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TOWARD A MODELIZATION OF MOBILE LEARNERS BEHAVIOR FOR THE DESIGN AND THE EVALUATION OF ADVANCED TRAINING SYSTEMS

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ABSTRACT

Mobile learning or m-learning (ML) is a new form of e-learning where students use wireless networks to exchange data (questions, notes, courses, demos …) with their teachers. It is accomplished with the use of mobile devices such as palmtops, PDA, smart phones, tablet PCs or any other handheld devices. The main contribution of ML is the large mobility it offers to the different actors of the training. We believe that the comprehension of this mobility is crucial in order to better design, deploy, and manage future wireless networks in a training context. In this article we propose an approach to more understand and analyze learners' behavior in wireless environments. Our idea is to integrate and visualize statically (e.g. infrastructure, Access Points position) and dynamically (e.g. users' itineraries, accessed data) extracted data in unique dashboard interface. This approach makes it possible to track real learners by providing, in addition to their graph of mobility, various views on their space-time behaviors. Moreover, it allows the comparison of behaviors evolution over several periods of time.

KEYWORDS

Mobile learning, mobility analysis, dynamic visualization.

1. INTRODUCTION

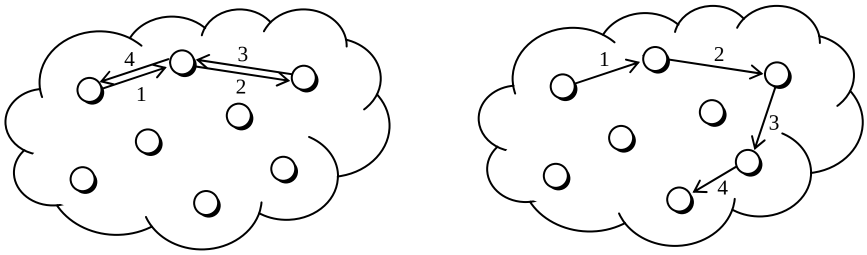
Mobile Learning (ML), sometimes called m-learning, may be considered as e-learning through mobile devices. In other terms, it refers to a situation in which learners use wireless networks and mobile handheld devices in their study. Since the last few years, this domain has been growing rapidly and has created opportunity for new field of research including a wide variety of new applications and training techniques. A lot of universities and companies are experimenting different solutions to apply mobile devices in their training. In fact, it reduces space and time restrictions and gives to learners more autonomy in acquisition of knowledge. So, they can work closely together but also discussing with their teachers when they are geographically separated. Recently, the CRED (Centre Romand d'Enseignement à Distance) [CRD04] have conducted a study on e-learning. They found that 80% of questioned students prefer paper support for the formation than audio cassettes, CD-ROM or Internet. Indeed, it is clear that the main characteristic of the paper support is its mobility. For example a book can be used wherever and whenever it is needed at the university, the library or at home. This mobility is also provided by the mobile devices which will encourage and strengthen the e-learning methods in different situations.

In the last decade, the exponential growth of mobile technology has accompanied and, in certain cases, reinforced the nomadism of learners by offering various very powerful mobile devices and an advanced multi-modal mobility (roaming between several wired and wireless networks). Mobile devices here refer to any autonomous handheld tools used for accessing content and interacting with other students and teachers by exchanging multimedia content (e.g. voice, images and written messages). This progress toward increasing mobile accessibility has also brought new challenges for wireless (networks and applications) designers and managers. For example, the question of learners localization, which was most of the time known with fixed technology (such as desktop computerized), becomes an unknown factor in situation of mobility. Therefore, contrary to the fixed communication, which is at first a technical problem, the mobile learning must take into account data from physical environment. Indeed, it is not enough that learners have mobile devices to be joinable; they must be, for example, in a coverage area. In fact, physical data such as location-based information can be used to improve user comfort, application software, operating systems and network infrastructures which are particularly intended for more conventional wireless environments.

From an usage perspective, there is an emerged aspect which is the connection between learning, work and leisure. An article appeared in Freedom magazine [FRE05] outlines that "*Leisure is only a problem in a society in which education is aimed at adjusting the individual to society instead of bringing out and developing the potentialities in him...*". So, in mobile environment, this aspect has a great relation with learners' mobility by the fact that they can join and be joined wherever and whenever by any one of their classmates and acquaintances. Also, they can use their devices for entertainments. So understanding usage patterns seems important to maintain a natural balance between work and leisure time.

This link between the physical mobility and the location-based exchanges tends to show a certain space coherence of the communication acts. This coherence worth a careful study to more understand learners' behaviors, but also to consider new location-awareness services related to mobile learning. Also it allows us to avoid some QoS (Quality of Service) problems like services disconnections and servers overload by deploying more content there where is needed.

In this context, we have developed an application which allows us to visualize tendencies in the itineraries followed by the learners in a wireless network. This tool also makes it possible to obtain synthetic indicators making it easy to extract conclusions on usage patterns. For example, for an identical distance covered among access points, some users move on a more significant area, whereas others do it on short areas. This difference can be observed when we notice that some limited movements are done around many access points whereas in certain cases the same number of movements is done around very few ones but more frequently. Another point is the persistence with which users visit various location and the sessions duration. This is very important in a training context which for example allows us to understand where and when students spend their time and which is the more visited location (see figure 1). Such information can be useful to deploy new content or send messages (giving directions to student/teachers for example).



a. Short area b. Large area

Figure 1. Same covered distance

Our tool was tested on short distance wireless technology which is 802.11 wireless LAN (WiFi) because nowadays it is the most used wireless network in universities campuses and companies. On the other hand, we can use it for other systems like long distance wireless technologies such as GPRS, 3G, and Satellite GPS (Global Positioning System) associated systems. This is possible simply by changing the background file in the graphic interface and redefining the AP (Access Points) coordinates file. It is a simplified way to have micro/macroscopic level of mobility. Also, it is possible to select a part of the same network in order to focus just on a specific locations and/or particular population.

This article shows these various points by locating them in the context of research. We start by giving a progress report on the work completed related to mobile learning and users mobility. Then, we argue on the various aspects of trace collection and we describe the mains components of our tool. After that, we show some results before concluding with some elements of discussion and prospects.

2. RELATED WORK

There are several topics in our work for which there exist related studies. In this section, we begin by exposing previous mobile learning and mobility modelling work studied in the literature. Next we discuss some general aspects related to the use of traces in order to deepen the understanding of mobile user activity.

2.1. Mobile learning

Over the last decades, many companies and universities have been interested in mobile learning which offers more flexibility and new opportunities for interaction. Lots of these work focuses on the technological infrastructures, new applications and potential uses and limitations of the mobile devices. In this article we complete theses studies by exploring a new important issue which is the learners' mobility. Let’s quote some of these studies.

Seppälä and Alamäki [SEP02] from the University of Helsinki report experiences showing how mobile technology was used by teachers and students. Their idea is to supervise discussions and sharing ideas through mobile devices (SMS messaging and digital pictures). Their main goal is to create new teaching solutions which will support all kinds of devices in different situations. The difference with our work is that they supervise the behavior of students and teachers from a pedagogical point of view whereas we focus on their mobility so, where and when they use devices.

In another study [CHA02] Chang and Sheu try to develop a wireless platform for building an Ad hoc classroom system. The idea is to reinforce the mobility of teacher and students by providing a new lively learning environment and to help them to create a mobile classroom (take lesson anytime and anywhere). So, students may enhance their learning performance without attending classes physically. The proposed system provides teachers with training aids, such as blackboard, colored chalk, voice recorder or video recorder. This system also provide student with electronic Schoolbag (or eSchoolbag) which packs electronic book, notebook, parents contact book, pencil case, etc. Comparing to this approach, our tool makes it possible to understand how students behave in such environment.

In the project WELCOME (Wireless E-Learning and Communication Environment) at the University of Regensburg, Lehner et al outlines the contribution and limits of mobile devices in mobile education [LEH02]. They conclude that these educational systems have to deal with several restrictions such as content distribution and presenting which will resemble today's learning solutions. Our contribution adds some important notes on the advantages and limits of these tools from the mobility point of view (looking for example if users with laptops move less than PDA ones).

All these previous work deal with the enhancement and the effects of mobile technologies in the educational area. Until now, there are limited studies on how the learners take advantage of these systems from the mobility point of view and how they behave in such situation. We believe that the study of learners' behavior is essential to more develop these new educational techniques in the future. It is the reason why we have developed the current tool which allows the learners displacements to be visualized and analysed. But before we begin its presentation, let's talk firstly about the completed work in the mobility study.

2.2. Mobility modelling

Recently, several researches on users' mobility have been done on several kind of wireless networks in order to understand usage patterns and performances. Kotz and Essien [KOT02] studied a University campus used by 1706 students throughout 11 weeks. They found that residential traffic is the most dominant especially in residences populated by newer students (which use particularly laptops as their primary mobile device). In addition, they were surprised by the number of roaming between AP (Access Points) which causes broken IP connections in cross-subnet roams. This special issue needs a solution to improve data speed and facilitate accesses. This study deals especially with the terminals activities, users' mobility and traffic characteristics (the most used protocols).

In a second study [LAI98] Lay et al. characterized the uses of mobility by carrying out a study limited of 8 laptops during 8 days. This study focused on the number of times that a laptop moves from a fixed network to a mobile one. The authors found that the average mobile device switches between wired and wireless network was of 14 times and that moves within the wireless network was of five times. They conclude that latency and network reliability are critical problems in wireless technologies which lead students to change their usage patterns when connected to the wireless network.

Tang and Baker [TAN00] present a 7 weeks traces study on a wireless metropolitan network composed of 177 access points with approximately 1366 users. Amongst their results, they found that locations visited by users on a daily basis are concentrated in a smaller areas and the distance covered follows a Gaussian distribution around the radius of the network.

In their study, Balachandran et al. [BAL02] examine the behavior of mobile users during the three days of the international conference SIGCOM of ACM held at U.C San Diego in August 2001. The objective was to characterize the behavior of these users by comparing and contrasting their workload with the previous studies. Amongst their results, they found that most sessions duration are relatively short (less than 10 minutes) and than longer sessions correspond mainly to connected but not used machine. Balazinka and Castro [BLZ03] completed the previous study by examining a four week trace in a corporate wireless network. They analyze user and load distribution across access points. They found that load is unevenly distributed across access points and is influenced more by users' presence even if they are few than in the number of users.

To take into account and to synthesize the results of these studies, researchers have developed visualization tools which facilitate the interpretation of the large volume of traces obtained. These can be classified in two main categories. Cartographic applications associated with real or simulated moves and metrological applications which rather give quantitative syntheses. Un example of the first category is the graphic open source tool NAM (Network AniMator) [NAM205] which make it possible to display results extracted from simulators such as ns2 [NS05]. These systems are based on simulation models like Random waypoint or Random Walk which are instructive but, in fact, not very realistic [YOO03] [JAR03].

Another category of tools present various maps exploiting real traces, obtained by a detection and analysis tools called wardriving. In this category we find some scripts and application like TrackNS [WAR05], carte.pl [CRT05], Stumbverter [NTS05] and GSPmap [MAP05]. The majority of these programs are intended for the APs localization or the covered areas visualization.

Other researchers [TNG99] adapted generic visualization tools to their own needs. This is the case of RIVET visualization environment for example [BSC00], one of the most complete visualization systems developed at Stanford University. However, the use of such tools requires a specific adaptation to each context. Moreover, the results are presented in forms which do not simplify for example the analysis of the users' behavior.

More recently, in order to facilitate the visual study of complex ad hoc networks, a visualization tool called ViTAN has been developed [FTZ02]. This tool offers a good way to visualize the connectivity and link quality (capacity) between the laptops in wireless ad hoc networks.

Each one of these approach allows the visualization of a particular sub-problem of comprehension under a specific angle. It is difficult to find an application which gathers up the visualization of users movements (in an individual or in group way) by accompanying them with descriptive statistics. The aim of our work is to improve the understanding of learners behavior in wireless environment by giving a realistic visualization tool which allows the integration of statically (e.g.: infrastructure, APs position) and dynamically (e.g.: users mobility, accessed data) extracted data.

2.3. Modelling from traces of activity

From our point of view the modelling of mobile user's behavior is imbedded in the more general paradigm of modelling from traces of activities. It is interesting to see that exploitation of traces is present in many fields of sciences. For example historian or economists exploit traces of past civilisation or economic exchanges (e.g stock market).

In the field of exact sciences as physics, traces collect and analysis are also unavoidable. For example, in astronomy, the observations result in fact from a trace called the fossil radiation. Indeed, due to the distance and to the light speed the image of some planets or stars can come to us even if the object no more exists. In the field of computer science this question raises a very important level since computer traces are everywhere, playing the role of memory and allowing easy reusability. (for more details on trace paradigm see [LAN05] [LAN01] [LAN06]). Outside of visualisation or modelling purpose, some study emphasis the importance of traces in phenomenon of collective intelligences in the context of implicit data reuse [LAN04]. As we will see, from the perspective of mobile user's behavior this memory of the user's activity can be conditioned in order to be visualized or used as model basis or new services proposal. [BEN05].

3. DESIGN AND IMPLEMENTATION

The main goals of our study are three-fold. First we have presented the research background. Second, we want to provide a general tool which facilitates understanding of wireless users behavior and that makes easy mobility modeling. Third, we want to use this tool in order to understand usage and propose location-awaress services in training context but also in global wireless networks. In this section we show some details about the design and implementation of our tool. We begin by introducing the context and the methodology of traces collecting, after that we expose the main modules and components of the tool.

3.1. Context of study

In this experiment we analyze a network traces of more than 300 researchers/engineers who reach on 17 WiFi APs distributed between the ground floor and the two floors of a corporate building which represents a surface on the ground of approximately 3000 m². This wireless network is configured to run in an infrastructure mode. The period of study stretch from mi-August 2004 to March 2005 so, about 210 days. Most of the users use individual wireless devices (such as laptops and PDA). The architecture of the building makes it possible for the users to move in a very easy way from any AP towards almost all the others. Mobile devices are used in the different activities of our population which necessitate mobility between offices, meeting rooms, conference rooms, labs and library.

3.2. Data collection

We have deployed a set of shell scripts which communicate with a Syslog server in order to collect events generated by the WiFi APs. These data are stored into a specific MySql database. Amongst information stored, we find the time and date, users' identification (represented by theirs MAC addresses) and events generated by the AP. These messages indicate that a user had associated, dissociated or roamed toward another AP. It can be:

ASSOCI: means that a mobile device is associated to this AP (defined also by its MAC address).

DIASSOC: means that a device leaves the AP to join another one or it is turned off.

ROAMED: means that a user has leaved the current AP to join another one. A disassociation message is generated every time a roamed message was generated. It contains, moreover, the MAC address of the new visited AP.

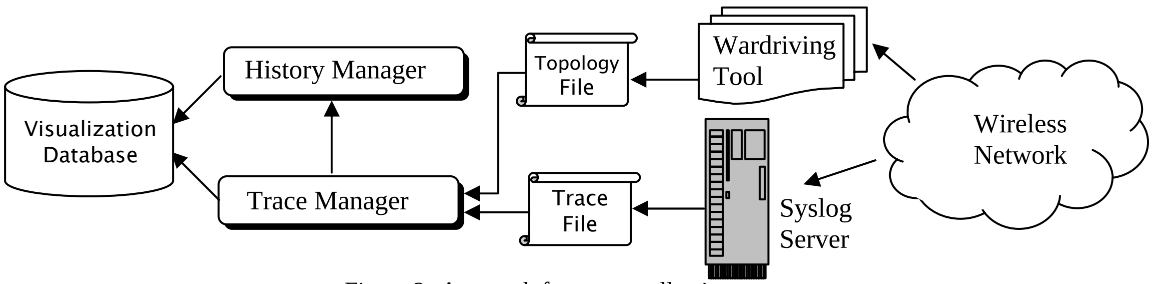


Figure 2. Approach for traces collection

3.3. Overall Architecture

The total system (figure 3) consists of three main modules. The first one is the trace collector component which extract the location of the access points and devices (represented by (x, y) coordinates) and the traces generated by the latter.

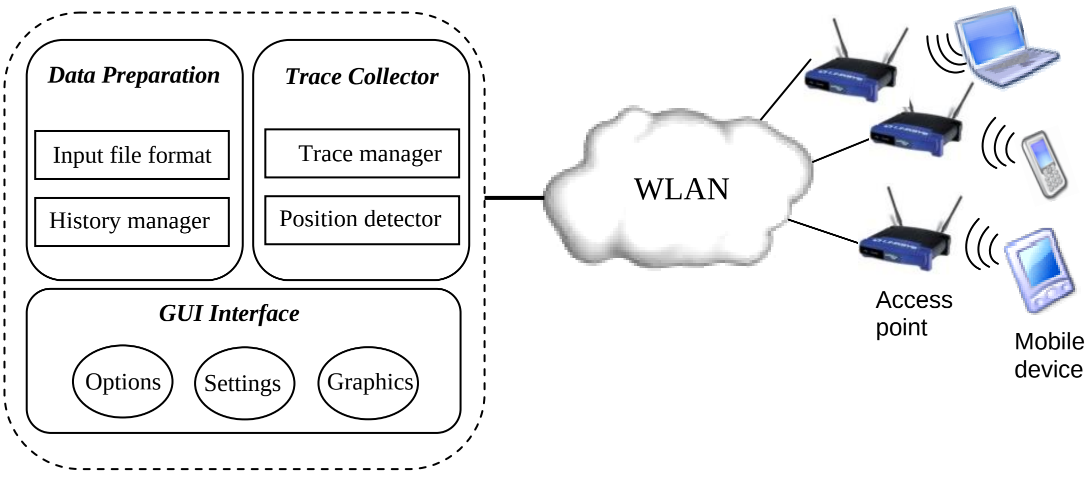


Figure 3. Overall architecture

All this information will be saved in two files: Network topology and Traces files (these two files will be described in the next section). The second module prepares the data for presentation and also for manages the history of both traces and network topology changes. This is very important in order to view the mobility evolution or to compare two or more periods. Finally, we have the GUI (Grapgic User Interface) component which shows the mobility graph and some space-time statistics.

3.4. Main component of the tool

After presenting the general architecture of the tool, let us details, now, its main components with some details.

- *Trace Collector Component*: This module contains two important parts; the first is the *position detector* which deals with the retrieval of access points positions and the second one is the *trace manager* which recuperate traces and handle the chronological events. We use a shell script to detect devices positions. It is combined with the wardriving tool *NetStumbler* which allows wireless network discovery and mapping. The trace management part uses a Syslog server [SYS05] and the SNMP protocol [SNM05] in order to scan and provide periodically traces and other information from the Wireless Access Points. These data are stored in two files: the first one is devoted to devices (or users) positions and the second one to the studied activities (users' mobility, messages exchanged etc). We use a MySQL [MYS05] database in order to gather all information about the wireless activities. This will facilitate the extraction of data and graphics.

- *Data Preparation Component*: it manages the input file format and the traces history in order to analyse the evolution of behaviors within several periods. The data offered by the Collector Component held information about users' space-time activities. The current module uses these data to generate a specific format as output. The figure 4 is an example of a generated file. We find in this file some information related to users activity and Access point events.

- *GUI component*: This module gathers a set of dynamic graphs related to the parameters selected by the administrator in the settings area. More details are given in the next section.

```
#
#NAME       Xpos  Ypos  TYPE  DATE TIME       MSG
#
AP-SAS05    130   67    APN   09/10 09:53:15  ASSOCI
AP-RC06     205   28    APN   13/10 11:31:27  ROAMED
AP-RC01     205   75    APN   13/10 11:31:27  DIASSOC
AP-SAS16    230   40    APN   21/10 16:02:48  ASSOCI
```

Figure 4. Example of an input file format

3.5. Dynamic Visualization Dashboard

The graphic dashboard regroups a set of parameters and options which make clear the visualization by drawing or not some details. We distinguish four main parts (figure 5):

The first part (part A in the figure 5) is intended for the selection of the context of study and makes it possible to choose the access points which we want to integrate into the analysis, the group of learners (a group of classmates for example), as well as the period of visualization. This variety of choices authorizes various visions of the practices. Initially a microscopic approach of a learners behavior (or a particular community of them) for a given period, and a comparison between the others results over a more or less limited period. It is also possible to have a more macroscopic view clarifying the main tendencies of movements. In our case, we highlighted the privileged routes for all the participants between certain APs in a relatively limited number, as well as regroupings of particular users in some localization (figures 6 and 7).

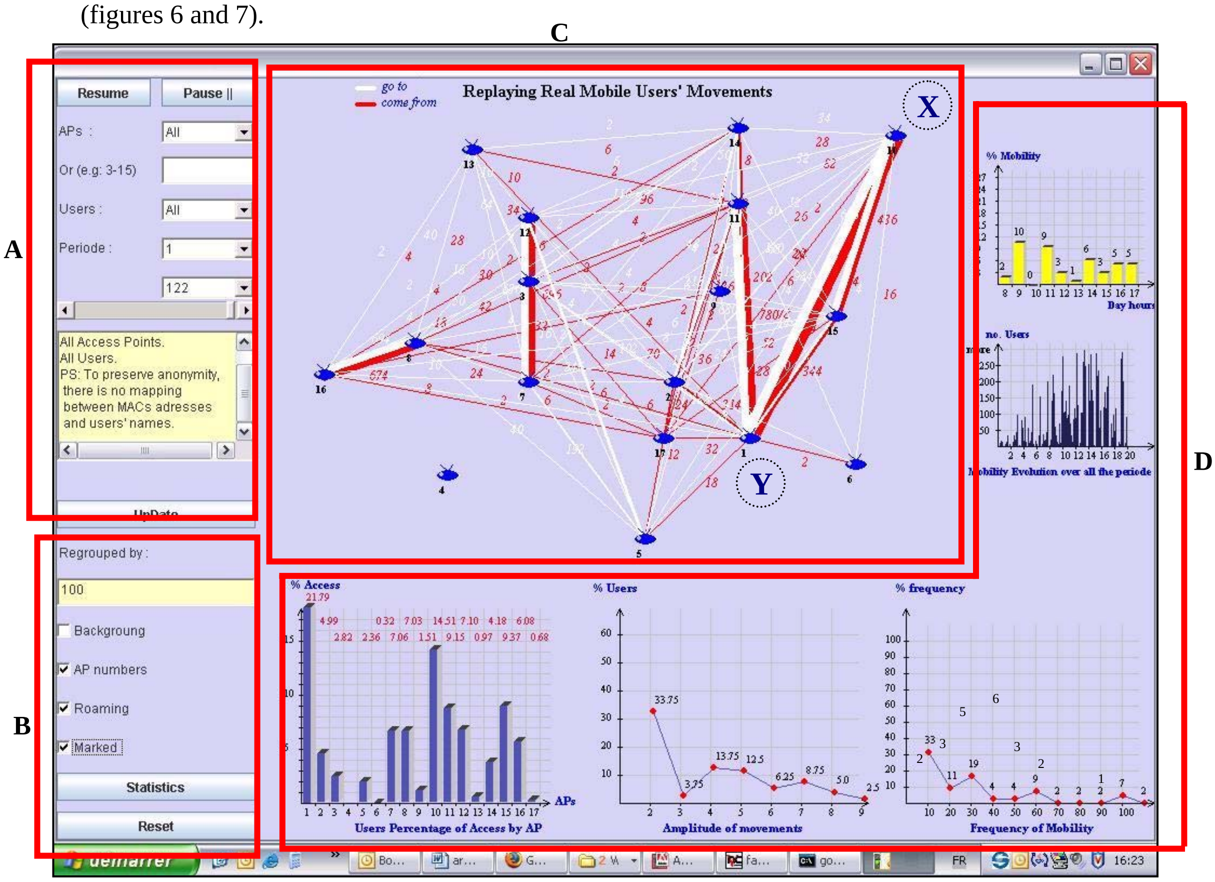


Figure 5. The tool user interface

The second part (B in figure 5) makes easy to configure the visualization of the routes, i.e. illustrating or not the roaming between APs, counting the movements and displaying of APs numbers with or without the building... It is a simple manner to make clear the visualization of movements for example by removing the APs numbers, the drawing of the building or the roaming between APs. For example in figure 6 we can see details on the roaming as well as information on the APs and the frequency of mobility, whereas in the figure 7 we focus on the graph in order to better clarify the concentration zones and the most common paths.

The third part (part C – figure 5) allows redrawing the evolution of real routes in an accelerated manner, which normally gives a dynamic vision of mobility tendencies. This approach makes it possible to highlight behaviors which are very difficult to distinguish on a static layout. It is the case in particular of the evolution of a collective behavior (ways often attended for some period of the month or the week). The placement of the APs on the diagram corresponds to their real co-ordinates. Each terminal is defined by three parameters (X, Y, Z): Z represents the floor in which the terminal is located whereas X and Y represent its localization on this floor. This approach makes it possible to adapt the graph according to the modifications of APs or the deployment of new ones.

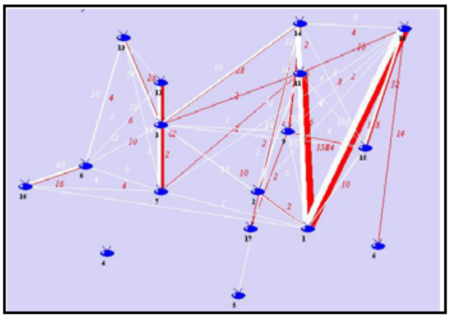


Figure 6. Roaming between AP

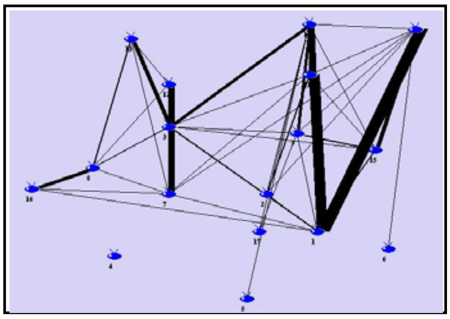


Figure 7. Concentration areas

Finally the fourth (part D – figure 5) displays some diagrams and statistics related to the analyzed period. The diagrams are updated automatically when the elements represented change (coupling with the dynamic routes described previously). It is possible to stop the progress of the Re-play at any moment and compare the statistics with other periods. The majority of the graphs are calculated according to access or users percentages, which give a clearer vision and allows a fast interpretation of the results. For example, the zone of concentration that we see between X and Y (figure 5), can be explained when we see that 46% of access are completed via the AP X and that the majority of accesses comes from the AP Y.

4. SOME RESULTS

This section examines results related to users' behavior based upon the studied period (30 weeks trace). We begin by analyzing the overall activity within all the period. After that, we talk about users' mobility among access points. Next, we focus on daily usage patterns. Finally, we argue the mobility frequency and the amplitude of displacement. Where appropriate, we give some comparison with previous studies.

First of all, we analyze users overall activity within the total period. The questions we asked were how, when and where the network is the most used? Figure 8 shows the total number of active users present on the network during the studied period. These patterns reflect the office environment work hours. In our case, the main period of activity was more or less foreseeable and situated in days period where we can observe that the activity is higher some days than another.

This kind of observation can be very useful in completely free period of activity including night and week end. In a context of overlapping between learning and leisure the activity become highly unstructured (there is no more “official” period of activity). In such case this tools can help to understand individual or collectives rules underlying the activity.

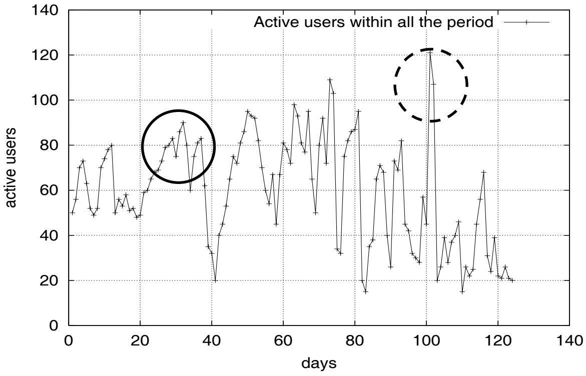


Figure 8. Total number of active users over all the period

Other results concern users mobility. We see in Figure 9 the frequency of mobility (i.e. the total number of users' roaming between APs) during the studied period on weekdays. The comparison of Figure 8 and 9 gives more details about users' behavior and the level of activity. Indeed, we see that for the same activity level in different days (figure 8), we can have large difference in term of mobility (high or limited roaming in figure 9).

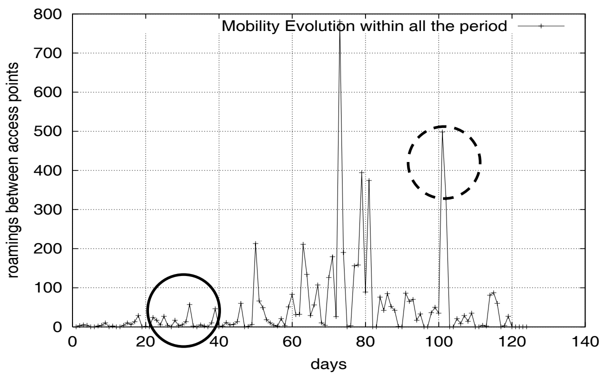


Figure 9. Mobility frequency each day over all the period

We can also observe in figures 10 (a and b), that for an identical distance covered among access points, some users move on a more significant area, whereas others do it on a smaller area. About 18% of users visit more than 50% of APs and 10% of APs see 90 of total users. The figure 7-a shows that most users moves around limited number of Access Points (34% of users visited 2 APs, 72% of them visited less than 8 APs during all the period and only 2.5% visited 9 APs) involving short area moves. Whereas the figure 7-b in complement shows that most of the users moves on a limited distances (more than 50% of the users moves less than 30 times during the studied period).

We can also observe users behavior showing sessions duration versus the concentration areas. The average session duration was less than 16min and only 13% are at least one hour (Figure 11). From other hand, we noticed that a few APs were used very frequently and held a large portion of the total number of sessions (AP 1, 10, 12 and 16 in Figure 5). This can be observed in mobility behavior but probably also in time events as session duration.

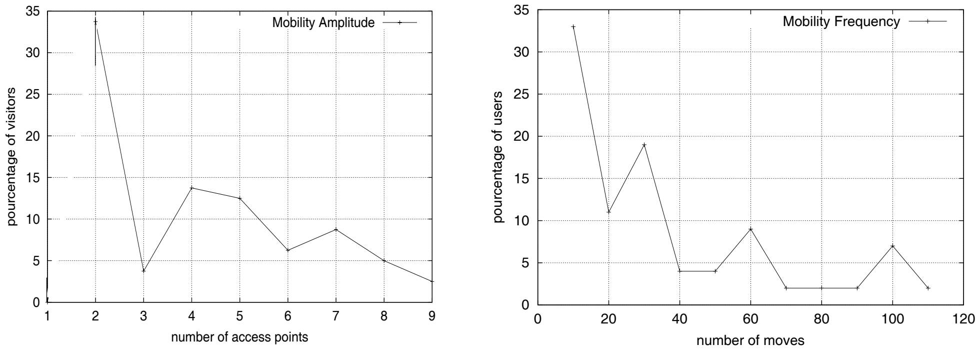


Figure 10. a. Amplitude of movements b. Frequency of movements

In order to clarify this idea, it is necessary to go ahead with more forward study that is outside of the scope of this paper. However, our tool provides all necessary data to feed these future studies.

These observations can draw us to several remarks. First there are clues showing that mobility context follow scale-free/small-worlds rules well known in other field of science [LAN06]. For example, it is well known that main of the human population leave on limited area (big cities).The corresponding behavior has been modeled through power law type (Pareto, Zipf, etc).

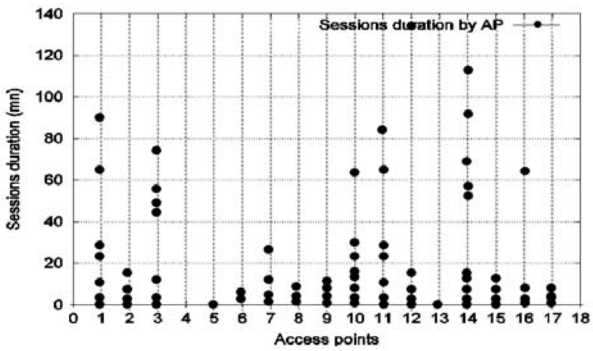


Figure 11. Session duration by AP

5. CONCLUSION AND PROSPECTS

Previous researches in mobile learning deal specially with technological and pedagogical problems. It seems important to us to highlight a particular problem related to this subject which is the learners' behavior in the wireless environment.

For that reason, we developed a tool destined specially for the analysis of the communication between individuals in a context of mobility. We insisted on the fact that an objective analysis required various elements which should be available together in the shape of a dashboard. From an ergonomic point of view, the interest of this approach is to facilitate comparison and analysis of several views of learners behavior (isolated or in groups, temporal dynamics, movement areas, etc).

We have showed some briefs results of preliminary analyses which we could carry out, but it is especially the description of the tool and its context for use that we wished to present here. In the continuation of our work, we will think about the use of this tool on a more significant population and over a longer period. Our goal is to get more detailed information on the link between the mobility routes and other forms of activities (meeting of learners, exchange and access to the data, etc).

Even if learners' behavior was the main topics of this paper, it should be considered that such tools can be apprehended in a more general goal in order to understand human or object mobility behavior. Indeed, mobile communication tools become parts of every one (e.g cellular phone) or every things (e.g RFID, GPS). In such complex pervasive world where computation and communication bring continuous link between humans and things, traceability and modeling methodology will offer keys for understanding and open perspectives. But as always rich perspectives may comes with drawbacks. Indeed, extended and not controlled application of mobility monitoring could represent a potential danger for individual liberty. These questions should be carefully considered.

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