Abstract—NFC (Near Field Communication) technology allows people to integrate their daily-use loyalty cards, credit cards etc. into their mobile phones. In addition to integrating those cards into mobile devices, NFC technology brings innovation opportunities to mobile communications. It enables two users to easily communicate and exchange data simply by touching two mobile phones to each other. The aim of this paper is to perform a brief review of the published NFC applications in literature and explored the benefits of these applications by classifying them in eight service domains. We believe that this analysis will provide valuable insights for performing rigorous and business relevant research on NFC applications and its service domains.

Index Terms—NFC, review, applications, service domains, classification, benefits.

I. INTRODUCTION

NFC as one of the enablers for ubiquitous computing is a combination of contactless identification technologies which requires bringing two NFC compatible devices close to each other, essentially touching them (Fig. 1). User first interacts with a smart object (either an NFC tag, NFC reader, or another NFC enabled mobile phone) using her NFC enabled mobile phone (NFC mobile). After touching occurs, NFC mobile can make use of received data, or can use provided mobile services such as opening a web page, making a web service connection etc.

NFC is a bidirectional short range, wireless communication technology. The communication occurs between two near devices within few centimeters. 13.56 MHz signal with a bandwidth not more than 424 Kbit/s is used. NFC technology is based on Radio Frequency Identification (RFID) technology and can operate in card emulation, reader/writer, and peer-to-peer operating modes where communication occurs between a mobile phone on one side, and an NFC reader, a passive RFID tag (NFC tag), or a mobile phone on the other side respectively [1].

Since NFC technology is started to be promoted, various real-life applications have been evolved. At the same time, NFC has become an attractive research area for many academicians due to its exploding growth and its promising applications and related services.

The purpose of this paper is to conduct a brief review of published NFC applications in literature and categorize these applications according to their service domains. This analysis will provide us valuable insights for performing rigorous and business relevant research on NFC applications and its service domains. Also we have exposed some challenging research issues on NFC applications for future research.

II. REVIEW OF NFC APPLICATIONS

NFC technology covers a wide range of applications and these applications provide real implementations or prototypes with experimental evaluations or testing studies. In this research, we investigate NFC applications in service domain perspective. We reviewed 78 papers that proposes or explores new NFC applications and published up to 2012.

Since NFC applications became an attractive research area, several promising applications are proposed up to now. Some studies have observed NFC applications according to their operating modes [2], [3]. With the exploding growth of NFC applications, the proposed NFC applications in one service domain may operate in one of the operating mode or may support more than one operating mode. Thus, observing NFC applications in service domain aspect provide us more challenging insights.

After review of NFC applications, we grouped NFC applications under 8 service domains:
1. Healthcare Services
2. Smart Environment Services
3. Mobile Payment, Ticketing and Loyalty Services
4. Entertainment Services
5. Social Network Services
6. Educational Services
7. Location Based Services
8. Work Force and Retail Management Services

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Fig. 2 shows the distribution of NFC papers that are
proposing or exploring NFC applications according to the service domains. As seen from the figure, approximately 21% of the published papers on NFC applications are proposals for developing smart environment. Then developing NFC enabled mobile payment, ticketing and loyalty systems (17%) and NFC enabled healthcare systems (18%) comes with similar levels.

III. NFC APPLICATIONS AND SERVICE DOMAIN ANALYSIS

In this part, we have presented the services domains of NFC technology and we reviewed published NFC papers in those service domains. At the same time, we have briefly explained the benefits of proposed NFC applications.

A. Healthcare Services

In the last decades, one of the fields where IT is playing fundamental role is healthcare. Providing effective and appropriate healthcare services is one of the most important objectives of information and communication technologies. It is seen from the literature that NFC plays significant role in health service domain due to its easy use with lower consumption property. NFC provides user-friendly remote health monitoring, controlling, and tracking systems [4]-[9], and electronic data capturing services [10]-[12]. There are also some services that aim to improve the care dependent people’s quality of life such as NFC enabled prescription system [13], storage of encrypted medical data on tags [14], adverse drugs reaction and allergy detection systems in pharmaceutical and medical care [15], [16].

B. Smart Environment Applications

In technological perspective, smart environment is defined in [17] as “a physical world that is richly and invisibly interwoven with sensors, actuators, displays, and computational elements and also embedded seamlessly in the everyday objects of our lives, and connected through a continuous network”. NFC technology can be also buried in applications that address diverse and heterogeneous needs and capabilities of users in the real world, and make users’ life easier.

Most of the smart environments are enabled by NFC tags that are distributed around (Fig. 3). In accordance with [18], “tags can provide support in user’s everyday life activities by establishing a bridge between the physical and digital worlds when they are ubiquitous in the everyday environments of users” and “the tags become an integral part of physical space, altering the way humans perceive and behave in it”.

It is possible to see innovative examples of smart environment in the NFC literature, which makes use of NFC tags to simplify utilization of existing functions of a system [19], to control a system and perform services remotely [17], [18], [20]-[24] and also to provide information channel [25]-[31]. N-CASH is another example for NFC enabled smart environment [32], [33] that clearly describes the creation of a smart space, which can be activated by NFC mobile to control devices such as home appliances. The appliances are controlled and driven by the request from NFC mobile that uses predefined ontology and rule based reasoning. So, NFC mobile acts as the key to enter the space as well as provide personalized control of a variety of appliances in that space.

C. Mobile Payment, Ticketing and Loyalty Services

With the market and technological developments, successful mobile payment solutions have already been launched over the world. Actually some countries are much more advanced in terms of deployed technology and implemented business cases since governments and influential mobile network operators (MNOs) in those countries have powerful impact on enhancing the development of mobile payment services [34]. Various technologies contributed for the development of mobile payment systems such as RFID technology, contactless smart cards, Short Message Service (SMS), USSD (Unstructured Supplementary Service Data (USSD), WAP (Wireless Application Protocol) IVR (Interactive Voice Response) and so on.

Currently, integration of NFC technology with mobile payment systems brought new and innovative business solutions. Payment, ticketing and loyalty applications are possibly the most well-known and promising everyday applications of NFC technology and have the most complexity in ecosystem aspect as well. Thus it can be seen that most of the trials and projects (e.g., Payez Mobile Project [35], Pay-Buy-Mobile Project [36], SIESTA Project [37]) are implemented in this application domain.
Some of these projects still continue with growing participating entities. From the academic point of view, some valuable studies have been performed as well as some fruitful usability and user experience analyses in payment and payment related application domains. Important examples are:

- An automated reservation and ticketing service for tourists, and a system for car parking access and payment system for ticketing [37], [38],
- Virtual ticketing system and secure mCoupon protocol [39]-[41],
- Secure payment service by Smart Touch Project [42],
- NFC Ticketing system with a simple architecture, including usability testing [43],
- NFC Loyal system including a secure data exchange model to promote payment and loyalty applications on secure elements [44] (Figure 4),
- Offline Tapango system for electronic ticketing process including comparison with traditional paper ticketing process [45],
- Offline NFC payment service with electronic vouchers [46],
- Secure payment system built on a Service Oriented Architecture (SOA) including payment authorization process [47].

D. Entertainment Services

Although NFC technology has high potential for applications like payment and ticketing, applying NFC technology in entertainment and social media applications is receiving more and more attention on user side. Some examples from the literature are Pass the Bomb and Exquisite Touch games [48] which are implemented with a multi-player purpose; Whack-a-Mole game [49], [50] which combines dynamic NFC displays to explore mobile interaction with tagged, physical objects can leverage mobile gaming; PhonePhone as an NFC enabled musical instrument [51].

E. Social Network Services

Currently, Internet based social network applications are booming with popular services like Facebook, LinkedIn, MySpace and Twitter etc. NFC technology is also an enabler for social networking tools and can be integrated with the existing social network applications [52]-[55]. Generally, these applications enable users to interact with tagged physical objects and publish information with the virtual world. Some trials are also using peer-to-peer mode to allow users to share and access their personal information, to create friendships in a more tangible and user-friendly way [56]-[58].

Another good way of promoting social network services is to provide also advertising and location based services such as TaggyNet [59].

F. Educational Services

Currently, universities and schools became a valuable research area for development and testing NFC technology. Various implementations of NFC services and prototypes in universities can be seen to create smart environments for the students as well as to perform efficient work force management and easier administration services for the staff. Up to now, diverse innovative NFC services in university settings are tested and implemented [60]-[63] such as identification, payment services in university cafes and restaurants, photocopy services, reservation and payment of sports facilities, and also resources control and management services, teaching services, dissemination of information and accessing to services.

Also NFC technology can be used in interactive learning process of students [64], [65]. For example, the proposed Moodle system in [64] enables use of games in teaching and learning process. It brings together the characteristics of a common strategy game with an evaluation system; and enables to motivate and reward students by using NFC mobiles.

Other valuable examples related with the efficient work force management in school settings are NFC enabled attendance supervision system [66], [67], and examination systems supported by NFC technology in universities [68].

G. Location Based Services

Location based services (LBSs) are used for enabling an information service by using the geographical position of the user’s mobile device. With the integration of LBSs with NFC technology, users’ behavior can be tracked and user experiences can be improved [69], [70]. Depending on the position of the user, most common examples are displaying friends nearby, broadcasting advertisement of stores nearby through SMS/MMS, and discovering nearest post office depending on our geographical position. Hence these services provide location based, customized messages or information to users [69], [71]. Such services can also be integrated with NFC enabled the indoor navigation systems [72], [70] to provide more value added services to the users, especially in shopping centers.

H. Work Force and Retail Management Services

Furthermore NFC technology contributes in solving the problems within the business world and work force management. For example, in retail industry, retailers face various problems in sales data management such as high cost, low security, and poor performance of real-time documentation [73]-[75]. Nowadays, it is possible to see the advantages of NFC technology in improving the existing business processes within companies [76]-[81].
IV. EVALUATION

Each NFC application provides different benefits and underlying values for its user. Also, the study in [3] performed a valuable review of literature and exploration of NFC applications’ benefits by classifying them into their operating modes (e.g., read/writer operating mode, card emulation operating mode, peer-to-peer operating mode).

In this part, we have summarized the benefits of NFC applications by classifying them into 8 service domains and explored the underlying values in a wide perspective. As seen in Table I, we provide a summary of NFC applications’ benefits in terms of their service domains.

TABLE I: SERVICE DOMAINS AND VALUES PROVIDED BY NFC APPLICATIONS

<table>
<thead>
<tr>
<th>Service Domain</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthcare Services</td>
<td>Improve quality of life, Increases mobility, Decreases physical effort, Efficient data capturing and tracking</td>
</tr>
<tr>
<td>Smart Environment Services</td>
<td>Easy to implement, Device pairing, Easy information sharing, Easy access to real-time information, Ability to be adapted by many scenarios</td>
</tr>
<tr>
<td>Mobile Payment, Ticketing and Loyalty Services</td>
<td>Physical object elimination, Easy access control, Secure data exchange, Secure authorization systems</td>
</tr>
<tr>
<td>Entertainment Services</td>
<td>Easy data exchange, Efficient mobile interaction, Ability to be adapted by many scenarios</td>
</tr>
<tr>
<td>Social Network Services</td>
<td>Easy share of information, Easy access to real-time information, Real-time updating of data, Increases mobility</td>
</tr>
<tr>
<td>Educational Services</td>
<td>Dissemination of information, Efficient resource control and management, Access control</td>
</tr>
<tr>
<td>Location Based Services</td>
<td>Value added and customized services, Easy access and share of information, Improve quality of life</td>
</tr>
<tr>
<td>Work Force and Retail Management Services</td>
<td>Efficient resource control, Easy data management, Improve workflows and processes, Increase business performance</td>
</tr>
</tbody>
</table>

V. CONCLUSION

NFC technology simplifies the human environment interaction in diverse service domains and enables users only to touch their NFC mobiles in order to trigger intelligent services.

Several proposals and examples of NFC applications are reviewed in literature, categorized and presented in this brief survey to point out the NFC application’s benefits in diverse service domains. Such a categorization provides valuable insights about the technology’s development in that service domain, usability, adoption and acceptance issues.

It is seen that some service domains (e.g., entertainment, social network, education, location based services, work force and retail management), still needs more rigorous studies in NFC technology perspective. The benefits of NFC technology in those service domains need to be searched and explored by researchers.

We also explored some open research issues that can be observed by academicians or practitioners:
   • Comparison of vulnerabilities of NFC applications in different service domains,
   • Analysis of compatibility and interoperability of different NFC mobile architectures in a service domain,
   • Development of design principles, methodologies and models for building specific applications such as context aware or smart environment,
   • Creation of user interaction models for different service domains,
   • Exploration of user perception and preferences for NFC systems,
   • Identification of barriers to and critical success factors for NFC adoption,
   • Exploration of different cultures and cultural norms impact on NFC usability case studies,
   • Exposure of psychological and relational issues in NFC adoption,
   • Implementation of longitudinal field studies on NFC usability with well-structured statistical results.

ACKNOWLEDGMENT

The comprehensive list of all reviewed 78 papers that corresponds to categorization scheme can be found at http://nfclab.isikun.edu.tr/icfcc2013/.

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Vedat Coskun is a Computer Scientist, Academician, and Author. He established NFCLab – Istanbul (www.NFCLab.com), the leading and pioneer research lab on Near Field Communication (NFC) technology worldwide, which aims to take initiative on sustainable evolution of the technology for creating a win-win ecosystem for all the actors in the game such as users and financial and technical organizations. He is currently working as Associate Professor of Information Technology department in ISIK University, Istanbul. He received “Excellence in Teaching” award from ISIK University in 2012. He also gave lectures in several other universities such as University of Thessaly, Volos / Greece, Malardalen University, Vasteras / Sweden, Inholland University, Amsterdam / Netherlands. He is specialized in Security, Mobile Technologies, Java technology, Android, and NFC. He has vast amount of conference and journal publications. He authored several books, including Near Field Communication: From Theory to Practice, which is published in 2012 by John Wiley & Sons Inc. He believes on the importance of academia & industry relationship, and takes role as consultant for national and international companies in this manner.