LARIISA Project

A Context-Aware Decision-Making Framework for Governance of Health Systems

(draft 5.0)

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Abstract

This work proposes a governance decision-making support model for public health systems. It encompasses and integrates the family in a new intelligent Health 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.

Key-words: *Integrated Health Network, Decision-making, Middleware GINGA, Brazilian Digital Belt, Context-awareness.*

Contents

1. 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 care systems for meeting the demand. Facing this challenge, many advocates for the use of innovative clinical approaches, including a bigger involvement of patients and the systematic monitoring of their conditions, rather than simply treating acute problems [1]. Information technology (IT), through to its ability to monitor and remotely interact with patients and caregivers, has attractive qualities for this role [2].

For instance, home telemonitoring applications could be used for exchanging health condition data between family homes and health professionals, improving coordination and effectiveness of primary health care. Telemonitoring effects could result, for instance, in the decrease of emergency visits, hospital admissions, and the average hospital length of stay. In this scenario, Digital TV (DTV) [7] [8] devices could be used as an efficient technology for home telemonitoring. As a matter of fact, using DTV one can set up a bidirectional communication for exchanging data between family homes and health care teams. DTV devices (i.e., Set Top Box) can retrieve clinical condition information of family members captured by sensors (e.g., heart rate, pulse, blood pressure), sending it to the responsible health care team. We called this data *health context information* and it can be exploited by health care systems for improving decision-making support. For example, when health conditions of monitored patients are deteriorating, the health care system could provide alerts and decision support for both patients and clinical team. Health care teams are also able to access remotely patient’s health data, allowing them to react appropriately to some changes.

At a higher level of use, health context information could be exploited by health care governance applications for improving their decision-making support. Health care governance [4] refers to the guidance role of all regulatory, administrative, professional, and clinical sectors in the achievement of collective goals (e.g., controlling an epidemic). Through a variety of organizational arrangements, social and relational processes, health care governance standards contribute to the achievement of "public goods”. Obviously, decision to be made by health care governance systems depends on the situation.

LARIISA Project (Laboratoire Réseaux Intelligence Intégration Santé) proposes 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 [4], 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 care system in order to make decisions." In order to capture the health context and the end-user interaction, LARIISA is built on the GINGA middleware developed for the Brazilian Digital TV system, which will be deployed in the whole country no longer than 2015.

LARIISA proposes a model for decision-making based on 5 (five) intelligence areas: (i) Knowledge Management; (ii) Regulatory; (iii) Clinical and epidemiological; (iv) Technical; and (v) Administrative Management Shared. It will be deployed on the Belt Digital Infrastructure Communication, which is a project that has been implemented by the Ceará Government. This infrastructure is based on an optical ring and the Wimax technology that, in 2010, will provide broadband Internet access to 82% of the urban population.

The LARIISA Project was designed from the experience of two post-doctoral research proposals that are currently in progress. They are described below:

- RIISO (Intelligent and Integrated Network of Health and its organization): it evolved from the post-doctoral project designed by Prof. Luiz Odorico Monteiro de Andrade at the University of Montreal. We identified that this proposal has a strong relation with the LARA project, process CAPES 33833-08-9.

- LARA (Laboratory of Computers Networks and Artificial Intelligence): a post-doctoral project designed by Prof. Mauro Oliveira at the University of Ottawa, Process CNPq 200363/2009-3.

We have experienced a governance decision-making scenario that serves to illustrate the functional requirements of LARIISA framework. In 2008, the Brazilian cities were affected by a major Dengue epidemic. As all the Brazilian cities, Fortaleza[1] had taken the general control

[1] This city is the state capital of Ceará (Brazil).

procedures and specific measures for this situation. The Dengue epidemic was controlled in Fortaleza thanks to a series of governance decision, which are reported by the Health Secretary who led the process:

> *"Once we realized the lack of a system able to provide reliable data and information in real time, offering correct information for making decisions, we have decided to transfer the Office of Health Secretary and his staff to the Control Center of Endemic Diseases and Zoonoses. This decision made possible the creation of a Situation Room, allowing an effective monitoring of Dengue and consequently controlling this disease."*

In the scenario above, this decision allowed us to obtain in real-time health context information (Local and Global Health Context) for improving governance decisions. Another important aspect to be considered in this case is the medical training of Health Secretary and his public health experience, political, social, and administrative expertise (Health Manager's Profile). Positive indicators enabled the Brazilian Ministry of Health to recognize the efficiency of health system in Fortaleza. Therefore, it is necessary to propose intelligent mechanisms to help health managers for making good decisions in similar situations, which is the main purpose of LARIISA framework.

The reminder of paper is organized as follows: Section II describes a scenario and discusses the motivation of this work. Section III presents the LARIISA framework and governance setting for decision-making support. Section IV shows a case study in a real scenario. Section V presents related work. Finally, Section VI concludes the paper and discusses future work.

2. RIISO (Intelligent and Integrated Network of Health and its organization)

2.1 Governance Aspects

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 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 [1].

Based on the field of business management, governance has been defined as the nature of the relationship between an organization and its owners. This definition is the basis of many policies promoted by the World Bank 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. Denis et al. proposed in [2] a framework for the analyses of governance in health care Organization that is illustrated in Figure 1.

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 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: the division of power within organizations and societies; to the procedures and practices that can improve the control, guidance, innovation/adaptation, and the mechanisms of accountability at all levels of decision making and action in a given system concludes that governance refers to how power is exercised in society and in organizations. 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 [1] [3].

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. However, as shown by the diversity of the fundamental ingredients of governance: the mobilization of power to achieve collective goals.

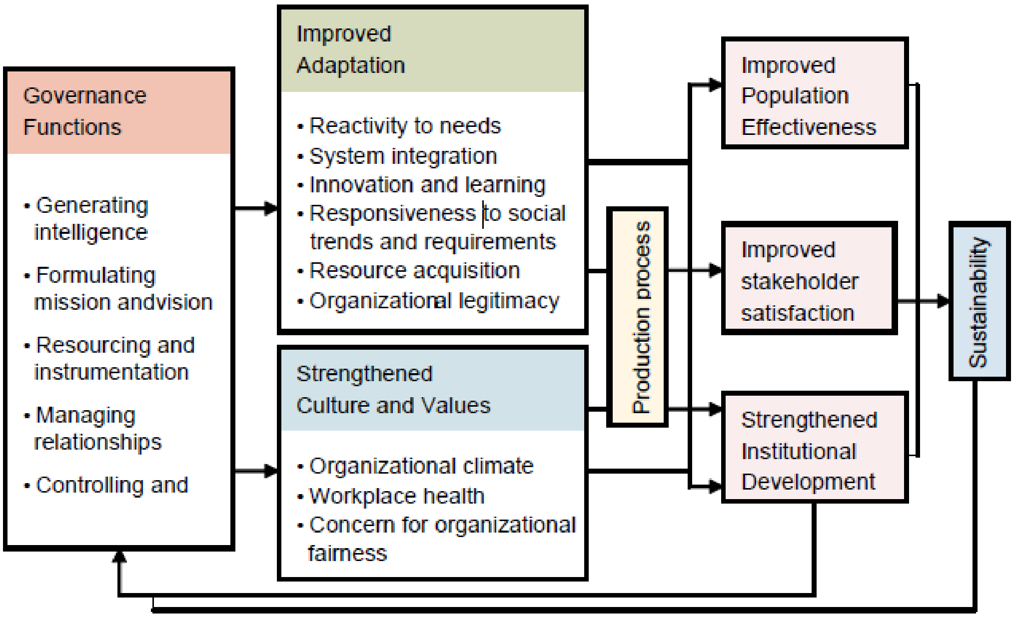

Figure 1: A Framework for the Analysis of Governance in Health Care Organizations

2.2 Scenario of Integrated Health Systems

The concept of integration in health systems was presented in all discursive process occurred in the 70's and was one of the main guidelines of the Brazilian Health Reform and the National Health System (SUS). This concept was born with the 1988 Constitution. The decade of 90 was marked by the process of decentralization of actions and services in health area, with an effort to build an integrated system in a federal state. The globalization and relentless technological advancement have become more demanding of resources for a growing number of interventions. The fragmentation of services for the integrated and decentralized systems can generates a system of poor performance and high cost, causing severe damage to society and the public finances, and do not meet the health needs of the population.

Many are the causes of fragmentation of health services, among them, decentralization poorly understood and practiced in a centralized manner, as the conditional transfer of resources. The Pan American Health Organization points out several of these causes, with emphasis on specialization systems (of the historical roots), according to social groups, creating social segregation and stratification incompatible with the equal right to health.

The fragmentation of these services increases the difficulties of the health authority to maintain the integration of the system, with damage to its governance that breaks and sprays. Several studies have been highlighting and made proposals on the importance of health networks and their systemic integration, since no entity or organization can ensure alone the integrity of health care, because of the interdependence of all beings and bodies. A health system to function as if it was a single system (interconnected, integrated, and interdependent) that needs to maintain integration based on five points (see Figure 2) [4]:

- SYSTEMIC INTEGRATION: it would all still thinking process and run the system;
- NORMATIVE INTEGRATION: it expresses values of societies, organizations and individuals involved in the network;
- FUNCTIONAL INTEGRATION: it is manifested by the number of components of the health services for the operational support or executive;
- CLINICAL TEAM INTEGRATION: this concerns the functioning of multidisciplinary teams that work seamlessly, and there should be mechanisms that help to mobilize the skills and knowledge;
- INTEGRATION OF CARE (health): it involves the coordination of clinical practice around specific health problems of each patient in a sustainable manner.

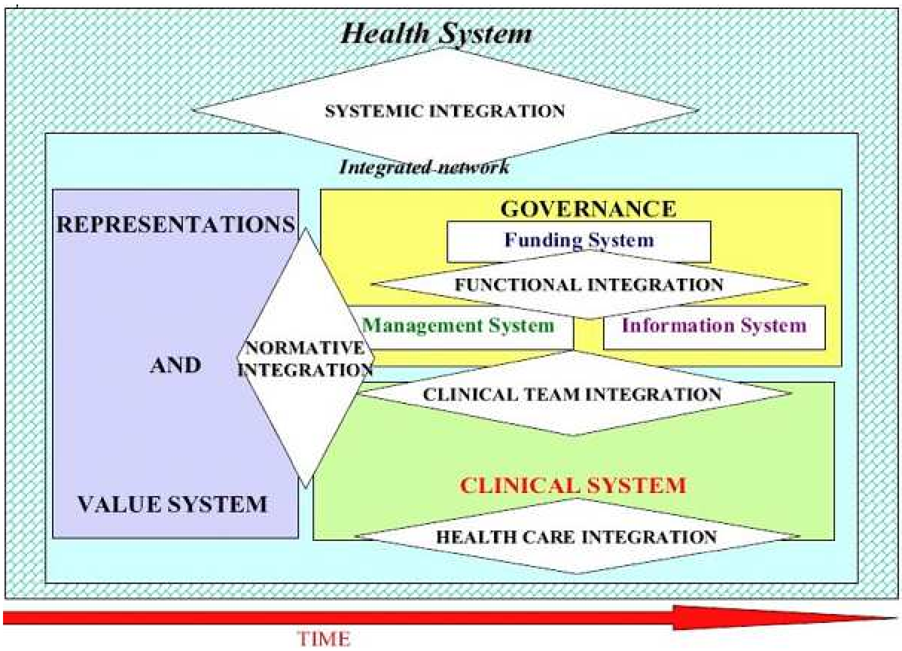

Figure 2: Integration of Health Care: Dimensions and implementations

2.3 Practical and Theoretical Context of Matricial System and Intelligence Management

The matricial model of health care networks and services, capable of producing Epidemiological Intelligence (EI) and Management Intelligence (IG) for Decision Making (TD) of the health authority from an integration built by line of Care, visualizes the health care network and services integrated into health systems the networks.

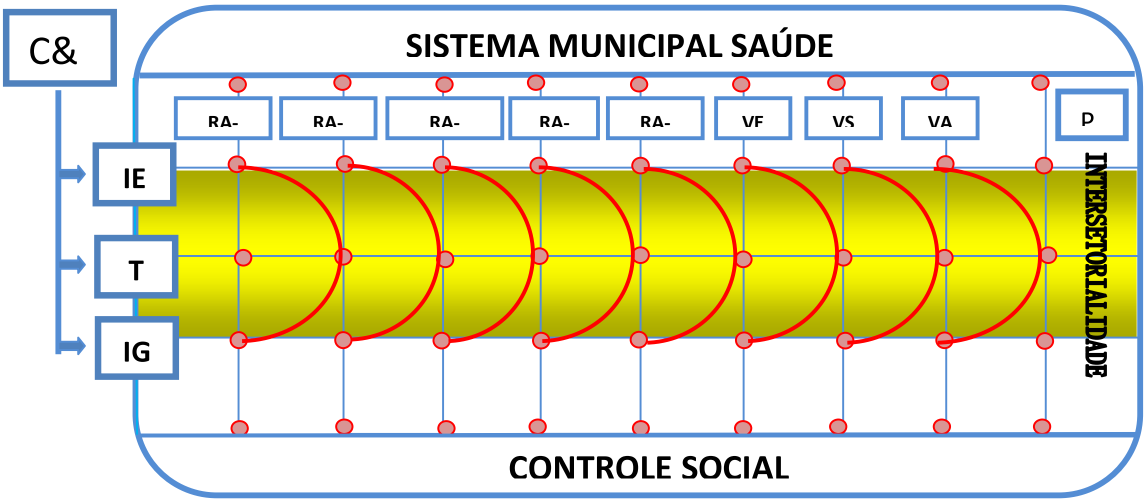

Figure 3: The Matricial Model of Municipal Health System

These are formed in order to promote the Functional Integration, Clinical Integration and Care Integration by matricial between them, through the rows of integral care for citizens.

The citizen in the network traverses the systemic points (services) into a spiral of complexity according to their needs through a multidirectional vector - line of care [5].

- INTELLIGENCE KNOWLEDGE MANAGEMENT: it is related to the processes that can produce, construct, maintain, and transfer the knowledge generated by formal processes of research, empirical processes and other ways for the generation of new knowledge and its improvement;
- REGULATORY INTELLIGENCE: it is related to the influence of public officials or managers of health in the drafting of law, aimed at the generation of standards that can, in fact, give consistency, concreteness and certainty to the system;
- EPIDEMIOLOGICAL INTELLIGENCE: the manager is to ensure knowledge of the health-disease processes, from the concept that health is as determining factors, biological, social, economic, genetic, lifestyle and influence of service health organized in networks;
- INTELLIGENCE OPERATIONS: related to the processes of management;
- SHARED INTELLIGENCE MANAGEMENT: It is related to the five levels of integration that should be shared by health managers.

2.4 RIISO Proposal

The need to guarantee the social rights, the demographic transition, the exponential production of knowledge related to the continuous search for technological advances, and the financial globalization process, produces on health system a permanent crisis situation. Consequently, the organizational structure of health services become daily more complex by requiring of its managers continuous challenges in governance to decision making in the management and monitoring of their realization.

Computerized Health Services have suffered from the same problems that others governance systems. Frequently, the components of these systems are different in terms of semantic structures and/or implementation languages, which it makes difficult the communication between them in search of a systemic and operational vision. From our point of view, the interoperability of these heterogeneous systems is not the only problem to be solved, even if we consider high-quality semantic data contained therein. Therefore, it urges the aggregation of intelligence on the knowledge management process of health systems. They should be able to self adapt flexibly, taking into account the health context.

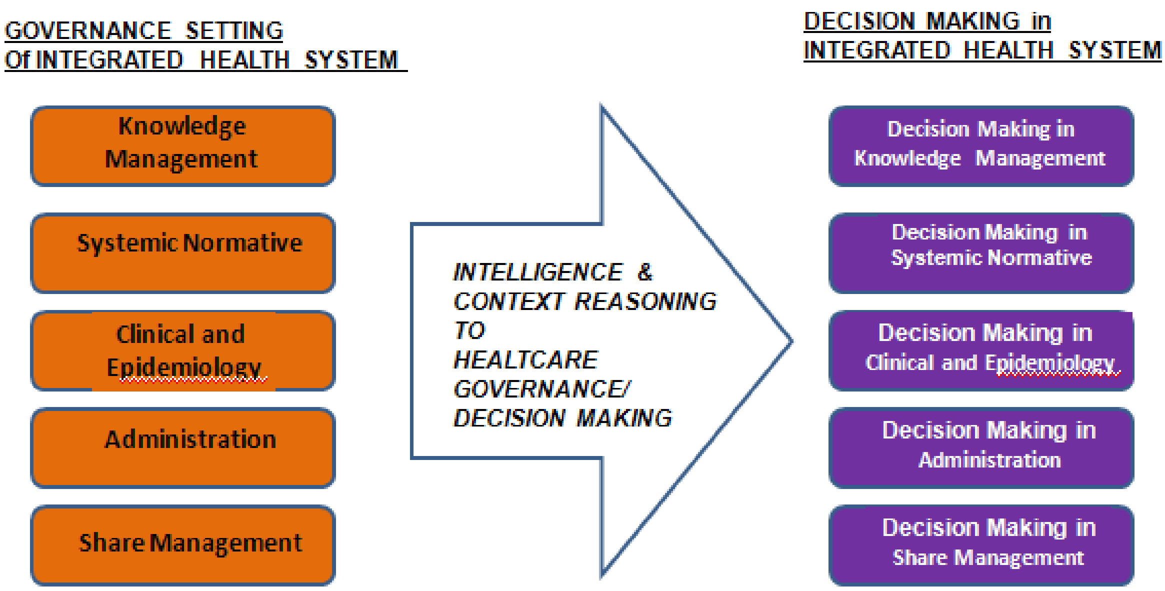

Figure 4: Governance Setting for Decision Making in Health System

RIISO Project is a system of governance Intelligence for decision making on Integrated Health Systems. It is based on five assumptions (see Figure 4): Intelligence Knowledge Management, Regulatory Intelligence, Surveillance Intelligence, Intelligence Technical and Administrative Management Shared Intelligence.

3. LARA (Laboratory of Computer Networks & Application)

3.1 LARA Scenario

The current computing technologies have become essential in everyday life, guiding the behavior of people toward the use of mobile devices and wireless communication technologies. These devices are becoming increasingly powerful in terms of hardware, such as processing power, memory, and computational capabilities. Therefore, applications and services are now being developed to bring services from the desktop environment to mobile devices. Some of these services include e-mail, web browsing, access to online banks, stream multimedia, and web services. Services designed for multi-domains, multi-environments and multi-communications should have a rapid growth.

However, the transition to heterogeneous environments of mobile device and communication is closely related with the findings in the areas of mobility management, network reliability, service, content adaptation and interoperability. Network and service providers need new solutions to access to broadband networks, where users could easily have the desired services tailored to his home, office or any other environment, always available, regardless the type of network and mobile device. These solutions should enable the development of new and exciting value-added services in various fields, such as health, distance learning, and electronic government.

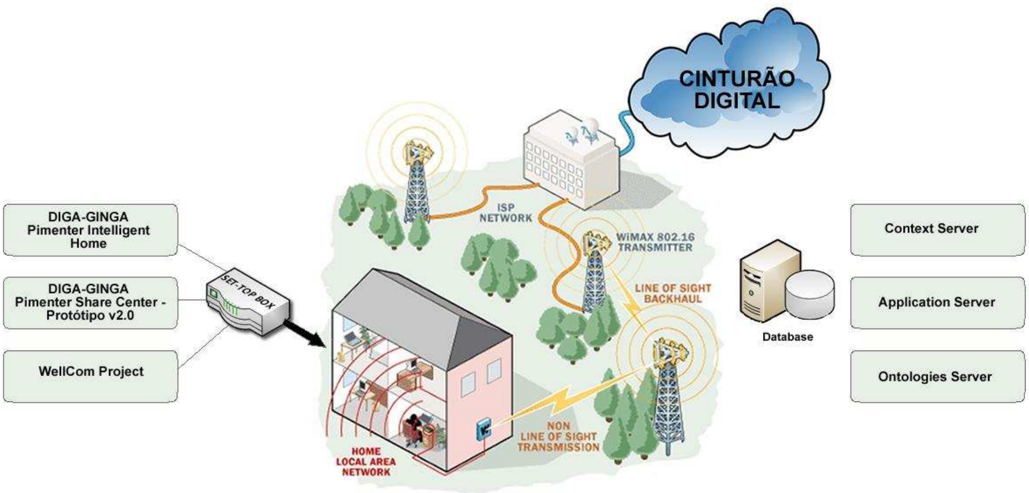

Figure 5: Scenario of the LARA Project

The main objective of the LARA project (Figure 5) is to find new innovative technologies for the Digital Belt [9], which aims to promote the socioeconomic development of the State of Ceará. Among the innovations stands WiMax technology and the concept of Context Awareness [10], which promise ubiquitous environments adapted to the situation of users.

3.2 GINGA, the Brazilian Digital TV Middleware

The impact of the new generation of television is much more significant than the simple exchange of an analogical system of transmission for digital, and much more than set top box improves of the quality of image and sound. An important component is the ability to expand the functions of the system for applications constructed on the base of a system reference standard. Such applications are computational programs resident in a receiving device. New services are available, as electronic guides of programs, banking services (T-banking), health services (T-health), educational services (T-learning), services of government (T-government), etc. But the most important characteristics in the Digital TV technology is the interaction of the viewing user, which could be delegated the control of the flow of a televising program, determining if one content must be shown or not. The necessary computational capacity to the new system can be integrated in the proper display device: a device of digital TV, a cellular one, PDA etc.

The main innovation is taking advantage of a break of a paradigm in the Brazilian scenario, when a Digital TV will take the place of the omnipresent analog TV, now available in practically all residences.

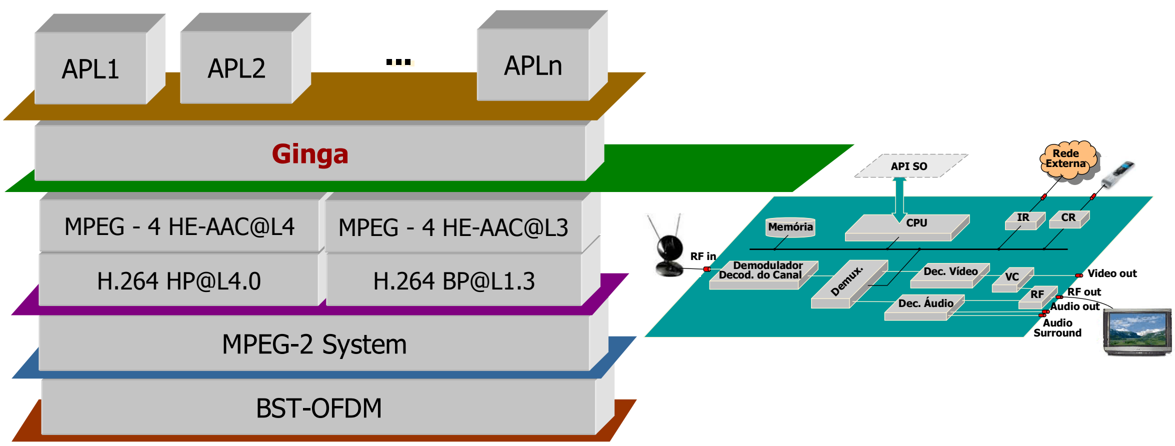

Figure 6: Digital TV Architecture and Hardware

3.3 Context Awareness & LARA Project

The LARA project will evaluate new technologies and architectures to provide a platform for delivery and management of integrated services that allows users to customize and use multiple devices and services with minimal effort. Users need to use different terminals and devices to access different services in different environments including their homes, offices, public places or even in transit, being forced to deal with the complexity related to the change of context, network devices, computing power of devices, quality of service, communication, security, etc.

In the process of investigating new technologies for the Digital Belt, the LARA project aims to develop, to specify, and to design a framework for service-oriented broadband communication so that it can provide universal access to networks with sensitivity to context centered to the user (User Centric Environment Concept), using the concepts of personalization and adaptation of services or Context (Context Awareness Concept).

Generally, the context is obtained from devices that operate at a lower level of abstraction, such as a GPS, accelerometer, thermometers, etc.. Other contexts, however, are not so simple to be represented by having a higher level of abstraction. The representation of context by itself is not a trivial task. The total area of knowledge representation is extremely important for computing context-sensitive, which the concept of ontologies is considered a powerful approach. Such artifacts of knowledge, as the preferences of users, for example, are called profiles. These profiles are, in most cases, difficult to obtain from Boolean concepts of "true and false" from the low levels of abstraction (sensors). Therefore, logical constructs such as fuzzy logic, machine learning techniques or data mining can provide a great help in the representation of context. Currently, the effective exploitation of various services is limited, since it requires access to multiple technologies and protocols, multiple devices and settings and multiple authentication mechanisms.

3.4 LARA Framework

Figure 7 shows a preliminary version of the LARA Framework, which is able to meet the requirements sought in the project. Initially, there is only the aspect of communication infrastructure outlined above [13] [14] [15].

The LARA's preliminary Framework is composed of the following:

- Context sensors: they are the first interface between the User and the system or device. They capture context information of low level of abstraction from a sensor (e.g., temperature, location, noise levels, motion), which is then analyzed and combined with previously stored information (e.g., User’s Profiles, the ability of the devices) and processed information in the context of higher level;

- Context providers: receive data from sensors - low level abstractions - and turn them into context information of higher level. For example, a location information of a User in the form outdoor_location (latitude, longitude, altitude) must be transformed into a context information such as: <adress:is rdf:resource="#user" />

- Ontologies: the vocabulary is structured in terms of objects and concepts of the entities of the environment and their interrelationships through axioms and relationships. Then, an ontological structure provides a common and shared understanding necessary to remove ambiguities in terminology and concepts, offering to do so, consistent semantic annotation that causes certain features, such as learning resources, to better adapt to specific contexts. For example, we have an ontology representing the environment hierarchically in sub-domains as field office, home, in transit, etc. Thus, due to the low capacity of devices such as mobile phones, palmtops, etc., each area has its own ontology lower level.

- Context-reasoning: one of the main requirements of the context-sensitive computing is the transparency of the system for the users. For this, at a high level of abstraction, it must be able to capture the "intuition" of the users. Unfortunately, "intuition" is a rather abstract concept, especially for machinery, which requires the separation between the way users define the contexts of their situations and to build applications to which the context is managed by the sensors of context. Context-reasoning refers to the appropriate type of adaptation that will be applied, i.e. the way the application will have to adapt to the context of user. However, there are cases where the context-reasoning methods require rules-based, expert systems or even change over time, which could require induction techniques, such as machine learning, data mining, etc. Thus, the context-reasoning is using inference techniques and first-order logic.

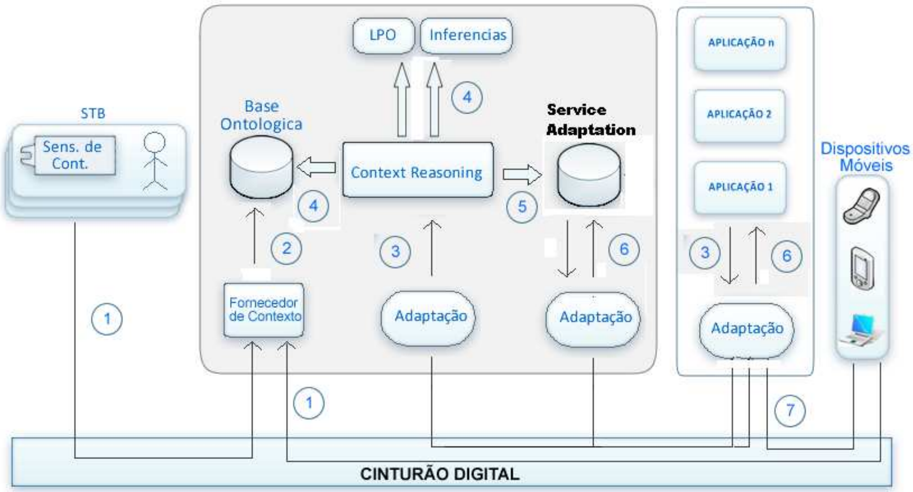

Figure 7 - The LARA Framework.

- Inference: as stated in the previous section, there are situations in which decisions are taken by the system must be inductive. In such cases, inference techniques should be used as data mining, machine learning, fuzzy logic, etc in order to try to translate the "intuition" of the users;

- First-order logic, or predicate logic is the logic for describing simple context situations, i.e. without the need to capture the "intuition" of the users through techniques of inference. For example, if the user "Mary" is in her vehicle, then her status is "in transit", which causes the system to select the ontology appropriate to this context and execute the appropriate actions while preserving transparency;

- Adaptation: once past the context-reasoning, it remains to adapt the application to the appropriate context of the user’s device. If the application runs on a set-top box or a mobile device, the system should adapt it properly;

- Applications: it refers to applications that are running in a specific context. It could be an educational application, a health care application, etc;
- Ginga: it was developed for the Digital TV standard in Brazil, the application may have an API designed to allow high interactivity. Recently, the GINGA became a recommendation H.761 by ITUT. As the system was designed specifically for applications developed for digital TV, the GINGA can be used as a middleware between applications and the STB [14];
- Set-top Box: output device of the system [15]. This is an important mechanism of mass-User Access to low-income Belt Digital [9];
- Belt Digital: infrastructure, broadband network with ring topology and composed of optical, as explained in section 4.1 [9].

4. LARIISA PROJECT

4.1 LARIISA Scenario

There is a strong relationship between the academic efforts in the LARA and RIISO projects, when the topic of Public Health appears to be an excellent application to Belt Digital Project (LARA).

The LARIISA project is the result of a synergy between LARA and RIISO projects. The objective of LARIISA is therefore to join forces to develop, implement, and adapt to the Digital Belt a system for decision-making for public health based on five assumptions of RIISO mentioned previously. The objective of LARIISA is therefore to identify the interface between these two projects in order to design and implement a context-aware framework that will be built on the digital belt infrastructure (LARA). This framework should support applications of health management system (RIISO). With this in mind, two aspects are originally considered:

- Communication Infrastructure;
- Health Applications.

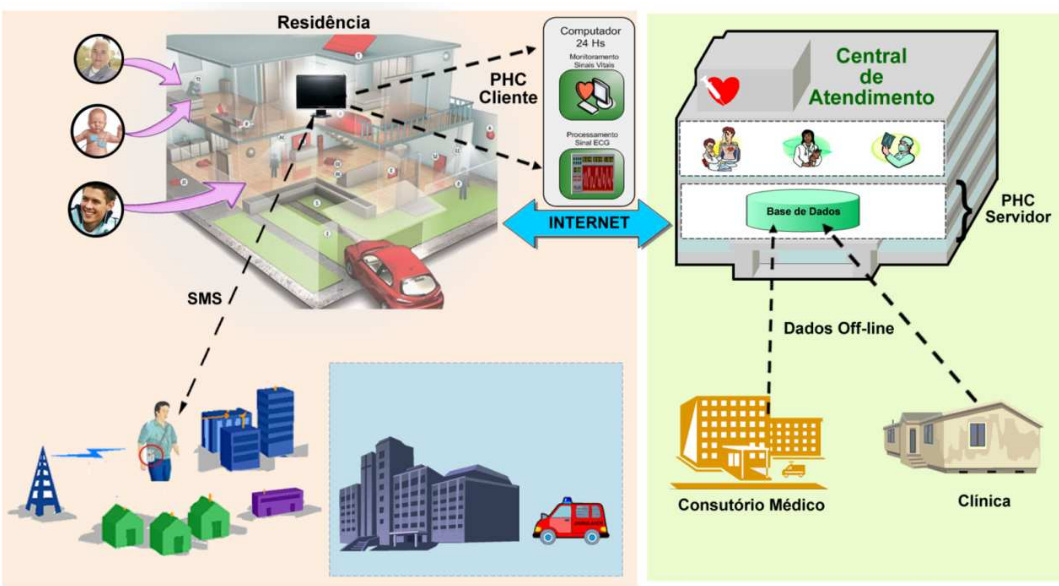

Figure 8: Scenario of LARIISA Project Application

4.2 Communication Infrastructure

The Belt Digital (Figure 9b) is a computer network infrastructure that will provide broadband services to 82% of the population of the State of Ceara in 2010. It is a network with ring topology with 3020 kilometers of fiber optic cable with 36 single-mode fiber. This infrastructure is composed of a main ring and several fiber connections to major cities, as shown in Figure 3. Connection on the call last mile will be with WiMax technology.

The aim is to develop a model that promotes greater socioeconomic development in the state providing universal high speed broadband connectivity and new services for people, business community and education with modern technology. In this context, two aspects can be highlighted:

- SERVICES: People use different terminals and devices to access different services in different environments including their home, offices, buildings and public spaces without being forced to deal with all the complexity of the system;

- ACCESS: Future broadband infrastructure requires ubiquitous availability. The access network solution, which consists of various technological options for the last mile (DSL, Cable, Mobile, etc), needs to be optimized so that it comes at a reasonable cost for the end-users.

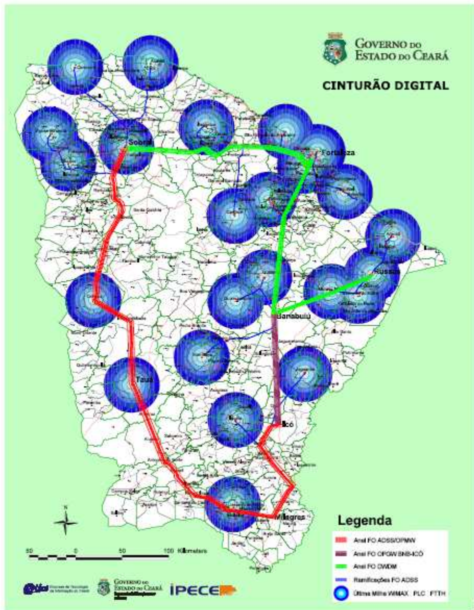

Figure 9a: Brazilian Cable Connection **Figure 9b: Digital Belt Project**

The framework should be context-aware by providing services that take into account the context of users (User Centric Context Environment), reacting and adapting applications in response to changes in the environment [9] [10];

LARIISA can be seen in a layout of layers, where the LARA lower layers are able to support the RIISO application layer, integrating intelligence technologies and IT needed to provide the main project features. The LARA architecture is presented as a unified platform for delivering context-aware services managed by policy-based mechanisms that are able of expressing simple and complex context structures.

Making RIISO applications completely adapted to the Digital Belt is a natural goal of LARIISA. However, the exciting challenge will be the synergy between health applications and context-aware adaptation processes. Health System should react to the environment changes, i.e., it is expected more reliable knowledge of this dynamic environment (users, devices, network infrastructure, etc) in order to deliver better information for decision-making applications. The result should be a strong organization throughout the system, allowing not only some system improvements in the governance process, but also making the target system more efficient for the end-users.

Therefore, there is an important open question related with the item 5.1.2:

> "How LARA framework will provide context-aware facilities for the intelligent and integrated health decision-making process?"

4.3 Knowledge to Action Model

The framework should provide context-aware facilities for each set of involved users (end-user, managers, health agents, etc). On the one hand, the framework should consider the 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" model proposed by Graham et al. [12] in order to reduce the gap present in the knowledge transfer process for health applications. This model (see Figure 10) 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.

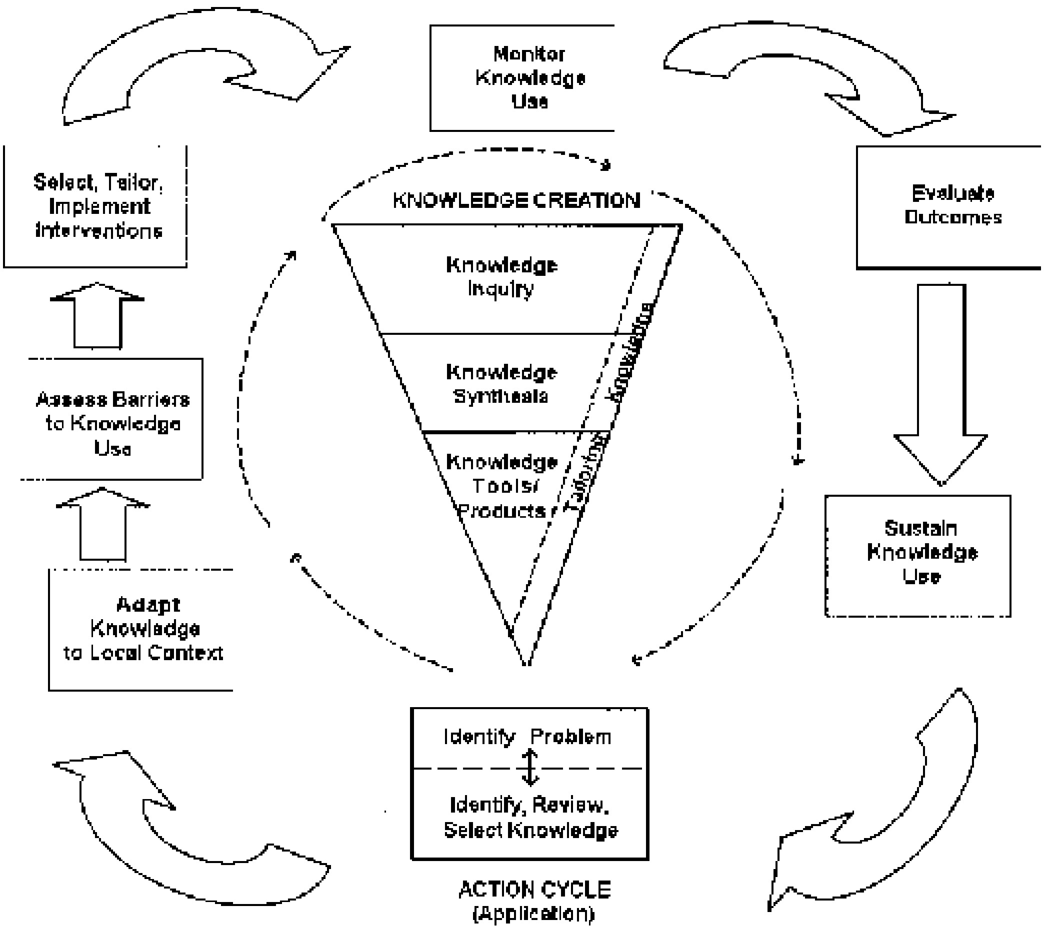

Figure 10: Knowledge to Action Model

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. They are:

- Identify Problem: Often involve a group or individual identifying that there is a problem or issue that deserves attention and searching for knowledge or research that might address the problem. They can also determine whether there is a knowledge-practice gap that needs to be filled with the identified knowledge;

- Adapt Knowledge to Local Process: Process individuals or groups go through as they make decisions about the value, usefulness, and appropriateness of particular knowledge to their setting and circumstances. It also encompasses those activities that they may engage in to tailor or customize the knowledge to their particular;
- Assess Barriers to Knowledge Use: The uptake of knowledge can be influenced by issues related to the knowledge to be adopted, the potential adopters, and the context or setting in which the knowledge is to be used. The barriers assessment should also identify supports or facilitators that can be taken advantage of;
- Select, Tailor, Implement Interventions: Planning and executing interventions to facilitate and promote awareness and implementation of the knowledge. This involves selecting and tailoring interventions to the identified barriers and audiences;
- Monitor Knowledge Use: determines how and the extent to which it has diffused throughout the potential-adopter group. It can also be used to determine whether the interventions have been sufficient to bring about the desired change or whether more of the same or new interventions may be required;
- Evaluates Outcomes: evaluates whether application of the knowledge actually makes a difference in terms of such things as health, practitioner, and system outcomes. Evaluating the impact of knowledge use is the only way to determine whether the efforts to promote its uptake were successful and worth it;
- Sustain Knowledge Use: While the barriers to ongoing use of the knowledge may be different from the barriers present when the knowledge was first introduced, the process for planning and managing the change should be the same.

These steps may occur in sequence or together. The same goes for the two cycles in the proposed model: the creation of knowledge influences their actions and *vice versa*, and this relation between the two cycles complex, dynamic and fluid. The expectation, the definitions, and the model-Knowledge-Action were designed in order to help the knowledge producers and users to understand the complex and organic knowledge translation.

5. LARIISA Architecture

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

5.1 Definitions

Figure 11 presents the LARIISA core architecture, which is an evolution of the LARA framework towards RIISO project aims. It incorporates classical components of ontology-based knowledge management systems, such as ontologies (OWL-DL ontologies), ontology instances, inference and derivation mechanisms, etc. Moreover, it proposes context-aware adaptation mechanisms, like the Service Adaptation component, that have an important role for the integration between LARIISA core framework and the KTA model, as will be shown later. Each entity of LARIISA framework is described below:

- Context Provider: this entity 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 to Set Top Box 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 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;

- Service Adaptation: it manages the main adaptation processes of LARIISSA core framework. 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 context; (3) offering context-aware health indicators that describe local and global context to the knowledge creation entities and decision-making applications;

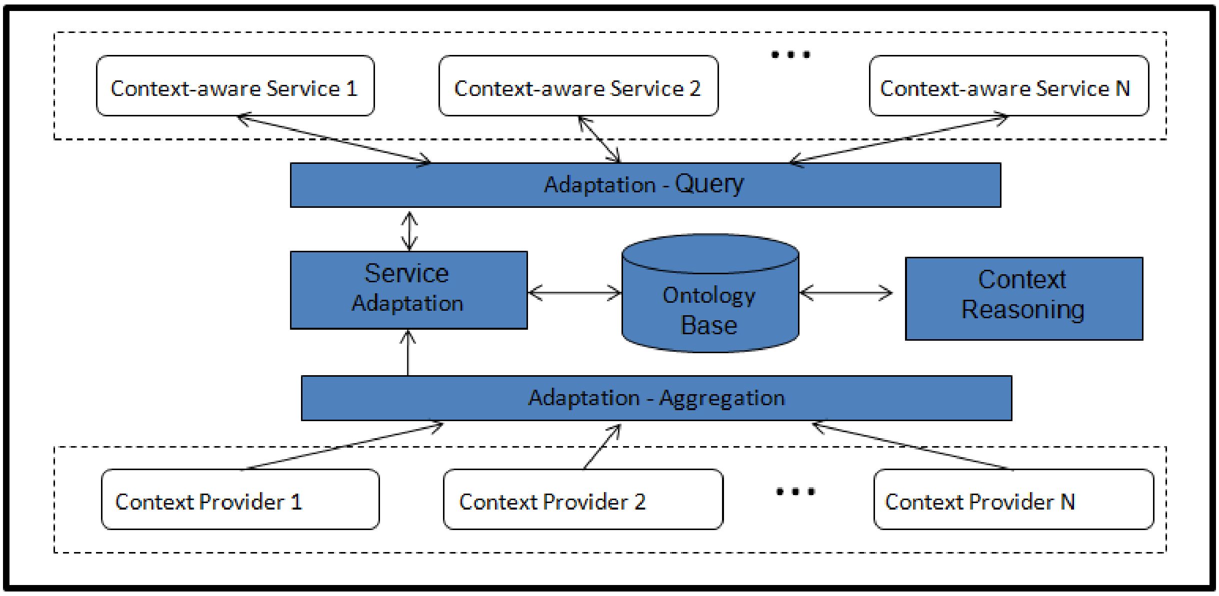

Figure 11: LARIISA Core Architecture

- Ontology Base: it provides knowledge management operations, which is semantically represented by ontologies. It stores ontologies, instances of ontologies, inference and derivation rules. Moreover, it allows manipulation and retrieval of knowledge by the Context Reasoner;

- Context Reasoner: it uses rule-based reasoning technologies in order to infer and derive high-level context information from gathered basic contexts for knowledge consistency in the Ontology Base;

- 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;

- Context-aware Service: it utilizes high-level context information obtained from the Service Adaptation in order to adapt their functionalities, taking into account changes of 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 illustrated in Figure 10.

5.2 LARIISA Architecture integrates to the KTA Process

Figure 12 shows the relationship between the LARIISA core Architecture and the Knowledge To Action (KTA) process.

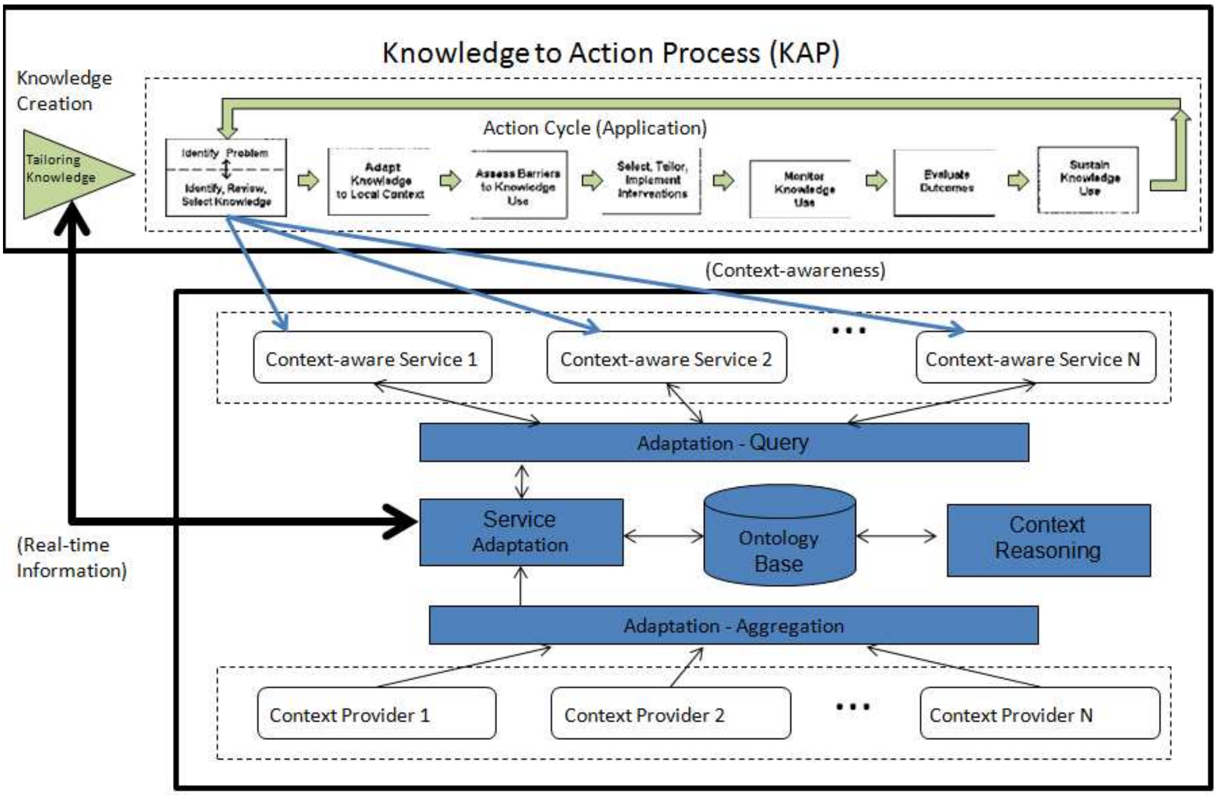

Figure 12: LARIISA Architecture and KTA Process

In this proposal, each step of KTA action cycle could be assisted by one or more context-aware services of the LARIISA core framework. As we have identified in Section 5.3.1, the third cycle allows the Knowledge Creation components of KAP process to 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.

5.3 Relationship between KTA process and LARIISA

Figure 13 shows the final LARIISA Architecture. Each Governance Decision-Making Application could be assisted by one or more Context-aware Services. The KTA model is a conceptual link between the Governance Decision-Making Applications and the LARIISA framework.

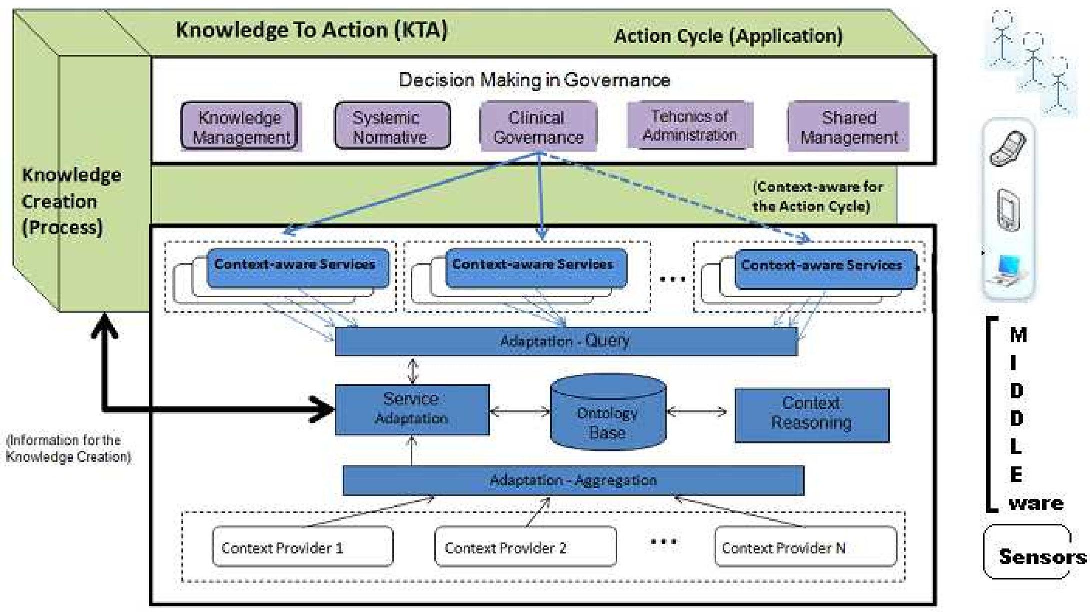

Figure 13: LARIISA Architecture and Governance Decision-Making Applications

In order to illustrate the flow into the architecture, consider context information captured by many sensors. This information is sent to the Context Provider components (CP) of the LARIISA framework. 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.

6. USING THE LARIISA ARCHITECTURE

6.1 Health Agent Case Study

Consider a Health Agent as a professional that deals daily with users of the health system, visiting homes, communities, etc. 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, captured by sensors at the house’s users or inferred/derived by the LARIISA framework, for example. 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 middleware's inference process describes before, a Context-aware Service obtains the context information in order to adapt as soon as possible the changing situation, updating the Health Agent's agenda;

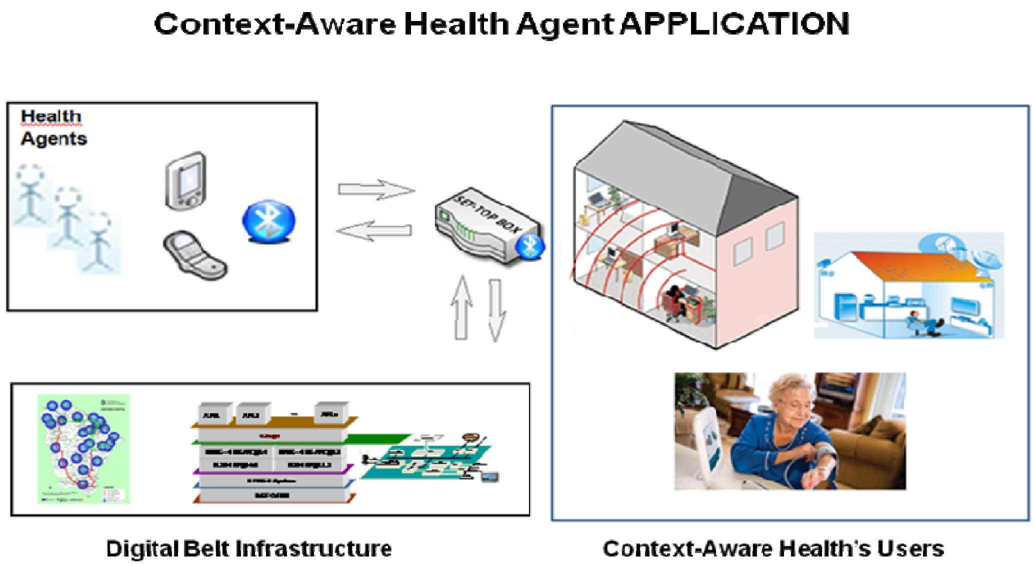

Figure 14: Health Agent Case Study

- A second flow considers the authentication process of the Health Agent, equipped with a wireless device equipped with Bluetooth, Wifi, and GPS, as shown in Figure 14. This authentication will allow the Health Agent, for example, to have access to the services required for the procedure during the visit and making decisions in real time, 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 data captured by sensors (detection of context) and to assist the routine of Health Agents.

6.1.1 Context-Aware Health Agent Application

Figure 15 shows the Context-Aware Health Agent Application represented by the Clinical Governance box which implements a decision-making Governance application. Figure 16 matches the Health Agent Case Study (figure 14) and the Context-Aware Health Agent Application (Figure 15), highlighting the information flow of this scenario.

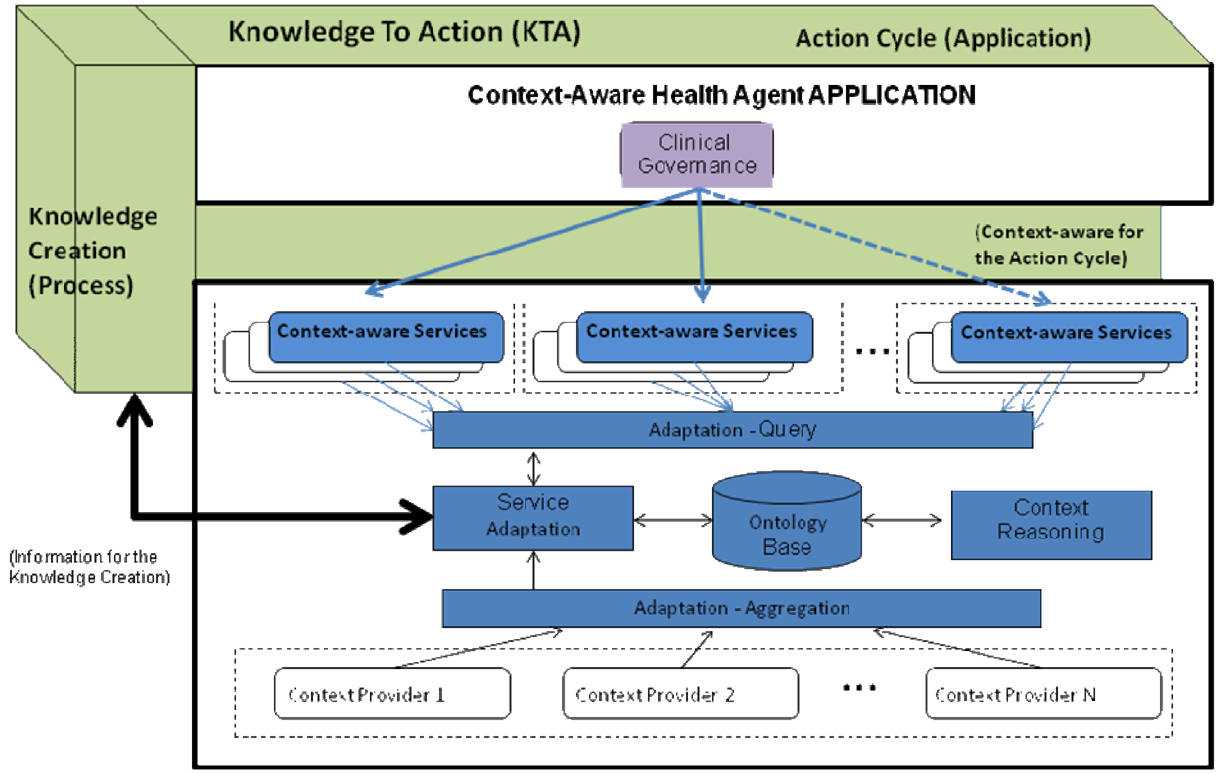

Figure 15: **Context-Aware Health Agent APPLICATION**

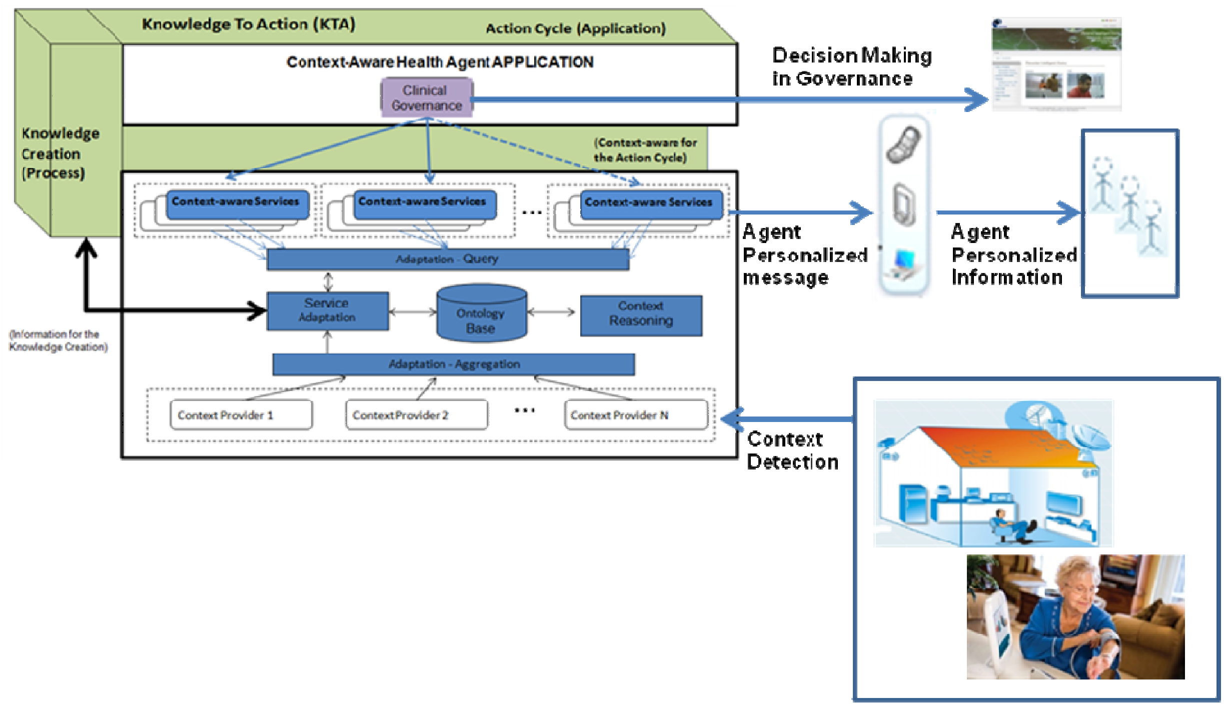

Figure 16: **Context-Aware Health Agent Application SCENARIO**

For processing the Context-Aware Health Agent Application, we classify the context into five categories: personal health context, environment context, task context, spatiotemporal context, and terminal context (Zhang 2004), as shown in the figure 17.

• **Personal health context** consists of two types: the physiological context and mental context. The former contains information like pulse, blood pressure, weight, glucose level, and retinal pattern. The latter includes context like mood, angriness, and stress etc.

• **Environment context** captures the entities that surround the users. These entities can be temperature, light, humidity, and noise.

• **Task context** describes the activities associated with the users. The task context can be described with explicit goals, tasks, actions, activities, or events.

• **Spatio-temporal context** refers to attributes like time and location.

• **Terminal context** is about the users' access network and devices. This includes information and attributes like: characteristics of the terminal (screen size, color quality of the screen, energy type, autonomy, OS, memory), interface (WIFI, Bluetooth, etc.), terminal type (PC, TV, PDA, STB, hand phone, etc.), media supported (audio, video, text, etc.).

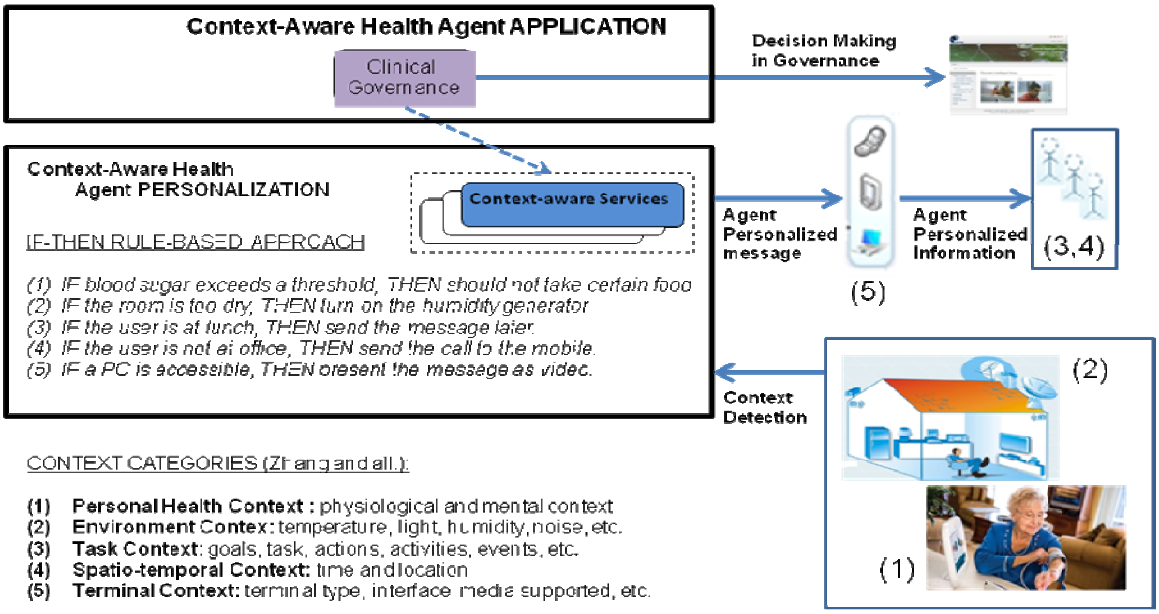

Figure 17: IF-THEN Rule-based Agent Health Personalization

6.2. Health Context Model

It is necessary to define a formal health context model in order to facilitate context representation, sharing, and semantic interoperability in the health care governance system. For this purpose, we have defined two OWL-DL[2] ontologies for modeling local and global health context information, respectively.

Local health context (Figure 18) describes the situation of any entity interacting with the governance system, such as end-users (patients), health managers, health agents, etc. This information is used for defining local health decision rules and for deriving global health context information. *Global health context* (Figure 19) describes high-level information derived from local health context that is used for making health governance decision. For example, it describes the number of Dengue cases confirmed in a region (e.g., neighborhood, city, community), during a given period of time (e.g., a day, a week). In fact, such information can be seen as global indicators used for improving governance decisions.

Based on the *Context top Ontology* we proposed in a previous work [16], we classify local and global health context information according to five dimensions (Figure 18 and 19 illustrate partially the proposed ontologies): *spatial* - any information characterizing the situation from spatial dimension (e.g. location, place, GPS coordinates); *temporal* - any information characterizing the situation from time dimension (e.g. timestamp, interval, period of day, month, year, day, season); *spatio-temporal* - any information characterizing the situation that is dependent of both spatial and temporal dimensions i.e., weather conditions, temperature, noise, luminosity; *social* - any information characterizing the situation from social relationships; *computational* - any information describing the situation from the computational characteristics (e.g. user device's capacities). Moreover, we have added a new dimension named *health_Element* for classifying context information from the health point of view (e.g., heart rate, pulse, blood_pressure). We are reusing GeoRSS[3] concepts to describe GPS coordinates and spatial geometric relations, and OWL-Time[4] to express temporal content. From the Context concept

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[2] http://www.w3.org/TR/owl-guide/

[3] http://www.georss.org/

[4] http://www.w3.org/TR/owl-time

described in the *Context Top Ontology*, we defined two subclasses named *Global_Health_Context* and *Local_Health_Context* (i.e. Global_Health_Context ∪ Local_Health_Context ⊆ Context).

These concepts capture from the context any information characterizing the situation that is relevant for improving health care governance decisions, i.e. it can be used for defining local and global health decision rules.

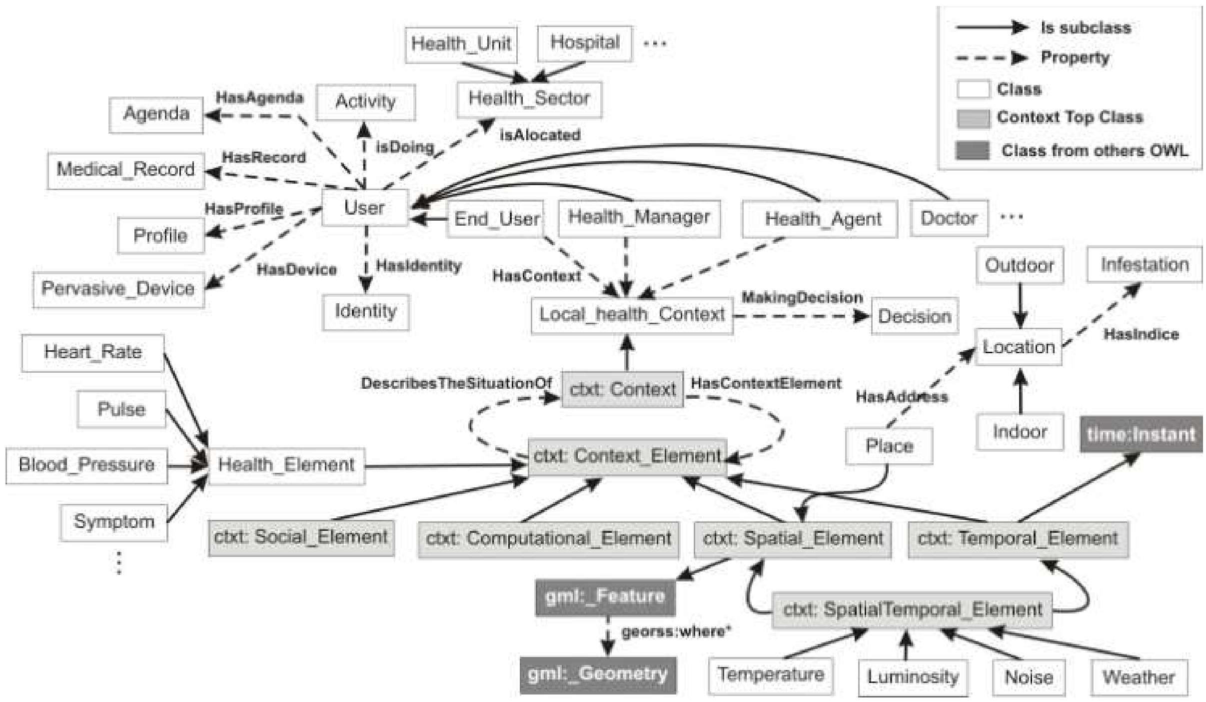

Figure 18: Local health context model

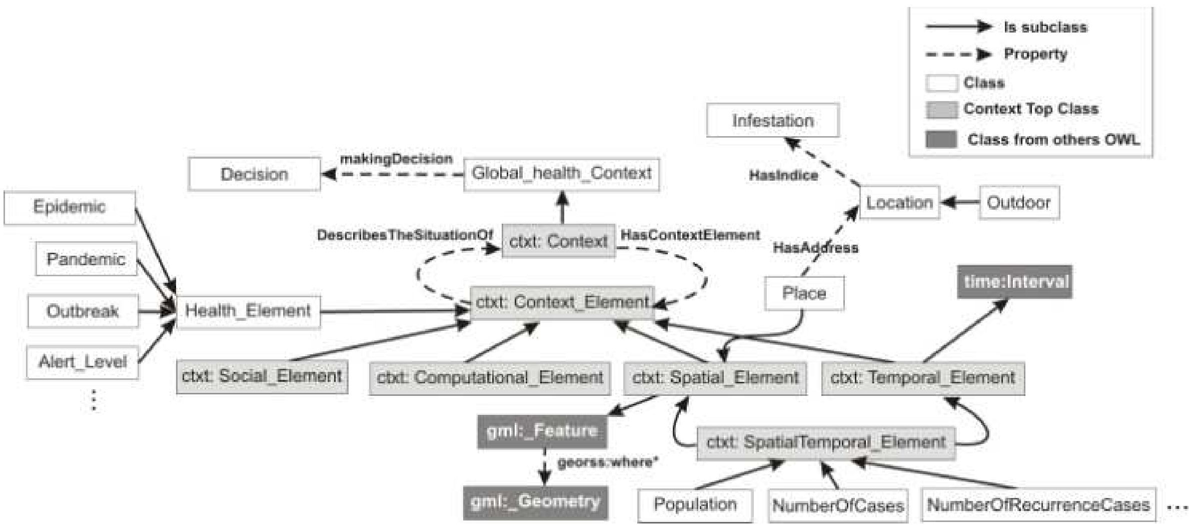

Figure 19: Global health context model

We use as basis the ECA model (Event-Condition-Action) [16] [17] for describing global and local decision rules that are translated into SRWL[5] rules. The Event represents the identification of changes on the context, Condition describes a set of valid context constraints, and the Action describes the decision.

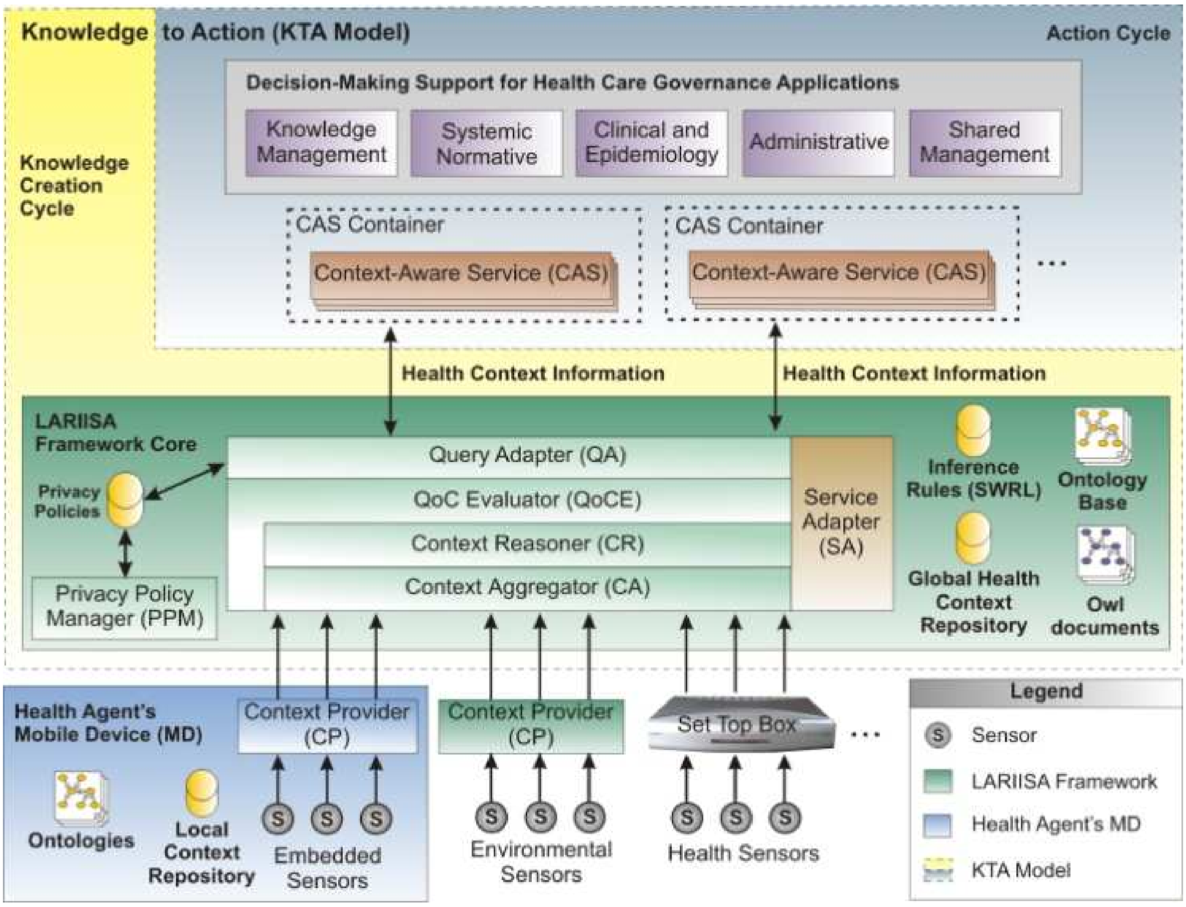

Figure 20: LARIISA Framework Core and Health Care Governance Decision-Making

Case Study: Health Agent Scenario

Let us consider the Health Agents that deals daily with users of health care system, visiting family homes and communities. Without an information system, the visiting schedule of Health Agents follows a linearity and not efficient agenda. The idea in this case study is to

[5] http://www.w3.org/Submission/SWRL/

improve the quality of health services provided by health agents. It can be achieved, for instance, adapting health agent's agenda to the current situation. Health agents could be recruited for visiting an area where there are insurgent signs of Dengue (i.e., Global Health Context) or people that need health care (i.e., Local Health Context). We identify two administrative decisions: i) Adaptation of Health Agent's agenda taking into account Global health context (i.e., global decision rule); ii) local adaptation of agenda taking into account only local health context information (i.e., local decision rule). Figure 21 illustrates these two rules described by SWRL decision rules, which will be enforced by the *Service Adapter* component, adapting the Health Agent's agenda.

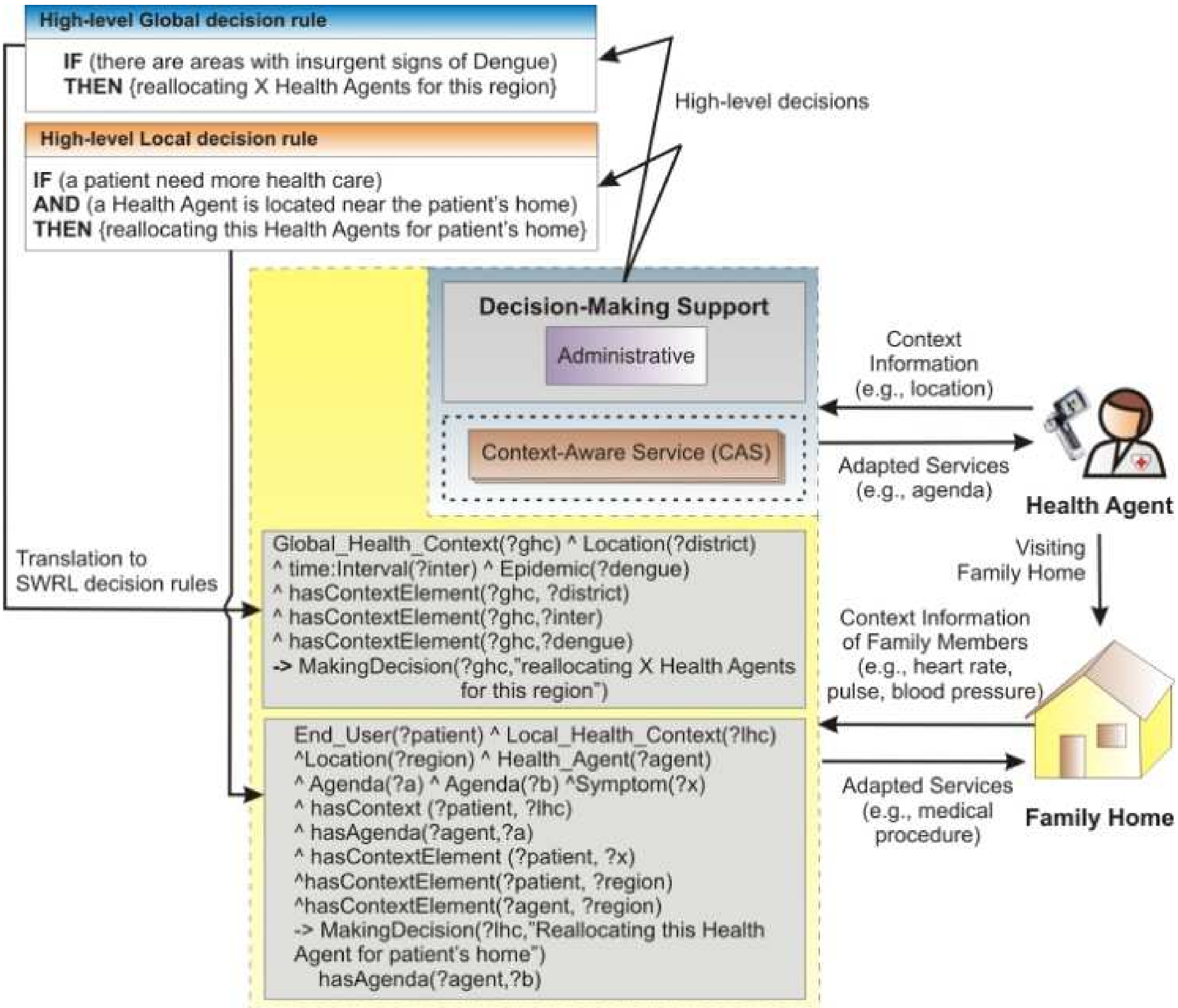

Figure 21: Case Study: Health Agent scheduling.

7. CONCLUSION

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

It is precisely in this scenario that the LARIISA Project may represent a paradigm shift in access to health. The Brazilian model of Digital TV / Set-top-box 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 applications for health care.

The LARIISA architecture is strongly aware of the health end-user situations, i.e. context awareness. This is an emerging field of research that has been suggested as a mechanism that provides dynamic interactions and adaptations autonomous. Context awareness is the responsiveness of the system according to the current conditions under which an entity or user, is considering issues relevant to them. In other words, just as we humans can adapt to the context in which we operate, the context-aware computing is the ability of devices to detect, sense, interpret context information and respond to the User and other devices, making applications dynamically change their behavior based on this information.

However, context awareness has limitations currently hampering its implementation. It is complex to capture, represent and process context data. Applications that involve background are usually limited to a restricted set of specifications for a particular area, for example, applications involving the context of a hospital and its actors - physicians, patients, beds, etc., may not apply to an educational context. Thus, we can see that it is difficult to apply a generalization to any context. There is lack of standard methods of representation and use of context and building applications and context-aware services. However, it is a trend in the next convergent generation of telecommunications systems.

The LARIISA Project proposes a context-aware solution in the health area, becoming a Laboratory of Intelligent and Integrated Network of Health care system, toward to decision-making applications in governance.

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