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ORIGINAL RESEARCH

Ambient intelligence and collaborative e-learning: a new definition model

Óscar García · Dante I. Tapia · Ricardo S. Alonso · Sara Rodríguez · Juan M. Corchado

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Abstract The constant evolution of mobile devices and Information Technologies allows users to enjoy a new variety of features that were unimaginable some years ago. In this sense, Ambient Intelligence (AmI) has emerged as a new discipline focused on people and aimed at facilitating their daily activities. This paper proposes a new definition model that helps designers to characterize collaborative e-learning systems based on AmI and Computer Supported Collaborative Learning. The use of mobile devices and Mobile Adhoc Networks is a key aspect in this model as they allow users to access resources from anywhere on demand. The proposed model is applied to a concrete case of study as an example of its application on real scenarios.

Keywords Ambient intelligence · e-learning · Computed supported collaborative learning · Mobile adhoc networks

Ó. García (✉)
School of Telecommunications, University of Valladolid,
Paseo de Belén 15, 47011 Valladolid, Spain
e-mail: oscgar@tel.uva.es

D. I. Tapia · R. S. Alonso · S. Rodríguez · J. M. Corchado
Department of Computer Science and Automation,
University of Salamanca, Plaza de la Merced, s/n,
37008 Salamanca, Spain
e-mail: dantetapia@usal.es

R. S. Alonso
e-mail: ralorin@usal.es

S. Rodríguez
e-mail: srg@usal.es

J. M. Corchado
e-mail: corchado@usal.es

1 Introduction

Currently, there is a wide range of mobile devices capable of communicating among them. These devices include mobile phones, laptops, PDAs and, more recently, smartphones and tablet PCs, among many others. During the last years the use of these mobile devices in learning environments is becoming increasingly widespread (Roschelle 2003; Anderson and Blackwood 2004). So much so that there is a new generation of people known as *digital natives* (Bennett et al. 2008). Digital natives are accustomed to using a wide range of information technologies and electronic devices, most of them fully connected to the Internet. Indeed, they are usually advanced users of the Internet and web applications, being these technologies an important pillar for their daily lives. Therefore, new research paradigms such as *Ambient Intelligence* (AmI) are being encouraged by these factors, thus rising quickly (Shadbolt 2003).

Ambient Intelligence proposes a new way to apply the technology in order to facilitate the execution of everyday tasks with variable complexity. In this sense, AmI proposes a new way of relationship between people and technology, where the use of this becomes ubiquitous, transparent for users and adaptive to the context surrounding them. This way, AmI is based on concepts such as ubiquitous computing, ubiquitous communication, context awareness, as well as the establishment of natural and non-intrusive human-system interactions (Cook et al. 2009). There is a wide range of scopes where such concepts can be applied: medicine, daily life, healthcare, security, industry or, which concerns us, education (Ducatel et al. 2001; Bohn et al. 2005; Tapia et al. 2010). Education is one of the areas that can be most improved by means of the application of AmI. Ambient Intelligence can increase and make better the learning methods and the way people learn and teach. New technologies, communication networks and intelligent devices open a new era of scenarios where students can learn through different, innovative and more efficient ways (Kinshuk et al. 2003).

Computer Supported Collaborative Learning (CSCL) (Economides 2008) is an interesting approach where participants (i.e., students and teachers) perform collaborative learning activities that require the interaction among them through computers and other devices. The development of CSCL-based applications takes into account aspects of the design of systems based on Computer Supported Collaborative Work (CSCW), such as mobility of participants, as well as both content display and interfaces problems in common working areas (e.g., coordination of both context visualization and text edition in a document that is being modified by two participants at the same time) (Trifonova and Ronchetti 2006). However, the design and development stages of systems based on AmI and CSCL are not easy, mainly because it is necessary to adapt them to their specific educational and social needs (Dimitriadis et al. 2004).

The definition model proposed in this paper is based on two of the cornerstones of the AmI paradigm: *ubiquitous computing and communication* and *context information*. Both of them can be covered through the use of Mobile Adhoc Networks (MANETs). A MANET is a network of wireless mobile nodes that organize themselves dynamically using temporary arbitrary topologies (Ylias and Dorf 2003). By means of MANETs, people and mobile objects can thus communicate among them without the existence of a previous infrastructure or when the utilization of such an infrastructure requires a wireless extension to be used on demand (Ylias and Dorf 2003). MANETs offer the capability to apply the use of mobile devices in the field of education so that students can freely move along with their devices. This new topic is called *MCSCL* (Mobile CSCL), which focuses on the use of mobile devices and wireless communication protocols to encourage collaborative learning situations that improve the whole learning process (Zurita and Nussbaum 2004).

This paper is aimed at presenting a model for defining some of the most important requirements needed to implement AmI-based scenarios where collaborative learning is possible. The main goal is ensuring that there will be connectivity between users anywhere and anytime. This must also include the capability to detect the proximity of potential partners to create working groups, registering any kind of interaction that has been carried out. This paper also presents an example scenario based on this model where users have full mobility and complete freedom of connection between them to exchange information transparently. All these features are performed under the supervision of teachers, in order to encourage collaboration and control the participation of all the students in the activities.

This paper is structured as follows. Next section justifies the creation of a new definition model that helps designers to characterize collaborative e-learning systems based on AmI and CSCL. After that, Sect. 3 describes the proposed model taking a set of conceptual and technical requirements as a starting point. Section 4 introduces a scenario where this model has been deployed. Finally, Sect. 5 presents the conclusions obtained and depicts the future lines of work to be followed.

2 Ambient intelligence and CSCL

The creation of e-learning systems and applications not only requires the participation of technical staff working together to design, implement and test them, but also needs the collaboration of educational experts. The educational component must be present especially in the design process, because teachers and students will be the final users and these systems and applications must be adapted to their specific social and educational needs (Echeverría et al. 2006).

Ambient Intelligence environments allow users to communicate in a ubiquitous way. Education, and more specifically CSCL, can benefit from the features provided by ubiquitous communication. Such features allow participants in CSCL activities to avoid the need to explicitly connect to a platform to share information among them. In order to facilitate CSCL, the approach presented in this paper proposes the use of mobile devices that provide enhanced ways of communication. Thus, students can learn together anywhere and anytime. To do this, they just have to utilize some mobile devices that allow them to connect to other users' devices in order to share information. Latest trends in mobile technology include devices that provide users with a wide range of communication capabilities, such as GSM/GPRS/EDGE, UMTS, HSPA, Wi-Fi, Bluetooth, Infrared, GPS or even ZigBee in a single device. These communication capabilities are especially useful in the field of education as they allow the creation of communication networks with ubiquitous features. Furthermore, the identification and localization of each user is made possible by means of the collection of context information through the sensors provided by mobile devices. In addition, there are different operating systems and platforms (e.g., Android, Windows Phone, Symbian or iOS) that allow developing and running user-friendly applications with a very interesting potential. As a result, there is an opportunity to develop intuitive interfaces and systems to facilitate the activities of individuals and the whole learning process in a transparent way (Trifonova and Ronchetti 2006). In this sense, Ambient Intelligence can help to enhance the learning process (Trifonova and Ronchetti 2006) by providing ubiquitous communication and context-awareness features that encourage learning and collaboration among users (i.e., students and teachers).

One of the most important aspects that must be covered by systems and platforms based on AmI and CSCL is that they should allow the creation of *working groups* (Koschmann 1996). These working groups can be either public or private. Therefore, each user can acquire different roles in order to interact with the rest of participants to perform distinct tasks. In addition, it is allowed the communication among participants anywhere and anytime by means of heterogeneous devices (Hummel et al. 2002). Therefore, participants can create collaborative tasks and exchange information. This way, students and teachers can generate guided discussions and share information of their interest. Furthermore, teachers can supervise the work in progress as well as the degree of satisfaction of the students when using a traditional e-learning platform through mobile devices (Andronico et al. 2004).

However, learning models that require a previous network infrastructure are difficult to use outside academic buildings and present important adaptation problems regarding the type of device (e.g., display or connectivity). More importantly, such models depend on a central element that provides the content to be accessed by students (Vasiliou and Economides 2008; Kinshuk et al. 2003), which hinders the distribution of computing and communication. Even worse, it is very difficult to collect context information with them (Andronico et al. 2004) and therefore it reduces the adaptability of the systems to the users. Thus, the lack of these features makes these kinds of solutions not be labeled as AmI-based approaches (Weiser 1999).

New ways to embed learning applications into mobile devices arise when trying to solve these shortcomings. One solution is to adapt the content of traditional e-learning to the especial characteristics of mobile devices (Kurbel and Hilker 2002). How to provide the information to students, how to determine which devices will be used and how the connection between them will be performed become the most important challenges to be addressed in the design stage.

3 Mobile adhoc networks and CSCL

The creation of collaborative networks in any place without a previous infrastructure, commonly known as *adhoc networking*, makes it easier the informal learning processes supported by mobile devices (Sharples et al. 2007). Even though all these features offer new possibilities, they present new problems that must be solved. Some of these problems are related to the heterogeneity of the devices. That is, most of the mobile devices have different displaying, networking and operating system capabilities (Kurbel and Hilker 2002). MCSCL proposes solutions to most of these challenges. There are many related works in this research area. Some research approaches are focused on the study of the educational characteristics of the new scenarios (Roschelle 2003). Other works approach the problem studying the technological requirements and proposing new architectures (Trifonova and Ronchetti 2006). It is easy to assume that the capability to interconnect different heterogeneous devices will be very useful to encourage the collaboration between students during the learning process and make it easier to develop tools that support MCSCL (Ellis et al. 1991). It can be made a rough classification of these developments by distributing them into three main groups: *m-learning collaborative solutions*, *MCSCL specific applications* and those that use *adhoc networking environments in MCSCL*. At this point it can be found two different trends. The first one seeks the integration of e-learning tools as traditional Web Services (Trifonova and Ronchetti 2004). Systems belonging to this trend have three basic functionalities for enhancing the operational and visual capacities of the devices: *Context Discovery*, Mobile Content Management and Adaptation (MCMA) and *Packaging and Synchronization* (Trifonova and Ronchetti 2006). The second trend tries to completely redesign digital courses so that they can be executed on mobile devices. In this tendency, it is usually prioritized the information that students should watch. Moreover, it is focused on developing tools intended for solving open problems, generating knowledge and encouraging the discussion of ideas (Kinshuk et al. 2003). This way, it is allowed the dynamic configuration of individual working groups, encouraging the collaboration between participants and providing the teacher with visual supervision capabilities. In addition to the adaptation of traditional e-learning platforms, there are applications specifically developed to support the CSCL using mobile devices. Such applications are considered as *real* MCSCL applications (Cortez et al. 2004) and provides an easier way to improve ubiquitous collaboration. There are approaches in which mobile devices are used to explicitly obtain a CSCL environment (Dvorak and Burchanan 2002; Kinshuk et al. 2003; Milrad et al. 2002; Zurita and Nussbaum 2004). However, these solutions do not meet the specifications of AmI since they are generally designed so that all participants use the same type of mobile device. Moreover, their architectures require a central element that provides the content and all devices must share the same communication protocol. Furthermore, these proposals are not able to create networks spontaneously, thus hindering ubiquitous communications, an indispensable aspect in Ambient Intelligence.

MANETs present a great advantage because they can cover groups of different sizes, to form different network topologies, as well as to use different communication protocols. Some requirements necessary to create a mobile adhoc learning application are socio-cultural, economic, technological (e.g., user interface, functionality, awareness, adaptation, reliability and maintainability, efficiency, connectivity) and others related to security (Economides 2008). These requirements must be taken into account when designing learning applications, even more when networks requirements are so specific. Several developments that enable the creation of adhoc networks in collaborative learning environments support the use of different communication protocols and the share of resources (Fuller et al. 2004). However, the need of both a previous network infrastructure and the configuration of the applications, as well as the limited number of participating nodes, limit the capacities of these kinds of developments. Moreover, there is also the challenge of working outside the classroom to enhance collaborative learning in museums, parks or other places with didactic interest (Vasiliou and Economides 2007). Besides the challenge of achieving peer communication without a previous infrastructure, as these kinds of activities require, it is difficult to avoid the client–server model that implements centralized network schemes (Zurita and Nussbaum 2006).

The creation of a MANET is very different in each development. In fact, the easiest way to create a network is to have a previous infrastructure, by means of either a wireless LAN deployed for this purpose, mobile nodes intended for providing the resources (Vasiliou and Economides 2007), or using nodes that create the network and register other nodes that are part of it (Zurita and Nussbaum 2006). The communication among devices is a key aspect in these kinds of networks (Vasiliou and Economides 2007). In order to solve network formation issues, it is usual to use *master* nodes, that is, network devices responsible for making up the MANET and allowing other nodes to access to it (Zurita and Nussbaum 2006). In such cases it is followed a client–server model in which the server is also used for providing with contents and services to the rest of the nodes. It is important to mention that the nodes not always have total freedom to move throughout the network. So, the mobility of the nodes and the way the teacher supervises the work must be specially taken into account. If a previous network infrastructure is needed, the nodes must be under the coverage of the network, whether formed by mobile (Vasiliou and Economides 2007) or fixed nodes (Fuller et al. 2004).

The most interesting cases for the scenario presented in this paper are those in which there is a mobile node acting as master. This way, teachers have at their disposal a terminal acting in this way and allowing them to supervise the established connections, who have registered in the network and even each of the interactions and the utilization of resources or applications made by each node (Vasiliou and Economides 2007; Zurita and Nussbaum 2006).

4 Conceptual and technical description

As depicted in the previous section, there are multiple factors that characterize the use of Ambient Intelligence, CSCL and MANETs in e-learning environments. Figure 1 shows the research areas used in our work to achieve a model based on AmI and CSCL using MANETs. In this figure, it can be appreciated how the two most important concepts covered in this paper (AmI and CSCL) converge in the use of a specific kind of wireless network as supporting infrastructure. This network consists of a set of mobile devices that can communicate among them without the need of a preplanned infrastructure.

5 Conceptual design

The conceptual design of the model is defined by answering the following six questions in order to delimit the problem:

1. *Where is the learning?* It is usual to find two kinds of learning: *formal* (inside the classroom) or *informal* (outdoors). The most common situation is the first one, while situations relative to informal learning usually represent sporadic lessons organized out of the

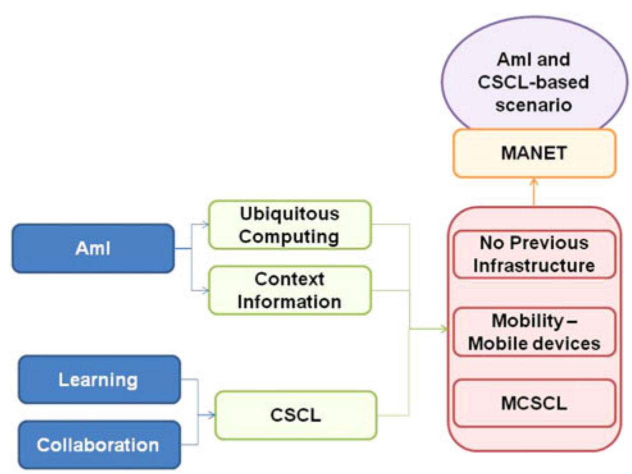

Fig. 1 Research areas addressed to use MANETs as the supporting infrastructure of an AmI and CSCL-based model

classroom (Vasiliou and Economides 2007). The latter one includes a remote access to the application, as in the adaptation of e-learning platforms, or learning examples in museums and through tourist travels (Simarro et al. 2005).

2. *Where are the actors?* Many applications that use MANETs are designed to be intended for face-to-face situations. However, there are very few approaches that handle remote learning. These support the classroom and usually the home of the participants. Thus, combined learning is not easy to find in the literature. This kind of learning is the most appropriate for the proposed scenario because it is very interesting to encourage spontaneous collaboration anywhere (e.g., classroom, home, park, etc.) (Fuller et al. 2004).
3. *Which are the most usual interactions between participants?* In the proposed model, both *student–student* and *student–teacher* interactions are considered. The most interesting scenario is that where both of these kinds of interactions are considered. Therefore, collaboration between students is encouraged, and teachers can provide support in real-time and know the status of interactions and communications in a specific workgroup.
4. *What kind of architecture is adopted?* This question is of vital importance in MANETs. On the one hand, a pure MANET should not depend on a central node that provides the connection. On the other hand, a peer-to-peer infrastructure cannot create an adequate interaction among all the participants (Zurita and Nussbaum 2006). For these reasons, those cases that describe hybrid architectures are the most useful for our purpose (Echeverría et al. 2006). These architectures include control nodes that manage communication and information exchange among the rest of the nodes. These control nodes are usually called *superpeers* (Schmidt 2005).
5. *Is some previous infrastructure used?* In order to deploy a pure MANET, there must not be a previous infrastructure (Zurita and Nussbaum 2006).
6. *What communication technologies are used?* The communication technologies utilized are often associated with the used devices. For example, mobile phones are associated with GSM, GPRS, SMS, or Bluetooth communications, while PDAs and laptops are usually related to Bluetooth and Wi-Fi protocols.

6 Model description

The purpose of this work focuses on exposing a model based on AmI and CSCL where collaboration among students is conducted through unplanned adhoc networks. The use of these new media, devices, technologies and the combination of all of them allow us to build learning communities anywhere and anytime, modifying the classic educational paradigm to accommodate into it the ubiquitous learning (Cope and Kalantzis 2009).

The model is used as a basis to describe a learning scenario where collaboration between students is improved through collaborative activities that take place both inside and outside the classroom. Therefore, each participant (i.e., student or teacher) will be able to create a network which provides resources, activities or a communication channel. These features encourage collaboration among participants and allow them to collect information, everywhere and every time. In addition, it is achieved a ubiquitous communication scenario in a natural way where none of these enumerated features has to be planned.

The main objectives set for this model are:

- There must be a deep collaboration between actors. Such collaboration is set both in formal and informal environments. Learning will not be restricted to the classroom or the activities proposed by the teacher, but informal learning must be also present. In this way, learning can occur in other places inside or out of the faculty when two students with the same subject meet.
- Teachers must know the status of the activities. Support will be given to teachers to control the activities they offer. In this way, they will be able to know and manage the formation of the groups, as well as the activity raised to each of them.
- Teachers must know the existing interactions. It is useful from the teachers' point of view to know the interactions between different students, either in the classroom or in the rest of the coverage area. This should take into account how the networks formed without the supervision of the teacher store information about their status.
- Moreover, any student should be free to collaborate with any other. However, teachers will be able to not allow a specific interaction if they do not consider it appropriate.
- Information must be able to be shared, both text (document files) and multimedia (audio, video), collected from anywhere where the activity could be carried on.

The achievement of these characteristics implies the need of an actor that offers the resources shared throughout the created network. It is proposed a peer-to-peer communication model where users are free to communicate and share data between them. Nevertheless, the communication, the access to resources or the exchange of data must be organized, controlled and registered. This way, there will be a master role that will allow a node to act as the master device, *superpeer* or *supernode* if it is able to collect information from the other nodes. Adhoc communication protocols will be adapted to the applications in order to improve neighbor discovering, connection establishment and heterogeneous devices interconnection. In this field, *superpeers* functioning will be designed and developed to reach a pure MANET infrastructure in the applications.

7 Technical requirements

After the conceptual definition of the model, it is important to describe the range of technologies that could help to achieve its design goals. In fact, the model allows using any protocol that provides communication among different devices (e.g., Bluetooth and Wi-Fi). A general description of the functioning of this is the following. No matter where users (i.e., students) are, each one of them will be able to detect others who are near to him/her (for example, in the coverage area of a Wi-Fi network) in order to exchange information. Students interested in establishing a partnership creates a network that peers can freely join.

The student who performs the formation of the network is who acts as *supernode*, recording all the time what happens in the collaborative network that he or she has created. That is, which users was involved, what information was exchanged, when the partnership was dissolved, etc. In addition, the other students keep replicas of this information for security and consistency reasons.

From these ideas, it is possible to define the technological requirements of this model as follows:

- In order to make learning performed in both a formal and an informal way, mobile devices must be used. In this case users carry tablet PCs or laptops to communicate through Wi-Fi and Bluetooth wireless interfaces.
- Collaboration and informal learning will be supported through the formation of MANETs. These networks are created through Bluetooth interfaces. Furthermore, the communication among the distinct MANETs as well as the access from them to the Internet are performed by means of Wi-Fi networks.
- In order to achieve an unrestricted informal learning it must be used a non-centralized architecture. This way, there can be a full independence from a previous network infrastructure because of the communication is peer-to-peer. Each node is capable of offering itself to create a new collaboration network through Bluetooth.
- It will be used master nodes or *superpeers* in order to provide the teachers with detailed information about the activities or interactions that have occurred in the created networks. *Supernodes* must be capable of collecting what has been happening in all networks into which they have been involved. The node that offers a new network will act as a *superpeer*. Voluntary students and teachers will act as *supernodes*.
- Software components will be installed in each device in order to be able to work in *disconnected mode* (i.e., without Internet connection). There will be two software versions. On the one hand, there will be a *light* version to be used by all the students. This version will offer all the functionalities that students will need to collaborate with each other. On the other hand, a specific software version will be developed for *Supernodes*. This will include specific functionalities to collect collaborative information and register any event.

In order to illustrate the previous statements, an example scenario is presented in the next section.

8 Example scenario

After describing the definition model, this section presents an application scenario, as an example of how this model can be applied. This scenario is focused on a university scope. Nowadays, much of the students of a faculty have mobile devices, especially laptops, PDAs or mobile phones. This fact presents an opportunity to utilize these devices in the e-learning process (Zurita and Nussbaum 2006).

To better understand the proposed model it is presented an explicit application scenario. Let's imagine a collaborative activity in the Urbanism subject at the Faculty of Architecture. The development of a partial urban plan involves an action on a specific city area without forgetting the status and the contents on the rest of the city areas, both neighboring and distant ones. There are items such as green areas, public spaces or buildings, rail or public transport infrastructures, etc. that affect equally all areas.

From the student side, the description and goals of the activities are as follows. The class is divided into several groups of students, the same number as the zoning of the city. Each group analyzes its area in depth collecting all the necessary town-planning information (topology, constructions, infrastructures, railways, public areas, private areas, etc.), storing it into data files, photos or videos. Each participant can create MANETs with peers to share information; exchange messages to organize the tasks; raise questions; complete, in a collaborative way, a concept map to reflect the organization of the area and its needs; or any other collaborative activity that may be raised. Furthermore, since the raised intervention will be the same for the whole city, it should be taken into account the information from the others. Therefore, it is necessary the collaboration with colleagues from other areas. Students can also gather information in public places (city council, land registry) which can then be spread by all participants. Furthermore, teachers can launch activities (i.e., create a new MANET) or interfere in other MANETs to observe the work status and guide students in their interactions. Similarly, the teacher can solve the questions raised by the students. It is interesting to set some partial milestones as well as a final one. This way, the teacher can collect results, assess the learning process and pick up the interactions to act accordingly (reconfiguring groups, modifying the activity, making a general explanation, etc.).

Figure 2 shows the first phase of the activity schema: there is an imaginary city divided into zones where different groups are working and whose participants will form *intra-group* (clouds) and *extra-group* (connections) MANETs. The figure shows intra-group into different clouds; while the arrows mean that each member can move from a zone to other one and form a new adhoc network with any of the participants from other groups. The teacher can move freely through all of them observing and collecting data. In this way, the scenario presents informal learning and students are capable of making collaboration achieve the goals in an easier and more effective manner. This case presents certain similarities with solutions for activities in museums (Simarro et al. 2005) or with activities raised for outdoor learning (Vasiliou and Economides 2007). However, this scenario raises an unplanned network type, in which students' collaboration is totally free, with possibility of intra and extra-groups communication. Moreover, it is not only considered the student–student interaction and the data collection by teachers (Zurita and Nussbaum 2006) or the teacher-student interaction to solve doubts or launch the activity and configure groups (Cortez et al. 2004). In addition, the teacher is involved in the whole process, being able to be part of any of the networks, solving doubts and, what we consider the most important, collecting information about occurred interactions and partial results to help him to reconfigure the activity if necessary.

Figure 3 represents the second phase of the activity. Students can share their information in class with other group members and reach through collaboration the objective planned by the teachers. Likewise, teachers can gather the information from each network freely formed and change the activity in order to better organize it to encourage the expected results.

The communication between devices is another aspect of this scenario. These are unplanned MANETs with communication between peer-to-peer participants, in which there are control nodes or *superpeers* to help them to train, organize and collect data. Previous works take into account existing infrastructures to form these networks (Zurita and Nussbaum 2004), while others utilize networks without infrastructure (Zurita and Nussbaum 2006). Nevertheless, they do not take into account either the interactions between participants or the role played by the teacher. In the presented scenario the collection of information is considered as one of the most important parts, so the teachers can know what is happening and take decisions dynamically, improving the learning process.

Nevertheless, the scenario that has been described is not the only one that can be covered by the model developed. There are many educational activities, related to collaborative learning that can take place and be enhanced by such a model. In this sense, the model can be applied to scenarios that include unplanned brainstorming activities or jigsaw activities (i.e., teaching technique where students are divided into groups with different competencies to share and explain new knowledge between them).

9 Conclusions and future work

Ambient Intelligence intends to build intelligent environments by combining the use of ubiquitous computing with technologies such as embedded and context-aware devices that adapt to the users' needs and preferences. In this sense, e-learning is an interesting area where AmI can be applied to improve the relationships between teachers and students and enrich the ways people teach and learn. Mobile Adhoc Networks can be used to add mobility to Computer Supported Collaborative Learning environments to include ubiquitous computing and context-aware capabilities, fitting the requirements that AmI demands. Existing approaches try to address these requirements, but the heterogeneity of devices is usually a problem to meet real models based on AmI and CSCL. Besides, the solutions described in the reviewed literature are aimed at solving specific problems. This implies that the generalization of these solutions is a difficult task so they cannot be applied to other educational activities or scenarios. In addition, these approaches are not able to create networks spontaneously, thus they do not provide real ubiquitous communication. Thus, they do not cover the key aspects of Ambient Intelligence. Furthermore, students, teachers and other education personnel should participate with developers when designing e-learning software, such as MCSCL applications and platforms. That is, developers should take into account all users' requirements in the design process. That is, users must be the most important part of such process.

In this regard, this paper defines some of the most important requirements to build a model based on AmI and CSCL using MANETs to meet the problems described above. Therefore, this paper proposes a model where students can collaborate anywhere and anytime, creating

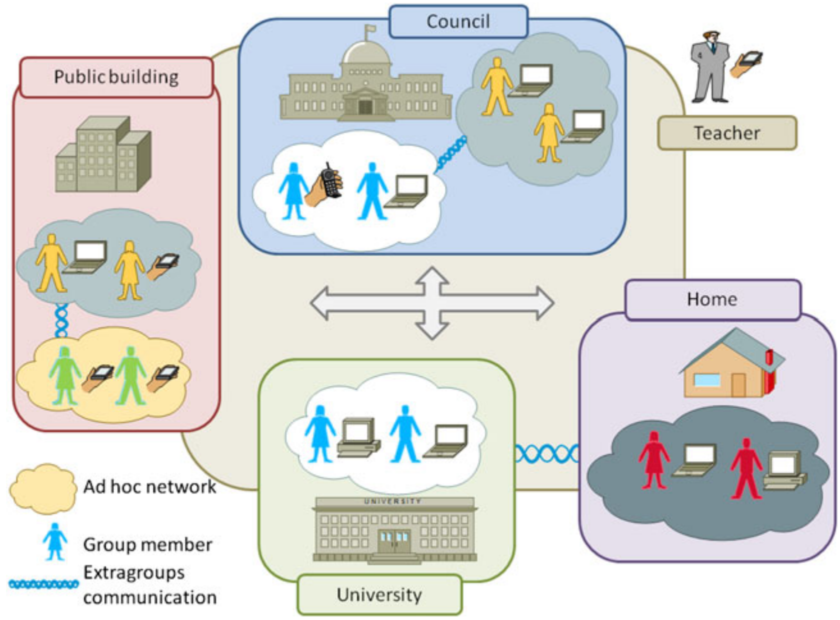

Fig. 2 Example of collaborative learning activity using MANETs outdoors. First phase of full activity

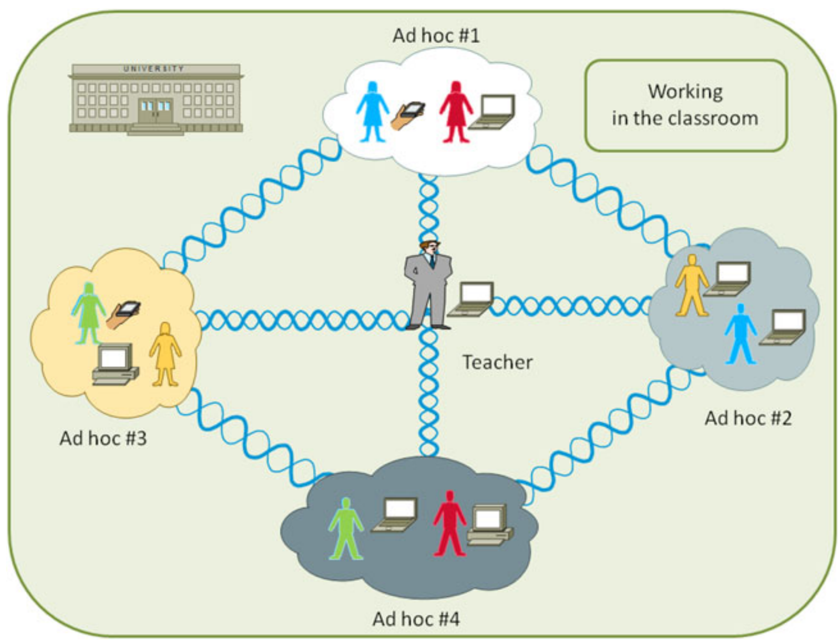

Fig. 3 Example of collaborative learning activity using MANETs in a classroom. Second phase of full activity

mobile adhoc networks to perform learning tasks and allowing teachers to monitor these tasks to guide and supervise the learning process. For this reason, this paper focuses on the conceptual description of the model without delving into technical aspects related thereto. The ultimate goal is that the model meets the expectations of an AmI educational scenario that serves as the basis for multiple and different tasks. Unlike other approaches, this model allows students to have total freedom to communicate between them anywhere and anytime. In this way, this work defines a general model that can be used in different educational scenarios and not only for a particular task or activity. In order to supplement and clarify the proposed model, a real example scenario is described. In this scenario, collaborative learning occurs naturally, in the same way than teachers' supervision, at any place where participants develop their work. The place where users perform learning tasks, the existence of a previous infrastructure and which wireless technologies are used for the learning activities are taken into account to propose the example scenario.

The first step in future work will be to improve the model and adapt and formalize it through the use of formal software engineering tools. Future work also includes the design and implementation in a real scenario of an architecture that gives support to the development of CSCL applications that meets the AmI requirements defined in this work. The real necessities of teachers and students will be taken into account during the design and development stages in order to implement fully functional e-learning applications. Furthermore, both the requirements of Ambient Intelligence and the necessities and most common learning situations where teachers and students are usually involved will be considered in order to choose the most adequate wireless technologies to address their necessities.

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