

MoViTo: a Generic Visualization Tool for Mobility Analysis

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Abstract—This paper describes the design and implementation of MoViTo (Mobility Visualization Tool) a generic visualization tool developed mainly to facilitate the observation and the understanding of mobility patterns in wireless networks. As an example, a WiFi environment has been chosen to display the usage of this tool but other context (such as ad-hoc networks) can be studied by adapting its generic entities (nodes, links, and graphics) and input data trace (e.g. signal strength instead of event log) to each situation. The starting point of our study is an overview of the literature on the field of mobility analysis in mobile telecommunication systems. These researches show the importance of understanding wireless usage and provide some related measurements. However, the interpretation of the results of purely statistical nature still remains difficult. For this reason we think that a visualization tool may be a fast and efficient way for characterizing the usage in such environment. Among our goals, we wish to develop an open tool, capable to be adapted to several contexts and to produce an easy interpretable dashboard. The monitoring can be focused on several parameters. For example it is possible to examine nodes moves over a given period and/or a specific geographical area. The preliminary analysis given at the end of this article relate to 21 week trace of a WiFi corporate network used by more than 240 employees carrying various kinds of wireless devices (laptops, PDA...) and communicating (Mail, Internet, IM, etc) via 17 WiFi Access Points.

Keywords— *Wireless network, Mobility, visualization.*

I. INTRODUCTION

The evolution of wireless networks has been one of the most exciting trends in the communication industry during the last decade. In fact, the convergence between wireless systems such as cellular telephony, fixed wireless and satellite communications and the explosion of new wireless devices, like smart phones, personal digital assistants (PDAs), and laptops provide users with information whenever and wherever it is needed. These innovative characteristics have encouraged ubiquitous interactions between users and/or devices. It seems very interesting to understand how, why, where and when mobile users and wireless devices move in order to provide more personalized timely and high-quality services. Furthermore, such understanding could help those who work on wireless technology to better design and deploy future networks and associated applications. Recently, several studies had been carried out to analyze the usage patterns in

real wireless networks such as corporate WLAN, university campuses, and metropolitan networks (see the state of the art section). In this paper, we extend these works by proposing a generic visualization tool intended mainly to facilitate the observation and the understanding of mobility patterns in wireless networks. It is composed of generic modules and components which can be adapted to several contexts in order to visualize different activities (users' mobility, ad-hoc network topology, exchanged messages, signal quality in wireless system ...etc.).

In the following, we first introduce visualization in wireless networks and related works in the literature. Then we present the design and the general architecture of the tool. The next section is devoted to describe a context of our study which is the analysis of office mobility patterns and finally we present some results before we conclude.

II. RELATED WORKS

A. Trace Studies

The analysis of traces has been used in a lot of context involving computer based devices. Several of these works, for example, aims at modeling and understanding the Web user behavior were used for CRM (Customer Relationship Management), intrusion detection, etc [2].

Within the few last years, different researchers performed various studies on wireless network usage characteristics and performances. Some of these works were focused on a particular network such as WLANs in [1][11] corporate wireless network in [10], university campuses [5][7] and a public hotspot [10]. Whereas, others deal with the usage characteristics of particular devices such as PDA [9] or laptops [15]. In addition to the main aim mentioned in the introduction section, there is another important reason to study wireless mobility which is the efficiency of simulation tools by discovering new more realistic mobility models.

In order to interpret their results, researchers provided a set of graphics obtained from different statistical tools which requires a specific adaptation to each context. Until now there was no tool which gives a complete visualization graphs about mobility of a group of nodes accompanied with statistical elements which explain what we are seeing in the graph. The

next section gives an overview of the existing applications and shows the contribution of our tool.

B. Visualization of wireless networks

The visualization tools used in the context of wireless networks can be classified in two main categories. *Cartographic applications* associated with real or simulated moves and *metrological applications* which rather give quantitative syntheses. Let us quote some of these works.

We find first, graphic open source tools like NAM (Network AniMator) [21] which make it possible to display results extracted from simulators such as ns2 (figure 1). These systems are based on simulation models like Random waypoint or Random Walk which are instructive but, in fact, not very realistic [18][19].

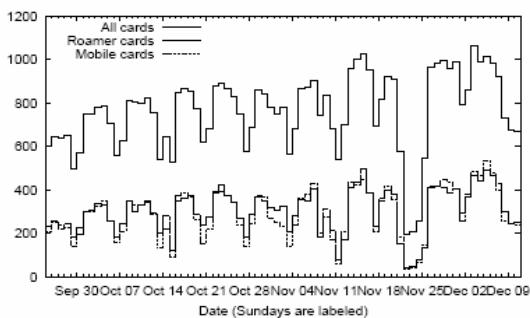


Figure 1. Mobility visualization [05]. Number of active, mobile and roamers cards per day.

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 [17], carte.pl [13], Stumbverter [22] and GSPmap [16]. The majority of these programs are intended for the APs localization (figure 2) or coverage areas visualization.

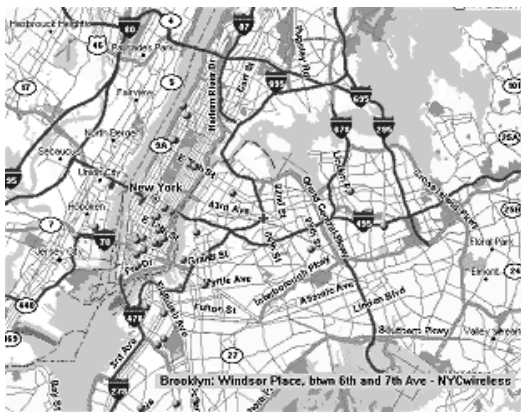


Figure 2. Visualization of APs localization. The points on the map show the APs recorded by NYCWireless (nycwireless.net) in the New York town.

Other researchers [23] adapted generic visualization tools to their own needs. This is the case of RIVET visualization

environment for example [4], 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 [6]. This tool offers a good way to visualize the connectivity and link quality (capacity) between the laptops in wireless ad hoc networks.

The majority of these applications helps to understand the mobility context under a particular angle. It is difficult to find an application which gathers up the visualization of dynamically changing mobility graphs accompanied with descriptive statistics. The aim of our research is to improve the understanding of wireless networks usage by giving an intuitive visualization tool which allows the integration of statically and dynamically extracted data.

III. MoViTo DESIGN

This section shows some details about the design of the tool we developed. It presents the methodology of traces collecting and the main modules and components of our tool.

A. Overall architecture

The motivation behind the development of MoViTo is to facilitate the interpretation of mobility patterns and discovering more realistic mobility models. The total system (fig.3) consists of three main modules. The first one is the collector component which extract the location of the access points and devices (represented by (x, y) coordinates) and also the trace generated or the signal quality (the item to be analyzed is chosen from a list of possibly extracted data).

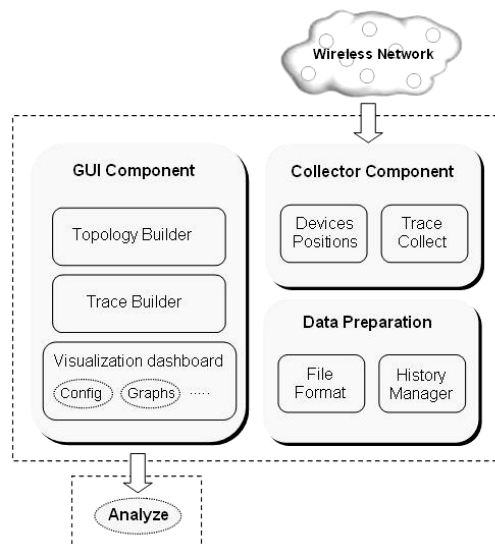


Figure 3. Overall architecture

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

B. Description of the main components

As we have said in the previous section, MoViTo is composed of three main components. In this section we will give some details about their design and functionalities.

- Trace Collector Component:** It is composed of two essential parts; the first one (position detector) deals with the retrieval of nodes positions and the second one (trace manager) for trace collecting and handling. The script used to detect devices positions can be combined with wardriving tools such as NetStumbler, Kismet or Aircrack-ng [17]. These tools offer wireless network discovery, mapping and traffic Analysis. Also the trace management part can use a Syslog [24] server and SNMP [25] in order to scan and provide periodically traces and other information from the Wireless Access Points. These data will be 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, link quality etc). We use a MySQL [20] database in order to gather all information about the wireless activities. This will facilitate the extraction of data and graphics.

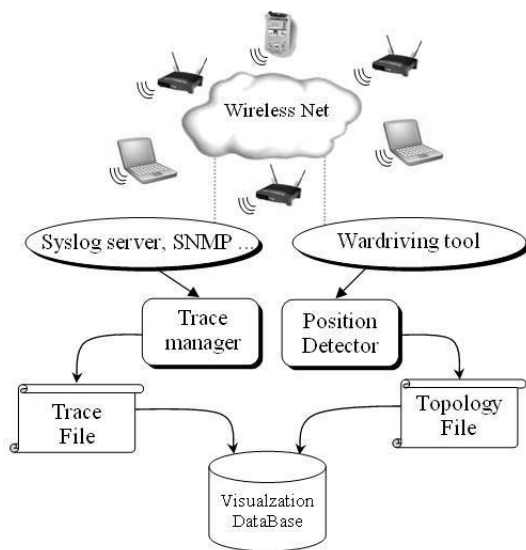


Figure 4. Approach for trace collecting

- Data Preparation Component:** this module deals with the specific input format for each context and manages the traces history in order to facilitate comparison of several periods for example. The files, generated from the previous module (Collector Component), hold information about nodes localization and their space-time activities. The current module uses these files as input and generates

a specific format as output. The figure 5 is an example of a generated file. We can see the device or Access point (AP) names and (X, Y) coordinates. It is followed by the date, time and several values which represent the data related to the other devices. For example Val 1 is the number of messages sent to node 1, Val2 towards node2 ...etc. In fact, each value represents the link between two nodes in the graph.

```
#
#NAME Xpos Ypos TYPE DATE TIME VLA1 Val2 VAL3 ... Valn
#
AP-SAS12 130 67 APN 20/03 21:40:03 18 32 24 ... 93
AP-RC16 205 43 APN 21/03 11:32:17 37 51 27 ... 91
AP-SAS12 98 107 APN 21/03 13:18:00 18 39 41 ... 65
```

Figure 5. Example of an input file format

- GUI component:** This component regroups a set of dynamic graphs destined to mobility analysis. It is divided into three main areas; a setup part, a graphic part and an options part. The setup part is dedicated to specify the context of study (i.e. the definition of the geographical area, the period of analysis and the group of nodes to be studied) see fig.6. The second part shows several dynamic graphs and histograms that are generated from the real traces. It integrates statically (such as Access Point names and positions ...) and dynamically extracted data (e.g. messages, devices moves, signal strength ...).

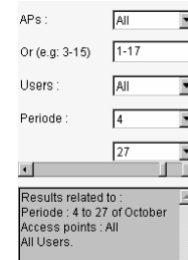


Figure 6. Set up part of GUI component

IV. IMPLEMENTATION

This section presents a specific implementation of the generic tool in the context of users' mobility study. It implements the generic entities presented previously. This tool is composed of a set of on demand graphical area that can be joined in order to monitor or replay mobility behavior. It makes it possible to visualize individual users' routes or routes of a group of users, and gives at the same time statistical results related to these movements.

A. Entities Adaptation

The need for adaptation of the generic tool entities can appear at each particular study. In our case, we adapted its generic entities to a specific context which is users' mobility. Indeed, the nodes represent the WiFi APs with their real coordinates whereas the links provide in replay mode the real users' movements in an accelerated manner, which provides a dynamic vision of mobility tendencies. The Values of these links are of two types: the first one is the color which represents the move to or from any AP. While the second gives

the frequency of movements which is interpreted by the links thickness. Consequently, the graphics highlight users' space-time behavior within the network which is difficult to distinguish in a separated statistic manner. In fact, the graphs are selected from a preset list of generic graphs. We can see in figure7 an example of five interesting graphs useful for understanding mobility. The diagrams are updated automatically when the observer change the parameters in the graphic dashboard (figure6). Let us take an example of these graphs. In figure 7 we see a first graph related to the percentages of access by AP during the replayed period. This will show the concentration areas and give an explanation in what we are seeing in the central graph. Whereas, the two next graphs illustrate the frequency of mobility versus the number of visited APs. It is possible to stop the progress of the Re-play at any moment and compare the statistics with other periods. The last two graphs show the time period when users move over the day hours and within the days of the month. Finally, we can note the session duration graph which is also important in this study.

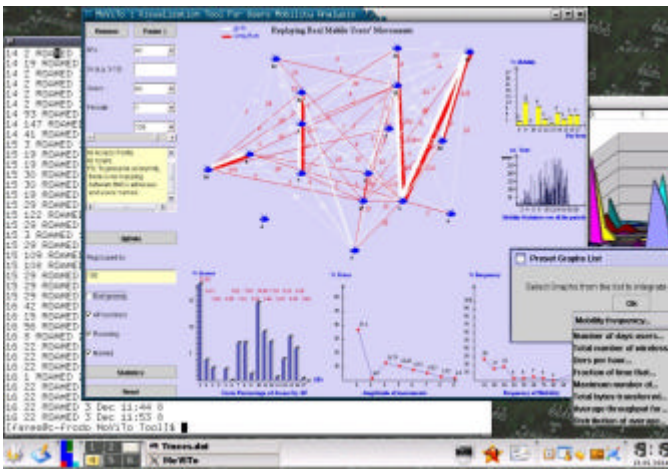


Figure 7. MoViTo adaptation for users mobility

B. Context of use

In this implementation, the trace collector component regroups a set of shell scripts which communicate with a Syslog server in order to collect events generated by the WiFi APs. After that, a Java program stores the data into a specific MySQL database. These messages indicate that a user had associated, dissociated or roamed towards another AP.

The experimentation is related to 240 engineers who reach on 17 WiFi APs, configured to run in infrastructure mode, over 21 week period. They use several types of wireless terminals but laptops were by far the predominant devices on the network. The deployed WiFi network was spread throughout the ground floor and the two floors of a large corporate building.

In this special case, the Syslog messages which we are interested in contain the users devices MAC address, the MAC address of the Access Points, the date and the hour and the type of the event. This last one can be:

ASSOCI: obtained when a device is associated to an AP.

DIASSOC: obtained when a device leaves the AP to connect on another one or it is turned off.

ROAMED: obtained when a user leaves an 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.

C. Graphic Dashboard

The graphic interface regroups a set of parameters and options which make clear the visualization by drawing or not some details. We distinguish four main parts (figure 7): the first one is used for the selection of the context of study which we want to integrate into the analysis. This allows us to observe in a microscopic way users' behavior for example we can focus on a certain area (represented by a set of APs) over a certain period. The second part is intended to improve visualization by drawing some details as soon as the animation is replaying. The third part replays users' movements between APs whereas the last part gives some chosen graphs about their space-time behavior related to the replayed period and APs integrated in the study.

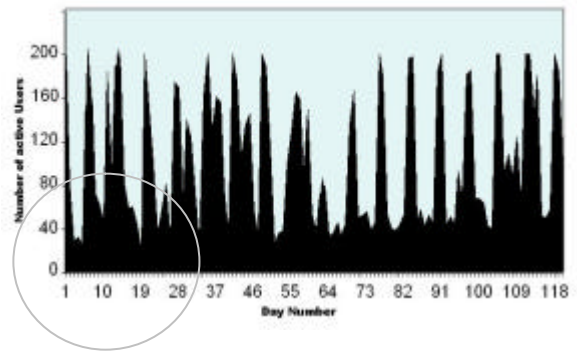


Figure 8. Total number of active users over all the period

D. Some interesting results

This section gives examples of some important results related to the study mentioned previously. More detailed results on a more significant population will be published soon.

First of all, we analyze users' activity within the total period. Figure 8 shows the total number of active users present on the network during different hours of a day. These patterns reflect the office environment work hours.

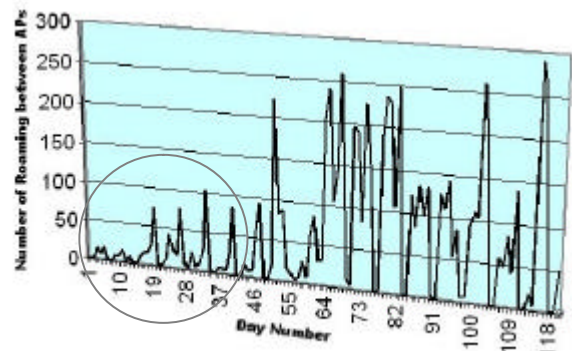


Figure 9. Mobility frequency each day over all the period

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 shows that the mobility frequency gives more details about users' behavior than the level of activity. Indeed, some users are more active than others and we noticed that for identical frequency of movements between APs, some users move at more significant distances than the others. About 18% of users visit more than 50% of APs and 10% of APs see 90 of total users.

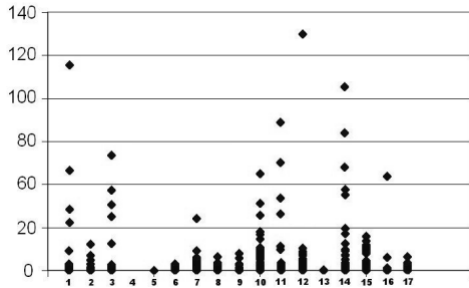


Figure 10. Session duration by AP

The last results related to session duration versus the concentration areas. The median session duration was less than 16mn and only 13% are at least one hour (Figure 10). From an 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, 3, 11 and 14 in Figure 10). These results are different from results on [5, 11, and 23] for example where users access the wireless network for both work and leisure.

V. CONCLUSION

We presented a generic tool destined for the analysis of wireless mobility. Such tool can be easily adaptable to several context of mobility. MoViTo can be use to study users behavior but also tools usage. For example we could wonder if the use of a PDA is more intensive for long distance mobility compared to laptops. It seems logical to answer yes to this question since PDA is more "portable" than a laptop but this is not sure. Only the analysis is able to answer accurately. In a more general case this tool can also be used to analyze car traffic for example to analyze reason of traffic jam or to identify best path for buses. In fact this tool can be used in all imaginable situations related to mobility. The main question remains how to catch basic mobility traces.

It seems interesting to us to gather various visualization elements in the same dashboard in order to make clear the analysis. This approach facilitates comparison of several views of devices and users mobility (individual and collective behavior, concentration areas, roaming time, etc).

In our future work, we plan to include a 3D views in the graphics module to enter another dimension in the visualization. We also plan to develop a mechanism to extract more detailed information on the relation between mobility and other activities, so we can define the new realistic access-

mobility models. More powerful applications such as local replication will then enable the improvement of users' access speed to data.

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