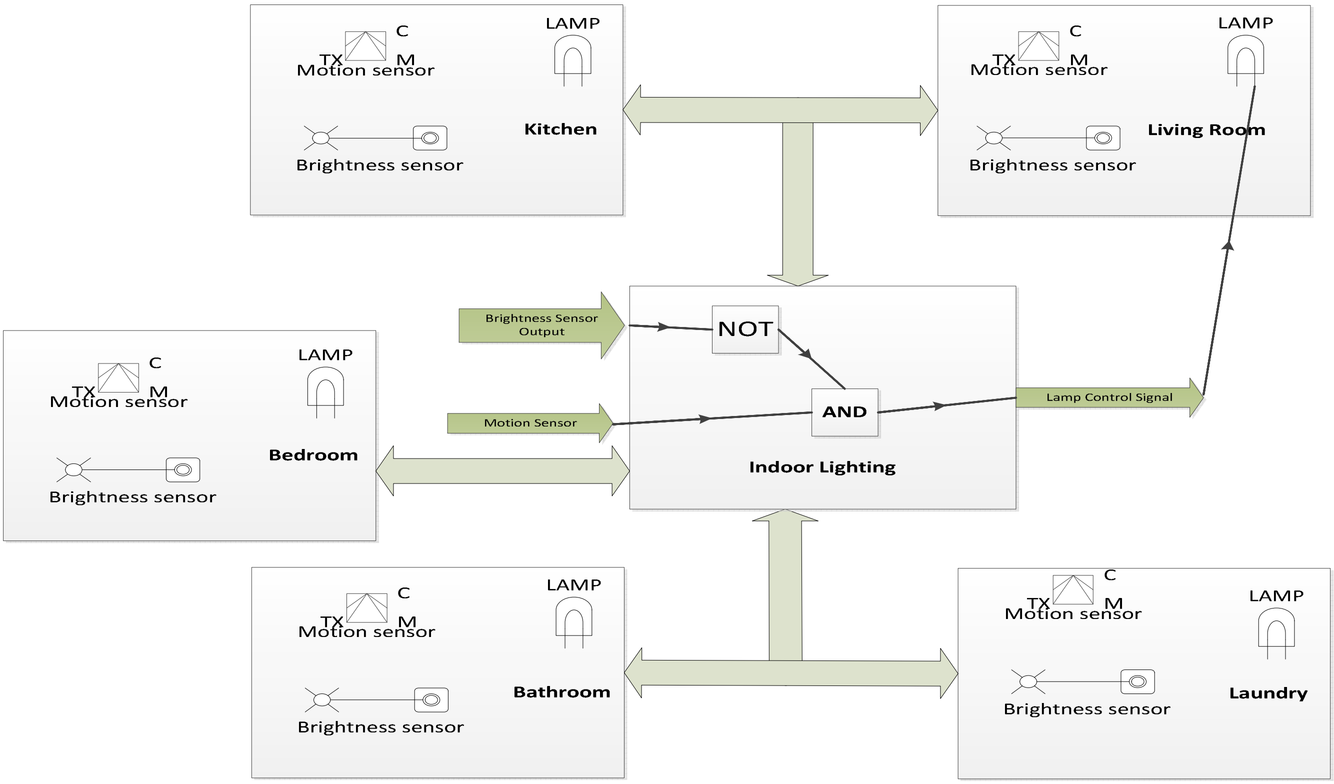

Figure 3: Conceptual Model for DHE-Smart Home Indoor Lighting System

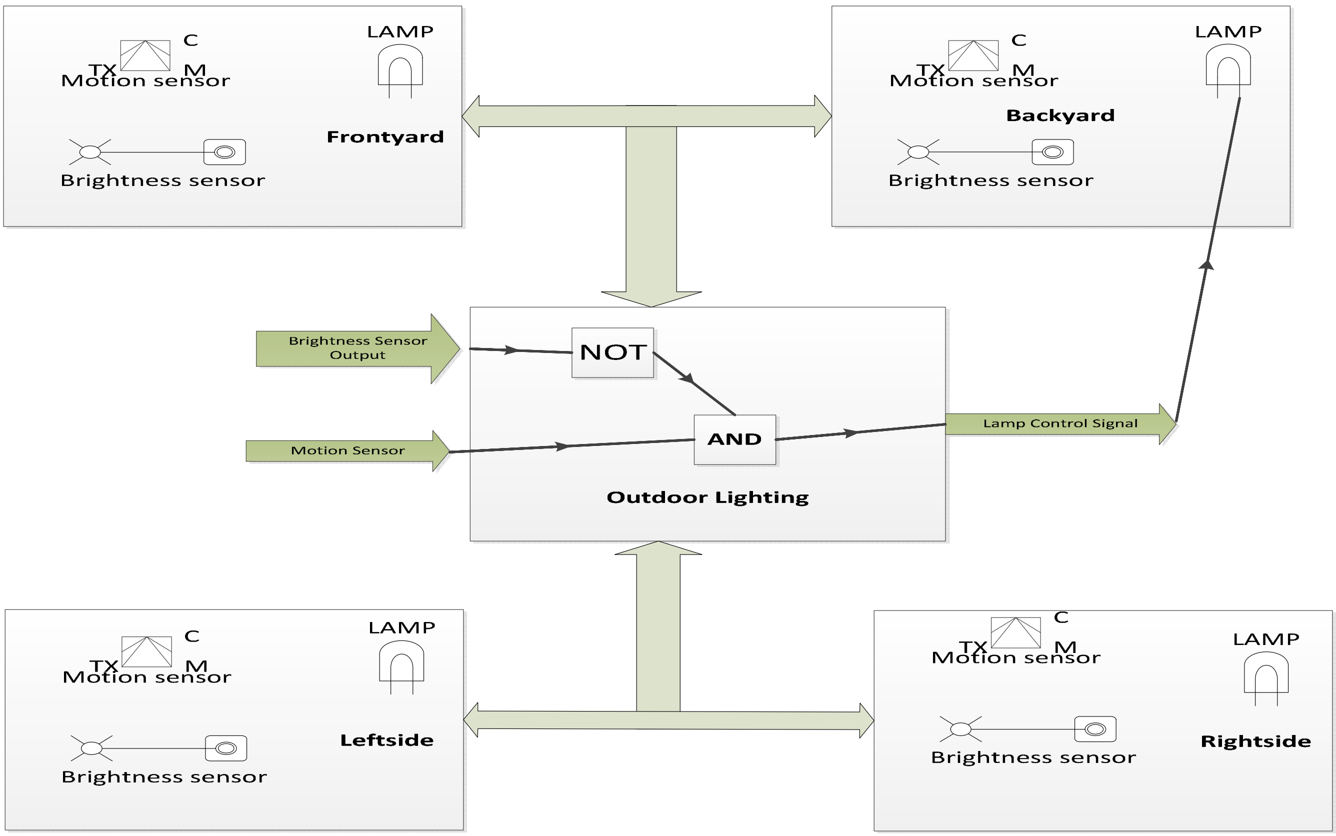

Figure 4: Conceptual Model for DHE-Smart Home Outdoor Lighting System

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IV. ILLUMINANCE CONTROL ALGORITHM

Based on Sache et al [5], the effective control algorithm will be used to derive DHEA smart home lighting system. We are taking a end-users day-to-day activity as an example to derive this algorithm. Table 2 shows the lamp status of the various the timing, it demonstrates in the input and output waveform.

The steps are as follows:

1. The getting up schedule starts at 6am-8am, there will be motion and brightness, so the lamp status is inactive.
2. During winter, under the same condition, there will be brightness therefore kitchen lamp is active. Between 0.00am-6.00am, there is no motion and brightness therefore kitchen lamp status in inactive, however if there is any motion during these time the lamp will automatically go to active state.
3. The same condition appears for 12pm-8pm, there is motion but there is no brightness, therefore the lamp is active.

Case 1:

1. First the user enters the kitchen, based on the brightness input the light has to turn on.
2. Each lighting sensor has to follow the instructions rely on illumination and motion in the in the indoor area, which consumes power and calculates the value of an objective function
3. Each lighting system talk to each other via central communication network to generate the required output based on motion.
4. Next level is if two users occupied two locations it will detect the illumination randomly within the occupied area.
5. Measuring illumination and motion by using brightness sensor and motion sensor apparently the correlation between the illuminations will be measured.
6. Then, the next occupied objective status will be measured and improved by following step 3 again, in case if there is a change in illumination, then it has to be cancelled and follow the step 2.

The main purpose of the lighting system of DHEA is to meet the criteria of selection as well as power-saving state shown in equation (1).

$$f = P + \omega \sum_{i=1}^{n} g_i \quad \text{...............(1)}$$

Where

$$g_i = \begin{cases} (Ic_i - It_i)^2 & (Ic_i - It_i) \le 0 \\ 0 & otherwise \end{cases} \quad \text{......(2)}$$

P-> Power consumption

Ic->current illumination

It->targeted current

ω ->weight

n -> number of brightness sensors

The objective function was derived from the amount of electric power *P* and illumination constraints g_i. Also by changing the weight factor ω , it enables changes in the order of priority for the light input and illumination constraint. It is indicated in equation 2 [6],[8].

Table 2: Lamp status

Timing	Kitchen Motion Sensor	Kitchen Brightness Sensor	Kitchen lamp status
0.00-6.00 am	0	0	0
6.00am-12pm	1	1	0
12pm-18pm	1	1	1
18-24pm	1	1	1
6.00am	0	1	0
17.30pm	1	1	0
19.00pm	1	0	1
21.00pm	0	0	0

Table 2 shows the lamp status of the various the timing, it demonstrates in the input and output waveform. The getting up schedule starts at 6am-8am, there will be motion and brightness, so the lamp status is inactive. During winter, under the same condition, there will be brightness therefore kitchen lamp is active. Between 0.00am-6.00am, there is no motion and brightness therefore kitchen lamp status in inactive, however if there is any motion during these time the lamp will automatically go to active state. The same condition appears for 12pm-8pm, there is motion but there is no brightness, therefore the lamp is active.

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12pm-18pm	1	1	1
18-24pm	1	1	1
6.00am	0	1	0
17.30pm	1	1	0
19.00pm	1	0	1
21.00pm	0	0	0

Table 3 shows the truth table utilized by the digital control system implemented for Lighting subsystem shown in Figure 4. As expected, the lamps are turned on only when there is motion and no sunlight. All the other cases require no further

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illumination, hence the system is kept out of operation.

Table 3 shows the activate and inactive state of the kitchen lamp

Motion Sensor	Brightness	Status
0 (No Motion)	0 (No Sunlight)	0 (Lamp Off)
0 (No Motion)	1 (Sunlight)	0 (Lamp Off)
1 (Motion)	0 (No Sunlight)	1 (Lamp On)
1(Motion)	1 (Sunlight)	0 (Lamp Off)

The logical equation utilized by the digital control system and its real-life implementation with digital logic gates are as given below in Equation (3) and Figure 5:

$$Lamp\ Status = Motion\ Sensor \wedge (Brightness\ Sensor)! \quad \ldots\ldots.(3)$$

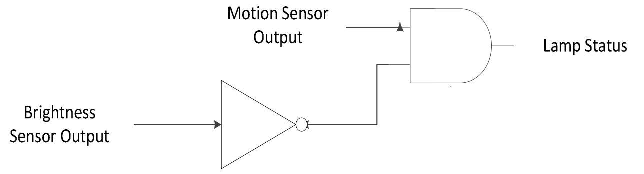

Figure 5: Digital System Implementation of Lamp status

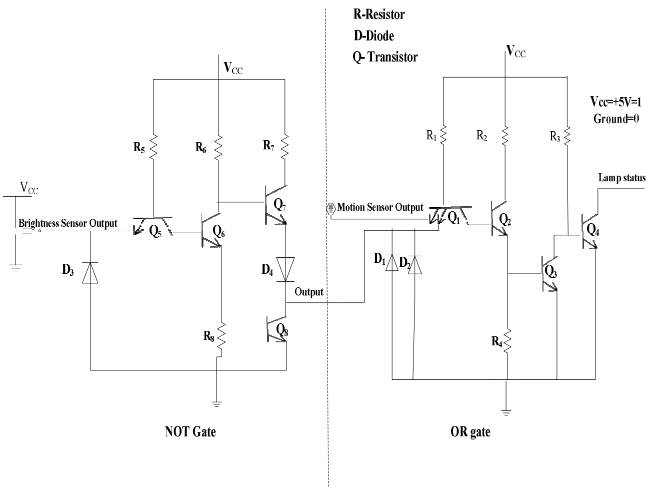

Figure 6: Analog Circuit diagram of Lamp status

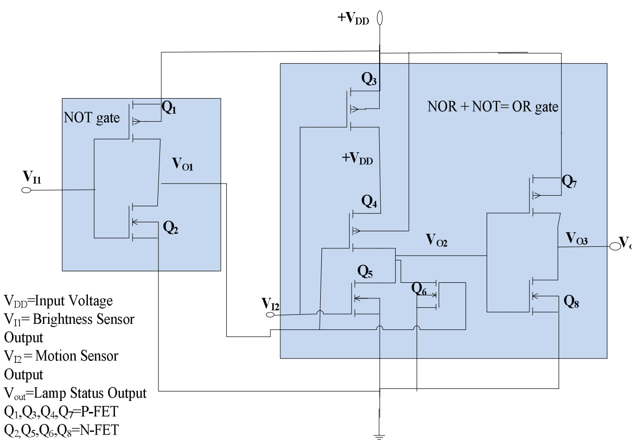

Figure 7: CMOS Implementation of Lamp status

In figure 6, the circuit is combined into the analog form of NOT and OR gate as implied in figure 5 which is the Lamp status. Figure 7, the circuit is composed exclusively N-type and P-type CMOS transistors. Let's analyse this circuit for the condition where the input is "high" or in a binary "1' state. We can simulate this by showing the input terminal connected to V_{dd} through switch as a brightness sensor input: V_{dd}=5 volts. If the Brightness sensor output is high .i.e the switch is in "UP" position, the input is high which is "1". Q1 will be reverse biased, there is no current i.e. I=0, the only purpose of D3 in the circuit is to prevent transistor damage in the case of a negative voltage(i.e V is –ve, rather than +ve, with respect to ground) [7].

Algorithm for lamp status

In Figure 5, 6 & 7the Brightness Sensor output acts as an inverter and Motion sensor output and the inverter in given to the OR gate to activate Lamp status. The following calculation is the simplified operation of the circuit diagram of Inverter

1. $Q_1$is OFF when $V_{I1}>V_{dd}-|V_{tp}|$
2. Q_1 is ON when $V_{I1}<V_{dd}-|V_{tp}|$, where V_{tp} is the threshold voltage of Q1 therefore V_{O1}=1
3. Q_2 is ON, when $V_{I1}>V_{tn}$,
4. Q_2 is OFF, when $V_{I1}<V_{tn}$, where V_{tn} is the threshold voltage of Q2, therefore V_{O1}=0

$$Vth(INR) = Vo1 = \frac{Vtn+\sqrt{\left(\frac{Q1}{Q2}\right)}(Vdd-|Vtp|)}{1+\sqrt{\left(\frac{Q1}{Q2}\right)}} \text{-------}(4)$$

Equation 2 shows the calculation of the inverter gate

The simplified calculation for OR gate is that the OR gate is the combination of NOR+NOT gate, therefore the input of the NOR gate is output from motion sensor (VO1) and the motion sensor output (VI2) is, therefore the output (V02) will be as follows,

5. If $Q_3=Q_4=1$ & $Q_5=Q_6=0$, $V_{02}=1$
6. If $Q_3=1$, $Q_4=0$ & $Q_5=0$, $Q_6=1$, $V_{02}=0$
7. If $Q_3=0$, $Q_4=1$ & $Q_5=1$ $Q_6=0$, $V_{02}=0$
8. If $Q_3=Q_4=0$ & $Q_5=Q_6=1$, $V_{02}=0$, therefore the $V_{02}$is calculated by following formula,

$$Vth(NOR) = Vo2 = \frac{Vtn+\left(1/2\sqrt{\left(\frac{Q3,Q4}{Q5,Q6}\right)}\right)(Vdd-|Vtp|)}{1+\left(1/2\sqrt{\left(\frac{Q3,Q4}{Q5,Q6}\right)}\right)} \ldots(5)$$

Equation 3 shows the calculation of the NOR, therefore

$$\text{Lamp status}=V_{out}=V_{03}=1/V_{O2}\ \ldots\ldots\ldots(6)$$

In order to verify proper operation the lighting subsystem is implemented and simulated in Matlab/simulink. The simulation is based on a basic scenario of a working professional. The person goes to kitchen at 5am. The cooking and having breakfast, dishwashing go until 7.20am. Then he leaves the house. Spends 10 minutes in the front yard. And goes to work. He comes back at 5.30pm and goes inside to cook dinner at 6.pm. The whole activity goes until 8.20pm. Then at 9pm he goes outside, to spend some time in his front yard until 10pm. All of these activities and their effects on the Indoor and Outdoor Lighting (i.e. Kitchen and Front yard Lighting) operations .Figure 8 shows the analysis of the indoor illumination system shows that there is motion in the kitchen between 5 am and 7.20 am as well as 6 pm and 8.20 pm. It is

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easily observed that kitchen illumination is not in-operation for the entire duration of these time frames. Rather, the kitchen lighting operates for a limited period of time before the sunrise and after the sunset. This is apparent from the lighting subsystem output which is the third waveform. Figure 9 shows the analysis of the outdoor lighting system. The motion outside the house is much less than what is inside. However, the lighting is still required outdoors. The outdoor motion happens between 7.20 am and 7.30 am as well as 9pm and 10 pm. In the morning, the sun is already up and no lighting is required. Outdoor lighting operates only at night when the sun has already set the the house owner is working in his front yard. The fundamental objective of this simulation is to make the model more reliable with high accuracy, more flexibility, cost effectiveness and ease of deployment **Error! Reference source not found.**. The key characteristics and benefits of this complete model are: good connectivity, minimal human interaction, fault tolerant, good network coverage for fast communication, operable in harsh environments and dynamic sensor scheduling.

The advantage of the suggested method is to determine the effect of the channel parameters: signal to noise ratio, attenuation and interference on the system behavior. The following section visually explains the complete simple section-based software architecture of DHEA. Consequently the lighting subsystem which has been explained so far has been modeled based on the following section based software architecture

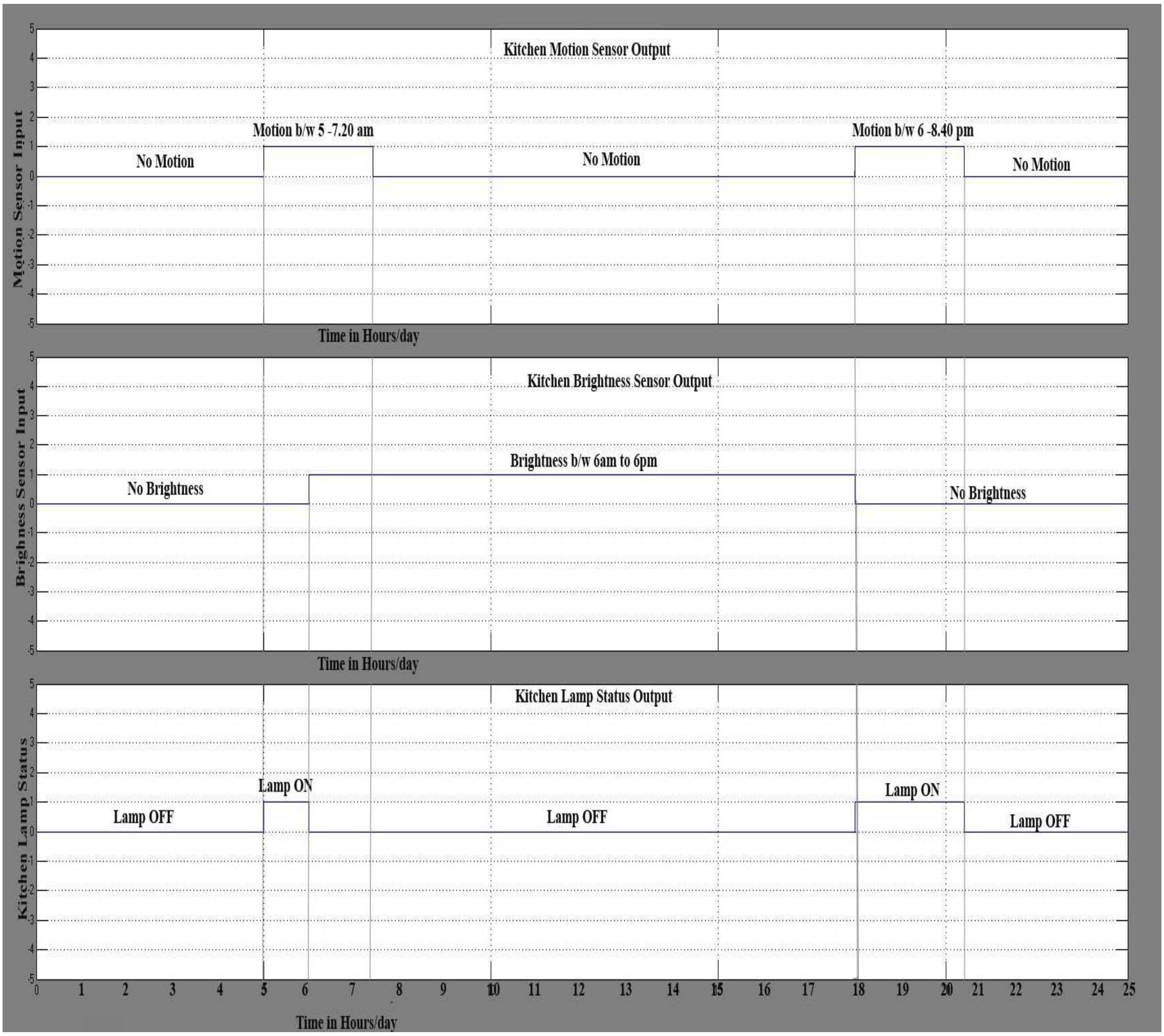

Figure 8: Input and Output Waveform of Kitchen lighting system

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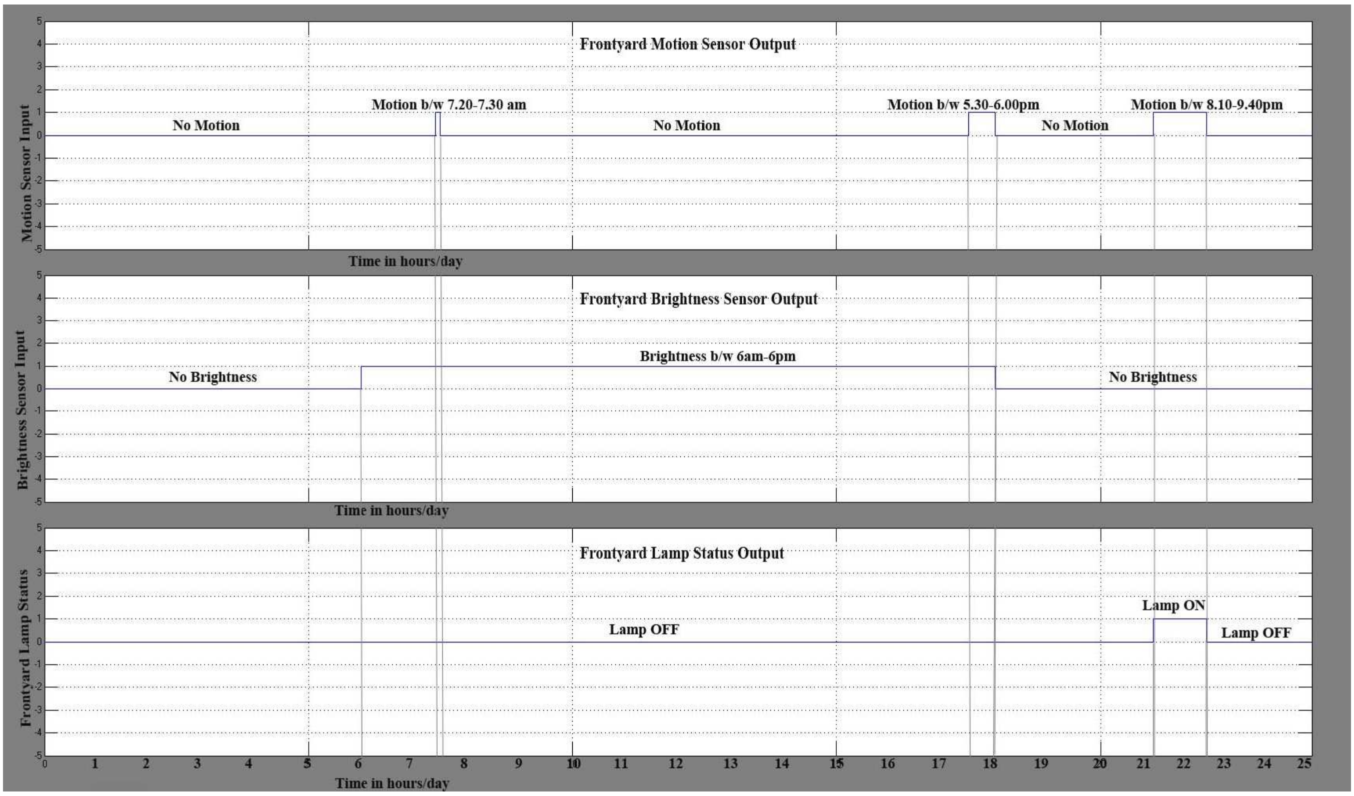

Figure 9: Input and Output Waveform of Front-yard lighting system

V. Conclusion

There isn't much architecture available to build a DE; however this DHEA is a newly derived concept for built environments. Therefore this current study aimed to investigate the different techniques and technologies to develop open architectures for DHEs. This part of the study has been completed with the development of the various architectures. Further, this study will concentrate on validating the result of the developed architecture. Later, the real-time implementation will be considered as a separate continuing research. As architecture for challenged networks, DHE incorporates many features that can be of great use in addressing these problems. Some of the mechanisms, such as in network buffering, have already been employed unilaterally, to meet needs of specific sensor networks. We believe it would be better, however, to do generic standardized format for the complete architecture (and perhaps select an appropriate subset for specific implementations), instead of building each feature independently for every deployment. Therefore this paper is targeted to explain the computation model and its simulation model of section based software architecture for DHEA with an example of the Simulink Model and Conceptual model for DHEA-Smart Home Lighting System. Future work is to develop the similar Simulink models for complete smart home system with simulation result of different schedules and scenarios which has been already explained and published as a conference paper: hierarchy model of DHEA.

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