The German Mobile Standards Battle

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Abstract

The diffusion of innovations has long been a research 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 technology battle between WAP and i-mode that is recently raging between German cellular service providers and to propose a possible diffusion path.

By adapting an existing network model of technology diffusion, key influences are identified and incorporated into a computer-based simulation model. In doing so, trade-offs like better presentation quality on i-mode cellular clients vs. higher service costs compared to WAP applications can be modeled to propose a systematic sensitivity analysis of factors influencing the success of the respective mobile technologies and associated services. Not at least, the simulation model supports mobile services providers to customize their prices for a faster market penetration through regarding not only indirect (WAP, i-mode) but also direct network effects (SMS, i-mail) as crucial factors for adopters.

1. Introduction

Much has been written about mobile (cellular) networks and expectancies concerning supposed killer applications and services. Unfortunately, these discussions are often either purely technological or political. 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 users or vendors, as has battles or decision guidelines for users or vendors, as has recently shown especially in the mobile sector.

While the commonality property of the 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. The 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 [8]) 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 phones and associated services, partly due the mostly general nature of the existing models and difficulties in applying them to practical problems and partly because the qualitative evaluation especially of younger technologies is sui generis difficult. Hence, it is most unlikely to find unanimous opinions on whether technology A is superior to B et 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 was chosen [4]. We have recently faced similar questions in discussing mobile commerce technologies and infrastructures. Fueled by considerable investments in 3G architectures and the absence of obvious services that might ever bring substantial returns to these investments, this paper is aimed at providing building blocks to the discussion on how to combine an economical and a technological view on mobile networks. Since network problems and the bridging of informational, economic, and social networks and

0-7695-1874-5/03 $17.00 © 2002 IEEE

methodologies are widely considered to be among the core research domains of IS, we try to bring together the paradigm of agent-based computational economics and relevant technological considerations associated with the very particular technology battle Germany is facing in the near future, when one of its largest mobile service providers (MSP) is offering i-mode services to its customers. Does i-mode stand a chance to gain a significant market share, are users rather using WAP over GPRS, and why?

To analyze these questions, in section 2 we give a brief overview of theoretical approaches that could be used for the analysis. It becomes clear that traditional approaches modeling the diffusion of innovations need to be extended in order to capture the intricacies of the mobile technologies at stake. That is why in section 4 an adapted network model is used to identify the most influential diffusion factors (see section 3). The results are incorporated into a single model based upon the mobile users' view on M-services. Using computer-based simulations in section 4 allows proposing a possible diffusion path for the particular technology battle. The findings are used to establish a framework for further adaptation to similar problems. Since diffusion problems even between the same technology will vary significantly for example in different countries, the analysis is mainly seen as a proposal on how to model particular decision and diffusion problems in mobile networks and cannot be more than one of many ways of developing a systematic view on the problem domain. Therefore, we invite interested researchers to use and re-parameterize the Java code and the approach presented to adapt the analysis to other problems. The Java applet written for the simulation is available at www.it-standards.de/applet1/index.html. We invite everyone to use the applet with different parameter values according to the respective assumptions. The authors also highly appreciate any feedback.

2. Theoretical approach

Despite the existence of many different diffusion models (for a comprehensive overview of the traditional diffusion models refer to [5],[12]), these approaches are not sufficient to model the diffusion of network effect products. Schoder names three areas of deficit ([17], pp. 46-50). First of all, there is a lack of analysis concerning the phenomenon of critical mass. Furthermore, the traditional diffusion models cannot explain the variety of diffusion courses. Third, the models do not sufficiently consider the interaction of potential adopters within their socio-economic environment, how adoption changes their relationship with other participants in the system, and how the willingness to pay a certain price changes with adoption within a certain group. Therefore, it is not surprising that the broad acceptance of logistic and semi-logistic approaches is found in areas where innovations have only small consumer interdependencies, where the acceleration of the adoption is characteristically slow, and where the diffusion function is similar to normal distribution ([17], pp. 48-49). All of these requirements are rather unrealistic for the diffusion of network effect goods like i-mode as a mobile standard.

2.1. Diffusion of innovations

The term diffusion is generally defined as "the process by which an innovation is communicated through certain channels over time among the members of a social system" [15]. The traditional economic analysis of diffusion focuses on describing and forecasting the adoption of products in markets. In particular, the question of which factors influence the speed and specific course of diffusion processes arises [20]. Traditional diffusion models are based on similar assumptions: Generally, the number of new adopters in a certain period of time is modeled as the proportion of the group of market participants that have not yet adopted the innovation. Based on this fundamental structure, three different types of diffusion models are most common [20],[11],[13]: The exponential diffusion model (also external influence model or pure innovative model) assumes that the number of new adopters is determined by influences from outside the system, e.g. mass communication. The logistic diffusion model (also internal influence model or pure imitative model) assumes that the decision to become a new adopter is determined solely by the positive influence of existing adopters (e.g. word of mouth). The semi logistic diffusion model (also mixed influence model) considers both internal and external influences.

2.2. Network models of Innovation diffusion

Besides the economic research approaches described above, many (mostly empirical) studies of diffusion processes can be found in various research areas (for an early overview of existing empirical studies refer to [16], pp. 44-96). Most of the models are based on the threshold and critical mass approaches which analyze the diffusion rate of innovations, collective behavior, or public opinion, e.g. [6],[14]. A long research tradition exists in the area of network models of diffusion of innovations. Mainly relying on empirical analysis, this field has a long tradition in various fields. Complementing the analysis of diffusion of innovations, network analysis in this context is an instrument for analyzing the pattern of interpersonal communication in a social network (for concepts of sociological network analysis e.g. refer to [7]).

Changing an existing network standard in a social system causes high setup costs. This so called lock-in effect is a hindering reason for a fast adoption of innovations such as new technologies or standards (e.g. [1],[10]).

In general, network diffusion models can be divided into relational models and structural models. Relational models analyze how direct contacts between participants in networks influence the decision to adopt or not adopt an innovation. In contrast, structural models focus on the pattern of all relationships and show how the structural characteristics of a social system determine the diffusion process ([19], pp. 31-61).

The occurring benefits when adopting a mobile communication standard are a mixture of direct and indirect positive network effects. The simulation model in this paper combined the structural and relational model to one diffusion model which depends on both, the positive direct and indirect network effects. The simulation and its underlying assumptions in section 4 suggest a possible course of i-mode diffusion in Germany in the future.

Besides helping to better understand, the multifaceted dynamics in networks from the perspective of theoretical network analysis, the framework might prove valuable for analyzing the implications of different pricing strategies on behalf of the mobile service providers and their interplay with consumers' willingness to adopt new technologies.

3. The German battle for mobile services

The diffusion and use of m-commerce applications was prophesied an amazing future which is accompanied by a dramatic change in all areas of life. The enormous speed of diffusion of cellular phones all over the world together with the ability of using the end devices as mobile Internet portables led to rising forecasts of mobile business. In spite of the large number of cellular phones and the heavy usage in the fields of telephony and SMS, the non-voice or m-commerce business has not yet lifted. One of the reasons might be the GSM based WAP standard in Europe, which allows only a restrictive use of possible Internet applications. Due to this, the telecommunication provider E-plus introduced the NTT DoCoMo i-mode service, which is very famous in Japan in Germany in March 2002. I-mode is based on cHTML, a subset of HTML and therefore usable like normal Internet pages. Furthermore, i-mode comes with a billing business model which allows content providers to charge the use over the telephone invoice. The mature technology based on cHTML together with a liable business model can be seen as an improvement or innovation on the existing WAP market as installed base in Germany.

3.1. WAP and i-mode: mobile standards with (primarily) indirect network effects

Indirect network effects result from the existence of complementary products and/or services for an installed base [3] of users of a special technology, e.g. the availability of WAP content services depends on the number of WAP capable cellular phones. Most research about installed-base effects is based on empirical ex-post analysis, focusing on existing networks. The forecast and constitution of such networks based on individual decisions in a social environment are yet underdeveloped. The simulations shown in section 5 are a possible contribution to this research field.

In Germany, the wireless application protocol (WAP) started in 1998 as a mobile Internet access protocol for the wireless markup language (WML) which can be interpreted through WAP browsers in mobile end devices. Due to the technical restrictions and the monochrome black presentation WAP has not the same large potential as the HTML based Internet using further embedded JAVA objects, for example. Furthermore, the WML version 1.0 pages are not yet a sub-system of HTML which makes the conversion of HTML to WML rather difficult.

Besides theses technical problems the GSM based time slot charging of WAP (approx. EUR 0.11 per minute) is one of the most hindering reasons for its low penetration in Germany. Using GPRS, the packet orientated charging model, the customers' anxieties about high prices can be reduced. Furthermore the programming quality of the WAP pages is rather low which led to various access errors. Altogether, there is a large gap between promised and realized service quality.

But not only WAP is providing mobile Internet access. Since 1999 the former telecommunication monopolist NTT DoCoMo offers i-mode in Japan, since March 2002 it is also available in Germany, provided by the mobile service provider (MSP) E-Plus.

E-Plus is the first European operator which provides i-mode. The expectations are high that German consumers will adopt the new technology as quickly as the Japanese.

NTT DoCoMo's i-mode in Japan serves more than 35 million subscribers with access to almost 60,000 Internet sites via their mobile phones. Much of the success of the "always on, always connected" mobile Internet service in Japan has been attributed to travel and hospitality services content providers.

Until September 2002 only one handset from NEC supported i-mode to offer colored content with high-quality sound in Germany. Based on GPRS, the content is displayed in real time without dial-in times. I-mode is based on the Internet language cHTML, which is a preliminary stage of the future XML based common standard for all European mobile communication providers, known as WAP 2.0, which is expected to be available in early 2003. After the full specification of cHTML in XML, i-mode will also operate with WAP 2.0. The provider hopes to gain a competitive advantage by installing an early market entrance towards 3G services in the future. The German i-mode service started with approx. 60 content providers and 500 i-mode sites. The content includes a large variety of different resources such as route planners, city guides, on-line brokerage, newspapers, weather information and erotic.

3.2. SMS and I-Mail: Mobile standards with (primarily) direct network effects

The dramatic growth of diffusion of SMS demonstrates the high demand for interpersonal non-voice services. The Short Messaging Service (SMS) was introduced in 1999. The further migration will be from SMS to Enhanced Messaging System (EMS) to Multimedia Messaging Services (MMS). I-mode uses a proprietary variant of EMS, so this paper compares SMS for WAP users with i-mail for i-mode users.

Compared to i-mode WAP is not accompanied by a special WAP mail service. The matchable standard in the GSM world is SMS. SMS allows cellular phone users to send and receive short messages up to 160 characters. In opposite to i-mail or EMS, SMS is restricted to a monochrome black display without the possibility of attachments. The usage of SMS is relatively inexpensive 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 i-mode mail or i-mail, E-Plus offers mobile e-mail messages that transfer sound files and colored e-postcards which can be sent to any regular e-mail address. With up to 1000 possible characters i-mail provides six times more characters per mail than SMS. Due to the push-channel solution based on GPRS, the always on-line functionality guarantees incoming and outgoing mails at real-time. Due to the higher transferable data volume i-mail is in comparison to SMS more expensive, but allows gaining a higher marginal network benefit per adopting neighbor than SMS.

4. A Simulation model for the German mobile service market

Due to the strategic pricing models of German MSPs the simulation model considers primarily qualitative aspects of the different technologies. Strategic pricing to gain monopoly or oligopoly benefits are shown by Economides and Himmelberg [2] or Katz and Shapiro [9]. The integration of theses pricing aspects are part of further simulation models in this research filed.

The simulations provided in this paper combine both, the direct and indirect network effects of adopters. The resulting utility depends strongly on the network topology and communication preferences of each user (see [21],[23]).

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 to adopt WAP again or to shift to the new standard such as i-mode. Due to this, actors are able to decide in each period 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. 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 [23]. In such a close network topology actors can be graphically illustrated as nodes, the communication vector as edges. 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 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 in Germany, adopters of i-mode have to invest in new mobile end devices. The current i-mode cellular phone which also enables WAP is subsidized by the MSP E-Plus and costs EUR 249.-. Under negligence of an interest rate and regarding the contract period of 24 months a basic price of EUR $\frac{249}{24}$ per month results. Besides these set-up costs, an adopter has to pay EUR 3.- per month for the i-mode service. 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 no further monthly basic price to pay.

Before the adoption of an i-mode end device, the actor is in the first stage of the model (phase 1). After the adoption (phase 2), the decision relevant basic costs decrease to EUR 3.- in each following period. This simulation model does not consider possible standalone benefits when adopting an i-mode cellular phone. If there are any standalone benefits, this would increase 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 when communicating with i-mail capable neighbors' *j* in comparison to SMS. The valued direct additional 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 direct additional 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 a 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 lead to further network effect benefits (and costs). 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 of the same technology *q*:

For WAP adopters:

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

(5) $C_{WAP,i}^{N} = C_{WAP,i}^{N}\left(B_{WAP}\right)$

For i-mode adopters:

(6) $U_{i-mode,i}^{N} = U_{i-mode,i}^{N}\left(B_{i-mode}\right)$ with costs

(7) $C_{i-mode,i}^{N} = C_{i-mode,i}^{N}\left(B_{i-mode}\right)$

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) $U_{WAP,i}^{N} = u_{WAP,i}^{N} \cdot B_{WAP}$

(9) $C_{WAP,i}^{N} = c_{WAP,i}^{N} \cdot B_{WAP}$

(10) $U_{i-mode,i}^{N} = u_{i-mode,i}^{N} \cdot B_{WAP}$

(11) $C_{i-mode,i}^{N} = c_{i-mode,i}^{N} \cdot B_{WAP}$

Under side condition:

$$u_{WAP,i}^{N} ; c_{WAP,i}^{N} ; u_{i-mode,i}^{N} ; \ c_{i-mode,i}^{N} \geq 0$$

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

(12) $nu_{WAP,i}^{N} = u_{WAP,i}^{N} - c_{WAP,i}^{N}$

(13) $nu_{i-mode,i}^{N} = u_{i-mode,i}^{N} - c_{i-mode,i}^{N}$

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_{ij}^{D} (see equation (3)). The substitution rate describes the substitution relation of i-mode services in comparison to WAP services. *Sub=1* means, there is no WAP service the i-mode adopting actor will use any more.

(14) $U_i^{INE} = \begin{cases} \left(nu_{i-mode,i}^{N}\right) \cdot B_{i-mode} - sub_i \cdot \left(nu_{WAP,i}^{N}\right) \cdot B_{WAP} & if \ \ U_i^{INE} > 0 \\ 0 & if \ \ U_i^{INE} \leq 0 \end{cases}$

The overall individual net benefit deriving from indirect network effects is defined as U_i^{INE}. The overall i-mode adoption benefit (in phase 1) is defined in equation 15:

(15) $U_{i-mode,i} = -\frac{249}{24} - 3 + \sum_{j \in NB_i} \left(nu_{ij}^{d} \cdot x_j\right) + U_i^{INE}$

subject to:

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

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

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

Due to the i-mode setup-investment in phase 1 the adopters net benefit function in phase 2 is reduced by the term 249/24. The setup costs of the adoption phase 1 have the character of sunk costs in the following phase 2. 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 *j* heuristically. The de-central standardization model of Weitzel et al. ([4], pp. 3-31) describes the probability p_{ij} with that actor *i* believes that actor *j* will adopt a technology. If *E[U(i)] > 0* then actor *i* will adopt. If actor *i* were certain of the behavior of his communication partners, p_{ij} correspond 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*. Because the technology adoption costs K_j and the information costs c_{ji} are the only costs regarding *j* known to actor *i*, 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*:

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

Whereas c_{ji} is equivalent to nu_{ij}^{d} and K_j equivalent to $\frac{249}{24}+3$ in phase 1. Furthermore, structural adaptations have to be undertaken for this simulation model. For the model, a low density of actors (similar to few communication edges) is assumed to perform the computer based simulation. The de-central standardization model assumes communication edges among all actors. This seems to be not realistic 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 is absolutely implausible for neighbor *j* to switch the current 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 (see section 2.1.) 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) $$E\left[U_{i,t}^{INE}\right] = \left(u_{i-mode,i}^{N} - c_{i-mode,i}^{N}\right) \cdot B_{i-mode,t-1} - sub_i \cdot \left(u_{WAP,i}^{N} - c_{WAP,i}^{N}\right) \cdot \left(n - B_{i-mode,t-1}\right)$$

The calculus of decision of a risk neutral actor *i* in period *t* depends on the estimated total benefit $E\left[U_{i-mode,i,t}\right]$. If the benefit is >0 than actor *i* will adopt an i-mode mobile end device. 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) $E\left[U_{i-mode,i,t}\right] = -3 + \sum_{j \in NB_i} \left(nu_{ij}^{D} \cdot p_{ijt}\right) + E\left[U_{i.t}^{INE}\right]$

Simulation design

The model was implemented in Java 1.3. The used parameters of the simulation were configured in a restrictive and conservative way. The network population n was defined with 1,000 actors. This is in comparison to the large potential WAP user market in Germany a relatively small population but a necessary assumption for a better performance of the model. The substitution rate was $sub_i = 1.0 \quad \forall i$, as defined above. The closeness of the network topology was assumed with $nb_i = 5 \quad \forall i$ (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 were assumed as normally distributed. The expectation was varied in the following ranges (equation 22 and 23), while the variation coefficient was 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

Ceteris paribus, during the simulation each parameter was varied by small incremental steps of 0.05 (nu^D) and 0.02 (nu^N). Each simulation run simulated one network. After generating the close network topology the actors' behavior was simulated over multiple periods until a stationary state was reached. The total number of simulations runs was 45,825.

5. Simulation results

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 we varied the expectation of the normally distributed direct and indirect additional benefits nu_{ij}^{D}, $nu_{WAP,i}^{N}$, $nu_{i-mode,i}^{N}$ while $nu_{i-mode,i}^{N}$ had to be greater than $nu_{WAP,i}^{N}$. The provided 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 one 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. Up from $E\left[nu_{ij}^{d}\right]$=3.5 the network will be completely equipped with i-mode end devices. The most interesting region is the interfacial area around $E\left[nu_{ij}^{d}\right]=\left[2.9;3.4\right]$. In this region the frequency of mixed solutions (i-mode and WAP) is maximal and the typical standardization phenomena occur such as the start-up problem [22] respective penguin effect [3] or tippy networks ([18], p. 176).

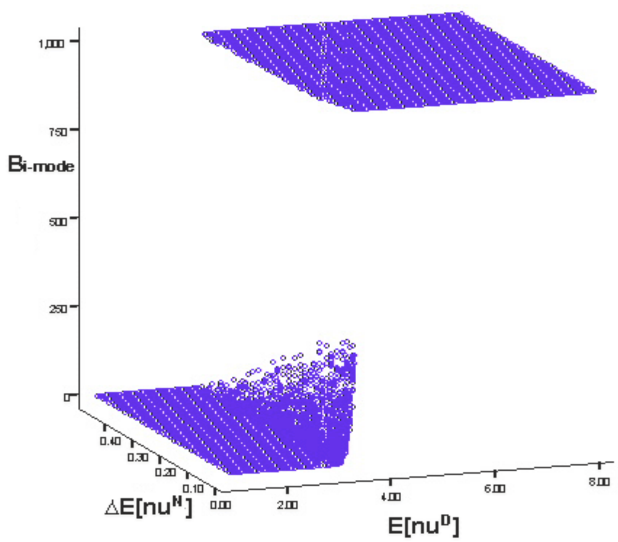

Figure 1. Number of i-mode users in the stationary state depending on the net utility parameters

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 (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. Stable networks are observable with less than 50 WAP users in the stationary stage. For a better illustration the frequency of mixed solutions is categorized by different i-mode penetration rates with a variation coefficient of 0.2 (see figure 2). As expected the occurrence of mixed solutions diminishes with the widening of i-mode penetration in the market.

Furthermore we explored the duration of the i-mode adoption process. The last period of i-mode standardization activities t_{stat} (=advent of the stationary state) depending on u_{ij}^{D} and Δnu_{i}^{N} is provided in figure 3. The different symbols represent the type of market equilibrium (a complete network equipped with i-mode, with WAP or a mixed solution). Due to the compatibility i-mode adopters are able to use the full WAP functionality in equilibria with mixed solution (i-mode and WAP). As seen in figure 1 and figure 2, the mixed solutions have a high market concentration (nearly monopolies) close to the lower WAP section.

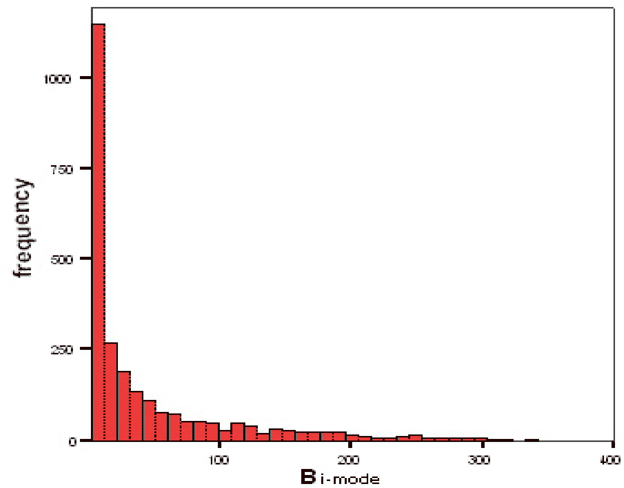

Figure 2. Frequency of mixed networks depending on different i-mode market penetration rates

In most cases, the adoption process finished after a very short time (figure 3), depending on the variation coefficient and the disregard of existing time lags of diffusion in reality. In the region of $E\left[nu_{ij}^{d}\right]=[2.9;3.4]$ the simulation needed 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.

Focal point of this research was to identify the different impacts of direct and indirect network effects on the adoption decision.

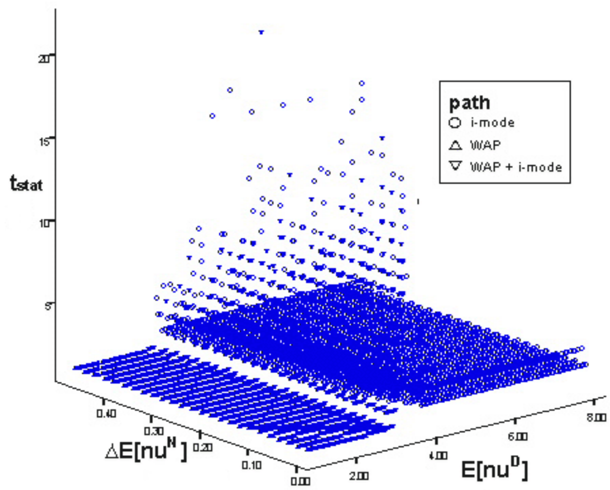

Figure 3. Stationary state access depending on the direct and indirect net benefit parameters

Figure 4 provides an exemplary diffusion path based on a particular parameter constellation, depending on the adoption behavior in each period. The diagram in figure 5 provides the expected user benefit (neglecting setup costs) in 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).

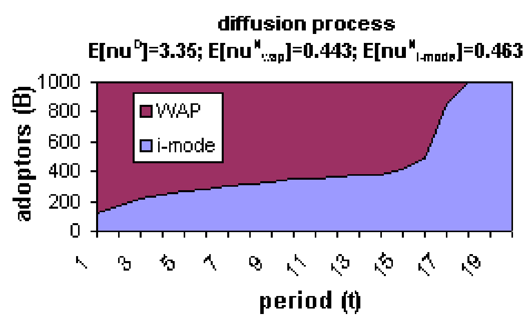

Figure 4. Diffusion process of WAP vs. i-mode

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_0>0 as estimator for B_1 to simulate the benefits of a virtual installed base.

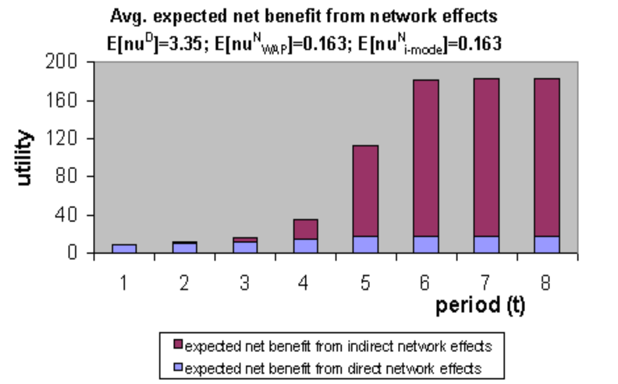

Figure 5. Diffusion process and progression of net benefit based on direct an indirect network effects

Figure 6 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 $\Delta E\left[nu_i^n\right]$.

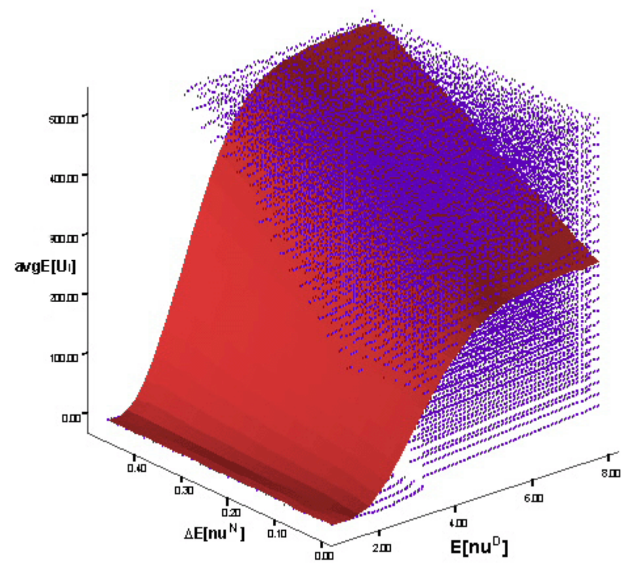

Figure 6. Average expected total net benefit per actor in the stationary state

The diagram shows again the break in the region around $E\left[nu_{ij}^d\right] = [2.9;3.4]$. Under this interval there were no standardization activities observable (the expected net benefits were similar to 0). If $E\left[nu_{ij}^d\right]$ was greater than 3.4, the average net benefit per actor is >0 and the networks were mostly complete equipped with i-mode. In this interval exist various solutions with different result levels of $avgE[U_i]$ for each combination of $E\left[nu_{ij}^d\right]$ and

$\Delta E\left\lfloor nu_i^n \right\rfloor$. This is due to the different absolute benefit levels of $E\left\lfloor nu_{WAP,i}^n \right\rfloor$ 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 $\Delta E\left\lfloor nu_i^n \right\rfloor$ 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 $\Delta E\left\lfloor nu_i^n \right\rfloor$ due to the large benefits from indirect network effects as the largest part of the total benefit (see figure 6) while the direct network effects started the adoption process in the early periods.

6. Conclusions

Drawing from diffusion theory and network effect theory, the simulation model in this is intended as a contribution to the emerging research field of network economics. Using the case of the mobile standards battle in Germany, we demonstrate the significant influence of often neglected direct network effects in mobile commerce. Vendor strategies of MSPs have often focused on strategic pricing aimed at 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.

The forecasted path of diffusion in figure 4 seems to describe properly the current i-mode development in Germany in a proper way. E-Plus could win 77.000 i-mode users after the first five months of introduction, offering only one i-mode enabled cellular phone. Such a relatively slow diffusion in early adoption periods as in figure 4 was also observable in Japan, even without a competitive standard such as WAP.

Furthermore, E-plus lowered the prices for an i-mail from EUR 0.22 to EUR 0.03 (the pure costs for a GPRS data submission). Regarding our simulation, the impact of i-mail as direct network effect $E\left\lfloor nu_{ij}^d \right\rfloor$ is important for a widespread usage and widening of the i-mode user community. The recent development of the cellular phone market in Germany seems to confirm our simulation results.

While this paper may offer possible explanations for some phenomena found in idealistic and realistic networks, one must be aware of the limitations, though. Despite a variety of ergonomic problems endemic to small mobile devices (like uncomfortable human to machine interfaces) the strong dependency of the results on particular aqssumptions made throughout this work need some more attention. That is why the next steps of future research will include a more elaborated parameterization of the model, incorporating the impacts of further determinates such as prices or the impact of heterogeneous substitution rates and a sensitivity analysis. Furthermore, a structural variation of the actor's perfect information about the net benefit of communication neighbors has to be handled more restrictively to become more realistic. The used indirect network effect estimator used in the paper $E[B_{i\text{-}mode,t}]$ will then be replaced by common estimators used in diffusion theory.

This paper provides a possible model to conduct a fast diffusion forecast of new standards. The interest in a comparison of i-mode vs. WAP might be diminish after the market introduction of WAP 2.0 or 3G technologies, but this model can also be used for prolongations of new competiting standards. Due to innovations, cellular phones are changing into smart phones with own processors and hard drives with software such as WML, cHTML or XHTML browsers which are no longer determined by the producer of the end device. The cellular phone user will be able to adopt different standards by decoupling the transmission layer from the content layer, e.g., i-mode is in Germany only available over GPRS from E-Plus. This will increase the MSP competition and enforces content providers to establish functional business models.

Acknowledgement

This research is supported by a grant from the U.S. National Science Foundation ("Globalization and E-Commerce", Grant No. 0085852), and by grants from the German National Science Foundation ("IT-Standards and Network effects", Grant No. 220352 and by the PhD Program 492 "Enabling Technologies for Electronic Commerce"). We gratefully acknowledge the financial supports.

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