Heart Monitoring System based on NFC for Continuous Analysis and Pre-processing of Wireless Vital Signs

Antonio J. Jara, Pablo López Martínez, David Fernández Ros, Benito Úbeda, Miguel A. Zamora and Antonio F. G. Skarmeta

Department of Information and Communication, Faculty of Computer Sciences
University of Murcia, Murcia, Spain

Abstract. Continuous and wireless transmission of vital signs is taking a high relevance in ubiquitous computing, ambient intelligence and Ambient Assisted Living (AAL). Integration of wireless communications technologies and embedded systems into health monitoring systems are tending towards solutions defined under the denominated Internet of Things (IoT). Specifically, IoT is based on technologies such as Radio Frequency Identification (RFID) to provide the capabilities for identification of devices/sensors, and the evolutions of RFID with Near Field Communication (NFC). NFC presents machine to machine (M2M) communication capabilities between sensors and personal devices. Thus, this allows to carry out the communication with just approaching the reader to the devices, i.e. contactless. This offers advantages mentioned in terms of easy use for elderly people in AAL environments, in addition to the mentioned ubiquity. For that reason, it is highly interesting for the development of AAL solutions, but this also presents challenges for the performance and efficient data transmission because the constrained resources and capabilities from the devices, and the latency introduced by the NFC technology with the refresh readers to exchange NDEF records. These challenges appear since it was originally considered for identification, and not for continuous data transmission. This paper discusses the feasibility of developing a monitoring system for continuous data transmission from an electrocardiogram (ECG). ECG has been considered among the available clinical sensors because its complexity. This presents an example of NFC communication via a USB NFC reader and an Android OS Smart Phone with NFC support. Over that scenario are analyzed the problems found with the original data from the ECG, and consequently it is prepossessed a pre-processing technique for the ECG wave trace. This preprocessing analyzes the signal in order to detect possible arrhythmias and mainly to reduces transmission overload (compression) in order to make suitable the transmission of continuous data through NFC.

1 Introduction

New generation of technologies based on Internet of Things (IoT) provides a mean through which obtain a larger amount of data with higher accuracy and context awareness. This enrichment of the information allows the development of more sophisticated monitoring solutions and systems. Our work is focused on the integration

J. Jara A., López Martínez P., Fernández Ros D., Úbeda B., Zamora M. and F. G. Skarmeta A..
Heart Monitoring System based on NFC for Continuous Analysis and Pre-processing of Wireless Vital Signs.
DOI: 10.5220/0003886500890099
In *Proceedings of the 2nd International Living Usability Lab Workshop on AAL Latest Solutions, Trends and Applications* (AAL-2012), pages 89-99
ISBN: 978-989-8425-93-5

of continuous data communications, in different contexts which covers from hydrological monitoring solutions [1] to assisted living environments. Particularly, this work is focused on the evaluations of NFC capabilities for the transmission of continuous vital signs from an ECG. This has been chosen, since ECG presents high communications requirements and challenges.

Flexibility in conjunction with ubiquity are the key requirements for data acquisition and monitoring solutions, such as the located at the clinical and Ambient Assisted Living (AAL) environments. This flexibility and ubiquity is what we can find in the Future Internet capabilities, and that is why those requirements are satisfied with the new capabilities to link sensors, devices and exploiting captured data that presents the so-called Internet of Things [2].

The evolution of consumer devices with high-capacity such as personal devices, smart phones and the evolution of wireless communications interfaces such Bluetooth 2.1, the new Bluetooth Low Energy (4.0), 6LoWPAN and NFC, make possible to extend the Internet to small sensors and devices, in order to identify and connect all the things, people and systems located around us.

Internet of Things is therefore considered one of the greatest advances in communications in recent years, since it provides the foundation for the development of autonomous applications and services that enable make a more scalable operation and maintenance. Currently, there are related jobs in areas such as home automation [3], intelligent transportation systems [4] and personalized healthcare [5].

Our research work is focused on analyze the different IoT technologies available, which are suitable for the integration of sensors and clinical devices. After, of the already integration found for Bluetooth 2.1 technology through the Health Device Profile (HDP) within the framework of the Continua Alliance, the previous study carried out for 6LoWPAN technology [6]. The present work is focused on analyze the capabilities from NFC. Finally, future work focused on Bluetooth Low Energy (4.0).

Specifically, this presents an analysis of the communication capabilities offered by NFC, with the communication protocol defined over NFC Data Exchange Format (NDEF) and the NDEF Push Protocol (NPP) to transmit data continuously from an RFID/NFC reader connected via USB (ACR 122 from ACS [7]) to a smart phone with NFC supports (Google Nexus S from Samsung). Fig. 3. presents both terminals running with the ECG application module.

The rest of the paper is distributed in the following way. Section 2 describes the capabilities for real-time communication from NFC technology. Section 3 presents the requirements from the continuous data transmission from the electrocardiogram. Section 4 and 5 present the pre-processing of the gathered data, in order to analyze the possible arrhythmias, compress the wave trace, and generate the NDEF messages. Section 6 presents the heart monitoring system developed. Finally, Section 7 analyzes the suitability of the solution and concludes the paper.

Table 1. Records in an NDEF message.

NDEF Message						
R_1 MB=1	…	R_r	…	R_s	…	R_t ME=1

2 NFC Capabilities for Continuous Communications

In this section is carried out a short review about the main technical properties and considerations about NFC, NDEF records and NPP protocol. For an extended version of NFC, NDEF and NPP, it is recommend the whitepapers from NFC Forum [8].

NFC is a contactless or proximity communication medium, which is based on magnetic induction. This works on the 13,56Mhz frequency. The theoretical distance of standard antennas (embedded in cards, tags or readers) is around 10 cm, with a practical working distance of 4 cm. The bandwidth/speed for data transmission is 106, 212 or 424 Kbits/s depending on the mode of transmission and hardware capabilities.

The communication in a NFC System is composed of two elements:

- **Initiator:** This starts the commutation and controls/manages the data exchange. An example of initiator is a reader.
- **Target:** The device that respond to the requirements of the initiator. An example of target is a card or a tag.

NFC devices can operate in two modes, passive and active.

- **Passive Mode:** In this mode, one device generates an electromagnetic field (reader), while another device modulates this field for data transmission (tag). It is founded on the conventional RFID technology. NFC technology allows to emulate a HF card in a smart phone, in order to act as a passive RFID HF card. NFC can also acts as a reader for HF RFID tags.
- **Active Mode:** In this mode, both devices generate a magnetic field and modulate the opposite magnetic field. This mode supports machine to machine (M2M) communication. NFC operates in this mode to talk between a reader and a smart phone, or between two smart phones.

2.1 NDEF Messages and NDEF Records

NDEF is a lightweight binary message designed to encapsulate one or more payloads in a single message. NDEF messages can be nested, and are composed by NDEF records. See Table 1 with the format and composition for a NDEF message.

The minimal NDEF message is a unique NDEF record with MB and ME flags set to 1, but a NDEF message can contains various NDEF records. MB and ME mark the start and end of a NDEF message. Table II shows the NDEF record format.

An NDEF record is not numbered, the application is responsible to respect the order of the records. NDEF records can be chained in order to support longer payloads (fragmentation), Chunk Flag (CF) marks the fragmented payload, SR the payload length which is between 0 and 256 bytes, and ID length (IL) indicates that the *ID_LENGHT* field is present in the NDEF record header with one byte.

NDEF record has three parameters describing the payload. Naming, TNF (Type Name Format) provides a context for the payload, Type length, Type to describe the type of payload. The value of the TYPE field must follow the structure and format encoding implicit in the TNF field value. ID field value is an identifier of URI form (RFC 3986). The referenced URI can be relative or absolute. The intermediate and final segments must not have ID field. Finally, it is defined the payload.

Table 2. NDEF Record format.

MB=1	ME=1	CF=0	SR=1	IL=0	TNF=001=0x01 (NFC Forum well-known types)
TYPE LENGHT = 0x01					
PAYLOAD LENGHT					
TYPE = ‘T’ (Text/plain)					
PAYLOAD (see Table III for the presented use case)					

2.3 NDEF Push Protocol (NPP)

The communication between the ACS ACR 122 USB reader and the smart phone is based on NPP protocol. NPP is a protocol built on top of Logical Link Control Protocol (LLCP) [8]. It is designed to push NDEF messages from one device to another.

NPP itself offers a simple one way communication, pushing NDEF messages from a client to a server. A device that supports NPP always run an NPP server (listening), and may also run the NPP client procedure when it has an NDEF message available to push. Thereby, this allows bi-directional NDEF exchange between NFC devices.

Although, the NDEF record can be until 255 bytes. It has been found a limitation with NPP, where it only can be sent 128 bytes of payload length. Therefore, in case that it is required to send more than 128 bytes, it is required more than one NDEF message, which means that it needs to reconnect using *Connect APDU* from APDU commands [9]. Therefore, such as it is presented in the following sections, in order to send wave traces from an ECG, it is required more than 127 bytes per heartbeat (see Table III). This introduces a high latency and consequently a cumulative delay.

Table 3. Wave trace from a wearable electrocardiogram. This frame has a total of 257 bytes to define the wave of a single heartbeat.

F8 (WAVEMARKER): ECG wave trace ->												78	77	77	77	78	79	79	79	7A	7A	7A	7A	7B	7B	7B
7B	7C	7C	7C	7D	7D	7D	7E	7E	7F	7F	7F	7F	80	80	80	80	81	82	82	83	84	85	85	86	86	87
88	89	89	8A	8B	8C	8D	8D	8E	8F	8F	8F	90	90	90	90	8F	8F	8E	8D	8C	8B	8A	88	87	86	85
83	82	81	80	7F	7E	7D	7C	7C	7B	7B	7B	7B	7A	7A	7A	7A	7A	7A	7A	7A	7A	7A	7A	7A	7A	7B
7B	7B	7B	7B	7B	7C	7C	7C	7C	7C	7C	7C	7C	7C	7C	7C	7C	7C	7C	7C	7C	7C	7C	7C	7C	7C	7C
7C	7B	7B	7B	7B	7B	7B	7B	7B	7B	7B	7B	7B	7B	7B	7B	7B	7B	7C	7C	7C	7C	7C	7C	7C	7C	7C
7C	7B	7B	7B	7B	7B	7C	7C	7C	7C	7D	7D	7D	7D	7D	7D	7D	7D	7D	7D	7D	7D	7D	7D	7D	7D	7D
7D	7D	7D	7D	7D	7D	7D	7D	7D	7D	7D	7D	7D	7D	7D	7E	7E	7E	7E	7D	7D	7D	7D	7D	7D	7D	7D
7D	7D	7D	7D	7D	7D	7D	7D	7D	7D	7E	7E	7E	7E	7E	7E	7E	7E	7E	7E	7E	7E	7F	7F	7F	7F	7F
7F	7F	7F	80	80	81	82	82	83	84	85	85	85	85	85	85	85	85	85	85	84	83	82	81	81	80	7F
7F	7F	7E	7E	7E	7E	7E	7E	7E	7E	7D	7D	7D	7D	7C	7B	7A	7A	7B	7D	82	88	91	9C	A7	B1	B8
BB	BA	B4	AB	A0	94	8A	82	7C	FA	(BPM)		44	->	68 beats per minute												

3 Native Model Sensor Communication

Clinical sensors present native protocols for communications, which provide from RAW data to sensors which formatted format following a standard such as Health Level 7 (HL7) and IEEE 1073 (X73). All of them require to be pre-procedssed from their original protocol to NDEF records, in order to make feasible the data transmission via NFC. This pre-processing and adaptation tasks allow to carry out complex data analysis for anomalies detection, data compression and security techniques applications. For example, the inclusion of Cyclic Redundancy Codes (CRC) for integrity, digital summary and signatures for authentication, and encryption for protection [6].

The sensor considered is an electrocardiogram (ECG). Specifically, the ECG module chosen is the EG 01000 from Medlab (see Fig. 2). This is characterized by providing a continuous data channel through a serial interface. This transmits the wave trace of the called V2 in cardiology. The original protocol has a sampling rate of 300 samples/second (Hz), and a high resolution mode with an accuracy of 150 values per mV.

Thus, let a sampling frequency (ω), with a value of 300 Hz. It is required in total for each pulse of χ bytes, equal to 236 bytes for the case of 76 ppm following the equation 1. Table III presents an example of the raw data.

$$60*\omega/\beta = \chi \quad (1)$$

In addition, it is important to determine how many time is required for each byte, in order to calculate the relevant medical intervals, which are able to be used for a pre-diagnosis analysis. Such as, it will be presented in the Section 4. The time the time required per byte is determined following the equation 2.

$$1 \text{ byte/sec} \ / \ 300 \text{ bytes/sec} = 3{,}3 \text{ ms/byte} \quad (2)$$

4 Arrhythmia Analysis

It is carried out an analysis of the ECG wave in order to determine medical condition of patient, through a heart arrhythmia and anomalies classification [10]. This does not replace the diagnosis process from a specialist, but this offers an initial approximation of the patient's health status.

The arrhythmia analysis is carried out through the reconstruction of the PQRST complex (see Fig. 1). It is pre-processed in order to obtain the segments, ranges, amplitudes and polarities for each one of the curves from the PQRST complex.

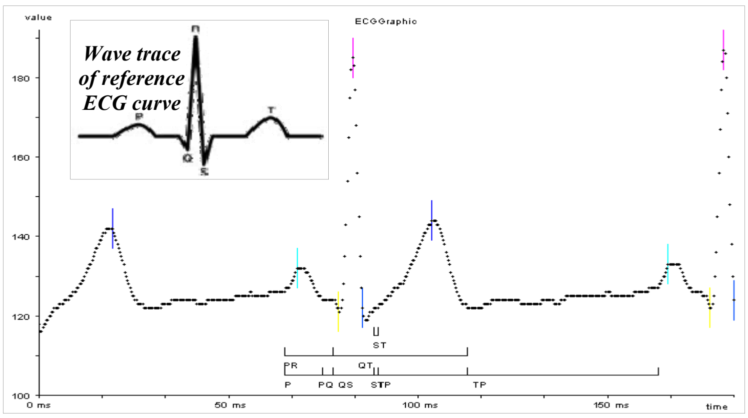

Fig. 1. Trace representation of pre-processed ECG. In the upper left is presented the reference wave. The points are P: green, Q: yellow, R: Pink, S: blue, and T: dark blue.

Specifically, the segments considered to reconstruct the wave are: starting of P (**P**), difference between P and Q (**PQ**), difference between S and Q (**QS**), difference between S and T (**ST**), segment T which presents from the beginning of wave T until its end (T), and finally the segment between T and P from the next heartbeat (**TP**).

In addition, it is considered a set of intervals with clinical relevance. The intervals considered are the **PR** interval, which is the combination of the P and PQ segments. The **PQ** interval is similar to the former is the addition of the segments QS, ST and T. Finally, the **QRS** interval coincides with QS segment, which is calculated for the reconstruction. You can distinguish these intervals in the Fig. 1.

Thereby, this analysis can be carried out directly over the reconstruction parameters, and consequently this does not require a more complex analysis. The described intervals, theirs respective amplitudes and polarities are evaluated following the next rules, which determine the possibility of that patient suffers of some arrhythmia or cardiological diseases [10]:

- ***interval QRS > 0.12 secs*** Ventricular hypertrophy, necrosis, BCRD, BCRI, pacemakers, cardiomyopathies, electrolyte abnormalities.
- ***Sign U <> Sign T*** Ischemic heart disease, hypokalaemia.
- ***interval PR > 0.20 secs*** First-degree AV block.
- ***interval PR < 0.12 secs*** Tachycardia, WPW, manners or headphones low rates.
- ***interval QT > 0.45 secs*** Antiarrhythmic medicines, ischemic heart disease, cardiomyopathies, hypocalcemia, mixedema, long QT syndrome.
- ***interval QT < 0.35 secs*** hypercalcemia, hyperkalemia, early repolarization, digoxin.

5 Communication Model Optimized for NFC

The data collected from the ECG module presented in Section IV can be transmitted directly, where approximately 250 to 300 bytes are required to transmit every beat. This direct transmission means a high overload and impact in the quality of service (delay and latency) and lifetime of the personal device. For that reason, it is defined an optimized communication model for NFC, in order to increase the lifetime of the system and considering the requirements of a personal system of this kind should reach a duration greater than hours, even days. The communication model considered to perform the pre-processed is the YOAPY module [6]. YOAPY has been already used with 6LoWPAN technology and offer a suitable solution to reduce dramatically the number of bytes required to transmit for each heartbeat.

The pre-processing and compression of an ECG trace are methods and techniques investigated throughout the literature. Some of the most relevant studies are based on methods based on “wavelet”, which achieves compression of about 18:1 [11]. These methods are focused on the complex formed by the QRS, which is the group of waves that are marked on the signal from the wave of the electrocardiogram. The QRS complex contains more clinically relevant data from the cardiology point of view. This will determine whether the patient´s condition is normal, or is occurring abnormality (arrhythmia) in the patient´s heart. Fig. 1 has shown the identification of the QRS complex and the other significant points in the captured waveform from the module shown in Fig. 2. The problem encountered is that wavelet-based methods are not entirely suitable for devices with limited experience as the NFC adapter electrocardiogram developed in our previous works and for embedded intelligent systems [12].

For that reason, this work is based on a more simple pre-processing solution, based on the representation of the waveform from its amplitude and time difference between each of the significant points of the curve [10], i.e., P, Q , R , S and T, since this is really relevant information. Thus, most of the points as close to the value "0x7F" in Table III corresponding to no signal, can be omitted.

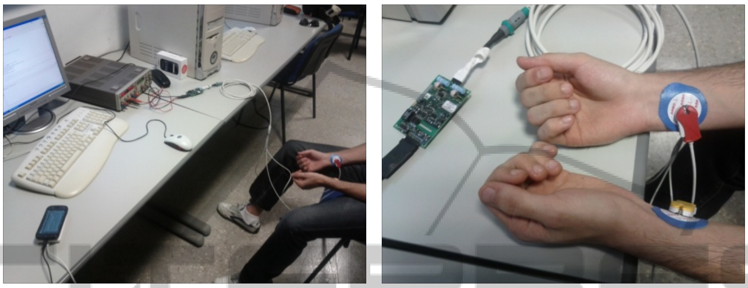

Fig. 2. Right: ECG module connected to a voluntary patient. Left: Evaluation environment formed by a wearable 3 leads electrocardiogram.

YOAPY module is based on detect maximums and minimums values in each wave of the PQRST complex, i.e.: P maximum, Q minimum, R maximum, S minimum and T maximum. In addition we get the more descriptive segments, what permit us transport, and redraw the PQRST complex. The segments can be differentiated on the presented and described Fig. 1 in Section IV, where the consecutive segments showed in the bottom of figure are for their reconstruction, and the intervals showed above the segments corresponds with the medical interest intervals.

YOAPY format data contains the most significant fields to represent and for the development of embedded intelligent systems for the detection of abnormalities. The data obtained information through YOAPY module defines the payload for the NDEF message, which is transmitted through NFC. YOAPY format contains five maximum/minimum values, six segments, the heart beats, and one byte for describe detected anomalies founded by a simple analysis about the length of some segments, this are 13 bytes.

The meaning of the fields is:

- **maxP:** Represents the height from the P wave onset (iniP), to the maximum value of the P wave. Ie: (P– iniP) 137 – 127 = 10.
- **minQ:** Represents the height from the Q wave onset (iniQ), to the minimum value of the Q wave.
- **maxR:** Represents the height from the R wave onset (iniQ), to the maximum value of the R wave.
- **minS:** Represents the height from the S wave onset (iniQ), to the minimum value of the S wave.
- **maxT:** Represents the height from the T wave onset (iniT), to the maximum value of the T wave.
- **segP:** Represents the length of the segment P, from the init P wave, to the final P

wave, as shown in Fig 2.

- **segPQ:** Represents the length of the segment PQ, from the final of P wave, to the init of Q wave, as shown in Fig 2.
- **segQS**: Represents the length of the segment QS, from the init of Q wave, to the final of S wave, as shown in Fig 2.
- **segST**: Represents the length of the segment ST, from the final of S wave, to the init of T wave, as shown in Fig 2.
- **segT:** Represents the length of the segment T, from the init of T wave, to the final of T wave, as shown in Fig 2.
- **segTP:** Represents the length of the segment TP, from the final of T wave, to the init of P wave, as shown in Fig 2. (Represented as unsigned byte)
- **BPM:** Represents de beats per minute (ppm). (Represented as unsigned byte)
- **Diagnostic Byte:** This byte indicates through his bits some diagnostics.
  - The 1st less representative bit a PR<0.12sec.
  - The 2nd less representative bit indicates PR>0.20sec.
  - The 3st less representative bit indicates QRS>0.12sec.
  - The 4st less representative bit indicates QT<0.35sec.
  - The 5st less representative bit indicates QT>0.45sec.

All values except the TP segment (**S_TP**) and BPM are represented by signed integers because their values never overflow the limit of 127.

Table 4. Pre-processed format (real values).

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*
P	**Q**	**R**	**S**	**T**	**S_P**	**S_PQ**	**S_QS**
6 0x44	*-4 0xFC*	*53 0x35*	*-4 0xFC*	*15 0x0F*	*34 0x22*	4 0x04	35 0x23
S_ST	**S_T**	**S_TP**	**BPM**	**DIAG**			
4 0x04	*63 0x3F*	*56 0x38*	*82 0x52*	*0 0x00*			

6 NFC Real Time Monitoring System

The system is composed of two parts with their respective software. On the one hand, the PC has a Java program that reads, analyzes, compresses, and encapsulates the received frames from the ECG module through the serial interface in a NDEF message. This NDEF message is sent through the NFC USB reader via the *smartcardio* library. On the other hand, an application for Android OS has been developed, for processing the received frames through NFC and presents it in a plot. Fig. 2 also presents the wearable ECG connected to a voluntary patient, and transmitting data continuously to the PC and Fig. 3 presents a capture of the smart phone receiving compressed frames and represented in a plot. In addition, it is available a video for watching the monitoring system running[1].

[1]DEMO video of the monitoring system: http://www.clitech.eu/ECG_continuous.mp4

The part of the PC corresponds to the data acquisition phase by a PC, which is focused to be replaced by an embedded device such as personal device previously developed and presented in [12], called Movital. For that reason, it has been also considered the mentioned constrains for the processing of the ECG wave trace.

The application for the Android OS is called *AppAndroidECGPlotter.* This application consists of a simple package that contains a Java class, whose functionality is responsible for obtaining from the Android Intent dispatcher, the NDEF packages received from the PC. NDEF record has the format presented in Table II, where the payload corresponds to the package described in Section V and Table IV. Finally note that the payload after pre-processing with YOAPY module is only13 bytes.

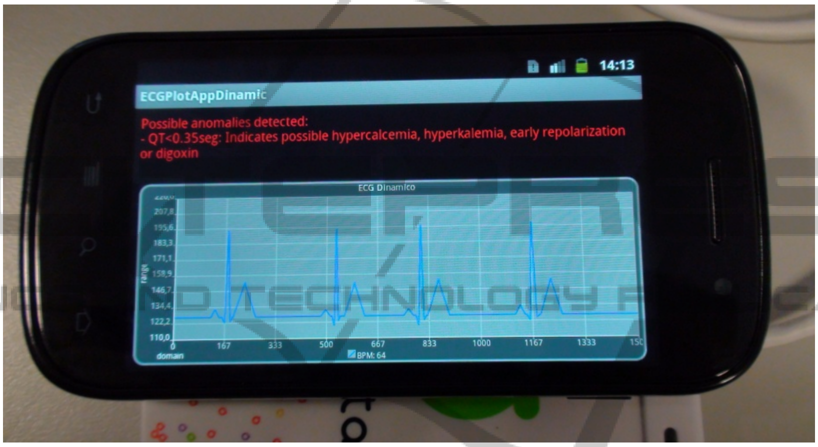

Fig. 3. Google Nexus S receiving data from ECG via NFC.

Fig. 3 shows the Android mobile device over the RFID/NFC reader. This shows the vital sign from the electrocardiogram, the top of the screen also presents the detected physical problem of the heart detected, if they were found. Remark, the picture corresponds to a real failure from one of our volunteers. Finally, this plots the waveform.

Finally, we have made a comparative and evaluation of the time and delay for pushing NDEF messages for a continuous monitoring from the USB RFID/NFC reader to the smart phone. It has been compared between a version of the solution based on the full wave trace transmission, i.e. the 250-300 bytes per heartbeat from the RAW mode, and the YOAPY pre-processed mode of sending only 13 bytes per heartbeat.

It has been found that for sending the 250-300 bytes received in RAW mode from the ECG, it is required to send from 2 to 3 frames, each of them is a complete frame as the Table IV, note that cannot chuck the payload for the NPP protocol restrictions (limited to 127 bytes such as mentioned in Section II). The average for the times for transmissions measured are 2372,25 ms (2 seconds) for RAW mode, and 22,5 ms (0,02 seconds) for the solution based on the YOAPY mode.

In conclusion, the RAW mode transmission produces a delay for real-time and continuous monitoring of vital signs. Since this requires more than 2 seconds for delivering a sample which is obtained each less than 1 second (76 bpm, means a heartbeat each 0,79 seconds). Therefore, the use of RAW mode is not feasible, since it produces an accumulative delay. This high time is because the time required between the pushing of the multiple NDEF messages. However, the use of YOAPY mode, and its compression to send this information allows to reach a short delay, around 0,02 seconds, which is under the threshold of the 0,79 seconds.

7 Conclusions and Future Work

This work presents the integration of a clinical device with continuous data transmission requirements in NFC technology. This has been concluded that the direct transmission of the collected data from an electrocardiogram is not feasible, since the delay introduced for the transmission of multiple NDEF messages, i.e. the time required for pushing a new NDEF message is excessive. But, this is suitable when the required frame size is compressed to fill in a single NDEF record, i.e. less or equal to 127 bytes because the NPP constrains. For that reason, it has been also presented a pre-processing module called YOAPY, which compresses and analyzes the vital signs making feasible its continuous and real-time transmission.

Future work is focused on extend de analysis of the capabilities for real-time transmission of NFC communications, and the extension of the integration to Bluetooth Low Energy technology.

Acknowledgements

This work has been made possible by the means of the Excellence Researching Group Program (04552/GERM/06) from Foundation Seneca, FPU program (AP2009-3981) from Education and Science Spanish Ministry, with funds from Science and Technology Program (PCTRM 07/10), through the project “Modelización Hidrológica en Zonas Semiáridas” from the Autonomous Region of Murcia (CARM), and in frames of IoT6 European Project (STREP) from the 7th Framework Program (Grant 288445).

References

1. Cristina Sotomayor Martínez, A. J. Jara, Antonio F. G. Skarmeta: “Real-Time Monitoring System for Watercourse Improvement and Flood Forecast”. Lecture Notes in Computer Science. Springer Verlag. Vol. 6935 pp 311-319. ISSN: 0302-9743, 2011.
2. L. Atzori, A. Iera, G. Morabito, "The Internet of Things: A survey". Computer Networks Vol. 54, No. 15, pp. 2787-2805, 2010.
3. M. A. Zamora, J. Santa, A. F. G. Skarmeta, “Integral and networked home automation solution towards indoor ambient intelligence, Pervasive Computing, 2010.
4. M. Castro, A. J. Jara, A. F. G. Skarmeta, “Extending Terrestrial Logistics Solutions Using New-age Wireless Communications based on SunSPOT”, V International Symposium on Ubiquitous Computing and Ambient Intelligence (UCAmI’11), 2011.
5. R. S. H. Istepanian, A. J. Jara, A. Sungoor, N. Philips, “Internet of Things for M-health Applications (IoMT)”, AMA IEEE Medical Tech. Conference on Individualized Health

care, Washington, 2010.
6. A.J. Jara, L. Marin, M. A. Zamora, A. F. G. Skarmeta, "Evaluation of 6LoWPAN Capabilities for Secure Integration of Sensors for Continuous Vital Monitoring", V International Symposium on Ubiquitous Computing and Ambient Intelligence (UCAmI'11), 2011.
7. ACS ACR122 NFC Reader Specification, http://acs.com.hk/drivers/eng/API_ACR122U.pdf, 2011.
8. NFC Forum, Innovision, "Near Field Communication in the real world - Turning the NFC promise into profitable, everyday application", "Near Field Communication in the real world - Using the right NFC tag type for the right NFC application", and "Logical Link Control Protocol", 2011.
9. NXP Forum, PN532 transmission module for contactless communication at 13.56 MHz used in ACR122 http://www.nxp.com/documents/user_manual/141520.pdf, and PN532 Application Note, www.adafruit.com/datasheets/PN532C106_Application%20Note_v1.2.pdf, 2011.
10. A. J. Jara, F. J. Blaya, M. A. Zamora, A. Skarmeta, "An ontology and rule based intelligent information system to detect and predict myocardial diseases",IEEE Inf. Tech. App. in Biomedicine, ITAB, 2009.
11. R. S. H. Istepanian, A. A. Petrosian, "Optimal zonal waveletbased ECG data compression for a mobile telecardiology system" IEEE Trans. Infor. Tech. in Biomedicine, Vol.4, no. 3, pp. 200–211, 2000.
12. A. J. Jara, M. A. Zamora, A. Skarmeta, "An Internet of Things–based personal device for diabetes therapy management in AAL", Personal & Ubiquitous Computing, Vol. 15, no. 4, pp. 431-440, 2011.