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### **Original Citation**

Mahmud, Hoger and Lu, Joan (2015) A generic vobe framework to manage home healthcare collaboration. *Journal of Theoretical and Applied Information Technology*, 80 (2). pp. 362-371.  
ISSN 1992-8645

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# A GENERIC VOBÉ FRAMEWORK TO MANAGE HOME HEALTHCARE COLLABORATION

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## ABSTRACT

In this paper we propose a conceptual framework to manage Home HealthCare (HHC) provision and stakeholder collaborations using the concepts of Virtual Breeding Environment (VBE) and Virtual Organisation (VO). Providing healthcare at home is gaining popularity as more and more patients prefer to receive care in the comfort of their homes. Providing care at home is complex and involves many stakeholders; collaboration and resource sharing between these stakeholders is essential for a successful home healthcare provision. In this paper we outline a framework to classify different parties involved in Home Healthcare (HHC) collaboration based on their roles. The framework consists of two main components which we call HHC-VBE and HHC-VO. The proposed framework is applied to a simple home healthcare case study and it is later evaluated. The result shows that the framework is simple and flexible and can be applied to other scenarios. This research contributes towards addressing the ongoing challenge of HHC collaboration management.

**Keywords:** *Virtual Breeding Environment (VBE), Virtual Organisation (VO), Home Healthcare (HHC)*

## 1. INTRODUCTION

In this paper we propose a conceptual framework to manage home healthcare (HHC) provision and stakeholder collaborations using the concepts of Virtual Breeding Environment (VBE) and Virtual Organisation (VO). The world's population is ageing and with it come many challenges, one of which is the increase in the number of people with long-term health conditions that require constant care. To tackle this challenge home healthcare is seen as one of the answers. Home healthcare refers to the healthcare provided in either specialized care homes or at patient's home. Specialized care homes are mainly set up as business, some are privately funded and some are state funded, for instance according to [1] there are 18,255 registered care homes in England. HHC is growing fast because more and more patients wish to receive treatments in the comfort of their homes. HHC service provision is cheaper compared to traditional hospital based care provision, [2] states that patients receiving home healthcare in the United States on average cost \$8,000 less than the ones stay in hospital. HHC is practiced daily, for example cancer patients that are in receipt of chemotherapy can now receive their dose of drugs

at home using a convenient infusion pump [3]. HHC is very complex and comprised of many stakeholders, [4] claims that the complexity of home healthcare can overwhelm the current management and coordination process, [5] and [6] also support this claim, hence the need for a better management and coordination mechanism. The focus of existing researches is on developing technologies for home telehealth, or home telemedicine [7], but [8] indicate that the focus should be on management aspect of home healthcare.

Moving away from a single provider of health care to multiple providers collaborating and working together across multiple teams is essential for a successful home healthcare provision [9]. In this paper we focus on the home healthcare services that can be provided virtually and propose a conceptual role and activity based management framework using the concepts of Virtual Breeding Environment (VBE) and virtual Organisation (VO).

VBE and VO are well researched concepts in computer science to address collaboration and coordination issues arising from highly dynamic and distributed organizations, section 2 provides more about the concepts. Generally speaking VBE collaboration environment is formed between a number of parties (for example, local health

authorities, health issuance companies and medical professionals) on a long-term base. VBE provides the supporting environment for VOs to be formed whereas VO is short-lived collaborations established between a number of parties to achieve a specific goal (e.g. guiding a patient how to take care after a surgery). In an ideal VO the needs of a patient can be fulfilled through a dynamically formed consortium of geographically dispersed medical specialist and other service providers when needed. This can provide an environment where patients feel secure knowing that care can be provided when required. However it is important to mention that not all types of cares can be provided in VO settings, for instance healthcare that requires physical engagement is beyond the scope of virtual healthcare organization.

We advocate that the proposed framework is capable of facilitating the management aspect of home healthcare in terms of representing roles and activities of actors in a virtual healthcare setting. The proposed framework help system developers and healthcare professionals to get a conceptual view of virtual healthcare roles and activities abstracted from implementation complexities.

The main contribution of this work is to show the potential of VBE and VO in facilitating the setup and management of home healthcare virtual collaboration. We also show that having a framework can help in identifying roles and services in home healthcare which in result help in raising the quality of care by being more organised. In section 4 we discuss the limitation of the proposed framework.

The rest of this paper is organised as the following, in section 2 we provide a brief background, related research and the methodology in brief. In section 3 we describe in detail our proposed framework. In section 4 we evaluate and discuss the framework, in section 5 we conclude.

## 2. BACKGROUND AND RELATED WORK

We provide a brief background about VBE and VO in section 2.1, present some related research in section 2.2 and briefly explain our research method in section 2.3.

### 2.1 VBE and VO introduction

Traditionally collaboration was done in a face to face medium, however recent technological discoveries such as the internet and telecommunications have introduced a new type of collaboration known as "virtual collaboration" [10] [11]. Virtual interaction and collaboration can facilitate the delivery of a number of essential

services, for example the concept has been researched for potential benefits in education, e-commerce, teleworking and teleconferences [12] [13]. With the emergence of virtual collaboration a new type of community known as "virtual community" (VC) developed. It is described as a group of people that exchange words and ideas in cyber space without having a face to face encounter [14]. For regulating the collaboration in virtual community the concept of Virtual Breeding Environment (VBE) and Virtual Organisation (VO) have been widely researched [15] [16].

In general a VBE is the supporting environment where VOs can be born and live for the duration of their task. VBE infrastructure is seen as permanent participants that provide and enforce the rules of collaboration amongst participants of a VO including resource sharing mechanisms, and partner responsibilities. Virtual Research Environment (VRE), Open Science Grid (OSG) and Enabling Grids for e-Science in Europe (EGEE) are examples of such environment [17] [18]. Lack of trust between parties that suppose to be involved in VO collaboration and how resources should be integrated are some of the challenges that VBE can tackle [19] and this provide a stable infrastructure for VO to be managed. [20] Outlines the lifecycle of a VBE in three main stages: initiation, operation and dissolution; they also present the functions supported in each stage.

VO on the other hand is described as "*A loosely bound consortium of organisations that together address a specific demand that none of them can (at the given time) address alone and once the demand has been satisfied the VO might disband*" [21]. The rapid formation characteristics of VO and no long term commitments for the members of a VO makes the concept very appealing to rapidly changing environments such as HHC. Resources are requested and shared by collaborating members of a VO and the collaboration is regulated and managed by the VO. According to [19] preparation, operation and dissolution are three stages that a VO goes through during its life cycle which is the same as VBE but in a much shorter life-time. In the preparation stage the right participants are identified for engagements and the required resources and infrastructure are put in place. In the operation stage the resources and skills are shared and the collaboration continues until the set task is accomplished, in the final stage the VO is dissolved. The need to form a VO usually arises when a number of participants can see a shared goal. The practicality issues of VO creation is beyond the scope of this paper instead we follow

a similar way as [22] and “concentrate on the functional and behavioural aspect in which partners and resources are involved without committing to the way in which they are effectively implemented”.

## 2.2 Related Research

VBE and VO concepts are recognised for their potentials to tackle collaboration challenges between organisations and parties in different geographical areas. According to [23] VO creates one face for interaction and brings all resources together to be shared and used with the aim of achieving common goals. [22] Propose a formal framework to model VBE and VOs at different levels of abstraction from both structural and behavioural prospective. Similar to our proposed framework they use general classification for different actors and resources. However their focus is on formally describing the structure and behaviour of VBE and VO rather than using the concepts to answer challenges such as management in a specific domain which is the aim of this paper. According to [24] the concept of VO is used to link health care providers, insurance companies and hospitals. [25] Studies management of virtual organization inside healthcare and uses grid technology as architecture for assigning roles and privileges as well as resource definition. Our framework is different in comparison since we consider the use of VO concept in managing healthcare collaboration rather than managing the VOs inside healthcare. However the study can be used as an extension for our framework to introduce role assignment, resource definition and access control techniques. The author in [26] proposes a framework to classify virtual community of practice (VCoP) in heath care sector. The framework is specific to help physicians identify the most active communities in order to participate in and use their resources effectively. Virtual community is one aspect of virtual healthcare that can benefit from such framework however a more holistic framework is required to consider all virtual services that can be provided in healthcare sector such as resource sharing and real time monitoring. We believe our proposed framework is generic enough to represent all actors

and services involved in virtual healthcare provision.

[27] Investigate the potential of cloud based collaboration, which is a form of virtual collaboration, in advancing healthcare provision and [28] see great potential in cloud computing for health record management. The authors research the use of the concepts without specifying how the contribution is made and how participants in cloud based collaboration are managed and organized. [29] Proposes a process approach supported by a home healthcare support system to tackle organizational aspect of home healthcare. Home healthcare is dynamic which means a process configuration suitable for a particular scenario may not be so for another, we believe a VO based framework can tackle the organizational aspect of home healthcare better than the proposed approach. [30] Propose a home healthcare system for depressed patients based on the cloud where integrating security and privacy into the cloud based system are their main concerns. The paper states a number of stakeholders such as professionals, GPs and pharmacists that are involved in the system but they fail to explain how these stakeholders are managed in the system. The proposed system has similar characteristics as VO, in way that the stakeholders can be from different geographical areas collaborating virtually. A virtual system for medical teams dealing with cancer patients at their homes is presented in [31] which have been implemented in Cyprus and the aim is to facilitate the dynamic creation and management of virtual medical teams. This system is an example of virtual collaboration concept realised, the framework we propose in this paper can help in the design and development of such systems. VO is also investigated in other areas for example A virtual research environment is proposed by [17] for researchers to collaborate and share resources virtually. In a previous paper [32] we propose a VO framework to model archaeological excavation and we show how the concept of virtual organisation can enhance the management process of an excavation. A framework to manage a VO breeding environment in the business arena is suggested by [20], which aim to show how a VBE can be managed based on

describing some general roles and services of VBE. However that they admit that the framework is not suitable for healthcare “*Clearly neither Competencies nor resources of the organizations in the VBE for Healthcare (e.g. Doctors practice office, insurance company, ambulance services, etc.) can be defined by the same ontology*” our framework is specific to healthcare and fills in the gap. Authors of [33] propose a formal framework to model virtual organization and classify participants in VO as agents according to the service they provide. In healthcare trust and security is very important therefore it is necessary that the agents are identifiable and accountable for the service they provide, but the proposed framework focus on the role of the agents and ignores the identity of the agent which makes it unsuitable for healthcare.

Our framework is different from all above because we use the concept of VBE and VO to outline a framework capable of managing virtual home healthcare provision and collaboration rather than the actual creation of VBEs and VOs.

### 2.3 Research Methodology

For the purpose of developing and understanding the framework we use case study investigation methodology as described in [34]. Case study is used in many researches and according to [35] it is essentially an empirical inquiry since it represents a real life scenario. To achieve the aim of this paper we take the following steps:

- 1-Survey available literature in the field of Home Healthcare and collaboration
- 2-Investigate the concept of VBE and VO and put together the Generic framework that aims to manage the communication and resource sharing between interdisciplinary entities concerned with Home Healthcare
- 3-Develop simple nontrivial Home Healthcare related case study
- 4-Classify the main participants and resources in the case study according to the framework
- 5-Visualise the case study using UML use case diagram
- 6-Evaluate the framework for strengths and weaknesses

### 3. FRAMEOWRK DESCRIPTION

In this section we describe the VOBF framework we propose and we call it Home Healthcare Virtual Framework (HHC-VF) see table 1. The framework is made up of two main

components (HHC-VBE) and (HHC-VO), in section 3.2 we begin by describing the HHC-VBE and In section 3.3 we describe (HHC-VO). We also describe a simple healthcare scenario and apply the proposed framework in section 3.4 to show the applicability of the framework.

#### 3.1 Assumptions

Caring for patients in their home settings present multiple challenges that require access to real time resource sharing and collaboration. Dynamicity is one of the main characteristics of home healthcare, which means the process and management of care provision changes according to the patient’s environment and state. Care givers need to answer patient needs and provide timely advice and guidance that can best serve the patient. [36] States that the duration of care provision also changes as it may run for a long period of time, in the case of chronic diseases, or a short period of time, in the case of accidental injury. Because of this dynamicity we believe a flexible and scalable management and coordination framework is essential to achieve high quality home healthcare. Before we explain the components of the framework it is important to state that in designing the framework we make the following assumptions:

- 1-Participants are capable of using electronic devices such as computers and smart phones or themselves are the devices for example a heart rate monitoring device at the patients home capable of communicating to other devices
- 2-Communications are carried out electronically via local networks or the internet
- 3-Services provided within the framework are achievable virtually, for example accessing a patient health status report or providing treatment related advices to patients.
- 4-Each role identified within the framework has the following attributes:
  - *Name*: String (the name which the participant is identified with e.g. Doctor, Nurse)
  - *Role*: String (The role of participant within the framework e.g. provider: provide catering service )
  - *SLA*: String ( electronic service level agreement between collaborating participants and resources)
  - *Start*: Time (the start time of service provision and collaboration of a participant )
  - *End*: Time (the end time of service provision and collaboration of a participant)
  - Collaborate : Data ( the data and information exchanged between participants and resources)

### 3.2 HHC-VBE

The idea of HHC-VBE is to recruit and organise interested members and required resources to provide a long-term infrastructure for the creation of dynamic short-lived and goal based ensembles called Virtual Organisation (VO). Members are geographically dispersed and they are recruited based on some criteria such as competence and profiling [20]. In designing our framework we follow other researchers such as [37] and use role-based classification for the members of the HHC-VBE. The VBE consist of two distinct classes of roles and one class of activity as shown in figure 1 and they are:

**1-Organiser:** Represent roles of all participants (could be for example healthcare professionals or organisations) who come together to establish the HHC-VBE to support healthcare service provisions to patients at their home. Organisers are two types; permanent which we call “P-Organiser” and semi-permanent which we call “S-Organiser”, each of these types of roles are explained below.

a)**P-Organisers:** participate in maintenance and management related activities of the VBE which we call ”Task”. This type of role is denoted by <<P-Organisor>> followed by its name and they provide the following services:

- Manage HHC-VBEs
- Recruit other permanent and semi-permanent members based on the need of a HHC-VBE
- Make sure required resources are available and can be accessed when needed
- Make sure opportunities are available for timely VO creation
- Decide on the creation of HHC-VOs
- Define Service Level Agreement criterion

b)**S-Organisers:** are recruited by permanent organisers (P-Organiser), they can also be suggested by customers (for example patients) of the VBE which we call “Requester”. They participate in HHC-VO and they will stay until the goal of the VO is achieved after that they will disappear. This type of role is denoted by <<S-Organiser>> followed by its name and provide the following services:

- Manage HHC-VOs
- Recruit temporal members into a VO, we call theses members “ Providers”
- Decide if the goal of a HHC-VO has been achieved and whether to end the VO or not.
- Make sure the required resources are available and provided to the HHC-VO in order to achieve its goal which we call “Service”.

**2-Support:** Represent the role of all electronic resources that can be used to support the operation of a HHC-VBE or HHC-VO such as a database or a decision support system. This role is denoted by <<Support>> followed by its name and should support the followings:

- Information storage
- Communication medium
- Collaboration and SLA policies
- Processing tasks
- Input mechanism
- Output mechanism

**3-Task:** Represent all the collaborative and non-collaborative activities necessary to manage and maintain the operation of the HHC-VBE. It is denoted by <<Task>> followed by its name and should support the following:

- Facilitate participant interaction within the task
- Regulate the usage of resources
- Define resource access policies
- Define participant roles and responsibilities

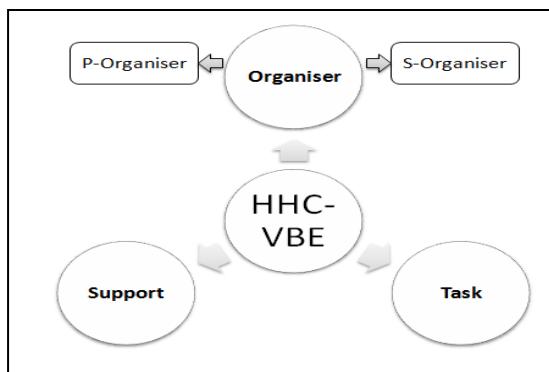


Figure 1: HHC-VBE components

### 3.3 HHC-VO

HHC-VOs are short lived services provided to customers (Requester) of the HHC-VBE and formed on the request of the customer (e.g. patient). HHC-VOs should generally support the following functionalities:

- 1-Analyse requests
- 2-Identify needed resources to deal with the request
- 3-Recruit necessary participants to provide services to the requester
- 4-Regulate resource sharing within the VO

The HHC-VO also consists of two main classes of roles and a class of activity as shown in figure 2 and they are:

**1-Requester:** Represent service requesting participants (for example patients or healthcare devices), they ask the HHC-VBE for a service

which subsequently be provided by a VO which we call “Service”. Requestors are denoted as <<Requestor>> followed by its name and implement followings:

- Request health related services
- Answer queries made by “Organiser” and “Provider” participants
- Rate services provided

**2-Provider:** Represent all members that provide service to a VO and they stay for the duration that they are needed to provide a service. For example a Pharmacist can be asked to provide details about a particular drug to a patient and disappear soon after. It is denoted as <<Provider>> followed by its name.

**3-Service:** Represent VOs that are formed based on the request of providers or organisers. Services should support activities which are the same as the ones supported by “Task” described in section 3.2 but they are short-lived and last only for the duration of the VO. It is denoted by <<Service>> followed by its name.

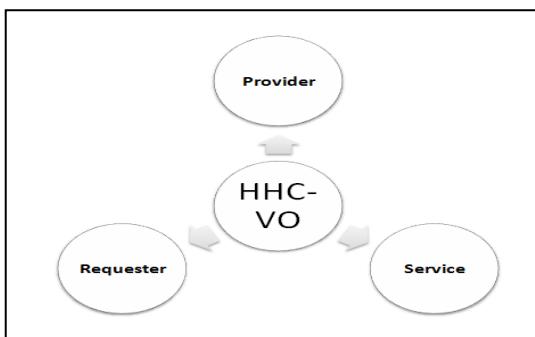


Figure 2: HHC-VO components

Table 1 is a summary of the six components, their names and attributes of the proposed Home Healthcare Virtual Framework (HHC-VF)

Table 1: HHC-VF Summary

	Stereotype (Role-based)	Naming Convention	Attributes
HHC-VBE	Organiser	<< Task>> name	Name: String Role: String SLA: String Start: Time End: Time Collaborate : Data
	Support	<<Support>> name	Name: String Role: String SLA: String Start: Time End: Time Collaborate: Data
			Name: String

	Stereotype (Role-based)	Naming Convention	Attributes
HHC-VO	Task	<<Organizer>> name	Role: String SLA: String Start: Time End: Time Collaborate: Data
	Requester	<<Requestor>> name	Name: String Role: String SLA: String Start: Time End: Time Collaborate: Data
	Provider	<<Provider>> name	Name: String Role: String SLA: String Start: Time End: Time Collaborate: Data
	Service	<<Provider>>	Name: String Role: String SLA: String Start: Time End: Time Collaborate: Data

### 3.4 Case Study and Models

To demonstrate the applicability of the framework we consider the following scenario, and visualise the result using UML use case diagram.

*To ease the pressure on hospitals a local health authority in Yorkshire- England would like to set up a HHC-VBE to help patients that need long-term follow up care after having a surgery.* Bearing in mind that a home healthcare needs to be managed, financed and patients’ progress and treatments need to be recorded, therefore to set up the HHC-VBE the health authority decide to:

- Appoint a clinical manager and a financial specialist as “Organiser”
- Install a monitoring support system connected to the central patient record system as “Support”
- Make sure necessary resources are available and accessible when required as “Task”.

The local health authority together with other organisers over sees the overall management of the HHC-VBE which provides the services described in section 3.2. To understand a process it has to be described in detail [38] suggests modelling the process is one way of doing it because modelling “increases the readability of a process and its evaluation”, and there is an axiom that states we need to model something before we can automate it [39]. To further clarify our framework we have modelled both HHC-VBE and HHC-VO in figure 3

and 4 respectively using UML use case diagram.

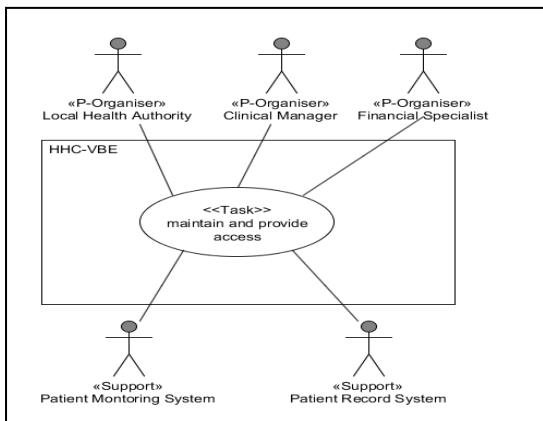


Figure 3: Use case Diagram for the HHC-VBE

#### 3.4.1 Using the HHC-VBE to Provide Care

Health care is very complex, having appropriate mix skills during health care provision is important to achieve a positive result for the care receivers. HHC-VO makes sure that the right care givers (providers) with the right skills are recruited by defining a set of recruitment criteria. In a timely healthcare provision cutting bureaucracy during health care provision is also important, by specifying roles and responsibilities a HHC-VO can deliver this requirement. We consider the following case study taken and simplified form [40] and visualised in figure 4.

*A female patient named X who recently had a right hip total joint arthroplasty after spending some time in hospital it has been decided to be sent home and cared for in the comfort of her home. The patient has a history of other illnesses such as hypertension, osteoarthritis and coronary artery disease. The patient lives alone and has a niece who visits her occasionally to care for her as much as she can. The patient has to take regular medications and her ability to move is currently limited by her recent operation.*

According to [41] a Surgical Site Infection (SSI) is a possibility after a surgery which is mostly caused by “contamination of an incision with microorganisms from the patient's own body during surgery”. This kind of infection can be life-threatening. To prevent surgical site infection occurring good collaboration between the professionals and the patient is essential. To demonstrate the applicability of the framework we consider the following:

Considering the condition of patient X her surgeon with agreement of the patient asks the HHC-VBE to set up a HHC-VO called “infectPrevention” for

the patient which should support the following functionalities

- 1-Enable patients and carers to access clear and timely information and advice at all stages of the care
- 2-Enable healthcare professionals such as surgeon or nurse to monitor the patient progress
- 3-Find and recruit other providers such as pharmacy and safety and medical equipment proving companies when needed
- 4-Find and recruit local businesses such as a catering company to provide food for the patient when needed
- 5-Find a recruit emergency services such as ambulance when needed

To achieve the goals of “infectPrevention” the following roles are required as per the framework:

- 1-S-Organiser: a Nurse to manage the care
- 2-Providers: a Surgeon to give advice when needed, a pharmacy to provide medication when needed, a medical equipment provider when needed, a catering shop to provide food to the patient and finally emergency service to get to the patient when needed
- 3-Support: Electronic Patient Record System to provide medical history of the patient to care providers and let the patient record progress
- 4-Requester: the requester of the service is patient X and the surgeon.
- 5-Service: infectPrevention which support all functionalities stated in section 3.3.

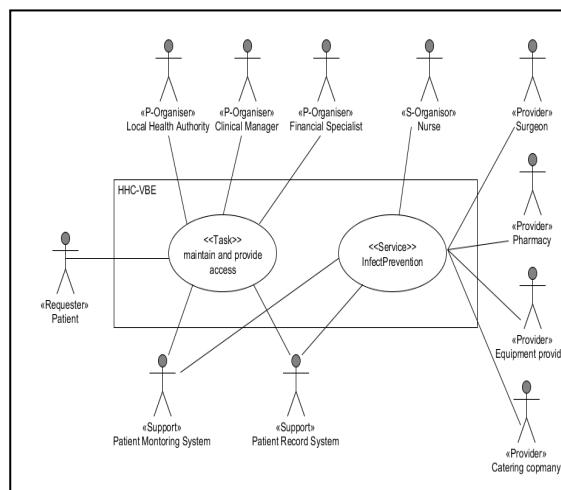


Figure 4: Use case Diagram for the HHC-VO

#### 4. EVALUATION AND DISCUSSION

The objective of home healthcare is to improve efficiency and quality of care through decentralization of healthcare. The framework presented in section 3 is designed to manage the decentralized parties in a simple and effective organization setting. It consists of six primitives only, which simplifies healthcare representation and it is flexible enough to be used for any home healthcare scenario. We have applied the framework to a simple case study in section 3.4 in support of this claim. The framework's main objective is not to show how the care delivery is implemented; it rather addresses the organization and management aspect of home healthcare stakeholders in an abstract setting. It is also important to mention that technological and technical aspects (e.g. type of signals, type of connections, and type of hardware) that might be used in implementing the framework is beyond the scope of this paper. Our framework is targeted at home healthcare providers and application developers to help them simplify complex scenarios and give them the ability to foresee management tasks. The framework benefits from the facilities provided by VBE and VO concepts which enable users of the framework to identify "provider" at run-time and recruit them to provide a timely healthcare for the "requester".

[42] Identifies a number of challenges in delivering home healthcare one of which is the lack of "*care-giving support in housing, meals, and transportation*". Our framework can enable patients to improve their care by self-activation and self-management through communicating and collaborating with other participants of HHC-VO. The framework is not specific to healthcare providers only; it is rather a holistic framework that all stakeholders of healthcare provision (Healthcare professionals and other providers such as catering company) can be recruited when needed. To support this claim let us compare the proposed framework with a collaborative healthcare provision system known as telehealth [43]. Telehealth system is a healthcare collaboration mechanism currently used to deliver care to patients located at different geographical areas. There are a number of services provided through telehealth for instance Case Management, Doctor-to-doctor consultation and Telestroke. The collaboration service provided by telehealth is limited compared to our framework, to elaborate more, let us consider a simple patient scheduling task for a telemedicine consultation.

According to  
[\(http://www.telehealthresourcecenter.org/\)](http://www.telehealthresourcecenter.org/) patients

can only be scheduled in a period of time set aside by specialist, which means patients can only be serviced at specific times only. Our framework enable patients to request services on the fly and be serviced on the fly, this is because patients request services from a pool of providers around the globe rather than a specific number of providers which is the case in telehealth.

The implication of the framework for home healthcare is significant if implemented, however there are a number of limitations that need to be addressed to make it more representative. Our proposal does not include direct human participation during care provision which is inevitable in the field of healthcare. Technical and social cultures of participants have not been considered in the framework which undoubtedly is an important factor that needs to be considered. The framework lacks participant identification and selection mechanism, it also lacks service level agreement (SLA) criteria for the operation of the HHC-VBE and HHC-VO without which a fair assessment on the effectiveness of the framework is difficult to be carried out. We intend to develop the framework further in our future works by addressing the weaknesses identified.

#### 5. CONCLUSION

Every year the demand of patients to be cared for at the comfort of their homes increase, with it comes many challenges one of which is the management aspect of home healthcare (HHC). Home healthcare refers to the healthcare provided in either specialized care homes or at patient's home. Healthcare provision is complex and many stakeholders are involved in the process. Researches show that the current management process for HHC provision is not efficient and new management techniques need to be developed. One way to increase efficiency is to facilitate real-time collaboration and resource sharing between all involved in HHC. In this paper we have proposed and explained a simple VO and VBE based home healthcare framework consisting of six primitives that can be used to organise and manage HHC stakeholders virtually. The framework evaluation shows that the framework is simple and flexible and can help HHC managers and system developers to get a conceptual view of virtual healthcare roles and activities abstracted from implementation complexities. The main contribution of this work is to show the potential of VBE and VO in facilitating the setup and management of HHC collaboration.

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