Leveraging StoLPaN host environment for Portable Diagnostic Health-Care Platform

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This paper reports on leveraging our recent achievement in StoLPaN project that combines mobile phones/PDAs with the Near Field Communication (NFC) wireless technology to further support a portable diagnostic health care platform (namely POCEMON) based on Lab-On-Chip (LOC) concept with the StoLPan host environment. StoLPaN provides a NFC enabled mobile phone based host environment, regardless of the phone type and the nature of the services required. In connection to this, a further insight on how this cutting age technology may establish a strong hold demand for its future viability in health care sector providing efficient point-of-care monitoring and diagnosis.

Index Terms— NFC, Micro-Array, Mobile, Lab-On-Chip (LOC)

I. INTRODUCTION

Combining the popular cellular handheld phones and PDAs with the Near Field Communication (NFC) technology has gained interest among the business community and has attracted researchers to overcome interoperability, infrastructural issues as well as creating new business cases. Major hardware manufacturers except a few are not yet supporting NFC in the manufactured devices and at present there is no common secured communication infrastructure over which interested partied from domains and actors can play their role with confidence in terms of security and trust.

To overcome these barriers, ‘Store Logistics and Payment with NFC’ (StoLPaN) project has defined open commercial and technical frameworks for NFC-enabled services on mobile devices. These frameworks will facilitate the deployment of NFC-enabled mobile applications across a wide range of vertical markets, regardless of the mobile device type and the nature of the services required. The host environment developed by StoLPaN also promotes the deployment of NFC-enabled mobile applications in many diverse application domains.

The recent out burst of the use of miniaturized devices is in molecular diagnostics, where the detection of genomic and proteomic sequences has diagnostic and large prognostic value. This impact can be easily enhanced by using diagnostic lab-on-a-chip devices at the primary care level for the diagnosis of the significant autoimmune disorders.

Pursued by a consortium of eighteen different health and ICT organizations under the large scale Integrating Project (ICT-2007.5.1) POCEMON (Personal Health Systems for Monitoring and Point-of-Care Diagnostics) project will have great impact on the methodologies available for both autoimmune diseases and drug discovery and consequently impact on the scope and throughput of new pharmaceutical developments. It aims to an increased European multidisciplinary research excellence in biomedical informatics and molecular medicine by fostering closer cooperation between ICT, LOC, portable devices, and pharmaceutical/biotech companies. POCEMON aims to create a portable diagnostic platform supplied with advanced software and hardware technologies for the diagnosis of autoimmune diseases, coupling fundamental bioinformatics sciences with technological advances in the fields of micromachining and micro-fabrication of silicon chips will lead to a lab-on-a-chip (LOC) for large-scale diagnosis of autoimmune disorders.

In this paper, we will report our plan to leverage StoLPaN host environment to deploy POCEMON LOC functionalities and a detail of POCEMON platform that will utilize mobile NFC technology.

The paper is structured as follows. Section 2 presents basic concepts and issues in mobile NFC based StoLPaN environment and a brief introduction to LOC. In Chapter 3, we describe an outline of proposed POCEMON platform that will be utilizing StoLPaN environment. We conclude with the impact of our current research and corresponding concepts on the future of leveraging StoLPaN application environment in health care domain in chapter 4.

II. BACKGROUND

A. Basics [3]

Near Field Communication or NFC, is a short-range high frequency wireless communication technology which enables the exchange of data between devices in close proximity (about a decimeters distance). It allows for the development of devices, including mobile phones that can be used like contactless cards. A shorter transmission range and slower data rates distinguish NFC from other short-range wireless technologies
such as Bluetooth, radiofrequency identification (RFID), Infra-Red and Wi-Fi.

In NFC, a device generates a low frequency radio-wave field in the 13.56-MHz spectrum. When another NFC device gets close enough to contact the field, magnetic inductive coupling transfers energy and data from one device to the other. This magnetic coupling is the principal difference between NFC and technologies such as Bluetooth and Wi-Fi.

### B. Applicability of NFC Technology in general [3, 4]

NFC may be used in many ways, including retail and service payments, event ticketing, computer-access control etc. It also could enter information from a buyer’s NFC phone to a suitably equipped PC for e-commerce transactions. An NFC device with an internal power supply is considered active. A device with no internal power supply, such as a smart card, is considered passive and. Inductive coupling causes a passive device to absorb energy from an active device when it gets close enough. Once powered up, the passive device can communicate and exchange data with the other device. The ability of NFC devices to work as both passive and active enables them to function as either contact-less cards or readers. Thus, an NFC phone could be used, e.g. to send payment information to a reader to make a purchase or to read information from an enabled advertising sign.

### C. Applicability of Mobile NFC in Health and Diagnostic Domain

Near Field Communication or NFC technology can be used in various health care applications as a robust way of gathering, processing and automating the process of e.g. reminding patients when it is time to take their prescribed drugs, based on the prescriptions provided by pharmacy [11]. Moreover, NFC-enabled devices can be used for off-line monitoring of heart rates, glucose or blood pressure [12]. Other application areas would be in making our environment friendlier, which applies mainly to disabled persons.

NFC-enabled mobile platforms are rapidly evolving, getting into our daily activities and are in general interests of ordinary people. Common mobile technology used with inexpensive easily available tags, and soon possibly sensors as well, makes the functionality widely available.

Networked medical devices will enable to provide healthcare where constantly gathered and analyzed information enables to protect patients continuously with ad hoc decision support system. Furthermore, NFC-enabled health monitoring and diagnostic platform will create new opportunities for the medical health care, but as well for the whole medical device industry. In addition, some of treatments will require no more regular doctor visits and should be achievable by integration of different NFC-enabled devices.

Besides, health measurements devices can support self-care [13], which could help societies to deal with illnesses caused by unhealthy living. For example, many of health problems might be related to overweight and in number of cases implementation of self-motivation system that stimulates efforts or eating healthy food could possibly solve, or at least marginalize the problem. Monitoring and presentation of analyzed data with goals matching could give feedback that will enable people to consciously keep fit and healthy.

### D. Lab-On-Chip (LOC) Basics

Lab-on-Chip (LOC) refers to a single chip miniature device that performs biological procedures in analytical chemistry enabling fast response and portable, low cost analysis data suitable for real-time operating conditions for a wide variety of health and life science applications such as the diagnosis of genetic disorders or the testing of food and water supplies for contamination etc[5, 6]. Such devices integrate fluid-handling functions such as sample preparation, analysis, separation, and detection and combines electronics with biology to open new application areas such as point-of-care diagnosis, on-chip DNA analysis, and automated drug discovery [10].

### III. StoLPaN Environment Supporting POCEMON

In order to accurately address the interoperability issues currently affecting the mobile NFC technology, various usage cases are to be defined within the StoLPaN framework and tested throughout Europe. These use cases will contribute to the identification of a common set of business rules, which will define the roles and responsibilities of every player in the NFC ecosystem. The results will then be submitted for approval to the relevant industry bodies for standardization of payments, mobile, transit and ticketing as well LOC applications.

Based on these findings, the consortium will look into the specifications for technical requirements and the security aspects of NFC-enabled applications. They will also explore the connection to existing contact-less platforms, easing the burden on individual providers. At the same time the project team will demonstrate how the business rules and technical requirements can be implemented in existing contact-less infrastructures. A NFC host application will be developed to support a range of services, including payment, access control, ticketing, loyalty, connectivity, and the retail check-out process; which consumers will be able to use with any NFC-enabled device.

### A. StoLPaN Objective and Scope

StolPaN objective is to develop a JAVA based mobile host application that provides a transparent environment for the simultaneous operation of various NFC based service applications, by neutralizing specifics of the handset design and taking care of resource, security and communication management. The focus if StoLPan is thus:

- Define the commercial and technical frameworks for the secure loading, management and use of the Service Provider’s applications on an NFC-enabled mobile handset
- The operation of the Service Provider’s application should not be affected by the medium (contactless card, key fob, handset) on which it is stored

The StoLPaN project designs, develops and demonstrates a universal mobile J2ME host application that will provide transparent uniform operating environment in the mobile handsets for the selected (and potentially other) NFC
applications neutralizing specifics of the handset design and taking care of resource management.

The application will on the one hand, hide the specifics of the various mobile handsets – different manufacturers, different operational specifics, different versions, etc – and will on the other hand provide all the necessary resources and features – communication access, security solutions, etc.- that were identified during the technical analyses for the individual NFC use cases. There will be one generic version of J2ME host application to be run on any selected mobile handset models.

B. Research Issues solved by StoLPaN

There is a number of research issues identified in StoLPaN that include activities related to e.g. security, legal, privacy and consumer protection issues relevant in case of RFID-NFC use and store operation.

1) Remote deactivation of unsorted multiple smart tags

The further improvement of tag reading mechanism and devices should also ease the strong resistance against the use of RFID tags in the retail world, which is due the fear that the tags provide such personal information about the customers that can be wrongly used. To avoid this situation and to be able to use the benefits of the new technology on a wide scale, the sensitive content of the tags need to be removed – made unreadable – before the products leave the store, but after the payment was performed. This requirement however may not spoil the optimized purchase process that was achieved through the use of the smart tags, it may not slow down the actual check-out. To fulfill both stated requirements a solution needs to design that can deactivate the tags remotely and accurately, without interfering with the customer movement, but at the same time must provide adequate security protection for the store operation as well. The reader must be able to capture the information and deactivate it, from a relatively large distance – large compared to general NFC standards – and must also be able to monitor beside the shopping cart, the customer, its bags and other belongings. The reader and deactivation mechanism must be able to differentiate between the temporary and permanent information stored on tags, and must perform deactivation without the slightest health hazard.

2) Specification of a new J2ME host for NFC business applications

The StoLPaN project plans to convert a regular mobile phone, irrespective of its vendor or type, into a general purpose payment terminal. For this purpose a new transaction platform is foreseen that covers the technical specification of the handset and allows device independent operation of the combined mobile payment application, but also of other business applications. For this purpose new J2ME host needs to be developed that handles the basic technology and also provides a general operating environment for the various business instruments that may individually be integrated into the application. The output of this research will have to be presented for future standardisation, otherwise handset independence is hard to realize. The same application would provide the operating environment for the NFC purse, establish the necessary connection between the handset’s resources and the chip. This solution most probably will be based on the extension of the general NFC Java API.

3) Establishment of secure bidirectional transmission between wireless channels and NFC chip

In the planned check-out scenario payment would be performed with a mobile device using proximity NFC communication. This solution is different from existing mobile approaches, where contactless purses are storing information on the chip itself and information can only be written onto the chip with special writers using contact interfaces. To achieve the planned functionality, where the mobile purse can be recharged over the air it must be ensured that secure communication can be established between the wireless channels and the NFC chip. The same functionality and technology is necessitated for the remote management of the various NFC applications that can be stored in the mobile host environment. Similar is the requirement in case when the mobile handset acts as payment terminal, where the secure communication between the chip and the wireless channels is required into the other direction.

4) Establishment of secure NFC chip-to-chip communication for P2P

If a new integrated NFC module is designed, it makes sense to extend its potential functionality as much as possible. Such a useful extension may be the elaboration of the technology that ensures secure chip-to-chip communication to facilitate direct purse-to-purse payment. This work does not only involve technical research, but has an operational and security aspect as well, as the applied technology must be supported with adequate operation and fraud prevention.

C. StoLPaN Host Environment [9]

The StoLPaN host application allows the collaboration among the diverse applications, diverse service providers, diverse network operators and the diverse of type of mobile devices.

FIG. 1 StoLPaN HOST ENVIRONMENT

The host is able to support multiple NFC services, provide access to the phone's resources and facilitates the loading, use, maintenance and deletion of third party NFC enabled applications via common API between the third party application and the mobile device's, common API between the service provider and the third party's application provisioning Platform, simplifying validation of adherence to their service
level agreements. Besides a common User Interface for applications loaded into the Secure Element or the host's JAVA storage, providing value added features to existing contact-less services. It will simplify the learning curve associated with any new application.

D. Future Exploitation of StolPaN in Health-care

The POCEMON platform has been aimed to develop a portable monitoring system for auto immune diseases such as rheumatoid arthritis (RA) and multiple sclerosis (MS) [14,15]. Health authorities aim to provide patients with personalised diagnosis and treatments, driven by state of the art diagnostic and communication technologies. The system is based on Lab-on-Chip (LOC) technologies that use microarray genotyping and microelectronics to carry out diagnostic testing at the primary healthcare level. The system provides rapid diagnosis via mobile diagnostic devices and wireless communications. Basically, it uses LOC technology to allow rapid DNA analysis from small quantities of blood/saliva. The chip functions by increasing the quantity of sample via replication of the patients' DNA, followed by hybridisation of the patients' DNA with a microarray of characteristic autoimmune disease gene templates. The microarray scanning and recording of genotyping results are controlled through the PDA via a multipurpose LOC adapter.

![FIG. 2 POCEMON OPERATIONS](image)

FIG. 2 POCEMON OPERATIONS

The genotyping data generated by the LOC are assessed using intelligent algorithms linked with the laboratory information system to provide detailed diagnosis and medical treatment advice. This process functions through the LOC's integration with mobile devices and communication with the laboratory information system via wireless communications.

Recent research efforts suggest the high-potential of NFC technology for short-range connectivity between health monitoring devices and mobile terminals and data stores propose practices to apply NFC to some health monitoring applications and study the benefits that are attainable with NFC. The value of these is significant, especially in long-term diagnostic analysis and in chronic disease management. From the usability point of view, wireless communication links are preferable to cables because they facilitate measurements and management of diagnostic analysis at real-life settings [8].

E. Application Scenerio for SToPaN environment hosting POCEMON LOC

The possible application scenario for the proposed POCEMON project with regard to StolPaN may be found in network topologies, information systems, or data systems based on distributed data stores etc.

The patient pathway from point of contact (usually a GP) to diagnosis involves collection of samples from patients and analysis at large scale laboratories. This process takes several days and involves a number of procedures to prepare and analyse the samples before a diagnosis can be made. State of the art diagnostic systems aim to reduce the length of time that it takes to reach the point of diagnosis. Figure 3, shows a POCEMON use case scenario where ccontinuously updated patient data ensures medical treatment is proper and coherent. Moreover, gathered data can be easily shared with laboratory technicians for further e.g. anomaly-based analysis, pattern recognition or creation of detailed description. Systems covers doctors requirements, but as well patients that can remotely access their profiles and get instruction about treatments, prescriptions, etc. Finally, the POCEMON platform enables data integration and analysis in large scale that can lead to more accurate treatments, illnesses prevention and early health disorders detection.

![FIG. 3 POCEMON USE CASE SCENERIO](image)

FIG. 3 POCEMON USE CASE SCENARIO

F. POCEMON Objectives

Major POCEMON objectives directly arises by the integration of multi-technology sets that underlie new functionalities, services and applications sufficient enough to provide portable and mobile ICT systems which facilitate point-of-care diagnosis at the primary care level. Also, new diagnostic software will be developed for PDA/Mobile devices making this technology more attractive to primary care and allowing future mobile devices to be used for health monitoring, even at home (connected any time, anywhere and to many services). The development of the diagnostic Lab-on-Chip device will lead to innovative technological achievements which will strength European microelectronics industry offering smaller systems, cheaper, smarter and friendlier.
G. POCEMON Innovations

The main part for the point-of-care diagnosis of autoimmune diseases is based on the development of the appropriate software capable to perform automated micro-array analysis to measure the genes expression. The software will be implemented for desktop workstations and for PDAs.

Image processing is an important part of every micro-array experiment. Reliability of this part strongly influences the results of data analysis performed on extracted gene expressions. The image analysis functions will use the filenames and the red and green channels of the spotted images. The main image analysis software will be developed using the following procedures:

Contrast enhancement - Most of the information is packed in the lower order parts of the image histogram. Improvements in the contrast can make the algorithm more efficient, but more importantly it will help to perceive the images better.

Sub-array extraction - Micro-array spots will be located in separate blocks on the slide referred as sub-arrays and it is required to extract the sub-arrays from the images. Therefore, in this stage the two channels will be combined as one image. This will be done by adding the images. In order to facilitate the discrimination of the sub-arrays, their locations will be highlighted with filtering. In more detail, it will be used morphological closing, which is a sliding window operator used to remove the dark details from the image, while leaving bright features relatively undisturbed. This property will be used to merge all spots in one sub-array with each other. Morphological closing is based on two fundamental operations in mathematical morphology:

Dilation and erosion - Next, the corners of each sub-array will be detected, using the horizontal and vertical projections of the filtered image. In a projection, all image pixels are added according to the projection direction. In this way, the two-dimensional image is represented as a one-dimensional signal. In the resulting projections it will be able to clearly distinguish the parts of image consisting of sub-arrays and the background. With horizontal and vertical projections, the corners of each sub-array will be automatically detected.

Extraction of individual spots - The sub-array coordinates will be extracted using the filtered image. After extracting each sub-array, the spot locations using horizontal and vertical projections will be detected. Similarly as previously, the projections are calculated individually for each subarray and the coordinates for individual spots are obtained from the local minima of the projections. As a result, the spots will be separated from each other. In the resulting image, one spot is surrounded by its local background as a spot patch. The algorithm will be able to extract all spots individually from the image. Therefore, the measurement of gene expression levels from each spot will be performed.

Information extraction - The final step in the automatic micro-array image analysis concerns the segmentation of each spot and the measurement of the corresponding gene expression levels. Using the previously implemented methods, it will be able to extract individual spot patches from the images. Since it is required to measure expression levels from both channels, we need to operate with both of the original images. Initially, one spot patch at a time will be extracted simultaneously from both channels. By using an automatic segmentation algorithm, each spot patch will be segmented to spot foreground and background. Thereafter, the average intensity will be calculated for the foreground and the background. For this reason, the true expression level of each spot will be calculated by subtracting the average background intensity from the average foreground intensity. In this way, for each spot in the micro-array the real expression level from both channels will be calculated. The analyzed micro-array data will be combined with the gene alleles which contribute to development of autoimmune diseases and diagnosis will be performed. All known gene alleles will be stored in the central database server with full details concerning their correlation with the autoimmune diseases, concerning the portable platform. Various tools for querying the database and processing the results will be stored in the PDA. The diagnosis mechanisms will be based on decision making algorithms implemented both at the desktop station and the mobile device. The majority of the 2,683 allele sequences of the IMGT/HLA gene database will be used.

Also, communication software will be developed both for information exchange and data transmission between the PDA/Mobile Device and LOC as well PDA/Mobile Device and the desktop station (Laboratory Information Server - LIS) which will be accommodated in a laboratory of a large medical centre. The communication will be mainly wireless (except for large-distance primary care diagnostic point-of-care places) using the well established internet communications protocols and the data will be transmitted securely in a private network. All these procedures will be developed as standalone software that will interact with the LOC from the PDA/mobile device. The detailed version of the automatic micro-array image analysis software and the diagnosis extraction mechanisms will be hosted on the LIS. Also the desktop station software will be capable to provide treatment advices for autoimmune diseases and the knowledge will be extracted by combining all the stored gene data. In order to allow new diagnostic tests to be performed and new decision rules to be applied the PDA software and the cards will be able to change.

IV. CONCLUSION

NFC is especially suitable for health and disease management [8] and we have presented here that how LOC can be used in conjunction with NFC for diagnostic purposes by utilizing the StoLPaN J2ME host environment that provide us a seamless interface for analyzing LOC data, without requiring any detail handling of hardware/software interface issue. As a result the thorough research carried out under POCEMON will be facilitated from StoLPaN environment (as depicted by figure 1) that will provide the delivery of mobile information services in the professional primary care environment, and to present solutions for providing decision support information on small, portable or wearable platforms. The main objective of providing mobile devices packaged with relevant high-quality software tools for health-practitioners in the near future will accelerate the establishment of interoperability standards and secure communication of health
diagnostic data between all involved partners of the project, including patients.

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