2011 Fourth International Conference on Information and Computing

Development of an Indoor Navigation System Using NFC Technology

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***Abstract*— Existing indoor navigation systems face with many different technical and usability problems. In this paper we present a Near Field Communication (NFC) based indoor navigation system called NFC Internal in order to eliminate the current indoor navigation problems. NFC Internal enables an easy data transfer for indoor navigation systems just by touching tags spread over a building or a complex. The proposed system has several benefits and has potential to increase the usability of these systems. We discuss the system requirements and explain the phases of NFC Internal through use cases.**

Keywords- Near Field Communication, Indoor Navigation, NFC Internal

I. INTRODUCTION

Navigation is starting at an origin, travelling along a path to arrive a destination point. Navigation systems provide reading, controlling and updating the movement of one's position and orient while she is travelling on an intended route. If any diversion to outside of the route occurs, reorientation or correction to the destination is done [6]. Since all people use PDAs, mobile devices or personal navigation assistants, and navigation systems can run on those devices, demand and usage of outdoor navigation systems are increasing incredibly today. Outdoor navigation systems are generally based on Global Positioning System (GPS) which is a space based global navigation satellite system that provides reliable location information in almost all weather conditions and at all times on or near Earth [2]. GPS based outdoor navigation systems is a well explored and standardized research area whereas GPS receivers cannot perform well indoor environments because of absence of line of sight to the satellites.

Indoor navigation system has become a recent research area due to the unavailability of GPS indoor environment. Variety of technologies is tested and new designs are generated for indoor navigation in order to circumvent the lack of excellence. The existing solutions for indoor navigation systems are generally grouped as network based navigation systems which are based on networking technologies such as sensor networks [4], and independent navigation systems providing autonomous user positions. Network based navigation systems use technologies such as Bluetooth, Ultra Wide Band (UWB), Wi-Fi, or Radio Frequency Identification (RFID). Position accuracy varies according to the technology used. Wi-Fi and UWB technologies provide higher position accuracy than Bluetooth and RFID technologies. Bluetooth is a simple, compatible short range communication technology which requires expensive receivers; and the position accuracy depends on the amount of cells used.

In case of RFID technology, position accuracy depends on the type of the tags, which is either active or passive, as well as the amount of these tags. Existing RFID based indoor navigation solutions are generally based on usage active RFID tags and require extensive usage of active RFID tags to get good position accuracy. Contrary to passive tags, active tags contain embedded batteries in order to increase the transmitting distance. The major drawback of using active RFID tag based solutions is the high cost of the active tags. Studies in this area [4] also indicate that it does not provide an efficient tracking system.

Wi-Fi and UWB technologies have their own limitations as well. Wi-Fi requires expensive access points in any area where the person needs to be tracked [4]. In case of UWB an efficient indoor navigation system cannot be ensured due to some technical problems of the technology (e.g. antenna mismatch, low power emission, and possible external interference from other systems).

The other popular systems are independent navigation systems based on dead reckoning (DR) methods [5]. When marking position of a person on a map, two types of positioning are defined. Fix position determines the location by using the help of enough number of assisting devices, such as satellites. In the contrary, estimated current position is calculated based on the last fix position, the route, the speed of the item, and the elapsed time between current time and time of the calculation of the last fix position. Navigation systems based on DR methods use this methodology. DR methods use Micro Electro-Mechanical Sensors (MEMS) which are electronic accelerometers, magnetometers, and barometers. The major drawback of DR method based navigation system is that performance of the system is affected by the large errors. The errors of the estimation process are cumulative when calculation of new position is based on previous DR position. Another independent, existing technology is assisted GPS (A-GPS) systems which enlarge the working area of the GPS technology [4]. With A-GPS systems, indoors GPS signals are processed efficiently through an assistance data server which is connected to a reference receiver. However, the signal strength sometimes is too low indoors.

A major limitation of indoor navigation systems is the high installation cost and the complexity of the system design. Additionally, most of the existing positioning systems are far from providing an accurate position in large buildings [4], [5]. Thus, an efficient and low cost indoor navigation system is

978-0-7695-4378-9/11 $26.00 © 2011 IEEE

DOI 10.1109/ICIC.2011.53

strongly required inside large buildings consisting of many rooms, floors and large halls.

Navigation systems for indoor environments can be desirable at any time. For instance a person entering a building for the first time may want to go to an office inside the building without spending much time. Such cases are very common at university campuses, airports, hospital complexes and shopping centers etc. A user-friendly indoor navigation system guiding people through huge buildings consisting of thousands of rooms can be helpful in such cases.

This paper presents an innovative, low cost indoor navigation system called NFC Internal which takes advantage of an emerging short range wireless communication technology; Near Field Communication (NFC). The main idea is to orient users by NFC enabled mobile phones which also have an embedded indoor navigation application. While application orients the user by gathering destination point from user; mobile device gathers the current position from NFC tags and shares the coordinate data with the application. Thus a user can determine her current position inside a building by touching her mobile device to the tags which are spread inside building.

The remainder of this paper is organized as follows. In section 2, NFC based solution to indoor navigation is presented together with the system design and the implementation of the system. Section 3 concludes the paper and highlights future work.

II. NFC Internal

NFC is a bidirectional short range, wireless communication technology. The communication occurs between two near devices within few centimeters. 13.56 MHz signal with a bandwidth not more than 424 Kbit/s [10] is used. NFC technology is based on Radio Frequency Identification (RFID) technology and can operate in card emulation, reader/writer, and peer-to-peer operating modes where communication occurs between a mobile phone on one side, and an NFC reader, a passive RFID tag (NFC tag), or a mobile phone on the other side respectively.

NFC Internal is very simple and easy to use. The user only needs to carry and use an NFC enabled mobile device. Indoor navigation application must be OTA (Over the Air) pre-loaded to the smart card. Than the user needs to simply touch to the URL Tag (NFC tag), that contains the URL of indoor map information just before entering the building or area. The map on the web site is OTA downloaded to user's mobile device from the MapServer (i.e. a web server containing the map information). The indoor navigation application on the mobile phone automatically starts and uses this map information afterwards. As the user selects destination point of her voyage inside the building, the indoor navigation application provides the optimal route to her destination. As the user navigates through the halls, she can touch to the Reference Tags (NFC tags) spread over the building to fix her current position on the map, and then get instructions to reorient her position to destination or to create a new optimal route to the destination as it is required. We believe that NFC technology is a seamless solution for indoor navigation systems when compared with all other existing solutions.

We can extend the use of NFC Internal to additional cases as well. The existing outdoor navigation systems and the NFC Internal can be coupled and such a solution provides higher functionality.

For instance, assume that a new student currently staying in her home and needs to meet with her advisor to perform course registration process, but she neither knows the location of the university campus in the city, nor the office of her advisor within the campus. In such a case, user needs an NFC enabled mobile device which includes a GPS-based mobile navigation system for outdoors and also an indoor navigation application. The student starts the process by entering the name of the university campus and name of the advisor. GPS-based mobile navigation application orients the student until she reaches to the university campus. Map of surrounding area is shown on the mobile device screen, which the student's current position and a route to the campus are also indicated as well [1]. As student moves to the destination, the mapped area and the student's position are dynamically updated on the map. GPS based mobile navigation systems can also provide speech guidance to the student as well. When student reaches to the university campus, she needs to simply touch to the URL Tag on the entrance in order to get indoor map information and navigate inside. After the map is downloaded from MapServer, the outdoor application quickly shares the destination information with the indoor application on the mobile device which is a seamless solution. So, the student does not need to enter the destination address again. Now, user can start to navigate inside the campus by touching to the Reference Tags as described above.

A. System Design

1) Spatial Information Maps: Current Indoor map databases are generally based on 2D graphical representations which are developed by CAD (Computer-Aided Design) systems [3]. In accordance with [7], the CAD drawings of an indoor environment can be separated into floor maps of each floor in the building, and each CAD drawing of floor plan can further be converted into separate spatial information maps that annotate structural features such as walls, doorways, elevators, and staircases. In each separate spatial information map, the reference points are also expressed in vector spatial data structure which uses the 2D Cartesian coordinate system and each map is stored in the MapServer of the Indoor Environment with a unique floor identifier, and also a unique building identifier if the indoor is a complex or campus.

2) Reference Tags for NFC Internal: To navigate indoor environment, NFC Internal needs spatial information to calculate all accessible paths [7]. The indoor environment of buildings or complexes has large number of Reference Tags in our model. These Reference Tags are placed on each rooms', elevators', and stairs' entrances and also in corridors. The number of these tags depends on the size as well as structure and complexity of the building. A description for each Reference Tag is used to allow easy search for destination points, and each Reference Tag includes location information which is comprised from a building identifier data, a floor identifier data and vector spatial data. We use a vector spatial data structure instead of using raster data structure. Usage of vector spatial data allows efficient encoding topology and also network linkages can be efficiently employed [9]. Thus it is more useful for accurate positioning.

3) Algorithm for NFC Internal: With a quick and reliable graph derivation algorithm, the maps downloaded from the MapServer needs to be converted into link-node model with topological relationships, as seen in [3]. A link/node model is composed of corridor, way, road, path between buildings, room, hall, stair, lift, door of interest. The indoor navigation application finds shortest path between the current position and the destination by using these link-node relations. The computation of optimal route is based on Dijkstra's algorithm which solves source-sink shortest path problems efficiently [3], [8], when both the start and end nodes are given.

B. How NFC Internal Works

This section shows how NFC Internal works in detail. The NFC Internal is comprised of two phases: initiating the indoor navigation system and navigating to destination. As described before, the main problem starts with the user who needs to reach to an intended point, but does not know the exact location of the place. In such situation, the user who has an NFC Internal system on her an NFC enabled mobile device is only required to follow the phases hereunder.

1) Initiating NFC Internal:

a) As seen in Figure 1, the user touches to the URL Tag which contains the URL of the indoor's map information on the MapServer. This tag is placed on the entrance of the building. The NFC enabled mobile device gets the address as it touches to the URL Tag.
b) Mobile device connects to the URL via OTA and requests the map information from the MapServer, and the map information is loaded to the mobile device afterwards.
c) After loading the map, indoor navigation application on the smart card automatically starts and converts the map data into link-node model as 2D network with topological relationships.
d) The application asks the user to enter the destination point. User specifies destination point just by choosing the person's name.
e) The application quickly computes the best route by using Dijkstra's shortest path algorithm.

2) Navigating to Destination: After the route is computed, the application starts to orient the user towards the destination. As the user navigates along the path, she can touch to any Reference Tag to validate her navigation. User is only required to touch to a tag on her way to get this valuable help. The location data on the Reference Tag is transferred to indoor navigation application at this moment. It is obvious that information on the tag also shows the user's current location. The application uses this information to check whether the user is on the intended route or not. The application forms simple plain instructions as forward, left, right, backward etc. to orient the user which can be easily followed by the users. Also there are instructions to use stairs upward / downward or to use elevator up / down to a specific floor. These instructions are displayed on the screen of the mobile device.

Let's concentrate on the simple case shown in Figure 2. According to the scenario, user wants to be directed to Office A, and starts navigating inside the building for this purpose. She touches to the first Reference Tag that she sees on her way, after which the location data on tag is transferred to the application on mobile device (Step 1'). So, the application figures out that she is on the intended route and gives user the first instruction as: "go straight ahead for 25 meters, turn right". Similarly user touches to another Reference Tag on her

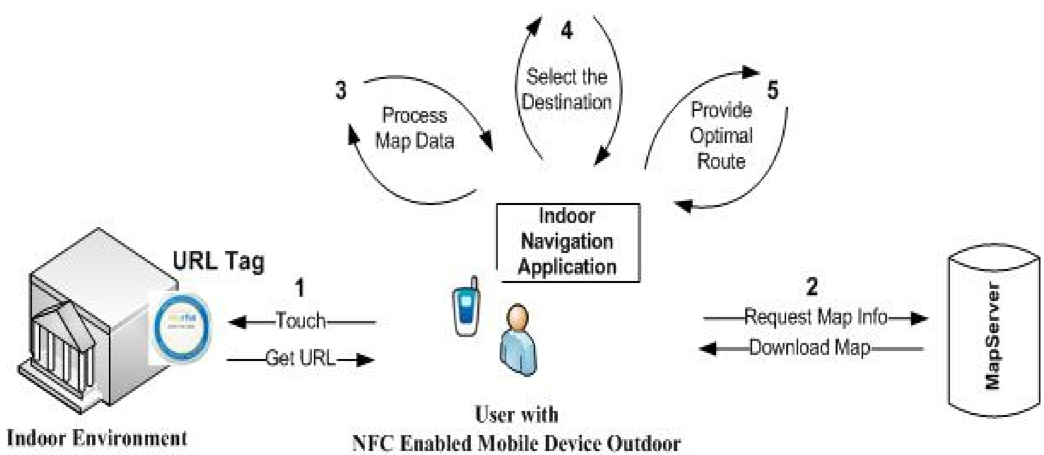

Fig. 1. Initiating NFC Internal

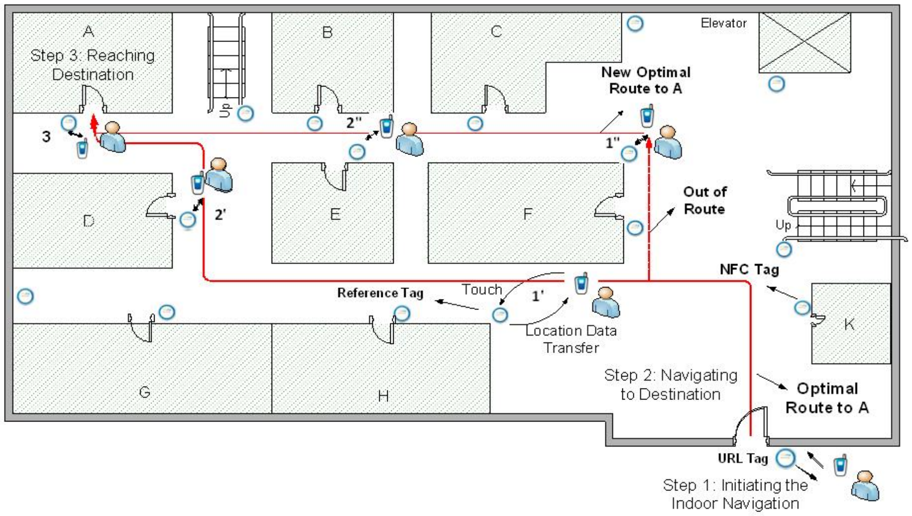

Fig. 2. Navigating to Destination

route and application finds out that user is still on the correct route, so gives instructions to the user (Step 2'). There is a possibility that the user might get out of the route, towards Office A for example, and touches to a Reference Tag which is not on her route (Step 1"). With the transfer of location data, the application figures out that the user is out of route and calculates a new shortest path to Office A and gives user a new instruction as: "go straight ahead for 50 meters". Similarly user touches to another Reference Tag on her new shortest route to Office A and application figures out that user is on the intended route indeed, and gives instructions to the user (Step 2"). As the user arrives the destination point, Office A (Step 3), the application tells user that she reached the destination.

III. Conclusion

This paper presents a new, reliable, and seamless indoor navigation solution that helps to create smart and context-aware environments. The use of NFC technology in indoor navigation systems has a potential to increase the usability of these systems. Comparing to other existing indoor navigation solutions, NFC Internal has many advantages hereunder:

- Reduces the cost of indoor navigation systems by using cheap passive tags,
- Minimizes response time, because the time required to transfer data from NFC tag to mobile device and the time required to generate application's new path is little,
- Provides accurate position and orientation information, so the orientation of the user to the destination is facilitated,
- Eliminates the need for a server or a terminal to orient position, so location privacy of the user guaranteed,
- Provides exclusive control over her location data for the user.

On the other hand there is a limitation of the proposed system. In the system, on the go position information cannot be provided, since user can learn her position information as she touches an NFC tag. Overall, we think that the proposed system is very simple to use and has several benefits to users. Furthermore, the use of NFC technology in indoor navigation systems has a potential to increase the usability of these systems. In future extensions of this study, we will further try to conduct usability and performance tests and evaluation of technical issues, e.g. generation of valuable instructions for user.

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