The Dynamics of Standard Setting

Vladislav Fomin
wlad@cc.jyu.fi
STAMINA research group

Faculty of Information Technology

University of Jyväskylä

Abstract

The purpose of this article is to analyse the dynamics of social networks in standard making process, and to show how a standard becomes a means for aligning complex social networks. Alignment of networks is nothing but an alignment of actors' interests involved in the standard making process. The standardisation process is communication rich and the dynamics of networks is based on information exchange flows, which take place at intra- and inter-organisational levels. Actors find themselves in a continuous process of negotiation of interests, powers, resources, etc. Even assuming that the stability of network is needed for a smooth project running, the networks are subject to change and the change is necessary condition for successful standard development. Both stability and transformation are embedded into social networks.

In this work we are approaching social networks by looking at standard making processes. Social networks are formed at different stages of standard development and service implementation. Three stages can be identified: inception of standard making process, also referred to as a knowledge creation cycle, the stage of technology diffusion from laboratory to the market, and the transformation stage from the knowledge creation to diffusion. These stages can not necessarily be distinguished on a time scale from one another. We argue that standards are boundary objects which align interests of both standard makers and adopters.

We are applying Actor Network theory (ANT) to analyse the dynamics of social networks in the standardisation process, a question which has been overlooked by researchers to date. The proposed approach is demonstrated on the analysis of the Nordic Mobile Telephone (NMT) standards development.

Keywords: actor network theory, networked organisation, standardisation, standards

BRT Keywords: AE, C UF CA1101

Introduction

The story of the Nordic Mobile Telephone (NMT) development is a story of success. NMT was not the only standard being developed back in 1970s. There were other cellular telephony systems also evolving in the United States, Germany, France, and Japan. Yet none of these systems had such a tremendous success as NMT (Bekkers, 1998; Mehrotra, 1994; Paetsch, 1993). The fact that while being technically very similar to each other, and being developed at the same time, some of these systems received more, and some less acceptance and not all of those systems witnessed commercial success suggests that technology is not a black box, but a complex socio-technical network (Callon, 1992; Lyytinen & Damsgaard, 1998; Pinch, 1988; Star, 1991; Williams, 1996). In order to analyse and reveal the factors of success of the NMT we must look at the dynamics of socio-technical networks which is embedded in the process of technological development.

Standard making process is a social process. Actors are involved in the process of continuous negotiation of their interests. Due to this fact standards became an object of analysis for scholars within the social shaping of technology theory (SST). Though usually scholars of this school take standards as material objects, they interpret technology as such, e.g., a bicycle, or a steam machines. In Information Technology (IT) domain standards are

intangible. Those are electronic data exchange formats, communications protocols, signalling protocols, etc. Wireless and mobile communications in particular, being a large field of IT, represent an interesting case for analysis. Present in mobile telephony's domain are *de jure* (e.g., GSM) and *de facto* standards (e.g., NMT). Also the broad scope and large scale of standardisation processes suggests non-unified pattern of standard making in this field and complex organisational structure. Mobile telephony's standard making processes implies large networks and numerous mandatory passage points. Taking into consideration the aforesaid characteristics of the standard making process we seek to answer the following questions:

How to study standard making in IT field where most of standards are intangible/abstract knowledge?

What is the nature of dynamics imbedded in the standard making process?

In order to answer those questions first a theoretical frame of studying the technological development is considered. Short review of related research is carried out and arguments for choosing Actor Network theory as a framework for analysis are suggested. Answers to the second question are put forward through a case study, involving the development of the Nordic Mobile Telephone system.

Related research

Technological determinism theories were popular in the late 1970s and early 1980s and suggested that particular paths of technological change were inevitable. They treated technologies as if they were an internally homogenous classes of objects, uniform in their characteristics, and stable over time. They assumed that technology offered a vehicle for achieving an organisational change, and overlooked difficulties in implementing technologies and their frequent failures to deliver predicted and desired outcomes. Models to approach technological change were named "Linear models" for they conceived an innovation as involving a one-way flow of information, ideas and solutions from basic research, through R&D, to the production and the diffusion of stable artefacts through the market to consumers (Williams, 1996). Thus technological determinism assumes that a technology is a "black box" with a pre-determinate impact on the organisation.

With the ever increasing number of technological innovations scholars and practitioners learned that often very similar technologies were bringing very different outcomes. This fact fostered treating technology not as a pre-determined object, but rather as an unpredictable socio-technical phenomena. Scholars had come to the conclusion that technology is socially shaped, or at least is dependent on social interactions of those involved in different stages of technological development, from it's conception, through the lab, to consumer. This understanding gave rise to a novel scientific school, namely Social Shaping of Technology (SST) (Williams, 1996).

Studying technology means studying organisational change. Technology can not exist without it's environment -- it won't be applicable. Treating technology as a black box assumes no influence of the environment, in which the innovation develops, upon the innovation. When parted from it's environment the technological system becomes closed system, implying a lack of, or at most pre-determined interaction with the "outer-world". Thus when talking about technology one should consider different non-technological aspects of the technology, which are brought in by the presence of the environment in the study model. Those are social aspects, such as social networks, power relations, knowledge creation/distribution cycles and other. Within a time of more than two decades different theories have been developed which are united by a common perspective -- acknowledging obsolescence of technological imperative school and arguing that technology has no pre-deterministic influence on the organisation. The most known theories nowadays address social networks (Nohria, 1992; Nohria & Eccles, 1992), power relations (Star, 1991), knowledge creation/ distribution processes (Cowan & Foray, 1997; Ikujiro, 1994; Michelis,

1997; Nonaka & Takeuchi, 1995), and techno-social networks of actors (Callon, Latour, & Rip, 1986; Callon & Law, 1989; Latour, 1993) in order to understand technological innovation process.

Actor Network theory

One of the popular theories explaining dependencies of complex techno-social networks is Actor Network theory (ANT) (Callon, Latour, & Rip, 1986; Callon & Law, 1989; Latour, 1993). ANT studies the development of a scientific field and is identifying points of "interpretative flexibility". When applied to technological development, ANT seeks to identify points in time, where technology could be designed in more than one way, and to explain the dominance of one choice over another. ANT sees scientific and technical creation, as well as diffusion and consolidation of its results, stemming from interactions between actors. The actors are not necessarily humans -- they could be well defined as technological artefacts. ANT concentrates on the analysis of possible choices made due to interactions between the actors (Callon, 1992): "How can we explain the fact that in certain cases, [technological] trajectories are successful and stabilize, whereas in others new configurations appear?" (p.72). Actor Network theory studies the particular role played by technology, and the impact that technological artefacts have upon the socio-economic context in which those exist (Callon, 1992): "the technical object is continually being reinserted into various socio-economic contexts, which constitute different possible network configurations" (p.77). ANT intensively addresses a notion of alignment. For instance, if standardisation process of cellular telephony is to become successful, alignment of interests of all involved has to take place. Alignment brings stability and irreversibility to the networks (Callon, 1992; Callon & Law, 1989), promising a "long life" to both the holders of the technological system, and to its customers. Actor Network theory is widely used to approach complex technological processes. Students of the domain are applying the theory to analyse the development and diffusion of material technical artefacts, such as, e.g., a bicycle or a steam machine (Callon, 1992; Star, 1991). In IT domain most of standards are intangible -- protocols, data formats, signalling levels, etc. There are only few attempts to apply actor network theory to analysis of abstract, intangible standards. One of those rare examples is the work of (Hanseth, 1997) on electronic data interchange (EDI) standardisation.
Applying ANT to the analysis of complex networked IT technologies, therefore, is a challenging task and requires introduction of several new perspectives to the theory. Uses of different levels of organisational analysis and treating standard as a boundary object we consider of substantial importance for more in-depth understanding of standard making process. Those two issues are discussed in the next two sub-sections.

Standard as a boundary object

Addressing the alignment of complex socio-technical networks, one should reveal the means by which the different interests of involved actors are negotiated. Such notions as "interpretative flexibility" and what Callon (1992) called "reinserting [of technology] into various socio-economic contexts" (p.77) suggests that the meaning of the technology under development is not the same for the parties involved. We come to the notion of "boundary object" -- an artefact, be it a material or intangible -- being able to cross boundaries of interests of different parties. As for our case the cellular telephony standard is the means of aligning and bringing stability to the networks, the standard is the boundary object.
Processes imbedded in standard making are communication–rich due to the fact that interests of those involved are continuously negotiated. We argue that the standard takes a role of negotiator, or a "peace-maker". Markus & Robey (1988) have shown the importance of communication in the high complexity process: "Unanalyzable, nonroutine tasks require rich information, capable of conveying complex and equivocal meanings; facial expressions and voice are

the media most capable of processing this rich qualitative information" (p. 587). Thus we can argue that a standard can be "communicated" between actors involved in the standardisation process. It becomes a mediator, an abstract artefact which aligns interests. The standard is the key to understanding social networks' transformation phenomena. By treating the standard as an abstract representation of technical knowledge, as a social phenomena knowledge creation and diffusion processes can be better understood, just as the standardisation process as such (See Figure 1).

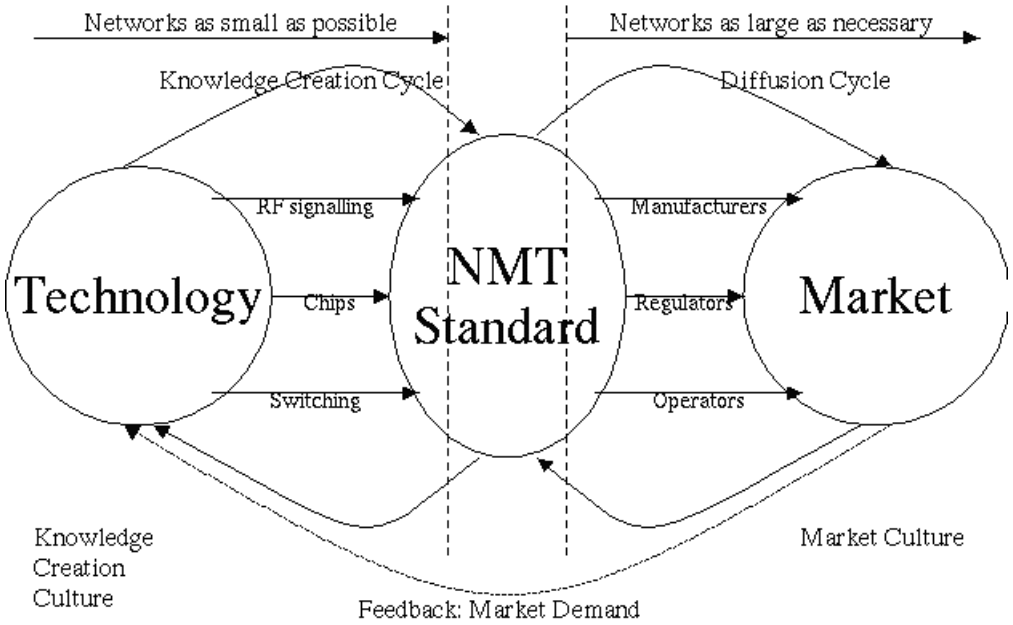

Figure 1. "Standard as a boundary object"

Micro & macro analysis

Innovation is a complex social activity, involving interactions amongst an array of actors and institutions involved. Because of this fact we need an understanding of both processes at organisational and individual levels -- macro and micro levels (Markus & Robey, 1988). Much of the early research in ANT has involved micro-level studies, focusing upon the scientific or R&D laboratory, and tending to examine nascent technological fields (Williams, 1996). More recently, however, researchers have shown more interest in broader institutional contexts and practices of innovation. Changing the level of analysis is a helpful tool to cope with the internal contradictions arising within the study.
Macro-level analysis implies studying organisations, environments, and social alliances. These entities are addressed as a whole: when there are decisions made the individual preferences and goals of those people involved are not taken into consideration. In contrast, micro-level analysis treats decision making as a process determined by individuals. In the case of micro-level analysis decisions are determined by believes, goals, and interests of individuals. It is not the organisation which makes decisions but individuals (Markus & Robey, 1988). When the research is based on only one of the aforesaid level analysis, the complete understanding of motivations and outcomes can not be obtained. Therefore it is helpful to address users and organisational context at different levels of granularity, by not only introducing a meso-level analysis /what (Markus & Robey, 1988) defines as mixed/, but also by looking for dependencies by moving inside of the organisational-environmental structure from processes occurring on macro- to meso- and to micro-level and backwards.

Research methods

As we argue that a causal agent for technological development is not a technology or

technical artefact, but a socio-technical context in which that artefact exists, we focus on technological change characterised by socio-economic interests and choose as starting point for analysis not a particular technological field, but a particular social context within which technical change takes place. According to Williams (1996) "the analysis proceeds “inwards”: the social processes, interests and goals typical of the context are identified, and attempts are then made to trace their influence on evolving technology" (p.870). The presented research work is based on qualitative methods, having an empirical case study as a framework.

Case study: enrolment, alignment, and the dynamics in the NMT standard's making process

Development and use of the Finnish national Auto Radio Phone (ARP) system have created the market and formed its channels (Knuuttila, Lyytinen, & King, 1996). It showed that there is a growing demand for mobile communications, it allocated human and material resources for a technical advance. Technology push and market pull forces were created and balanced over time of 20 years in Nordic countries. It is quite obvious that the initial idea of pan-Nordic mobile radio phone system was generated by "market pull" situation due to the ever-growing demand for ARP system in Finland and the like in other Nordic countries. During the process of balancing market pull and technology push, highly motivated radio and telephony engineers acted as go-between among various Nordic PTTs' and industrial organisations (Knuuttila, Lyytinen, & King, 1996). The enrolment of engineers proved crucial in the shaping of the standard and its resulting success. The technological basis was there. A vision of market enlargement based on the growth experience of manually switched analogous ARP system was there. These reasons where seen as sufficient motivation to move ahead, to develop technological skills, and to create services and systems that could meet the growing demands for mobile communications (Knuuttila, 1997).
Not only economic factors fostered the Nordic co-operation. There were numerous cultural or ethnic factors to be considered. Traditionally international co-operation is such that parties co-operate if there are mutual benefits to all parties involved. The history of Nordic PTTs knows cases when administrations have co-operated even if there hasn’t been an evident benefit to every country (Haug, 1999). North American AMPS system, which was technologically very similar to Nordic NMT has spent almost 15 years "on a shelf", for the regulatory body was not willing to allocate licenses for the cellular telephony (Bekkers, 1998; Mehrotra, 1994; Paetsch, 1993). The Nordic approach to the same problem seems to be somewhat different (Haug, 1999):

> A: To take an example, the frequency problem was a problem that caused Sweden a lot of difficulties, because the 450 band was the most suitable for Norway and Denmark, and Finland. In Sweden 250 would be much better, but 250 was unacceptable in Norway and Denmark, because it was NATO band. [Details are uncertain as to the Finnish situation], but in Sweden the 450 band was blocked by military people. Whilst it was available in times of peace, it had to be held "on ice", because the military had a lot of equipment which they wanted to be able to use in an emergency [case]. So it was a true collision [of interests], but after a year or so Swedish military people said "OK, you can use it in the peace time". We haven’t had a war after that, so it worked out quite well.

It shows that there was a vision of success among those involved. The deployment of Nordic traditions of co-operation as a given fact played thus an extremely important role in making the NMT standard and the following technological success. The Nordic co-operation spirit gave every participating individual a motivation to present his own, his organisation’s and country’s "voluntary" expertise to the standardisation arena that was based on a free flow of innovations, inventions, contributions, and experiences (Haug, 1999). According to Myhre (1998), "We did not focus on that Dane should be there, or Finn should be there, etc. We put groups and the most competent guy was a chairman. And we were 5-6-7-8 people in each group. Different background, but all of them had interest in making these specifications".

Good insights of driving forces behind the standard's making of both Nordic cellular system and North American one can be drawn from interview of the chairman of the NMT committee (Myhre, 1998):

> Q: We had discussion with non-Nordic colleagues. For them it is nearly impossible to understand this model of co-operation, that there were no lawyers, no accounting, and it was just doing this thing.
>
> A: Yes, I think at that time when I came in at the late 70s, we saw that they had a trial system in US. When you look at the map of America, you can see big lakes and there is a river going north-east -- it was a trial system at that area. But they never lifted it up. They made a trial system, but they had problems of making it commercial. The driving element behind this, as they said, was serving customer. It was very much focused on serving the customer. We had a manual system, and we had waiting lists for telephones here in Norway [...it was the same in Finland...] but it was driven by enthusiasm. And we did not look at the commercial side. Well, we did look, but it was not about the competition. We-were co-operating, no fights, we had a support from the top management -- it was driven by a common goal. And we saw that the only way to get this all to operation was by working together -- we could not do it separately. [The project was] too big and the suppliers would not support us.

It becomes clear from the aforesaid, that the approach to the development process was different than that of US. We would argue that the enthusiasm of radio engineers and the support from the top management of Nordic PTTs were crucial success factors, and that successful operation at only one of the organisational levels would not bring the same results. They were aiming at service, when the new-developing standard was intended to become a part of the socio-economic welfare system of the Nordic Countries. The story of the success of the NMT, indeed, proves once again that technology is not a black box due to the fact that in US, Europe, and Japan they failed to bring the same technology to commercial success, when in the Nordic countries it was flourishing.

The way work is organised in a group(s) has substantial impact on the outcomes of the process. The following excerpts are illustrations that do not seem to match the traditional understanding of a large-scale multi-national project's settings. It reveals organisational flexibility and low-centred decision making in the NMT group (Haug, 1999):

> A: ... Proposal for automatic system was not accepted -- they said they needed a manual system, which is a countrywide. But it was never meant as anything else as a stopgap. We had to do something, so let us do it cheap and use it for 450 MHz frequency band, and when the fully automatic system comes, it will take over. So it was not meant to be something forever.
>
> Q: Was like a strategic decision?
>
> A: Yes, we've got to do something.
>
> Q: And when the teleconference established the NMT group it did not say much what to do, was it so?
>
> A: Yes. Ridiculous, really.
>
> Q: So the group itself had to decide what they are doing and on what level?
>
> A: Yes, exactly.

Another interesting aspect of initiation of the developing standard -- the NMT -- is a separation of service requirements from technical specifications. There were already requirements for quality and operational principles, to some extent, implied by fixed network. As Meurling and Jeans (1994) stated: "Many conditions to be met by mobile technology are conditions set by fixed networks -- the mobile network doesn't and can't have its own private set of rules" (p.9). In February 1973 the NMT development group proposed a number of important planning principles in its report to the Nordic Teleconference held the same year. This document of 23 pages pointed out the guidelines for the development of the system without

any technical solutions (Toivola, 1992). Only formulated ideas. Though that was sufficient, and when the technical specifications were finally developed, these were offered to international industrial marked free of charge. None of the NMT specifications and technical solutions were patented: the Nordic Administrations would be offering industry throughout the world a specification for an open international standard -- free of charge (Meurling & Jeans, 1994).

Any standard encompasses a body of knowledge and a social system (Pinch, 1988). Widely accepted Rogers's (1995) theory on diffusion of innovation was criticised as being inappropriate to account for complex technological innovations for it treats a technology as a material object lacking a social part of it (Lyytinen & Damsgaard, 1998). Thus understanding of standard from inside, both as a body of knowledge and as a social system (Pinch, 1988) is needed in order to explain a success or failure of particular standardisation process. Cellular telephony, and NMT in particular, is a good example of complex, non-unified technology or its interpretative flexibility (Lyytinen & Damsgaard, 1998). The meaning of cellular technology under development was not the same for those involved. Operators aimed at long-term operation, profits were seen only in a long run (Meurling & Jeans, 1994; Myhre, 1998). Producers aimed at immediate profits and high volumes of production. Users aimed at the availability of service, its quality, high network coverage and affordability of the service. Regulatory bodies had to implement Pan-Nordic policies and resolve policy conflicts (Meurling & Jeans, 1994; Myhre, 1998; Toivola, 1992). When faced with diverse social networks in innovation process, alignment of multiple interests is required for the social construction of the innovation's significance, the negotiation of standards' scope and content, and the legitimisation of the acceptable uses of the innovation (Lyytinen & Damsgaard, 1998). All this incorporates the notion of interests' and powers' balance or, in other words, equilibrium, the notion of transformation of socio-technical networks and contexts according to the current needs of the running standardisation process and its demands.

Nowadays the cellular handsets are a mundane commodity. It seems to be self evident that a subscriber of cellular network must have a cellular terminal (a handset) in private possession. To come to this understanding back in 70s was not a simple task, though it was a crucial decision. The case of private possession of NMT terminals is a good example of a boundary object which tied up interests of operators, manufacturers, telecom administrators, and users of the cellular service (Haug, 1999):

> Q: There was only couple of issues mentioned, e.g. that terminal trade was liberalised in Sweden.
>
> A: Yes, I think it happened later. We realised that the terminals at that time were not really up to the standard, up to the quality that we needed, so we had to define them. I think there was some atmosphere from the regulatory people and from the monopoly period, and there are always those who think that authority must regulate everything, more or less, and we had some of that [kind]. But at the end of course we said: "OK, there are many manufacturers of manual stations. They've got to be type approved, but apart of that [we should] leave the market open." It was for MTD. We had the same discussion for NMT later.

Results

Drawing from the theory and empirical observation we sought to answer the following questions:

- How to study standard making in IT field where most of standards are intangible/abstract knowledge?
- What is the nature of dynamics imbedded in the standard making process?

The introduced concept of a standard as a boundary object makes it possible to address both the standard making process as such, and the embedded in it dynamics. The dynamics of standard making settings is about the actors who find themselves in interaction with each

other and who are involved in a continuous negotiation of interests and political powers, which are but social communication activities. In the complex organisational settings actors represent interests of different hierarchical levels. Multi-layered hierarchical structure reveals the necessity of using both micro and macro analysis. Negotiation space needed for aligning networks can be only created if there are common interests for those involved, if there is a balance of powers. We argue that the standard while being a "peace maker", meaning that it aligns divert interests, can be also seen as a rope walker's pole, helping the actors to keep equilibrium in a social negotiations. The negotiation space once formed never remains stable due to the need of new re-arrangements of interests to be made. Social-technical networks undergo small-scale transformations at each of the standard making stages, and large-scale transformations from one stage to another. The standard making process continuously faces both internal and external contradictions which serve as impetus for adaptive network's transformation. It is only when the stability is reached the transformation from knowledge creation cycle to the diffusion cycle becomes possible. It is also a transformation from R&D culture to the market culture, from mind settings of standard developers to mind settings of standard adopters. Those are actors themselves serving as blacksmiths and transforming the meanings of standard according to their needs. As the transformation lap is over, a new equilibrium is to be found.

Those conclusions are drawn on theory of social interaction, namely Network theory (Nohria, 1992; Nohria & Eccles, 1992) and Actor Network theory (Callon, Latour, & Rip, 1986; Callon & Law, 1989; Latour, 1993), as well on the case of the NMT standard's making. To reveal the factors of success of the NMT standard making story, we shall look at dynamics of the social networks being formed during the process's running period. Those networks should be as small as possible during the development stage in order to allow quick decision making and reflections on the needs of the development process. At the diffusion stage the networks should embrace as many players as possible in order to form channels for the spread of technological innovation. We have identified and listed several facts of the NMT making process, which in our opinion had a significant influence on the standardisation process and "dressed it for success". The list given below (See Table 1) is neither complete nor exhaustive. We can not state that all the process' characteristics selected are with no doubt related to the understanding of the dynamics of the social networks. Though we believe that analysis of those factors is needed for better understanding of social patterns of the standardisation process, of the distributions of powers and the negotiation of interests. The content of Table 1 is drawn from (Haug, 1999; Knuuttila, Lyytinen, & King, 1996; Meurling & Jeans, 1994; Myhre, 1998; Toivola, 1992).

Table 1. "Small vs. large networks in the NMT standard making process"

Knowledge Creation Cycle	Knowledge Diffusion Cycle
Small, though competitive specifications development groups: - fast discussion making - low-centred power source	Large network of equipment manufacturers and parts' manufacturers: - involving parts' manufacturers enormously enlarged the potential suppliers network
Separation of service requirements from technical specifications: - splitting the problem domain in two sub-domains - lowering levels of decision making	Service requirements are those of the fixed network: - creating network externalities
No lawyers, no royalties: - lower number of actors	No lawyers, no royalties: - openness results in bigger market (manufacturers, operators, etc.)
Development by PTTs and adjacent universities laboratories: - easier co-ordination, smaller funds - challenging spirit of universities'	Open standard inviting a large list of producers: - further development open to any manufacturer/operator

engineers and engineers-to-be	
Proprietary character of the mobile stations: - avoiding manufacturer-operator tie-up relationship	Proprietary character of the mobile stations: User is the owner: - psychology aspect of private possession - handset is a commodity
Computerised automatic call charging: - no personnel/training needed	Charging policies: - no fee for call reception
Transparent roaming in any country: - automatic roaming: no personnel/ training needed	Transparent roaming in any country: - larger market

Conclusions and Future Research

In this article we have addressed the problem of how to study standard making processes in the IT field where most of standards are intangible, abstract representations of knowledge. Our findings are as follows:

- It is appropriate to use Actor Network theory to analyse social-technical networks engaged in the standard making process.
- Treating the standards as boundary objects provides a better understanding of alignments of interests, which help to explain the social processes of standard making.

Our empirical findings suggest that dynamics of socio-technical networks can be characterised as such: **keeping networks as small as possible at the knowledge creation cycle and keeping networks as large as necessary at the diffusion cycle**.

Nonetheless, the further research is needed on the patterns of dynamics of social networks in the standard making process. We suggest that both micro and macro analysis of organisational settings is required for better understanding of continuous negotiation of powers and interests, which takes place during the network's stabilisation process. This suggestion is based on the fact that the negotiation takes place between actors from different hierarchical organisational levels, from different organisations, etc. Therefore looking at the social processes through the lens of only macro or micro factors won't give comprehensive results. Such aspect as actors' involvement should be studied. We argue that the actors' involvement is the basis for the interests negotiation process and, therefore, for the alignment of network. Understanding the roles and powers of actors will shed some light on the patterns of social networks' dynamics.

Interesting and unanswered questions arising from this work ask, for example:

- Where does the impetus for transformation come from: from the socio-technical environment of the standard making process or from the technology itself?

Answering those questions requires more in-depth analysis of the standard making process (Fomin, 1999).

References

Bekkers, R. a. S., Jan. (1998). Mobile Telecommunications: Standards, Regulation, and applications. Boston, London: The Artech House.

Callon, M., Latour, B., & Rip, A. (Eds.). (1986). Mapping the Dynamics of Science and Technology. Basingstoke: Macmillan.

Callon, M., & Law, J. (1989). On the Construction of Sociotechnical Networks: Content and Context Revisited. Knowledge and Society, 8, 57-83.

Callon, M. (1992). The Dynamics of Techno-Economic Networks. In P. S. Rod Coombs, Vivien Walsh (Ed.), Technological Change and Company Strategies: Economic and sociological perspectives (pp. 517): Harcourt Brace Jovanovich, Publishers.

Cowan, R., & Foray, D. (1997). The Economics of Codification and the Diffusion of Knowledge. Industrial and Corporate Change, 6(3), 595-622.

Fomin, V. V. (1999). The Dynamics of Standard Setting: Equilibrium and Transformation in Social Networks. Paper presented at the 1st IEEE Conference on Standardisation and Innovation in Information Technology, Aachen, Germany.
Hanseth, o. M., Eric. (1997). Inscribing behavior in information infrastructure standards. Accounting, management and information technologies, 7, 183-211.
Haug, T. (1999). Interview on the NMT and GSM systems' development [Interview]. Stockholm.
Ikujiro, N. (1994). A Dynamic Theory of Organizational Knowledge Creation. Organization Science, 5(1, February), 15-37.
Knuuttila, J., Lyytinen, K., & King, J. L. (1996). The Parturition of Mobile Telephony Revisited: The case of Standardization and Institutional Intervention in the Nordic Countries : University of Jyväskylä, dept. of Computer Science and Information Systems.
Knuuttila, J. (1997). The Ancient Success Regimes of ARP, NMT and GSM Standards: The Rise and... of Chronocracy or Somersaults Backwards for the People. Unpublished lecinciate thesis, University of Jyväskylä, Jyväskylä.
Latour, B. (1993). Ethnography of a "High-Tech" Case: About Aramis'. In P. Lemannier (Ed.), Technological Choices . London: Routledge and Kegan Paul.
Lyytinen, K., & Damsgaard, J. (1998). What's Wrong with the Diffusion of Innovation Theory? The case of Complex and Networked Technology. Jyväskylä: University of Jyväskylä.
Markus, M. L., & Robey, D. (1988). Information Technology and Organizational Change: Casual Structure in Theory and Research. Management Science, 34(5), 583-598.
Mehrotra, A. (1994). Cellular Radio: Analog and digital systems. Boston, London: The Artech House.
Meurling, J., & Jeans, R. (1994). The Mobile Phone Book. London: CommunicationsWeek International.
Michelis, G. D. (1997). Cooperation and Knowledge Creation. In I. Nonaka & T. Nishiguchi (Eds.), Comparative Study of Knowledge Creation. New York: Oxford university Press.
Myhre, H. (1998). Interview on the NMT system's development [Interview]. Oslo.
Nohria, N. (1992). Is a Network Perspective a Useful Way of Studying Organizations? In N. Nitin & R. G. Eccles (Eds.), Networks and Organizations: structure, form, and action . Boston: HBS Press.
Nohria, N., & Eccles, R. G. (Eds.). (1992). Network and Organizations: Structure, Form, and Action. Boston (Mass.): Harvard Business School Press.
Nonaka, I., & Takeuchi, H. (1995). The Knowledge Creating Company. New York: Oxford University Press.
Paetsch, M. (1993). The evolution of Mobile Communications in the U.S. and Europe: Regulation, Technology, and Markets. London: Artech House.
Pinch, T. (1988). Understanding Technology: Some Possible Implications of Work in the Sociology of Science. In B. Elliott (Ed.), Technology and Social Process . Edinburgh: Edinburgh University Press.
Robey, D. (1995). Theories That Explain Contradiction: Accounting For The Contradictory Organizational Conseqences of Information Technology. Paper presented at the International Conference on Information Systems, Amsterdam, The Netherlands.
Rogers, E. M. (1995). Diffusion of Innovations. (4 ed.). New York: The Free Press. A Division of Simon & Schuster Inc.
Star, S. L. (1991). Power, technologies and the phenomenology of conventions: on being allergic to onions. In J. Law (Ed.), A Sociology of Monsters: Essays on Power, Technology and Domination. London: Routledge.
Toivola, K. (1992). Highlights of Mobile Communications development. Helsinki.
Williams, R. (1996). The Social Shaping of Technology. Elsevier, 865-899.