# Study of a Wireless Local Area Network Designed for Remote Monitoring of Mobiles

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*Abstract* - **Some wireless local applications, for example remote monitoring of patients in a care center, have to deal with specific constraints, such as migratory phenomena or the ability to support different qualities of service. Mainly used in office automation networks, IEEE 802.11 standard presents some specific characteristics (cellular coverage, DCF and PCF MAC functions) that fit our needs. One of the main difficulties that is identified in this article deals with the impact of the cell mechanism exchange (not defined in IEEE 802.11 standard) on the network global performances.**

## I. INTRODUCTION

The 90s saw the expansion of general public services and applications dealing with wireless digital communications. The world wide success of mobile telephony services (GSM, etc.) constitutes a significant example. The beginning of the 21st century will see the advent of systems designed for high data rate services (videophony, Internet, etc.) for mobile stations (UMTS, etc.).

Such services are provided on a city, a national, or global scale through public networks. Wireless Local Area Networks (WLAN) can meet specific needs (for instance industrial robotics and medical remote monitoring) without any operator.

This study introduces the research themes initiated by our team. The numerous research projects [1,2,3,4,5] also prove the interest in wireless local communication systems.

The aim of this paper is to study an indoor local communication system which satisfies the following constraints:

- Communications are limited to a bounded area (industrial building or hospital).
- Communicating entities may be mobile (people, robots, etc.), of which there may be several dozen. Their typical maximum speed is about 1 m/s.
- Number of mobiles per area unit is not uniform (preferential path, migratory phenomena, etc.).
- Traffic within a network may need different priority levels (alarms, orders, downloading, etc.).
- Mobile entities must be roughly localised for a rapid intervention (medical alarm, breakdown, etc.) without any additional hardware apart from a network card.
- The type of chosen modulation (radio, microwaves, infrared spectrum, etc.) must be compliant with the application environment (electromagnetic compatibility, electromagnetic pollution in industrial environment, etc.).

This paper is organised in the following way. First, we will present the wireless indoor communications domain. Then we will present the aims of the study and justify the choice of cellular coverage. Finally, the action plan adopted for this project is explained.

## II. STUDIED DOMAIN: INDOOR WIRELESS COMMUNICATIONS

To satisfy the numerous indoor wireless applications, neighbouring but distinct WLANs must be able to coexist. Here we find the generic problem consisting in sharing a medium (hertzian domain or infrared spectrum, for example). The first principle that can be applied consists in sharing a given *frequency* × *time* space corresponding to the medium use. But this principle is not sufficient. For example, the free ISM (Industrial, Scientific, Medical) radio bands or other free bands which are compatible with modern technology solutions are limited. So, the use of different radio bands for each application is not a realistic solution.

### *A. Advantages of a short-range medium*

The chosen solution consists in sharing a short range medium so as to facilitate reuse of a frequency band, a time section, a spreading code [6], etc. For example, stations of two networks that are out of range from each other can communicate within each network by using the same radio frequency band, without generating significant mutual interference. The transceiver range in a given communication area depends mainly on emitting power, receiver sensitivity, radiation directivity and exploitation environment (surrounding noise, obstacles, etc.).

The emitting power, on portable equipment, is limited both by the supplied energy, which depends on the size and the capacity of batteries, and by regulations setting the maximum emitting power. According to the type of carrier (person, robot, etc…), a compromise must be found between weight, size and autonomy of the transmission equipment. Indeed, considering that the equipment has to be designed to be carried by a person, for example in the case of medical supervision, it has to be of a « handset » type, light weighing (about 100g), and with an autonomy of several days.

*B. Configuration types*

The use of a short range wireless medium naturally results in considering two types of configurations for wireless local area networks, as shown in figure 1:

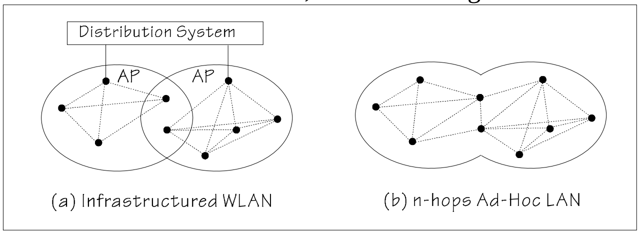


Fig. 1 - Typical configurations for wireless local area networks

Infrastructured WLAN (fig. 1(a))

One or more cells cover the communication area. A backbone network enables cell interconnection through access points (AP). Cells can partially overlap, allowing continuous coverage in which mobile entities can move.

This configuration type requires the preliminary installation in the communication area of an infrastructure backbone. This configuration is ensured by the IEEE 802.11 standard [1], and by the HiperLAN type II project that is about to be standardised by the ETSI (European Telecommunications Standard Institute) [3].

Ad-hoc and multi-hop WLAN (fig. 1(b))

In this case, no infrastructure is used. If two stations are out of range from each other, the source station uses one or more intermediate stations whose task is to relay data to the target station. This approach is used in the ETSI HiperLAN I standard [2]. Ad-hoc wireless local area networks are especially suitable for use when infra-structures are not to be installed (temporary installations, protected sites, etc.).

## III. AIMS OF THIS STUDY

Among the potential applications, we will center our study on the medical remote monitoring of people. Typically, the traffic on the network consists in exchanges between a fixed or mobile service supplier (master) and a mobile entity (slave). We will assume that the transmission equipment has an insufficient range to allow direct communication between the service supplier and a mobile entity. This is mainly due to the compromise regarding autonomy, weight, size and radiated energy, which would be, for example, the case of a communicating cardiac sensor carried by a person. Energy consumption clearly influences these considerations and thus cannot be neglected.

It is now necessary to determine which configuration described previously seems best adapted to the constraints of the study:

*A. Density and mobility*

The density of mobile entities per area unit is generally neither uniform, nor random. Phenomena of concentration may occur, such as concentration of people in a conference room, of mobile robots in a storage area, etc.

Covering the communication area with low dimension cells (micro-cells with a radius of a few meters) enables traffic absorption of huge densities of mobile entities. Managing mobility in a cellular wireless network necessarily implies the implementation of a cell mechanism exchange (handoff). Each mobile is affiliated to only one access point at a given time. When a mobile reaches its current cell coverage limits, and if it can be affiliated to one or more access points with better transmission conditions, the handoff mechanism must affiliate the mobile to one of these access points.

In an ad-hoc network, mobiles have to transmit both their own data and relayed data from other stations. Greater concentration of mobiles in an area enables more connection possibilities. Conversely, stations may be isolated or out of range from the application server. In fact, efficiency of the relay mechanism depends on the connectivity of the network [7].

In addition, as the application has to limit energy consumption of mobile entities, it seems inappropriate to let moving entities support relayed traffic between stations that are out of range from each other. In an ad-hoc network, the energy needed for communication depends on the distance between the mobile and the application server, and on the density and the distribution of mobiles between these two entities.

*B. Quality of service (QoS)*

Applications designed for remote monitoring of mobiles may need different kinds of traffic (alarms, orders, downloads, etc.). Each may require different performances (delay for alarms, reliability for downloads, etc.). The standards mentioned include the concept of *quality of service* (QoS). Different classes of traffic are defined to satisfy those requirements and to allow deployment of solutions having real-time constraints.

In the case of network congestion, (heavy traffic due to mobile concentration in a cell, multiple simultaneous changes of cells, etc.) the system must permit important traffic classes to access the medium. Consequently, the network must either share the medium bandwidth between all the stations, or give an advantage to determined traffic classes.

In a cellular network, quality of service may be managed independently in each cell. For example, within its cell, an access point can play the part of a coordination point and poll its affiliated mobiles for data, according to the various required classes of traffic.

In an ad-hoc network, implementation of quality of service is much more complex. Difficulties arise directly from the network architecture. Because of mobile entities, choosing coordination points is a difficult task. In addition, mobility can involve concentration or isolation of stations, making quality of service management, and more generally communication, very precarious.

*C. Geographical localisation of the mobiles*

With cellular coverage, access points can represent reference points in terms of position, such as for example a room or a corridor. At any time, the affiliation of a mobile to an access point enables the calculation of an approximation of its position. The accuracy of the localisation thus depends on the size of the cell.

In an ad-hoc network, there is no point of reference. Geographical localisation is impossible to implement without using an additional device.

Taking into account the constraints mentioned above, cellular coverage using an infrastructure seems best adapted to our project.

## IV. ACTION PLAN

*A. Inventory of existing solutions*

Taking into account the needs expressed previously (management of several qualities of service, localisation, etc.), use of an infrastructured wireless solution seems more adapted for a local area network designed for monitoring mobiles. Among the proposed solutions that are based on this architecture, several can be used potentially (GSM, DECT, HomeRF, BlueTooth, Hiperlan II, IEEE 802.11, etc.). Nevertheless, apart from IEEE 802.11, all the other solutions do not fully satisfy our needs (GSM uses cells that are too large for our application, and must be used through an operator ; no manufacturer proposes products based on the Hiperlan II protocol). Until now, IEEE 802.11 has constituted with DECT one of the only solutions that can be really explored (the emitting power and consequently the cell size can be specified, quality of service is managed with the option called Point Coordination Function (PCF), and several manufacturers propose compatible products).

Figure 2 shows a standard office architecture using existing IEEE 802.11 products in infrastructure mode.

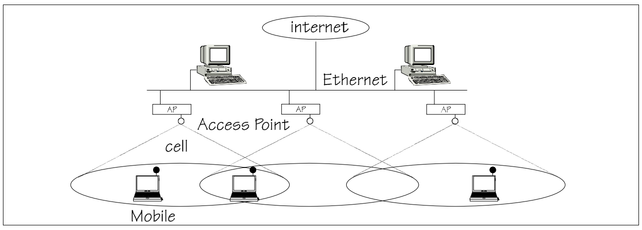

Fig. 2 - Typical IEEE 802.11 office WLAN

Typically, this kind of architecture extends the wired network to personal computers that use an IEEE 802.11 compatible card. These personal computers can then communicate with both stations that are connected to the wired network and other wireless stations.

Generally, manufacturers guarantee that their products are fully compliant with the IEEE 802.11 standard [1]. Nevertheless, it's not sufficient to satisfy the specific needs of a monitoring application for mobiles. For example, as PCF is only an option in the standard, it might not be implemented by manufacturers. Moreover, if the ability of current solutions to manage cell exchanges is beyond doubt, we have to establish the real performances of this process. The requirements of our application may exceed the performance of the cell exchange process (in duration, use of bandwidth, energy consumption, etc.) Finally, proposed solutions are adapted to office automation use, and may not be suitable enough for our specific use.

*B. Specificities of a wireless local area network designed for monitoring of mobiles*

Figure 3 illustrates the network studied for remote monitoring of mobile entities.

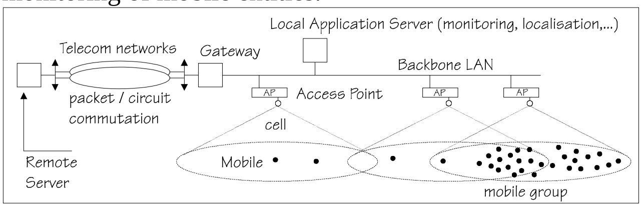

Fig. 3 - Network studied for mobile entities remote monitoring

The studied network has several requirements, which are:

- heterogeneous distribution of the mobiles; several mobiles (several dozen), can be concentrated at one moment in the same cell (a television room for patients, a warehouse for robots, etc.).
- cell exchange of several mobiles (several dozen) during a short lapse of time, according to modelable migratory laws (patients leaving a television room at the end of a movie, etc.).
- management of several qualities of service (alarms, orders, downloads, etc.).
- localisation of mobiles (implementation of primitives to access affiliation tables in order to know which access point a mobile is affiliated to, and accessible by higher protocol layers).

- optimised energy consumption management (use of a standby mode with periodical active mode, transmission power setting according to the distance between the mobile and an access point, etc.).
- the ability to interconnect the system to distant servers using a telecommunication network (ISDN, etc.). In this case, the system must guarantee a continuity of the quality of service from the mobile to the distant server.

All these requirements must be studied and may necessitate specific research in order to check the adaptability of existing solutions to satisfy our needs.

### *C. Study of a wireless local area network designed for monitoring of mobiles*

Adapting a wireless local area network to mobile monitoring implies the investigation of different fields (handoff, quality of service, localisation) that are not primordial in office automation use. The system must also be able to adapt itself to the behavior of the mobiles (migration effects, immobility of mobiles in a coverage area, etc.). The particular context of an application designed for mobile monitoring implies observation of migratory laws and a study of the typical distribution of those entities within the communication area (for example, a room shared by all the patients has to be able to support a greater traffic than a private room).

Different kinds of transported data require different qualities of service. Evaluating the needs must be preceded by a stage during which traffic is classified. It consists in evaluating the requirements of all the different kinds of traffic the network will have to transport, and defining minimal performances that the network will have to provide for them. For example, a handoff must be performed within a predefined time, and must be effective within a predefined mobility speed limit.

The handoff mechanism which is generally not standardised (IEEE 802.11 standard specifies only necessary tools to implement it, for example measurements of signal-to-noise ratio, reception power of the signal), must be perfectly known, in order to enable an implementation that satisfies our needs (in terms of delay, bandwidth, energy consumption, connection conservation while moving, limits, etc.).

### *D. Specific developments and intervention strategies*

Several intervention strategies have been evaluated [8,9]. Among these solutions, some can be implemented. Choosing one depends on many criteria, the main ones being the technical support of manufacturers, and the training necessary for mastery of the different development and model tools.

The simplest solution would consist in modifying the existing driver and firmware sources of a card in order to add new functions. This strategy inevitably requires getting a card driver source and is very dependent on manufacturers.

An other solution which is much more independent of the hardware, consists in developing a virtual driver between the network layer and the data link layer, i.e. between the IP stack and the card driver [8].

An other solution consists in letting the driver manage the whole data link layer, the card performing the basic functions of transmission and reception [9]. This solution requires rewriting the whole data link layer protocol. It is both difficult and time consuming, and much less powerful, as new software managed functions were previously managed by the hardware. In our specific case, where real-time is an important need, this solution appears to be less applicable than the two preceding ones.

Whatever strategy is chosen, knowledge of writing drivers is necessary.

## V. CONCLUSION

In this paper, we have presented the main functions that a WLAN designed for remote monitoring of mobiles must offer. Cellular coverage best satisfies the specific needs of this application, in terms of Quality of Service, rough localisation and migratory phenomena. We chose to explore a solution based on the IEEE 802.11 standard. Future studies will enable us to evaluate, first in theory, and then by experimentation, the limits of such a solution subjected to this kind of application.

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