Defining New Structural and Mobile Support to Improve Hospital Facilities Access and Usability

Alessandro Carlini[1,3], Pierluigi Dalla Rosa[2], Bartolomeo Montrucchio[2], Ivan Cenci[1], Francesca Maria Claudio[1], Giovanni Luongo[1], Jacopo Spigaroli[1], and Giuseppina Gini[1]

[1] ASP, Politecnico di Milano, piazza L. Da Vinci 32, Milan, Italy
[2] ASP, Politecnico di Torino, Corso Duca degli Abruzzi 24, Turin, Italy
[3] University of Bourgogne, Dijon, France

{pierluigi.dallarosa,ivan.cenci,francesca.claudio, giovanni.luongo,jacopo.spigaroli}@asp-poli.it, alessandro.carlini@u-bourgogne.fr, bartolomeo.montrucchio@polito.it, gini@elet.polimi.it

Abstract. Our target was to improve mobility services within a large hospital center. We considered a modern hospital as case study. Our work had the valuable support of the San Raffaele Hospital (hSR). About patients and visitors' mobility we found vast room for improvement in terms of user-orientation and support to disabled people. We analyzed people flows and service accessibility, to design an integrated mobility support service and generate the final solution. As smartphones provide a countless variety of communication channels, the challenge was the definition of an effective solution for people mobility exploiting these devices. After choosing a location-aware WLAN for tracking Wi-Fi devices, we defined the characteristics of the application for smartphones, and implemented a prototype. Many indexes, such as smartphone adoption growing rates, promising profitability studies, and massive portability of the mobile device indicate a smartphone application as an innovative and valuable support to improve mobility in hospital centers.

Keywords: Hospital areas, mobile services, support for disabled, orientation and navigation.

1 Introduction

The healthcare system is currently facing the challenge of integrating medical care with services able to improving liveability and access to services, for patients and personnel.

The authors had the opportunity to work in the REMEDIA - REinvent MEDIcal Ambient Project, sponsored by the Alta Scuola Politecnica (ASP) school (*www.asp-poli.it*), whose objective was exploring new opportunities to design the "hospital of

J. Weber and I. Perseil (Eds.): FHIES 2012, LNCS 7789, pp. 55–71, 2013.

the future”, where medical care goes along with liveability and socialization in a technologically-advanced environment.

The medical partner in this project was the San Raffaele Hospital (hSR), an hospital which is actively responding to this challenge creating many services to improve the effectiveness in care and liveableness (a zoo to entertain the youngest patients, pet therapy, shops and bars to make the medical environment more enjoyable, an hotel to give the opportunity to relatives to take care of patients, etc).

Today hospitals are facing new challenges and traditional (continuous) necessities to improve cost-effectiveness and liveability of the proposed services. Beyond the “pragmatic” aspect of the services effectiveness, today every hospital administration has to plan carefully any economical aspect, with more attention than in the past.

This is one of the reasons why today we can notice a reversal trend, toward a unification of distinct facilities. This unification has an important role in charges reduction, and could lead to fewer equipments and brand new performing machines; nevertheless the inevitable consequence of the unification is the increasing in system complexity and the more difficult access to services [4, 9].

The development of the technology field continuously equips us with new tools and –possibly– new solutions. The aim of the present work is to marry these new technologies to the new approaching necessities of the hospital environment.

The first indefeasible duty is the access to services, which mostly consist in the physical access to buildings, structures, rooms. New hospitals are frequently characterized by wide areas and many buildings. As a result, the simple activity of finding the way for a specific ward can become a real challenge for patients and visitors. The problem is further amplified for visually impaired patients, who experience difficulties in reading signs; and to wheelchair users, whose mobility is restricted to particular paths.

In our project we addressed the issues described above, aiming at designing an integrated and innovative mobility support system capable of helping users navigate and reach given places and deliver desired services.

It is important to note that the main objective of the project, i.e. the improvement of the liveability of services offered to users, comes with objectives reflecting other stakeholders' perspectives as well. On the one hand, a hospital needs to guarantee and improve profitability and visibility. On the other hand, several public and private authorities push towards the improvement of the working conditions within hospitals. Following a win-win approach, the present project was developed to meet these different needs and requirement at the same time.

The macro-activities identified as significant, carried out, and described in the following Sections, are:

- Objective focus. In this phase the Team investigated the actual state of “user-oriented” services, and pointed out the opportunity of improving the mobility support service;
- Stakeholders' requirements analysis. Once detailed the scope of the analysis, we worked to elicit Stakeholders' requirements. Particular attention was reserved to patients and visitors, the final users of the service: their requirements were investigated through semi-structured direct interviews;

- Flow analysis. In order to detail the current situation of the hospital mobility service, we analyzed the actual state of patients and visitors' flow within the public areas. The analysis maps the macro-blocks that compose the hospital and the paths connecting them;
- State of the Art analysis. The analysis of best practices in mobility was useful to explore opportunities and generate new ideas. The Team developed a broad investigation, also taking into consideration best practices outside the medical environment but relating to different contexts, as mobility support is an issue that several contexts have in common;
- Generation of new ideas. Thanks to the analysis carried out and leveraging on the academic background, the Team generated new solutions to address the mobility and the access to service issues. Two concepts emerged particularly: the use of Terminal Units (*TU*) and the use of a Smartphone Application (*SA*);
- Valuation and choice of the final solution. The concepts were evaluated according to relevant criteria, namely resolution of users' mobility problems, popularity among users, applicability of the solutions to the different clusters, impact on hospital key requirements and sustainability. Downstream, the *SA* was chosen as the more interesting and advantageous solution to the mobility issue;
- Detailing the final solution. The *SA* was detailed in terms of functionalities, hardware configuration, software deployment, and interface;
- Economical analysis. We developed an "evaluation tool" to support the investment assessment and to estimate benefits in adopting the new solution. The tool was made run with standard hospital data; the outcomes were used to perform a sensitivity analysis on the most critical variables;
- Demonstrator building. The point of arrival is represented by the development of a *SA* able to simulate the navigation along a demonstrative path. It provides information about directions and time to destination, name of the final destination, ads and extra contents.

2 User Requirements

Being this a research for a new solution, the first step necessarily was the identification of the stakeholders; then, their needs and requirements were analyzed and validated.
The identified stakeholders are:

- patients and visitors: all patients receiving treatments in hospital and all people accompanying or visiting such patients;
- hospital personnel: doctors, nurses, et;
- hospital technical area; in our case the Team had the valuable support of the IRIS (Innovation & Research in life and health Services Unit) technical department of the hSR;
- Customer Service, the office responsible for customer relation management.

Other stakeholders identified in the present research, although only indirectly involved in the project, are *Regione Lombardia* and *Ministero della Salute*, respectively the local administration and the ministry of the Italian government addressing public health.

Each stakeholder has specific needs that determine the requirements to be taken into consideration to ensure the success of the project. The needs and requirements were gathered through meetings, and were validated by analyses of the context. In particular, the validation of patients and visitors' requirements was carried out through direct interviews, and subsequent cluster analysis.

The scheme above well fits a “mutually beneficial collaboration” [3], meaning that the problems posed relate more on organizational implementation rather than on conflicts among stakeholders. Indeed, the improvement of the mobility support service meets the main needs of the different stakeholders.

2.1 Interviews

The identification of users' requirements in relation to mobility was carried out through about 30 closed questions, elaborated on the basis of a Fishbone Diagram (Figure. 1).

Fig. 1. Fishbone diagram

We interviewed 128 patients and visitors. The interviews, any of which lasted between 15 and 40 minutes, were composed of two parts. The first part consisted in 30 questions with closed answers, aimed to identify the main problems of the users in relation to mobility; the second part was an open-question session aiming to gather the personal insights and suggestions for possible improvements. In the development of both parts the Team was supported by the hSR Customer Service Department.

The answers were classified, normalized, translated in quantitative parameters (where necessary) and analyzed [5]. The analysis was performed through a Pareto approach [8] that allows ranking the problems and defining the priorities of intervention. The main results show the macro-causes of the scarce level of satisfaction towards the mobility support service, namely long waiting times, scarce information, and bad passageways organization.

Following we synthesize the results of the first part of interviews. About information availability the main criticalities are shown in Figure 2; their causes, derived using a Pareto approach, are depicted in Figure 3.

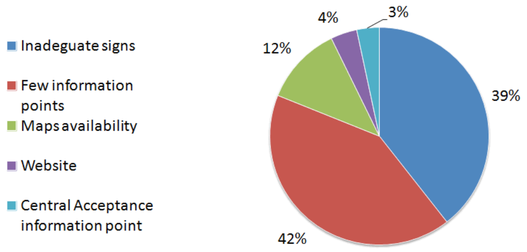

Fig. 2. Pie chart representing an example of the main criticalities and the possible improvements in the current Mobility Support System

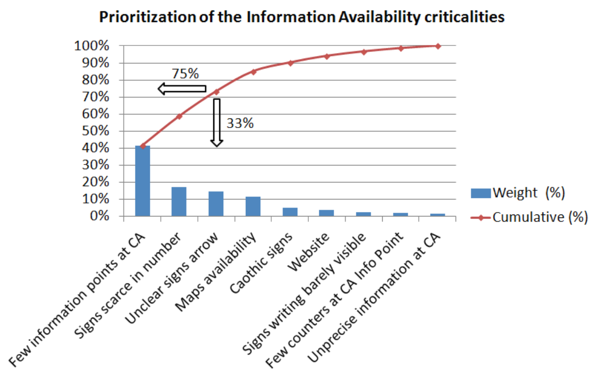

Fig. 3. Third-level causes (with relative weights) of the macro-cause “Information availability”, ordered from the most relevant to the least relevant. On the basis of the Pareto law, the arrows underline the dominant causes (CA = Central Acceptance).

Two questions addressed the problem of waiting times. Their analysis showed waiting times at the Central Accepting Office as the “perceived as more relevant” problem; other criticalities are related to the scarceness of parking lots, the distance of no-fee parking, and the path from the parking to the entrance of the structure.

2.2 Cluster Analysis

We explored users' requirements through a Cluster analysis. This analysis is justified by the principle that the totality of patients and visitors is not homogeneous: different typologies are characterized by distinct habits and preferences. Three segmentation criteria were considered predictive to determine the attractiveness of the new solutions:

- How familiar they are with technological devices;
- How familiar they are with hospital structures;
- How they reach the hospital.

The familiarity with technological devices was related to the age. Using these criteria eight significant clusters were identified. In addition, two additional clusters representing people with mobility problems were added.

2.3 Analysis of the Visitors Flow

The aim of this analysis was delineating the macro-blocks that compose the hospital public areas, and reporting the problems related to the paths interconnecting these macro-blocks.

The macro-blocks that generally compose the hospital public area are: (1) wards, (2) reception / acceptance offices, (3) administration offices, (4) arrival points of public transports, (5) car parking; and occasionally: (6) hotels and refectory, (7) education centre.

Results show that the paths from the main access points to the Acceptance, and from the Acceptance to the principal wards, are characterized by a flow density much greater than the others; consequently designers must pay much attention to the characteristics of these paths. Other –very common– critical points (also confirmed by the interviewed' answers) are the lack of attentions to relevant aspects like (1) the excessive length of paths, (2) the absence of coverage over the outdoor paths, (3) the limits of the infrastructure for wheelchair users, and (4) the absence or the unclearness of direction signs.

3 Devising Solutions

Today innovative disciplines and new tools allow for infrastructural improvement providing better visualization of routes and simplification in localization and identification along the path (using colours codes, for example), offering more accessible information to the users by innovative way, and so on.

Considering the present trend, the proposed solution gives priority to the use of innovative digital tools. In particular, on the basis of the requirement analysis, we developed two possible solutions to improve the mobility support within the hospital environment: the use of *TU* and the use of *SA*. The two solutions were analyzed and compared in terms of functionalities, performances, sustainability, adoptability, and compatibility with the current hospital structure. All the details are freely available in the whole report at http://home.dei.polimi.it/gini/ASP/REMEDIA.pdf.

3.1 Terminal Units (*TU* Solution)

The *TU* technology can effectively support the mobility in the hospital areas: the "kiosks" equipped with terminal units can provide a variety of services such as "path-finding" and "map-printing", reducing queues at the information points.

We considered that the main reception represents a very important convergence node. We divided the way towards the wards into two parts: the first encompasses the paths linking the main reception to the three access points, while the second one is represented by the segment which separates the main reception from the wards themselves.

It was evident that users who reach the hospital by bus or place their car in the outer parking have difficulties in finding the way to reach the right hospital ward. Consequently it is necessary to place the *TUs* at least in these areas (i.e. near bus stops, outer and underground parking, ward entrances, etc..).
Seven functionalities were identified for the use of *TUs*.

1. Person Identification
For the access to special services or the diffusion of some information it will be necessary to identify the user. The "Carta regionale dei servizi" could be useful for this purpose.

2. Way Finding
The kiosks could represent an important solution to help people find their way through the hospital structures. In particular, way finding could be supported by a traditional "point to point" navigation system (using more powerful systems like 3D representation and way simulation); or by more effective services, such as user & prescription identification for the automatic path generation, a more readable and "pleasant" interface to help people unfamiliar with technology, destination and path colour code explanation, and so on. The way finding function would let people flow inside the village easier, reducing the routing time to the final destination and improving the effectiveness of hospital services.

3. Booking of Visits/Exams
This function would represent an alternative to the traditional booking channels; this interface (also available through the internet, for example) could display dates and timetable to reserve a visit or an exam, modify a pre-existent condition, or give access to a personal area for more detailed services (i.e. report delivery, report history, vaccinations list, clinic folder, etc.).

4 General Document Printing
As the mobility support and the visits/exams booking, this service and the following (content download, payment, etc) could require the protected user identification.

5 Content Download
Technology-oriented people may find it useful to download contents from the kiosks to their portable devices via wireless connection (e.g. Wifi or Bluetooth). Downloadable contents can be both informative (for example, clinic specialties list) and recreational

6 Payments
The payment function includes the possibility to pay for some services (like parking) and to buy prepaid cards to be used in the bar or shops located inside the hospital village. The payment of services or prepaid cards can be made through *TU* via cash or credit card.

7 Parking Support Service
The main issues related to the parking are two, namely the difficulty to remember where the car is parked, as the parking area is huge, and the cost of parking. The use of *TUs* can help to address these issues: kiosks and parking terminal units could print on the ticket the necessary information to locate the car, and also to pay at the exit.

3.2 Smartphone Application (*SA*)

Smartphones provide phone services, email, multi-protocol wireless communications, PDA capabilities and are now migrating from an embedded architecture to a more distributed and programmable one. These multi-functional phones are becoming an effective new way of dealing with digital technology, as they interact with a hybrid real-virtual environment. Smartphones are accessible to most of the people, are personal and are always in our pocket.

These characteristics show the power of smartphones that is going to grow further in the years to come. Smartphone applications, as presented in the state of the art analysis within medical environment, are already used within hospitals. Indeed, the use of a personal device can help users understand information provided in a more effective way rather than an ad-hoc designed embedded system, although the latter could have a better cognitive interface.

Synthetically, the *SA* can support mobility through guiding the user during all his/her movements within the hospital structure. To do so, the system needs data on user's actual position, final destination and every node inside the hospital. The set of functionalities supported would be:

1 Personal Identification
When booking a visit, either via telephone or on-line, patients register using an account linked to their telephone number. Therefore when they arrive at the hospital and connect to the wireless network through the smartphone, the system automatically recognizes their identity via phone number and provides access and application download. Alternatively, visitors or patients that get to the hospital with a different telephone number from the one associated to their booking can access the services provided connecting to the wireless network manually (i.e. entering their identification data).

2 SMS Alerts
The telephone number is fundamental not only for patient identification, but also for extra services like SMS alerts before the visit. The day before the visit the user receives an SMS reminding him/her of the visit and providing information about how to use the *SA* service. The SMS contains a link to the application, which is downloadable from the internet.

3 Payments
The possibility to pay through the device is really advantageous. Indeed:

- It can optimize queues and reduce people stress;
- It improves sustainability by reducing tickets and receipts printing;
- Discounts for mobile payments can be offered to boost people's use of the Smartphone application.

The use of mobile payments is a strong paradigm-changer because of its new way of looking at money transactions. The user can access mobile payment and use phone credit or credit card to pay for medical services, parking or just having a coffee. People can avoid queues and directly present a digital ticket with a signature that matches up with the transaction. Smartphones often have a good resolution of the screen that allows the use of 2D scanners to read bar-codes on the monitor of phones. When the user pays, the system sends him/her a two-dimensional bar code that will be read when the user needs to show proof of payment for the service.

4 Way finding
The way finding feature, which is the core of the present research and the REMOBILA ASP project, works with three degrees of complexity depending on the choice of the users. Consequently, users could choose within three different visualization modes. First, users can let the smartphone guide them or choose to watch the map where it is shown where they are and the suggested route to destination (if the destination is set). Second, if users are technology-oriented they can choose to interact with the map, other than visualize it. Third, if the user is a patient the application could also show some notes about timing, how much time left before the visit, and an estimation of the time left to destination. The system can manage queues in real-time thanks to the tracking feature. If the patient has problems, he/she can request the help of an operator through the application.

5 General Services
The application could provide some general services too, such as booking online. The *SA* represents a powerful platform that can be exploited for different purposes. For example, it could be used for ethic marketing, such as sponsoring the donation of the “5x1000” to the hospital, or signalling the presence of bar, shops or other services when searched by the user. What is more, the way to provide messages must be careful planned, in order to respect the environmental and manners rules and the users’ tranquillity.

6 Physically Impaired People
About mobility inside a hospital structure, a note about physical impaired people is necessary. We focused on two categories of physical impaired people that could take advantage from the *SA*:

- People using wheelchairs: the system can recognize their disability thanks to information given during the registration, or can be notified of a temporary wheelchair use by the users themselves. Consequently the system can guide the users along the best route for wheelchairs.
- Visually impaired people: the system can recognize these users in the same way described for people using wheelchairs. Then, a text-to-speech system can drive the

patients, also providing next step and timing information. This support would be useful also for people whose sight is not good enough to read signs or to read the mobile's monitor.

3.3 Solution Evaluation

The evaluation was conducted on the basis of the following criteria:

- *Resolution of users' mobility problems* - The interviews pointed out that the mobility issues are perceived as a priority.

- *Popularity among users* - The interviews conducted not only gathered users' requirements, but also tested the popularity of possible solutions among users, adopting the Co-Creative approach. Answers showed the most appealing solutions to be the *TU* rather than the *SA*.

- *Applicability of the solutions to the different clusters* - Another important criterion of evaluation was the analysis of the clusters supported by the different solutions. Three segmentation criteria were applied: technological attitude, familiarity with the hospital, mean of transportation used to reach the hospital (see paragraph 2.2). The interview outcome showed that the percentage of people appreciating the *SA* solution increases with the decrease of age. It results that Terminal Units are well-adapted to all users, while –today– the *SA* is tailored for users younger than 64. It is important to point out that the number of people supported by the *SA* is doomed to increase in the next years.

- *Impact on hospital key requirements* - Another important criterion is represented by the solution impact on hospital key performances, as illustrated in Section 2. Both solutions guarantee improvements in patients' satisfaction and hospital image, respecting patients' safety. Nevertheless, they are different as far as profitability and privacy are concerned. A preliminary comparative profitability analysis sees <u>the *SA* solution prevail</u>. Indeed, assuming comparable additional revenues, software costs, and interface development costs, the *TU* solution also requires the purchase and the installation of the kiosks, which are generally expensive. On the contrary, the smartphones solution has the advantage of exploiting a device -the smartphone- whose cost has been sustained by users themselves. Smartphones prevail in guaranteeing privacy too. Indeed, each demanded Terminal piece of information can be seen not only by the patient currently using the kiosk, but also by other people passing by. On the contrary, smartphones are strictly personal, guaranteeing privacy.

- *Sustainability* - The comparison between the *TU* and the *SA* solutions leads to the following considerations. While mobility is supported by the kiosks through the possibility of printing the path to follow, the *SA* provides all the information on the display of the device. Therefore, smartphones allow eliminating the paper depletion implied in the usage of the terminals. Furthermore, the use of smartphones enables mobile payment, that further reduces paper waste (given by tickets, receipts etc.). Finally, the *TU* solution requires the installation of several kiosks within the hospital, which implies high levels of resource consumption both for the production phase and for the operating phase. On the other hand, the *SA* adds functionalities to a device that is already owned by users, so that additional resources depletion for producing and operating the devices are eliminated. Summing up, the comparison between the two solutions sees *SA* to prevail.

In conclusion, the Smartphone device appears as better supporting the user mobility and the service depletion. The device is purchased by the owner in reason of other personal uses/benefits; the confidentiality of information, as well as identification and customization, are a natural consequence "by design". The "portability" of information and services is at the maximum value (the device is following the person, where for the "totem" solution we obtain the opposite condition). Finally, the present availability of services and software assisting peoples with handicaps (e.g. TTS, Screenreader, voice control and dictation input, "Ray Phone", "Fifth Sens", "VizWiz", etc.) suggests the Smartphone-based solution as the more egalitarian and by consequence the finest.

4 The Profitability Analysis

Profitability represents a fundamental requirement. For this reason the financial impact of the solution was studied associating strategic impacts (e.g. increased mobility service level) and main actions (e.g. purchase and installation of infrastructures) to the financial dimensions (i.e. revenues or costs) they have an impact on. The analysis was based on the evaluation of some profitability indexes, namely Net Present Value and Payback Time. Nevertheless, some differences arose with respect to the standard evaluation process [6, 10].

Therefore, an "evaluation tool" was developed. This tool, built on the basis of the analysis of revenue and cost drivers of the project, could be used by any hospital partner for a more precise evaluation of the investment. It has a general validity, and it supports the evaluation of the *SA* solution in wide range of contexts. What is more, the tool was also used to perform a sensitivity analysis on critical variables. Main results are presented hereafter.

The first step of the economic analysis for the *SA* was the translation of strategic impacts into financial impacts [1], as illustrated in Figure 4.

The following feasibility analysis studied main financial impacts, reasoning in differential terms from the actual state case.

The new mobility solution is expected to have a positive impact on hospital revenues, given by the increase in the mobility Service Level (SL) and the ethic proximity marketing. As a result, the total additional revenues per user of the *SA* can be calculated as in Eq 1:

$$\Delta R = \Delta R_{fromCoreActivityPerPerson} * \text{Num-users} + \Delta R_{fromMarketingActivities} \tag{1}$$

where ΔR, the total additional revenues, is given from the sum of the additional revenues from person related health services times the Num-users (= number of users adopting the smartphone solution) and the additional revenues related to additional services (not health related).

A fundamental revenue driver is the number of users adopting the solution. The main parameters that influence this number are:

- number of persons in need of mobility support that go to hospital per day.
- percentage of smartphones in Italy (nowadays around the 25% of phones);
- adoption rate of the new solution by patients and visitors. A conservative value for this parameter, suggested by hSR, is 3%. The internal variables that would influence this number are: effectiveness of the interface, accessibility to impaired people and "Service Level" perceived by users.

Therefore, the total number of users (including in and out patients and visitors) in the year t is calculated as in Eq 2:

$$Users^{t} = Num\text{-}people * \%peopleNeedingMobilitySupport * Adoption.rate * (Adoption\text{-}rate\text{-}growth)^{t} \quad (2)$$

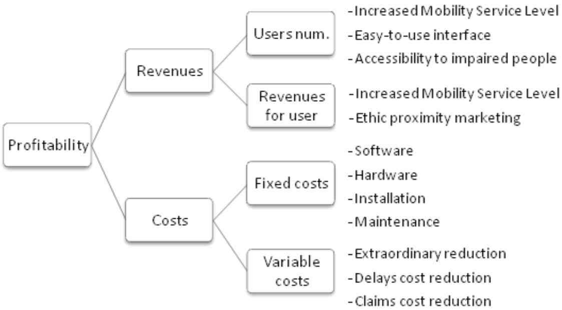

Fig. 4. Transposition of the strategic impact into the financial impact

About costs estimation, we observed that the main impact of the solution would be an increase in efficiency, reducing the cost per person if he/she adopts the solution. Cost efficiencies, which increase with the number of users, would be given by:

- extra hours cost reduction (the new solution would reduce visits delays);
- claims cost reduction (traditionally people experiencing delays result in both image costs and a out-of-pocket costs, like reimbursements and similar);
- delays cost reduction (out-of-pocket costs, such as unexploited machinery activation, unused solution preparation, and similar).

The solution is also associated to additional cost entries, concerning new hardware, software, installation, and training (we detailed and evaluated a possible package; in the present article we avoid to present specific solutions and commercial brands).

5 Final Design and Demonstrator Implementation

5.1 Choice between "Intelligence" Located on the Client or Server Side

The first decision taken was whether to put the "intelligence" (i.e. main database and main elaboration) on the client side or server side. In both cases the user, who owns a smartphone, has to register online - typically at home; then when arriving at the hospital he/she can access information previously downloaded, or may receive networked information. In the client side approach the smartphone is aware of the location of the patient and it is also responsible for location discovery, route calculation and identification. The knowledge of the structure is embedded in the client so the user can simply open the service on the smartphone, enabling it to show information. Using a server to process all the requests about way finding can be more complex but the hospital could have some extra benefits: more control on the system, awareness of the position of users in real-time and possibility to give users only the information they need. The server-side intelligence solution appears to be the most interesting; it guarantees a wide accessibility and a lighter client-side burden. Therefore this model is considered to be the most convenient to develop.

5.2 Designing the Infrastructure

The standard solutions exploiting GPS signals are not sustainable due to the lack of GPS coverage in indoor areas. To support the smartphone location the installation of a location-aware WLAN might be sufficient; this structure might also satisfy other hospital needs nowadays emerging, such as asset tracking, or providing different and new services to the patients.

We found, on the commercial market, systems able to track up to 2500 devices simultaneously, a number in line with the visitors to a modern extended hospital (we verified the presence of other systems with more powerful performances as well).

The chosen system [2] uses a distance-based technique (lateration) to discriminate the position of the mobile device by using received signal strength (RSS) measured by at least 3 access points surrounding it. Proper placement of access points should be respected in order to exploit the full performance potential of the system. Antennas should be mounted such that they have a clear 360° view, without being blocked at close range by large objects. The distance between deployed access points can have an impact on location performance, as well as the performance of co-resident voice and data applications.

In our pilot study, we considered the criticalities of paths in the hospital and we dimensioned the system accordingly (Figure 5).

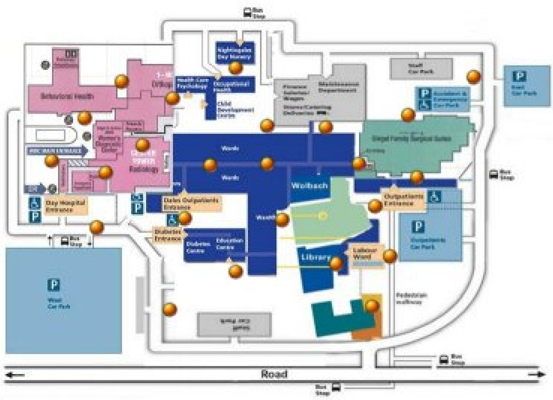

Fig. 5. An example of deployment of the access points

The WLAN infrastructure allows the installation of third-party location clients to reside in the Unified Wireless Network in a complementary fashion to Wireless Control System (WCS), or in substitution to it. WCS is meant to keep track of every device located in the controlled area, but does not send this information to the objects tracked. For this reason it is needed an additional location client with the duty of notifying each single smartphone of its own position. Besides the plain sending of the position to the tracked device, according to the "Server-Side Intelligence" philosophy the system has to calculate the route from the current position to the destination and send it to the smartphone. Finally, an ad-hoc SW installed on the smartphone has the task of showing this information and managing the interaction with the user.

5.3 Designing the Software Application

The point of arrival of the project is represented by the development of a software application to be installed on a smartphone that simulates the navigation along a demonstrative path. In this context, the user interface should guarantee the most clear and quick access to the functions of the application. The demonstrator mainly consists in the elaboration of the mobile application interface, which is a key element in determining the success or the failure of the solution. We developed different interfaces [11] for the different clusters of users identified.

Two alternative scenarios were taken into consideration: smartphone models that do not support native applications and smartphone models that support native application.

- *Web-based location system interface* - This solution is referred to smartphones that have access limitations, due to the API provided by common browsers and poor performance of non compiled code. For these smartphones we developed a simplified solution based on the access to services via browser. When the user joins the hospital wireless network, the main landing page could automatically pop up and open the hospital web service. The website provides a really simple interface where users have to identify themselves. Note that the system uses https protocol as security measure.
- *Native application interface* - This solution is referred to smartphones that have full access to all functionalities provided by the application. When users join the hospital wireless network, the main landing page automatically pops up and supplies the link to download the native application. Its interface can change from user to user according to their specific needs and aptitudes.

A 2D map cannot cover all the floor areas that compose the hospital buildings at one sight. A good compromise between simplicity and completeness is given by a really essential 3D map, where the volumes are represented by few lines while the visualization of the floors remains in 2D. The full-3D representation is the best solution for navigating the hospital space, since it allows virtual navigation and supports next step information properly. Indeed, 3D virtual space combined with a camera model is one of the most accepted ways to create virtual interactive environments [7].

On the basis of the above considerations, we developed and prototyped three different solutions, selectable from the home page: (1) next move information, (2) 2D map, and (3) 3D map. The three associated icons are located in the home page in an effective way. In western culture, attention focuses first on the top-left corner of the screen, and then jumps to the areas with the biggest characters. The easiest navigation modality view, targeted to non-digital natives, has hence to be located where the attention focuses (top-left corner) and is associated to a graphic icon. The three modalities, illustrated in Figure 6, are detailed as follows:

Simplified Navigation view - It shows essential information only, i.e. next step from current position to next node. This kind of interface can be used with headphones too, thanks to a text-to-speech software agent. Consequently, it is suitable for people that prefer audio indication and, more important, for visually impaired people and wheelchair users. We consider that wheelchair users would be facilitated by the use of headphones because it guarantees the possibility to free their hands.

2D Navigation view - This view gives access to the 2D map. Through it, it is possible to see an overview of the whole path from the current position to the final destination, and to search for places of interest. The application highlights the places of interest in relation to the user condition. This view is also useful when leaving the hospital, as the "park button" could guide the user to the car.

3D Navigation view - This last view is the most complex, since the application shows a 3D visualization of the whole hospital structure. Users can navigate the 3D map with the typical gestures of interaction in mobile applications (e.g. tapping).

Fig. 6. The three interfaces for path finding

6 Conclusions

REMEDIA project has been a remarkable example of synergic work, where the harmonization of different expertises (engineering, management, and architecture) of the team members has permitted the success of the project, combining media-oriented interfaces, architectural reproductions of hospital buildings, and studies of technical and economical feasibility. The outcome of this collaboration is the design of the Smartphone Application (*SA*) for guiding users, which is a novel interpretation of the mobility support in which technology represents an important but not fundamental tool.

Indeed, the most challenging task to be faced nowadays is not the development of the technology, which has reached remarkably high levels, but its adequate use in relation to users' needs. To do so, hospital users' interviews were of extreme value, providing requirement insight for the final solution. A strong contribution was also given by the evaluation of the actual state of patients and visitors and the flow within the hospital public areas, which allowed us to spot the problems related to the outer hospital paths.

Translating the theoretical design of the solution into an implementable concept was an interesting and challenging task. We chose wireless triangulation for the assessment of smartphones location, dimensioned the infrastructure in terms of access points and proposed a break-even implementation approach. With regard to the feasibility of the solution, we developed an "evaluation tool" to be used by the hospital for the precise evaluation of the investment. Finally we developed a software application to be installed on smartphones that simulates the navigation along a demonstrative path, including a variety of navigation modalities tailored to different segments.

The designed solution is now taken into consideration by hSRl, presently under huge management transformation, and definitively in favour of extending e-services.

Acknowledgments. The authors acknowledge the Alta Scuola Politecnica for hosting their REMEDIA Project, aimed at designing the "hospital of the future". The work would not have been possible without the strong interaction with Alberto Sanna, head of the "IRIS" Scientific Institute San Raffaele in Milan.

References

1. Azzone, G., Bertelè, U.: Valutare l'innovazione. Analisi e controllo degli investi-menti. Etaslibri, Italy (1998)
2. Cisco Systems Inc.: Enterprise Mobility 4.1 Design Guide, San Josè, CA, USA (2009).
3. Dente, B.: Public policy between authority and consensus – private communication (2011)
4. Hospital Build Asia 2011 Exibition & Congress, Marina Bay Sands, Singapore (2011)
5. Ishikawa, K.: Cause and effect diagram. In: Proceedings International Conference on Quality Control, Tokyo, Japan, pp. 607–610 (1963)
6. Jovanovic, P.: Application of sensitivity analysis in investment project evaluation under uncertainty and risk. International Journal of Project Management 17, 217–222 (1999)

7. Manovich, L.: The Language of New Media. MIT Press, Cambridge (2001)
8. Mathur, V.K.: How Well Do We Know Pareto Optimality? How Well Do We Know Pareto Optimality? Journal of Economic Education 22(2), 172–178 (1991)
9. Optimizing Patient Flow: Moving Patients Smoothly Through Acute Care Settings. IHI Innovation Series white paper. Institute for Healthcare Improvement, Boston (2003)
10. Pindyck, R.S.: Irreversibility, Uncertainty, and Investment. Journal of Economic Literature 29(3), 1110–1148 (1999)
11. Raskin, J.: The Humane Interface: New Directions for Designing Interactive System. Addison Wesley (2000)