Technology Evolution of Mobile Peer-to-Peer Communications

Mikko V. J. Heikkinen
TKK Helsinki University of Technology
Department of Communications and Networking
P.O.Box 3000, FIN-02015 TKK, Finland
mikko.heikkinen@tkk.fi

Sakari Luukkainen
TKK Helsinki University of Technology
Department of Computer Science and Engineering
P.O.Box 5400, FIN-02015 TKK, Finland
sakari.luukkainen@tkk.fi

ABSTRACT

We built a technology evolution analysis framework for a single case study of mobile peer-to-peer (MP2P) communications. We identified three different evolution paths for MP2P communications: Internet-driven, telecom-driven and proprietary. We used P2PSIP, IMS and Skype respectively to represent the evolution paths. According to our analysis, P2PSIP is an alternative to existing networks in situations where lower costs are desired, IMS is a foundation for operator-controlled services, and proprietary services are the first wave of MP2P communications services. We proposed the evolution of mobile client-server voice over IP services as a significant determinant for the evolution of MP2P communications services.

Categories and Subject Descriptors

C.2.4 [**Computer-Communication Networks**]: Distributed Systems – *Distributed applications.*

K.6.0 [**Management of Computing and Information Systems**]: General – *Economics.*

General Terms

Economics, Management, Theory

Keywords

IMS, Mobile Peer-to-Peer, P2PSIP, Skype, Technology Evolution

1. INTRODUCTION

The emergence of high-end mobile multimedia devices and efficient mobile data transfer technologies are technical incentives for developing novel mobile services. On the other hand, peer-to-peer (P2P) technologies have emerged in fixed networks, accounting over half of the Internet traffic [17]. The combination of mobile data transfer and P2P technologies creates discontinuity and initiates a variation phase in the evolution of mobile communications.

WICON'08, November 17–19, 2008, Maui, Hawaii, USA.

It is typical of the telecommunications industry that possibilities for new technologies continuously open up even though no clear market need exist. Both failures in the commercialization process and unexpected success stories happen unexpectedly. The technology evolution dynamics is very complicated, as many conditions on success have to be met simultaneously. The aim of this paper is to study from a holistic techno-economic point of view the success factors of mobile P2P (MP2P) communications. We especially focus on the divide between operator-controlled "walled garden" and open Internet-based service platforms.

According to our knowledge, MP2P communications technologies have not been previously qualitatively compared to each other. Our study is a novel qualitative and comparative approach to MP2P communications.

The research methodology in this study is a single case study approach. In such an intrinsic study the aim is to understand the behavior of a specific case, while an instrumental study uses multiple cases to explain larger theoretical phenomena [42], [50]. Before the case study, a literature review is made both in the areas of innovation management and MP2P communications. The review relates the study to the previous theory and findings.

Without a research focus it is easy to become overwhelmed by the volume of data [9]. As a consequence, we define the research scope adopted in the study to be limited to its own framework of the existing literature in order to obtain insights into the research target. We describe the framework and relevant MP2P communications technologies in Section 2. We then apply the research framework to three different evolution paths that characterize alternative evolution paths typical to the variation phase of MP2P communications in Section 3. Finally, based on the case analysis, we give recommendations for successful management of MP2P communications in Section 4.

2. LITERATURE REVIEW

2.1 Technology Evolution

Technologies evolve through periods of incremental change punctuated by technological innovations. Competence-enhancing discontinuities complement the existing competences and are initiated by incumbents. In contrast, competence-destroying discontinuities make the previous competences obsolete. Incumbents are not willing to cannibalize their existing products and services. [46]

Incumbents tend to develop technological performance finally exceeding even the most demanding customers' needs. Typically at the same time new cheaper technologies start to gain market

Digital Object Identifier: 10.4108/ICST.WICON2008.4812
http://dx.doi.org/10.4108/ICST.WICON2008.4812

share among less demanding customers. These technologies, originally ignored by the incumbents, begin to gain share of the mainstream market. These technologies and the related innovations can be characterized as disruptive. [7]

In the beginning of the evolution of new technologies there is a phase called variation, where emerging technologies and their substitutes seek market acceptance. The development in this phase is slow, because the fundamentals of the technology and new market characteristics are still inadequately understood. During this phase, the companies experiment with different forms of technology and product features in order to get feedback from the market. [2]

The standardization and related openness increases the overall market size and decreases uncertainty. Companies can also differentiate their products by promoting an own de-facto standard. Rival de-facto standards can have a negative impact on the success of the technologies developed in the formal standardization process. However, a trade-off between openness and control exists: proprietary technologies tend to decrease the overall market size, and the optimum solution lies in between these extremes. [37]

An incumbent that has a large installed base and locked-in customers can gain a competitive advantage by a controlled migration strategy. The company can prevent backward compatibility from new entrants with its own legacy systems by influencing the interface definitions of the standard and by introducing an early new generation of equipment with the advantage of backward compatibility. [37]

Evolution of compatibility and revolution of compelling performance are distinguishable, and their combinations are also possible. There is a trade-off between these extremes, because improved performance decreases customer switching costs, while in evolution existing customers can be better locked into the supplier. An ideal solution would be an improved system or product that is also compatible with the existing installed base of the company. [37]

An important factor affecting technology evolution is the relative advantage and added value over older technologies. Experimentation then relates to the extent to which the product or service can be experimented with a low threshold. Easy experimentation possibilities of the end-users enhance the technology diffusion. [15], [34]

In a virtual network of technologies that share a common platform, complementarities influence the value of individual parts of the system. The complementarities between interdependent technologies can have both negative and positive effects on the success of the technology evolution. [37]

The variation phase is closed when the market selects a dominant design. Typically the new technology and the related standards do not become the dominant design in their initial form, and the dominant design is not based on the leading edge of the technology. The dominant design does not embody the most advanced features, but a combination of the features that best meet the requirements of the early majority of the market. The dominant design tends to command the majority of the market until the next technological discontinuity. Companies now gain a deeper understanding of the technology, and its performance improvement starts to accelerate. [2]

A dominant design emerges out of the competition between the alternative technological evolution paths driven by companies, alliance groups and governmental regulators, each of them with their own goals [47]. Especially regulation has a significant impact on the success of new technologies. Regulation defines the general boundaries of the business, while standardization provides a filtering impact which reduces the uncertainty by increasing predictability [24].

The above literature review forms a basis to construct the following framework for the purposes of this study. The factors affecting technology evolution are categorized to the dimensions described in Table 1 based on the literature.

Table 1. Research framework

Dimension	Meaning
Openness	The extent of new technologies available for all players in the industry
Competence change	The extent of required new competences
Existing market leverage	The extent of redirection of existing customer to new services
Added value	The relative advantage over older technologies
Experimentation	The threshold of end-users to experiment with new services
Complementary technologies	The interdependence between complementary technologies
Regulation	The influence of regulation
System architecture evolution	The extent of required new network infrastructure
Incumbent role	The product strategy of existing players

2.2 Mobile Peer-to-Peer Communications

Both terms “mobile” and “peer-to-peer” are used ambiguously. We refer by mobile communications to the domain of battery-powered small-scale communications devices, e.g. cellular phones, with a wireless connection to a network. Adapting one definition [43], we define peer-to-peer systems to have “mainly decentralized self-organization and resource usage”. Symmetrical functionality as clients and servers instead of centralized coordination of clients by servers is characteristic of P2P systems.

[36] studied the effect of MP2P on business models of mobile device vendors and mobile operators by conducting group interviews using a propositional framework. MP2P brings new features to devices and low-cost or free services to different communities. The technological uncertainty of MP2P is low: the technologies are established but there is no standardized approach to them; the market uncertainty is high: MP2P solutions are fragmented. Operators expect MP2P to cannibalize text messaging services to some extent and lead to service quality problems. Due to local usage and low volumes, the creation of profitable service concepts is difficult. MP2P is not disruptive for device vendors,

Digital Object Identifier: 10.4108/ICST.WICON2008.4812
http://dx.doi.org/10.4108/ICST.WICON2008.4812

but operators may experience disruption if MP2P leads to a paradigm change. Finally, operators expect MP2P to increase the bargaining power of customers.

[18] studied MP2P service usage by doing a scenario planning analysis based on a literature study and a questionnaire study. They developed three distinct scenarios differentiating on firewall and flat rate dimensions: open, restricted and operator-controlled MP2P. According to their analysis, MP2P will not have a significant effect on mobile industry structure. MP2P will be taken into use gradually to as "an alternative technology to implement certain mobile services".

According to our understanding, mobile P2P communications is currently in the variation phase of technology evolution described by [2]. The variation phase is characterized by a competition of several alternative technologies. We discuss three possible technologies for mobile P2P communications: P2PSIP, P2P-IMS and Skype. We have chosen the technologies because they represent distinctively the different evolution paths we have identified. Other candidates for mobile P2P communication technologies include, for example, the Jingle extension to the Extensible Messaging and Presence Protocol (XMPP) [49] which we do not discuss in detail.

2.2.1 P2PSIP

Session Initiation Protocol (SIP) [35] is the current Internet standard for implementing communications services. Different call, instant messaging and presence services can be implemented with SIP. [38]

The ongoing P2PSIP standardization effort done by the Internet Engineering Task Force (IETF) aims to provide a peer-to-peer alternative for the client-server SIP. P2PSIP replaces the client-server structure of SIP with a P2P overlay network. The overlay provides a distributed mechanism for mapping names to network locations, thus it replaces the location server function of the original SIP standard. The overlay also contains a transfer function for transferring SIP messages between any two nodes in the overlay.

The overlay consists of nodes called P2PSIP peers which use SIP to communicate and run collectively a distributed database algorithm. The algorithm can be realized with a distributed hash table (DHT); cf. [25] for a comparison of several DHT implementations.

Nodes called P2PSIP clients can also be part of the overlay if they are accepted to the final version of the P2PSIP standard. A client is responsible for a subset of the functions of a P2PSIP peer. The decision in assigning peer and client roles is based on available resources, such as battery consumption, transmission speed and storage capacity, or service operator policy.

Both peers and clients need a protocol to form the overlay. An application-layer binary protocol P2PP [4] is a strong candidate but other alternatives exist. In P2PP, SIP-based applications deployed with the overlay use a separate P2P protocol layer to access the transfer layer protocols.

The overlay also enables network address translation (NAT) and firewall traversal, and interaction with non-P2PSIP entities related to for example interconnection to client-server SIP or to Public Switched Telephone Network (PSTN). These capabilities can be implemented as additional functionalities in peers or as peers dedicated to certain capabilities.

[27] studied the applicability of P2PSIP in the mobile domain and implemented a working prototype of a mobile P2PSIP VoIP service. The prototype relies on centralized elements for NAT and firewall traversal. These relay servers are implemented as P2PSIP clients but they can also be integrated with peers. The use of standard NAT traversal mechanisms can completely eliminate the need for NAT relays. Mobile phones are P2PSIP clients in the prototype, but it is also possible to implement the P2PSIP functionality solely within peers to which mobile phones connect by using conventional SIP signaling.

Several both open-source and commercial implementations of P2PSIP are available [5]. The implementations are based on different IETF standard drafts.

2.2.2 P2P-IMS

IP Multimedia Subsystem (IMS) is a framework architecture being standardized by the 3rd Generation Partnership Project (3GPP). IMS aims at the convergence of fixed and mobile Internet Protocol (IP) based networks and services. [23] introduce an extended P2P service layer to IMS. The layer enables the integration of P2P services with IMS. IMS is expected to be a framework for deploying services in converged IP networks consisting of different wired and wireless access networks. Currently operators are planning to use IMS mainly as a part of a service delivery platform which could be extended to include P2P-based services [13], [33]. IMS provides "service integration, execution, and control" and concentrates on "charging, accounting, quality of service, mobility, and interoperability across different administrative domains" [23]. However, current IMS products already have some interoperability issues [13], [33].

IMS consists of four layers: access layer, session control layer, service layer and application layer. The access layer masks the complexity of heterogeneous access networks to upper layers. The session control layer consists of SIP servers and proxies which control and manage sessions. Service layer provides the support functions for running services. Application layer consists of the actual applications accessing the service layer to provide services to users. [6] has more extensive description of IMS. [45] contains the detailed technical specifications of IMS.

[23] built a prototype of a service layer providing P2P functions to P2P-IMS applications. It consists of components handling core P2P functionality: overlay network management, group management, presence, and authentication, authorization, and accounting (AAA); and components accessed directly by P2P applications: execution, publish and search, resource sharing, group policy management, charging, and digital rights management (DRM).

Other viewpoints to combining the IMS and P2P domains are available. Some of the standard IMS functionalities of the session control layer can be implemented using P2P overlays [22], [26]. Modifications of protocols used in IMS can be used to control P2P traffic [11]. We do not discuss these aspects in detail.

2.2.3 Skype

Skype is an overlay peer-to-peer network which provides several communications services, such as calls, instant messaging and presence. Unlike P2PSIP, Skype is a proprietary architecture

Digital Object Identifier: 10.4108/ICST.WICON2008.4812
http://dx.doi.org/10.4108/ICST.WICON2008.4812

which is not defined publicly. [3] analyzed the functionality of Skype by studying the network traffic generated by it. The Skype network consists of two types of nodes: ordinary hosts and supernodes. Any host may be promoted to supernode status if it has enough resources to contribute to the overlay. Also, centralized nodes called login servers exist in the network. A host joining the network must connect to a supernode and register itself at a login server.

Each node builds a locally stored list of reachable supernodes. User names and passwords are stored at the login servers, but user information and search queries are stored distributed in the Skype network. The traffic in the network is encrypted. A call is established using a challenge-response mechanism. If NATs and firewalls are on the traffic path, the messages are routed via additional nodes as needed for traversal.

[19] experimented using Skype in public Wideband Code Division Multiple Access (WCDMA) networks and concluded that WCDMA is sufficient for Skype calls. Fring [14] provides free mobile Skype calls via its own servers. Iskoot [21] interconnects existing mobile networks and the Skype network. The operator 3 Mobile offers a Skype mobile phone [39]. Skype is also available to Playstation Portable, Nokia Internet Tablet, Windows Mobile, and some phones operating in wireless local area networks (WLANs) [40]. Recently Skype released a beta version of a mobile thin client which interconnects certain mobile phones to the Skype network for a fee [41].

3. CASE ANALYSIS

In this section we apply the research framework to the three different evolution paths of mobile P2P communications: Internet-driven, telecom-driven and proprietary evolution paths. Our analysis is based on a literature study referenced in Sections 2 and 3, and discussions with subject experts.

3.1 Internet-driven evolution path

The Internet-driven evolution path is characterized by openness and freedom of most current Internet technologies. P2PSIP represents this evolution path.

3.1.1 Openness

P2PSIP is an open standard which any stakeholder may utilize freely. However, the utilization requires extensive technical knowledge and possible co-operation with other stakeholders. Basically the development of P2PSIP applications is possible on open mobile development platforms such as Java and Symbian, but extensive deployment of the applications requires co-operation with mobile operators and device vendors. Either P2PSIP becomes an integrated feature of high-end mobile devices or operators market it as a value-added service. Integrated features suit well to communications in unrestricted networks such as WLANs; whereas operator services are most convenient within operator networks.

Because P2PSIP is being openly standardized in the IETF, the probability for intellectual property disputes is low. Companies can develop proprietary extensions to the P2PSIP standard. Their success will depend on the market power of the company and the usefulness of the extension. However, historically IETF standards have remained in relatively open use, and no grounds exist for P2PSIP being an exception.

3.1.2 Competence change

For mobile device vendors, P2PSIP is a competence-enhancing technology. Many advanced mobile devices already support client-server SIP [29], therefore P2PSIP fits into the technology continuum of most device vendors.

For mobile network vendors, P2PSIP is a competence-enhancing technology. Network vendors have been concentrating their R&D efforts in IP-based data transfer networks. P2PSIP can create demand for increased mobile data transfer capacity and act as an incentive for further development of IP-based mobile networks.

For incumbent mobile operators, P2PSIP is a competence-destroying technology. Most operators base their business model on circuit-switched voice. P2PSIP has potential to shift mobile operators towards the business model of Internet service providers which offer data transfer capacity to a fixed price.

3.1.3 Existing market leverage

P2PSIP can take advantage of the customer bases of client-server SIP and PSTN services by providing compatibility to them. However, most client-server SIP users are within corporate networks and the administrators of them are not willing to deploy P2PSIP in most cases due to sunken investments and technology risks. The users of proprietary P2P communications services such as Skype can be willing to adopt an interoperable service based on P2PSIP when it becomes technologically mature.

3.1.4 Added value

The most significant added value of P2PSIP is cost efficiency. Flat-rate mobile data pricing enables users to make calls without additional monetary cost within a P2PSIP network. The cost of sharing resources such as network capacity and battery power is the true cost of using P2PSIP. However, recent results on MP2P battery consumption are optimistic [31].

3.1.5 Experimentation

The experimentation feasibility of P2PSIP depends on the implementation of the service. If the service is implemented by operators or device vendors and integrated with their current service framework or devices, the barriers for experimentation are significantly lower than if the service is implemented as a third-party application which the user has to download and install.

P2PSIP services are restricted by the requirements posed by the relevant standards. The standards will define a minimum level of functionality which can be complemented with other features. Interoperability retention is essential for P2PSIP not to reduce into a proprietary service.

3.1.6 Complementary technologies

P2PSIP is not a significant threat to established mobile communications services before mobile networks optimized for IP traffic become commonplace. Worldwide Interoperability for Microwave Access (WiMAX) and Long Term Evolution (LTE) are good candidates for these networks. Although current High Speed Packet Access (HSPA) networks provide good data transfer capabilities, it is not reasonable for operators to endorse the use of P2P services taking into account the technical limitations posed by the networks.

Digital Object Identifier: 10.4108/ICST.WICON2008.4812
http://dx.doi.org/10.4108/ICST.WICON2008.4812

3.1.7 Regulation

The extent of operator control over their networks is an important determinant for the success of MP2P communications services. At the moment in Finland, one major mobile operator disallows the use of P2P applications in their terms of service [10], and another prohibits the "excessive" use of P2P applications [8]. The true applicability and validity of these clauses remains to be seen.

Emergency dialing [38] and legal interception [1] can be required for P2PSIP services. The probability for these requirements depends on the extent a P2PSIP service aspires to replace current PSTN services. The realization of these requirements is transparent as P2PSIP is an open standard.

3.1.8 System architecture evolution

P2PSIP is an architecture evolution from client-server SIP. However, implementing client-server SIP is not required for the implementation of P2PSIP. Theoretically, a minimal P2PSIP deployment only requires a sufficient data transfer network. P2PSIP can generate a lot of data traffic and can thus require updates to existing mobile data transfer networks. In addition, practical deployments can require dedicated peers for bootstrapping, gateway and traversal functions. In both cases, deployment cost is significantly lower compared to client-server SIP which requires dedicated servers also for the basic connectivity functions of the network.

3.1.9 Incumbent role

Mobile device vendors have been keen to add new features to devices as they are able to collect better sales premiums from advanced devices with a large set of features. P2PSIP could be included in the feature set. They will face pressure from incumbent mobile operators not to advocate P2PSIP because it is a threat to established business models. However, at least in operator-independent sales, device vendors should have sufficient incentives to encourage P2PSIP use.

Mobile network vendors will both gain and lose if P2PSIP becomes an established technology. The need for mobile data transfer infrastructure would likely increase, whereas the need for server infrastructure would decrease. However, it is unlikely that mobile devices could solely handle the burden of maintaining a large-scale P2PSIP network. Therefore, the need for servers would not be eliminated in P2PSIP networks. All in all, network vendors are probably neutral towards P2PSIP.

From the viewpoint of a mobile operator, the increased P2P traffic can impose challenges, as has been evident in fixed networks [17]. Furthermore, mobile networks are limited on more technical aspects than fixed networks, such as capacity. The operator has to establish a balance between increased revenue from mobile data usage, increased cost from network investments and revenue losses from decreased circuit-switched voice usage. In general, operators have no incentives to encourage P2PSIP use.

3.2 Telecom-Driven Evolution Path

Telecom-driven evolution is characterized by the control of incumbent operators over P2P communications services. P2P-IMS represents this evolution path.

3.2.1 Openness

IMS is being openly standardized but its development and deployment are controlled by major mobile network vendors and mobile operators. Potential competitors have little possibilities to affect its development. IMS is seen as a continuum to the "walled garden" development in the telecommunications domain: IMS is a closed system which maximizes operator's control over its users.

Although IMS is being developed to enable interoperability between different systems of operators and vendors, they have incentives to reserve parts of their systems closed to hinder competition. IMS also has potential to generate intellectual property disputes among vendors, similar to those with current mobile technologies.

3.2.2 Competence change

For mobile device vendors, IMS is a competence-enhancing technology. The capability to handle client-server SIP has been built-in with many advanced mobile devices [29]. This capability suggests the device is ready to handle most IMS-based services. Implementing P2P services on IMS may raise requirements for devices but follows a clear incremental improvement path as P2P is added as an additional functionality to the IMS service layer. Based on these facts, established mobile device vendors are already capable of developing P2P-IMS-enabled devices if sufficient incentives exist.

For mobile network vendors, IMS is a competence-enhancing technology. IMS provides a controlled incremental improvement path to existing mobile network technologies. IMS is an incentive for vendors to develop novel network solutions with improved interoperability to other networks while maintaining possibilities for product differentiation.

For incumbent mobile operators, IMS is a competence-enhancing technology. Operators can create controlled "walled garden" environments with IMS where they control service provision and charging as with current mobile communications services. They may even be able to throttle P2P traffic with IMS if IMS-based P2P solutions become commonplace. Furthermore, operators can apply revenue-enhancing pricing models also to P2P services if P2P-IMS gains popularity.

3.2.3 Existing market leverage

Incumbent mobile operators can use their existing customer base as a significant leverage when deploying P2P-IMS services. The established customer base has potential for a controlled migration strategy to P2P-IMS instead of other P2P communications services. If the controlled migration strategy is implemented successfully and combined with a fixed-term bundling strategy of devices and services, a strong possibility for a lock-in situation exists.

3.2.4 Added value

P2P-IMS claims to bring increased usability and reliability compared to existing P2P communications services. IMS enables the tight integration of services with operator infrastructure which in some cases may lead to those benefits. However, opponents of IMS are claiming it cannot deliver its promises due to technical complexity and implementation cost [48]. Furthermore, whether end-users are willing to pay a premium for the benefits of IMS is

Digital Object Identifier: 10.4108/ICST.WICON2008.4812
http://dx.doi.org/10.4108/ICST.WICON2008.4812

highly uncertain as historical failures, such as the Wireless Application Protocol (WAP), demonstrate.

3.2.5 Experimentation

Users will have low barriers to experiment P2P-IMS services if they are implemented properly in the IMS-based service delivery framework of the operator. Users can use P2P-IMS based communication seamlessly if it is tightly integrated with the client-server SIP-based communication. Under some conditions, IMS can utilize P2P-based communication without user's knowledge.

The customization of P2P-IMS-based services is possible in the constraints of relevant standards and interoperability requirements. As most P2P-IMS services are to be deployed by operators, their customization is limited by stagnant processes: commonly operators' service deployments result in a one-fits-all solution with a fixed set of features.

3.2.6 Complementary technologies

P2P-IMS is bound to the success of both advanced IP-based transfer networks and service delivery platforms. Incumbent operators must adopt both before an IMS control layer and P2P-IMS-based services can be deployed.

3.2.7 Regulation

Regulators are probable to see P2P-IMS services as replacements to PSTN, therefore subjecting P2P-IMS to regulatory requirements such as emergency calling and legal interception. Operators can possibly reduce the extent of regulatory requirements by deploying P2P-IMS services via a third-party service operator.

3.2.8 System architecture evolution

P2P-IMS is an architecture evolution from IMS: P2P-IMS adds additional components to the service layer of IMS. P2P-IMS is also a modular architecture: its functionalities can be implemented when required. However, the requirement of implementing IMS makes P2P-IMS an architecture revolution for most operators because IMS requires significant changes to existing networks, even if the operator has an up-to-date data transfer network.

3.2.9 Incumbent role

Mobile device and network vendors generally benefit from P2P-IMS as it creates demand for advanced mobile devices and networks. Because P2P-IMS shifts more control to operators in service provisioning, some vendors may hesitate its endorsement and even concentrate their efforts on Internet-driven technologies such as P2PSIP. However, most vendors are likely to take a neutral stance towards P2P-IMS and continue its support among other technologies.

Mobile operators whose strategy is based on preserving the existing value networks based on circuit-switched voice are likely to endorse P2P-IMS if other P2P communications services gain a sufficient market share to threaten their established positions. Operators may also be inclined to use P2P-IMS as a means to control P2P traffic in general and to protect their established revenue streams from their own communications services.

3.3 Proprietary evolution path

Proprietary evolution path is characterized by proprietary solutions promoting themselves as de-facto standards. Skype represents this evolution path.

3.3.1 Openness

Skype is a closed technology which is controlled by Skype Technologies S.A. Skype has complete control over its users, services and partners. Initially Skype was only providing free calls but now it is collecting revenue by offering value-added services such as interconnection to PSTN and product bundles. Some third-parties are offering unofficial mobile Skype services, but Skype can hinder their operation by modifying the Skype service or resorting to intellectual property rights.

3.3.2 Competence change

For mobile device vendors, Skype is enhancing their competences: it acts as an incentive for R&D efforts on more advanced mobile devices. Skype also acts as an enabler for mobile software platforms: it can motivate users to switch to the more advanced platforms.

For mobile network vendors, Skype is enhancing their competences similar to P2PSIP: it creates demand for IP-based mobile data transfer networks and incentives for their development. Skype may also create demand for solutions throttling P2P traffic in mobile networks [30].

For incumbent mobile operators, Skype is competence-destroying: as a proprietary P2P technology, it does not fit into their R&D framework as they cannot control it. Some operators may choose to co-operate with Skype but it will not be a mainstream strategy due to the cash-cow stature of circuit-switched voice.

3.3.3 Existing market leverage

Skype has an extensive existing customer base in the fixed domain which it can use as leverage in the mobile domain. By providing seamless connectivity between fixed and mobile users, Skype can induce its existing fixed users to adopt its mobile services. Skype has also managed to establish a partial lock-in situation: its users may face significant switching costs in terms of connectivity and interconnection cost if they switch from Skype to another P2P communications service.

3.3.4 Added value

Skype's main added value compared to previous technologies is its low cost to the end-user. By applying the P2P paradigm to communications, Skype has circumvented the cost of servers and is able to provide its basic service for free. However, Skype is strongly dependent on device and network resources, such as battery power and data transfer capacity. Consumption of them is a cost to the user.

3.3.5 Experimentation

Skype and other proprietary services commonly require installation of an application to access them, unless the application has been bundled with the access device. This can raise the experimentation barrier significantly unless sufficient incentives are provided to install the application.

Proprietary services can be customized when needed. The only constrain for customization is the installed application base: in

Digital Object Identifier: 10.4108/ICST.WICON2008.4812
http://dx.doi.org/10.4108/ICST.WICON2008.4812

some cases, interoperability to older versions of the application has to be maintained.

3.3.6 Complementary technologies

As with P2PSIP, mobile Skype benefits from the diffusion of IP-based mobile network technologies. Mobile Skype also benefits strongly from the diffusion of advanced mobile devices as it is strongly dependent on device capabilities.

3.3.7 Regulation

Skype cannot be considered a substitute for PSTN services but it may alter the probability of selecting particular markets to ex ante regulation [16]. Skype could act as a potential competitor limiting incumbent operators' price control. However, especially mobile operators could limit the effect of Skype by establishing "walled garden" environments where Skype is either blocked or controlled.

A regulator [12] has determined that the Skype service is almost completely out of its jurisdiction. All requirements related to offering public telephone services, such as the requirement to offer emergency calls, are not valid in Skype's case. However, Skype is responsible for providing legal interception. If it is done obscurely, Skype could jeopardize its reputation.

3.3.8 System architecture evolution

Skype does not directly affect architecture evolution: it does not require any fundamental changes to data network infrastructure. Skype increases data transfer volume and can thus require updates to network capacity.

3.3.9 Incumbent role

Mobile device vendors have shown interest to collaborate with Skype [28], but the collaboration efforts remain limited. Some device vendors may be unwilling to bundle a mobile Skype application with their devices due to operator opposition or general doubt against proprietary technologies which are not their own. All in all, device vendors are likely to be neutral towards Skype.

Mobile network vendors are probably neutral towards Skype: for them, Skype acts as a source of additional traffic for mobile data networks and therefore potentially increases capacity demand. Skype may also create need for controlling P2P traffic in mobile networks by solutions which network vendors can develop [30]. Skype could affect server sales negatively, but the significance of the effect is probably small.

Operators do not regard Skype as an immediate threat due to their current competitive advantages, such as coverage and stability [32]. Instead of rapid embracement, operators are more likely to introduce Skype-like services gradually. According to our understanding, most incumbent operators will remain hostile towards proprietary services which are not their own and are a threat towards their established services, including Skype.

3.4 Summary

Table 2 summarizes our discussion on the three possible evolution paths. The Internet-driven path benefits from its openness but is characterized by operator resistance. The telecom-driven path is the only one endorsed by operators; even though it is revolutionary to them. It also enjoys significant market leverage and low experimentation barriers, but faces probable regulatory requirements. The proprietary path has the least incumbent endorsement, the highest level of customizability and is the most dependent on device capabilities.

Table 2. Case analysis summary

	Internet-driven	**Telecom-driven**	**Proprietary**
Openness	Open	"Walled garden"	Closed
Competence change	Device vendors: competence-enhancing, network vendors: competence-enhancing, operators: competence-destroying	Device vendors: competence-enhancing, network vendors: competence-enhancing, operators: competence-enhancing	Device vendors: competence-enhancing, network vendors: competence-enhancing, operators: competence-destroying
Existing market leverage	Intermediate	Significant	Depends on existing customer base
Added value	Cost efficiency	Usability and reliability	Cost efficiency
Experimentation	Varying barriers and high customizability	Low barriers and intermediate customizability	Intermediate barriers and very high customizability
Complementary technologies	IP-based networks	IP-based networks and service delivery platforms	IP-based networks and advanced devices
Regulation	Possible: blocking by operator, emergency dialing, legal interception	Probable: emergency dialing, legal interception	Possible: blocking by operator, legal interception
System architecture evolution	Evolution from client-server systems	Revolution from legacy systems	Independent evolution; capacity updates possible
Incumbent role	Device vendors: positive, network vendors: neutral, operators: negative	Device vendors: neutral, network vendors: neutral, operators: positive	Device vendors: neutral, network vendors: neutral, operators: negative

Digital Object Identifier: 10.4108/ICST.WICON2008.4812
http://dx.doi.org/10.4108/ICST.WICON2008.4812

4. CONCLUSIONS

We built a technology evolution analysis framework for a single case study of mobile peer-to-peer communications. We identified three different evolution paths for MP2P communications: Internet-driven, telecom-driven and proprietary. We used P2PSIP, P2P-IMS and Skype respectively to represent the evolution paths.

P2PSIP is not a probable replacement for client-server SIP in the near future due to its technical immaturity, but it can serve as an alternative to existing networks in situations where lower costs are desired, for instance in consumer roaming, ad-hoc networks in conferences and similar gatherings, and in private communication networks at homes or in small offices. P2PSIP can act as a replacement to existing networks when they are not available, for instance during disaster or overload situations.

The possible implications of IMS have been discussed widely, but most of the discussions have not realized into actions. IMS can be a foundation for operator-controlled services if its key promises are fulfilled. However, the inherent complexity of IMS, operators' inflexibility in service deployment and customers' avoidance of additional cost are significant limits to the adoption of IMS-based P2P services.

Skype and other proprietary solutions have the potential to fulfill most of the promises of P2P communications, especially cost efficiency, without the delays in standardization and service integration to operators' systems. However, interoperability issues and operators' resistance limit their adoption significantly.

Managing the three evolution paths is a challenge: they all are at very early stages and their future development is unclear. Managers can use our research framework to evaluate the three paths in respect to their own strategies.

Proprietary services are the first wave of mobile P2P communications services. Whether the second wave is open and Internet-driven, or "walled garden" and telecom-driven, remains to be seen. Internet-driven technologies are easier to deploy than telecom-driven solutions, but operators' resistance slows down the wide-scale deployment of Internet-driven technologies.

We propose the evolution of mobile client-server voice over IP (VoIP) services as a significant determinant for the evolution of MP2P communications services. If VoIP has a late entry to the mass market, also the development of MP2P communications services will be delayed. If VoIP is provisioned in the Internet using SIP, P2PSIP is a strong candidate for a dominant MP2P communications technology. If SIP is not used, proprietary services are likely to form small niche clusters for different user bases. In the case VoIP provisioning in an operator-controlled network, P2P-IMS has good prospects if operators choose to deploy MP2P communications. Some operators can choose to allow the deployment of P2PSIP services having interconnectivity based on SIP to P2P-IMS services leaving little room for proprietary services.

Future research could include the verification of our results by conducting a survey among subject experts. The evaluation of the three technology paths could be formalized by building quantitative models for instance using the system dynamics [44] or the techno-economics [20] method. Also, a comparative case study of P2P technologies to client-server based technologies could render interesting results.

5. REFERENCES

[1] Adrian, J. E. 2005. VoIP on tap: whether the FCC should apply wiretapping standards to voice over Internet protocol. Administrative Law Review 57, 2 (2005), 647-668.

[2] Anderson, P. and Tushman, M. L. 1990. Technological discontinuities and dominant designs: a cyclical model of technological change. Administrative Science Quarterly 35, 4 (Dec. 1990), 604–633.

[3] Baset, S. A. and Schulzrinne, H. 2004. An analysis of the Skype peer-to-peer Internet telephony protocol. Technical Report CUCS-039-04. Columbia University, New York, NY.

[4] Baset, S., Schulzrinne, H. and Matuszewski, M. 2007. Peer-to-peer protocol (P2PP). IETF draft-baset-p2psip-p2pp-01. Work in progress (Nov. 2007).

[5] Bryan, D. A. and Broadbent, T. 2008. P2P SIP: implementations. http://www.p2psip.org/implementations.php (accessed May 28, 2008).

[6] Camarillo, G. and García-Martín, M.-A. 2006. The 3G IP Multimedia Subsystem: Merging the Internet and Cellular Worlds, 2nd Ed. Wiley, Chichester, UK.

[7] Christensen, C. M. 1997. The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail. Harvard Business School Press, Boston, MA.

[8] DNA Ltd. 2007. Contractual terms, March 1, 2007 (in Finnish).

[9] Eisenhardt, K. 1989. Building theories from case study research. Academy of Management Review 14, 4 (Oct. 1989), 532-550.

[10] Elisa Ltd. 2008. Elisa's general contractual terms and conditions for consumers, February 1, 2008.

[11] Filho, E. L., Hashimoto, G. T. and Rosa, P. F. 2008. An IMS control and access layer PR-SCTP based network. In Proceedings of the Fourth International Conference on Networking and Services (Gosier, Guadeloupe, March 16 - 21, 2008). ICNS '08. IEEE, 61-66.

[12] Finnish Communications Regulatory Authority. 2005. Statement no. 587/532/2005 (in Finnish).

[13] Fried, J. and Sword, D. 2006. Making IMS work: current realities, challenges and successes. Business Communications Review 36, 5 (May 2006), 43-51.

[14] Fringland Ltd. 2008. http://www.fring.com/ (accessed May 23, 2008).

[15] Gaynor, M. 2003. Network Services Investment Guide: Maximizing ROI in Uncertain Times. Wiley, Indianapolis, IN.

[16] Gonçalves, R. and Ribeiro, R. 2005. Skype and the new regulatory framework. Communications and Strategies 59 (2005), 141-158.

[17] Haßlinger, G. 2005. ISP platforms under a heavy peer-to-peer workload. In P2P Systems and Applications, R. Steinmetz and K. Wehrle, Eds. Springer, Berlin, Germany, 369-381.

Digital Object Identifier: 10.4108/ICST.WICON2008.4812
http://dx.doi.org/10.4108/ICST.WICON2008.4812

[18] Heikkinen, M. V. J. and Hämmäinen, H. 2008. Scenario planning of mobile peer-to-peer service usage. In Proceedings of the 7th International Conference on Mobile Business (Barcelona, Spain, July 7 - 8, 2008). ICMB '08. IEEE, 145-152.

[19] Hoßfeld, T. and Binzenhöfer, A. 2008. Analysis of Skype VoIP traffic in UMTS: end-to-end QoS and QoE measurements. Computer Networks 52, 3 (Feb 2008), 650-666.

[20] Ims, L. A. 1998. Broadband Access Networks: Introduction Strategies and Techno-Economic Evaluation. Chapman & Hall, Oxford, UK.

[21] Iskoot Inc. 2008. http://www.iskoot.com/skype.php (accessed May 23, 2008).

[22] Le, L. and Kuo, G.-S. 2008. A novel P2P approach to S-CSCF assignment in IMS. In Proceedings of the Fifth Consumer Communications and Networking Conference (Las Vegas, NV, January 10 - 12, 2008). CCNC '08. IEEE, 510-515.

[23] Liotta, A. and Lin, L. 2007. The operator's response to P2P service demand. IEEE Communications Magazine 45, 7 (July 2007), 76-83.

[24] Longstaff, P. H. 2002. The Communications Toolkit: How to Build and Regulate any Communications Business. MIT Press, Cambridge, MA.

[25] Lua, E.K., Crowcroft, J., Pias, M., Sharma, R. and Lim, S. 2005. A survey and comparison of peer-to-peer overlay network schemes. IEEE Communications Surveys and Tutorials 7, 2 (Mar. 2005), 72-93.

[26] Matuszewski, M. and Garcia-Martin, M.-A. 2007. A distributed IP Multimedia Subsystem (IMS). In Proceedings of the IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks, 2007 (Espoo, Finland, June 18-21 2007). WoWMoM '07. IEEE, 1-8.

[27] Matuszewski, M. and Kokkonen, E. 2008. Mobile P2PSIP: peer-to-peer SIP communication in mobile communities. In Proceedings of the Fifth Consumer Communications and Networking Conference (Las Vegas, NV, January 10 - 12, 2008). CCNC '08. IEEE, 1159-1165.

[28] Nokia Corporation. 2007. Nokia shares vision of convergence with new Internet collaborations, new products at CES 2007. Press release, January 08, 2007.

[29] Nokia Corporation. 2007. S60 3rd edition: SIP settings configuration guide. White paper, version 1.0, November 9, 2007.

[30] Nokia Siemens Networks Corporation. 2007. Nokia Siemens Networks Flexi ISN: implementing fair service usage policies for peer-to-peer traffic. White paper.

[31] Nurminen, J. K. and Nöyränen, J. 2008. Energy-consumption in mobile peer-to-peer: quantitative results from file sharing. In Proceedings of the Fifth Consumer Communications and Networking Conference (Las Vegas, NV, January 10 - 12, 2008). CCNC '08. IEEE, 729-733.

[32] Rao, B., Angelov, B. and Nov, O. 2006. Fusion of disruptive technologies: lessons from the Skype case. European Management Journal 24, 2-3 (Apr.-June 2006), 174-188.

[33] Rehbehn, K. 2007. IMS: a dream deferred? Business Communications Review 37, 7 (July 2007), 56-60.

[34] Rogers, E. M. 2003. Diffusion of Innovations. Free Press, New York, NY.

[35] Rosenberg, J., Schulzrinne, H., Camarillo, G., Johnston, A., Peterson, J., Sparks, R., Handley, M. and Schooler, E. 2002. SIP: session initiation protocol. IETF RFC 3261 (June 2002).

[36] Sainio, L.-M. and Puumalainen, K. 2007. Evaluating technology disruptiveness in a strategic corporate context: a case study. Technological Forecasting and Social Change 74, 8 (Oct. 2007), 1315-1333.

[37] Shapiro, C. and Varian, H. R. 1999. Information Rules: a Strategic Guide to the Network Economy. Harvard Business School Press, Boston, MA.

[38] Sinnreich, H. and Johnston, A. B. 2006. Internet Communications Using SIP: Delivering VoIP and Multimedia Services with Session Initiation Protocol, 2nd Ed. Wiley, Indianapolis, IN.

[39] Skype Ltd. 2008. http://www.skype.com/allfeatures/3skypephone/ (accessed May 23, 2008).

[40] Skype Ltd. 2008. http://www.skype.com/mobile/ (accessed May 23, 2008).

[41] Skype Ltd. 2008. http://www.skype.com/download/skype/mobile/ (accessed June 6, 2008).

[42] Stake, R. E. 1995. The Art of Case Study Research. Sage Publications, London, UK.

[43] Steinmetz, R. and Wehrle, K., Eds. 2005. P2P Systems and Applications. Springer, Berlin, Germany.

[44] Sterman, J. D. 2000. Business Dynamics: Systems Thinking and Modeling for a Complex World. McGraw-Hill, Boston, MA.

[45] 3GPP. 2008. 3GPP TS 23.228: IP Multimedia Subsystem (IMS); Stage 2.

[46] Tushman, M. L. and Anderson, P. 1986. Technological discontinuities and organizational environments. Administrative Science Quarterly 31, 3 (Sep. 1986), 439-465.

[47] Tushman, M. L., Anderson, P. C. and O'Reilly, C. 1997. Technology cycles, innovation streams and ambidextrous organizations. In Managing Strategic Innovation and Change: A Collection of Readings, M. Tushman and P. Anderson, Eds. Oxford University Press, New York, NY, 3-23.

[48] Waclawsky, J. G. 2005. IMS: a critique of the grand plan. Business Communications Review 35, 10 (Oct 2005), 54-58.

[49] XMPP Standards Foundation. 2008. XEP-0166: Jingle. Work in progress (June 2008).

[50] Yin, R. K. 2003. Case Study Research: Design and Methods, 3rd Ed. Sage, Thousand Oaks, CA.

Digital Object Identifier: 10.4108/ICST.WICON2008.4812
http://dx.doi.org/10.4108/ICST.WICON2008.4812