A COMMUNITY-CENTERED ARCHITECTURE FOR THE DEPLOYMENT OF UBIQUITOUS TELEMEDICINE SYSTEMS

Federico Cabitza, Marco P. Locatelli and Carla Simone
Università degli studi di Milano-Bicocca, Via Bicocca degli Arcimboldi 8, 20126 Milano, Italy

Keywords: Ubiquitous Computing, Home Care, Telemedicine, Hypertension, Awareness.

Abstract: In this paper, we present an ubiquitous and pervasive computing architecture, CASMAS, aimed at supporting cooperation among the members of a community and their devices. We also show how CASMAS can be augmented by the WOAD framework, which was developed independently to model and express coordination mechanisms in document-mediated communities. We take the distributed hypertension monitoring case as an exemplifying and sufficiently complex scenario to show the feasibility and advantages of the our *semantically informed modular* approach. The scenario is then declined in terms of architectural components and cooperation-oriented mechanisms that are shared between the devices and entities of the designed community of care.

1 INTRODUCTION

The technological trend toward Ubiquitous/Pervasive Computing allows for an easy and cheap connectivity among the various actors involved in the care of patients with chronic diseases: the patient, her family doctor and relatives, the caring facilities of the city where they live, and so on. Being connected however is not enough. What it is needed is to make those connected people a social network that could provide the patient with a communication environment where she can feel *safe*. This is obviously true for elder people who can otherwise experience loneliness and fragility with respect to their disease but it also holds true for people who are engaged in full time activities involving work, family care, leisure and so on. What is different is the kind of *social network* that is needed in the various situations to deal with the normal monitoring of the disease development and to face unexpected conditions when ad hoc treatments which can involve several actors at the same time are needed. On the other hand, even if the physical conditions are the same, patients and their relatives are not alike when confronting those events: individual and family history can generate different psychological states that require a strongly personalized communication to avoid that these factors have a negative impact on the caring process. The communication dimension is a necessary factor for this to happen but it is not sufficient: for a patient to feel safe, for a family to feel confident and for a doctor to feel able to achieve the best possible results, they all need to be part of a caring process where they cooperate to achieve a common goal. The technology has to be challenged against this richer view, in that technological solutions should not only be conceived from an engineering point of view to make connectivity robust, fast, protected since it involves sensible data, and so on, but equally from the point of view of the disciplines that take cooperation *through* and *in interaction with* the technology as their main concerns. In this respect, Computer Supported Cooperative Work (CSCW), Computer Human Interaction (CHI) and what has been recently called Computer Supported Cooperative Care (CSCC) (Consolvo et al.,) offer a rich set of indications that are mostly derived from observations and studies in the field and from experimental practices oriented to the evaluation of the impacts of technology introduction both in work and every day life situations. Too often indeed technology adoption is considered a "secondary" problem to be considered "after" that the technology has been already put there. We like to take the opposite attitude: since technology can be "easily" put there, we have to anticipate its impacts on the basis of a stratification of experiences (sometimes of failures) that the above mentioned studies offer to the research and development of new solutions. This paper is a step in this direction.

Cabitza F., P. Locatelli M. and Simone C. (2008).
A COMMUNITY-CENTERED ARCHITECTURE FOR THE DEPLOYMENT OF UBIQUITOUS TELEMEDICINE SYSTEMS.
In *Proceedings of the First International Conference on Health Informatics*, pages 9-16

1.1 Our Main Contribution

Telemedicine (as any other tele-*something* involving cooperation) is not a technological field that aims to reproduce the current social relations among the involved actors nor to change them in a predefined way by "optimizing" communication patterns. Both goals have been proved impossible: technology becomes an effective support if its developers and users understand that technology is unable, on the one hand, to reproduce the reality without losing some of its peculiar and tacit aspects; and, on the other hand, to constrain human behavior to prescriptive rules that can hold just in a virtual world. In telemedicine (as in any other application domain), technology has to harmonize with real life in both directions: i.e., toward both the offering of new possibilities and capabilities, and the modification of the current ones without disrupting or disregarding existing individual and social behaviors. For these reasons, we like to speak of *communities of care*, which are constituted by the patient, close relatives, selected health assistants and nurses, the family doctor and possibly involved specialists: practitioners are members of a number of communities, one for each of their patients. Accordingly, in order to conceive of a supportive technology, we claim that design has to be based on an application layer (i.e., a layer on top of the unavoidable one that guarantees physical connectivity) that reflects the nature and needs of those communities. To this aim, we propose a framework that incorporates the notion of community as a first class object and it allows to express the community's cooperation mechanisms abstractly, i.e., at the semantic level of articulation work. From the technological point of view, the framework recognizes the need of allowing for a high degree of flexibility and adaptability to the actual domain and current situation since it separates the cooperation and communications concerns of all the entities involved in a telemedicine systems by taking a *semantically informed modular* approach. These characteristics make our approach quite different from that recently adopted to make computation "ambient aware" (Baker et al., 2007). Indeed, our proposal is not only aimed at making the members of a community of care aware of what happens in the enlarged environment. Rather, it is aimed at making these distributed and heterogeneous actors aware of the local conventions by which they can make sense of environmental conditions, consider them as meaningful parts of a patient-centered logic environment of care and trust, and correlate those conditions with timely and effective behaviors whenever they occur. Consequently, for our implementation, we do not adopt third-party middlewares that are mainly devoted to context awareness, such as the Context Toolkit (Salber et al., 1999) or the Java Context Awareness Framework (JCAF) (Bardram, 2005); these can provide "only" the *context abstraction and reasoning* part of our model. Conversely, we need, and achieve, support for both coordination and propagation of awareness information, in addition to the ability to enhance the behavior of any application by providing it with a larger access to its context of use (Dey et al., 2001).

Our approach will be illustrated by means of a reference scenario that is described in the next section. The following sections present the approach and illustrate it through a subset of functionalities we focus on for the sake of simplicity. We chose the domain of hypertension monitoring as the reference domain where to place our technological proposal since high blood pressure is recognized as one of the most dangerous silent killer (Hoel and Howard, 1997) and the main concern of physicians involved in its treatment is that many hypertensive persons are unaware of the importance of following monitoring and treatment with commitment in a lifelong perspective (WHO/ISH, 1999).

2 AN INTEGRATED CARE SCENARIO

Let us imagine that a patient, Ms Dorothy, has been inserted in the Hypertension Monitoring Programme (HMP) by her family doctor, Dr. Robert. HMP patients suffer for a kind of hypertension that requires both lifestyle change and medication. For this reason, Ms Dorothy is provided with a series of devices aimed at making continuous monitoring easier and seamless with respect to her daily life at home: these devices are, namely, (1) an electronic agenda; (2) an automatic drug dispensing machine; (3) an automatic blood pressure machine; (4) an electronic paper form; and (5) a simple mobile phone (her own was fine). All these devices are able to transmit and receive information from the communication network, although in different ways (e.g., via GPRS, cabled ADSL, wifi and GSM) and have been selected to require an as much as natural interaction with the patient, which in many cases can lack the necessary skills and practice to use personal computers, palmtops and complex smart-phones.

In order to take her blood pressure, Ms Dorothy uses the Automatic Blood Pressure Machine (ABP). She can use it on her own since the process is completely automatic and does not require a specific technological skill. Today, Ms Dorothy has just taken her blood pressure and her values are 140/90 mmHg. Then, she switches on the electronic paper form (EPF) to send those values to her family doctor, Dr Robert. The EPF is an A5-sized touch screen using E Ink's technology[1] that is thinner than a postcard, has the clarity of a traditional paper sheet, can be bent with no distortion and can be inscribed with a regular stylus. Once switched on, the EPF presents Dorothy with a regular form, where her latest pressure values, the current date and her identity data (e.g., name, social security number) are copied in the corresponding fields of the form automatically. As any other HMP patient, also Ms Dorothy is supposed to fill in additional fields by hand. The most important is the 'further remarks' field: this is where she is asked to annotate the pressure data with some notable past event or condition that could help the doctor make sense of the pressure measurement (e.g., "I had a discussion with a neighbor the morning before I took the pressure"). While the patient is left free to either jot down her remarks or not when all is well, the system invites her to add a further justification to collected data whenever it has detected unexpected pressure values, with respect to either previous data, current trends or medication regimens.

Since today Ms Dorothy exhibits a blood pressure that is fairly high for a person under pharmacological treatment and with her risk factors (i.e., overweight, smoker), the system also automatically imports from Dorothy's personal agenda those items that she had labeled as 'work overload' (i.e., a series of meetings in the previous two weeks), according to some conventions agreed upon with Dr Robert: specifically, they agreed upon the need to note into an electronic agenda Ms Dorothy's daily engagements and, whenever reasonable, to characterize her schedules in terms of simple categories of events, like 'passive sport' (e.g., watching a football match on tv), 'active sport' (e.g., working out at the gym), but also 'business meeting', 'office assignment delivery' and any event that could be associated with stressful states, discomfort and anxiety. These conventional data allow the doctor to find specific correlations between high pressure peaks and risky behaviors and to isolate the actual risk factors of a specific person in order to identify more discriminating dietary and less generic practice restrictions and hence a better and patient-focused treatment. Obviously, these schedule data are strictly confidential and Ms Dorothy can remove the entries reported in the EPF. If she leaves them, Dr Robert can read them only after that Ms Dorothy also gives explicit consent by signing the form. Since the pressure values are high and Dorothy was used to be an intensive smoker, the system also asks Ms Dorothy to fill in the form and to report how many cigarettes she has smoked in the last week (if any), as well as any event that could justify these values. Also this rule has been agreed upon by Dr Robert and Ms Dorothy. She reports she did not take any cigarette in that time lapse and jots down in the remark field that she has often had evening headaches, fatigue and anxiety. Moreover, since Dr Robert has prescribed her a low-calory diet, the form displays a field where to fill in the current weight also. Indeed, the EPF form can change its structure according to the doctor's requests and additional fields can be presented to patients to be filled in; in this case, after that Ms Dorothy has annotated her weight on the EPF, Dr. Robert can also assess if the dietary regimen is yielding its fruits and give her some feedback on that. To put it briefly, the EPF form is a regular document that can hold extra-data beyond what regularly fed in by digital devices. It is used to consolidate those health data, in that to sign it implies giving an explicit consent for their management. Besides the reasons of legal accountability, the form is also used to have patients get an active approach in monitoring their own blood pressure, since trend awareness and active inclusion in the monitoring process can give patients the necessary motivation to change her lifestyle if this is the case. The EPF form is also used to enable asynchronous communication between patients and their doctor via either typed or handwritten messages. Asynchronous messaging is used in order to reduce the number of phone calls that could interrupt doctors during their work. This kind of messaging is particularly appreciated by Ms Dorothy since the EPF represents a written source of information to rely on for those doubts that do not require vis-a-vis or phone talks. Handwriting with a regular stylus is allowed to enable patients that do not have - or are not confident with - personal computers and keyboards to write messages and send them online. As last thing before signing the form, Ms Dorothy writes down in the question field whether she can have some herb tea before going to bed. Then she puts her signature at the bottom of the form and, in doing so, the form content is sent to the Dr Robert officially. Besides being an input device, the EPF is also a flexible output device. The form can also serve to reproduce the official headed notepaper where the doctors jots down drug prescriptions and puts her signature. In this way, the form can be used to buy drugs at the pharmacist. Likewise, prescriptions can be updated by the doctor even remotely without any effort by the patient. The mobile phone is the other main output device at patients' home. The mobile phone is used to convey small messages to remind the pa-

[1] http://www.eink.com/products/index.html

tient, for instance, that she has to take the pills, that the family doctor has changed the therapy remotely (and it is available at the EPF) or that he has just sent her a message.

The doctor, Dr Robert, is informed of the incoming message from her patient while he is going upstairs, headed to his office. Indeed, also family doctors are endowed by a couple of smart devices that are supplied for the HMP to convey alerts when they are not at their desktop or are engaged in some important administrative task. These alerts regard the occurrence of extremely high pressure values of a patient or, less critically, the notification that a patient has sent a message via the electronic form. Then Dr Robert's mobile phone vibrates and a short message tells him that Ms Dorothy has written him. He cannot recall exactly who she is and puts away the mobile as he opens the door of his office. When he sits at his desk, he switches on a small, flat monitor and sees a couple of pulsating circles on it. This monitor is much alike a digital picture frame like the WidgetStation[2]. This smart frame (SF) runs various "widgets", i.e., small, user-tuned applications that perform a variety of tasks, like displaying current agenda, calendar, website and news feeding. One of these widgets is devoted to represent the patients involved in the HMP programme. Each patient is a small dot and the color indicates whether she is under drug therapy or not and whether her last pressure values are on average or not. If the dot's border winks, the corresponding patient has sent the doctor a message that has been also forwarded to his email client and to his mobile if he is out of office. If pressure values of a patient become critical, the corresponding dot enlarges to become a small quivering circle whose color indicates the seriousness of the case (e.g., red, orange, yellow). By touching the circle, the doctor can have the electronic patient record of the related patient displayed, as well as a timeline overview of the pressure data collected so far and the related medications (in a manner quite similarly to that used in the Danish TMBP project (Bardram et al., 2005)). Once seated, Dr Robert touches the only circle whose border is also winking and the station displays the name 'Ms Dorothy'. He then tips again on the circle and maximizes in a two-side view both the last page of Dorothy's personal record and her current pressure trend. Since the trend over a two month period does not show any significant pressure reduction, Dr Robert decides that the previous therapy is not enough and an additional drug is necessary. He then changes the current drug regimen in the Ms Dorothy's file within his electronic patient record. Finally, he opens his mail client and finds the message from Ms Dorothy quite immediately amidst the daily spam since the system has assigned the message a high priority as it comes from a patient of the HM programme. Dr Robert answers Ms Dorothy that herb teas are fine as long as they do not contain theine. This message will be displayed on the EFP of Ms Dorothy in a thread-like fashion inside the question field the next time that she will switch the form on. In a while, a number of devices at Ms Dorothy's side react to the new drug prescription. Ms Dorothy's mobile rings once and a short message notifies her that a message and a new prescription have been dispatched from Dr Robert. The prescription can be displayed at full screen on the EPF form so that it can be presented to the pharmacist at due time.

Also the Automatic Drug Dispensing Machine (ADD) receives the prescription data. According to these data, the ADD provides the patient with the right drugs by dispensing just the right dosage and by allowing the patient to open the drug-till only at the right interval of time. When the patient withdraws the drug pill, the ADD records the drug administration as accomplished. In our vignette, the ADD detects that the new drug is not loaded in its tills. Consequently, both Ms Dorothy and her closest relatives are notified of it by mobile phone. Specific relatives or friends that were pointed out as the patient's closest helpers are also notified whenever the patient has skipped two drug administrations in a row or if she presents very high values of hypertension. This is done to commit the relatives in paying attention to their dears and in reminding them due commissions at due time.

3 THE CASMAS ARCHITECTURE

In the architecture that we defined in (Cabitza et al., 2006), ubiquitous-computing systems are viewed as constellations of dynamically defined *communities* of human and technological *entities* that interact through *cooperation* mechanisms and coordinate themselves on the basis of *awareness* information related to the community context. Communities are identified by points of aggregation, called *community fulcra*: entities gather around them to access the information that characterizes the community and contributes to its definition. The structure of an entity and how it relates to the other elements of the model is described in Figure 1. Each entity — composed of inner elements as depicted in Figure 1.a — is depicted as a rounded rectangle, and can be linked to multiple fulcra to enable intra- and inter-community coordination

[2]http://www.emtrace.com/widgetstation/

(see Figure 1.b) and to awareness *topological spaces* (represented as graphs, space site in Figure 1.a) to promote awareness information sharing. More specifically, a *Coordination agent* (C-agent, C in Figure 1.a) is instantiated for each connection to a fulcrum, i.e., for each of the communities in which the entity participates; an *Awareness agent* (A-agent, A in Figure 1.a) is instantiated for each connection to an awareness space.

An example of technological entity is the ABP device; this is typically connected to a fulcrum of an entity that represents a person, Ms Dorothy in this case, so as to be part of the community of devices that are associated to that person. The notation used to depict this situation is showed in Figure 1.c; in this case, a C-agent is created when an entity connects to another one and it docks to its own *entity fulcrum*. Figure 2 represents the set of entities corresponding to the patient community of care described in Section 2: in this case the community encompasses both human and technological entities.

Once created, all C-agents are provided with generic inference capabilities and with a set of entity-specific facts (i.e., declarative data structures) and mechanisms (i.e., rules). By being connected to a *community fulcrum* (Figure 1.b), C-agents associated to entities can share information (facts) and acquire community-specific behaviors (mechanisms) that are either defined at design-time or injected into the fulcrum by other entities at run-time. To this aim, the model provides mechanisms, for instance to either insert facts into fulcra (i.e., `assertion`) or to move facts from a source's to a destination's fulcrum (i.e., `translation`), by which to define the behavior of C-agents (Cabitza et al., 2006).

The behaviors of C-agents might be influenced by the *degree of participation* of entities in communities, according to additional context information that is supplied by the part of the model that manages awareness promotion (on the basis of the above mentioned awareness spaces and A-agents populating them). This part of the model has been illustrated and used in a previous work (Locatelli and Simone, 2006) and will not be further described since the degree of participation is not used in the considered scenario. Instead, we give more details on the part of the architecture that computes the awareness information to be promoted, in a simplified way, to entities that occupy isolated nodes of the awareness spaces (i.e., without using the space topology). From now on, we will use entities without any further reference to their internal structure since they support the semantically based modular approach mentioned in the introduction.

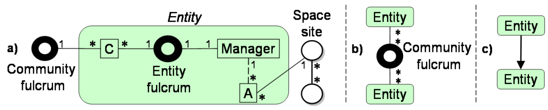

Figure 1: Notation used to represent the entities.

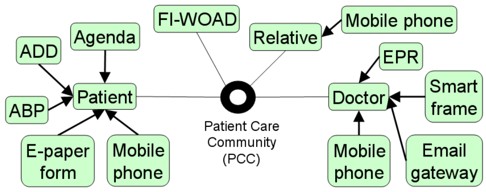

Figure 2: The involved entities in the scenario.

3.1 The Woad Framework

Within the CASMAS architecture, the WOAD framework is what we used to model community conventions and mechanisms of awareness provision. WOAD is a conceptual and design-oriented framework that we proposed (Cabitza and Simone, 2007b; Cabitza and Simone, 2007a) to provide a set of high-level concepts – like those of *documental artifact*, *fact*, *fact space*, and *fact interpreter* – that guide the design of a rule-based reference architecture for context-aware and coordination-oriented electronic document systems. In the CASMAS architecture, the community fulcrum can be seen as a fact space and one of the agents can plays the role of fact interpreter. This agent would be supposed to import into its private fulcrum (i.e., its working memory) the WOAD mechanisms of the related community of care and then apply them to the content of the community fulcrum so as to produce consistent awareness information. In WOAD, two main abstract kinds of components are distinguishable: a *fact space*, i.e., a common and shared repository where contextual information – i.e., what we call *facts* – is stored; and a *fact-interpreter*, i.e., an inference agent that is able to react to the content of the fact space and produce new contextual information, usually meta-data by which *situational awareness* (Endsley, 1995) information is associated to data. Situational awareness is any information about either an event or new contextual condition which the system can convey in any way (e.g., visual, aural, textual) to support the user become aware of it, know what is going on and figure out what to do consequently. The WOAD language is a high-level programming interface by which to express mechanisms of awareness provision and conventional patterns of data production and routing. These mechanisms are intended to reflect the local conventions that practitioners and patients can agree upon about how to manage data and interventions within a given community. WOAD mechanisms can be shared into a fact space and be used by any fact-interpreter sharing this space to (a) provide suitable awareness information to support human actors in articulating their activities of integrated care; and (b) to process the content of a document according to locally defined and agreed patterns of coordination. WOAD encompasses a set of both static and dynamic constructs by which the designer can express either contextual, organizational or procedural knowledge about a work arrangement in a declarative manner, that is by focussing on the expression of what a system should do, rather than worrying about how it really accomplishes it. These static data structures and dynamic behaviors are expressed by two specific constructs: *facts* and *mechanisms*, respectively. In the WOAD language, whatever is given the suffix *-fact* (e.g., *activity-fact*, *relation-fact* and *awareness-fact*) is a *key-value* data structures, by which the programmer can characterize the relevant entities of a documental domain by simply assigning a value to specific attributes. The WOAD language provides designers with templates (i.e., *entity-facts*) for the most generic categories of articulation work (cf. (Simone and Divitini, 1997)), like those of actor, activity and artifact; yet, by means of its *extends* primitive, it also allows for the definition of domain-specific entities (such as patient, doctor and care activity) that inherit from and specialize those general categories. Mechanisms can be seen as simple conditional statements, like *if-then* rules: they produce some output according to the actions expressed in their *consequent* (the *then* part) whenever specific contextual conditions, which are expressed in their *antecedent* (the *if* part), are evaluated true by matching their patterns with the internal state of a fact interpreter (i.e., usually but not necessarily, the working memory of the rule-based system). Mechanisms are hence intended to make explicit the relationship between some contextual conditions regarding either the existence or the content of some facts within the *fact space* and some behavior (i.e., functionality) that the system should exhibit in that particular situation, whenever it occurs. In our application domain, the production of suitable awareness information is conveyed as attached to some contextual or documental data. In the next section we will see two examples of information flows derived from the scenario depicted in Section 2.

4 APPLICATION TO THE HM SCENARIO

The scenario described in Section 2, identifies a community, called Patient Care Community (PCC), that contains the following logical entities interacting through the *PCC fulcrum* (see Figure 2): *`Patient`* (we denote entities with this *`typographical notation`*), *`Doctor`*, and *`Relative`* i.e., entities managing the information pertaining to each person involved; *`ADD`*, *`Agenda`*, *`ABP`*, *`E-paper Form`*, and *`Mobile phone`* are linked to *`Patient`*; *`Smart Frame`*, *`Mobile phone`*, *`EPR`*, and *`Email gateway`* are linked to *`Doctor`*; finally, *`Mobile phone`* is linked to *`Relative`*. Moreover, there is a framework-specific entity, *`FI-WOAD`*, that is the WOAD *Fact Interpreter*; this entity perceives the facts published by the entities that take part to the patient care community and infers on them. The patient care community provides the involved entities with proper mechanisms to coordinate and exchange information as illustrated in the scenario. In the following, we give some examples of mechanisms involving *`Patient`*, *`FI-WOAD`*, *`Doctor`* and *`Relative`*. *`Patient`* is in charge of making available in the PCC's fulcrum the fact representing that the form has been signed (generated by *`E-paper form`*), and the fact that a specific drug is unavailable (generated by *`ADD`*): this transfer of information is realized by means of the `translation` mechanism, which accomplishes a mere copy of information from the source's to the destination's fulcrum.

By using the same mechanism, *`Doctor`* (associated to Dr Robert) can put into the PCC fulcrum mechanisms expressing criteria to evaluate pressure values for the patient at hand and identify "critical values" accordingly. In this way, *`FI-WOAD`* can acquire them to assess when pressure values are critical for the patient at hand and publish both alerting and reminding facts, in particular those on critical blood-pressure values and, in a similar way, on new prescriptions.

Let us now consider a more articulated situation. According to the conventions established between Dr Robert and Ms Dorothy, her *`Agenda`* publishes in the *`Patient`*'s fulcrum the events labeled as "work overload" (see Figure 3.a, step 1a). When Ms Dorothy takes her blood pressure using the ABP, *`ABP`* publishes this information into the *`Patient`*'s fulcrum (step 1b); *`E-paper form`* reacts to this information (step 2) and shows the form to Ms Dorothy so that she can fill in the pieces of information required by the EPF's structure that is dynamically set

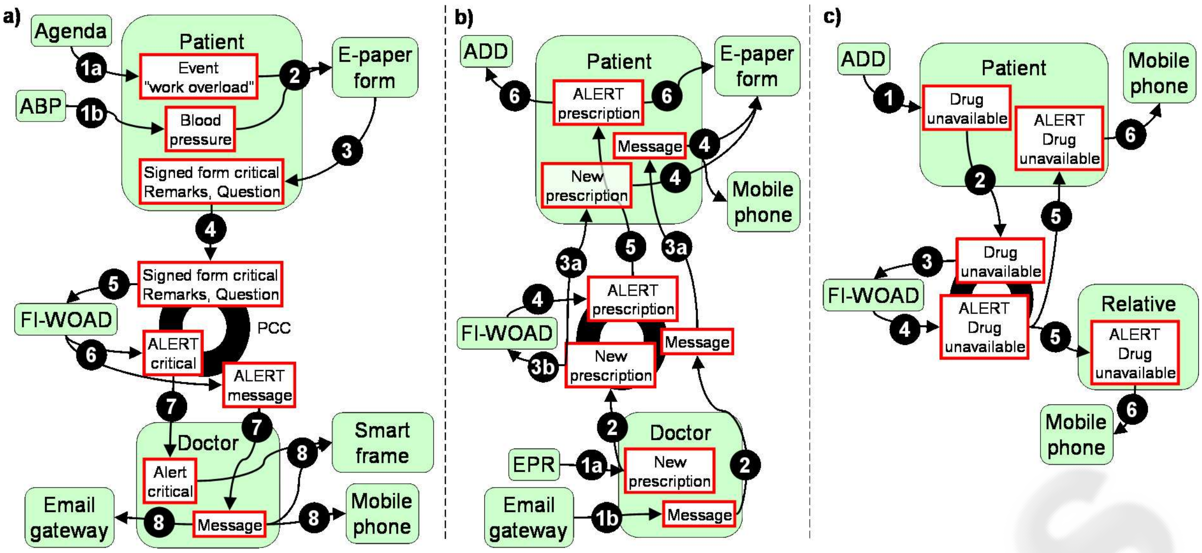

Figure 3: The step sequences for the three main cases depicted in the scenario.

by Dr Robert for her, such as her weight, and write her remarks and questions. Ms Dorothy signs the form to submit the information and `E-paper form` publishes the form to the `Patient`'s fulcrum (step 3); then `Patient` publishes the signed form into the PCC fulcrum (step 4). Once the signed form is published into the community fulcrum, all the entities in charge of managing the form's content can perceive it; in our case, `FI-WOAD` perceives the form (step 5) and, due to its mechanisms, it asserts an alerting fact both for the critical pressure values and for the message that contains the Ms Dorothy's question (step 6). Since Dr Robert must be warned of alerts, `Doctor` reacts on these facts and `translates` the information into its fulcrum (step 7) to make it available to the entities of its private community. The alert about critical values is rendered only by the SF that executes the HM awareness widget; the message activates other three entities (step 8): `Email gateway` `translates` the message into an email for Dr Robert, `Smart Frame` provides awareness about the received message, and `Mobile phone` notifies Dr Robert of the incoming message since he is not in his office.

Dr Robert evaluates the received information and writes the new prescription in the EPR; once Dr Robert is done, `EPR` asserts the new prescription into the `Doctor`'s fulcrum (see Figure 3.b, step 1a); moreover, Dr Robert replies the question of Ms Dorothy using his email client. This event is caught by `Email gateway` that extracts the information and asserts the corresponding message in `Doctor`'s fulcrum (step 1b). `Doctor` `translates` both the message and the new prescription into the PCC fulcrum (step 2) to make them available to the community. Then `Patient` `translates` this information into its fulcrum (step 3a) and, concurrently, `FI-WOAD` reacts on the new prescription (step 3b) and asserts an alert to the community (step 4). Now `Patient` `translates` also the alert into its fulcrum (step 5). `E-paper form` reacts to all this information because it has to (a) convey Dr Robert's reply, (b) show Ms Dorothy the new prescription, and obviously (c) alert her by providing awareness of the changes occurred (step 4 and 6). Due to the importance of these changes, Ms Dorothy is also notified by her mobile phone that a new prescription has been made available. Also the ADD is programmed to react on changes of prescription (step 6): it checks then whether the drug is available in its tills or not. Consequently, `ADD` detects that the new drug is not available and asserts this information into the `Patient`'s fulcrum (see Figure 3.c, step 1). `Patient` `translates` this information in the community fulcrum (step 2), `FI-WOAD` perceives it (step 3) and asserts an alert (step 4). In this situation, the relative selected by Ms Dorothy is involved too: `Relative` perceives the alert fact (step 5) and `translates` the corresponding information into its fulcrum so that the relative's devices (such as her mobile phone) can warn her. The same happens for Ms Dorothy when she is informed by her mobile phone (step 5 and 6).

5 CONCLUSIONS

The paper presented the CASMAS architecture. This architecture is aimed at the development of applications that take advantage from ubiquitous/pervasive computing to support cooperation among the members of a community. The paper also showed how CASMAS could be used in the construction of mechanisms that are useful to enhance cooperation in a specific domain, namely within communities of care that take patients as their “fulcrum”. Two are the main features of the proposed approach. On the one hand, the identification of the components is guided by the idea that they all have access to information (i.e., local conventions and mutual awareness) that constitutes the glue of the community but they are also left free of using the shared information autonomously in order to contribute to the community’s good functioning and behavior. On the other hand, the mechanisms supporting cooperation are defined in terms of a modular and declarative approach that defines them in an abstract manner as reactive behaviors with respect to the changes of the shared information mentioned above. These two features implement the *semantically informed modular* approach and support the application flexibility and adaptability to the context that we mentioned in Section 1: indeed, each behavior (from a whole component up to the atomic constituents of a single mechanism) is aimed at the goal of supporting cooperation and awareness provision between the members of the community (of care). Hence, these community-specific behaviors can be naturally externalized and appropriated by the members, also while they are interacting with the community designers, in order to adapt the application to the single context of usage. This context is always locally characterized by the kinds of patients and their diseases, their family relationships, the local caring structure and conventional practices and so on. In addition, the above mentioned separation of concerns applies to the devices too (seen as a special kind of community “members”) so as to define a clear interface toward any underlying layer that guarantees the general purposes of the communication infrastructure. The future work is aimed at making the integration between the CASMAS architecture and WOAD framework more transparent and at improving its usability from the designer’s point of view. In doing so, we would provide an integrated framework that responds to the basic requirements of cooperation within communities (of care) and that can be fully validated in the field.

REFERENCES

Baker, C. R. et al. (2007). Wireless sensor networks for home health care. In *AINAW’07 proceedings*, pages 832–837, Washington, DC, USA. IEEE Computer Society.

Bardram, J. E. (2005). The java context awareness framework (jcaf) - a service infrastructure and programming framework for context-aware applications. In *Lecture Notes in Computer Science*, volume 3468, pages 98–115. Springer.

Bardram, J. E. et al. (2005). Designing for transformations in collaboration: a study of the deployment of homecare technology. In *GROUP ’05 proceedings*, pages 294–303, New York, NY, USA. ACM Press.

Cabitza, F., Locatelli, M. P., and Simone, C. (2006). Designing computational places for communities within organizations. In *CollaborateCom’06 proceedings*, Atlanta, Georgia, USA, pages 1–10.

Cabitza, F. and Simone, C. (2007a). A language for the executable specification of coordinative functionalities for electronic document systems. In *CHItaly’07 proceedings*, Padova, Italy, June, 28–30.

Cabitza, F. and Simone, C. (2007b). “…and do it the usual way”: fostering awareness of work conventions in document-mediated collaboration. In *ECSCW’07 proceedings*, Limerick, Ireland, 24–28 September.

Consolvo, S. et al. (2004). Technology for care networks of elders.

Dey, A. K. et al. (2001). A conceptual framework and a toolkit for supporting the rapid prototyping of context-aware applications. *Human-Computer Interaction*, 16(2–4):97–166.

Endsley, M. (1995). Toward a theory of situation awareness in dynamic systems. *Human Factors*, 37(1):32–64.

Hoel, D. and Howard, R. (1997). Hypertension—stalking the silent killer. *Postgrad Med Journal*, 101(116–121).

Locatelli, M. P. and Simone, C. (2006). Supporting care networks through an ubiquitous collaborative environment. In Nugent, C. and Augusto, J., editors, *Smart Homes and Beyond*, volume 19, pages 204–211. Assistive Technology Research, IOS Press.

Salber, D., et al. (1999). The context toolkit: Aiding the development of context-enabled applications. In *CHI’99* proceedings, pages 434–441.

Simone, C. and Divitini, M. (1997). Ariadne: Supporting coordination through a flexible use of the knowledge on work processes. *Journal of Universal Computer Science*, 3(8):865–898.

WHO/ISH (1999). *Guidelines for the management of hyper-tension*, volume 1. Blood Press.