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Near Field Communication

Which Potentials Does NFC Bring for Teaching and Learning Materials?

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***Abstract*—Near Field Communication (NFC) is deemed to be a future technology with a lot of potential in many areas. One of those areas, learning and teaching, will be covered in this article, showing possible usages of NFC with teaching and learning materials. With a lot of new NFC capable devices presented recently, this technology can be utilized in many areas, including the arbitrarily growing field of mobile learning.**

Mobile devices, especially smartphones, can help to close the gap between printed media and online media. Several methods, e.g. two-dimensional barcodes, have already been used to connect the digital world with printed media but almost all of them caused inconveniences or difficulties. NFC presents an easy to use way to share and communicate directly between capable devices or tags that can be applied almost anywhere.

In this publication a first insight to the potential of NFC for teaching and learning content is given. A prototype is programmed to allow data transformation between the print media and the smartphone. It can be summarized that NFC will be the logical successor of QR-Codes.

***Index Terms*—Mobile Tagging, NFC, QR-Code, Technology Enhanced Learning**

I. INTRODUCTION

Information technology is one of the fastest growing branches; especially the mobile sector expands very quickly and is introduced in many new areas. According to a recent ITU report [11], very soon there will be as many mobile-cellular subscriptions as people inhabiting the planet, with the figure set to surpass the seven billion mark early in 2014. On the other side, printed materials are still needed in many cases and are enhanced by additional online content. Combining digital and printed materials is one of the biggest challenges of today as well as tomorrow. For example, mobile tagging is considered as one possibility to close the gap between digital and printed media [18]. One (publisher) can apply an optical code that encodes an URL to the online media on a printed media. The user (reader) scans the optical code with a mobile device and retrieves the decoded URL that can be opened on the mobile device without typing [12] [7].

However, doing so requires a scanning application on the mobile device that uses the integrated camera of the device to read the code. At first glance this sounds very easy and handy, but there are a couple of disadvantages. An optical code can be damaged easily or even get dirty enough to become unreadable even with improved error correction features as for example so called QR-Codes have, using Reed-Solomon Code with maximum 30% of code-words restorable [2]. Too, the process of scanning may take a considerable amount of time, depending on the code size, structure and error level of the code and the used camera hardware of the mobile device.

Our research idea is whether passive Near Field Communication (NFC) tags that can be applied to the printed media instead of an optical code can simplify that process or not (see Fig. 1). This paper gets granular on the potential of NFC as well as on a first prototype assisting daily teaching and learning processes.

NFC itself is a set of standards defined by the NFC Forum, which consists of many companies [14]. NFC tags are more robust than optical codes and are independent of the ambient light. The reading process is usually faster and can easily be done by simply getting the mobile device close to the tag. This method is technically similar to the well-known and established RFID (Radio-Frequency Identification), with mainly the data format and range specification being different. For further information read the tag specification published by the NFC Forum [15].

II. SIMILAR TECHNOLOGIES

However, nowadays two-dimensional codes are still the most common solution in mobile tagging applications mostly used for marketing [8]. Beside the widely used one-dimensional barcodes, frequently used types of two-dimensional codes are for example Data Matrix and QR-Code [21]. Both are nowadays used in printed media to provide URLs to websites or even handle shopping, as the Korean company Tesco introduced in a subway station in Seoul. Customers scan QR-Codes on products and order them this way [1]. Another example is using QR-Codes as Business Cards [3] or for additional information of tagged geo-locations [25]. Additionally, payments using QR-Codes have been implemented, for example at Starbucks [24].

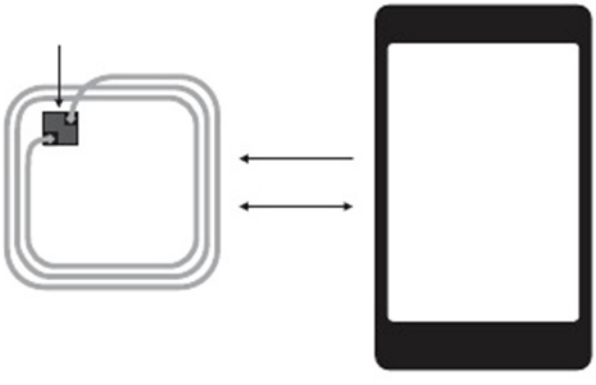

Figure 1. NFC tag (http://www.nxp.com)

Another technology that is very similar to NFC is RFID. Passive RFID tags are compatible to NFC as they work in the same way. An antenna is used to illuminate the tag with power from the radio field generated by the sender to send the response data [26]. RFID applications include any remote identification needs to be done, for example in logistics for stocktaking [17].

The following chapter points out how NFC can be used to connect digital and printed materials, using teaching and learning materials as an example.

III. POTENTIALS OF NFC FOR TEACHING AND LEARNING MATERIALS

A. Mobile Learning

Mobile learning has become very important since mobile devices have recently been widely spread. Younger generations are usually very familiar with new technologies and quickly learn how to use them. Those new technologies have a lot of unused potentials in mobile learning and can induce additional values for all involved [10]. NFC potentials have not been closely examined but literature research yet; first practical tests have shown promising results.

According to [20] mobile learning adds the following values:

„The value of mobile learning

Tutors commented on the value of mobile learning as follows.

- It is important to bring new technology into the classroom.
- Mobile learning could be utilised as part of a learning approach which uses different types of activities (or a blended learning approach).
- Mobile learning supports the learning process rather than being integral to it.
- Mobile learning needs to be used appropriately, according to the groups of students involved.
- Mobile learning can be a useful add-on tool for students with special needs. However, for SMS and MMS this might be dependent on the students' specific disabilities or difficulties involved.
- Good IT support is needed.
- Mobile learning can be used as a 'hook' to re-engage disaffected youth.
- It is necessary to have enough devices for classroom use."

In the described survey of this paper, learning games have been developed. Those games use SMS for communication. This requires everyone being capable of writing SMS or MMS, which can cause problems especially with handicapped users. In addition to this, SMS and MMS are fairly "old" technologies and have some constraints that might not be suitable for the growing information flow. Nevertheless, it is a widely used possibility especially in developed countries because of missing infrastructure of Internet access [9].

One of the biggest challenges of mobile learning is to connect digital materials and printed materials. Thus, NFC is a technology that offers a way to close the gap between both media. It serves as a kind of interface for digital and printed materials to link each other.

However, several barriers currently (as of April 2013) block further expansion of the NFC technology, like incompatibilities between certain NFC tags and chips. That usually depends on the manufacturer of the chips and tags. For example, chips produced by NXP Semiconductors perfectly work with their own tags but other tags are not readable by chips produced by other manufacturers although their data format is the same.

The data format has been specified and published by the NFC Forum and is called NFC Data Exchange Format (NDEF) (NFC Forum, 2006). A current example of that case occurs in tags of the type of MifareClassic (sizes 1 and 4 KB). An NXP Semiconductors manufactured NFC chip is integrated in a Google Nexus S smartphone, while Google's current (as of April 2013) flagship Android smartphone Nexus 4 integrates a Broadcom NFC chip. Inspite of the fact that Google regards the Nexus series smartphones as the reference products for most of their published Android versions, those incompatibilities occur. However, those should not be hindering to define some potential for the future of learning and teaching contents.

B. Prototype implementation

A prototype for testing has been developed. As example, the NFC chip should enhance the well-known German lecture book on Technology Enhanced Learning, shortly L3T. This book was written by more than 130 authors in the German speaking area and all 50 chapters are available via open access at http://l3t.eu [5]. The whole project compromises not only the digital or printed book, but also apps for android, iPhone, and iPads as well as much additional material on the web like bookmarks, videos, or exercises. So there is also a big support for m-learning activities. [4].

The prototype for testing the NFC potential is written for the Android operating system that fully supports NFC and provides an additional feature called Android Beam, to transfer data via NFC directly between two Android devices. The prototype enables sharing of all L3T article links to NFC tags and devices and also reading from tags. It cannot display articles read from NFC tags or devices yet (the necessary reader is missing) but it shows the potential of the technology by simply listing different data types of received data. It is based on the boilerplate implementation published by the ndef-tools developer [23].

So from a given article, the user can use the options menu to choose a sharing method or even read from another tag. If a tag is read, data will be presented in a list (see Fig. 2), showing type information of the NDEF record.

The tag read from in Fig 2. was written by the tag writer of that app that currently writes a static text and a dynamic URI depending on which article is currently viewed. The written data could be extended by interface actions done by the user. This does not require the user having knowledge of the exact data that is written and thus simplifies any application involving writing data.

The following chapters point out how NFC can be additionally used and applied with some further use cases, according to the research work gained in the prototype test.

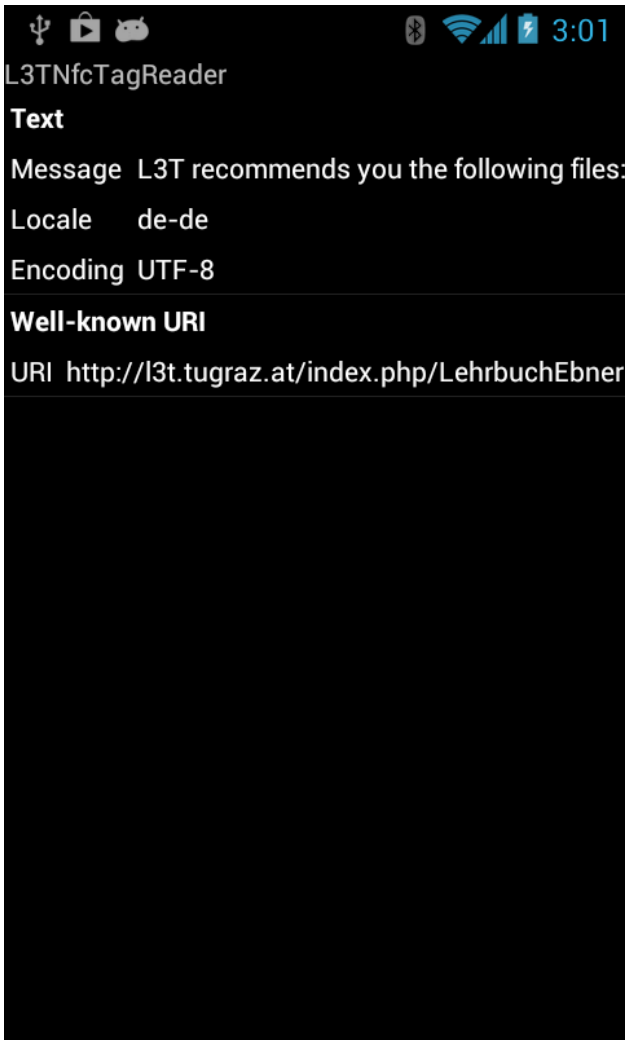

Figure 2. NFC tag content type information

C. Distributing materials

NFC can be used to distribute teaching and learning materials. Imagine the following scenario:

A lecturer wants to distribute current materials in his/her lecture hall where no IP-based network is available and he/she cannot upload them to a webserver. There are more than 300 students in the lecture hall who want to use digital materials in practical exercises. The most common way would be to deliver those materials as printed scripts to each single student. Although this can be accomplished in an appropriate time frame, it causes also extremely high costs to create 300 copies. Additionally, printed materials are not suited for some applications, for example technical studies that apply code fragments, scripts or other chiefly digitally used materials.

In that case, the lecturer can either place an URL to the materials, or the materials themselves on a NFC tag before the lesson starts. Students can retrieve the materials by simply touching the NFC tag with their mobile devices. Furthermore NFC tags will most likely increase in capacity to store large amounts of data, so the content can directly be put on the tag. Current tags are optionally rewritable, cheap and thus can significantly reduce cost of the distribution of materials.

Additionally, NFC tags featuring authentication methods can be protected against unauthorized writing or manipulation attempts.

D. Additional information to materials

Smartphones, tablets and other mobile devices will probably play an even more important role in the future. NFC simplifies several user interactions to a single touch action on a tag. For example, if a teacher presents a video in his/her class, there is certain equipment required. This equipment can also be expensive and thus it is shared in many cases and therefore it is not always available. To avoid that kind of problem, the students' mobile devices can be used to display multimedia content like a video that is linked to with a NFC tag. The students simply scan the tag which can be applied to printed materials as a sticker and their device loads the movie. It also enables the users to directly save the movies on their devices. This could be easily accomplished by a single NFC touch action using an application without requiring no other external equipment. This also applies to external materials of all kinds that cannot be delivered using the printed materials, shortly called learning objects (LO). So the teacher simply applies a NFC tag sticker to certain spots linking to the external data source that can also be updated, without replacing the contents of the tag.

E. Sharing of materials

With additional NFC related features like Android Beam users can easily share data directly between capable devices without using any other data transformation technology like wireless network, Bluetooth, or cell phone network. This may be useful for students who want to forward or share materials or URLs pointing to those materials. It is very simple to add Android Beam functionality to applications; so even people with less affinity to technology can easily use those apps.

In case of bigger data is needed to be shared, other connections should be used because NFC is limited to a bandwidth of 424kbit/s, as specified by the NFC Forum [16]. But NFC can play a major role in that case as well. NFC can be used to establish a connection like Bluetooth, which handles the transfer of the data afterwards. Bluetooth in its default mode is considerably slower at establishing connections than NFC and also might need user interaction like entering a key when pairing devices. That step can be skipped and simplified because the connection will be established using data exchanged via NFC while simply touching the devices. Nevertheless, to exchange larger amounts of data via NFC only, the specified bandwidth should be increased in the future because it may often not be feasible to keep devices very close to each other during the data transfer.

F. Delivery of practicals

As NFC tags can be configured to execute pre-defined actions, students may deliver their lesson results at the end of an exercise unit using their NFC capable device. The tag holds the necessary information about the delivery template and the device holds information about the student as well as the involved study and course he/she enrolled in. The way the information is shared and managed can be defined on the tag. The delivery itself than can be executed via email for example. In that email, all necessary information will be arranged and presented as defined

on the tag and no other interaction is required as all actions can be conducted with the simple touch of the tag.

The lecturer can set up a filter that automatically assigns retrieved emails to a specified folder and also receives additional information about the student which he/she would need to look up elsewhere. This also reduces the time needed for administration related actions.

G. Integration of social networks

NFC tags could be used to integrate social networks like Facebook or Google+. There are numerous possibilities for using for example Twitter in academic environments [6].

Furthermore, a private social network for students could be created to support mobile learning and to offer an additional channel for sharing knowledge related to materials. This could be a linking system for bookmarks that simplifies sharing of single sentences or paragraphs.

For example, a student can bookmark a paragraph by means of a special marker tool on the user interface. That bookmark is added to the device local bookmark library and can be shared in the social network using NFC either to connect to another device directly with Android Beam or similar transfer methods or to a tag on his/her printed material which can be read by another student. Another possibility is to use a tag to identify the social network and upload the data using the connection information retrieved from that tag. In any case a shared learning network is created that allows students to simplify joint learning for exams. A group of students could easily split the chapters and share their thoughts when merging their elaborations using NFC. This would be very easy to use as students just need to tap an NFC tag and can use onscreen touch navigation on their mobile devices. The mobile device does not require any external tools. The user does neither need training to apply the described solution nor knowledge about the network connection as identification, authentication; establishing of the connection can be done in a single NFC touch event.

H. Access control to materials using NFC

As NFC tags support authentication methods a teacher/lecturer can control access to materials or parts of those.

NFC can be useful to create a standard access method that is independent of the used background system. That replaces the usual input form login mask that is not protected from phishing by secure NFC authentication that also provides identification.

Restricting access to materials could be executed by various methods. If a teacher/lecturer wants to give access to currently present students, he/she can require reading a NFC tag that holds access information to the linked materials, or even provides direct access to those protected materials. Additionally, he/she can use the access control combined to a payment system using NFC.

Also, a teacher can use persistent access control to check which student accessed which material at which time. The resulting data could influence the evaluation of training success that could help the teacher to adapt materials accordingly.

I. Examinations

NFC could replace or complement any previous used identity card. The teacher/lecturer could verify the identity using NFC and automatically connect to the administration system to check whether the student is allowed to participate in the examination or not and thereby verify his/her presence too. In that case, paper lists could be omitted and thus save costs. Even more, the verification process is accelerated and simplified.

NFC could also be used in examinations that allow the use of digital materials. In that case, NFC can be used to check who is accessing which part in the digital materials and measure how long a student needs that part. This additional knowledge could have impact on the evaluation of the given answer and the teacher can draw conclusions from the student's understanding of the related chapter. Especially from a Learning Analytics perspective this can be from high interest [22].

J. Links and Bookmarks

All hypertext links and bookmarks will be removed from learning materials. If you need to refer to an Internet email address or URL, currently you must type out the address or URL fully in regular font. With a NFC tag all URLs will be transmitted directly to the mobile devices and can be accessed easily.

IV. OTHER USES OF NFC

The current most known and most promising field of application of the NFC technology used to be payment systems. In the last years many companies ran experiments to test NFC to be used as wallet, cooperating with well-known payment providers like MasterCard and their PayPass system [13].

Transactions are rather small because, for example, the eurozone of the European Union limited payments via NFC to 25 EUR and the United Kingdom to 20 GBP, as reported by [19].

Additional uses are identification purposes and access control that can be done very simple and without any other action than approximating the device to a tag or other device. This removes possible unsafe input methods and allows secure identification of the device holder. However, protection against the loss of the device is still poor as many users do not block their device with a PIN code.

V. CONCLUSIONS

NFC offers several methods to connect digital media and printed media. It simplifies and reduces several interactions to a single action of narrow contact and can be easily used even by handicapped people. It allows integrating digital media into printed media using a mobile device with NFC as interface. As NFC is a standardized protocol, the used hardware following that standard is interchangeable.

Compared to other tagging methods using two-dimensional codes like QR-Code or DataMatrix, NFC offers more flexibility and is easier to use. Data on an NFC tag can easily be replaced without replacing the tag-hardware or the underlying structure it is applied to. This reusability can significantly reduce costs if the contained data is designed to be replaceable. Also, NFC tags offer more capacity than optical codes that are limited by the space they need and their specification.

Further, reading from a NFC tag is usually faster than scanning optical codes and is also independent of the

environment. Reading optical codes requires a source of light and a not malformed or obstructed surface. Error correction of QR-Codes is still fairly good. According to the specification, it can restore about 30% of the code-words using „Level H“ [2]. However, it also reduces the amount of data the QR-Code can store because of the consumed error correction symbols.

NFC tags instead can be applied to almost all objects. The only problem that has to be dealt with is that the tag cannot be applied to metal surfaces without modification because the antenna needs to act as inductor to create the electric power for the chip when using passive tags.

Table 1 summarizes the potential of NFC with a special focus on teaching and learning contents. It can be concluded that this contact-free technology will have a great impact on data exchange because of its simplicity and speed. The presented prototype gave a first insight to the forthcoming possibilities. Nevertheless, additional research work needs to be done to reduce the theoretical ideas to practice.

TABLE I.
POTENTIALS OF NFC AND THEIR IMPLEMENTATION

Potential	Implementation
Distribution of materials	NFC tag with URL to materials or materials themselves
Additional information to materials	NFC tag with URL to integrate external media
Sharing of materials	Peer-to-peer communication between devices
Release of lesson results	NFC as interface to an automatic delivery system
Integration of social networks	NFC as support for learning group with distribution of bookmarks in social networks
Access control to materials	Linking payment system and authentication methods using NFC to privide access to materials
Exams	NFC as interface to verify identity and access control to digital media that are permitted to be used during the exam

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