Learning and knowledge accumulation as sources of influence for actors during path constitution: the example of the emergence of NFC technology

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The emergence of a technological path is considered the result of constant negotiations among groups of actors (Pinch and Bijker, 1987; Garud and Rappa, 1994). Authors who focus on technological path constitution describe the interplay between deliberate actions taken by actors to shape this path and the path's emergent evolution (Meyer and Schubert, 2007). As the shaping of new technologies takes a long time, knowledge about the technology and new alternatives are built. Literature on path dependence has generally perceived knowledge creation as being dependent on the initial conditions in which the technology emerges; actors therefore gain knew knowledge through localized learning (Antonelli, 2006). Thus, the learning process will be limited to the perimeter of a given technology (Ibid). However, as actors need to take into account the perspective of different stakeholders to ensure a broad acceptation of the technology (Akrich *et al.*, 2002), actors share their knowledge with a network of other actors, a process we call knowledge accumulation. Knowledge accumulation could result in a new process of learning, as actors from other industries and with different perspectives become involved.

In this article, we demonstrate that learning and knowledge accumulation impact the influence of different groups of actors during path constitution. Initial learning provides an advantage for the group of individuals that has the relevant expertise, as these individuals have a privileged access to a resource. However, as knowledge accumulates in the network of actors, the flows of power among actors change. Furthermore, as other actors learn about different technological alternatives, they use different sources of influence to shape the technological path.

Several authors have tried to explain the influence gained by different actors during technological path emergence and how the actions taken by different individuals can shape the technological path (Garud and Karnoe, 2001). This article brings new insight by proposing an evolutionary process between learning, knowledge accumulation and the tactics of power used by actors to shape technological path constitution.

We study the emergence of near field communication technology, which enables consumers to perform contactless transactions between electronic devices in a simple and safe way. The emergence of this technology can be considered as an extreme case, as more than 100 companies from different industries (such as bank, Internet or electronics good producers) were involved in its standardization.

1. Theory

1.1. From path dependence to path constitution.

The most cited example of path dependence is certainly the standard of the QWERTY keyboard studied by David (1985). By analysing the dominance of the standard in the presence of more efficient alternatives, he introduces the idea of an irreversible state that results in a specific path of action and that cuts off organizational flexibility. This entrapping process can be characterized by four general properties: non-predictability, potential inefficiency, inflexibility, and non-ergodicity (Arthur, 1989). Although these properties are widely adopted in the existing literature, Vergne and Durand (2010) identify a lack of conceptualization by addressing path dependence either as a process or as an outcome and by using it at three levels of analysis (macro, meso, and micro). The two authors propose a clear definition of path dependence as "a property of a stochastic process which is obtained under two conditions (contingency and self-reinforcement) and causes lock-in in the absence of exogenous shock" (2010: 737). Contingency and self-reinforcement reflect the path process, whereas lock-in its outcome. The emergence process is "not determined by any particular set of initial conditions" (Goldstone, 1998: 834). Therefore, the path originates from accidental events that may determine the outcome. These events are called "small events" (Arthur, 1989; Pierson, 2000), "chance elements" (David, 1985) or "contingency" (i.e., unpredictable, non-purposive, and random events) (Vergne and Durand, 2010). Once the path is selected, various endogenous mechanisms sustain its self-reinforcement loop by decreasing the relative attractiveness of alternatives (Kay, 2005). Six self-reinforcing mechanisms are basically proposed in economic studies: economies of scale, network externalities, learning effects, adaptive expectations, coordination effects, and complementarities (Schreyögg and Sydow, 2010). Then, the lock-in is a specific state of persistence that does not necessarily represent the optimal path and that cannot be escaped endogenously (Vergne and Durand, 2010). Therefore, from this perspective, it is only possible to break away from the path consecutively from an exogenous shock (Arthur, 1994).

Facing this deterministic approach, the path creation perspective, labelled by Garud and Karnøe (2001), has been developed around the idea that the emergence is a mindful process guided by human agencies. Because actors are embedded in the phenomena, they build the path based on selected prior experience and pursue their own alternatives. However, events

make it easier to pursue certain courses of action, whereas others become more difficult. Therefore, the lock-in is just temporary. Moreover, "what is exogenous and what is endogenous is not given, but instead depends on how actors draw and redraw their boundaries" (Garud *et al.*, 2010, p.769).

At the core of the path dependence logic lie self-reinforcing mechanisms (Sydow *et al.*, 2009). These mechanisms generate progressively organizational (and inter-organizational) rigidities, stickiness or inflexibility because the organizations ultimately become locked in. However, most studies following this path dependence approach do not explore the internal processes leading conjointly with external phenomena to a lock-in. To fill this gap, Sydow *et al.* (2009), and subsequent articles from Sydow and its co-authors (e.g. 2012, 2013, 2014), develop a theoretical approach to path dependence that integrates internal and external mechanisms of such processes. They propose their own integrative notion, linking the path dependence, path creation and path generation approaches, associated with a specific methodology: the path constitution analysis, or PCA for short (Sydow, Windeler, Schubert *et al.*, 2012; Sydow, Windeler, Müller-Seitz *et al.*, 2012). The PCA assumes the idea that path dependence and self-reinforcement mechanisms not only constrain actions but also promote specific actions connected to the path. Furthermore, they propose a dynamic framework of path dependence that represents the successive restrictions of the scope (Sydow *et al.*, 2009).

Their framework differentiates three developmental phases of path dependence by distinguishing the specific periods of the process in which the four general properties advanced by Arthur (1994) occur (non-predictability, non-ergodicity, inflexibility, inefficiency).

Phase I – the Preformation Phase – is an open situation characterized by a broad scope of options whose effects are unpredictable. In the beginning, several outcomes are possible. The process consists of reducing the scope of options, but it is neither pre-determined nor random (i.e., non-ergodic). While the outcome is not known when the process begins, the selection of a particular option is influenced by several events. However, instead of the traditional view of path dependence, emergence cannot be disconnected from historical influences without substituting the idea of a wide range of choices. Path imprints give a better understanding of the selection process because "since organizations are social systems […], triggering events in organizations are likely to prove to be not so innocent, random, or "small" " (Sydow *et al.*,

2009: 693). The Preformation Phase ends when an initial choice operates as a point of transition, initiating the self-reinforcing process, which stimulates the second Phase. This point of transition is called the "critical juncture" (Collier and Collier, 1991), "bifurcation" (Kauffman, 1993), or "triggering event" (Sydow, Windeler, Müller-Seitz *et al.*, 2012).

Phase II – the Formation Phase – progressively reduces the range of options by making decisions contingent on the initial choice. Whereas the majority of decisions converge to a fixed dominant design, choices are still possible. However, the six basic economic self-reinforcing mechanisms are not sufficient to explain a path (Schreyögg and Sydow, 2010). Again, the authors suggest integrating organizational forces (emotional reactions, cognitive biases and political processes) and, precisely, all kinds of positive feedback cycles in the analyses. Furthermore, it is relevant to consider various organizational contexts.

Ultimately, Phase III – the Lock-in Phase – illustrates the persistence of this unique and predominant pattern of actions. It is persistently reproduced, becoming deterministic in its extreme form of lock-in. In such cases, organizations occult any other alternatives even though they may be better, and their actions are predictable. The path becomes inefficient. However, this restrictive conceptualizing should be attenuated to allow some scope for variation, reflecting the organizational capacity to develop other interpretations of the dominant pattern. In addition, the degree of inefficiency refers to a specific level of analysis, which should then be clarified. Although it does not constitute a phase of the model, a deliberate breaking of the path may also occur (Garud and Karnøe, 2001). However, conceiving this phenomenon again advocates a less deterministic view of lock-in. Path-breaking intensity varies from evaluating new or latent alternatives, such as in Phase I, to switching to a superior alternative and even to destructing the dominant design. In all cases, the intensity is generated by the restoration of a choice situation with at least one superior alternative (Arthur, 1994). It requires an interruption of self-reinforcing loops. From this perspective, actors need to develop a deep understanding of path dependence drivers (e.g., learning effects, coordination effects) that reflect the identification of hidden patterns.

1.2. Learning and knowledge accumulation as sources of influence during technological path constitution

Learning as well as knowledge accumulation by actors are processes that shape technological path constitution (Garud and Karnøe, 2001). Multiple actors are involved in emerging technological paths in real time (Garud, 1997, Pinch and Bijker, 1987). These actors generate learning as they experiment with new technologies (Garud and Karnoe, 2003). Different actors have different pieces of knowledge that need to be shared. Through knowledge sharing in networks of actors, knowledge accumulation is generated. New knowledge that is gained by others actors may lead them to deviate from the established path (Garud and Karnøe, 2001).

Although actors do not completely understand the process of path constitution, they may try to control it by coordinating knowledge accumulation or by constraining the access to their own knowledge (Sydow, Windeler, Schubert *et al.*, 2012). The success of a given technology results from a concrete expression of tacit agreement among actors (first users, producers, and distributors of complementary products, among others) (Willinger and Zuscovitch, 1993). Thus, actors favour a collective choice, and certain actors try to influence the decisions made during the technological path development by an intensive learning process. Then, they try to control the access to information by preventing others from having access to new knowledge and decision centres or by changing the meaning of the knowledge that is generated. However, those actors also need to share their knowledge with other actors to get the new technology accepted and to develop a product that corresponds to customers' needs (Carlile, 2004). For example, they set up a consortium to rally allies to the new technology development (Sydow, Windeler, Schubert *et al.*, 2012). Thus, they may lose their power as knowledge flows among diverse actors.

The aim of this research is to analyse the interplay between learning and knowledge accumulation and the tactics of power used by actors during path constitution. In most studies, power is defined as "the ability to get things done in spite of resistance and the ability to influence people through personal appeal and magnetism (which is termed charisma) (Krackhardt, 1990: 344). There are different sources of power, which are related to learning and knowledge accumulation among actors during the different phases of the PCA.

Learning:

A technological path does not emerge in a vacuum. Organizations make certain choices and follow paths of actions according to their former routines, practices and experiences. As organizations experiment, they develop new learning about technologies, customers' needs and institutional practices in the new domain. Actors who have absorbed new knowledge through a dynamic learning process have a better understanding of clients' needs and can determine the requirements to elaborate a standard. Consequently, they can be in a better position to influence the path creation phase.

In reality, during this first phase, different technologies may compete and externalities may determine the success of a technology. Consequently, actors try to influence others and to impose their choices. Actors may use different tactics to dominate others and influence decisions made in the beginning of the PCA. First, most studies considered power as related to resource control and dependencies (Salancik and Pfeffer, 1978; Astley and Sachdeva, 1984). Meyer and Schubert (2007) note that actors can observe the development of the path and decide whether they want to devote resources to influencing the different possible options. Thus, actors who have easier access to resources such as knowledge can be in a better position to influence the path creation phase. Actors involved in a learning process also have superior access to information through privileged relationships with universities, clients or suppliers. They can decide which piece of information they want to share with other actors. Thus, other actors who are less familiar with the technology or the market are dependent on actors who have information and may even imitate their choices (Lieberman and Asaba, 2006), which would foster the ability of knowledgeable actors to impose their decisions.

As the technological path develops, self-reinforcing mechanisms become prevalent, and there are little deviations from the technological path (Sydow *et al.*, 2009). Those self-reinforcing mechanisms are characterized by the formation and reproduction of patterns and are often associated with "increasing returns", which means that a pattern exhibits increased benefits with its adoption. It then becomes difficult to change the pattern (Mahoney, 2000). As actors carry on learning about the technology and market, they may discover better alternatives. However, actors are also constrained by initial conditions, and they do not always choose the preferred outcome because they cannot perceive the consequences of their decisions (Liebowitz and Margolis, 1995).

Actors' agency can even reinforce path dependence, as actors can try to influence the meaning that others give to a technological path. Thus, actors can use their knowledge of the field "to shape perceptions, cognitions and preferences so that individuals accept the status quo because they cannot imagine any alternative" (Hardy, 1996: 8). As described by Meyer and Schubert (2007), that dimension of power can be used to stabilize the technological path and prevents actors from exploring other options. For example, actors can reuse formerly generated knowledge to constrain the ability of other actors to perceive the consequences of the new technological path (Carlile, 2004). Thus, actors try to use their learning experiences to shape the technological path and to avoid deviations from other actors.

Knowledge accumulation:

Those actors whose learning is embedded in a specific sector have to negotiate with actors from other fields to ensure innovation success (Akrich *et al.*, 2002). Thus, they have to share their knowledge, and knowledge flow can lead to different power tactics among actors. Van den Ende *et al.* (2012) describe how organizations that set up a standard seek new members' participation by allowing them to change the standard. An increasing number of participants in a standardization committee are required to ensure the standard's adoption. However, changes in the standard, which contribute to knowledge accumulation, may lead established companies to lose their influence compared to newcomers in the field.

Then, actors collaborate to converge on a dominant technology. Thus, the ability of actors to understand knowledge flows among organizations and how decisions are made, enable them to influence technological choices (Hardy and Dougherty, 1997). Hardy and Dougherty called this dimension the power of processes, which addresses the fact that dominant groups can exclude others from the decision-making process (Hardy, 1996). Examples of uses of this dimension of power can be found in the literature on path creation: Garud and Karnoe (2001) describe how an actor can understand the different processes that shape path creation to better influence these processes.

The power of process can be particularly used as new actors attempt to deviate from the technological path. Deviation is then often attributed to actors who have gained knowledge in other fields and have transferred their knowledge to a new field (Hargadon and Sutton, 1997). Thus, actors can also deviate from the technological path and create a niche. As these niches lead to applications in different domains, established technologies are sometimes abandoned

(Dijk and Yarime, 2010), leading to a new distribution of power among actors. In reality, actors whose knowledge is embedded in a specific field may not have the required flexibility to adapt their practices to the technological path evolution and may be trapped in rigidities (Baden-Füller and Pitt, 1996). Thus, they may try to exclude the niche's players from the decision-making process.

In this research, we analyse the constitution of the near field communication (NFC) technology. Different groups of actors are involved in this technological path: semiconductor companies, smart card makers, telecom operators, application designers, the financial services and banking industry, electronics goods producers (handset, computer and peripherals producers) and manufacturers of other types of products, such as car makers and other service providers. As this technology is characterized by network externalities and returns to adoption, actors have to collaborate to enhance the development of a dominant design, and self-reinforcing mechanisms are particularly prevalent.

2. Research Settings and Method

Following the recommendations by Garud *et al.* (2010) to study path creation, we conducted a qualitative case study. Furthermore, we applied the PCA methodology, which "allows the integration of both research strands on path development" (Sydow *et al.*, 2012: 156). We consider three levels of analysis: organizations, collective activities (collaborative projects, conferences, workshops…), and the whole network. However, as national policies and cultures play a major role in our case, we focused our analyses on the French territory. Indeed, we first considered payment services. However, different payment schemes existed worldwide at the time of the study. In particular, the U.S. market, which is also the largest, used magnetic stripe credit cards, whereas Europe and Asia paid with chip cards. In this second case, it was less difficult to migrate the payment terminals towards contactless systems. Moreover, the French industry is characterized by extremely high organizational complexity, with many actors that must be conversely fitted to, for instance, Japan, where there is a central actor that operates a mobile network and delivers bank and transportation services. Finally, the French government allocates many funds to the development of NFC mobile services. Some collective activities are also determined by clustering initiatives launched in 2005 by the French government. These initiatives, called "pôles de compétitivité", promote collaborative innovation between firms, research centres, universities

and local authorities in specific domains. Although this focus on the French territory is needed to reflect the local influence, we do not neglect supranational decisions that also shape the path (patenting, standardization…).

The longitudinal process analysis covers a period from 2002 to 2014 and is nurtured with different sources of data. First, an in-depth comprehension of the whole network was developed. The first author signed a research contract with a semiconductor R&D site, spending 4 years on the site (from 2007 to 2011). The second author signed another research contract with an electronic cluster, contributing to the definition and/or execution of four collaborative projects from 2008 to 2011. We also maintained relationships with the actors after the contracts ended. Thus, the data collection occurred at different levels of analysis.

Then, we conducted 42 semi-structured interviews with 37 different persons. These persons were central actors in the network and were interviewed several times to understand the rapidly changing underlying dynamics. Interviews lasted between 45 minutes and 2 hours and were transcribed. Whereas our period of analysis was relatively long (12 years), some of the interviews were related to past events. We have ensured that the persons did not streamline ex post or forget these events by asking the same questions at different points in time and by triangulating the information with additional sources. Complementary data came from websites, newspaper articles, meeting notes and reviews, and internal publications.

We encoded the transcripts to provide a content analysis. Our aim was twofold: identify and sequence the path and appreciate the interplay between learning, knowledge accumulation and the tactics of power used by actors. To sequence the path, we used the PCA method.
Then, to appreciate tactics of power, we coded the quotes and used secondary sources of data to appreciate learning and knowledge accumulation.

Path phases:

To sequence the path, we used constitutive features of the path and their underlying indicators derived from theory. Sydow, Windeler, Müller-Seitz *et al.* (2012) distinguish six constitutive features: level of interrelatedness, triggering event, non-ergodic processes, self-reinforcing processes, lock-in, and multiple actors. We identified the three periods as defined by Sydow *et al.* (2009): the preformation phase, the formation phase and the lock-in. However, after the

lock-in, we also observed a deviation from the path. The six constitutive features are proposed in the following table:

Table 1: Constitutive features and potential indicators of paths

Constitutive features	Definition	Indicators
Level interrelatedness	A focal level of analysis that needs to be conceptualized in relation to surrounding micro and macro levels of analysis.	Actors and/or observers relate their activities (1) recurrently, (2) intensively, (3) and to an important extent, not only to a focal extent, but also at the same time to micro and macro levels of analysis.
Triggering event	Incident that potentially induces the current and/or future trajectory of a path.	Actors and/or observers assess an incident as (1) being decisive or (2) initiating self-reinforcing processes for an option's likelihood to be prevalent in the future…
Non-ergodic process	Course of simultaneous and/or sequential events that lead to an outcome, which is automatically determined from the onset but is not arbitrary, either.	From the onset, (1) options of equal potential are (2) narrowed down to (3) a final solution.
Self-reinforcing processes	Course of interlocking simultaneous and/or sequential events that are progressively aligned to one another, thereby fostering the overall course of a path in an overall direction and potentially leading to momentum; in this connection, certain initial conditions are connected with certain results.	Over time, (1) overarching (interorganizational) institutions that serve to formulate and pursue joint objectives are established, (2), the design and usage of complementary management systems with regard to organizational aspects, and operations, (3) learning effects reinforce…
Lock-in	Situation or outcome where the trajectory of a path becomes confined to a single solution that does not need to be efficient.	(1) Investments are stable or increase with regard to the prevailing option, (2) investments in alternatives are reduced, (3) alternative options are considered to be niches…
Multiple actors	Constellations of individual or collective agents.	(1) Number of actors (more than two), (2) properties of actors, (3) actors bound together by set of relations…

Sydow, Windeler, Müller-Seitz et al. (2012: 159)

Tactics of power

To understand the interplay between learning and knowledge accumulation and the tactics of power developed by actors during path constitution, we used 3 of the dimensions proposed by Hardy (1996) and Hardy and Leiba-O'Sullivan (1998) to assess sources of power. This model expands Luke's work (1974) by emphasizing both power that is mobilized in the face of conflict and opposition and power that is used to ensure that conflict does not arise. That latter type of power, which is used to preserve the status quo and to prevent conflict, has received less attention in the literature. However, numerous works demonstrate that the emergence of new technology as well as path dependence can be explained by the effort of particular groups of individuals to maintain or change the cultural frame (Geels, 2005). Thus, groups of actors

can dominate others by shaping perceptions. The code used and the definitions found are summarized in the following table:

Table 2: Codes and definitions used to characterize tactics of power

Codes	Definitions
Power through the control of resources	Power is linked to the "control of scare resources on which others depend, such as information, expertise, credibility, prestige, access to higher echelon members, and the control of money, rewards, and sanctions" (Hardy and Leiba-O'Sullivan, 1998, p.454). Interorganizational power derives from the official authority, capacity for obtaining resources from the environment and controlling the supply of these resources to others through processes of exchange and the centrality of locations within the organization's network of workflow linkages (Astley and Sachdeva, 1984).
Power through decision the process	Power is related to the ability of actors - to prevent others from accessing the decision-making arena/extending memberships to the decision-making arena - to define the subject on agendas of the decision committee - to obtain a deep understanding of how to exploit a complex decision-making process (Bachrach and Baratz, 1962).
Power of meaning	Power is related to the ability of actors to prevent resistance by (Hardy, 1985): -legitimizing their position and decision -shaping meanings and perceptions -reducing other actors' awareness of critical issues.

Learning

We used the classification proposed by the NFC forum, differentiating between semiconductor, smart card/radio-frequency identification (RFID), Internet, consumer electronics, computing and computer peripherals, financial services/banking, mobile handsets, telecom, testing, consulting, and automotive companies. We grouped these company types into 7 categories: Electronic goods, Other products, Application/Payment/System Integrators, Telecom/Internet, Smart Card, Semiconductors, and Knowledge centres. We analysed the learning process of these different categories of actors by computing the percentage of patents filed by each category of actors. We used the European patent office database and queried only patents published on the European application. During the period studied, 440 patents were filed. Table 3 summarizes the percentage of patents filed by each category of actors for each period. The relative number of patents filed by a category of actors is used to assess the intensity of learning for that category.

Knowledge accumulation

To assess knowledge accumulation, we collected data on the development of the main committee for the standardization of NFC technology: the NFC Forum. This forum was formed "to advance the use of Near Field Communication technology by developing

specifications, ensuring interoperability among devices and services, and educating the market about NFC technology."[1] We collected articles published in their newsrooms and noted the number of participating organizations in each period (maximum number), the company of the elected chairman and vice-chairman (if there were changes) for each period, the list of sponsor members for the period and the names of the principal members who joined during the period. Each sponsor member had one representative on the board of directors of the forum and was allowed to appoint one voting member to the working groups and to the committee; principal members also have the right to appoint voting members.

Moreover, to develop our focus on France, we computed a list of collaborative projects concerning NFC. As we have already mentioned, in France, collective activities are clustered around specific competences. There are 2 "pôles de compétitivité" with strong expertise in contactless technologies. Therefore, we collected data on these 2 "pôles de compétitivité", completed by projects formalized in response to two national calls for projects in the field of contactless technologies. We identified 45 projects. Then, we grouped the different partners into the 7 types used to classify patents, and we used an additional category of actors: service providers. We computed two series of percentages. The percentage of participation distinguishes each type of organization according to the relative weight for all projects. For the percentage of representation, we checked if the different types of organizations are present in the projects. One or more organizations of each type that participate in a project count for 1, whereas no participation counts for 0.

Then, we listed different associations and work groups related to NFC technologies. We completed a press review from 2002 to 2014 by collecting articles on specialized and contactless IT in France. We built a database including approximately 175 articles after removing articles that addressed the same event. Based on this database, we identified 19 events related to associations and work groups' creation or dissolution. We selected only overall events and events related to the French territory. Finally, we confirmed these events with data from the interviews.

[1] http://nfc-forum.org/about-us/the-nfc-forum/

3. Case description

We studied the emergence of contactless mobile services using the NFC technology. NFC technology allows sharing information between two connected devices at a distance less than 4 centimetres. It is already widely used with contactless cards. As it triggers the convergence of several industries (mobile phone, banking, transportation, and retail, among others), this technology initiates a new path. Its creation is characterized by fast-paced technological and service novelty and a plurality of underlying competing technological options. Therefore, organizations are bargaining to become the most influential actor in the field. The NFC technology is derived from the RFID technology.

The path started in 2002, when Sony and Philips/NXP decided to co-develop the NFC technology. This decision was not random, and it depended on the fact that both CEOs had a previous affinity. The path was characterized by a wide range of options, and in particular, the first choices that had to be made were related to the support device for the technology (i.e., technical alternatives). This critical juncture occurred when Philips/NXP and its direct partners favoured the mobile phone market, as it was the biggest growth catalyst at the beginning of the 21st century. The formation phase began in early 2004, when the NFC Forum was launched with a mobile handset manufacturer (Nokia), acting as the particular option suggested by the utility calculus. Self-reinforcing mechanisms were related to reflections about the technology by actors from the mobile phone industry. In particular, telecom operators experimented with mobile services (e.g., transportation, payment) in Germany, France, and the U.S. since late 2004. Moreover, smart card manufacturers patented a solution to store sensitive data. Choices were still possible, as actors had to adopt one of the three available technological alternatives[2] related to the storage of sensitive data. This adoption reflected the emergence of a dominant design that was agreed upon and initiated the lock-in. It occurred in early 2007, when the telecom operators' association (GSMA) announced its preference for the SIM Centric solution. From that time, mobile contactless services were based on this alternative. First, the actors tested mass services such as transportation and payment, and progressively, they moved towards community services. The path became increasingly inefficient, as the SIM Centric solution provide a relational architecture too complex for these community services, with many intermediaries. Therefore, we observed a deliberate breaking of the path in late 2010, when the Android OS integrated NFC

[2] Three technological architectures competed: SIM Centric, embedded Secure Element, smart microSD.

functionalities. At this point in time, several actors began to evaluate some new alternatives related to the storage of sensitive data (e.g., HCE, tokenization) proposed by Internet players. Currently, several technological alternatives for data storage coexist. Moreover, to counter the threat from Internet players, historical actors explored new markets (gaming, health) and latent technical alternatives (consumer products).

4. Results

4.1. Measures computed

We identified 4 periods through the path constitution analysis:

- Phase 1: Pre-formation: 2002 to early 2004;
- Phase 2: Formation: early 2004 to early 2007;
- Phase 3: Lock-in: early 2007 to late 2010;
- Path deviation: late 2010 to 2014.

Then, we computed several measures for these different periods to assess the level of learning and knowledge accumulation.

Concerning learning, we computed the percentage of patents filed by the different categories of actors. The repartition is shown in the following table:

Table 3: Percentage of patents filed by the different categories of actors during the four periods

Type of organizations	% for the 1st period	% for the 2nd period	% for the 3rd period	% for the 4th period
Semiconductors	50	32	24	26
Knowledge centres	0	5	2	0
Smart Card	0	3	11	7
Telecom/Internet	0	13	4	6
Application/Payment/System Integrators	0	22	21	8
Electronics goods	25	20	34	49
Other products	25	5	4	4

During the first and second periods, semiconductor companies filed more patents than other categories of actors, whereas electronics goods producers accumulated more knowledge during the third and fourth periods.

Concerning knowledge accumulation, we detailed the evolution of membership of the NFC Forum (Table 4). Then, we computed percentages related to collaborative project participation by the different categories of actors (Table 5). Finally, we listed different associations and work groups that were set up for NFC technologies (Table 6).

Table 4: Evolution of membership at the sponsor and principal levels of the NFC forum

	Sponsor members	Joining principal members	Elected chairman and vice chairman	Members
2004	Founded by Nokia, Sony, Philips/NXP			
Second period	Mastercard, HP, Matsushita, Microsoft, Nokia, NEC, Renesas, Philips (NXP), Samsung, Sony, Texas Instrument, Visa, Panasonic	SK Telecom, Qualcomm, Telefonica, Broadcom	Philips (NXP) (chairman) Nokia (Vice chairman)	100
Third period	HP, Mastercard, Microsoft, NEC, Nokia, NXP, Panasonic, Renesas, Samsung, Sony, Visa ST, Inside contactless, NT Docomo, Innovision Research and Technology	Marvell, Rogers, Globe telecom, Legic, Identsystems, SCM Microsystem, Toppan forms, Semiconductor Energy Laboratory, Sony Ericson mobile communications	Sony (Chairman) Mastercard (Vice chairman) Nokia (Vice chairman)	150
Fourth period	Broadcom, Inside secure, Mastercard, Microsoft, NEC, Nokia, NTT, NXP, Renesas, Samsung, Sony, ST, Visa, Barclay card, Intel, Qualcomm, Google, Dai nippon	Google, CSR, Intel, Canon, HP, Infineon technology, Yahoo Japan, Verizon wireless, Discoveries finance service, Thinfilm, Xerox	Sony Nokia, Mastercard, NXP Broadcom	180

Table 4 describes memberships to the NFC Forum. During the second period, semiconductors producers and electronics goods producers were the most involved. During the third and fourth periods, major players such as Google, Yahoo Japan and payment companies and telecom companies upgraded their memberships.

Table 5: Percentage of project participation by the different categories of actors per period

Type of organizations	2nd period		% for the 3rd period		% for the 4th period	
	% of participation	% of representation per project	% of participation	% of representation per project	% of participation	% of representation per project
Semiconductors	8	29	4	30	5	27
Knowledge centres	23	71	25	78	36	100
Smart Card	4	14	8	52	9	45
Telecom/Internet	15	57	7	44	5	27
Application	19	29	24	85	17	64
Electronics goods	8	29	6	37	10	55
Service providers	4	14	20	67	12	27
Financing and banking	8	29	4	22	6	27
Other products	12	43	2	15	0	0

Regarding the project participation (Table 5), the high rates for knowledge centres are related to the French policy that encourages public-private cooperation. During the second period, telecom operators contributed fully to the projects. However, their levels of representation decreased during the next two periods in favour of application and service providers.

Table 6: Collective activities' creation and dissolution[3]

	Second period	Third period	Fourth period
International / European scope			
Associations, Workgroups	2004.03: NFC Forum creation 2005: NFC Research Lab (Austria) foundation 2006 to 2007: GSMA's NFC services project: 19 mobile operators	2007.02: StoLPAN 2007 to 2011: GSMA's Pay-Buy-Mobile program: 62 mobile operators 2008.10: AEPM creation	2014.10: AEPM dissolution
Congress, Workshops		2007.04: 1st WIMA Monaco 2009: 1st International Workshop on NFC	2011.09: 1st NFC World Congress (Smart Contactless World since 2015) 2011.11: 1st WIMA USA
National scope (France)			
Associations, Workgroups	2006.11: P€gasus	2007: Ulysse 2008.04: AFSCM creation 2008.10: Forum SMSC creation 2008.11: Ergosum	2014.10: Forum SMSC dissolution
Congress, Colloquium			2012.03: colloquium: Les territoires NFC 2012.09: 1st Université NFC des territoires

[3] The different collective activities are depicted in Appendix 1.

During the third and the fourth periods, many collective activities sustained the development of the NFC technology (Table 6). The multiplication of the international congress extended the possibilities to diffuse knowledge among a broad range of actors. The local dimension of these collective activities began during the third period.

4.2. Case study

Pre-formation phase

Philips/NXP first signed an agreement with Sony to develop the technology in 2002. Philips/NXP had acquired a company called Micron and had obtained the license for a technology called MIFARE for contactless products, which was widely used in ticketing and public transport. Sony had implemented Felica technology, which was widely used in Japan to allow contactless payment in train stations or in convenience stores. Another standard for contactless ICs was supported by competing semiconductor companies. As Philips/NXP and Sony dominated the market for contactless services, they aimed to use their prior learning to extend their influence in the consumer market. However, to achieve this goal, the companies first had to face internal challenges. Inside Philips/NXP, the team that worked on the NFC chip included people from different locations. On one side, engineers who used to work for the start-up company called Micron had accumulated substantial knowledge on MIFARE, and on the other side, there were engineers trained in Philips/NXP. The relationships among these different subgroups were characterized by flows of power, and knowledge was not disseminated among the different entities, as shown by the following quote:

> *"It had always been trench warfare. We wanted to learn more about their IP to design homogeneous chips, but they did not want to give us information, so we took back a chip, and we had to integrate it and test whether it was working, but we could not change it."*

First, Philips/NXP and Sony needed to evaluate different technical alternatives, i.e., identify the most appropriate device to integrate the technology (e.g., mobile phone, computer, television, etc.). They set up a joint venture to develop chips, as well as several bilateral agreements with different device manufacturers. The two companies wanted to use their knowledge to demonstrate to other actors that they should invest in NFC, and they began to work on a prototype. As described in Table 3, semiconductor companies filed the most patents during this phase.

The prototype contributed to knowledge accumulation about NFC among the first network of companies, as described in the following quote:

> *"The first step was to create use cases and to promote them to clients to convince them that NFC can bring added value. The second step, once the clients were interested in the technology, was to set up a standard (…) to cover interoperability among solutions." (An engineer, Philips/NXP)*

Finally, the companies chose mobile phones as the main application, as the market was supposed to generate more revenues, and they had strong prior knowledge on the market:

> *"What drives us on NFC technologies is the mobile market because there are large quantities: 1.4 billion phones are sold per year. Consequently, if the technology is integrated in phones, it is going to represent huge volumes." (An engineer, Philips/NXP)*

As the major objective of the NFC technology was to achieve global compatibility, Sony and Philips/NXP realized that they needed to integrate competing technologies to ensure the broadest adoption of the technology.

During this first period, Sony and Philips/NXP dominated the market thanks to their prior learning. However, they were not the only companies able to influence the path. The ability of a company to generate new knowledge is a key factor for it to gain influence. Thus, power is related to the control of resources and, particularly, innovative knowledge, as described in the following quote:

> *"You need to impose certain choices, and as MIFARE was a leader in the market, we could impose MIFARE in the standard. (…) It allowed attracting partners [such as Nokia]. (…) However, you do not need to be a big company to be recognized. One of our competitors is a small company that is very innovative, and it participated in the technology deployment and standardization." (An engineer Philips/NXP).*

To conclude, during the pre-formation phase, prior technological learning and innovative knowledge accumulation are the most important inter-organizational levers of power, increasing influence based on resource control. Moreover, prior knowledge related to context and especially to other markets reinforces this influence. The issues related to knowledge control also occur inside the firm, as different groups of actors are willing to keep their internal influence and not share it.

Formation phase

As the mobile phone market was chosen, managers of Philips/NXP, Sony and Nokia realized that they needed to get banks, phone operators, application developers, and service companies involved in the technology to provide use cases for customers. Consequently, they set up the NFC Forum in early 2004 and chaired the committee, monitoring the network expansion and the flows of knowledge between actors. They drove the self-reinforcement process and enhanced power by controlling the decision-making process.

> *"It is a good thing to be in a small committee to be a source of proposals and then to validate what has been decided by other persons who have not been involved, instead of having everybody around the table, and then, we cannot write a document because everybody sticks to their positions." (An engineer, Philips/NXP)*

The companies also participated in different standardization committees. For example, Philips/NXP participated in more than 100 field tests with others actors throughout the world. Its goal was to "educate" closer and more distant partners (i.e., clients of their clients) so that they became interested in the technology and adopted it. Finally, the word "education" shows that they used the power of meaning to influence clients and to focus their attention on a limited range of technological options.

> *"To create an ecosystem, you need to spend a lot of time educating people." (An engineer, Philips/NXP)*

The interest in NFC technology grew rapidly: more than 100 companies joined the NFC forum within two years. During this period, the applications focused on payment and transportation. However, they remained in an experimental stage. The choice to focus on payment applications reflected the growing influence of financial institutions in the NFC Forum. A self-reinforcing effect also occurred, as Philips/NXP was a leader in security solutions for payment cards:

> *"NXP had a secured microcontroller (for payment applications), and it allowed market entry knowing the whys and wherefores, and it helps the different partners." (An engineer, Philips/NXP)*

As Philips/NXP began to work with a broader range of actors, it had to learn about new complementary technologies:

"We had to bring changes to our chips, and it was a big step in our learning process, as one of the constraints to having RFID technology adopted in the consumer market is to have a technology that is compatible with all existing infrastructures. This was not the case for NFC in the beginning, so we had to add technological evolutions." (An engineer, Philips/NXP)

Moreover, the company developed complementary knowledge to increase its power of process by addressing several positions in the value chain. For example, it created specialized divisions in application development and security management.

However, the main focus in terms of standardization concerns the secure element. Three architectures competed, generating conflicting interests among the major actors (semiconductor manufacturers, digital security providers, telecom operators and mobile handset manufacturers).

"There is a certain form of protectionism. People want to maintain their market shares. Consequently, the place where the secure element is going to be implemented is a key point." (A founding member, SMSC Forum)

During this second period, Philips/NXP and Sony were not able to monitor all the flows of knowledge, and they needed to allow knowledge from other fields to enter. Consequently, knowledge accumulated in the network, and telecom operators and electronic goods producers increased their learning. As described in Table 5, telecom/internet companies and knowledge centres were involved in most projects carried out on NFC technologies and began to generate their own learning processes. As they had specific knowledge and direct access to customers, they were able to impose their solutions, increasing their influence based on knowledge control:

"In the first instances, our clients were happy that we were dealing with their clients because they did not know a lot about the technology. They were not objecting to anything. Then, the situation changed, we were believed to be the king of oil because we had invented everything, we had created the market, but our clients were improving their knowledge of the technology, and eventually, they took charge of the technology and asked for things that were different from what we proposed." (A manager, Philips/NXP)

To conclude, during the formation phase, power related to technological knowledge control may remain temporary. The need to involve progressively more actors in the path generates risks for the most influential actors to be overrun by these new incomers, as they accumulate knowledge from the nascent field and control specific knowledge from other fields. To address these risks and maintain their influence, actors activate the power of meaning and the power of process.

Lock-in:

Finally, mobile phone operators that had formed a standard committee (GSMA) chose the SIM Centric solution proposed by smart card manufacturers and locked in the path in early 2007. This security architecture is far more difficult to develop by semiconductors manufacturers. After internal questioning, Philips/NXP decided to carry on investing in the technology development by focusing on chip designs and by collaborating only with phone makers. In fact, phone makers confirmed that they still wanted to work with Philips/NXP, as the company's know-how was advanced. However, the product functionalities and market alternatives were not clearly defined, and the products that were designed integrated a broad range of technologies. Philips/NXP also sold its division dedicated to developing applications to a smart card manufacturer in 2008. Moreover, Philips/NXP needed to generate new learning, as the technological solution that had been chosen disrupted its knowledge base:

> *"We were present in all sectors, from the beginning to the end of the value chain, recording standardization, but for 1-2 years, we began to refocus because people who are in the value chain have no intention whatsoever for NXP to tell them what to do." (a project manager, Philips/NXP)*

Telecom operators, electronic goods producers, and smart card manufacturers, which had progressively gained influence during the formation phase, sustained their power. For example, French telecom operators and smart card manufacturers participated in approximately half of the projects and in the major workgroups (Tables 5 and 6). The electronic goods producers filed the largest number of patents (Table 3). Consequently, these actors began to control different sources of power, such as access to resources and decision-making centres.

However, new tensions occurred between the main service providers (payment and transportation) and the telecom operators. The SIM Centric alternative was coupled to a business model that was not agreed on by these services providers:

> *"There was a lobbying between telecom operators and companies, which were designing the SIM element, so that applications were embedded into the SIM. However, actors who were designing bank applications, such as Visa and MasterCard, feared that telecom operators would take a percentage of each transaction. So, we needed to find an agreement." (An engineer, Philips/NXP)*

The lock-in also generated a local dynamic in several countries. As the lack of agreement between actors slowed the initial goal achievement (developing a global standard), some actors decided to direct their effort mainly to their local markets. In France, several projects were set up by telecom operators, universities, or Philips/NXP to test applications and develop business models in cities such as Caen or Nice (27 projects, for a total of 45). These French projects were supported by local institutions and competitive clusters, which provided resources for technology development by coordinating and diffusing knowledge across the network. Telecom operators also stimulated market development by addressing use cases around local services (e.g., swimming pool access, theatre subscriptions, city itineraries) and by initiating direct collaborations with financial institutions and transport companies. Consequently, they gained more influence, using their learning of the nascent field to shape perceptions of new incomers, such as service and application providers. Moreover, by initiating projects with new actors, such as tourism agencies and small shops, they participated in knowledge accumulation in the network. For example, Orange aimed to propose a tool kit for small actors to be able to develop their own applications:

> *"It is more than a knowledge transfer, it is really to make things easier." (A project manager, Orange)*

Another consequence of the global knowledge accumulation that was not envisioned by telecom operators was that the new incomers developed a better understanding of the nascent field, progressively gaining influence. For example, incomers' knowledge accumulation was supported by their representation in most projects (Table 5). Moreover, the power of the telecom operators depended on the service providers' acceptance of the architecture that they defined.

The broadening of the network to new actors also led to a debate on technological applications, with a struggle among different categories of actors, as described in the following quote concerning actors' behaviour during projects:

> *"We know that people came in for a precise reason: whether they wanted to develop something, or they had a component and they wanted to value it. However, we do not want them to come with their part and just implement it by saying it cannot be otherwise." (A project manager, Orange)*

Deviation:

At the beginning of the fourth period, telecom operators were still dominating the path. As they were very active in several standardization committees, they used their knowledge to shape perception, as described in the following quote:

> *"A recent publication of the AFSCM on the rules and good practices in NFC products and services shows a graph in which the secured element is at the centre of the world."(A CEO of an application provider)*

Whereas the technical elements were commercialized (NFC chips, phone and smartphone operating systems with NFC functionalities), the applications struggled to be launched. The local dimension invited authorities to participate in the path constitution by stimulating the services' commercialization. In France, they established a roadmap and allocated financial resources (approximately 43.2 million euros).

However, the service and application providers that integrated the path during the lock-in did not agree on the SIM Centric alternative, which is costly. As their services needed a lower level of security, voices began to rise against the power deployed by telecom operators, and certain actors voiced concerns about the complexity of the solutions proposed by operators:

> *"We do not need telecom operators to do transportation. We know how to do it without them." (A representative of a transportation company)*

They considered other technological alternatives for the storage of data, which were determinants of the path efficiency:

> *"The main part of the market may be ticketing or small applications for which you do not need a very complex solution or a labyrinth, as most applications are based on an ID." (An engineer, University of Nice)*

The smartphone's developments induced a new range of technologies, such as Bluetooth Low Energy and Host Card Emulation technologies, proposed by Internet players such as Google and Apple. They proposed a disintermediated architecture, running the services without telecom operators and banks. They enhanced their power of process by introducing knowledge from other fields to the path. Moreover, these big actors, such as Google or Yahoo Japan, began to play a bigger role in the network, as shown in Table 4. They became active in the NFC Forum, and because they controlled resources, they managed to impose their technological solutions on semiconductor companies:

> *"Until now, as we were the leading provider of the technology, we used to send the specifications, and the client had to adapt its solutions to those specifications. Currently, we have design-in with well-known clients in the PC field, such as Google, and the relationship is different. They want to impose their solutions, and we are adapting our technology." (An engineer, Philips/NXP)*

As the market share of the Android OS grew rapidly, Google gained influence in the smartphone market, and its control of resources enabled it to impose its decisions on a new field.

In reality, two main directions were envisioned in the technological path and related to different applications:

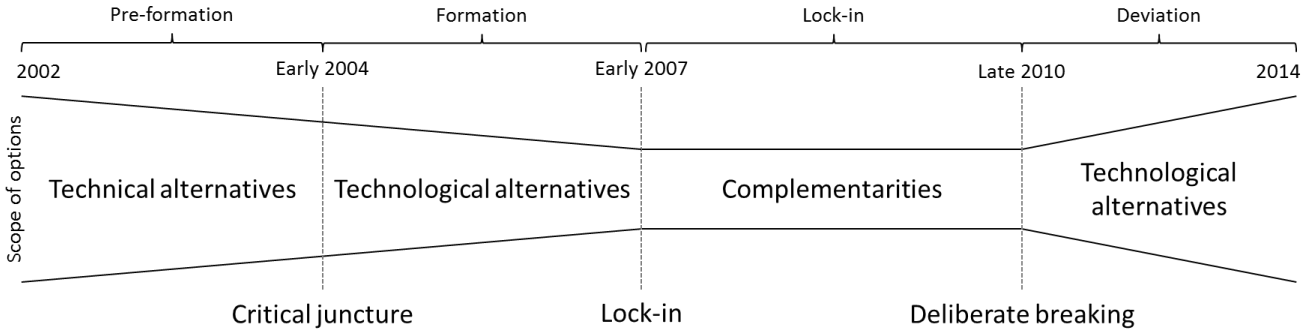
> *"The first type of usage is promoted by people who are benefitting from secured solutions, particularly by telecom operators, as in mobile handsets, they have the SIM card and they want to use it as a secured container to develop applications such as payment or ticketing… The second approach is favoured by people who do not support mobile handsets but are benefitting from the infrastructure. We have a nice example with Google." (A CEO of an application provider)*

> *"There are two main approaches in NFC, there are those which favour NFC usage with little interaction with users, for using NFC to have highly secured applications such as payment, ticketing…And there is a second type of application that is more interactive, such as tag reading or more complex applications." (A CEO of an application provider)*

5. Discussion

We summarize the different flows of knowledge and the related types of influence during the NFC path creation as follows:

Figure 1: Interplay between learning and knowledge accumulation and the tactics of power used by actors during NFC path constitution



	Intra-organizational challenges: the case of Philips/NXP			
Know-ledge	Managing prior knowledge: dissemination accross individuals	Generating complementary knowledge accumulation	1. Refocusing on specific knowledge 2. Adapting knowledge accumulation to other path options	Adapting knowledge accumulation to other path options
	Inter-organizational challenges: the case of the whole NFC network			
Most influential actors	Semiconductors manufacturers	Semiconductors manufacturers	Telecom operators Electronic goods producers Smart Card manufacturers	Internet players Service and application providers
Knowledge	1. Taking advantage of prior knowledge 2. Generating knowledge accumulation	1. Monitoring incoming flows of knowledge 2. Imposing individual knowledge	1. Taking advantage of prior specific knowledge 2. Monitoring flows of knowledge 3. Imposing individual knowledge and initiating knowledge accumulation	1. Generating knowledge accumulation 2. Enforcing incoming flows of knowledge
Influence	Power related to resource control	Power of process Power of meaning	Power related to resource control Power of process Power of meaning	Power related to resource control Power of process

- The first period was characterized by a multitude of technical options related to the support device of the NFC technology, and it can be tracked from 2002 to early 2004. During that period, Philips/NXP and Sony influenced the path development. The emergence of the path relates to prior learning, as the two semiconductor manufacturers had developed strong knowledge about contactless and secure transactions, coupled with strong knowledge on different markets (e.g., phone, appliance and ICT industries). Moreover, they generated innovative knowledge accumulation to reinforce their influence. Consequently, the path

initiation was determined by power related to resource control, which came from prior learning and the ability to generate knowledge accumulation.

On the intra-organizational level, individuals also used their control of prior knowledge to gain influence. For the case of Philips/NXP, there were conflicting interests between two groups of people. A first group of people from MICRON, based on prior localized learning on the MIFARE technology, did not want to share the technology. Others actors from Philips/NXP wished to acquire this knowledge, but their voice was not heard.

- The beginning of the second period was determined by the choice to focus on the mobile phone market. This period (2004 to 2007) was characterized by technological alternatives. Three main technological alternatives concerned the secure element, and two conflicting perspectives were explored by the technology founders and the new path incomers (particularly telecom operators and smart card manufacturers). During this period, semiconductor manufacturers remained influential, but their power was related to the decision-making process and meaning. In fact, marketers and engineers working for Philips/NXP thought that they would impose their solutions on telecom operators, as they had a privileged access to knowledge. They used the power of meaning, as interviewees described how they "educated" clients. They tied all actors involved in the technology emergence and tried to impose their vision of the standard related to a technological alternative. Thus, knowledge accumulation occurred among an increasingly larger group of actors. Moreover, the companies monitored incoming flows of knowledge through their power of process to reinforce the acceptation of their vision.

However, telecom operators progressively improved their knowledge of the technology and profited from specific prior learning, as they had direct access to end-users and service providers. Consequently, they gained power related to resource control, and they were able to impose their vision, which relied on another technological alternative.

Internally, Philips/NXP needed to generate complementary knowledge accumulation to sustain their influence. On one hand, they tried to attract new incomers by developing a wide range of complementary functionalities to the NFC technology. On the other and, they managed to occupy several positions in the value chain by developing complementary activities.

- During the third period (2007 to 2010), telecom operators and electronic goods producers dominated the development. However, during that period, technological development and market emergence were slower than expected. To address these difficulties, they attempted to develop new services related to local markets. As the most influential actors changed, a new loop of knowledge exploitation, creation, and accumulation occurred, following the same logic as they did during the first two periods. First, actors used their power related to resource control by taking advantage of prior specific knowledge. Then, they shaped meaning and controlled the decision-making process through monitoring flows of knowledge, imposing their vision, and initiating knowledge accumulation.

The loss of influence generated a refocus on specific knowledge and knowledge adaptation by Philips/NXP. In sum, the efforts made during the second period had become obsolete.

- During the fourth period (since 2011), the same dynamic as in the previous period was replicated. New actors involved in the technology, i.e., service and application providers, gradually accumulated knowledge from the field during the third period. Additionally, as they perceived their potential influence related to resource control, they were able to deviate from the path. In fact, their agreement on the technological alternative was essential. Thus, they were able to exert a power of process. A second phenomenon reinforced the deviation, as Internet players that previously had power in other fields input knowledge from these fields into the path. The change of influential actors was deterministic, as the locked option generated path inefficiency. Thus, several technological alternatives now lived together, corresponding to the differences between the wide ranges of services envisioned. However, this multiplicity sustained conflicting interest between actors.

Again, Philips/NXP needed to adapt its knowledge to the new path options.

Conclusion:

In this article, we explain the emergence of NFC technology. We address both deliberate actions taken by actors to shape the path and the reinforcing mechanism. In particular, we focus on learning and knowledge accumulation during the technological path and demonstrate that these actions can provide opportunities for actors to change power flows in the network and change the technological path. Actors can use different tactics of power that relate to the power of meaning and to the control of the access to resources and to decision centres. Those different tactics are used by different groups of actors during the phases of technological path constitution.

We can draw a few conclusions from this article. First, existing companies, which are the first to enter a new technological field because of their previous learning, may become embedded in this knowledge. They are able to organize knowledge sharing in the network, but as knowledge accumulates, other actors can propose changes to the path.

As knowledge progresses, new technological alternatives emerge. However, companies that are already involved in the technological path may not understand the full potentialities of those alternatives. They may even use the power of meaning to prevent other actors from considering those alternatives. Consequently, changes to the technological path are likely to be brought by actors from other industries that have followed a different path.

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Appendix 1: Different associations founded

AEPM:

AEPM is a European association founded in October 2008 to promote mobile payment based on NFC technology. Its members published a wide range of technical specifications and conducted experiments. Its objectives were achieved in October 2014. This date indicates the dissolution of the group.

AFSCM:

AFSCM is a French association launched by the telecom operators. Its goals are to facilitate technical development of mobile contactless services and to promote their use.

Forum SMSC:

Forum SMSC was a three-year governmental initiative launched in October 2008 and renewed in 2011.

NFC Congress Austria:

In March 2007, the NFC Research Lab Hagenberg hosted the 1st NFC Congress in Austria. Approximately 220 attendants from 12 countries joined the conference.

NFC Research Lab:

Founded in 2005, the NFC Research Lab focuses on new NFC use cases, hardware implementations and security aspects.

StoLPAN:

The StoLPAN Association (Store Logistics and Payment with NFC) contributes to the establishment of an open, interoperable, technologically transparent service environment for the dynamic post-issuance operation of NFC applications.

Ulysse:

Ulysse is a French workgroup of telecom operators and passengers' transportation companies. It publishes technical guidelines for ticketing and transportation.

WIMA:

WIMA is the world’s leading exhibition and conference enabling business and innovation exclusively for the NFC Ecosystem with events in both the U.S. and Monaco.