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Methodology and Framework to Construct and Integrate Digital Habitat Ecosystem Architecture

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ABSTRACT

The Digital Ecosystem (DE) concept is a new emerging paradigm based on self-organizing Information and Communication Technology (ICT) nodes and links. A DE comprises digital devices also referred to as the Interdependent Digital Species (IDS). We extend the DE idea to that of a Digital Habitat Ecosystem Architecture (DHEA) where a DHEA is a DE used in built up environments. Although the DE concept was introduced some years ago for business enterprises, it does not have a formal development methodology. In this paper, we propose a methodology and a framework to create DHEA's. The methodology will discuss the knowledge of sharing, integration and collaboration of existing digital devices which can be incorporated in one dynamic system. Furthermore, it will give the brief idea to develop a framework for the development of the DHEA. This methodology and framework proposes a pathway to develop a dynamic model that can monitor and control existing wireless devices available in the home environment, instead of using separate static devices. The dynamic model is to incorporate all the basic and advanced requirements. Additionally, this dynamic DHEA will identify the shortcomings of data communication and networking challenges in Digital Species (DS) and propose solutions to overcome those issues.

Keywords: *Digital Ecosystem, Sustainability, Wireless Technologies, Multimedia, Methodology, Framework, Web services.*

I. INTRODUCTION

DE is a computer based system to manage an open and loosely coupled network of self-organizing Information and Communication Technology (ICT) nodes and links. Initially, this technology was introduced in the European Small to Medium Enterprise Networks (SMEs) and named as Digital Business Ecosystem (DBE) [1]. Afterwards, this concept moved to the marketing, media and education fields [2]. This new research being carried out aims to introduce a new DE concept called the Digital Habitat Ecosystem Architecture (DHEA) to manage the use and reuse of the natural and generated sources such as water and electricity in built environments, e.g. homes.

DHEA is a self-organizing ICT-based system providing services for monitoring the usage of resources and exerting control to maximize their utilisation. The use of multimedia content and wireless communication technologies is predicted to be an integral part of the proposed DHEA's. Multimedia content will be used to transfer and display information, using emerging technologies that include the Internet, Web services, Animation, Wireless and Mobile communication systems.

This paper has been structured as follows: Section 2 presents the history of Digital Ecosystem concept and existing DE models. Section 3 describes the existing intelligent automation and energy management system in built up environments. Section 4 describes the proposed DHEA and its conceptual model. Section 5 briefly describes the existing framework and methodology for developing DEs. Section 6 describes the proposed methodology for designing proposed DHEA. Section 7 explains how to develop a framework for new DHEA. Section 8 describes existing ICT systems required to develop DHEA's, and expounds some data communication and networking issues related to DHEA's. Section 9 presents the conclusions.

II. HISTORY OF DIGITAL ECOSYSTEM

The term Ecosystem is described as a combined form comprising physical and biological components in a given environment. More simply it is "*a system of all systems*" [1]. Therefore, a DE can be any distributed, adaptive and open socio-technical system, which is self-organizing, scalable, and consequently sustainable; these

aspects are based on the properties exhibited by natural ecosystem [3].

The DE concept was first proposed in Europe around 2002. In general, an ecosystem is a loosely coupled, domain clustered environment inhibited by a variety of species, each proactive and responsive regarding its own benefit while conserving the environment in which it lives [1]. These species need to interact with, and balance out each other. Additionally, the environment should also support the needs of its various species so they can continue to evolve generation after generation [2], [3]. The DE concept originates from this naturally occurring biological phenomenon and refers to "an open, loosely coupled, domain clustered, demand driven, self–organizing agent environment, where each agent of each species is proactive and responsive regarding its own benefit/profit but is also responsible to the overall system"[2]. In simple terms, the DE infrastructure comprises the knowledge required for sharing resources, leading to integration, distribution and evolution of digital components [4]. The digital components can be expressed in a digital language which can be transported within the ecosystem and processed by human beings or by computers [4].

Initially, the DE concept was developed for the enterprise networking of European business activities and was referred to as the DBE [5]. A DBE is defined as the digital environment that can be used for the advancement of business enterprises, especially for small to medium enterprises [6]. It helps in the negotiations between the buyer and seller transactions in a business network.

With time, the DE concept became an application oriented technology, which was developed and implemented in various environments such as marketing, media, and education. A DE application can act as a "Client-Server Virtual Machine" which can be activated either by the local client, or at the remote server [5]. For its operation a DE uses a number of core technologies, such as: multimedia, web services, mobile communication, wireless technologies and smart systems.

Smart technology is the integration of a variety of home systems such as lighting system, climate control, security, sensor networks etc [9]. This technology has emerged as a result of successful development of "intelligent" commercial systems that incorporate a range of proven integrated and automated systems such as Automatic Meter Reading (AMR) which is used to collect the data from the water, electricity and gas meter automatically and transfer data to the central data base for billing, trouble shooting and analysing. A Smart Water Meter (SWM) is a normal water meter linked to a device that allows continuous electronic reading and display of the water consumption. It negates the need to manually read the meter dial. Once this information is available as an electronic signal, it can be captured, logged and processed like any other signal. Mobile phone technology, wireless modems, the internet and other data distribution technologies make it possible to bring this signal readily to a computer [9]. One big advantage with smart meters is that there will be no local meter readings needed anymore. The readout of the meters is automated and the utility have access to the data immediately. The main advantage of this system is that billing can be based on near real-time consumption rather than estimation of previous or predicted consumption [9]. This AMR technology includes handheld, mobile, network technologies based on wired and wireless platforms, Radio Frequency (RF) or power line transmission. But, the main disadvantages of this system are loss of privacy and increased security risk from the network or remote access. Therefore, the proposed DHE will analyse the above mentioned issues.

III. INTELLIGENT AUTOMATION AND ENERGY MANAGEMENT IN BUILT UP ENVIRONMENTS

One of the objectives of this paper is to introduce a standardization of devices used in the built up environments. In this paper, the terminology standardization refers to standardizing the device information models and communication services in a common format to reduce the traffic path while communicating. The standout of this process has been the IEC 61850 standard [18]. IEC 61850 is an abstract application layer protocol aimed at providing interoperability between a variety of intelligent automation and wireless devices by describing how devices are to communicate in intelligent automation as well as related smart home system requirements. Therefore, to implement this technique, the application view model will be developed for the various built up environment automation systems such as temperature controlling model, electricity management model, water management system model. Furthermore this application model will be presented by the use of Object Oriented (OO) methodology and the techniques for modelling and implementation of the logical nodes and logical devices.

In [15] the authors have designed and implemented the Simple Object Access Protocol (SOAP) based residential management system. In this system, they

consider two main issues such as heterogeneity and interoperability. Heterogeneity, in this terminology defines issues related to the existence of multiple appliances and services in smart home systems. Interoperability, in this instance refers to various differences in hardware, operating system, programming languages and resources accepted by smart home systems. They analysed and met these challenges in their work by implementing SOAP based residential management system, connected together in Ethernet configuration.

In [16] the authors have designed and implemented a computer interacted Smart Home System based on Programmable Logic Controller (PLC), in this system, terminal and components are controlled and observed via computer interface using PLC, thus such systems are easily accessed over the computer and status variations of them are successfully monitored using the interface. Furthermore, several operations have been monitored and controlled over the use of central control units such as switch ON/OFF of electricity connection, open or close the water and gas valves, turn ON/OFF security system and heat control system of each room.

In [17] the authors have created new Smart Home Energy Management System using IEEE 802.15.4 and ZigBee; this work clearly demonstrates the smart home devices description and standard practices for demand responses and load management of "Smart Energy" applications needed in a smart based residential environment. They introduced smart home interfaces and device definition to allow interoperability among ZigBee devices produced by various manufacturers of electrical equipment, meters and smart energy enabling products to provide intelligent service for users.

In [18] the authors have designed an Object model of data and datasets in the International Standard IEC 61850. IEC 61850 is an international standard for substation automation system that started out as the Electronic Power Research Institute. It effectively reduces the diversity and complexity of the utility automated solutions minimizing operations, maintenance and engineering cost. Therefore this research aims to investigate this IEC 61850 standard and create the object model for smart home systems by using this technology. Therefore our future work is to create various object models for smart devices used in built environments using OO Methodology.

IV. DIGITAL HABITAT ECOSYSTEM ARCHITECTURE (DHEA) FRAMEWORK

The proposed DHEA is a self organizing system which can integrate a plethora of devices, referred to as Digital Devices (DDs), used in the home or other built up environments. This DHEA is designed with the help of wireless sensor networks, making it an open and loosely coupled network. It aims to help the various DS share their information using sensors and wireless nodes. Furthermore, it aims to use web technologies to control and monitor vital resources, such as water and electricity. To make this possible, it is important to analyse and identify data communication issues such as the time delay, jitter and skew, as well as error rate, when data and multimedia information is exchanged between the various devices using the wireless sensor network.

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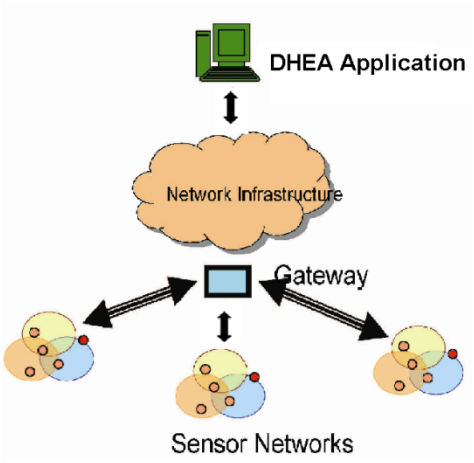

Figure1. Conceptual Model: DHE Monitor and Control (M&C) System.

Figure 1 shows the conceptual model of the proposed DHEA Monitoring and Control (M&C) system. Its main function is monitoring and controlling the usage of water and electricity in our built environments to minimize their consumption.

In terms of its development, the entire system can be viewed as comprising of two sub-systems: the software and hardware sub-systems. The hardware sub-system comprises a Wireless Sensor Network (WSN) that can gather information from all sensor devices and also deliver control signals to the various devices. This WSN can itself be monitored and controlled by a desktop computer and / or handheld mobile devices

The software sub-system is called the Digital Habitat Ecosystem Monitoring and Control (DHE M&C) sub-system. This is proposed as a software model that can collect all the information available from the various wireless devices in the home environment. It will be a dynamic system that can monitor, control, manage, analyse and synthesize all the information related to the home digital devices, so that anybody can monitor and control their home network by using their hand held devices such as mobile phones, laptops, and PDAs. To create this dynamic DHEA, there is a need for a methodology and framework. Framework is a high-level bare-bone model of a proposed system. To be able to design and develop the proposed DHEA systematically, a framework and a methodology must first be in place, to first visualize the specific DHEA. The next section analyses an existing methodology for developing DEs [11] and then expand into a proposed methodology for creating the proposed DHEA, taking into account that there are many interrelated processes happening within a DE. Most of these processes are based on knowledge of sharing and cooperation. The study outlined in this paper contributes to knowledge by not only proposing a new methodology and framework for the DHEA, but also by investigating its application for the general DE concept. The study outlined here takes that as the basis and proposes further enhancements to incorporate more detailed information. The following section describes the existing framework.

V. EXISTING FRAMEWORK FOR DEVELOPING DEs

Till a few years ago there were no frameworks or new methodology available for systematically developing DEs. However, the existing framework and related methodology were proposed by [11], which comprise the following five steps:

- Defining the digital species goals
- Creating intelligent digital species
- Defining collaborations of the digital species
- Enabling, improving and constructing individual digital species
- Implementing security requirements to protect the Digital Ecosystem

Although the above-mentioned methodology is not explicitly stated or addressed, each step requires a software engineer/developer to write codes for use within the DE. This first methodology is suitable for developing Digital Business Ecosystems [11]. As per this methodology: When considering capabilities of different DS, it is important to:

- Establish an intuitive Action, Information and Transaction (AIT) flow
- Identify DS's goals to establish the intuitive flows
- Identify different DS types.

VI. PROPOSED METHODOLOGY FOR DEVELOPING DHEA's

The proposed methodology to develop the DHEA contains the following additional steps:

- Collecting a list of digital species such as wireless sensors, wireless detectors.
- Constructing a separate network of selected species.
- Sharing the data using the network using the Publish/Subscribe and Multicasting communication mechanisms.
- Integration of the overall data within a central controller.
- Standardization of the data to be communicated across the network.
- Analysing the data communication and networking issues.
- Implementing the requirements to protect the digital species.

Using this methodology, the DHEA will be developed by creating step-by-step an understanding of the knowledge required for sharing of information, through integration of distributed Digital Species (DS) in a built environment. These DS, comprising hardware and software, communicate with each other via digital networks and related protocols [12].

This proposed methodology is superior to the existing methodology widely used in the literature because it allows for the following advantages:

- The DHEA system will automatically detect the various DS connected to the network and acquire the information regarding the functionality of the connected species. Hence, there will be no need to manually define the goals of DS.

- The DHEA system will automatically integrate the various DS according to their area of functionality.
- The data and information within the network will be communicated across the network to the relevant DS using a Publish/Subscribe communication mechanism. This is superior to the Client/Server communication mechanism as it is regarded to be very suitable for loosely coupled and scalable networks such as a DE [14].
- The information available within the network will be integrated within a central communication device, which will be responsible for controlling the utilisation and recycle of vital resources from a single source. Furthermore, it will analyse the data communication delays while sharing data with the central communication network.
- Multicast messaging allows the user to send a single copy to the data stream, which will then be replicated and forwarded to consumers that have previously signalled their interest. Therefore, instead of sending thousands of copies, the sender transmits a single copy directed by routers on the network to consumers that have indicated their interest in the message [14]. Consumers usually indicate their interest by joining a particular multicast session group. Thus, multicast messaging reduces the amount of traffic over the network yielding an increased efficiency for both the user and network with a number of other performance improvements.
- A solid base for interoperability will be provided by standardizing the device information models and communication services. This will be a major contribution to knowledge in this research and might even lead to the development of an International Standard in the near future.

  The following sections elaborate the steps outlined above, and show how this proposed framework can be used to model a DHEA's collaborative nature.

a. Wireless Architectures

In the proposed DHEA methodology, all species have to connect to each other via wireless networks and communicate with each other. Figure 2 demonstrates the conceptual communication links between all the devices.

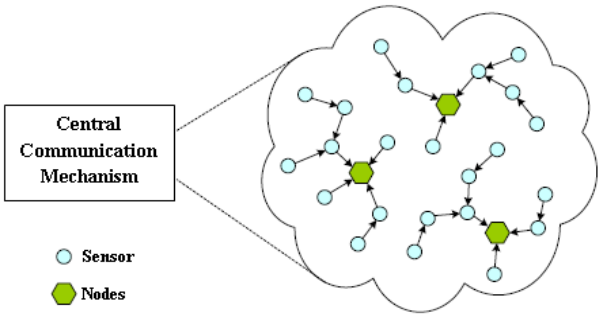

Figure 2. Integration of wireless sensors and nodes.

Table 1 presents a list of digital devices widely used in our homes. The central controller within the system will gather all the nameplate information of all the connected devices. The Central Controller will then group them according to their area of service.

The Central Controller Processor is a device used to transfer the information to the appropriate destination. All the sensors will communicate via central processor to get the information. In the Wireless Local Area Network, (WLAN), it links two or more devices using some wireless distribution mechanism to provide a connection through an access point to the wider internet. The sensors listed in Table 1 will be integrated using wireless gateways. There are some known challenges that arise within the WLAN network i.e. reliability (delay and interference), speed and power consumption [14]. Therefore, our research aims to investigate the reliability, speed and power consumption of the wireless sensors used in built environments by using the new proposed DHEA. The concept of proposed DHEA is to automatically sense and detect the wireless devices without doing any initial set up.

Table1. List of sensor devices used at homes

No	Devices	Function
1	Motion sensor	Detect motion in and around the home.
2	Door sensor	Monitor if a door is open or close
3	Window sensor	Monitor if a window are open or close.
4	Gas sensor	Detect the presence of gas in and around the home.

5	Water sensor	Detect the leakage of water in and around our home.
6	Gas valve	Enable/disable delivery of the gas
7	Water valve	Enable/disable water flow
8	Light detector	Detect whether the light is on/off.

b. Analysis of data integration using the network

With publish/subscribe networking, subscriptions provide routing information for efficient message delivery. Just as Internet Protocol (IP) routing uses information about network topology and IP address locality to establish efficient and resilient paths between IP packet senders and receivers, publish/subscribe networking can use information about network topology, location and subscriber interests to establish the best paths. Non-real time activities such as getting publication or subscription rights happen outside the real time loop ideally at the start-up. On the other hand, the generation, transfer and reception of messages are real-time activities happening in the real-time loop requiring very fast response times. There are two main types of nodes. Subscriber nodes can only subscribe to messages whereas publisher/subscriber nodes can publish messages as well as subscribe to messages published by other nodes [13]. Data from the wireless sensors and detectors can be shared with each other to transfer the result. To share the information in the developed DHEA the concept of Multicasting will be used to collaborate shared data.

In Multicasting systems, the information can be shared using communication protocols. Once after the integration and sharing of data from various nodes finishes, then the data will communicate with each node to share the information from one another. Hence, the collaboration takes place in two different forms such as self-organization and pre-set organization. Figure 3 shows the collaboration between the wireless sensor network and the system without any external element. The self-organization is a process where a structure or pattern appears without any external element, i.e. the different digital elements organize as a predominant structure. The preset organization is a process of data which do not have freedom to group with each other. Therefore, it's a collaborating and communicating process.

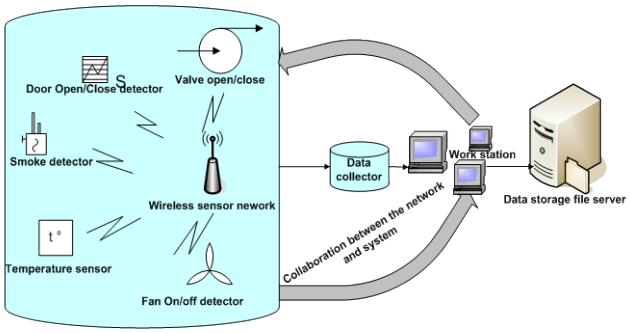

Figure 3.Collboration between network and the system.

c. Requirements to Protect Digital Species

DS can be protected by using functions such as authentication, availability, confidentiality, non repudiation and integrity [11]. These occur inside the DE, but can also occur outside such as the time during the interaction with the environment. Hence, while designing DE, a range of important aspects must be considered. These include identifying the issues such as time delay, jitter and other security, addressing those issues, setting the boundaries and encoding the knowledge which can be understood by all digital species of the DE [11].

VII. FRAMEWORK TO DEVELOP DHEA

According to DHE, the proposed framework will consider as a collection of existing hardware components together to create a dynamic software system. Figure 4 shows the overview of the DHEA framework.

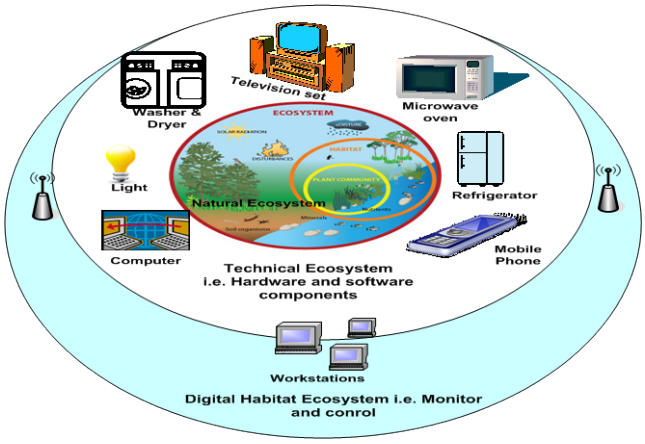

Figure 4. Overview of DHEA Framework

Table 2 shows the three dimensions of ecosystems that must be taken into consideration when designing a framework. These are the:

- **Natural ecosystem**: Ecosystem such as vital resources used in the home environment
- **Technical Ecosystem**: Hardware and software system to collect information from the vital resources.
- **Digital Habitat Ecosystem**: Combined form of natural and technical ecosystem

Table 2: Overview of DHE Framework

Natural Ecosystem	Technical Ecosystem	Digital Habitat Ecosystem Architecture
Ecosystem such as vital resources at the home environment	Hardware and software system to collect information from the vital resources	Combined form of both natural and technical ecosystem
Water Electricity	Sensor Detectors Wireless networks Web system	DHEA Monitor & Control

VIII. INFORMATION & COMMUNICATION TECHNOLOGIES FOR DHEA

DE is pursued with Cyber engineering and human space computing. Cyber engineering represents the digital domain of our ecosystem, social networks, web services, Web 2.0 and Web 3.0. Human space computing represents the study of technologies such as Telecommunication, Wireless technologies, Third Generation (3G) and Fourth Generation (4G) mobile technologies, and Personal Digital Assistants (PDA's). The advanced Information and Communication Technologies (ICT) such as Web services, Multimedia, Wireless technology, Smart systems is used to develop the DE. It is defined as the man-to-machine communication that would enable automated processing of web resources and serve as the foundation for the "Semantic Web" [8]. Multimedia content is used to transfer data from wireless to 3G and 4G mobile networks [6]. The Wireless Integrated Sensor Network (WISN) is a new networking paradigm with monitoring and control capabilities and can be implemented in different environments such as manufacturing, households, safety and security [9].

a. Quality of Service Challenges in Data Communication

In DE, the data can be transmitted as digital data and multimedia information. The consistency with which this information can be transmitted depends upon the required bandwidth as well as the coding and compression techniques used for encoding the multimedia elements. Furthermore, the transport services provided by the communication and the network systems greatly influence the Quality of Service (QoS) that can be provided to the application [7]. There are possibilities of delay, error rate, and jitter occurring while transmitting the information.

Most multimedia applications need to transmit not only the core information but also associated meta-information. For example, there is always a need for intimation of information arrival. The transmitted information itself can be simple digital data or textual information, such as a text email, or a mobile text message (i.e. SMS). Often transmission of digital data and simple text messages does not encounter QoS issues such as delay or jitter [10].

However, as we move towards transmission of audio or video messages, the need for bandwidth increases, and any delay in transmitting the message lead to reduced QoS [10]. If the different parts of a message encounter different delays, it leads to jitter. If there is too much jitter, an audio message can become incomprehensible. Jitter in transmitted video will lead to a shaky picture, and may defeat the original purpose of transmitting the video in the first place. Therefore, the selection of the type of information to be transmitted needs to be considered carefully in relation to the application requirements and the communication technologies used in the different parts of the system.

b. Input and Output Data transfer for DE

This section discusses the input and output data for the DE and their QoS issues. Normally multimedia content such as text, audio, video, picture and animation will be used to transfer the information and display the

operation of the DE system. Technically these contents should be based on digital signals with bandwidth, frequency and time.

Table 3 explains the different levels of Communication mode and the data of the multimedia content and its usage. In pre 1980's only the electronic home systems such as basic radio, telephone and television was introduced with wired/wireless connection. In early 1990's computer systems and electronic devices played a major role in the day to day life. During the late 1990's and early 2000's, the wireless and communication technologies occupied and improvised in various stages of usage such as mobile phones, internet, online system, e-learning, e-finance, all become a web based managed. Though these technologies are more vibrant and still in use, many researches have been undertaken on intelligent technologies to introduce more innovative and effective systems. This DHEA research will extend the new transition in the built-up environment. In other words, to investigate the wireless home system and create Object Oriented model for those smart systems and standardise the different types of system to common code using IEC 61850 standard. The recent technologies are improvised version of the existing devices in different parameters with some betterment i.e. higher in bandwidth, frequency and speed, lower in power consumption and less QoS issues.

Table 3: Home systems data and usage

DHE Level	Communication mode/adoption era	Multimedia content and its usage
3	DHE-Intelligent Home Systems: 2010+	*Power consumption:* Low *Communication bandwidth:* Good *Delay:* Low *Programmability:* Very high *Performance*: High Speed *Operation*: Sensor based (Wi-Fi) *Technology:* advanced Multimedia, digital, wireless and some wired will be expected *Set up*: Automatic *Generation:* 3G and 4G
2	Smart Home Systems: 2000's	*Power Consumption:* Good *Communication bandwidth:* High *Delay:* High *Programmability:* Medium to High *Performance:* Normal Speed *Operation:* Remote control operation *Technology:* Multimedia and wireless, some wired *Set up*: Initial Configuration *Generation*: 2G and 3G
1	Electronic Home Systems: 1990's	*Power:* High *Communication bandwidth:* Low *Delay:* Low *Programmability:* Low *Performance:* Low speed *Operation:* Manual Switch on/off *Set up:* Manual and wired *Generation*: earlier stage
0	Home Systems pre 1980's	*Power consumption:* High *Communication bandwidth: High* *Delay: High* *Programmability:* Not much Programs available *Performance:* Nil *Operation:* Basic *Set up*: Nil *Generation*: Not introduced ***Note***: Not much electronic devices available to use, only basic components easy to handle such as Radio, Telephone, Basic Television

IX. CONCLUSION AND FUTURE WORK

This paper has provided an overview of the concept of DE, and introduced a new concept for DHEA. The DHEA is defined as a self-organizing system integrated with list of DS available in the home environment using wireless sensors and detectors. The work outlined in this paper discusses the need for the development of a methodology and framework for creating

a DHEA. This novel methodology and framework will lead to a pathway when developing a dynamic model that can monitor and control existing wireless devices available in the home environment, instead of using separate static devices.

The existing framework used when developing DE applications has been summarized and shortcomings of this framework have been discussed. The framework proposed in this paper includes many innovative ideas to solve the issues associated with the existing framework. Future work is to include the development of a more detailed hierarchy of DHEA framework leading to the creation of object model and architecture for the DHEA.

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