NFC Research Framework: A Literature Review And Future Research Directions

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Abstract
Near Field Communication (NFC) is one of the emerging and promising technological developments, provides means to short range contactless communication for mobile phones and other devices alike. NFC has become an attractive research area for many academics due to its exploding growth and its promising applications and related services. An understanding the current status of NFC research area is necessary to maintain the advancement of knowledge in NFC research and to identify the gap between theory and practice. In this paper, we present a literature review on NFC. To facilitate the analysis of the literature, we propose a research framework and organize the NFC literature into four major categories; theory and development, applications and services, infrastructure, ecosystem. This rigorous and holistic literature review with the objective of bringing to the state-of-art in NFC design science research provides advancement of knowledge in NFC research and further research directions.

Keywords: Near Field Communication, Literature Review, Taxonomy, Classification Framework

Introduction

Today the rapid development and adoption of information technologies is changing the way of doing business significantly. The growing interest on electronic commerce to perform business transactions brought vital improvements, especially in contactless technologies [16]. Near Field Communication (NFC) has become one of the promising technological developments in IT industry. NFC technology is a short-range, high frequency, low bandwidth and wireless communication technology based on Radio Frequency Identification (RFID) technology. It allows us to transfer data within few centimeters. One of the advantages of NFC over other wireless technologies is simplicity (Madlmayr et al. 2008): transactions are initialized automatically after touching a reader, another NFC device or an NFC compliant transponder. Due to its simplicity, it has become a new and exciting area for practitioners, many NFC enabled applications and services are developed which are operating in three different modes; reader/writer, peer-to-peer and card emulation [58]. The integration of NFC technology into mobile devices offers many reliable applications; specifically payment, ticketing, loyalty services, identification, access control, content distribution, smart advertising, peer-to-peer data/money transfers, and set-up services.

NFC has become an attractive research area for many academics due to its exploding growth and its promising applications and related services. Due to its nature, large proportion of the NFC research can be represented as a design science research (Hevner et al. 2004) which aims to propose an innovative design artifact and has a problem relevance and rigorous nature. As we shall present, for the last few years, there has been a considerable amount of increase in the number of research papers and activities concerning NFC. However, understanding the current status of NFC research area is necessary to maintain the advancement of knowledge in NFC research and to identify the gap between theory and practice. Thus, an academic review of literature is necessary to fulfill the needs.

The purpose of this paper is to conduct a holistic review, classify the NFC literature that was published so far. The paper is organized as follows: first the related studies and resources for our literature review are examined; second the research methodology of this study is described clearly; third the NFC research framework is presented; fourth NFC literature is classified and findings are reported appropriately; and finally, future research questions and directions are suggested.

Related Review Studies

Reviewing academic literature in a research area is a necessary work for providing contributions, taxonomy, research frameworks and signifying open research areas, as well as future research directions. Such a work about NFC research area has not performed so far in a discipline and rigorous way. To provide a literature review on NFC research, primarily related review studies - information systems, electronic commerce, mobile commerce and RFID - are examined in detail.

Hevner et al. (2004) propose the difference of behavioral science and design science research. Design science is inherently a problem solving process that creates and evaluates Information Technology (IT) artifacts intended to solve identified organizational problems. They mainly focus on the importance of design science in information systems research areas and creates a research framework which maintains relevance and rigorous of the research. They provide seven critical guidelines for researchers to achieve effective design-science research in Information Systems (IS). Thus, achieving a complete, effective NFC design science is a crucial and necessary issue, in these days. Today most of the NFC academic literature can also be considered as a design science rather than a behavioral science.

Another related and a broader research area is electronic commerce (e-commerce) because of its novelty and increasing growth. One can find several review studies on electronic commerce in different times and from different perspectives. Today, we see that e-commerce has a great coverage area due to growing interest on it. In accordance with some e-commerce literature reviews such as Ngai et al. (2002) and Wang et al. (2007), researchers generally express e-commerce research taxonomy in four dimensions (applications, technology, support and implementation, other issues) and comparative analyses have a great impact for determination of problems and future research areas. The most considerable suggestion has been made on the development of "rigorous research methods of articles and further empirical studies" which is also a guideline for design science researches (Hevner et al. 2004). Thus, rigorous of NFC literature as a new emerging technology and research area has to be examined.

Likewise, mobile commerce (m-commerce) literature reviews are also good sources those can be used when creating a suitable NFC taxonomy. E. Ngai et al. (2008) identified the gaps between theory and practice and future research directions for m-commerce papers clearly through a well structured classification framework and analyses. In fact, RFID research area's further investigation was also proposed in here strictly. When we narrow the research areas close to NFC literature, Radio Frequency Identification (RFID) research area -as a related technology to NFC - is also a part of e-commerce and m-commerce world. E. Ngai et al. (2008) reviewed RFID academic literature and organized studies as "technological issues, applications areas, policy and security issues, and other issues". As stated by E. Ngai et al. (2008), such a study can be a good resource for anyone who is interested in this area and provides useful insights on the anatomy of the RFID literature.

Actually, all of these advances can be identified as motivations for this paper that is one of the promising NFC research review. Such a rigorous and holistic review with the objective of bringing to the state-of-art in NFC design science research will initiate further research on the growth of NFC technologies.

Research Methodology

The aim of this study is to understand NFC research as a design science research area by examining the current literature in order to provide insights for NFC practitioners and researchers. Since NFC is a rather lately emerging technology, research papers on NFC are relatively recent, so that the first NFC related papers are published starting from 2005. Thus the scope of this survey is limited to the time frame of 2006-2010; this 4 year period can be representative of the NFC literature.

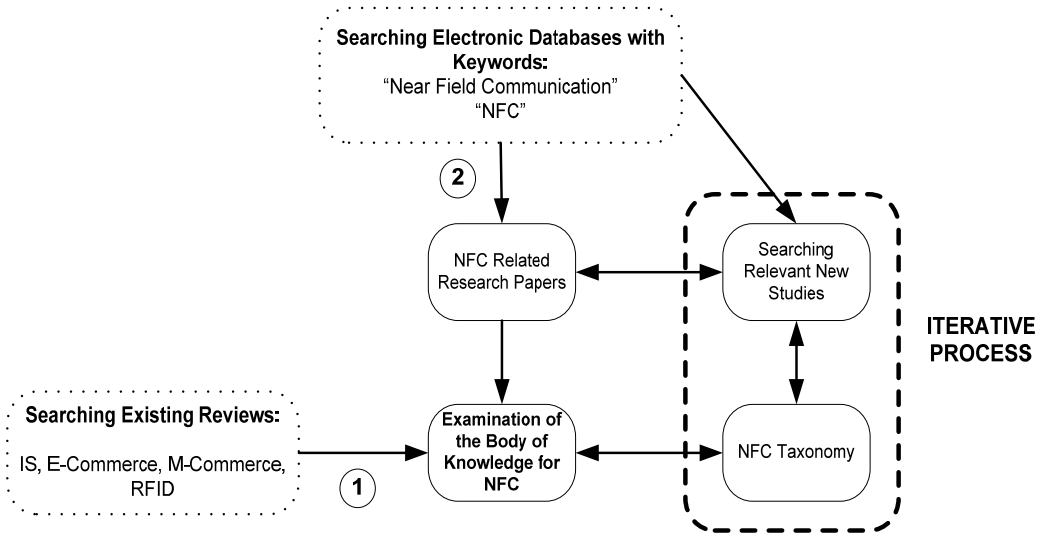

Fig 1. NFC Literature Review Strategy

This survey is based on articles in journals and mostly conference proceeding papers. We exclude master's theses, doctoral dissertations, textbooks, unpublished working papers, and white papers. Researchers and practitioners often use journal papers to acquire information and to disseminate new research findings (Wang et al. 2007), thus most of the existing literature reviews exclude conference proceeding papers, too. However, we did not exclude conference papers in our literature review as the proceeding papers provide also "the high level of research, both in width and breadth (Wang et al. 2007)" after journals. At the same time, we exclude some writings those are published as editorials, news reports or book reviews.
After performing the search for the papers as defined above, we have found 74 articles (see Figure 1, Step 2). The literature search was based on two descriptors; "NFC" and "Near Field Communication". It was conducted using the following electronic databases:

1. IEEE/IEE Electronic Library
2. Association for Computing Machinery
3. ISI Web of Knowledge
4. Academic Search Complete
5. Computer and Applied Science Complete
6. Science Direct
7. Emerald Full Text

Sometimes the abstract, but mostly full text of each article was read to identify whether the article has high relevance to NFC. The literature review strategy followed for this study was an iterative process as a backward strategy, while working on the classification of NFC literature. We tried to find and add new studies about NFC, to our review. In doing so, we are able to provide academics and practitioners with a comprehensive base for better understanding of NFC research.

NFC Research Framework

We propose an NFC research framework which includes a content-oriented classification (Ngai et al. 2008) of the NFC literature. We classified the NFC academic literature in four major categories (see Figure 2) and signified the bidirectional relationships between categories: NFC Theory and Development, NFC Infrastructure, NFC Applications and Services and NFC Ecosystem.

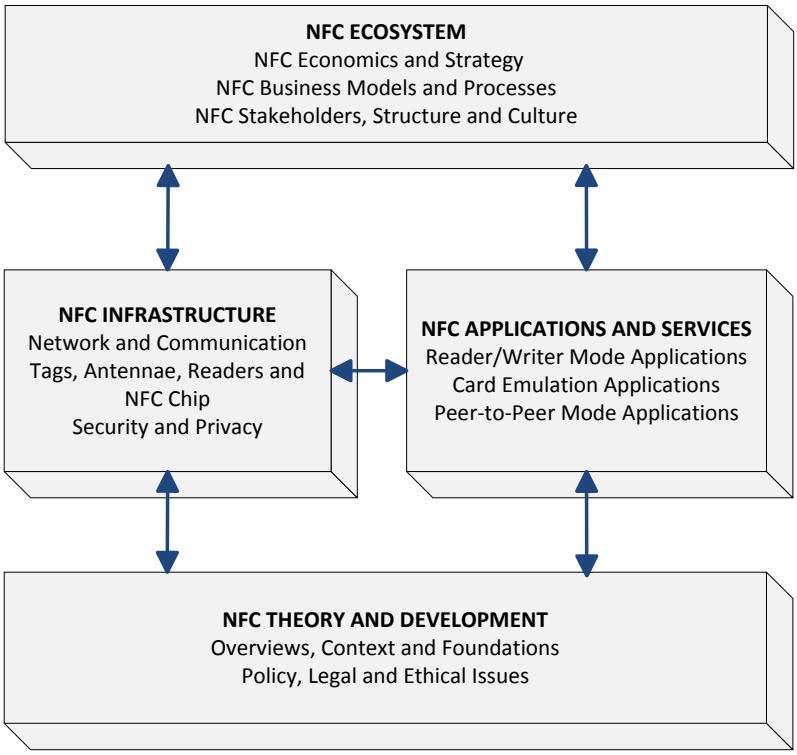

Fig 2. Classification Framework for NFC Research

NFC Theory and Development

This is the fundamental level of the proposed NFC research framework. It includes the studies related with the development of NFC technology and applications. We examine this level in two aspects. The first one is "Overviews, Context and Foundations" which includes general introductions, assessments, reviews about NFC, foundations or standards on NFC technology, performance analysis and measurements and new guidelines for the development of NFC enabled applications or services. The second one is "Policy, Legal and Ethical Issues" such as security and privacy issues, regulations, and legal requirements. These papers generally focus on more behavioral issues and behavioral sciences which seek to develop and justify theories, rather than developing a design artifact. It is true that these theories underpin and are effected by design decisions (Hevner et al. 2004). Development of papers dealing with this level influences upper levels that focus on design science in NFC research.

NFC Infrastructure

In fact, this intermediate level is introduced as NFC technology which is examined in terms of three major aspects; "Network and Communication" issues (e.g. data aspect, new communication protocols, OTA transactions), hardware issues dealing with "Tags, Antennae, Reader and NFC Chip", "Security and Privacy" issues (e.g. vulnerability analysis, availability, confidentiality, integrity, authentication, authorization, non-repudiation) that focus on developing design artifact rather than behavioral issue. This layer is positioned with pre-defined business related with to existing technology infrastructure, applications and existing ecosystem. That is, the proposed framework shows the direct linkages of "NFC Infrastructure" with other categories. Moreover, NFC infrastructure related research facilitates new business needs due to the search process nature of NFC.

NFC Applications and Services

Another middle level of NFC framework as NFC enabled Applications and Services. This is influenced from other three categories and provides a problem space or new business needs. NFC technology covers a wide range of applications and these applications provides real implementations or prototypes with rigor design artifact evaluations such as experimental, testing or field studies etc.

We investigate NFC applications from the standpoint of NFC operating modes. "Reader/Writer Mode Applications" provides NFC devices to read and modify data stored in NFC compliant passive (without battery) transponders, "Card Emulation Mode Applications" provides NFC devices to behave like a standard smartcard (e.g. payment and ticketing applications), "Peer-To-Peer Mode Applications" enables two NFC devices to establish a device to device link-level communication to exchange contacts or any other kind of data [58]. Indeed, design artifacts which proposes composed applications or services operating in two or more modes can be seen in NFC literature.

NFC Ecosystem

NFC Ecosystem as the highest level of the NFC Research Framework can be also refered as a part of the problem space or environment of NFC research, the improvements or changes in middle and fundamental layers affect NFC Ecosystem significantly. We examined NFC ecosystem in three major categories. "NFC Economics and Strategy" and "NFC Business Models and Processes" are dealing with more business requirements, analysis and managerial sides of the NFC technology. Third aspect is the "NFC Stakeholders, Structure and Culture" which is dealing with more social sides of NFC technology such as roles, characteristics and capabilities (e.g. user acceptance, usability, adoption, reliability, manageability) of stakeholders (e.g. MNO, service providers, end users), culture of NFC enabled services. Stakeholders play a crucial role in facilitating the NFC research and development. In accordance with Hevner et al. (2004), in a NFC ecosystem, there are the goals, tasks, problems, and opportunities that define business needs as they are perceived by the stakeholders. These perceptions are shaped by the roles, capabilities & characteristics of stakeholders are evaluated within the context of economics & strategies, structure & culture, and business models & processes.

Results and Analysis of NFC Framework

A total of 74 studies were classified with respect to our proposed framework. These articles were analyzed by year of publication and by topic area. This analysis will provide us challenging and promising guidelines for pursing rigorous and business relevant research on NFC and its applications, services.

Distribution of Papers by Year of Publication

The distribution of the papers by their publication year is presented in Figure 3. As shown in Figure 3, research on NFC as a promising design science research area grew significantly in recent years, especially after 2008. Furthermore, we have found 16 studies on NFC up to April in 2010.

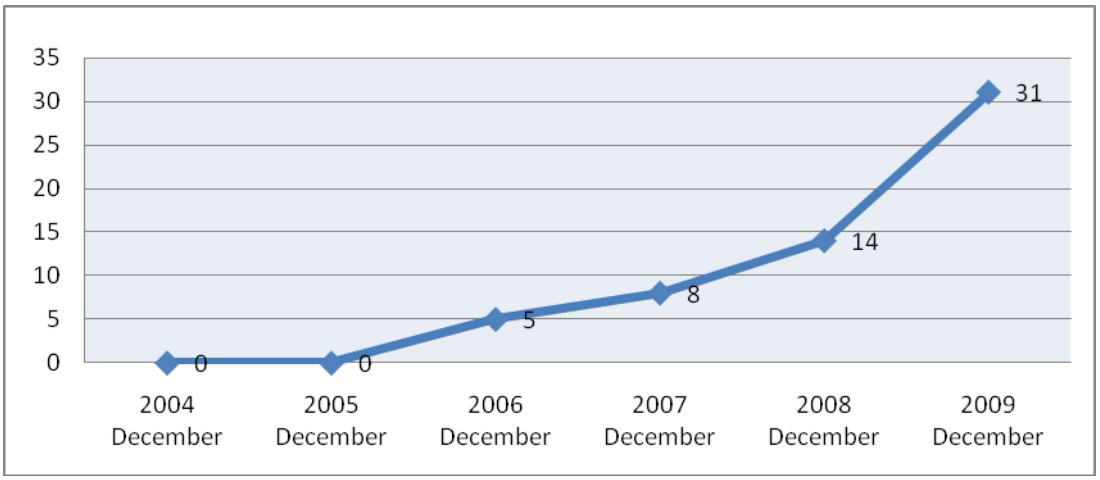

Fig 3. Distribution of papers by year

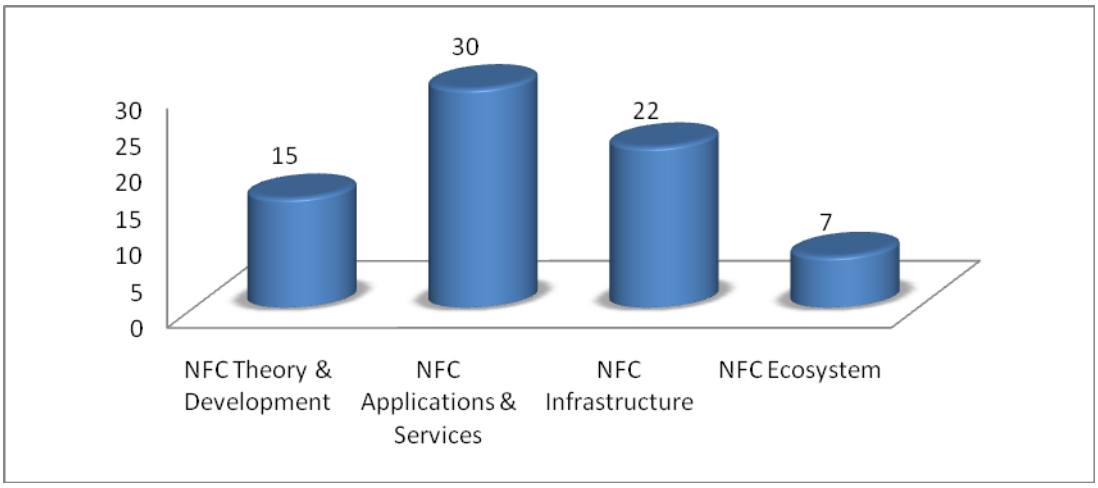

Fig 4. Distribution of Papers by Subject

Distribution of Papers by Subject

A majority of NFC research papers (64 out of 74 or %86.49 of the total) were published in conferences or symposiums. This shows that there is still a clear need for more rigorous and concrete NFC research articles to be published in journals yet. In this way, academicians and practitioners can benefit from these highest level of research represented in journals.

The distribution of NFC research papers by subject is shown in Figure 4. A majority of the NFC research (30 out of 74 or 40.54% of total) is related to NFC Applications and NFC application development, while a few of them were on "NFC Ecosystem", covering only 7 published papers out of 74.

Table 1 includes the classification of the reviewed NFC literature according to our classification framework as shown in Figure 2. As mentioned before, the majority of NFC research as "NFC Applications and Services" (40.54%) is examined in a standpoint of operating modes of NFC, in three broad topics. More than half of the academic papers in this category deal with applications and services of NFC that is operating in reader/writer mode (19 academic papers). At the same time, the academic literature related with "Reader/Writer Mode Applications" is the largest proportion (25.68%) of the NFC literature (e.g. retailing, health, education, supply chain management, museums, social networking, shopping, electronic voting, multimedia controller, smart posters etc.). The second largest topic is "Card Emulation Mode Applications" (e.g. payment, mobile coupons, ticketing, electronic key) with 10 academic papers out of total. The fewest number of papers were on the "Peer-To-Peer Mode Applications".

The second largest category of NFC literature is related to "NFC Infrastructure" (29.73%) which provides "Security and Privacy" issues made up the largest topic (36.36%) within this category. The other topics discussed were "Network and Communication" (31.82%) and "Tags, Antennas, Readers and NFC Chip" (31.82%). In fact, within this category distribution of NFC Infrastructure literature among topics is quite proportional.

The third category as "NFC Theory and Development" is examined in two broad topics. "NFC Overviews, Context and Foundations" with 12 related academic papers is the large proportion of this category. At the same time, this topic is the second largest topic (16.22%) after papers related with NFC Applications in Reader/Writer Mode. The other topic on theory and development discussed in NFC literature is "NFC Policy, Ethical and Legal Issues" (3 academic papers). These findings reflects the fact that NFC is relatively a new, promising research area, so that there is a clear need for more academic study on regulations, privacy, and legal issues surrounding NFC to sustain its development. As seen in Table 1, there were relatively fewer academic research papers on "NFC Ecosystem" (9.46% out of the total). This category is examined in three broad topics, unfortunately there were not

any "specific" academic paper dealing with NFC Economics and Strategy for NFC technology's development, improvement. There were research papers mostly that are surrounding "NFC Business Models and Processes" (3 research papers out of 74) and "NFC Stakeholders, Structure and Culture" (4 research papers out of 74). In fact, most of NFC related papers contribute new ideas, such as on security, hardware or business models while proposing a new, unique NFC enabled application or a new communication protocol. In such situations, we tried to discover the paper's main contribution, focus point, and made the appropriate classification scheme. Table 1 gives a summary of all of the reviewed academic papers clearly in classification scheme. This table should be a beneficial and helpful resource for anyone who is searching for NFC related papers on a specific area.

Table 1: Classification of the Reviewed NFC Literature

Classification Criteria	Number of Papers	References	Percentage by subject	Percentage by all subjects
NFC Theory and Development				
NFC Overview, Context and Foundations	12	[5, 6, 18, 22, 37, 39, 49, 50, 62, 64, 72, 82]	80,00	16,22
NFC Policy, Ethical and Legal Issues	3	[19, 38, 69]	20,00	4,05
Total	**15**		**100,00**	**20,27**
NFC Applications and Services				
Reader / Writer Mode Applications	19	[9, 10, 13, 21, 22, 26, 32, 33, 34, 35, 36, 48, 54, 55, 56, 68, 71, 74, 77]	63,33	25,68
Card Emulation Mode Applications	10	[3, 12, 17, 24, 41, 52, 53, 57, 63, 73]	33,33	13,51
Peer To Peer Mode Applications	1	[70]	3,33	1,35
Total	**30**		**100,00**	**40,54**
NFC Infrastructure				
Network and Communication	7	[14, 25, 40, 46, 79, 80, 81]	31,82	9,46
Tags, Antennas, Readers and NFC chip	7	[15, 23, 29, 47, 51, 67, 75]	31,82	9,46
Security and Privacy	8	[1, 30, 31, 42, 43, 45, 65, 66]	36,36	10,81
Total	**22**		**100,00**	**29,73**
NFC Ecosystem				
NFC Economics and Strategy	0	[-]	0,00	0,00
NFC Business Models and Processes	3	[4, 7, 44]	42,86	4,05
NFC Stakeholders, Structure and Culture	4	[2, 8, 20, 57]	57,14	5,41
Total	**7**		**100,00**	**9,46**

Discussion and Future Research Directions

NFC as a new emerging research area has attracted the attention of both practitioners and academicians. As cited before, academic research activities on NFC area have increased significantly after the year 2006. We believe that, this study is the first academic literature review on NFC technology. With this literature review, we want to shed light on the current status of NFC research.

This review identified 74 academic papers composed of studies from 2006 to 2010 April. Although today, literature review on NFC does not provide so many articles published in journals, this study will provide useful insights into the NFC literature, future research directions and will identify the gap between theory and practice. The results from NFC classification scheme and from design science guideline evaluations have several important implications.

- It is true that, NFC technology has become a promising, challenging research area in recent years. There is a clear need for more journal publications to provide business related and rigorous research papers on NFC technology.

- It is not surprising that most of the academic research papers were related to "NFC Applications and Services", especially operating in reader/writer mode. The reason of such interact on this mode is that development and implementation of such services or applications are much easier than developing applications operating in other modes. Unfortunately we did not find many rigorous research papers on "Peer-To-Peer Mode Applications".

- The second largest proportion of the papers is related with the "NFC Infrastructure". Our review shows the importance of focusing on technical issues of a new technology again, rather than issues related to realizing economics, business values or strategies for NFC development, dissemination and marketing. As seen in Table 1, literature dealing with technical issues on NFC is useful for anyone who is studying on "NFC Infrastructure". We expect more specific research to be conducted on business issues, economics of NFC technology.

- While developing new NFC enabled applications or services, ecosystem of NFC technology clearly needs to be considered. Such new applications or services can bring new business models, processes with new players. Especially the capabilities, characteristics and roles of stakeholders need to be evaluated and modified when necessary, in order to satisfy the requirements of new business models and processes. Cultural differences on adopting NFC enabled technologies could be an interesting area for investigation.

- In terms of theory and development, most of the research papers those are published in journals were overviews and assessments on NFC technology rather than proposing a new design artifact. The articles in journals that we found are not sufficient for development of NFC literature. We expect more rigorous design science research on NFC to be published in journals.

- Policy, ethical and legal problems which can be referred as behavioral issues were other important and demanding research areas for development of a new, emerging technology. However, it is hard to find papers dealing with the public policy or legal problems (e.g. taxation problems, trust, fraud, privacy issues for internet privacy, financial privacy). Indeed, this should prompt academic researchers to investigate this area.

- The research methodology that is employed for this academic literature review has some limitations. The first challenge is about the limited number of journal papers found for the literature review. NFC technology as a new emerging technology is also a new, promising research area for academicians and practitioners, as seen in Figure 2. Because of the short interval, the findings are based on mostly conference proceeding papers. Although we believe that, such a literature review on NFC research is comprehensive for this moment. Second possible limitation is that the determination of the research papers to be included was subjective. Although the selected research papers were reviewed and evaluated to make more objective decisions.

Conclusions

The literature review presented in this paper aims to provide a holistic review and a comprehensive base for understanding NFC research. According to our findings, 40.54% of the NFC literature concentrates on developing NFC applications and services in different operating modes. We expect

more attention on less developed research areas in particular economics, strategy, business values, culture, policy and legal issues. In accordance with Ngai et al. (2008), also for NFC practitioners, more useful guidelines for the development of NFC enabled applications or NFC infrastructure is necessary within the context of "NFC Theory and Development". In addition to our evaluations, we would like to propose some research directions for further research in NFC:

- Development of required NFC standards from policy, regulations and legal points of view
- The economic performance of NFC developments
- Potential NFC-enabled applications that are operating in peer-to-peer mode, adoption issues
- Possible implications of cultural differences on adoption of NFC technologies
- Impacts of NFC technologies on companies, organizations and business models

As stated by Ngai et al. (2008), it is important for business and social science researchers to understand new emerging technologies such as RFID, NFC. With the development of more and innovative NFC enabled applications, the need for standards and policies is increased. At the same time, strategy for diffusion of NFC systems and economy of NFC systems need to be considered while developing new services, which includes the costs of designing, developing, controlling and updating of such systems.

As a matter of fact, we believe that more sub-topics should be added and updated in our proposed classification framework after an extent to which a mature body of knowledge is achieved. With the development of NFC literature more rigorous and highest level of research as articles will be published in journals. At that moment, such a literature review on NFC should be performed again to find new research areas and open research questions.

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