Published in *First International Workshop on Sensor Networks (SN 2008)*, in conjunction with ICCCN 2008, August 4-7, Virgin Islands, USA, 2008.

The AmICriM Project: A Truly Body Area Network Application

José Esteban García Ruiz
Telefónica R&D
Emilio Vargas, 6
28043 Madrid (Spain)
E-mail: jegr@tid.es

Jean-Pierre George
Université Paul Sabatier
Route de Narbonne, 118
31062 Toulouse (France)
E-mail: george@irit.fr

Gauthier Picard
École des Mines de Saint-Etienne
Cours Fauriel, 158
42023 Saint-Etienne (France)
E-mail: picard@emse.fr

Abstract

The major aim of this work is to present the AmICriM (Ambient Intelligence for Crisis Management) current activities as an upcoming research challenge in the area of body area networking by using intelligent embodied devices for supporting new crisis management services.
The research outcomes of the AmICriM project will show also future directions in the area of body-area networks and communications, as well as its applications to novel approaches in which firemen would receive critical and valuable information when acting in real situations of crisis, as in case of fire in a building.
This work will boost development of new technologies and solutions that will be used in the future for networking embodied intelligent devices. Moreover, the AmICriM developed technologies will be evaluated through a real service for assisting firemen in crisis situations.
Keywords*—body area sensor network, embodied intelligent devices, crisis management services, ambient intelligence*

1. Introduction

The main objective of AmICriM (Ambient Intelligence for Crisis Management) is to enable a body area network of embodied intelligent devices to interact dynamically for proactively providing valuable information in situations of crisis [1]. AmICriM investigates new paradigms and models for the next generation of embodied intelligent devices, such as:

- **Socio-technical interaction** models,
- Adaptive **individual, social and coordinated behaviours** for intelligent devices,
- **Intelligent self-organising** behavioural models for embodied devices,
- Middleware **mechanisms adapting to changes** in highly and unsecured environments.

AmICriM will develop an engineering framework for building body area networks of physically embodied intelligent devices [2] that proactively provide and compose services as to support a well-defined set of future crisis management scenarios. This framework is structured along layers that propose (from user to hardware) the following three main areas of research:

- **User-centred ambient crisis management** making possible the interaction and collaboration between heterogeneous entities such as embodied intelligence devices present in body area networks,
- **Pervasive, adaptive and self-organising embodiment** supporting the execution of services given the current context of the crisis, which relies on self-organisation, regulation and control by loose coordination policies that permit the embodied devices to adapt and self-organise taking profit of these policies,
- **Semantic and adaptive middleware** [3] supporting cooperation of the self-organising agents and their adaptive embodiment on the different hardware used in crisis management environments.

2. AmICriM Concept and Objectives

Crisis management is a twofold problem [4]. Firstly, it is a socio-technical problem, which characteristic feature is the interaction and collaboration between heterogeneous entities: hardware and software components and human and organisational agents. Secondly, crisis management is a location-based and context-dependent problem, as the way a crisis is managed depends crucially on its location, the state of the environment, availability of resources, etc. Although, it is widely recognized that an AmI (Ambient Intelligence) based supporting system would facilitate the management of a crisis, there are no complete engineering tools for the development of such systems [5].

The main objective of AmiCriM project is to provide the technological framework for a body area network formed of embodied intelligent devices by building an engineering framework to support the development of crisis management systems [6], [7]. This framework will include (a) a modelling language and analysis techniques for social and agent behaviours, (b) methods and methodological guidelines for developing collective and individual agent behaviours, and (c) an infrastructure for the deployment and execution of AmI-based crisis management applications.

The following Figure 1 shows the concept idea of the AmICriM project.

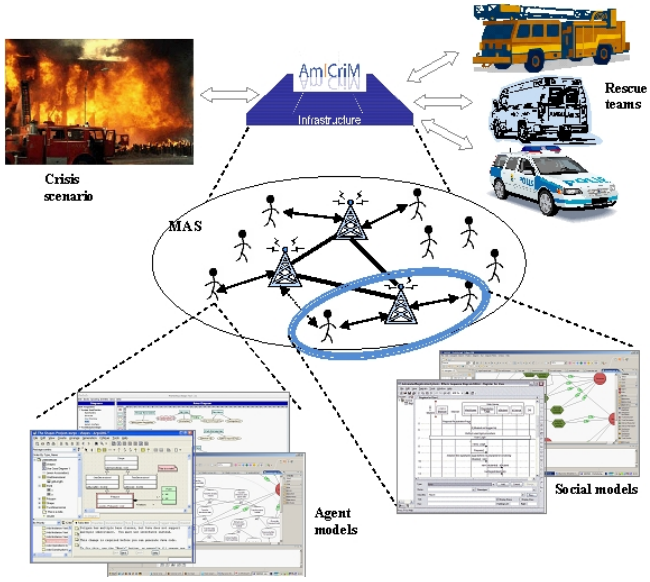

Figure 1. The AmICriM system concept.

3. Body Area Sensor Network Challenges

The AmICriM project concerns the rising challenges we find in embodied, intelligent devices by exploiting ambient intelligence, autonomic, pervasive and ubiquitous computing especially concerning challenges identified to body area networking.

Its ambition is to answer these challenges, among others, in a new way by progressively designing artificial systems that are strongly relying on self-organisation mechanisms and emergence [8].

This requires both theoretical researches and numerous experimental validations. The scope of these challenges in hardware and software infrastructures is intrinsically multi-disciplinary (networks, communication, architectures, interfaces, artificial intelligence, models, security constraints,...) [9], [10].

This project fits in the scope of future technologies with the necessary characteristics of being pervasive, ubiquitous, highly dynamic, open, robust, resilient, offering security and being the backbone for a large variety of new applications in Ambient. We aim at providing service architectures, platforms, technologies, behaviours, methods and tools for the design of devices with the ability to freely and cooperatively interact so as to exhibit, as whole, relevant, safe and useful behaviours which will emerge when confronted to the constraints of the environment and the needs of the users. This will enable new applications in Ambient Intelligence, in particular a pervasive crisis management application.

An approach of the software design relying on adaptation, self-organisation and emergence will open doors to new horizons for artificial systems which are currently stalled by the sheer complexity of these future systems. Ambient intelligence is typical of those systems and the expected results of this project could lead to a real breakthrough where we would not be limited by having to implement specific applications but where the applications would be spontaneously produced by all the devices whatever the needs of the users and the situation, being it a crisis situation or simply on a day to day basis. Computers and electronic devices would truly be responding and adapting to humans needs.

The main difficulty for the industry when designing a new electronic device with new functionalities is to anticipate the situations in which they will be used. Thus, current services provided to the user are very limited and mostly stand-alone. The AmICriM project would lead to eventually providing the industry the framework and tools needed to quickly design the behaviours of their devices for them to interact in a rich and productive way with other devices. The result is the ability for industrials to create new dynamic and adaptive services, new applications relying on interoperability and improved mastery of complex systems composed of AmID (Ambient Intelligent Devices) offering adaptability in a more natural way, and truly integrated in our everyday environments

4. A New Body Area Network Application for Crisis Management

A very critical application of the AmICriM system based on this new development of body area networking, addresses how to assist public tasks forces (e.g. firemen) in situations of crisis (e.g. in case of fire in a building).

Crisis management, apart from the human decisional process and the resulting activity, is mainly about having the right person possessing all the needed information. Typically, a rescue team needs to know where the victims are, what their state is, the situation around them, etc. The best way to collect all this data is to have the Ambient Intelligent Devices (AmID) exchange in the most efficient and relevant way all this data. The capability for initiative and reactivity also plays a huge role as AmID can react quickly and autonomously to changes in their environment.

This sample scenario puts the stress on what happens at the different layers of the socio-technical system (users, agents, middleware, and hardware). Before the crisis occurs, the area network of this intelligent system is formed by the devices contained in the building (camera,

PDA, laptops, etc.). Once the crisis happens, this pervasive network constantly adapts, since some devices become unavailable, others appear or disappear. Thereafter and with the arrival of rescue teams (firemen), the original network can integrate new devices, actors and functionalities such as the firemen and their associated services.

4.1. Phase 1: a fire starts in the building

The building in which this scenario will unfold is not unusually equipped with electronic devices but we will assume that there are Wifi capabilities, a LAN network, some cameras and PC's. Also people working have electronic equipment (phone, PDA, laptop...). The AmICriM system is deployed in this environment and all AmID (AmI-Devices) are hosting AmI-agents.

Now some victims have their personal agent activated in background, and the following 5 phases will describe chronologically how the AmICriM system will react and adapt to this situation.

1. A **fire starts** at 5 pm on several locations of the first floor, fire alarm has a dysfunction and the victims are partly isolated (some exits are still free).
2. **The AmICriM system detects the crisis**: an AmID (camera) detects a fire. Since the fire alarm is down, the alarm has to be raised by the AmID detecting an anomaly. For a camera, it can simply be an abnormal proportion of specific colours (fire). The AmID Agent representing the camera can reason on this new perception from its environment. Since it cannot be sure of its conclusions, it can send a message to the nearest AmID agent which has the ability to confirm, using ad hoc or infrastructure Wifi, or even GSM if necessary. One agent in the vicinity reacts to this message since it is representing a mobile phone and thus has the ability to warn the user and ask him to check the incident. As soon as the user confirms, this AmID agent starts alerting all the others AmIDs, using the same communication medium.
3. As usual**, the automatic warning system of the building is activated**, without any AmICriM control, but thanks to information gathered by AmI-agents. In fact, AmICriM does not interfere with build-in equipment such as rings, automatic door closing, etc. Nevertheless, if the crisis is confirmed, AmI-agents inform rescue organisations they know, using SMS. Now fire fighters are aware and are preparing for intervention.
4. Since the fire breaks out at 5pm, traffic is as usual awful. As soon as the crisis situation is confirmed and its importance evaluated by the rescue team HQ, AmID on the zone can be authorised to start and try to **reroute the traffic to liberate the access** to the zone both for arriving vehicles and departing ambulances. This rerouting is here also done in a collective and emergent way as AmID near the zone start communicating warnings and requests to change courses to AmID approaching the zone, using ad hoc Wifi or Bluetooth. Moreover, the services of the city responsible for traffic surveillance and regulation are contacted via SMS.
5. **The AmICriM system activates the local rescue procedures** by proactively informing fire wardens[1]. According to their profile, some AmI-agents are informed that a crisis is occurring by the AmI-agent that detected the fire. Such agents proactively inform their owners, in case they are not aware of this situation. Once informed, the fire wardens received from their AmI-agent a reminder of the procedure to execute as to evacuate the building properly, and activate some useful services, such as localise the people he is responsible for and inform them about a safe meeting point. He can also access to a service calculating the safest path to the exit

The following figure shows the actions in Phase 1.

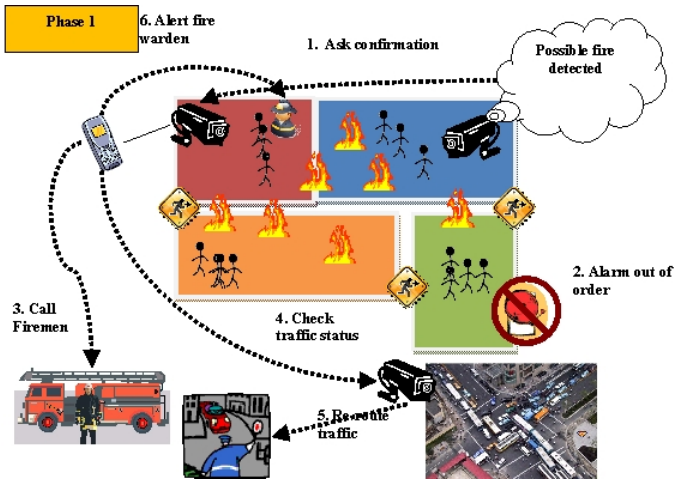

Figure 2. AmICriM in action: Phase 1.

4.2. Phase 2: What happens before the arrival of the rescue forces?

1. **Rescue procedures are adapted to the situation**: e.g. a fire warden who is responsible for an area is not able to help people since he is blocked by fire or injury. This blocked fire warden that cannot answer to the call is perceived by other AmI-agents as unavailable (timeout or disconnected state). In such a state, the fire wardens role and responsibilities are delegated to another victim in the vicinity,

1 a local evacuation leader responsible for a group of people during an evacuation, volunteer in charge of checking that all the rooms of the building have been evacuated.

according to his profile, embedded within his AmI-agent, after a negotiation thanks to his situation and capabilities. As a consequence, the new responsible has now access to new rescue services (mapping, alerting people, accessing to dedicated data) as to fulfil his new tasks, via his AmI-agent. This situation requires to adapt the predefined organisation, by negotiating and evaluating the capabilities of AmI-agents.

2. **Every AmI-agent helps its user to follow a predefined procedure**, according to its role within the rescue workflow, by indicating or adapting prescribed actions, according to the current situation (evaluated thanks to communication with other AmI-agents) and the current state of the user. Agents know some predefined procedures and evacuation workflows, which can be adapted by agents if necessary by evaluating the situation. E.g. the stairs that must be used for evacuating are unavailable due to fire; AmI-agents then propose a new path as soon as they are aware of this situation. This new path is calculated using the knowledge accumulated during the crisis.
3. **AmI-agents communicate as to create a distributed map of the crisis** as soon as they collect enough usable information. AmI-agents collect data thanks to their captors or their interactions with users and other agents. These data contain information about the state of the building, the state of the user and their localisation within the building. Using these data, agents can cooperatively build a map of the crisis, with a coordination supported by some specific agents with enough computing and communication capacities.
4. A group of user requests **the AmICriM service displaying the shortest path to the exit**. Since the organisation of the victims is specified within the agents, they can act as groups of agents representing groups of humans. E.g. a fire warden and the people he is responsible for form a group. Their AmI-agents know that and can optimise information not to be redundant: the optimal path is calculated once by the AmID having the highest computing capacities, thanks to the current map that AmICriM system has already built (according to user's state, building's state, the size of the group, etc.), in a coordinated way, by communicating with other agents as to avoid panic effect.
5. **Some victims reach the exit**. Others are blocked due to fire or injuries, etc. AmI-agents of people reaching the exit can now inform AmI-agents of people still in the building of the safety of the path they followed. They can also upload all the data to dedicated AmI-agents with higher computing capacities that can begin to record all the crisis in order to replay it if necessary, when rescue forces arrive.

4.3. Phase 3: What happens when the rescue forces arrive and deploy their resources?

1. **Firemen deploy their own AmIDs** that are integrated by the AmICriM system of the building. Their AmICriM services are now available to other permitted users and they can access already computed data available in the AmICriM system, such maps, lists of victims, etc. Firemen's AmICriM services are now enriched by the existing services, which produce emergent functionalities. E.g. firemen's rescue procedures are combined to the local rescue procedures enacted by victims, and adapted to the local configuration (several fire spots, only one exit, etc.). Their AmIDs are available for hosting victims' AmI-agents as to adapt the crisis management embodiment, if the building network is too damaged, for instance. Conversely, AmIDs of the building can be used by firemen to get up-to-date information or to use more efficient computing or networking capacities.
2. **A fire commander requests a service on his PDA to map the zone** as to know as precisely as possible the situation (number of victims, number of secured victims, degree of injuries, etc.). Unfortunately, his PDA capacities are not sufficient to compute all the data. His PDA AmI-agent then tries to contact other devices in its neighbourhood (BlueTooth of Wifi) and forward this request. Each contacted AmI-agent will autonomously decide how it can answer the best depending on its capacities (of perception, decision and action) and to whom to forward it in turn given the limitations of its situation. Information will then start to return to the initial AmI-agent as a distributed operational view construction process is taking place by cooperation between ambient devices. Since capacities of the fireman's AmID are not sufficient, it only receives already compiled data coming from a more powerful device.

The Phase 2 and Phase 3 are illustrated in the following figure.

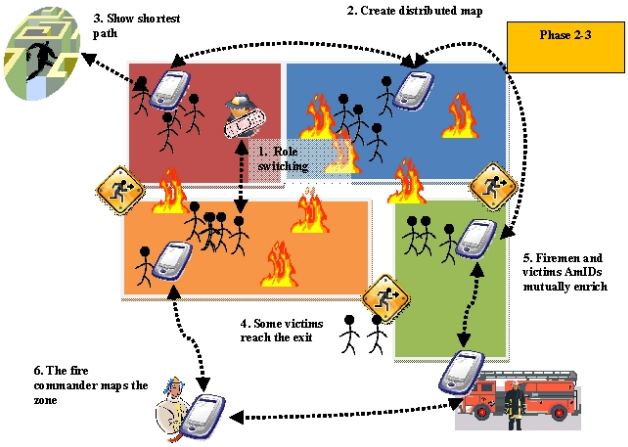

Figure 3. AmICriM in action: Phase 2 and Phase 3.

4.4. Phase 4: The rescue forces are in action

1. **The firemen tasks forces start to deploy** and are aware of the number of victims and the state of the building. They now begin to execute their classical procedures with more knowledge than usually thanks to AmICriM system. The fire commander also informs victims of their presence as to minimise panic effect and to coordinate firemen and victims' actions. Even if firemen are not all equipped with AmID, the fire commander can visualise the overwhole situation thanks to his PDA. He receives information from other AmID (Wifi or Bluetooth) and firemen (radio or GSM). He also can adapt the procedure to target top-priority victims by using the victim listing service. He also can contact specific people skilled for intervention on particular victims (blocked, seriously injured, etc.).
2. **Firemen can reroute victims still in the building** that are moving to a dangerous area. The fire commander is aware of this fact by following the crisis on his PDA. The progression of the victims is known thanks to AmID still functioning in the building or information coming directly from victims. He can inform the victims indirectly (via AmI-agents) or directly (using phone numbers shared by AmI-agents) to change their procedure as to be coordinated with firemen.
3. A **medical staff member discovers from some AmI-agents that someone is injured and blocked**. This victim has previously communicated with other agents, but does not have anymore power supply. AmICriM helps the doctor to adapt his procedure and equipment as a consequence. The victim's AmI-agent is no more executing, but other AmI-agents remember its presence and know, thanks to the middleware, that this agent is no more connected and therefore can help rescue teams to find him and to contact him. If necessary and possible, the medical staff can also directly phone to the victim thank to the number they get from other AmI-agents, as to evaluate more precisely his situation.

4.5. Phase 5: End of the crisis situation

1. **An external doctor in the zone is identified rapidly** (his PDA is authorised to diffuse its owner's profile in certain situations) and guided to the nearest victim or one needing urgent treatment (distributed cooperative evaluation of priorities concerning the victims), once evacuated from the building. Requests can also originate from people in the zone, in danger, unable to move or limited in their access to information. Victims has also access to new services from the rescue teams, such listing doctors in the vicinity. The community of AmID tries to satisfy to its best the needs of the users (graceful degradation). Information about the victim state, only transits via authorised AmI-agents.
2. The fire commander can compile all the data from the AmID to **replay the crisis** as to enhance the procedure or identify flaws in the building.

The Phase 4 and Phase 5 are finally illustrated in the following figure.

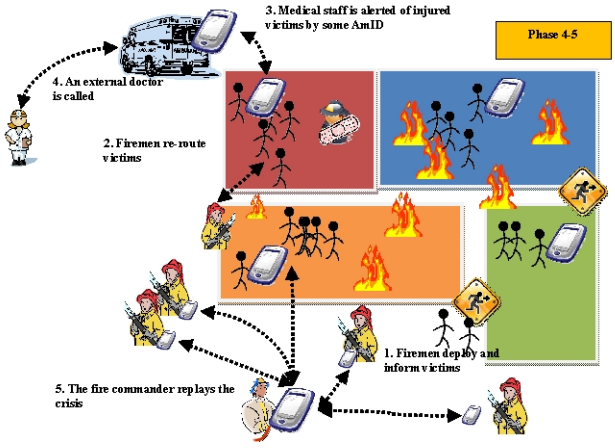

Figure 4. AmICriM in action: Phase 4 and Phase 5.

5. Conclusions

We have described the objectives of the AmICriM system actually under development and its suitability for developing a pervasively embodied application for crisis management. The networking and behavioural aspects of the embodied devices are constantly adapted as the crisis evolves: embodied devices dysfunctions, communication breakdown, new device arrival, etc. Moreover, the embodied functionalities can evolve too, since the system can host newcomers and their skills/procedures (e.g. firemen arriving on the ground). From a global point of view, it can be considered as an intelligent decision-making and decentralised coordination entity

Finally we argue that the AmICriM system can provide information on demand, but also propose proactively computed data: presence of newcomers, localisation of new victims and a pre-ordered victim list (as to optimise the response) as one valuable application of body area sensor networks for assisting rescue tasks forces in crisis situations.

6. References

[1] M. Portmann, A. A. Pirzada, "Wireless Mesh Networks for Public Safety and Crisis Management Applications," IEEE Internet Computing, vol. 12, no. 1, pp. 18-25, January/February, 2008.

[2] A. Tate. The "Helpful Environment": Geographically Dispersed Intelligent Agents That Collaborate, Vol. 21, No. 3, IEEE Intelligent System, May/June 2006.

[3] P. Costa, G. Coulson, C. Mascolo, L. Motolla, G. P. Picco and S. Zachariadis. A Reconfigurable Component-Based Middleware for Networked Embedded Systems, International Journal of Wireless Information Networks, Springer, 2006.

[4] A. May, V. Mitchell, J. Piper, L. Hannah, S. Hailes, and K. Koumpis. Opportunities and Challenges for Configurable Sensor Networks for Enabling Effective Fire-in-Tunnel Response, Proc. 14th Annual Conference Disaster Recovery and Relief: Current & Future Approaches (TIEMS 2007), 2007.

[5] T. Catarci, M. Leoni, A. Marrella, M. Mecella, B. Salvatore, G. Vetere, S. Dustdar, L. Juszczyk, A. Manzoor, HL. Truong, "Pervasive Software Environments for Supporting Disaster Responses," Internet Computing, IEEE, vol.12, no.1, pp.26-37, Jan.-Feb. 2008.

[6] Suchman, L. A. (1987). Plans and Situated Actions: The problem of human machine communication, Cambridge University Press.

[7] M. Maris and G. Pavlin. Distributed Perception Networks for Crisis Management. In Proceedings of the Third International Conference on Information Systems for Crisis Response and Management (ISCRAM 2006), New Jersey, USA, May 2006.

[8] Thompson, P.A., Wu., J., and Marchant E.W. "Modelling Evacuation in Multi-storey Buildings with Simulex." Fire Engineers Journal, Vol. 56, no. 185, pp. 6-11, 1996.

[9] J.-P. Georgé, M.-P. Gleizes, Experiments in Emergent Programming Using Self-organizing Multi-Agent Systems, In Multi-Agent Systems and Applications IV (CEEMAS'05), Springer, LNAI 3690, pp. 450-459, 2005.

[10] P. Giorgini, F. Massacci, J. Mylopoulos and N. Zannone. Requirements Engineering for Trust Management: Model, Methodology, and Reasoning. *The International Journal of Information Security*, 5(4):257-274, 2006.

[11] A. Agrawal, M. Amend, M. Das, M. Ford, C. Keller, M. Kloppmann, D. König, F. Leymann, R. Müller, G. Pfau, K. Plösser, R. Rangaswamy, A. Rickayzen, M. Rowley, P. Schmidt, I. Trickovic, A. Yiu, M. Zeller. Web Services Human Task (WS-HumanTask), Version 1.0, 2007.