Vasiliou, A. & Economides A.A. Mobile collaborative learning using multicast MANETs", *International Journal of Mobile Communications,* Vol. 5, No. 4, pp. 423-444, 2007

Mobile collaborative learning using multicast MANETs

Alexandros Vasiliou
and Anastasios A. Economides*

Information Systems Department,
University of Macedonia,
P.O. Box 1591, Egnatia 156, 54006 Thessaloniki, Greece
E-mail: avasil@uom.gr E-mail: economid@uom.gr
*Corresponding author

Abstract: Collaborative learning outside the classroom is vital for many educational disciplines. Three educational scenarios held outdoors are analysed. In the first scenario, students investigate the ancient architecture, archaeological artefacts and historical location at an archaeological site. In the second scenario, students investigate the environmental and natural resource management, endangered species and flora at a national forest. The third scenario describes collaborative game-based learning at outdoors. Multicast Mobile Ad Hoc Networks (MANETs) are employed to support students' communication and collaboration. Simulation results show the feasibility of multicast MANETs to support students' communication and collaboration during these three outdoor educational scenarios.

Keywords: collaborative education; collaborative learning; game-based learning; MANET; mobile learning; mobile networks; multicasting; outdoor learning.

Reference to this paper should be made as follows: Vasiliou, A. and Economides, A.A. (2007) 'Mobile collaborative learning using multicast MANETs', *Int. J. Mobile Communications*, Vol. 5, No. 4, pp.423–444.

Biographical notes: Alexandros Vasiliou received his Diploma Degree in Electronic Engineering from the Technological Educational Institute of Thessaloniki in 2002, and his MSc degree in Information Systems from the University of Macedonia, Thessaloniki, in 2004. His research interests are in the areas of mobile networks and tele-education.

Prof Anastasios A. Economides received the Diploma degree in Electrical Engineering from Aristotle University of Thessaloniki in 1984, and the MSc degree and PhD in Computer Engineering from the University of Southern California, Los Angeles, in 1987 and 1990, respectively. His research interests in the areas of mobile learning and networks.

1 Introduction

It is generally recognised that traditional teaching methods have numerous drawbacks. One of them is the fact that very often students attend the course, take notes and leave without any collaboration in the classroom. Collaborative learning tries to solve this inefficiency. It is an educational method in which students work together in small groups towards a common goal (Dillenbourg et al., 1996; Hafner and Ellis, 2004). The teacher acts as a coach, mentor or facilitator of the learning process. The successful achievement of the common goal is shared among all group members. The students take initiative and responsibility for learning. They actively learn by doing, by practice, by experience.

Collaborative learning is a student-centred, task-based, activity-based learning approach that provides several advantages to the student. It assists the student to enhance the following skills:

- Communication
- Interpersonal and social
- Cooperation, sharing and caring
- Openness
- Flexibility and adaptability
- Knowledge retention
- Higher-order and critical thinking
- Creativity
- Management
- Practicality
- Responsibility, trustworthiness and dependability
- Involvement, engagement and participation
- Commitment and persistency
- Motivation
- Confidence and self-efficacy

Students work together on a task, exchange their views, experiences and opinions, discuss and negotiate strategies, actions and results. They assist, explain, teach, understand, review and influence each other. By developing a learning community, they combine the special abilities of everyone to achieve the common goal.

Mobile learning technology is gaining a wide acceptance in education as it is opening many possibilities. Usually, education is restricted to a single room without the opportunity of moving and still keeping close interaction among the students, tutors and teachers. However, there is the need to free learning both from time and space restrictions. Mobile learning can do this. Mobile learning is an application of mobile computing to the education. Using hand-held devices, the students can freely move, learn and communicate over wireless networks. For example, the students may be distributed across a field and be moving either on foot or on a vehicle. They may collaboratively observe (e.g. archaeological artefacts), examine (e.g. plants), watch (e.g. animals) or collect information (e.g. temperature) and educational objects (e.g. minerals). The teacher coordinates the group tasks and activities. He also advises and guides the groups (teams).

Each person carries a hand-held device through which he/she sends and receives messages, voice, sound, pictures, video, etc.

Outdoor learning provides an opportunity for direct learning experiences, which can enrich the school curriculum in different subject areas, such as natural sciences, architecture visual arts and industrial/civil engineering (Roccetti et al., 2001). This experience-based instruction can be effectively enhanced by computer-based learning environments, by providing each student with a mobile device fully connected to the internet and to its worldwide resources. Such a device can be used by a student to access customised information, which may be related to the places that constitute the outdoor environment. So additional resources are made available to teachers to carry out their teaching activity, and students' traditional experiences in the classroom may be enriched and complemented with real experiential knowledge obtained on the field. In essence, outdoor experiential activities can facilitate the construction of abstract concepts and enhance the meaningful learning, providing for long-term awareness of the reality. Through outdoor-based programmes, students may gain a realisation of their relationship to the real environment, which cannot be learned through abstract sources.

Using a hand-held device, the student can perform any of the following tasks: read educational material, record audio and video, take photos, write text, draw pictures, sketches, diagrams and charts, see pictures and video, listen to voice and audio, ask/answer questions, send/receive multimedia mail, exchange objects, communicate with others, be guided using maps, compass and Global Positioning System (GPS), be directed by teacher, be instructed by teacher, etc.

Mobile learning can potentially enable students to share information, coordinate their tasks and, more broadly, function effectively in collaborative settings (Gay, Rieger and Bennington, 2002). Thus, mobile learning may support group work on projects and enhance communication and collaboration. In order to support the rich forms of collaborative learning, learners need appropriate tools to share, exchange and negotiate their ideas (Milrad, Perez and Hoppe, 2002). The use of wireless, networked, hand-held computers in education is rapidly increasing, thus providing new opportunities to engage students in collaborative activities, independent of time and space. Hand-held computers will become an increasingly compelling choice of technology for K-12 classrooms, because they will enable a transition from occasional, supplemental use to frequent, integral use (Soloway et al., 2001). Wireless interconnected hand-helds can support an environment that favours constructivism and collaboration in order to achieve the creation of new knowledge (Zurita and Nusbaum, 2004a). The students can build up their own knowledge (based on previous one), while working jointly among them in a reflexive process directed by the teacher.

The integration of mobile devices, wireless communication and networking technologies into the education environment could enhance the learning (Weiser, 1998). Mobile devices enable the teacher and students to utilise the computing power anytime and anywhere, while the internet and wireless technologies enable mobile devices to interconnect with other computing devices seamlessly. Recent empirical studies have suggested the advantages of by using wireless technologies and mobile devices in learning environments, including enhancing availability and accessibility of information networks (Gay et al., 2001). Roccetti et al. (2001) describe a general architecture of a mobile web-based distance learning service for interactive outdoor learning along with its design guidelines. They also evaluate it in order to confirm the adequacy of the approach and to determine the future development of the system.

Kurbel and Hilker (2002) discuss the characteristics of mobile communication with respect to e-learning and e-learning platforms. They outline mobile learning scenarios and examine the requirements for a mobile e-learning platform. They provide a case study for displaying learning content on the current and future WAP/UMTS-based devices. Hummel, Hlavacs and Weissenböck (2002) created and evaluated an e-learning platform designed for enhancing courses to allow guided discussions, to access the information and communicate anytime, anywhere and from arbitrary device types. Furthermore, the platform supports team activities and offers additional services like personal status information and a barometer for student satisfaction.

Milrad, Perez and Hoppe (2002) describe the design and implementation of a mobile and wireless application to support collaborative knowledge building. They support the exchange and discovery of key ideas among students by using wireless optical readers, hand-held devices and a Java and Extensible Markup Language (XML)-based application. Dvorak and Burchanan (2002) describe a University project where students and faculty members are equipped with IBM laptops connected to a wireless network. One course was re-designed to foster more collaboration and active learning by first delivering the educational material online and asking collaborative assignments to be done during the classroom time. Students found the course challenging and they rose to meet that challenge.

Kinshuk et al. (2003) combine the characteristics of digital portfolios with the functionality of open problem-solving and idea generation tools. Andronico et al. (2003) consider models for mobile learning, the evaluation of learning processes in mobile learning environments and the technological aspects of mobile learning, and on their integration with e-learning systems. Colazzo et al. (2003) investigate the use of mobile computing technologies and their integration with e-learning systems to support the learning.

Zurita and Nusbaum (2004b) develop a constructivist learning environment, supported by hand-helds, for the teaching of reading for first graders. Children performing the activity supported with technology were observed to have significantly higher word construction test score improvements than the children performing the paper-based activity.

Yatani, Sugimoto and Kusunoki (2004) support children's collaborative learning in a museum. Two children form a group and communicate by using Personal Digital Assistants (PDAs) and transceivers. They have to answer 13 questions related to the exhibitions. Russell and Pitt (2004) outline the possible teaching environments that would facilitate students in giving anonymous or known real-time feedback for the teacher. The teacher will see the feedback immediately and has a possibility to react depending on the comments given. They believe that this will increase students' participation and collaboration. Trifonova and Ronchetti (2004) present an architecture where the functionalities of the e-learning platform are presented as web services. On top of it, a Mobile Learning Management System (MLMS) is taking the responsibilities of adapting those services for the mobile users and for providing additional mobile-specific services. Such a system should have three main functionalities – 'Context Discovery', 'Mobile Content Management and Adaptation' (MCMA) and 'Packaging and Synchronisation'. Trifonova and Ronchetti (2006) investigate the hoarding problem in mobile learning. They find the parameters for efficient learning content selection to be pre-fetched on the mobile devices' local memory for the following session.

In Section 2, we investigate the suitability of current wireless networking technologies for outdoor mobile collaborative learning. Then, in Section 3, we describe the pragmatic outdoor educational scenarios and propose to support mobile collaborative learning using multicast MANETs. In Section 4, we investigate via simulation whether multicast MANETs can efficiently enhance the communication and collaboration for these outdoor educational scenarios. Finally, in Section 5, we conclude and suggest the directions for future research.

2 Wireless networking technologies for outdoor education

As wireless technologies evolve, the coming mobile revolution will bring dramatic and fundamental changes to the world (Siau and Shen, 2003). In outdoor educational activities, the students should freely move, communicate and be connected anywhere and anytime using wireless networks. The bandwidth requirements needed for audio communication ranges from 8 kbit sec^{-1} (telephone quality), 31 kbit sec^{-1} (AM quality), 96 kbit sec^{-1} (FM quality), 128 kbit sec^{-1} (acceptable music quality) and 256 kbit sec^{-1} to 320 kbit sec^{-1} (near CD quality). The bandwidth requirements for video communication ranges from 16 kbit sec^{-1} (videophone quality), 128–384 kbit sec^{-1} (business-oriented videoconferencing system quality), 1 Mbit sec^{-1} (VHS quality), 5 Mbit sec^{-1} (DVD quality) to 15 Mbit sec^{-1} (HDTV quality).

Personal Area Networks (PANs) using Bluetooth may support voice, audio and data communication among the students at 1 Mbit sec^{-1} for up to 10 m distance. Wireless Local Area Networks (WLANs) may support communication across longer distances. The main WLAN technology is Wi-Fi (IEEE 802.11). The 802.11b can achieve throughput at 5.9 Mbit sec^{-1} over TCP and 7.1 Mbit sec^{-1} over UDP. The 802.11a achieves a throughput of 20 Mbit sec^{-1} (with a maximum raw data rate of 54 Mbit sec^{-1}). The IEEE 802.11g achieves a throughput of 24.7 Mbit sec^{-1} (with a maximum raw data rate of 54 Mbit sec^{-1}). The future 802.11n is expected to reach a theoretical 540 Mbit sec^{-1}. Another WLAN technology is High-Performance Radio LAN (HiperLAN), which supports rates up to 24 Mbit sec^{-1}, and the HiperLAN2 up to 54 Mbit sec^{-1}. For longer distances, Worldwide Interoperability for Microwave Access, IEEE 802.16 (WiMAX) can connect Wi-Fi hotspots with each other and to other parts of the internet. Practically, it can connect users 5–8 km away (theoretically, 50 km away). Real-world tests show practical maximum data rates between 500 kbit sec^{-1} and 2 Mbit sec^{-1} (theoretically, 70 Mbit sec^{-1}).

In Public Cellular Networks (PCNs), a student located in a specific cell communicates with other students in the same cell through the cell base station. If the students are located far away, the corresponding cell base stations communicate by using a path of intermediate cell base stations. In 1980s, the First Generation (1G) mobile telephony was analogue. In the early 1990s, the generation 2G Global System for Mobile Communication (GSMC) could not support the digital audio/video communication. However, the 2.5G General Packet Radio Service (GPRS), Enhanced Data rates for GSM Evolution (EDGE) provided digital telephony and low and medium data transmission rates at 9,600 bit sec^{-1}. GPRS supports data transmission rates at 30–80 kbit sec^{-1} (with a theoretical maximum of 171.2 kbit sec^{-1}). It is able to support text, images and low-quality pre-recorded audio (at 8 kbit sec^{-1}). EDGE supports data speeds up to 384 kbit sec^{-1} (with a theoretical maximum of 473.6 kbit sec^{-1}).

The third-Generation (3G) wireless networks deliver broadband throughput to cell phones and other mobile devices. With speeds between 144 kbit sec^{-1} and 384 kbit sec^{-1} mobile, as well as 2.4 Mbit sec^{-1} static, a student can download files, surf the web, send and receive e-mail or stream music and video over the cellular networks. The two main versions of 3G are Universal Mobile Telecommunications System (UMTS) and Code Division Multiple Access (CDMA). UMTS supports data transfer rates up to 1,920 kbit sec^{-1}. EVolution Data Optimised (EVDO), which is an evolution of CDMA2000, supports the downlink data rates up to 3.1 Mbit sec^{-1} and uplink data rates up to 1.8 Mbit sec^{-1}. CDMA2000 supports data rates of 144 kbit sec^{-1} to 3 Mbit sec^{-1}. The 4G will offer 2 Mbit sec^{-1} mobile and 10–600 Mbit sec^{-1} static, and the 5G will offer 100 Mbit sec^{-1} mobile and 600 Mbit sec^{-1} static. NTT DoCoMo is testing 4G communication at 100 Mbit sec^{-1} while moving, and 1 Gbit sec^{-1} while still.

There are many fields where the mobile communication can be deployed. Industries such as transportation and logistics, financial services, health services (Varshney, 2006), commerce (Bai et al., 2005) and many others should be able to improve their performance by implementing wireless mobile technologies (Shim et al., 2006). Most previous studies on using wireless networks for mobile learning suggest the use of GMS/GPRS, UMTS, Wi-Fi and Bluetooth technologies (Hummel, Hlavacs and Weissenböck, 2002; Kurbel and Hilker, 2002; Colazzo et al., 2003; Trifonova and Ronchetti, 2004). However, all these networking technologies require fixed infrastructure or cover a small area. However, there are educational cases where the class should move to places where there is no communication infrastructure (e.g. sea, wilderness, dessert). In order to fully exploit such educational opportunities without restrictions and compromises, we need easy deployment of a network anywhere at anytime.

In these cases, it is important to rapidly deploy autonomous, self-organising and flexible communication infrastructure. We suggest the use of MANETs for mobile learning in such cases. In MANETs (Figure 1), the mobile nodes are autonomous and communicate by wireless network without the need of any pre-installed communication infrastructure. If the mobile nodes are in the transmission range of each other, then they communicate directly. Otherwise, the sender passes on the message to its neighbour mobile node along the path to the destination; Then that node forwards the message to its neighbour mobile node towards the destination and so on. So, the autonomous mobile nodes can establish connectivity among them via multi-hop wireless communications without relying on any existing infrastructure (e.g. fixed antennas, towers and electricity).

In order to achieve collaboration among the students and the teachers, there should be an efficient communication mechanism. We suggest the use of multicasting, which is the one-to-many or many-to-many efficient communication (Figure 2). Instead of submitting the same message from the sender to every recipient multiple times, the original message is transmitted from the sender to the recipients once and it is duplicated only when it is needed. In other words, the original message is transmitted only once on links, which are shared by the paths from the sender to the destinations. This message is duplicated only at the points where the paths diverge. However, multicasting in MANETs is a very difficult problem due to the variable and unpredictable network topology and traffic. The network topology and node connectivity are continually changing due to the node mobility, signal strength variability, environment landscape, etc.

Figure 1 MANET (Mobile Ad-Hoc Network)

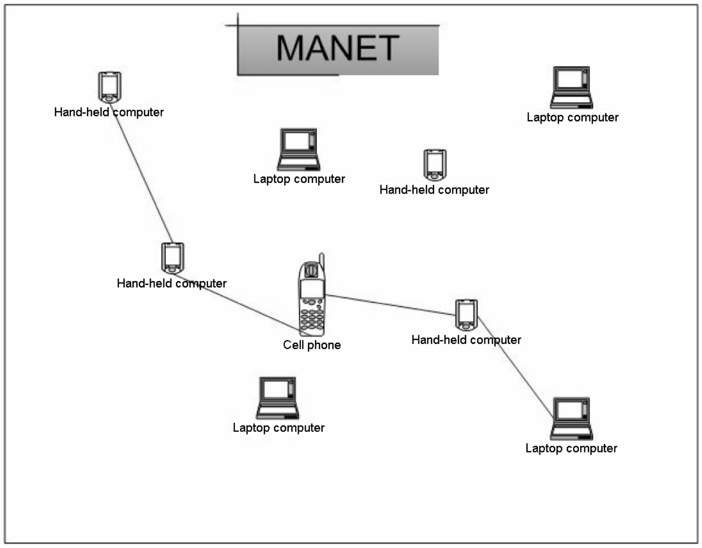
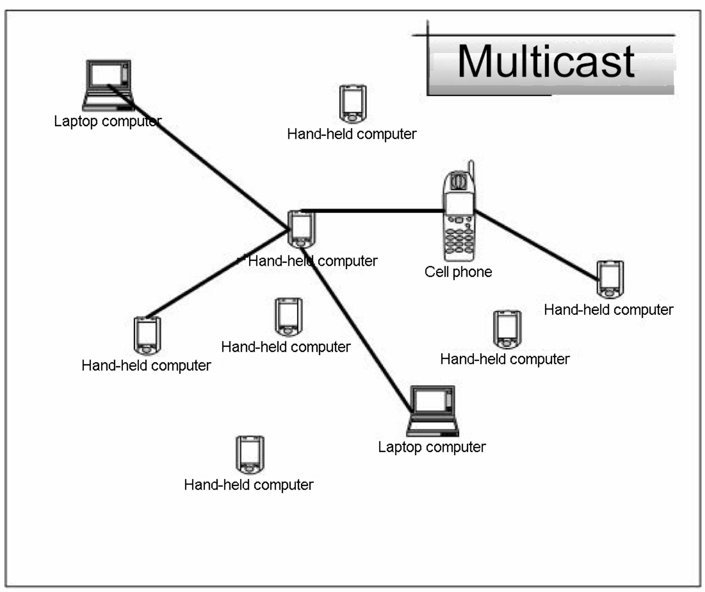


Figure 2 Multicasting in MANET



However, the mobile wireless communication is inherently unreliable and may face severe problems: sudden loss of connection, relatively low bandwidth and high bandwidth variability, heterogeneous systems and devices, possible security risks due to radio communication, low power supply, weak computation power and small storage capacity of the portable devices (Hummel, Hlavacs and Weissenböck, 2002). A typical problem is related to the typical low value of available bandwidth and the high latency that characterise the network access through mobile devices (Roccetti et al., 2001). This problem is typically exacerbated when streams of multimedia data are transmitted. The most important technical requirements for efficient mobile collaborative learning are the availability and the responsiveness of the communication and collaboration learning activities. The corresponding network requirements are the network reliability and latency. So, we are interested in investigating whether MANETs can satisfy these reliability and latency requirements. Several multicast protocols have been proposed for MANETs. The selected protocol has to be very proof to the nodes' speed. Moreover, it should respond fast to any topology changes and find reliable and minimum delay paths from the sender to the receivers. Mesh-based multicast architectures provide multiple paths, making the protocol more proof to network changes. On the contrary, tree-based architectures provide only one path from the sender to destination. In addition, the protocol should efficiently manage the heavy traffic since some educational applications may require video transmissions. It should also efficiently support both unicast and multicast traffic. After extensive investigation and simulation, we selected the ODMRP protocol (Bagrodia et al., 2000; Hong, Xu and Gerla, 2002) as the multicast protocol to use in our experiments. ODMPR is an on-demand protocol based on mesh architecture. The sender discovers multicast routes when it has something to send. It is a soft state protocol, meaning that if a node wants to leave from the multicast group, then it is overpassing the group maintaining messages. No explicit control message is required to leave the group. When a node has packets to send and no route to the destination, it broadcasts a join Query message. Finally, it supports both unicast and multicast traffic.

This paper proposes the deployment of MANETs to support communication among students, tutors and teachers in places without communication infrastructure. Furthermore, it proposes multicasting to support the collaborative learning activities among participants. Finally, the paper investigates whether multicast protocol may efficiently support the collaborative learning activities. In Section 3, three realistic mobile collaborative learning scenarios at outdoors are described.

3 Outdoor educational scenarios

Many studies (Gibbons, 1999) emphasise that the team-building skills would be enhanced through outdoor educational activities. Students participating in outdoor activities increase their self-efficacy, motivation and confidence while they enjoy learning. In general, students like and enjoy the outdoors; hence learning would be enjoyable and challenging. Such activities may also develop positive relationships among the students as well as the teachers. The required close collaboration among them can enhance their social, communication and cooperation skills. Orion (1993) suggests that field trips should be properly pre-designed with minimum extemporaneity and focus on an active interaction process between the students and the environment. In the following Table 1, we provide some possible outdoor collaborative learning scenarios for students from various departments or classes.

Table 1 Outdoor collaborative learning scenarios

Scenarios	*Department or class*
Wilderness, forest, mountain, desert, lake and river	Environmental engineering and natural resources
	Forestry
	Ecology
	Botany
	Zoology, animal science
Mineral site	Mining engineering
	Geology
	Mineralogy and petrology
Geyser site	Geophysics and geothermics
Farm	Agriculture engineering
	Veterinary
	Crop science
Sea, fishery and desert island	Marine biology
	Ichthyology
Archaeological site	Archaeology
	Architecture
	Palaeontology
Tribe, native village (remote, isolated)	Anthropology
	Ethnography
	Culture sciences
	Geography
Historical site	History
Technical museum	Electrical, computer or mechanical engineering
Rural area	Rural and surveying engineering
	Rural development
Glacier climbing, skiing, mountaineering, kayaking and caving	Physical education and sports sciences

Next, we describe three innovative mobile collaborative educational scenarios based on pragmatic situations. The first scenario is related to a visit to an archaeological site. The second scenario is related to flora investigation in a park. The third scenario is related to an orientation game. All scenarios are based on real parameters. Table 2 shows the correspondence between the simulation technical parameters (nodes, groups etc.) and what they represent in reality (classes, number of students, etc.).

Table 2 Correspondence between parameters in simulation and education

Parameters in simulation	*Parameters in education*
Nodes	Teachers and students
Groups	Classes (only students are members)
Senders	Teachers or assistants
1 m sec^{-1} speed	Average walking speed
20 m sec^{-1} speed	Speed of a vehicle

3.1 Archaeological site visit

The first scenario is related to visiting an archaeological site. For example, the second grade of a high school is visiting an archaeological site (Figure 3). In a regular educational visit, all students together observe the archaeological site and listen to the teacher or the docent. If they do not have any access to databases or to internet, they cannot investigate the exhibitions further. They visit the archaeological site to only see in real what the history book describes. However, this is only a part from the benefits that students could have from a visit to an archaeological site. Using collaborative learning and wireless technology, they could have access to databases, so they could retrieve information in real time, work as groups and exchange photographs, audios, videos, etc. Also, the teacher could contact every student at any time and transmit useful information, or answer questions or place quiz for assessing the students' knowledge. In our experiments, three classes have entered for this visit. Every class has a responsible teacher and 20 students. The archaeological site covers an area of 1,200 × 400 m. All the students and the teachers are moving randomly on foot so the average speed of every person is 1 m sec^{-1}. Some archaeological sites in prosperous countries would have wireless infrastructures, so Wi-Fi networks would be used. However, it is not sure that all archaeological sites everywhere would have such established networks, and that these networks would be 100% compatible with any wireless device carried by a student. Moreover, special permissions may be required to be taken from the archaeological site administrator to establish a private network over their installed network. So, we propose the use of MANETs. Every class, which represents a multicast group, is accepting multicast packets only by the responsible teacher. This means that there are one sender and 20 receivers. We measure the Packet Delivery Ratio (PDR) and the Latency (average end-to-end delay). We are interested in finding for which conditions 'mobile collaborative learning using MANET multicasting' is feasible. We investigate the factors (speed, traffic, number of receivers, number of senders and groups) that affect the communication reliability and the delay. During an educational visit to an archaeological site, the main factor that can seriously affect the communication reliability and delay is the amount of the sent and received traffic by the participants. We define traffic as the number of packets that are sent in 1 sec. Furthermore, the traffic is Constant Bit Rate (CBR), which means that packets are send continuously with the same rate. During an educational visit to an archaeological site, it will be very common to transmit multimedia applications as videos or audios, applications that produce heavy traffic to the network. For example, the teacher sends video streaming packets to the students, resembling the exhibits they see. The traffic is either 10 kbytes sec^{-1}, 20 kbytes sec^{-1} or 50 kbytes sec^{-1}. The packet size is either 256 or 512 bytes. We use the NS-2 simulator for performing these experiments. NS-2 is an open source simulator. Many researchers show the reliability of the NS-2 simulator (Lucio et al., 2003). Numerous researchers have used it to implement their simulations. Moreover, it is easy to use it giving the opportunity to modify handily various simulation parameters and protocol specifications. The simulation parameters are described in Table 3. So, we want to investigate whether MANETs multicasting may efficiently support the mobile collaborative learning activities under heavy traffic conditions.

Figure 3 MANET in an archaeological site visit

Table 3 Simulation parameters for the archaeological site scenario

Parameter	*Value*
Nodes	60
Groups	3
Nodes/group	20
Senders	1
Movement	Random
Bit rate	10 kbytes sec^{-1}, or 20 kbytes sec^{-1} or 50 kbytes sec^{-1}
Area	1,200 × 400 m
Speed	1 m sec^{-1}
Protocols	ODMRP
Simulation time	180 sec
Packet size	256 bytes or 512 bytes

The simulation time for this experiment was 180 sec. In all other experiments, it was 900 sec. Due to the very heavy traffic that is created in the archaeological site scenario, the trace files from the NS-2 are over 1 GB. So, the simulation and the batch process of data mining useful information from the trace files last several days. In order to be accurate, we compare the results of running the experiment one time for 900 sec simulation time and several times for 180 sec. The difference was small enough (0–5%). So, we run it several times for 180 sec and take the average values.

3.2 National park exploration

The students from three university departments (environmental engineering, veterinary and agriculture departments) are taking an educational trip to a National Park (Figure 4). From every department, one class and the responsible teacher are participating in this trip (20 students and one teacher). The purpose of this trip is different for every department. The students of the environmental engineering department will investigate the natural resources management and preservation structure of the national park. The students of the veterinary department will observe some species in their natural environment. The students of the agriculture department will examine the flora of the park. It is obvious that the students from different departments have different benefits from this trip. Therefore, multicasting among the students of each department is needed. However, it is also possible that the department of agriculture and environmental engineering have a common task (e.g. examining trees). Then multicasting in two groups is needed. Finally, when a notice has to be delivered to all students from all departments, multicasting in three groups is needed. So, in this scenario we investigate the communication reliability and delay with respect to the number of receivers. The students will be moving in an area of 2,000 × 800 m. Wireless technology is the only mean for these students to communicate.

A National Park should be left untouched from human structures. So, it is not a good idea to install towers and antennas in such environmentally protected areas. Furthermore, it is not easy and cost-effective to install and maintain the networking infrastructure at such a wilderness and desert location with rough terrain and rubs, with limited access (e.g. roads) and resources (e.g. electricity). It is preferable that every team that visits a national park to be autonomous and self-sustained carrying its own mobile wireless network. MANETs do not require pre-existing infrastructure.

In this scenario, we consider that the traffic is not the main factor that affects the communication reliability and delay. The students exchange mainly photographs and messages. Therefore, the traffic is kept low. However, the speed is a factor that can affect the communication reliability and delay. The students are moving unpredictably either on foot, on bicycles or on slow vehicles. So, we also investigate the impact of the speed. We investigate two speed meters:

1. 0–1 m sec^{-1}, which is a normal walking speed
2. 0–20 m sec^{-1}, which is a vehicle's speed.

The teacher and the students exchange messages (e.g. answers, questions and comments), files and photographs. The traffic is set to two packets per second. Each packet is 256 bytes long. The simulation duration is 900 sec. The packet transmission starts after the 13 sec, and lasts until the end of the simulation. The simulation parameters are described in Table 4.

Figure 4 MANET in a national park exploration

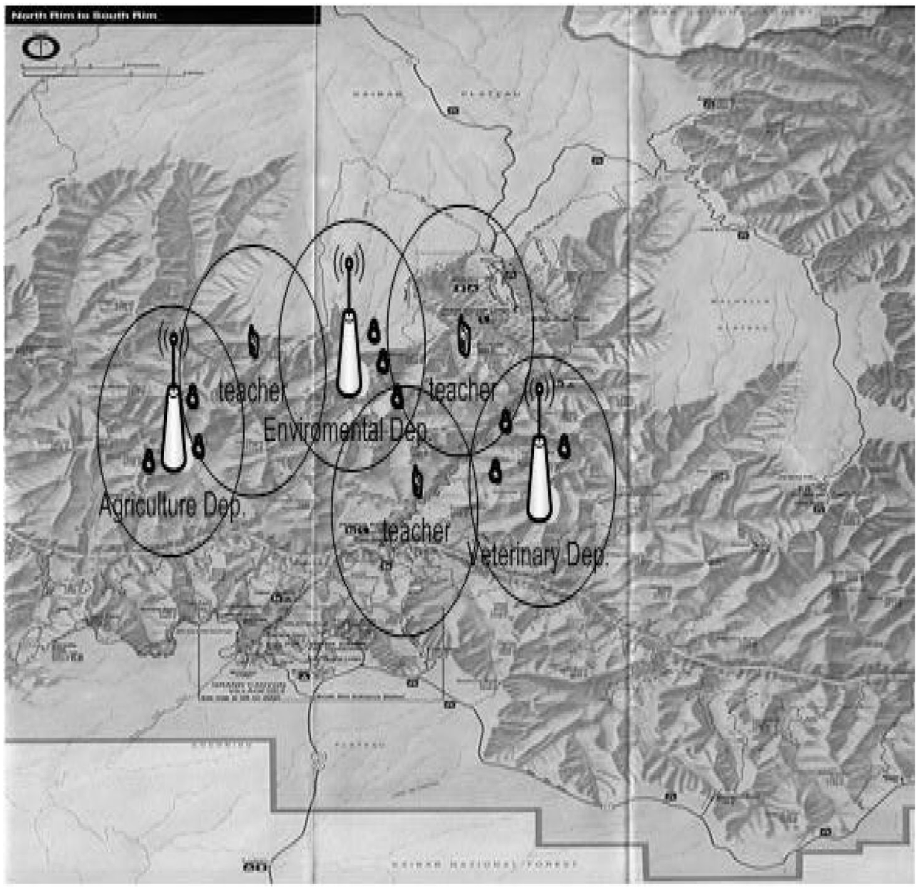


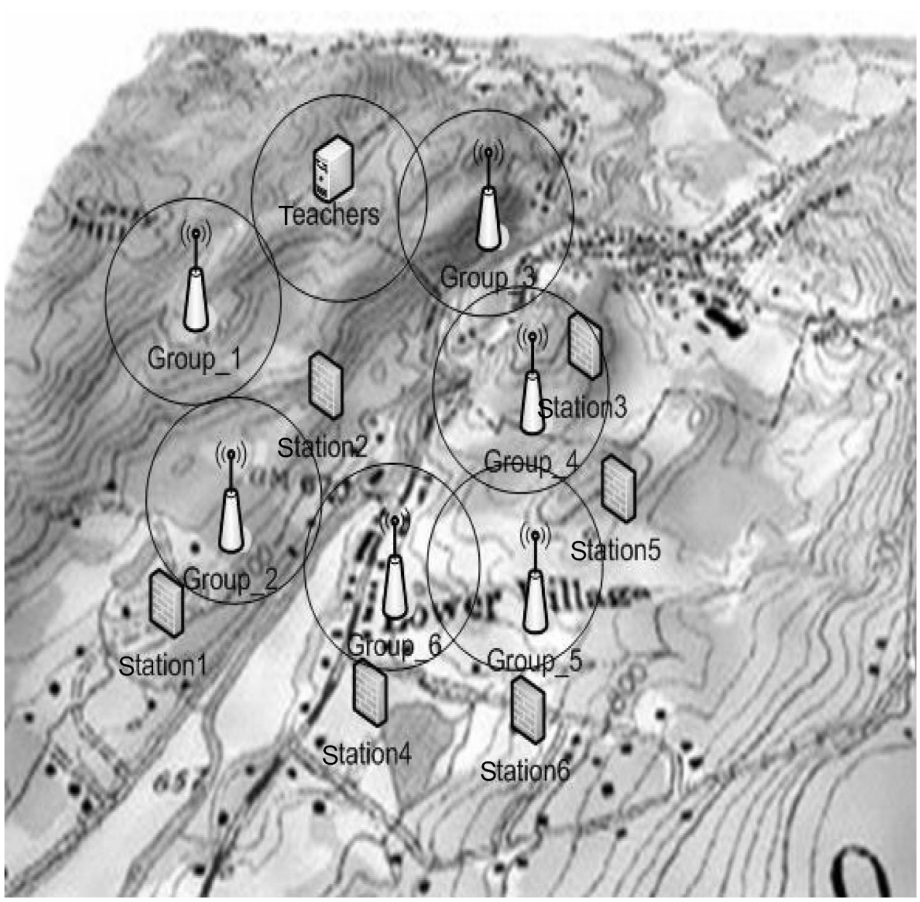
Table 4 Simulation parameters for the national park scenario

Parameter	*Value*
Nodes	60
Groups	3
Nodes/group	20
Senders	1 or 2 or 3
Movement	Random
Traffic rate	2 packets (2 × 256 bytes sec^{-1})
Area	2,000 × 800 m
Speed	1 m sec^{-1} or 20 m sec^{-1}
Protocols	ODMRP
Simulation time	900 sec

3.3 Orientation game

The orientation game aims at initiating collaboration among kids using an educational game. There are 60 kids and a teacher. The kids are divided into six groups. Every group consists of ten kids. The game is performed on an area of 1,000 × 1,000 m (Figure 5). Every group should pass from a number of stations. The students should collaboratively do some activity at every station. If the group succeeds, then the teacher sends to them directions about the next station. For example, when a group arrives at a station, the teacher asks to collect and recognise ten species of flora. The students of the group scan the area, find the species of flora, recognise them and send the answer to the teacher. The teacher collects the answers, marks them and sends directions (e.g. using a map and compass) about the next station. The group that successfully completes all assignments first is the winning group. This orientation game offers active learning, collaborative learning, true educational trips, friendly competition, etc. If it is possible for the administration to have internet access then, through a proxy server, internet can be established to all the groups, expanding the possibilities for this collaborative game. For example, the recognition of the flora can be made with the use of an internet flora database.

Figure 5 Outdoor orientation game with MANET



Every kid has a hand-held device with wireless connectivity, and the teacher has a strong transmitter/receiver. Every group elects a group leader, who is responsible for communicating with the teacher and with the group members. The teacher sends the task instructions and questions to the group leaders. The group leaders send them to their group members. The group leaders may ask the teacher for help. The group members may collaborate among themselves. However, the groups are not allowed to communicate among themselves. If internet connection can be established, then it is shared by all group leaders. That means the traffic between the teacher and the group leaders is heavy. Therefore, the traffic is an important factor that affects the communication reliability and delay. We choose traffic 8 kbit sec^{-1} when no internet is present, and 64 kbit sec^{-1} when internet is present, as a simple ISDN connection. The simulation parameters are described in Table 5.

Table 5 Simulation parameters for the orientation game scenario

Parameter	*Value*
Nodes	60 + administrator
Groups	6
Nodes/group	10
Senders	6 + administrator
Movement	Random
Traffic rate	8–64 kbit sec^{-1}
Area	1,000 × 1,000 m
Speed	1 m sec^{-1}
Protocols	ODMRP
Simulation time	900 sec

In Section 4, simulation is used to implement these scenarios and investigate the achieved performance and reliability of the communication and collaboration.

4 Simulation results and discussion

Quality of Service (QoS) is important for efficient communication. Achieving high QoS for MANETs is not an easy task. MANETs have certain unique characteristics that pose several difficulties in provisioning QoS, such as dynamically varying network topology, lack of precise state information, lack of central control, error-prone shared radio channels, limited resource availability, hidden terminal problems and insecure media; and little consensus yet exists on which approaches may be optimal (Li, Jia and Du, 2006). There are many studies that try to improve QoS in MANETs (He et al., 2006; Li, Guizani and Kazakos, 2006).

Depending on the application and the required fidelity various, QoS can be described. For example, conversational voice can be supported by a network with average delay of 150 msec. However, even a delay of 400 m sec may be acceptable. Other applications afford higher delays. For example, interactive games tolerate delay of 250 m sec, voice messaging tolerates delay of 1 sec and still image and one-way video tolerate delay of

10 sec. So it is a matter of QoS tolerance to decide about the ability of a MANET to support the application.

4.1 Archaeological site visit

The simulation results for the archaeological site scenario are presented on Figures 6 and 7. We investigate the communication reliability and delay in heavy traffic. We measure the PDR and the latency. PDR is the percentage from the send messages that was actually delivered. It represents how reliable the communication is. Latency is the average time delay that a packet needs to traverse the network. It is the amount of time between sending a packet from the originating node and receiving it at its destination node. Figure 6 presents the PDR with respect to the three different bit rates using two different packet sizes. Figure 7 shows the latency with respect to three different bit rates using two different packet sizes.

Figure 6 PDR vs. traffic with various packet sizes for the archaeological site scenario

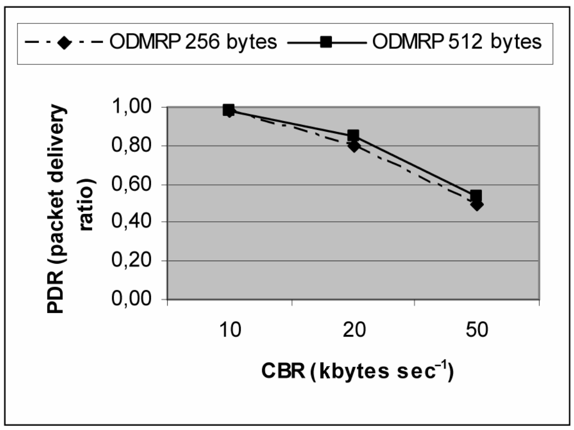
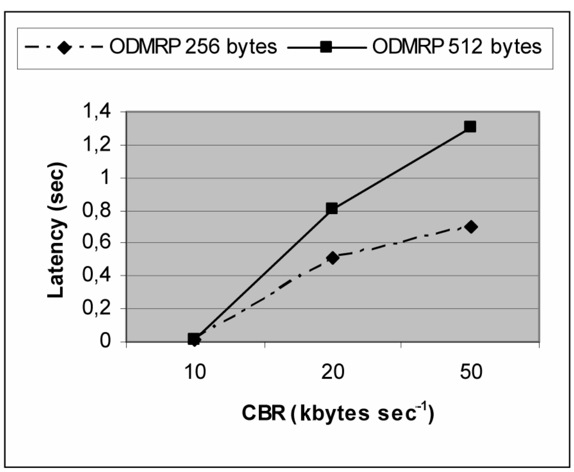


Figure 7 Latency vs. traffic with various packet sizes for the archaeological site scenario



In Figure 6, we observe the PDR when the traffic becomes heavy. We use two different packet sizes (256 and 512 kbytes). As we expected, using 512 kbytes packet size achieves a better PDR. Using 512 kbytes packet size, we need only half of the packets per second to achieve the same CBR as when using 256 kbytes packet size. The best PDR is achieved when the traffic is 10 kbytes sec^{-1}, good PDR when the traffic is 20 kbytes sec^{-1} and poor PDR when the traffic is 50 kbytes sec^{-1} (only half of the packets are delivered).

However, using larger packet sizes, bigger quantity of information has to be retransmitted in case of failure, causing extra delay to the system. As we observe in Figure 7, the latency deteriorates when the packet size is 512 kbytes. In some cases, the latency becomes very large. So a MANET can support the communication and collaboration during the archaeological site visit in most of the cases. Specifically, we can achieve good communication and collaboration when the traffic is below 20 kbytes sec^{-1}, which is already very heavy traffic. Depending on whether PDR or latency is more important, we can decide which packet size to use. Concluding, mobile collaborative learning is feasible during an archaeological site visit using MANET multicasting.

4.2 National park exploration

The simulation results for the National Park exploration scenario are presented on Figures 8–11. We investigate the communication reliability and delay with respect to the number of senders, the number of receivers and the node speed.

Figures 8 and 9 show the PDR. For 20 receivers, PDR is best with three senders. For 40 receivers, PDR is best with one sender. For 60 receivers and speed 1 m sec^{-1}, PDR is best with two senders. While for 60 receivers and speed 30 m sec^{-1}, PDR is best with three senders. Increasing the number of receivers increases the PDR, so the communication reliability deteriorates. The PDR is good in almost all cases except with one sender and 20 receivers.

Figure 8 PDR vs. number of receivers with various senders and speed = 1 m sec^{-1} for the national park scenario

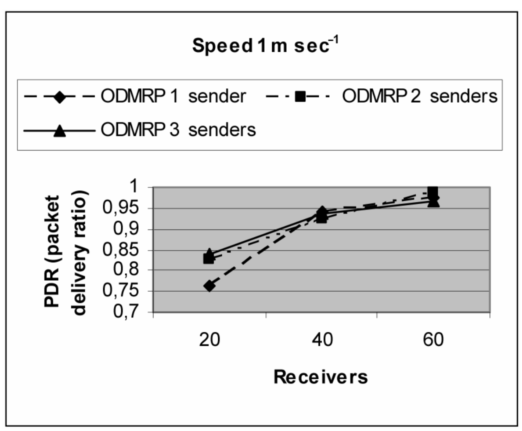
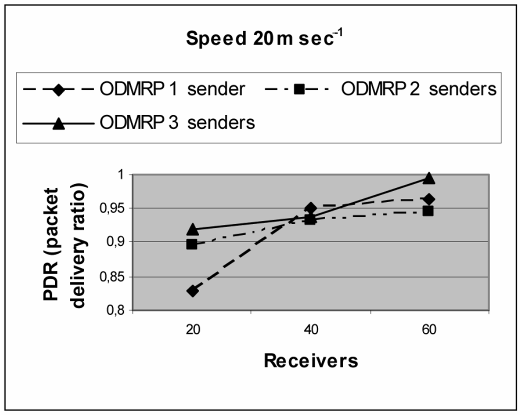


Figure 9 PDR vs. number of receivers with various senders and speed = 20 m sec^{-1} for the national park scenario



Figures 10 and 11 show the latency. The best latency is with one sender than with two and three senders. In all the experiments, the achieved latency makes communication feasible. Concluding, mobile collaborative learning is feasible during a park exploration using MANET multicasting.

4.3 Orientation game

The simulation results for the orientation game scenario are presented on Figures 12 and 13. Figure 12 shows the communication reliability, and Figure 13 shows the delay when there is an internet connection (heavy traffic at 64 kbit sec^{-1}) as well as no internet connectivity (low traffic at 8 kbit sec^{-1}).

Figure 10 Latency vs. number of receivers with various senders and speed = 1 m sec^{-1} for the national park scenario

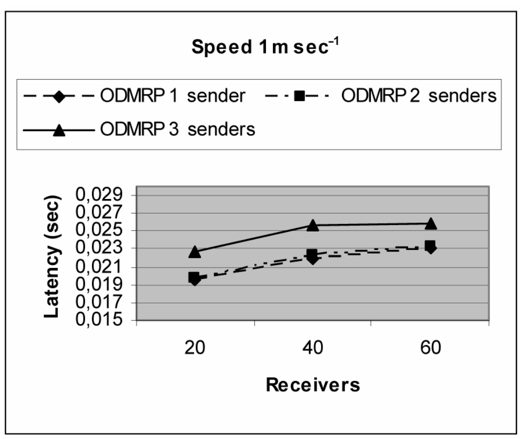


Figure 11 Latency vs. number of receivers with various senders and speed = 20 m sec^{-1} for the national park scenario

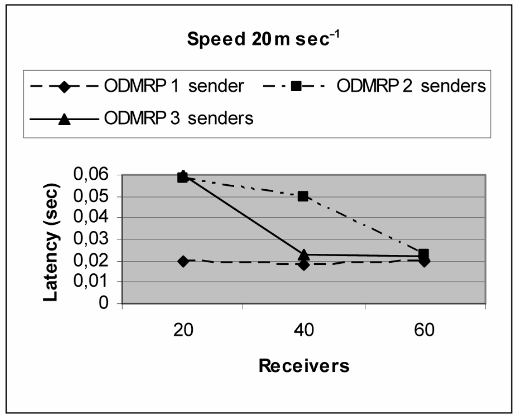


Figure 12 PDR vs. CBR (with or without internet connectivity)

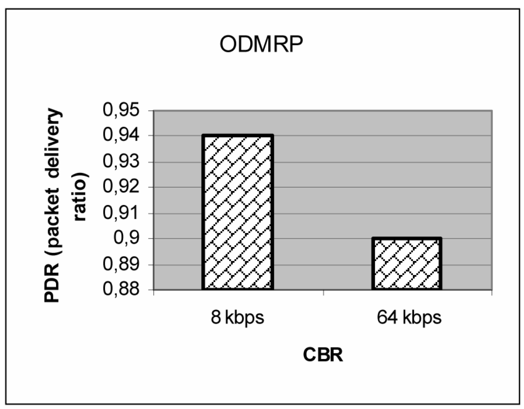
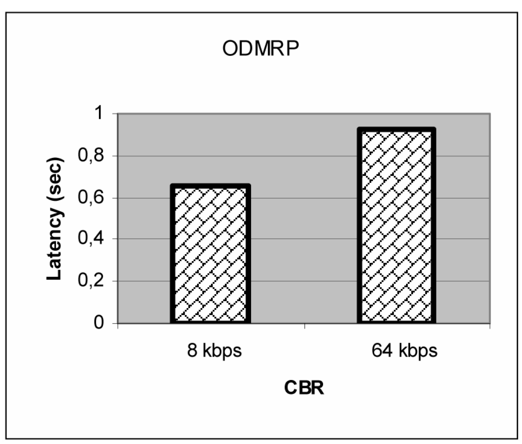


Figure 13 Latency vs. CBR (with or without internet connectivity)



Observing Figure 12, we see that both PDR values (for 8 and 64 kbit sec^{-1} traffic) are very satisfactory. As it was expected, the PDR is worst when the traffic is 64 kbit sec^{-1} than when it is 8 kbit sec^{-1}. More traffic causes more packet loss and lower PDR values. Observing Figure 13, we see that both latency values are high (0.65 sec for 8 kbit sec^{-1} traffic and 0.92 sec for 64 kbit sec^{-1} traffic). This means that if we multicast a video, then probably the receivers will see it discontinuing. New video compressions algorithms help multicasting a video with good quality and low bit rate. This delay is annoying in multimedia applications; but if this traffic is created by internet surfing, then the end-users will understand it as a slow internet connection. We loaded the network with heavy traffic that resulted to annoying delay. We considered that everyone is sending and receiving packets most of the time. In reality, the traffic will be less since the students have to do their task and not continuously communicate. Moreover, we used old wireless technology with transmission rate at 11 Mbit sec^{-1}. However, new wireless technologies will increase the transmission bandwidth to 55 Mbit sec^{-1}. Also, new video compression algorithms will enable multimedia applications to require less bandwidth. Concluding, mobile collaborative learning is feasible during an orientation game using MANET multicasting.

In Section 5, these results are further discussed, conclusions are drawn and future research directions are given.

5 Conclusion and future research

Wireless technology gives us the opportunity to establish the collaborative learning by letting students move and learn at outdoors. Not only knowledge is transferred to students with the most pleasant way but also the students experience pragmatic activities in the real world, new challenging and motivating activities, outside of the school environment. They familiarise themselves with real life; discover new places; feel and touch the learning objects. Learning becomes not only abstract but also practical. MANETs provide flexibility in rapidly and easily deploying a mobile wireless network anywhere at anytime. They are infrastructure-independent, which means that they do not depend on the specific areas infrastructure and resources (e.g. antennas, towers and electricity). So, the teachers may design and develop learning activities to be taken place at any outdoor area. The teacher knows the exact objectives of the learning activity and he should control it. He is the responsible person to guide the learning activity without any need or interference by other people, such as network administrators. The students can freely move around and perform these learning activities without any restrictions on infrastructure and resources. MANETs seem to be the future in the outdoor learning process**.** As wireless technology develops in vast rhythms, Ad Hoc networks become more reliable and more economically accessible to students and schools. IEEE 802.11x standard gives up to 54 Mbps transmission rates, so bandwidth restriction becomes a not so crucial factor. In this paper we use the wireless technology in teaching, so we did not consider any security restrictions. If there are security considerations, MANETs offer several methods for building a secure network (Hsieh, 2006) Also, as hardware productivity increases, wireless devices get cheaper. The One Laptop per Child (OLPC) association (MIT Media Lab) announced the creation of 100$ laptops only for students. The laptops will have wireless broadband that, among other things, allows them to create an ad hoc, local area network. This project will reduce dramatically the cost of the wireless devices. Our experiments show that the multicast MANETs provide reliable (high PDR values) and efficient (low Latency values) communication. So, mobile collaborative learning may be taken place in the described realistic outdoor scenarios using multicast MANETs. Future research will implement these scenarios in the real field. Every student will carry a hand-held device supporting IEEE 801.11x and multicast MANETs. Real experiments will validate the simulation results on mobile collaborative learning using multicast MANETs.

References

Andronico, A., Carbonaro, A., Colazzo, L., Molinari, A. and Ronchetti, M. (2003) 'Models and services for mobile learning systems', Paper presented in the Proceedings of the *Mobile HCI 03 Workshop on Mobile and Ubiquitous Information Access.*

Bai, L., Chou, D., Yen, D. and Lin, B. (2005) 'Mobile commerce: its market analyses', *Int. J. Mobile Communications*, Vol. 3, pp.66–81.

Bagrodia, R., Gerla, M., Hsu, J., Su, W. and Lee, S-J. (2000) 'A performance comparison study of ad hoc wireless multicast protocols', Paper presented in the Proceedings of the *19th Annual Joint Conf. of the IEEE Computer and Communications Societies*, pp.565–574.

Colazzo, L., Molinari, A., Ronchetti, M. and Trifonova, A. (2003) 'Towards a multi-vendor mobile learning management system', Paper presented in the Proceedings of the *E-Learn 2003 Conference.*

Dillenbourg, P., Baker, M., Blaye, A. and O'Malley, C. (1996) 'The evolution of research on collaborative learning', in E. Spada and P. Reiman (Eds), *Learning in Humans and Machine: Towards an interdisciplinary learning science* (pp.189–211). Oxford: Elsevier.

Dvorak, J.D. and Burchanan, K. (2002) 'Using technology to create and enhance collaborative learning', Paper presented in the Proceedings of the *14th World Conference on Educational Multimedia, Hypermedia and Telecommunications (ED-MEDIA 2002)*, Denver, CO, USA.

Gay, G., Stefanone, M., Grace-Martin, M. and Hembrooke, H. (2001) 'The effects of wireless computing in collaborative learning environments', *Int. J. Human–Computer Interaction*, Vol. 13, pp.257–276.

Gay, R., Rieger, R. and Bennington, T. (2002) 'Using mobile computing to enhance field study', in H. Koschman and Myake (Eds), *CSCL 2: Carrying Forward the Conversation* (pp.507–528). Mahwah, NJ: Lawrence Erlbaum Associates.

Gibbons, S. (1999) 'Team building through physical challenges', Paper presented in the Proceedings of the *Connections '99: Proceedings of a Faculty Conference*, Victoria, British Columbia, Canada.

Hafner, W. and Ellis, T.J. (2004) 'Project-based, asynchronous collaborative learning', Paper presented in the Proceedings of the *37th Hawaii International Conference on System Sciences*.

He, Q., Cai, L., Shen, X.S. and Ho, P. (2006) 'Improving TCP performance over wireless ad hoc networks with busy tone assisted scheme', *EURASIP Journal on Wireless Communications and Networking*, Vol. 2006, pp.1–11, Hindawi Publishing Co.

Hong, X., Xu, K. and Gerla, M. (2002) 'Scalable routing protocols for mobile ad hoc networks', *IEEE Network, Special Issue on Scalability in Communication Networks*, Vol. 16, pp.11–21.

Hsieh, W-C. (2006) 'The proactive intrusion prevention for wireless local area network', *Int. J. Mobile Communications*, Vol. 4, pp.477–496.

Hummel, K.A., Hlavacs, H. and Weissenböck, H. (2002) 'Web based online-learning in technically equipped and mobile student societies: a case study', Paper presented in the Proceedings of *the Interactive Computer Aided Learning (ICL) Workshop*, Villach, Austria.

Kinshuk, S.J., Sutinen, E. and Goh, T. (2003) 'Mobile technologies in support of distance learning', *Asian Journal of Distance Education*, Vol. 1, pp.60–68.

Kurbel, K. and Hilker, J. (2002) 'Requirements for a mobile e-learning platform', Paper presented in the Proceedings of the *IASTED International Conference on Communications*, pp.467–471.

Li, D., Jia, X. and Du, H. (2006) 'QoS topology control for nonhomogenous ad hoc wireless networks', *EURASIP Journal on Wireless Communications and Networking*, Vol. 2006, pp.1–10, Hindawi Publishing Co.

Li, W., Guizani, M. and Kazakos, D. (2006) 'Quality of service in mobile ad hoc networks', *EURASIP Journal on Wireless Communications and Networking*, Vol. 2006, pp.1–3, Hindawi Publishing Corporation.

Lucio, G.F., Paredes-Farrera, M., Jammeh, E., Fleury, M. and Reed, M.J. (2003) 'OPNET modeler and Ns-2: comparing the accuracy of network simulators for packet-level analysis using a network testbed', Paper presented in the Proceedings of the *3rd WEAS International Conference on Simulation, Modelling and Optimization*, ICOSMO 2003.

Milrad, M., Perez, J. and Hoppe, U. (2002) 'C-notes: designing a mobile and wireless application to support collaborative knowledge building', Paper presented in the Proceedings of the *IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE'02)*.

Orion, N. (1993) 'A practical model for the development and implementation of field trips as an integral part of the science curriculum', *School Science and Mathematics*, Vol. 93, pp.325–331.

Roccetti, M., Salomoni, P., Ghini, V. and Pau, G. (2001) 'Interactive outdoor web-based distance learning using mobile terminals', Paper presented in the Proceedings of the *International Conference on Simulation and Multimedia in Engineering/Western MultiConference on Computer Simulation (ICSEE/WMC'2001)*, in H. Vakilzadian (Ed.), *The Society for Computer Simulation International* Phoenix, USA.

Russell, G. and Pitt, I. (2004) 'Visions of a wireless future in education technology', *Journal of issues in Informing Science and Information Technology*, Vol. 1, pp.747–752.

Shim, J.P., Varshney, U., Dekleva, S. and Knoerzer, G. (2006) 'Mobile and wireless networks: services, evolution and issues', *Int. J. Mobile Communications*, Vol. 4, pp.405–417.

Siau, K. and Shen, Z. (2003) 'Mobile communications and mobile services', *Int. J. Mobile Communications*, Vol. 1, pp.3–14.

Soloway, E., Norris, C., Blumenfeld, P., Fisherman, B., Krajcik, J. and Marx, R. (2001) 'Handheld devices are ready-at hand', *Communications of the ACM*, Vol. 44, pp.15–20.

Trifonova, A. and Ronchetti, M. (2004) 'A general architecture to support mobility in learning', Paper presented in the Proceedings of the *IEEE International Conference on Advanced Learning Technologies (ICALT'04).*

Trifonova, A. and Ronchetti, M. (2006) 'Hoarding content for mobile learning', *Int. J. Mobile Communications*, Vol. 4, pp.459–476.

Varshney, U. (2006) 'Using wireless technologies in healthcare', *Int. J. Mobile Communications*, Vol.4, pp.354–368.

Yatani, K., Sugimoto, M. and Kusunoki, F. (2004) 'Musex: a system for supporting children's collaborative learning in a museum with PDAs', Paper presented in the Proceedings of the *2nd IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE'04).*

Zurita, G. and Nussbaum, M. (2004a) 'Computer supported collaborative learning using wirelessly interconnected handheld computers', *Computers & Education*, Vol. 42, pp.289–314.

Zurita, G. and Nussbaum, M. (2004b) 'A constructivist mobile learning environment supported by a wireless handheld network', *Journal of Computer Assisted Learning*, Vol. 20, pp.235–243.

Weiser, M. (1998) 'The future of ubiquitous computing on campus', *Communications of the ACM*, Vol. 41, pp.42–43.