A Context-Aware Framework for Healthcare Governance Decision-Making Systems: A model based on the Brazilian Digital TV

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***Abstract*— This work proposes a governance decision-making support model for public health care systems. It encompasses and integrates the family homes in a new intelligent Health Care Information System. In order to support end-user interaction with this system, the proposed model is built on the GINGA middleware developed for the Brazilian Digital TV, whose full access will be country-wide in 2015. Based on five intelligence management domains, namely knowledge, normative, clinical-epidemiological, administrative, and shared, the model relies on an Optical-WiMAX communication infrastructure (Brazilian Digital Belt), which will reach 82% of urban population of the Ceará State in Brazil. In additional, we present a context-aware decision-making support framework, which offers context-aware services that can be reused for implementing the proposed conceptual model.**

Keywords-component; Integrated Health Network, Decision-making, Middleware GINGA, Brazilian Digital Belt, Context-awareness.

I. INTRODUCTION

Nowadays, the increasing incidence of diseases (e.g. epidemics, pandemics, outbreaks) represents a major challenge for health systems. The resources dedicated to the patients and their associated costs intensify the pressure on health systems that cannot meet the demand. Faced with this challenge, many advocates the use of innovative clinical approaches, including the encouraging greater involvement of patients and the systematic monitoring of their conditions, rather than simply treating the acute problems [1]. The information technology (IT) thanks to their ability to remotely monitor and interact with patients and caregivers, have attractive qualities for this role [2].

Home telemonitoring to health care can be defined as the use of information technology and communication for exchange of information between the residence of families and health professionals to improve coordination and the effectiveness of health primary care

In this scenario, the digital TV (DTV) can be seen as a device installed at the residence of families to serve initially as a tool for unidirectional transmission of health knowledge. Moreover, using DTV we are able to establish bidirectional communication in order to promote the exchange of information between families and health care teams. For instance, it could be used for retrieving information (i.e., passive use of health sensors) or gathering relevant information regularly (i.e., active sensors) about the clinical condition of family members (e.g, health vital signs, intensity symptoms), called health context information.

This health context information could be explored by a knowledge management system, which is able of analyzing that data, in order to make health care decisions based on inference rules. Thanks to these smart features, the system could, if the patient's condition deteriorates or fails to remain within the limits, provides alerts or decision support to the patients as well as clinical teams. Moreover, the care team could access remotely real time or delayed patient's data, allowing the patients to react appropriately and quickly *in situ*.

Thus, this work proposes the LARIISA[1], a context-aware framework for healthcare governance decision-making systems, based on the digital TV technology. It encompasses and integrates the family homes in a new intelligent health care information system. In order to support end-user interaction with this system, the proposed model is built on the GINGA middleware developed for the Brazilian Digital TV [3] whose full access will be country-wide in 2015 [4].

[1] Acronym obtained from the following French words: Laboratoire, Réseaux, Intelligence, Intégration, Santé, Aplication.

Based on five intelligence management domains (knowledge, normative, clinical, administrative, and shared) the proposed model relies on an Optical-WiMAX communication infrastructure (Brazilian Digital Belt) [5], de which will reach 82% of urban population of the Ceará State in Brazil.

The reminder of the paper is organized as follows: Section II presents an overview on governance concepts. Section III describes the Larissa framework and the adopted governance setting for decision-making support. Posteriorly, Section IV explains a case study in a real scenario (Dengue epidemic). Section V presents the Diga-Ginga, a DTV prototype used by LARIISA framework. Finally, Section VI discusses related work and in Section VII we conclude the paper and discuss future work.

II. OVERVIEW ON GOVERNANCE

Governance is a multi-dimensional concept that has emerged in the business management and public administration areas. In general terms, governance refers to the conduct of *Collective Action* from a *position of authority*. *Collective Action* is associated with the formal organizations such as hospitals and community health, as well as less formal arrangements such as partnerships with community and health networks. *Position of authority* refers to the formal or legal legitimacy of a particular body to control and develop the adaptive capabilities of an organization or system. Formal authority is necessarily associated with certain responsibilities, such as the legal responsibility of a hospital in the quality of care provided by their clinicians [6].

Based on the field of business management, governance has been defined as the nature of relationship between an organization and its owners. This definition is the basis of many policies promoted by the World Bank[2] in order to increase the performance of hospitals and health organizations in low and middle income countries. In the private sector, governance refers mainly to the relationship developed between shareholders and the director of an organization, the chief executive officer (CEO) or the senior management. In the public sector or non-profit contexts, governance often refers to the relationship between an elected or appointed board of directors and the organization management.

Governance does not refer strictly to the role of a board under the guidance of an organization, but with the roles of all regulatory, administrative, professional, and clinical to pursuit of collective goals. In other words, the governance of public institutions is different from day-to-day operating management of its underlying regulations. Governance refers to how power is exercised in society and in organizations to the pursuit of collective welfare and social improvement.

Specific organizational arrangements and processes are necessary for achieving those goals, suggesting that a definition of governance should go to: (1) the division of power within organizations and societies; (2) to the procedures and practices that can improve the control, guidance, innovation/adaptation; (3) the mechanisms of accountability at all levels of decision making and action in a given system. Through a variety of organizational arrangements, social and relational processes, governance standards generate enough energy to contribute to the achievement of "public goods" that can be defined differently depending on the sector in which an organization operates. In the private sector, collective goods can be strictly defined as the achievement of the goals of shareholders or more broadly defined, emphasizing the social responsibility of a company. In the public sector, improving social or collective well-being can be seen as a fundamental objective of the government.

Of course the debate about the practice of governance varies from context to context. Moreover, it is clear that the objectives underlying governance differ accordingly to the situation. With this in mind, Denis *et al.* [7] proposed a framework for the analyses of governance in health care Organization that is illustrated in Figure 1. Therefore, one of our main goals is to propose an infrastructure (LARIISA) for governance decision-making support assisted by DTV technologies.

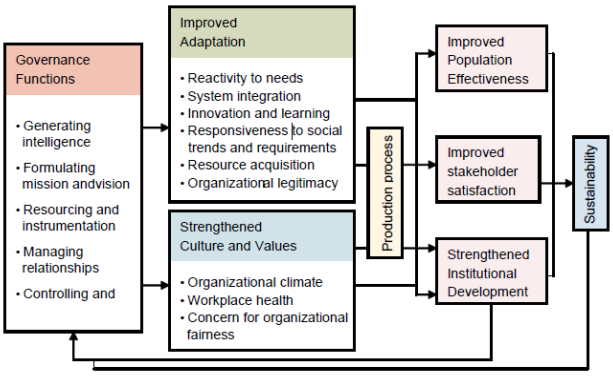

Figure 1: A Framework for the Analysis of Governance in Health Care Organizations

III. LARISSA FRAMEWORK

LARIISA is a governance decision-making support model for public health systems, which the information paradigm is centered on the concept of health context. Based on the Dey's definition of context [8], we consider health context as *any information that can be used to characterize the situation of an entity in a health system. An entity is a family member, health agent, health manager, etc, that is considered relevant to the interactions between a health manager and a health system in order to make decisions.*

LARIISA is based on five governance setting assumptions (see Figure 2): Knowledge Management, Systemic Normative, Clinical and Epidemiology, Administrative, and Shared Management. Each governance setting is described bellow by means of examples that was applied in Fortaleza[3] city. In additional, we show the rules that LARIISA framework should offer mechanisms in order to improve the governance decision-making support.

[2] http://www.worldbank.org/

[3] This city is the state capital of Ceará.

A. *Examples of the Lariisa Governance Setting*

1) *Knowledge Management*

Decison: Allocation of all professionals trained in the case, strengthening the training and adapting them to the health context and to the new management health system.

Rule: **IF** (the number of trained professionals) < (amount needed in public health units) **OR** (in the hospital network)
THEN {request *M* new employees and train *N* professionals in *X, Y, Z* skills}

Result: Mobilization of all professional staff of the Municipal Health School and then reallocating resources from other sectors of lower priority.

2) *Systemic Normative*

Decison: Assessing the value and application of sanctions envisaged in the Law X.

Rule: **IF** (the waste deposit of an establishment did not obey the law) **AND** (it is a recidivist)
THEN {apply the fine and close the establishment}

Result: Several waste deposits have been warned, some were closed and many have improved significantly.

3) *Clinical and Epidemiology*

Decision: Implantation of intravenous hydration procedure in health units in the suburbs.

Rule: **IF** (there is the case of disease reinfection) **AND** (there is a disease epidemy symptoms)
THEN {priorize to create in the unit a new intravenous hydration procedure and classify red alert}

Result: Improving the management of severe health cases in the Hospitals, reversing the flow of care at the hospital for the health unit.

4) *Administrative*

Decision: Creation an Emergency (ER) for the clinical management of severe case (ER-SC).

Rule: **IF** (the patient contracted Dengue more than once) **AND** (lives in an area of high infestation indices) **AND (**has symptoms *A,B,C*)
THEN {you must consult the ER-SC about this case. There is a high probability of being of a Dengue case and the patient should be sent to ER}

Result: Fortaleza has become a capital with lower mortality due to a series of strategies, notably the application of the rule above.

5) *Shared Management*

Decision: Mobilization of Civil Society and health Organizations for the creation of a Special Committee.

Rule: **IF** (a workplace belongs to the "yellow list") **AND** (the building is in construction for more than *X* months) **AND** (it is located in an area where the disease infestation > 0.5%)
THEN {this workplace should be included in the "red list" for monitoring by the Special Committee}

Result: Decreasing of infestation rate and increasing the involvement of civil society.

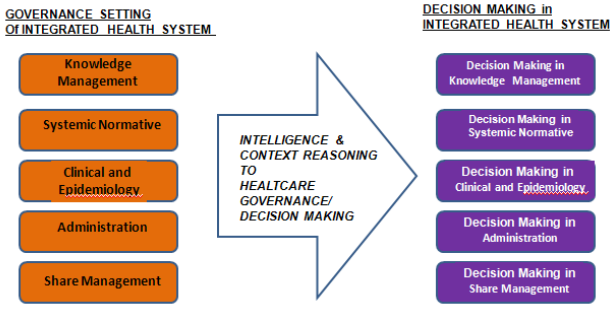

Figure 2: Governance Setting for Decision Making in Health System on the Lariisa

B. *Knowledge to Action (KTA) model and LARIISA*

The framework should provide context-aware facilities for each set of involved users (e.g., end-user, managers, and health agents). On the one hand, the framework should consider the governance decision-making process requirements in order to achieve a more effective and integrated health care system. On the other hand, generally there is a gap between knowledge creation, information detection, and knowledge application processes.

With this in mind, LARIISA is using as basis of specification the *Knowledge to Action (KTA)* model proposed by Graham et al. [9] in order to reduce the gap present in the knowledge transfer process for health applications. This model was designed to help knowledge transfer practitioners, researchers, policy makers, patients, and the general public to understand how knowledge and practice interact and influence each other. The model consists of two cycles: the cycle of knowledge creation and the cycle of action. *Knowledge* in this model comes from various sources and includes both personal experience and researching.

In the cycle of creation, knowledge is treated through filters, becoming more refined and, presumably, more useful for the object of interest. It starts with questions (Knowledge Inquiry), then proceeds to the synthesis of the knowledge created (facing research and information from other sources) in order to generate products (delivering the right information in the correct format). The authors suggest that knowledge creation is a process of adaptation, where research questions are designed to address problems identified by users, while the results of research and the dissemination of these results are tailored to meet the needs of specific audiences.

In the cycle of Action, the authors call the theory of planned action to describe what happens in the cycle. These theories are models used to predict the likelihood of change. These parties have eight models, which Graham et al. suggest may help research into action.

The LARIISA framework, similarly to the creation of knowledge and action process in the Graham's model, there is a gap between the health context detection process that will adapt the knowledge to the local situation and how this context affects the related health applications (Action).

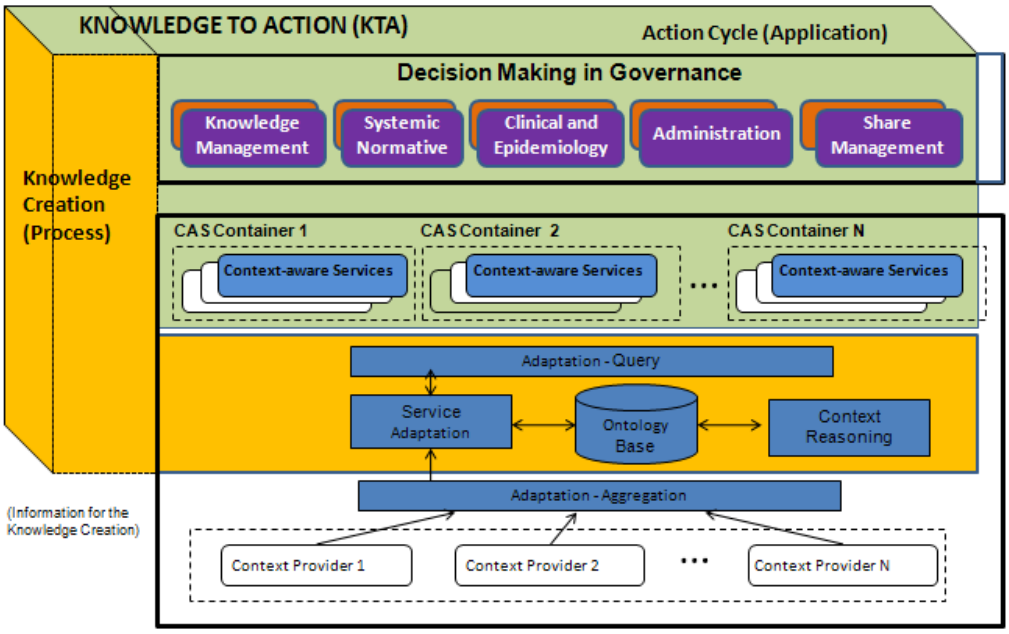

Figure 3 - LARIISA Architecture and Governance Decision-Making Applications

Therefore, we are reusing the Graham's model as basis for designing the LARIISA framework, in which we are able to identify clearly the needs for adaptation process in each action cycle step.

C. *LARIISA Components*

Figure 3 presents the LARIISA core architecture. It proposes the Service Adaptation component, a context-aware adaptation mechanisms [10] that manages the main adaptation processes of LARIISSA core framework. The Service Adaptation has an important role for the integration between LARIISA core framework and the KTA model, which is a conceptual link between the Governance Decision-Making Applications and the LARIISA framework. In the following, we present the LARIISA components:

- **Service Adaptation:** It is in charge of identifying context that is relevant to the three identified cycles: knowledge creation process, health decision-making process, and health context-aware actions. Moreover, it handles the following functions: (1) context-aware adaptation of health local rules taking into account governance decisions; (2) context-aware adaptation of health local rules taking into account the local health context; (3) offering context-aware health indicators that describe local and global context to the knowledge creation entities and governance decision-making applications;
- **Context-aware Service (CAS):** it utilizes high-level context information obtained from the Service Adaptation in order to adapt their functionalities, taking into account changes on the global and local situations. These context-aware services will compose health decision-making applications, which are designed according to the Action Cycle Application from the KAP model;
- **CAS Container**: each CAS Container represents a group of CAS, as shown in Figure 3. One or more CAS Containers implements a governance decision-making application. This means that each CAS Container represents a complete cycle of the *Action Cycle*.
- **Context Provider:** it is in charge of gathering raw context data from the environment and mobile sensors, which will be sent to the adaptation-aggregation layer. These sensors could be physically connected with the Set Top Box of the Brazilian Digital TV or they could establish wireless connection in order to transmit the gathered context data;
- **Adaptation – Aggregation:** this layer is in charge of receiving raw context information from various context providers and running context aggregation operations in order to have useful high-level context information. Moreover, they offer high-level context information to the Service Adaptation, which could be used by health knowledge creation entities and governance decision-making applications in order to adapt the knowledge and decisions to the global situations, respectively;
- **Adaptation – Query:** it handles persistent context queries of context-aware services that are composing

health decision-making applications, extracting desired context information from the Ontology Base via the Service Adaptation;

D. LARIISA Architecture Dynamics

In order to illustrate the flow into the framework, consider the health context information captured by many sensors. This information is sent to the Context Provider components (CP). The Adaptation-Aggregation component (AA) gathers and aggregates context information from the CP, sending it to Service Adaptation component (SA). The SA provides persistent context storage, deciding what context instances should be directly addressed to the Knowledge Creation entities (KC) and to the Ontology Base (OB). The OB stores this context information and allows manipulation and retrieval by the Context-Reasoner component (CR). Moreover, The SA ensures to the context requesters to retrieve appropriately relevant context information. Finally, the Adaptation Query component (AD) provides a communication interface with the Context-aware Services in order to extract relevant context information from the system.

Knowledge Creation cycle of KAP model can adapt their process taking into account global and local context information obtained from the LARIISA Architecture. We consider this cycle more complex than the Action Cycle. We suppose it has specific dynamic characteristics, which could be assisted by intelligent systems, independently of the Action Cycle. Therefore, it is beyond the scope of capability implemented by the entities of LARIISA framework. Nevertheless, these components use context-aware information provided by the Service Adaptation component in order to adapt their Knowledge Creation processes.

IV. APPLYING LARIISA FRAMEWORK

One of the authors of this paper experienced a scenario of decision making and governance that serves to illustrate the functional architecture of LARIISA. In 2008, the Brazilian cities were affected in a major Dengue outbreak. As all the Brazilian cities, Fortaleza had taken the typical general epidemic processes and specific measures relating to the context of the disease. The epidemic was controlled in Fortaleza, obtaining positive results thanks to a series of decision-making, which is worth noting the report of Health Secretary who led the process:

"Once we realize the lack of a system capable of providing reliable data and information in real time, unable to provide correct information for decision-making that the situation demanded, we decided to transfer the Office of Health Secretary and his staf for Control Center of Endemic Diseases and Zoonoses (where information focus of Health). This decision made possible the creation of a Situation Room, allowing more effective monitoring of the process endemic and consequently a more efficient control of the disease."

A. Analisys of Context-aware Aspects

In the scenario above, the Situation Room allows to obtain health context information (**Personal health** Context) in real time. Another important aspect to be considered in this case is the medical education of Health Secretary and its experience in public health, associated with its political, social and administrative expertise (**knowledge Profile** Context).

The above statement allows us to draw two significant events and individuals relevant to illustrate the features contained in the LARIISA framework.

1) Personal health Context (end-user)

- Obtaining reliable health context data in real-time;
- Detecting the context in which these data were involved.

2) Knowledge Profile Context (health manager)

- Expertise on healthcare domain;
- Experience in Public Health policies.

These two set of health context information were essential to the success in controlling the Dengue epidemic in Fortaleza. They were fundamental to the achievement of good results, which indicators enabled the Brazilian Ministry of Health recognize the efficiency of health system installed in Fortaleza for controlling the Dengue epidemic in 2008.

In summary, the decision of create a Situation Room *in situ* and the knowledge profile of health manager, which is not part of profile of any health manager and are not necessarily aligned to the daily orthodoxy of the government routine. Moreover, natural factors (e.g., rain, snow), socio-political raisons (e.g., transport strike), technical constraints (e.g., failures in telephone systems) that could hamper the epidemic control.

It is therefore necessary intelligent mechanisms to help the ordinary managers for making good decisions in a similar situation. This is the main purpose of LARIISA framework.

B. A Governance Decision-Making Application on LARIISA Framework

Consider the administrative governance example described in Section III (Figure 2). As shown in Figure 4, we have the following actions:

Context-Provider: gathering of health context, which is sent to the Context-Reasoning component, via Service Adaptation.

Ontology Base/Context Reasoning: The IF-THEN rule defined in the administrative example is verified by using SWRL inference rules (it is a Semantic Web Rule Language). The result of this reasoning process on health context data (e.g., *Dengue symptoms, area infestation indices*, etc) is sent to the Context-Aware Service, via Service Adaptation.

Context-aware Service (CAS): It makes high-level decisions based on health context information, such as *Creation an Emergency (ER)*. Moreover, it could reconfigure the scheduling of Health Agents (see Section V).

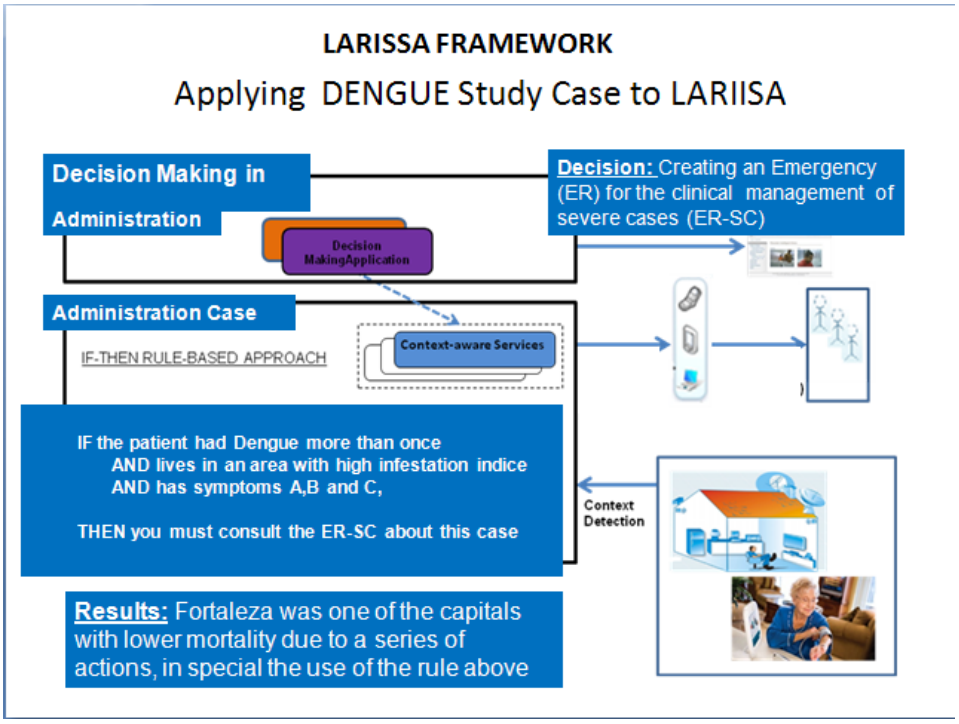

Figure 4: Administrative Governance on LARIISA Framewotk

- **CAS Container:** Each CAS Container corresponds to a complete *Action Cycle* [9]. The block *Identify Problem* of Action Cycle, for example, could identify the problem *What mechanism should be created for management of severe cases?*, which resulted in making the decision *Creating an Emergency (ER)*. Then, the administrative decision-making application, as shown in the figure 5, is implemented by a group of CAS Containers.
- **Service Adaptation:** it provides health context data to the context-aware Services requested by the administrative governance application. This component also implements the interoperability between the administrative governance application and the KTA blocks, i.e. *Knowledge Creation* and *Action Cycle*.

V. DIGA-GINGA PROTOTYPE

The Diga Ginga [11]is an innovative system for home care that aims to implement the resources of data persistence and interactive channel on LARIISA project [12]. It proposes new functionalities to the GINGA middleware [13][14], such as monitoring and control in home automation, optimizing the use of set-top box that is being built for the Brazilian Digital TV (SBTVD) [15]. To this end, DIGA use sensors present on the homes (see Figure 6) that communicate with the *set-top box* and the Digital TV via wireless network (IEEE 802.11). The idea of Diga Ginga is to share the computational structure of the set-top box, adding services to citizens at home, such as monitoring the physical environment (safety of homes and businesses) personal monitoring (vital signs), automation residential and applications that stimulate the production of content between users. It uses the Sun SPOT Java Development Kit [16].

A. *Health Agent Scenario*

Consider the Health Agents that deals daily with users of the health system, visiting homes and the communities. Without an information system, the visiting schedule of Health Agents, for example, follows a linearity and not always efficient agenda, established for sometimes of poor historical and outdate information.

The main idea of using LARIISA architecture in this case study is to improve the quality of health services provided by the agents. It can be achieved, for instance, offering to the Health Agents an agenda adapted to the current situation of health end-users, i.e. aware of local context. For example, Health Agents could be scaled for an area where there are insurgent signs of endemic or people that need more health care. Moreover, Health Agents with some professional specific profile could be allocated to local more adapted to their professional competences. Let us consider two flows in order to better illustrate this Health Agent scenario:

The first flow is related to context information about several health end-users, which is captured by sensors present in the homes or inferred/derived by the LARIISA framework. They could be sent, via set-top box/Digital Belt or via Health Agent Mobile Application, to the LARIISA Architecture (Context Provider component). After all the inference/derivation process realized on context information by the framework, a context-aware service obtains the high-

level health context in order to adapt as soon as possible the changing situation, updating the Health Agent's agenda.

A second flow considers the authentication process of the Health Agent, equipped with a mobile device equipped with Bluetooth, Wifi, and GPS (see Figure 5). This authentication allows the Health Agent, for example, to access the services required for the procedure during its visit making decisions in real time. Moreover, she could participate in user communities under its supervision, use social networks of its professional context, among other activities.

Therefore, by using the set-top box the Heath Agent application is able of sending family context data captured by sensors and to assist the routine of Health Agents.

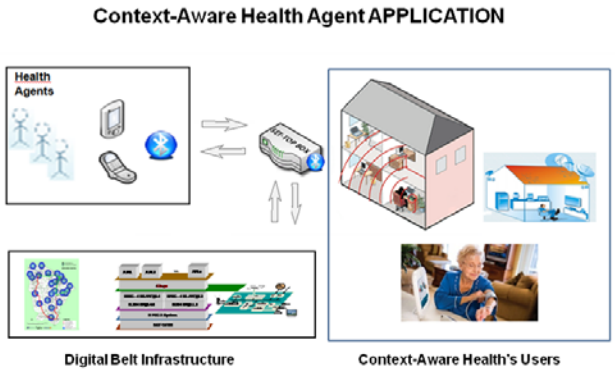

Figure 5. Health Agent Case Study

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B. *Diga Ginga Application*

Diga Ginga architecture follows up a set of vital signs such as temperature, heart rate, pulse, respiratory rate, and blood pressure. In addition, it provides access to the digital TV services, such as programming announcements on TV telling the exact time for taking medicaments, facilitating the lives of older people with memory problems.

For the patients in the postoperative stage, it is necessary careful attention, such as the monitoring of certain vital signs in order to assess their health status (physical and psychological). Currently, people in these situations are usually admitted to health facilities (with high costs).

With regard to professional advice, this system contributes to a better doctor-patient interaction, even the latter being in their home.

Finally, the project Diga Ginga increases the potential of LARIISA with tracking features in health, through their sensors and components, serving as proof of concept for an extra set of applications that can be developed.

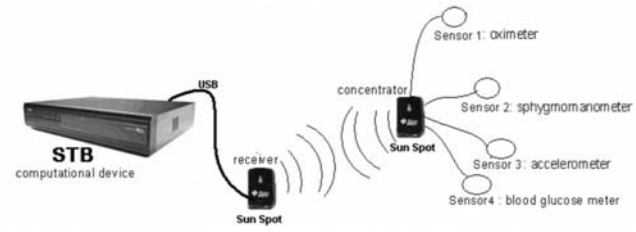

Figure 6. Integration of Diga Ginga devices.

VI. Related Works

To the best of our knowledge, none of the existing approaches proposes a governance decision-making model for public health care systems. However, several research works aim to use context-aware platform in order to improve the health care systems.

The work in [17] presents the framework called Context-Aware Service Integration System (CASIS) in order to integrate applications and services. This work presents context-aware services that have been developed in order to demonstrate how context technologies and mobile web services can help enhance the quality of health care.

The authors in [18] propose the adoption of mobile health information. They introduce an ontology-based Context Management System (CMS) that allows the user to define contexts using terms from the medical field. In a highly sophisticated and complex field like health care, a generic or 'one-size-fits-all' context aware approach does not meet specialized requirements. The CMS is extensible to allow the context aware system to develop and evolve in domain-specific ways. Like these works, LARIISA has the same classical mechanisms for knowledge management. The main difference is the Service Adaptation component that allows governance applications to be oriented to the KTA model [9], besides the use of the Digital TV as user access terminal.

The approaches proposed in [19] and [20] use context-aware and Digital TV Technology. The first one use the personalization aspects for the authentication process via set-top-box, and the second involves the design, development and evaluation of a context-aware middleware framework and an interface with the underlying system services. These propositions represent functionalities on the LARIISA framework, using the Ginga middleware.

VII. Conclusions and Future Research

Health systems worldwide have to cope with a changing environment. However, these systems are not responding satisfactorily to those situations. Western society has built its healthcare systems centered in hospitals, where the output is coming back to the families. It turns out that traditional tools cannot handle this new scenario. The result is a need for new approaches to health system problems.

In this scenario, the LARIISA framework may represent a paradigm shift in access to health. The set-top-box of Brazilian Digital TV is contemplated strategically to serve as terminal access in the LARIISA, considering the universal soon, this equipment in households in Brazil. In this happening, LARIISA would allow the less privileged class in Ceará to have access to context-aware service-oriented [21] for health care and other social applications [22].

The LARIISA framework is strongly aware of the health end-user situations as a mechanism to improve the support for decision-making in governance applications. In order to verify the feasibility of this technological innovation, a large-scale trial using 1000 set-top-box will be conducted in the municipality of the Ceará state, Brazil, in 2010.

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