THE NETWORK EFFECT HELIX[1]

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ABSTRACT

The development and diffusion of network markets and underlying standards is an important domain in IS research. Yet, there is no sound theory nor practice to fully understand the complex mechanisms behind networks of users who are tied together by compatibility requirements as is frequently witnessed in information and communication networks. The goal of this paper is to identify key determinants of the diffusion of network effect goods by studying the battle between two mobile communication standards to propose possible diffusion paths. In the early phase of diffusion, the adoptor of the new standard benefits from direct network effects with other adopters and the estimated indirect network benefits when additional content and services will be provided. The diffusion process starts therefore with early adopters due to the existence of direct network effects in the first place and force-up by additional indirect network effects which attract further adopters. We call this effect the network effect helix, with positive feedbacks on the ongoing diffusion process.

Keywords: Standardization, network effects, ICT, diffusion, innovation, direct network effects, indirect network effects.

INTRODUCTION

Standards and Network Effects

Network analysis is often based upon the theory of positive network effects which describes a positive correlation between the number of users of a network good and its utility (Katz, Shapiro 1985). A common finding is the existence of *network effects*, i.e. the increasing value of a

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network as the number of its participants increases (demand side economies of scale) leading in many cases to unfavorable outcomes (Pareto-inferior results of diffusion processes). Network effects describe "the change in the benefit, or surplus, that an agent derives from a good when the number of other agents consuming the same kind of good changes" (Liebowitz, Margolis 1995; see Thum 1995, pp. 5-12 for different sources of network effects). Katz and Shapiro (1985) first differentiated between direct network effects in terms of direct "physical effects" (Katz, Shapiro 1985, p. 424) of being able to exchange information and indirect network effects, arising from interdependencies in the consumption of complementary goods (Braunstein, White 1985) (Chou, Shy 1990) (Church, Gandal 1992) (Teece 1987). Indirect network effects can also be established by be the availability of after sales services (Katz, Shapiro 1985, p. 425) (Katz, Shapiro 1986, p. 823), learning effects, uncertainties about future technology availability or the existence of a market for used goods (Thum 1995, pp. 8-12). Since network effects are especially found where *compatibility* is important, according to our definition above, the term network often describes the "network of users" of certain technologies or standards such as the network of MS Word or SAP R/3 users (Besen, Farrell 1994, p. 117). Therefore, compatible technologies (or standards) are considered to constitute networks.

The pattern of argument in network effect theory is always the same: the discrepancy between private and collective gains in networks under increasing returns leads to possibly Pareto-inferior results. With incomplete information about other actors' preferences, *excess inertia* ("start-up problem") can occur as no actor is willing to bear the disproportionate risk of being the first adopter of a technology and then becoming stranded in a small network, if all others eventually decide in favor of another technology. This renowned *start-up problem* prevents any adoption at all of the particular technology, even if it is preferred by everyone.

While the traditional models contributed greatly to the understanding of a wide variety of problems associated with the diffusion of standards (the evolution of networks), more research is still needed, especially when trying to develop solutions to the aforementioned problems (Liebowitz, Margolis 1994). Additionally, there are only a few contributions supporting standardization decisions on an individual level. Furthermore, the specific interaction of potential technology adopters within their personal socio-economical environment and the potential decentralized coordination of network efficiency are neglected. As a result, important phenomena of modern network effect markets such as the coexistence of different products despite strong network effects or the fact that strong players in communication networks force other participants to use a certain solution cannot be sufficiently explained by the existing approaches (Liebowitz, Margolis 1994) (Weitzel, Wendt, Westarp 2000).

Other areas of research are also concerned with networks. In contrast to *network effect theory* focusing on compatible technologies constituting networks, *diffusion theory* analyses relational and structural interaction patterns to explain the diffusion of innovations. Besides these essentially economic research approaches, many (mostly empirical) studies of network phenomena in the form of diffusion processes can be found in various research areas such as anthropology, early sociology, rural sociology, education, medical sociology, communication, etc. (for an early overview see Rogers, Shoemaker (1971, p. 44-96)). Other related areas include actor network theory emphasizing the social construction of networks (Callon 1991) (Giddens 1988), contributions concerning the dispersion of the Internet (David, Steinmueller 1996), policy issues in networks (David 1995) (Liebowitz, Margolis 1996) and inter-temporal coordination problems when building infrastructures (Thum 1995).

Network Effects as Externalities

When discussing network efficiency, quite often the objective is an overall measure, such as duration of production processes throughout an entire value chain or aggregate (i.e. supply-chain-wide) cost efficiency (centralized solution). Still, in corporate reality such an overall solution, derived from an implicitly assumed collective utility function, does not describe the strategic investment decision of all the particular actors or agents. Instead, they seek for an individually rather than collectively optimal decision (decentralized solution). This discrepancy is partly responsible for many network infrastructures to stay far behind their potential and is known as start-up problem in network effect theory. This start-up problem can also be described as the not yet totally described components of a network effect good. In traditional neoclassical economics, there is no difference between these settings if the validity of the fundamental theorems of welfare economics (Hildenbrand, Kirman 1976) can be proven. This is the case when certain premises are fulfilled as especially the absence of externalities. Unfortunately, network effects as a constituting particularity in networks are a form of externality, thus disturbing the automatic transmission from local to global efficiency (Weitzel, Wendt, Westarp 2000).

In economics, an *externality* is considered to be present whenever the utility function $U_i(.)$ of some economic agent *i* includes real variables whose values are chosen by another economic agent *j* without particular attention to the welfare effect on *i*'s utility. Generally speaking, in accordance with traditional literature on economics, a *network externality* exists if market participants fail to somehow internalize the impact of a new network actor on others; with positive network externalities the private value from another actor is smaller than the social value, leading to networks smaller than efficient. Thus the question arises how to internalize these effects, or in other words, how to find coordination designs to build better networks. The answer to this question may be found in a more differentiated analysis of the *Penguin effect* (Farrell, Saloner 1986, p. 943). Hungry penguins are sitting on a floe and waiting until the first one jumps into the water because they fear the presence of predators. Each prefers to wait and see what happens with the first one. This *wait-and-see* behavior occurs with each new standard adoption decision, but it is still unsettled, why the first one jumps into the water. In presence of network effects, there is no real *stand-alone* utility of, e.g., being the only one with a telephone device. Analogue to the first moving penguin, which has seen the first fish, or a special dish only he prefers while the rest is waiting for the dish of the day, there are also heterogeneous preferences and network market determinations responsible for the first-mover to lock in a new standard which are different from the determinants of the following adaptors. As the network grows, the ratio of achievable direct and indirect network benefits grows and varies in an upwards spiral with positive feedback to each other. This *network effect helix* phenomenon will be described in more detail in the following sections, with the mobile commerce market as example.

NETWORK BATTLES: THE MOBILE NETWORK MARKET

The development of cellular phone networks attracted a lot of attention in recent scientific publications (Funk 1998), sometimes supposed to be a killer application in ICT markets. Unfortunately, these discussions are often motivated solely by a pure technological or normative political focus. The absence of a sound theory of networks leaves quite substantial gaps when trying to forecast (intermediate) results of imminent technological diffusion battles or decision guidelines for potential customers or suppliers.

While the public property characteristic of network elements providing compatibility among its elements has been discussed mainly in contributions to network effect theory and diffusion of innovations theory, the externality property associated with network effects establishes quite a complex coordination problem. Network effects can derive from both, vertical compatibility requirements (like between the (proprietary) cellular phone and its application software, sometimes termed the "hardware-software-paradigm" in network economics, or indirect network effects, as a prerequisite to use standardized services (Katz, Shapiro 1985)) as well as horizontal compatibility requirements (like communication partners supporting compatible software). While network effect theory can offer valuable insights into general patterns of behavior in networks it is difficult to apply these findings to real networks such as cellular telephone markets and associated services, firstly, due to the overly general nature of the existing models and difficulties in applying them to practical problems and secondly, because the qualitative evaluation of recent technologies is sui generis difficult. Hence, it is most unlikely to find unanimous opinions on whether technology A is superior to B or vice versa. There are many famous discussions in the literature concerning the question if in battles such as nuclear power technology or keyboard layout the better technology is chosen. Since network problems and the bridging of informational, economic, and social networks and methodologies are widely considered to be among the core research domains of IS, the combination of the paradigm of agent-based computational economics and relevant technological considerations associated with a particular technology battle seems to be a fruitful contribution to the domain. The chosen standards' "battle field" is the competition between i-mode and WAP to discuss the network-relevant components which form the motive for customers abandoning WAP for i-mode.

The Standard Battle

The diffusion and usage of new mobile commerce applications has been prophesied an amazing future which is accompanied by a dramatic change in all areas of life. The rapid uptake of cellular phones' diffusion together with the ability of using the end-devices as mobile Internet portables led to rising forecasts of mobile commerce. In spite of the large number of cellular phones and the heavy usage in the fields of telephony and SMS, the non-voice or mobile commerce business has not yet lifted off. Two standards are competing in this area in Germany, The Netherlands and Japan: i-mode and WAP. While WAP offers only a restrictive usage of possible Internet applications, i-mode is based on cHTML (a subset of HTML) and therefore offers regular Internet-like browsing experience. Furthermore, i-mode comes with a billing business model which allows consolidating charges for the usage of third-party content providers' services into the single telephone service invoice. Choice of matured technology (cHTML-based) coupled with a liable business model in the case of i-mode can be seen as an improvement or innovation compared to WAP.

Indirect network effects in this case result from the existence of complementary products, content and/or services for an installed base (Farell, Saloner 1986) of users of a special technology, e.g., the availability of WAP content services depends on the number of WAP capable cellular phones. But Internet access is also possible with i-mode. After the full specification of cHTML in XML, i-mode will also operate with WAP 2.0. Offering i-mode today as mobile services provider (MSP) means to gain probably a competitive advantage by installing an early market entrance towards 3G services in the future. I-mode mobile Internet content includes a large variety of different resources such as route planners, city guides, on-line brokerage, newspapers, weather information and adult entertainment.

While Internet content is part of possible positive *indirect network effects* for adopters the multilateral exchange of data in form of Short Messaging System (SMS) or now i-mail between adopters is part of direct network effects. Compared to i-mode, WAP is not accompanied by a special WAP mail service. A comparable standard in the GSM world is SMS. Generally, SMS allows cellular phone users to send and receive short messages up to 160 characters. In contrast to i-mail or Enhanced Messaging Service (EMS), SMS is restricted to a monochrome alphanumeric display without the possibility of attachments. The current introduction of Multimedia Messaging Service (MMS) can be seen as a technological progress resulting in higher direct network effects but can not compensate the still low quality of Wireless Markup Language (WML) based Internet pages of WAP. The current widespread usage of SMS is driven by the relatively inexpensive pricing due to the low transferred data volume. Low marginal costs per adopting communication partner (neighbor) to exchange SMS with are accompanied by relatively low marginal network benefits in comparison to i-mail. With up to 1000 possible characters i-mail provides six times more characters per mail than SMS. Both technologies support the push-channel solutions based on GSM/GPRS, the always on-line functionality guarantees incoming and outgoing mails instantaneously. Due to the higher transferable data volume, i-mail is in comparison to SMS more expensive, but allows gaining a higher marginal network benefit than SMS per adopting neighbor. Therefore, the standards' battle in this contribution is SMS (for WAP adopters) vs. i-mail (for i-mode adopters).

Simulating the Diffusion of Standards in mobile service markets

Due to the strategic pricing models of mobile service providers, the simulation model considers primarily qualitative aspects of the different technologies. Strategic pricing to gain monopoly or oligopoly benefits (Economides, Himmelberg 1995) (Katz, Shapiro 1986) are not modeled. The simulation model combines both, the direct and indirect network effects of adopters. The resulting utility depends strongly on the network topology and communication preferences of each user (Wendt, Westarp 2000).

Parameterization of the factors for the description of the considered i-mode diffusion scenario leads to the following computer based simulations, which generate qualitative statements about the impact of each parameter on the speed of i-mode diffusion:

Assumed is a network of n independent actors using WAP enabled cellular phones as installed base. Due to the broad distribution of WAP enabled mobile phones, nearly all users can be seen as potential WAP customers. Each actor i has to decide in each period (i.e. one month) to continue to use only WAP or to shift to a new standard such as i-mode, i. e. adopting an i-mode cellular phone (i-mode capable devices also support WAP). Due to this, actors are able to decide in each period anew for i-mode or against it. According to their bounded and dynamically adapted information set deriving—among others—from past technology adoption decisions of the direct neighbors of i, actors can adopt i-mode in one period and drop it in the next.

Furthermore, the actors use mobile data services such as SMS or i-mode mail to communicate directly with their nb_i neighbors. Visualized, actors and their relations can be illustrated as nodes and edges in a graph. To create a close network topology, the participating actors are randomly located in a unit square. Afterwards, actor i activates a vectored communication to the nearest neighbors nb_i in Euclidian distance. Such a graphical illustration represents the social network of actors and does not determine the geographical location.

The calculus of decision of each actor is to evaluate the monthly benefit surplus using i-mode in comparison to WAP and SMS as counterpart. The following cost and benefit aspects are of importance for the adopting decision:

Set-up costs: In comparison to the widespread penetration of WAP capable cellular phones as quasi standard, adopters of i-mode have to invest in new mobile end-devices. In 2002, only one i-mode cellular phone model was available (which also enables WAP) for a retail price of EUR 249.- , including a 24 months contract and subsidized by the MSP. Under negligence of an interest rate and regarding the contract period, this results in a basic price of EUR $\frac{249}{24}$ per month. Besides these set-up costs, an adopter has to pay EUR 3.- per month as additional fee for i-mode services in 2002. Due to the subsidization by the MSP, it is assumed that the costs for adopters repurchasing an only WAP capable end-device during the regarded period are negligible. Furthermore, adopters of the WAP service have to pay no further monthly basic fees.

Two adoption phases are distinguished: Prior to the adoption of an i-mode end-device, the actor is in phase 1. After the adoption (phase 2), the decision relevant basic costs are reduced to the monthly fee of EUR 3.- in each following period. Ex post, the investment into the cellular phone can be regarded as sunk costs. The simulation model does not consider any additional stand-alone benefits of an i-mode cellular phone, compared to not i-mode capable cellular phones. The integration of any conceivable stand-alone benefits into the simulation model would accelerate the speed of adoption.

Direct network effects: Due to the usage of i-mail, the i-mode adopter *i* gains more benefits from the new mobile standard through communicating with i-mail capable neighbor *j* in comparison to the usage of SMS. The valued additional direct benefit u_{ij}^{D}, using i-mail per period per communication with neighbor *j* , is calculated as the difference of $u_{ij}^{D,i-mail}$ less $u_{ij}^{D,SMS}$:

(1) $u_{ij}^{D} = u_{ij}^{D,i-mail} - u_{ij}^{D,SMS}$

Analog to the benefits, the additional direct costs c_{ij}^{D} can be described as the additional costs of the communication relations between *i* and its neighbors *j*:

(2) $c_{ij}^{D} = c_{ij}^{D,i-mail} - c_{ij}^{D,SMS}$

The resulting additional net benefit coefficient nu_{ij}^{D} is:

(3) $nu_{ij}^{D} = u_{ij}^{D} - c_{ij}^{D} = u_{ij}^{D,i-mail} - c_{ij}^{D,i-mail} - \left(u_{ij}^{D,SMS} - c_{ij}^{D,SMS}\right)$

subject to: $nu_{ij}^{D} \geq 0$

Indirect network effects: The model describes an unique monotonously increasing correlation between the diffusion of a new technology in an existing network and the offered i-mode services and content. The strong usage of i-mode services and content (and therefore the increase of adopters) will motivate content and service providers to augment their supply, what again leads to further network effect benefits (and costs). As the network grows, the ratio of achievable direct and indirect network benefits grows and varies in an upwards spiral with positive feedback to each other. A self-perpetuating *network effect helix* occurs. Due to the compatibility of i-mode end-devices with WAP content sites, the indirect network benefit is ≥ 0 for i-mode adopters in each period.

The resulting indirect network effect benefits per period accompanied with the usage of the technology or standard are therefore a function of all standard adopters $B_{q,t}$ of the same technology q:

For WAP adopters:

(4) $U_{WAP,i,t}^{N} = U_{WAP,i}^{N}\left(B_{WAP,t}\right)$ with costs

(5) $C^N_{WAP,i,t} = C^N_{WAP,i}\left(B_{WAP,t}\right)$

For i-mode adopters:

(6) $U^N_{i-mode,i,t} = U^N_{i-mode,i}\left(B_{i-mode,t}\right)$ with costs

(7) $C^N_{i-mode,i,t} = C^N_{i-mode,i}\left(B_{i-mode,t}\right)$

The simulation model uses the absolute number of i-mode users instead of the fraction of users mobile commerce users today as well as the (growing) number of users in the future is hard or nearly impossible to predict. In fact, in networks, a provider not only wants to cannibalize users from other MSPs but wants also to attract new adopters. Furthermore, the interpretation of used functions (or in more detail: the used coefficients in equations (8)-(11)) would be quite difficult. The computer based simulation model uses a linear proportional function. The influence of an assumed sigmoid function curve will be part of further research.

(8) $U^N_{WAP,i,t} = u^N_{WAP,i,} \cdot B_{WAP,t}$

(9) $C^N_{WAP,i,t} = c^N_{WAP,i} \cdot B_{WAP,t}$

(10) $U^N_{i-mode,i,t} = u^N_{i-mode,i} \cdot B_{WAP,t}$

(11) $C^N_{i-mode,i} = c^N_{i-mode,i} \cdot B_{WAP,t}$

Under side condition:

$u^N_{WAP,i}\,;c^N_{WAP,i}\,;u^N_{i-mode,i}\,;\;c^N_{i-mode,i} \geq 0$

Using equations (8) and (9), as well as (10) and (11), the following net benefit coefficients $nu^N_{WAP,i}$ (12) and $nu^N_{i-mode,i}$ (13) can be derived:

(12) $nu^N_{WAP,i} = u^N_{WAP,i} - c^N_{WAP,i}$

(13) $nu^N_{i-mode,i} = u^N_{i-mode,i} - c^N_{i-mode,i}$

The term "net benefit" is orientated on each technology benefit regarding indirect network effects while the direct network effects are defined as the difference of the technology orientated net benefit coefficient nu^D_{ij} (see equation (3)). The substitution rate describes the substitution relation of i-mode services in comparison to WAP services. *sub=1* means, e.g., that there is no WAP service an i-mode adopting actor will use any more.

The overall individual net benefit deriving from indirect network effects is defined as $U^{INE}_{i,t}$ (equation 14).

(14) $$U^{INE}_{i,t} = \begin{cases} \left(nu^N_{i-mode,i}\right)\cdot B_{i-mode,t} - sub_i\cdot\left(nu^N_{WAP,i}\right)\cdot B_{WAP,t} & if\;\; U^{INE}_{i,t} > 0 \\ 0 & if\;\; U^{INE}_{i,t} \leq 0 \end{cases}$$

Decision Calculus: The overall i-mode adoption benefit (in phase 1) is defined in equation 15:

(15) $$U_{i-mode,i,t} = -\frac{249}{24} - 3 + \sum_{j\in NB_i}\left(nu^d_{ij}\cdot x_j\right) + U^{INE}_{i,t}$$

subject to:

$x_j \in \{0;1\}$ (Indicator for the i-mode adoption by actors' j)

$0 < sub_i \leq 1$ (Actor i's substitution behavior using i-mode instead of WAP)

$n = B_{i-mode,t} + B_{WAP,t}$

The adoption decision is based on uncertain and imperfect information about the adoption decision of other users, so adopter *i* has to estimate the adoption decisions of neighbor *j* heuristically. The decentralized standardization model (Westarp et al. 1999) describes the probability p_{ij} as actor *i* believes that actor *j* will adopt a technology. If $E[U_{it}] > 0$ then actor *i* will adopt. If actor *i* is certain about the behavior of his communication partners, p_{ij} corresponds to 0 or 1. Every communication edge *ij* with costs c_{ij} contributes to the amortization of the adoption costs of the incidental actor *i*. The decentralized standardization model furthermore assumes, that the technology adoption costs K_j and the information costs c_{ji} are the only costs regarding *j* known to actor *i*. Therefore, actor *i* can assume that the edge *ji* is representative of all of *j's* edges. Combining all assumed data, actor *i* can then develop the following probability estimate p_{ij} for the probability of technology adoption on behalf of actor *j,* where c_{ji} is equivalent to nu_{ij}^{d} and K_j equivalent to $\frac{249}{24}+3$ in phase 1:

(16) $$p_{ij} = \frac{c_{ji} \cdot (n-1) - K_j}{c_{ji} \cdot (n-1)}$$

Further structural adaptations of the decentralized standardization model are necessary for the simulation model. In the case of the mobile service markets, a low density of related actors (similar to few communication edges) is assumed to perform the computer based simulation. The standardization model assumes communication edges among all actors. This seems to be unrealistic for the observed cellular phone case. The term *n-1* is therefore replaced by nb_j which describes the number of communication partners or neighbors *j*. The used heuristic estimation has to consider the indirect network effects of the technology adoption decision by neighbors. Therefore, the numerator in this model is extended to the expected indirect network effect net benefit of the neighbors ($E\left[U_{jt}^{INE}\right]$).

(17) $$p_{ijt} = \frac{nu_{ji}^{D} \cdot nb_j - \left(\frac{249}{24}+3\right) + E\left[U_{jt}^{INE}\right]}{nu_{ji}^{D} \cdot nb_j}$$

If neighbor *j* uses i-mode in the previous period, p_{ijt} is equivalent to 1. Actor *i* believes that it is absolutely implausible for neighbor *j* to switch the currently chosen new standard immediately in the next period. A simplification of the model is the supposed assumption, that actor *i* has complete information about the direct and indirect net benefits components of its neighbors *j*.
The impact of the indirect network effects depends on the total number of adopters. To forecast the adoption rate, estimations of the diffusion theory can be used. This simulation model refers to a restrictive estimation for adopting i-mode ($B_{i\text{-}mode,t}$), orientated on the installed base of i-mode users in the previous period:

(18) $$E\left[B_{i-mode,t}\right] = B_{i-mode,t-1}$$

The anticipated benefit of indirect network effects in period *t* is:

(19) $$\begin{aligned} E\left[U_{i,t}^{INE}\right] = &\left(u_{i-mode,i}^{N} - c_{i-mode,i}^{N}\right) \cdot B_{i-mode,t-1} \\ &- sub_i \cdot \left(u_{WAP,i}^{N} - c_{WAP,i}^{N}\right) \cdot \left(n - B_{i-mode,t-1}\right) \end{aligned}$$

The calculus of decision of a risk neutral actor *i* in period *t* depends on the estimated total benefit $E\left[U_{i-\mathrm{mod}e,i,t}\right]$. If the benefit is >0, then actor *i* will adopt an i-mode mobile end-device. Each actor can decide once per month (i.e. per period).
The calculus of adoption in phase 1 (20):

(20) $$E\left[U_{i-mode,i,t}\right] = -\frac{249}{24} - 3 + \sum_{j \in NB_i} \left(nu_{ij}^{D} \cdot p_{ijt}\right) + E\left[U_{i.t}^{INE}\right]$$

The calculus of adoption in the phase 2 (after the investment in an i-mode cellular phone):

(21) $E\left[U_{i-mode,i,t}\right] = -3 + \sum_{j \in NB_i} \left(nu_{ij}^{D} \cdot p_{ijt}\right) + E\left[U_{i.t}^{INE}\right]$

Implementation: The model is implemented in Java 1.4. The used parameters of the simulation are chosen in a restrictive and conservative way. 1,000 actors are defined as the network population *n*. This is in comparison to the large potential WAP user market a relatively small population but a necessary assumption for a better performance of the model. The substitution rate was $sub_i = 1.0 \;\; \forall i$, as defined above. The closeness of the network topology was assumed with $nb_i = 5 \;\; \forall i$ (that means that actor *i* has 5 direct neighbors). Setup costs occur in phase 1 (EUR $\frac{249}{24} + 3$) and EUR 3 in phase 2. The net benefit expectations for direct and indirect network effects are assumed as normally distributed. The expectation varies in the following ranges (equation 22 and 23), while the variation coefficient is constant to 0.2 for all parameters:

(22) $E\left[nu_{ij}^{d}\right] = [1.00;\;\; 8.00]$ for direct network benefit

(23) $E\left[nu_{i-mode,i}^{N}\right] = [0.004;0.5]$ $\;E\left[nu_{WAP,i}^{N}\right] = [0.003;0.5]$ for indirect network benefit

The assumed values of the parameters vary by small incremental steps of 0.05 (nu^D) and 0.02 (nu^N) during the simulation to provide a (ceteris paribus) sensitivity analysis. Each simulation run is equivalent to one simulated network. After generating the close network topology, the actors' behavior is simulated over multiple periods until a stationary state is reached. The total number of simulation runs was 45,825. The Java applet written for the simulation is available at www.it-standards.de/applet1/index.html. The authors invite everyone to use the applet with different parameter values according to the respective assumptions. Any suggestions or feedback is highly appreciated.

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The first simulation results presented in figure 1 provide the number of i-mode adopters in the stationary state (a period after the last standardization activities were measurable). During the simulation, the expectations of the normally distributed direct and indirect additional benefits nu_{ij}^{D} , $nu_{WAP,i}^{N}$, $nu_{i-mode,i}^{N}$ have been varied, while $nu_{i-mode,i}^{N}$ had to be greater than $nu_{WAP,i}^{N}$ .The results depend directly on the expectations of net benefit nu_{ij}^{D} and $\Delta nu_i^N = nu_{i-mode,i}^{N} - nu_{WAP,i}^{N}$. It must be pointed out that the conducted transformation is only possible if sub_i is equal to 1 for every actor *i*.

In figure 1, the cumulative number of i-mode adopters is represented in the stationary state, depending on nu_{ij}^{D} and Δnu_i^N . Each data spot represents the result of a single simulation run. Two main sections and a small interfacial area can be identified. On the lower section, nobody standardizes or adopts i-mode. The results are only slightly influenced by the marginal indirect network effects. Starting with $E\left[nu_{ij}^{D}\right]$=3.5, the network will be completely equipped with i-mode end-devices. The most interesting region is the interfacial area around $E\left[nu_{ij}^{D}\right] = [2.9;3.4]$. Inside this region, the frequency of mixed solutions (i-mode and WAP) is maximal and the typical standardization dilemma occurs, such as the start-up problem respective penguin effect (Farrell, Saloner 1986) or tippy networks (Shapiro, Varian, 1998, p. 176).

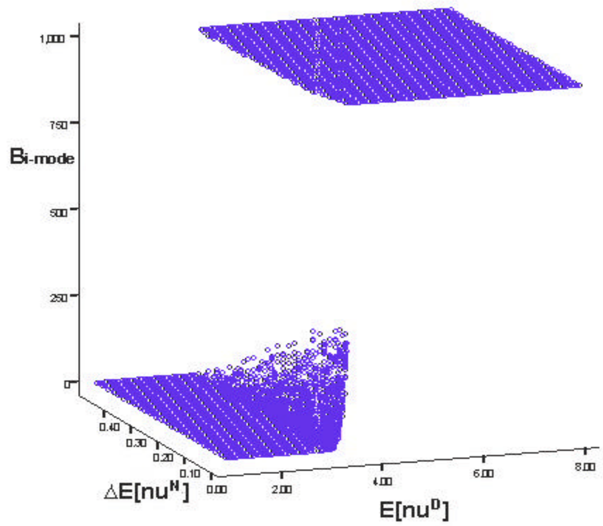

Figure 1. Number of i-mode users in the stationary state, depending on the net utility parameters

The influence of Δnu_i^N in this region forces the tippiness of the network, which means, that an increase of Δnu_i^N does not raise the number of i-mode adopters ($B_{i\text{-mode}}$) in mixed networks but enforces the shift towards an i-mode monopoly. Due to the low variance of marginal benefits (similar to homogenous interests of network participants), only few mixed networks occur. By raising the variation coefficient from 0.2 to 0.5, the percentage of oligopoly solutions (mixed networks) increases by factor 1.12. Steady networks are observable with less than 50 WAP users in the stationary stage. In most cases, the adoption process is finished after a very short time (figure 2), depending on the variation coefficient and disregarding existing diffusion time lags in reality. In the region of $E\left[nu_{ij}^D\right]=[2.9;3.4]$, the simulations need the most processing time up to 22 periods. The correlation between Δnu_i^N and t_{stat} is slightly negative in this region with a significant Pearson correlation coefficient r = - 0.179.

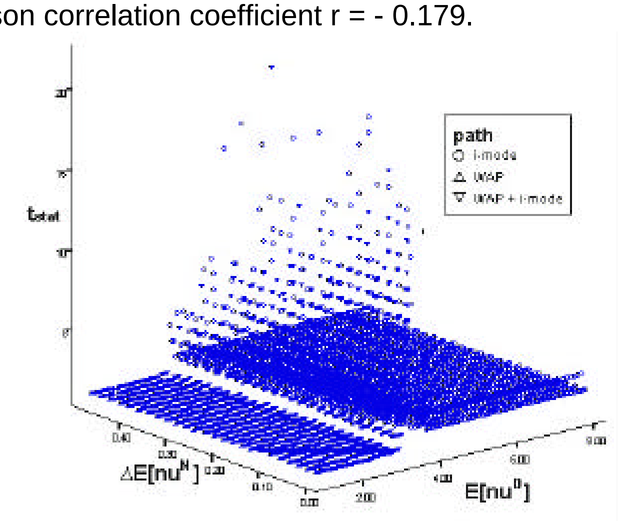

Figure 2. Stationary state access, depending on the direct and indirect net benefit parameters

Figure 3 provides an exemplary diffusion path, based on a particular parameter constellation, depending on the adoption behavior in each period. The diagram in figure 4 provides the expected user benefit (neglecting setup costs) on average, based on direct and indirect network effects ($E\left[U_i^{INE}\right]$). In the initiation periods 1 and 2 the diffusion process is only driven by the expected direct network benefits. After the second period the expected indirect network benefits $E\left[U_i^{INE}\right]$ become more important for the adoption decision, based on the restrictive estimator for B_t (see equation 18).

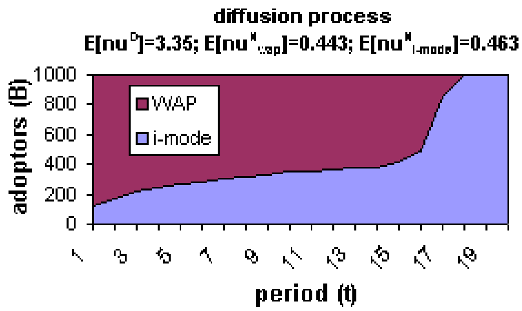

Figure 3. Diffusion process of WAP vs. i-mode

It could be a dominant supplier strategy to offer a variety of services even without having customers in the first period. This can be regarded as virtual indirect network effects, based on expected services in future, if a critical mass of adopters occurs. The i-mode provider has to signal that there will be enough services. Due to the importance of direct network effects in the start-up phase, a subsidized i-mail offer would increase the speed of adoption. Such strategies could be implemented easily in this simulation by valuing an exogenous parameter $B_{i\text{-}mode,0}$>0 as estimator for $B_{i\text{-}mode,1}$ to simulate the benefits of a virtual installed base.

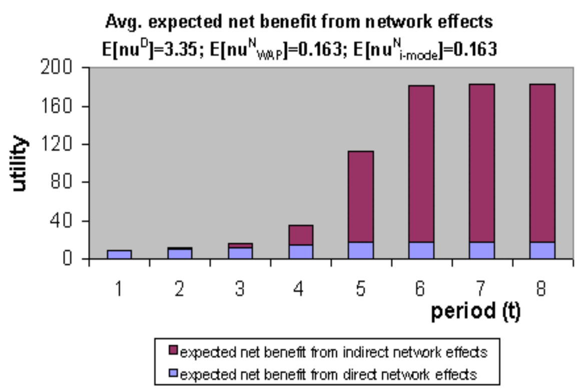

Figure 4. Diffusion process and progression of net benefit, based on direct an indirect network effects

Figure 5 provides a view on the expected total net benefits per actor in average. The average expected total net benefit for one actor in the stationary state is *avgE*[U_i], depending on $E\left[nu_{ij}^D\right]$ and $\Delta E\left[nu_i^N\right]$.

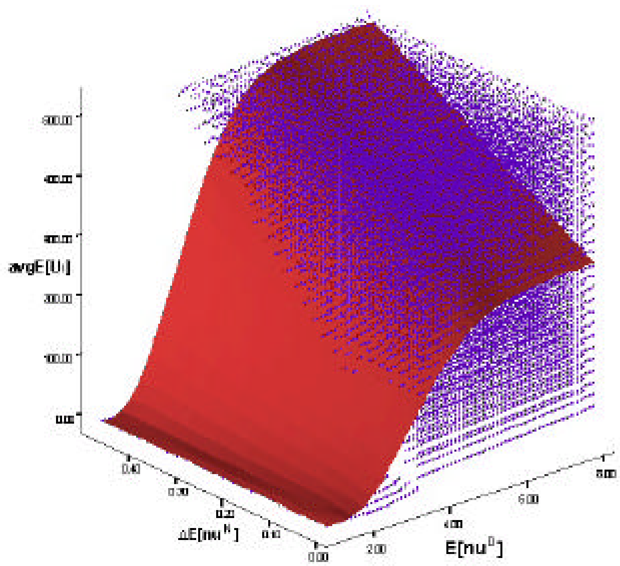

Figure 5. Average expected total net benefit per actor in the stationary state

The diagram provides the break in the region around $E\left[nu_{ij}^{D}\right]=[2.9;3.4]$. Under this interval, there are no standardization activities observable (the expected net benefits were similar to 0). If $E\left[nu_{ij}^{D}\right]$ is greater than 3.4, the average net benefit per actor is >0 and the networks are mostly complete equipped with i-mode. Within this interval, various solutions exists with different result levels of *avgE*[*U*$_i$] for each combination of $E\left[nu_{ij}^{D}\right]$ and $\Delta E\left[nu_{i}^{N}\right]$. This is due to the different absolute benefit levels of $E\left[nu_{WAP,i}^{N}\right]$ which are not visible in the diagram. The higher the values of $nu_{WAP,i}^{N}$ the greater are the benefits of indirect network effects, even when $\Delta E\left[nu_{i}^{N}\right]$ is equal to 0, because in equation (19) $nu_{WAP,i}^{N}$ will be multiplied with 0 while $nu_{i-mode,i}^{N}$ will be multiplied with 1000.

The increase of *avgE*[*U*$_i$] is almost proportional to $\Delta E\left[nu_{i}^{N}\right]$ due to the large benefits from indirect network effects as the largest part of the total benefit (see figure 5), while the direct network effects started the adoption process in the early periods.

CONCLUSION

Using the case of the mobile standards battle, we demonstrate the significant influence of often neglected direct network effects in the early phase of diffusion. In the case of mobile commerce standards, provider strategies of MSPs have often focused on strategic promoting of indirect network effects such as "mobile" content while ignoring the importance of direct network effects like those deriving from SMS or i-mail exchange, which has often resulted in serious and costly market problems after an initial market entrance.

If a new standard like i-mode has not reached the critical mass of adopters in the early phase of market introduction, then the probability increases that the standard cannot be established in the market at all. The simulations have shown that to reach this critical mass a MSP has to take care about the changing composition or ratio of direct and indirect network effects. The crucial adoption reasons of the early adopters mainly driven by direct network effect benefits are no longer sufficient or available, in order to serve and attract additional adopters and their preferences. These adopters take further, now available indirect network benefits into account for their adoption decision. This phenomenon of an interdependent system of direct and indirect network effects that amplifies the number of adopters stabilize the ongoing diffusion process. We call this empirical observation the network effect helix.

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