**Antoni Nowakowski, Abdullah Zair**

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*ANTONI NOWAKOWSKI*
*ABDULLAH ZAIR*
**West Pomeranian University of Technology**

# THE MODEL OF A MOBILE SYSTEM OF PATIENT CONDITION MONITORING UTILIZING THE NFC TECHNOLOGY

## Introduction

Application of mobile technologies for the purpose of providing remote health care, or telemedicine, may be called an effective way of crossing certain barriers related to accessing health care, particularly in the rural communities or those not located near health care centers. In other words, telemedicine is a way of reaching a patient regardless of his or her geographical proximity. Mobile technology, thanks to its dynamic development during the last 20 years, can ensure such communication and provide a patient with basic health condition monitoring services.

Patient monitoring guarantees flexible and firm supervision of a patient[1] thanks to the fact that a patient can carry a device at any time and at any place. A significant challenge for health care providers, political decision makers, hospitals and patients is increasing feasibility and convenience of mobile health care. The main challenge is ensuring uninterrupted health care services to those patients who must carry wireless medical devices. Numerous patients

[1] A. Pioruńska, *Telemedycyna szansą na poprawę jakości usług opieki zdrowotnej*, "Rzeczpospolita", http://www.rp.pl/artykul/449096.html?print=tak&p=0 (2009).

are concerned about privacy issues in terms of releasing patients' personal data by opening wireless channels. Thus, one of the most crucial and demanding issues that a health care provider must deal with is the way to secure patients' data and eliminate access of unauthorized persons to private records. This paper presents a general description of the NFC technology, an overview of the structure of the smart mobile system of patient condition monitoring and a general structure of the medical system. The article also discusses the mobile NFC technology as a structural design of the proposed model system that may be used in effective monitoring of patients. This technology can increase functionality of telemedical systems, make wireless communication possible within health care systems as well as improve the safety of data within those systems.

## 1. The description of the NFC technology

NFC (Near Field Communication) denotes short range communication[2]. It is a set of wireless communication standards. NFC is also a norm including communication protocols and data exchange formats. It builds further upon the RFID technology (Radio Frequency Identification). RFID is a technology enabling automatic and contact-less identification as well as accessing data via radio waves, which, in turn, developed upon the bar code technology[3].

It would be fair to state that NFC has nearly unlimited range of applications. The attractiveness of NFC stems from its user-friendliness. According to the research conducted by American Express, payments via NFC are 60% faster than cash payments and 50% faster than via credit cards. That means that NFC may be widely used and quickly introduced. Juniper Research, on the other hand, conducting research on the development of mobile technolo-

[2] T. Bhuvaneswari, *A Devendran*, International Journal of Scientific and Research Publications, www.ijsrp.org/research_paper_jan2012/ijsrp-jan-2012-61.pdf (2012); NFC Forum: *The keys to truly Interoperble Communications*, www.nfcforum.org/resources/white_papers/nfc_forum_marketing_white_paper.pdf (2012).

[3] J. Bartnicka, M. Smolorz, *Zastosowanie technologii RFID w zarządzaniu zasobami w placówkach opieki zdrowotnej*, konferencja „Komputerowo zintegrowane zarządzanie", t. 1, Zakopane 2010 [in Polish]; Opinia Europejskiego Komitetu Ekonomiczno-Społecznego w sprawie identyfikacji radiowej (RFID), Dz. Urz. UE 2007/C 256/13 [in Polish].

gies worldwide, estimates that there will be around 300 million NFC-enabled smart phones on the market in 2014 and this number will increase to 500 million in the year 2015[4].

The NFC technology has been created by combining radio identification (RFID) with interconnection technologies. In June 2006, NFC Forum made a significant step towards enabling manufacturers and developers to use applications for creating powerful new products targeted at consumers by presenting the architecture of the NFC technology and announcing the first five specifications during the online press conference.

Furthermore, there have been announced four initial tag formats based on the norms ISO 14443 type A and 14443 type B (ISO 14443 is a four-part international standard for contact-less short range cards working within the wave of 13,56 MHz with a reader and an antenna) as well as the norm ISO NFC 18.092.

Those specifications include:

- (NDEF) NFC Data Exchange Format,
- (RTD) NFC Record Type Definition,
- (URI) NFC Uniform Resource Identifier Service Record, Type Description,
- NFC (Text Record Type Description),
- NFC (Smart Poster Record Type Description).

The NFC technology distinguishes two types of communication modes: passive and active. The passive communication mode, as an initiating device such as a payment terminal, enables portable tag reader. The active communication mode works as an initiator and communicator for target devices.
The devices equipped with the NFC technology are capable of transmitting and receiving data simultaneously.

[4] Giesecke & Devrient GmbH, www.gide.com/en/trends_and_insights/nfc_mobile_phones/nfc-mobile-phones.jsp (2013).

## 2. The general structure of the smart mobile system of patient health condition monitoring

In the health care sector, it is possible to notice an increasing interest in applying smart multi-agent systems. It is achievable thanks to the development of the cellular network technology which has prepared an appropriate environment for the creation of mobile agent systems. There still remains a lot to be done before the implementation of smart agents in mobile devices such as smart phones or PDA becomes possible. It will probably be a major step, in health care systems as well, towards a widespread use of MAS at any time and at any place[5].

Figure 1 shows a fragment of the general structure of the mobile system of agent-based patient condition monitoring.

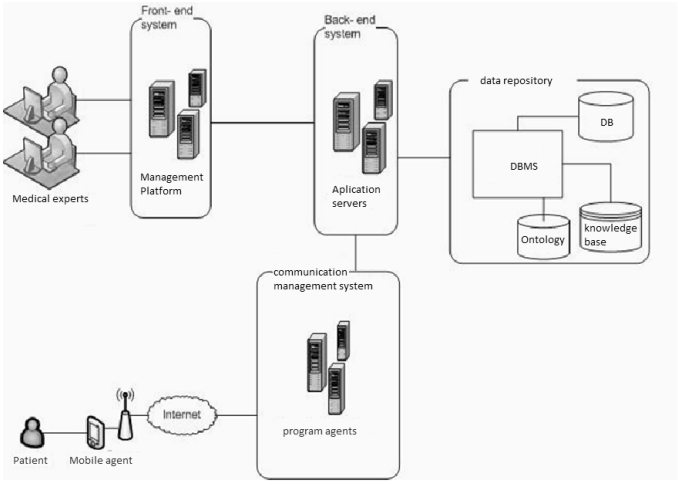


Fig. 1. A fragment of the general structure of the mobile system of agent-based patient condition monitoring

Source: own interpretation based on: A. Nowakowski, A. Zair, *op. cit.*, p. 183; Open NFC™ Developer Site, Open NFC – Security Stack Specification, http://open-nfc.org/documents/STS_NFC_1104-242%20Open%20NFC%20-%20Security%20Stack%20Specification.pdf (2012).

[5] A. Nowakowski, A. Zair, *Zastosowanie technologii agentów programowych w systemach opieki zdrowotnej na przykładzie mobilnego systemu monitorowania stanu pacjenta*, Polskie Stowarzyszenie Zarządzania Wiedzą, Seria: Studia i Materiały, nr 56, Bydgoszcz 2011 [in Polish].

The most important element for the data repository, which gathers information on patient in the data base and in the knowledge base along with the ontology base, is the system. The tasks of the agents working on the application servers include user authorization and supporting the proper flow of data between the user interface and the knowledge repository.

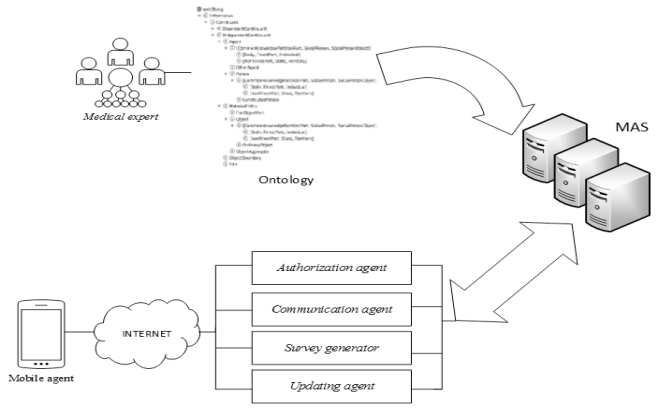


Fig. 2. The operations of the MAS mobile system
Source: own interpretation based on: A. Nowakowski, A. Zair, *op. cit*., p. 184.

The operation of the mobile MAS system has been presented in Figure 2. Each task is to be performed by a mobile agent installed directly in a patient's device and is defined on the basis of ontology by a medical expert (a physician).

A mobile agent's elements include the following:

- agent's knowledge base,
- data base,
- communication elements – elements ensuring exchange with measuring devices in order to record a reading of a patient's condition and communicate with the communication management system,
- user interface – involves interaction with a user by monitoring doctor-ordered test results (for example, in case of diabetic patients it could be a blood sugar level test). An agent analyses a patient's condition based on the results of all the tests along with data gathered from daily surveys consisting of control questions. In case of worsening test re-

sults, an agent may suggest certain actions for the patient to undertake and, in special cases, contacting a doctor.

Server application includes five agents. Their tasks consist in supporting proper communication with a patient as well as proper transfer of data:

Authorization agent, communication agent, survey generator, survey validator, updating agent.

The authorization agent's function is to follow procedures of user authorization (checking for correct certification, user data, device data, etc.).

The communication agent serves two functions:

- communication from Mobile Device to Server during synchronization of data gathered in a mobile agent's base with the system data base.
- communication from Server to Mobile Device when there is a need to send new information to a mobile agent or locate a patient at a given moment.

The survey generator is a mechanism creating relations and deduction methods as well as particular survey templates for each patient based on knowledge gathered by system agents and data entered by medical experts.

The survey validator is a mechanism designed to check data correctness within the surveys received by the server of a mobile device. It monitors the required fields whether they have not been left without an answer and analyzes interdependencies between a patient's answers.

The updating agent informs a mobile agent about the availability of a new version of an application or updates templates and models of a mobile agent's knowledge base.

## 3. The architecture of the mobile system

The architecture of the proposed system model is founded on two environments:

1. The server environment, where patient records are gathered,
2. The mobile client environment which is divided into two elements:

- The SDK (Software Development Kit) Environment which provides a set of tools that can be used to create applications and allow communication between NFC-enabled measuring devices used in health care.

– A set of components and program agents ensuring communication and safety of data processing.

Figure 3 presents elements of an SDK mobile client along with its basic components.

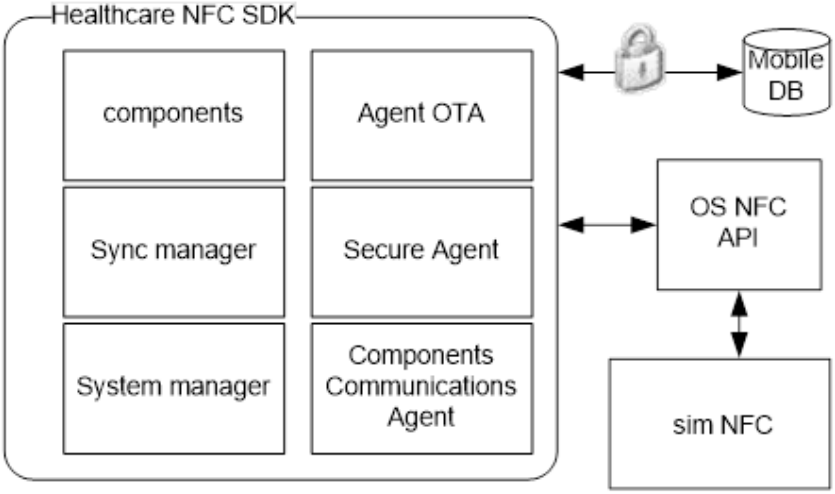


Fig. 3. Elements of an SDK mobile client and its basic components

Source: own interpretation based on: Open NFC™ Developer Site…; NXP Semiconductors N.V., www.nxp.com/documents/data_sheet/PN512.pdf (2012).

"OTA (Over-the-air) Agent" is responsible for receiving OTA information for the purpose of sending demands, for example requests for a measurement or enforced data synchronization.

"Secure Agent" is an agent responsible for the safety of records gathered in the mobile data base. Using a certificate stored in a smart SIM card, it is capable of encoding and decoding of the recorded data.

"Components Communications Agent" is an agent serving a supervisory function over the flow of information between the components. It ensures communication between the NFC reader in a SIM card and the application gathering information via an API (Application Programming Interface) component of an operating system that functions as an intermediate layer between an NFC-enabled SIM card and SDK.

"Sync Manager" is an application responsible for synchronization of patient data and the mobile data base with a health care center.

"System Manager" is a component serving a managing function within an application.

The operations model of the mobile system may be defined via several basic functionalities:

- reading the measurements of medical measuring devices, that is placing a mobile phone near the reader of an NFC-enabled medical device. An application will be enabled in order to record the measurements and activate other agents to verify the validity of the measurement;
- the program agent may react by informing a patient or a patient's caretaker about the measurement being repeated;
- the system is able to perform automatic synchronization of data from a medical center for the purpose of updating a patient's test results.

## Conclusions

The development of information systems and technology enables fast access to patient data, which facilitates access to his medical history, and appropriate diagnosis. This paper presents the problem of multiagentsystems used in healthcare systems. There is also presented an example of a mobile system for monitoring the condition of the patient and its overall structure. Also has been discussed a mobile NFC technology, which can be used for an effective remote monitoring of patient's condition. The most important role in the construction of such systems play a SIM card equipped with the NFC technology. NFC is here intermediate layer ensuring problem-free, constant transmission of an independent medical measurement as well as the safety of gathered patient data. Constant monitoring of the patient's condition minimize the risk of error in the process of his treatment and recovery. It gives a complete picture of his health condition. Such systems may also play an important role as one of the prophylactic activity.

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NXP Semiconductors N.V., http://www.nxp.com/documents/data_sheet/PN512.pdf.

*Open NFC™ Developer Site, Open NFC - Security Stack Specification*, http://open-nfc.org/documents/STS_NFC_1104-242%20Open%20NFC%20-%20Security%20Stack%20Specification.pdf .

*Telemedycyna szansą na poprawę jakości usług opieki zdrowotnej*, A. Pioruńska, "Rzeczpospolita" 2009, http://www.rp.pl/artykul/449096.html?print=tak&p=0.

Nowakowski A., Zair A., *Zastosowanie technologii agentów programowych w systemach opieki zdrowotnej na przykładzie mobilnego systemu monitorowania stanu pacjenta*, Studia i Materiały nr 56, Polskie Stowarzyszenie Zarządzania Wiedzą, Bydgoszcz 2011 [in Polish].

**Summary**

The paper presents select elements of a model of a smart mobile system used to monitor a patient's condition. The use of SIM cards equipped with the NFC technology (Near Field Communication) is presented as an intermediate layer ensuring problem-free constant transmission of an independent medical measurement as well as the safety of gathered patient data. The model of communication integration of the mobile system with diagnostic health care centers is also discussed.