Standard Selection Modes in Dynamic, Complex Industries: Creating Hybrids between Market Selection and Negotiated Selection of Standards

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Abstract. Several sectors within Information and Communication Technology demonstrate a shift from purely market-based selection of standards or purely negotiated selection of standards to hybrid selection processes, where both market competition and negotiation play a role. Negotiated standard setting processes (such as those organised by the ITU) assure interoperability of technical components and services. Private firms, however, increasingly tend to undercut these collective actions. Their innovations jump-start new developments, but also create incompatibilities, lock-in effects, and pockets of market power. A case study on Internet telephony shows how firms, standard setting alliances, and political institutions create a hybrid market-based / negotiated standard setting environment. The interaction between technological and strategic imperatives explains the shift to a hybrid standardisation mode.

Keywords: Standardization, alliances, Internet telephony

JEL codes: L63, L86, L96, O3

1. Introduction[1]

Standardization consists both of technological processes of developing and testing standards, as well as of economical, political or social processesthat select standards from competing alternatives. The selection process of standards can consist of the market mechanism, but there are alternative selection mechanisms. In recent years, changes in technology and regulation of the Information and Communication Technology industries (ICT) have created a variety of selection mechanisms or modes. This variety reflects both technological constraints on the standardisation process as strategic imperatives of firms. The paper analyses the interaction effects of technological and strategic imperatives on standardisation processes.

There are two extreme forms of standard selection. In the case of the market selection mode of standards, the product market decides about the evolution (dominance or obsolescence) of incompatible standards. Competition in the market place, a standards battle, decides which technology becomes dominant. The combination of competition instruments that firms have access to decides which firm and standard is most likely to win (see Van Wegberg, 1996, for an application to multimedia). In the negotiated standard selection mode a permanent standard setting body (which may be connected to the government) develops, selects, and imposes a standard. Depending on regulation, firms must submit a standard proposal to this body, or they are free to do so.

Which standard selection mode exists, used to be industry-specific. Standardization in the computer industry mainly evolved through the market place (Garud & Kumaraswamy, 1993) or through voluntary standards organizations (David & Greenstein, 1990) such as the ISO[2]. In telecommunications, standards were mostly defined or selected in official standards bodies, such as the ITU[3], which is a formal treaty organization and run under the auspices of the United Nations (Cargill, 1989; Besen & Saloner, 1989). In the Internet, standards were completely open and established within the research communities of universities.

In the 1990s, traditional standard setting modes give way to new forms. Pure forms of standard selection (market selection and negotiated selection) are giving way to hybrid market competition / negotiation selection modes. This is visible in the computer industry (Heywood *et al.*, 1997) as well as in the telecommunication industry (David & Steinmueller, 1994; David & Shurmer, 1996; Genschel, 1997).

[1] We thank researchers at KPN Research (Jeroen de Muijnck and Menzo Wentink) and Ericsson (Hans Bisseling, Marion Kok and Lucas Klostermann) for their insightful discussions.
[2] International Organization for Standardization
[3] International Telecommunications Union

We begin our analysis with an overview of the literature. This leads to a framework, which identifies factors that drive the trend towards hybrid standardisation modes. Two case studies illustrate this framework.

2. Systems evolution which combines Complexity and Dynamics

Recent developments in ICT have two dominating characteristics: complexity (of interdependent systems) and dynamics. These two trends used to be contradictory. A complex interdependent system tends to evolve very slow. In almost every country the railway system and the telecom network illustrate this inertia. Firms in ICT gradually developed an answer to these contradictory environmental demands. They split up their products into *modules* (separate units with a large degree of autonomy) (Langlois & Robertson, 1992; Garud & Kumaraswamy, 1995). Each module can be fairly simple, simple enough to allow for rapid change. The complexity results from coupling modules. Both chaos theory and evolutionary economics realized that a repeated self-organising interaction between relatively simple components (such as boundedly rational people, or companies with routine behaviour) can give rise to complex processes and outcomes. Modular systems build on the same insights.

There are joints between the modules that allow them to interoperate to create a complex, interdependent, system. They have to interoperate to generate a value added for the user. If there are several alternative joints that can connect some modules, each module should be able to cope with these various possible joints with other modules. The advantage of simplicity would be lost. Hence, it is imperative to define standards for joints linking particular modules. The complex whole of standards that govern how a system and its modules interact, is called an *architecture* (Ferguson & Morris, 1994). Within an architecture, each module is a black box: the architecture and its modules only know about a particular module which inputs and outputs it has; they do not know the internal functioning of the module.

Modular systems exhibit various kinds of fast dynamic processes. One dynamic is called *transmutational change* (Garud, Jain & Phelps, 1997) or *modular innovation* (Henderson & Clark, 1990). It consists of leaving the architecture roughly unchanged, while changing some modules (but not their joints to the rest of the system) very fast. Examples are the answering machine, which adds functionality to the telephone, the VCR, which is a modular innovation for the television, and the harddisk which greatly added to the usefulness of the personal computer. By remaining loyal to the underlying architecture of a system, firms guarantee enough compatibility for customers and suppliers (subcontractors) to upgrade from one product generation to the next. Innovations and improvements are embodied in the modular components. These can be fitted into the system when needed, and can also be removed once obsolete. A rapid succession of small, incremental (modular) changes, can lead to an outcome that is radically new. This hybrid situation combines compatibility between generations (path dependence; architectural inertia) with a fast succession of generations (path creation; modular innovations).

The opposite of modular innovation is *architectural innovation*: the modules do not change (or not very much), but the architecture that connects them does (Henderson & Clark, 1990). The architectural innovation can be fast too, as the modules that it needs already exist. What is needed is new joints between these modules. New standards, and some new modules that embody these standards, are all it takes for an architectural innovation. The rapid spread of the Internet in the 1990s is an example. The Internet illustrates how important standards are to an architectural innovation: the key players in the Internet evolution are standard setting bodies such as the World Wide Web consortium (W3C) and the IETF (Internet Engineering Task Force).

Modular and architectural innovation are the extreme cases. Many real world situations reflect intermediate forms. During an evolution, the relative position of modules within the architecture can change. A modular innovation can become architectural if it transforms the whole system. It may become the anchor point for other innovations. The CD-ROM, for instance, was a single module that initiated a transformation of the PC from a text-based system to a multimedia computer. We may call this a *modular transformation*. Our case study will illustrate its importance. Our case studies identify three kinds of modular transformations, one of which we discuss in this paper.

There are several varieties of a modular transformation. In the case of a *modular complementary innovation*, complementary modules emerge that increase the potential of the new module. Together, the complementary modules form a sub-system within the architecture. In the PC, the CD-ROM ushered in complementary innovations, such as a faster processors, soundboard, sound boxes, and a colour screen. The result was a sub-system in the PC that created the multimedia computer. The CD-ROM did not evolve into an architectural node as its complementary modules (such as the soundboard) linked directly into the existing system, rather than into the CD-ROM equipment. The inventors of the CD-ROM, Philips and Sony, did not, therefore, acquire architectural control over the personal computer.

Modular upgrading may occur when a new or improved module spawns complementary modules. If the complementary modules link to the new module, rather than directly to the original system, the new module becomes in itself a node in (a sub-set of) the architecture. Since the 1990s, new application software tends to link to Windows rather than to the underlying MS-DOS software code. As a result, the Windows graphical user interface upgraded from being a module (a software application for the MS-DOS computer operating system) into an architecture. In this case, the new architecture went so far as to compete with, and ultimately replace, the MS-DOS architecture. A similar development may occur now with the browser.

As a third form of modular transformation, a new module may act as a *bridge* between two different architectures. Computer Telephony Integration and Internet telephony are combinations of hardware and software that integrate the data and voice communications industry. This requires integration at the level of technology and standards as well as integration at the level of standardisation and other decision making processes.

As a result of these types of evolutionary processes, a modular system can be dynamic even if it is highly complex. A proposition can summarize these ideas:

Proposition 1: The development of modular systems increases the dynamics of complex industries.

3. Standard selection mode in Complex / Dynamic Industries

The architecture / modules approach has important implications for the mode of standard selection. Complexity (interdependence) and dynamics impose conflicting demands upon standard selection. In a figure:

Complexity

↓

Modules ⟵⟶ Standards

↑

Dynamics

Figure 1: Evolution and standards

Standards are important because they solve the problem of how to combine complexity with dynamics. In order to survive in a complex / dynamic environment, business strategies create modular systems so as to be able to incorporate new developments in the firm's existing system. Firms try to design new technologies into modules that they can fit into their existing system architecture.

In complex, interdependent systems, all elements in the system need to fit tightly together. This offers little scope for the kind of experimentation that goes on in market selection of standards. Coordination is of paramount importance. Historically, in these industries the government tended to intervene to make sure that coordination would occur. Interdependent systems, such as a telephone network, also tend to require public access to the technology involved. Firms can submit their technology to a negotiated process, which means they can receive license fees if their technology is adopted, but only on conditions such as that they make the technology publicly available.

In dynamic markets, instead, negotiated standard selection takes too much time. Firms want to push forward their own technology. Rather than waiting for consensus to grow, or the governement to make up its mind, a firm will introduce its product in the market. This also gives it the opportunity to recover its investments in new technology. The advantage of self-controlled introduction of new technology is that it can try to impose conditions on the market that maximize its own gains from the technology. Under certain conditions, such as high entry barriers and market power, a go-it-alone strategy can offer high rewards to a succesful innovator.

The problem about modular systems is that they are *both* complex and dynamic. Hence, there are compelling reasons to combine the benefits of market selection (speed and appropriability) and negotiated selection (coordination and public access). We do not argue that firms simply choose between market selection and negotiated selection, taking the above mentioned (dis)advantages into consideration. Instead, they develop hybrid standard selection modes, that combine elements from competition and negotiation and that try to optimally reflect the weight of these factors (Farrell and Saloner, 1988). The table summarizes these conjectures.

Standard selection mode			
		Complexity	
		Low	**High**
Dynamics	**Low**	**(undetermined)**	**Negotiated selection**
	High	**Market selection**	**Hybrid selection mode**

The lower right cell in the table represents the following proposition:

Proposition 2a: In cases (industries) that combine complexity and dynamics, the standard selection mode tends to be a hybrid.

Combining propositions 1 and 2a gives:

Proposition 2b: Modular systems exhibit a trend towards hybrid standard selection modes.

Propositions 1 and 2 give the general framework to our analysis of standards selection. Figure 2 presents the key concepts and their relationships which we elaborate in the subsequent sections.

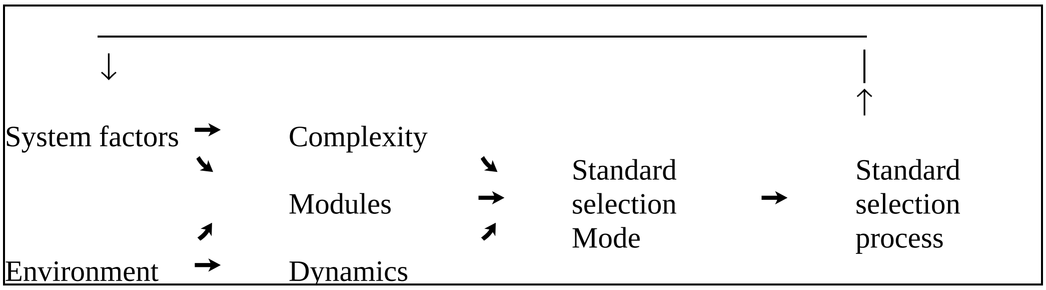

Figure 2: The choice of a standard selection mode

Figure 2 indicates that the combination of complexity and dynamics makes the development of modular systems imperative. But they also undercut attempts to select the standards required to make modular systems effective. This may explain the slow and error prone progress towards modular systems. Complexity and dynamics impose conflicting demands on the standard selection mode, e.g., the former calls for coordination and the latter for speed. Feedbacks abound in this approach. The outcome of a standard selection process, namely the existence and relative importance of standards, affects the systems and set of modules (or architecture), which in turn affects the standard selection mode. This two-stage standardisation process (comprising both the selection of a standardisation mode and the selection of a standard) is therefore one of the determinants of the speed and direction of the evolutionary process towards complex / dynamic / modular systems.

4. Environmental and Systemic Factors that Affect the Mode of Standard Selection

We begin our analysis of the framework in figure 2 with the systemic and environmental determinants of the evolution of complex / dynamic / modular systems. Subsequent paragraphs wil trace the subsequent steps of the framework.

4.1. Modular systems

Modular systems are important because they make it possible to combine the two imperatives of modern business activity: complexity and dynamics. The complexity/ dynamic dialectic is both a driver of business strategies toward modular systems (to adopt innovations in an existing architecture) as well as an impediment (as it makes the choice of a standard selection mode more difficult).

Intensified competition is a determinant of business strategies oriented at modular systems. Business strategies affect both the environmental and systemic determinants of the standardisation mode as well as the standardisation mode itself. At the level of determinants, business strategies towards outsourcing, teleworking, and business process redesign are part of a process of deconstruction of the value chain into separate value processes. Deconstruction in turn facilitates the allocation of value processes to specialized firms, which generates specialization advantages. Firms develop modular systems in order to create the technological conditions for deconstructing the value chain. By designing modules that conform to standards, firms can develop complementary modules simultaneously, while economizing on coordination among themselves in the design phase. Standards will guarantee the interconnection of the resulting modules.

We focus our research on two general types of modular systems. We believe that they represent the dominant forms of modularity in ICT.

Networks

A network is a system of autonomous nodes with links between them (Tanenbaum, 1996). The units that make up the network are computers (in the case of a computer data communication network), people (in an organization), or organizations (in an alliance). Decision making is decentralized in that the nodes are able to take decisions within contraints: they are autonomous, but interdependent. The system is complex (think of the Internet, or a firm), but the units can be simple or limited (like individual people or personal computers). It can accommodate innovations by including new modules or nodes into the network.

Modularity is built into contemporary communication networks by a layered architecture (see Tanenbaum, 1996). Each layer in the network provides a particular range of services to the layer above or below via a precisely defined interface. As a result, each layer can in principle have its own product life cycle and its own degree of networking externalities.

Hardware and software

Modularity has been built into computers in various ways. The hardware and software can be decoupled from each other. For example, the Windows NT operating system operates on various microprocessors. The hardware itself is modular when there are various slots or connections to expand the PC by means of adding peripherals or chip-sets. PCI slots and USB connections offer leading examples of standard interfaces to expand the PC. An individual user’s computer is thus a complex system, consisting of various modules, one of which is the PC itself.

These examples suggest that in ICT, modular systems are increasingly important. A proposition summarizes the environmental (competitive) and systemic factors that drive a modular system:

Proposition 3: The following competitive or systemic factors stimulate (+) or impede (-) the development of a modular system:

- Specialization: different parties develop different modules (+)
- Diffusion: innovations can be adopted by including new modules in the architecture (+)

- Scale flexibility: the size of the system can be increased (decreased) by adding (removing) modules from the system (+)
- Product differentiation: each combination of modules is a separate product, that may cater to the needs of different individual users (+)[4]
- Heterogeneity of system elements (different technologies, or different generations of technologies) (+)
- Coordination failures between modules (-)
- Resources devoted to linking and coordinating modules add overhead to the system (-)
- Creating an effective system by connecting modules (assembly) is a non-trivial task which requires expertise (-).

4.2. Dynamics

There are various developments in the market that affect the degree of perceived dynamics, which in turn affects both the need for a modular (re)design as well as the standard selection mode. An important concept in dynamics is path dependence (Arthur, 1989): past developments and choices have a large influence on today’s options. Investments, technologies, and routines by people and in organizations are acquired over time and constrain future developments.

4.2.1. The product life cycle

Products tend to stay in the market for a limited time, and this product life seems to have decreased in the past decades (D'Aveni, 1994). The technologies underlying these products are often more durable. In some industries, however, the lifetime of a technology too has been greatly reduced. The computer industry is an example (Brown & Eisenhardt, 1997). The Internet contributes to shortening life cycles of software by offering a rapid distribution and diffusion network for new software programs.

Modular systems may contribute to obsolescence by making it more easy to replace obsolete modules. They may also, however, lengthen the lifetime of other modules. Even if a system undergoes fundamental or rapid changes, some modules may be good enough, and each new generation of the system may inherit these modules from the past. Old modules can be recycled by tying them into a new architecture. In this way, mainframes survive to the present day. They have changed their role from being the dominant piece of equipment in the IT system, to being a module within an ICT architecture. The year 2000 problem may illustrate the unexpected longevity of many software programs. Modularity

[4] This is an advantage for customers, but also for suppliers: a supplier which licenses the technology involved, can differentiate its products from those of its rivals by selecting a different combination of modules.

is a way to cope with the resulting heterogeneity. It enhances flexibility by reducing the lifetime of some modules, and raising the lifetime of others.

With short product-life cycles, a negotiated settlement of a standard may now take too much time. Firms may want to be the first-mover with a technology. The outcome of several individual innovation efforts can be that these rivals introduce incompatible standards on the market. Rapid change favours market activity instead of negotiated selection of standards.

4.2.2. Path dependence and the institutional context

The Internet, the telecom and the computer industry created different institutional contexts for developing and selecting standards. The obvious way to select a particular standard is likely to be the one that is supported by these traditional ways and institutions. Some developments may disrupt this inertia. Convergence between formerly separated industries, computers, telecoms and broadcasting, can be noticed, among others because of the still increasing importance of information exchange via communication networks.

Thus convergence, innovations, and shortening product lifecycles induce a rethink of institutions and routines (Egyedi, 1994; David & Shurmer, 1996).

4.2.3. Installed base of previous investments

When users have already invested in a particular technology, they are unlikely to switch to an incompatible standard (Farrell & Saloner, 1986; David & Greenstein, 1990). If a firm anticipates this, it may prefer market selection of standards, in an effort to lock in customers to its proprietary standard. Customers, however, have become increasingly sophisticated. They realise that market selection is a game in which they run the risk of buying the wrong standard. Therefore, they become increasingly reluctant to participate in this game (Farrell & Saloner, 1985). Their reluctance may stall the adoption of all incompatible standards submitted to the market. For instance, the incompatibility between Sony's MiniDisc and Philips' Digital Compact Cassette (DCC) led consumers worldwide to abstain from buying either product. Market selection then selects out any new technology that is incompatible with existing standards. To overcome this hurdle, firms may have to negotiate among themselves a joint technology if they want to convince customers that their products are viable. This implicit bargaining power of customers increases if they already own substitutes to the new technology. In a mature environment, that ICT industries are slowly becoming, customers' preference for viable technologies seems to become an increasing factor in favour of negotiated standard selection.

To summarize the argument on the impact of dynamics on the mode of standard selection:

Proposition 4: Market selection tends to gain (+) or lose (-) importance if

- Product life cycles become shorter (+)
- Market selection is the traditional approach to standard selection (path dependence) (+)
- Customers are sophisticated and already own substitutes to new, incompatible, standards (-).

4.3. Complexity

Complexity is a third major factor influencing the mode of standard selection. There are many reasons why firms experience or perceive an increasing extent of complexity. Within ICT industries, convergence of the ICT technologies (as indicated, e.g., by inter-industry licensing or technology development partnering) and markets (as indicated, e.g., by inter-industry entry or partnering) is the main driver of increasing complexity. The convergence process seems to be part of an evolution towards communication networks that support a whole range of multimedia applications. Networks increase the interconnectedness of people, organizations and systems. This increases both the complexity of ICT products and the complexity of decision making.

There are *increasing returns to adoption* when the larger the network is, the more useful to its participants. Two quite distinct reasons exist for increasing returns to adoption (Matutes & Regibeau, 1996). Direct network advantages exist if users are primarily interested in interacting with each other. Examples are telecommunication and datacommunication networks. Indirect network advantages exist if users of a product care about its high quality or low cost. These features in turn, may depend on the number of other users of the product due to economies of scale or scope. If there are network advantages, adoption decisions by individual users depend on their observations and expectations of the adoption decisions by others. This tends to make decision making more complex.

Proposition 5: The following factors increase complexity and stimulate negotiated selection of standards:

- Convergence of technologies
- Convergence of markets
- Standalone products from the computer and consumer electronics industries acquire (voice or data) communication functionality
- (Direct or indirect) network advantages

To recap this paragraph, firms face a range of standard selection modes in between the two extremes of market selection and negotiated selection. They also face a plethora of environmental factors that affect their choice: some of which operate to make their market more dynamic, or complex, or both. They also face systemic factors, over which they have some degree of control, such as the existing architecture(s), standards, and modular systems. The interesting situations are those where interaction effects exist as modularity, complexity and dynamics are present simultaneously. Combining propositions 3, 4 and 5 indicates numerous possible cases. The following table shows the predicted outcomes if two particular dimensions of dynamics (shortening product life cycles) and complexity (direct network advantages) co-exist. We should emphasize at this point that other systemic and environmental factors (such as market structure and business strategy) can modify these hypotheses.

Choice of Standard Selection Mode			
		Direct network advantages (proposition 5)	
		Yes	No
Product life cycle (proposition 4)	Short	Hybrid	Market
	Long	Negotiated	(Undetermined)

The main example for the case with direct network advantages and long product life cycles is the telecommunication industry, where standards are indeed routinely negotiated. The designated standard setting organization is the ITU (International Telecommunications Union), where government officials of the member states used to negotiate on standard selection. The computer industry shows the case where there are few direct network advantages (at least prior to the networked computer era), and where product life cycles are brutishly short. The standard selection processes do indeed tend to be market-based (Cargill, 1989).

5. A Case Study of Standard Selection: Internet Telephony

We now discuss a case study about standard selection that illustrates business strategies and the interaction between systemic and environmental factors. It illustrates our argument that hybrid standard selection modes are a general feature of industries that are complex and dynamic, and where network economies play an important role.

We drew our data from professional journals and a small number of interviews with technical experts from companies involved in standardization bodies. We developed a longitudinal database using articles of the Dutch IT and telecom newspapers *Automatisering Gids* and *Computable*. We also used articles from *Data Communications* and *IEEE* journals, both well-known in the field of computer networking and telecom technical experts. We conducted two interviews with experts on Internet Telephony standardization of KPN Research of Leidschendam, The Netherlands (2 people) and Ericsson Telecommunications of Rijen, The Netherlands (3 people) in order to test and further sharpen our framework.

Internet telephony, and telephony in general, is a service which depends on direct network advantages - communication between users is essential. Internet telephony is an alternative to traditional telephony in that the Internet instead of the traditional telephone network (PSTN[5]) is used to transport speech from one user to the other and vice versa.

Figure 3 about here

There are several ways to realize Internet telephony (Babbage et al., 1997). First it can be provided as a PC-to-PC service, so users involved in a conversation need a desktop computer with modem, microphone and soundcard. Second, it can be implemented as a telephone-to-PC, PC-to-telephone, or even telephone-to-telephone service, in which case a gateway between the Internet and the PSTN is required (Greenfeld, 1997). As a telephone-to-telephone service, the Internet serves as backbone, i.e. as the pipeline to transport speech from one telephone to the other. Finally, Internet telephony can be provided as a private service for companies over an Intranet - i.e. an internal Internet - thereby avoiding several of the management problems, such as congestion of traffic, occurring when providing it over a public Internet infrastructure.

The company Vocaltec is credited with introducing Internet telephony commercially in 1995. Their product, Internet Phone, is a software-only product that enables a PC user to telephone from PC to PC via the Internet. A major element in the technology of this innovative product is transforming speech into a digital data package that can travel over an IP-network. Soon numerous rivals entered the market place, such as Quarterdeck, also a software company. Subsequently, web browsers of Microsoft and Netscape integrated such applications.

The software that Vocaltec pioneered set in motion new developments that profoundly affect both the Internet and the telecommunication networks. Internet telephony, Computer Telephony

[5] Public Switched Telephone Network

Integration (CTI) and deregulation tie these two networks increasingly closer. This convergence works at various levels:

- Technology: using the same digital technologies in computers, cables, user terminals, software, etc., for both networks, thus raising the revenues from innovation.
- Network capacity: using the same cables and other infrastructure for both speech and data, thus making a more intensive use of capacity, and lowering costs.
- Use: new functionality can be offered, such as: (1) Mobile telephony and computing, where a user has everywhere access to all data and people. (2) Integrated messaging, where the user has an integrated in-box, which contains all messages that people send to or receive from him, such as fax, e-mail, voice, etc. (3) Multimedia conferencing, where people can cooperate over a network by simultaneous use of telephony, video-conferencing, and shared access to a document ('whiteboarding') or an application (application sharing). (4) E-commerce, where a website may offer all kinds of information plus the ability to speak to someone in the organisation by clicking on a button on the website. From the supplier's perspective, this combines the website with the call center.
- Market: if people phone over the Internet, an Internet access provider becomes a telecommunication operator.

A new module in computer software for Internet users, Vocaltec's pioneering Internet telephony software program, thus set in motion a dynamic process that changes the architecture of both the Internet and telephony. Originally, a datacom platform like the Internet was not intended to transport the real-time traffic that goes with telephony and videoconferencing services. The priorities in sending information differ between a datacommunication network, where avoiding data loss is the number one priority, and voice telecommunication, where avoiding delays is more important. Standardization is required to adapt the Internet network architecture to the demands of real-time traffic. To realize the direct network advantages of communcation, Internet telephony needs to connect to the telephony network (PSTN). Innovation and standardization are necessary to connect and integrate these two (voice and data) communication networks. For the same reason of direct network advantages, Internet telephony should also gain access to corporate networks. In these (Local Area or LAN) networks, firewalls protect the network against invading virusses from the Internet. The same technologies often keep out Internet telephony too. Again, innovation and standardization are needed to combine safety of internal networks with new functionality.

As a result of the convergence between data and voice communication, a multitude of standards bodies, both official bodies and industry alliances, influence the standards process. Examples are the

ITU and ETSI as official bodies for telecommunications, the IETF as the official standards body for the Internet, and the VoIP forum, part of IMTC, the ITC and the Interoperability Now consortium as industry alliances (see the appendix). All these institutions have different histories and a different vision on how a service like Internet telephony should be implemented technically. Therefore, the multitude of organizations involved in the standards process again increases complexity (Genschel, 1997).

The ITU developed the H.323 architecture which covers all aspects of Internet telephony. The umbrella standard H.323 comprises a multitude of standards modules, some of which already existed before, some of which have been newly developed, and some who are still under construction. The standard enables the end-user product to interoperate with the network, to set up connections with other users and terminate them, and to negotiate capabilities between end-users, e.g. 'do we have the same speech codecs or speech codecs that can at least interoperate with each other, so we are able to have a conversation?' and to use gateways between the tradional telephony network and the Internet. The underlying network (the Internet) is seen as a black box, which can thus have its own standard selection mode. This reflects a modular approach (proposition 3).

H.323 is not a standard in the normal sense of the word: several speech codecs are admitted, but not all products in the market support all speech codecs, so even if capabilities can be negotiated, a solution may not be found when trying to set up a conversation. This means that the standard selection mode is a hybrid one, because within the negotiated umbrella standard there is a *de facto* standards battle going on between the different variations in modules possible (propositions 2a and 2b). Firms and standards bodies agree on certain codec standards (negotiated), but the market ultimately decides which one(s) is (are) going to be the standard(s). An example is Microsoft's Internet telephony module NetMeeting, part of its Internet browser and developed through an alliance of Microsoft, Intel and Picturetel, which does not support all codecs, but only a few of them. As a result, the dominance of Microsoft in the browser market may also result in a *de facto* standard for parts of the H.323 umbrella standard.

It should also be noted that there are not only several standards bodies and alliances involved in formulating H.323, it has also a competitor within IETF, the major Internet standards body: SIP/SDP (Cordell et al., 1997). Interestingly, the same vendors that are negotiating H.323 in the ITU/ETSI, are also involved in formulating SIP/SDP. Whereas some of the literature focuses on the technical differences between the two standards (Cordell et al., 1997), our interviewees remarked that the historical differences between the two kinds of standards bodies also played a role - competences and division of labour between the study groups of different standards bodies, ITU, ETSI and IETF, were still under negotiation. This illustrates the possible important influence of path dependence on the standards selection mode (see also Egyedi, 1994 and 1996) (proposition 4).

Firms are able to circumvent the possibly negative influence of the battles over competence by participating in all the relevant standards bodies at once and postponing their definitive choice until it becomes clearer what the best bet will be, both from a technical and a market perspective. Work started on integrating the best of the two in another standard, called SUCCESS (Cordell et al., 1997). The outcome of these competing processes is still unclear.

Internet telephony illustrates three features that we emphasised in this paper. It is dynamic, as new functionality and new players appear in rapid succession. It is complex, as it combines heterogeneous networks, technologies, institutional (regulatory) arrangements and countries. And it is modular, as various pieces of the system are relatively loosely coupled and can be (dis)connected without destroying the network. Gateways are among the modules that connect various elements of the network: they connect the Internet telephony network to the telecommunication network. Modularity is the key to combining dynamics (e.g., new technologies) and complexity (heterogeneity resulting from mixing established with new technology, among others).

Given these characteristics, our propositions predict that the standardisation mode should be hybrid. Our case study confirms this prediction. Standardisation in Internet telephony is a hybrid process. Two official organisations develop and select architectures: the IETF and the ITU. The ETSI and three corporate alliances focus on interoperability of the Internet telephony products and services. The open (not completely specified) character of the Internet telephony architectures allows the IETF and the ITU to speed up developments, but also creates the interoperability problems that the other groups try to resolve. This enables corporations to bring their market power to bear by influencing how interoperability is achieved. This hybrid setting, therefore, combines speed, coordination and market power.

6. Conclusion

Competition is a game where the actual play constantly changes the rules of the game. Firms alternate between competition and cooperation. Moreover, their cooperation alternates between ad hoc efforts and institutionalized attempts to coordinate structural decision making. Systemic and environmental factors influence their strategies in this regard. We focused notably on modular design characteristics of systems, and two sytemic and environmental features: complexity and dynamics. The interplay of these characteristics tends to determine how firms select a standard selection mode. Future research can test our propositions, and may enhance the analysis of the interaction effects between determinants and strategies, as well as between private and public players.

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Appendix

Standard setting alliances			
Date	Alliance	Aim	Members
30-8-1996	Internet Telephony Interoperability Consortium (ITIC)	Promote open standards via the IETF or W3C. Stimulate interoperability by developing standards for middleware.	AT&T, Lucent, MCI, Microsoft, Netscape, Netspeak, Nokia, Sprint, Telecom Italia, Telia, US Robotics, Vocaltec
9-10-1998	Voice over IP Forum (VoIP)	Improve the interoperability of IP telephony products	3Com, Cisco, Microsoft, Nortel, US Robotics, Vocaltec
21-12-1998	Interoperability Now (iNow)	Create interoperability between IP telephony platforms (gateways and gatekeepers)	Ascend, Cisco, Clarent, Dialogic, Itxc Corporation, Lucent, Natural Microsystems, Siemens, Vocaltec

Permanent standard setting body		
ETSI	European Telecommunications Standards Institute	Interoperability
IETF	Internet Engineering Task Force	Coordinates standardization of the IP protocol, RSVP
ITU	International Telecommunications Union	Developed speech codecs for modems (G.729) Developed H.323 umbrella standard (architecture)

Figure 3: Internet telephony

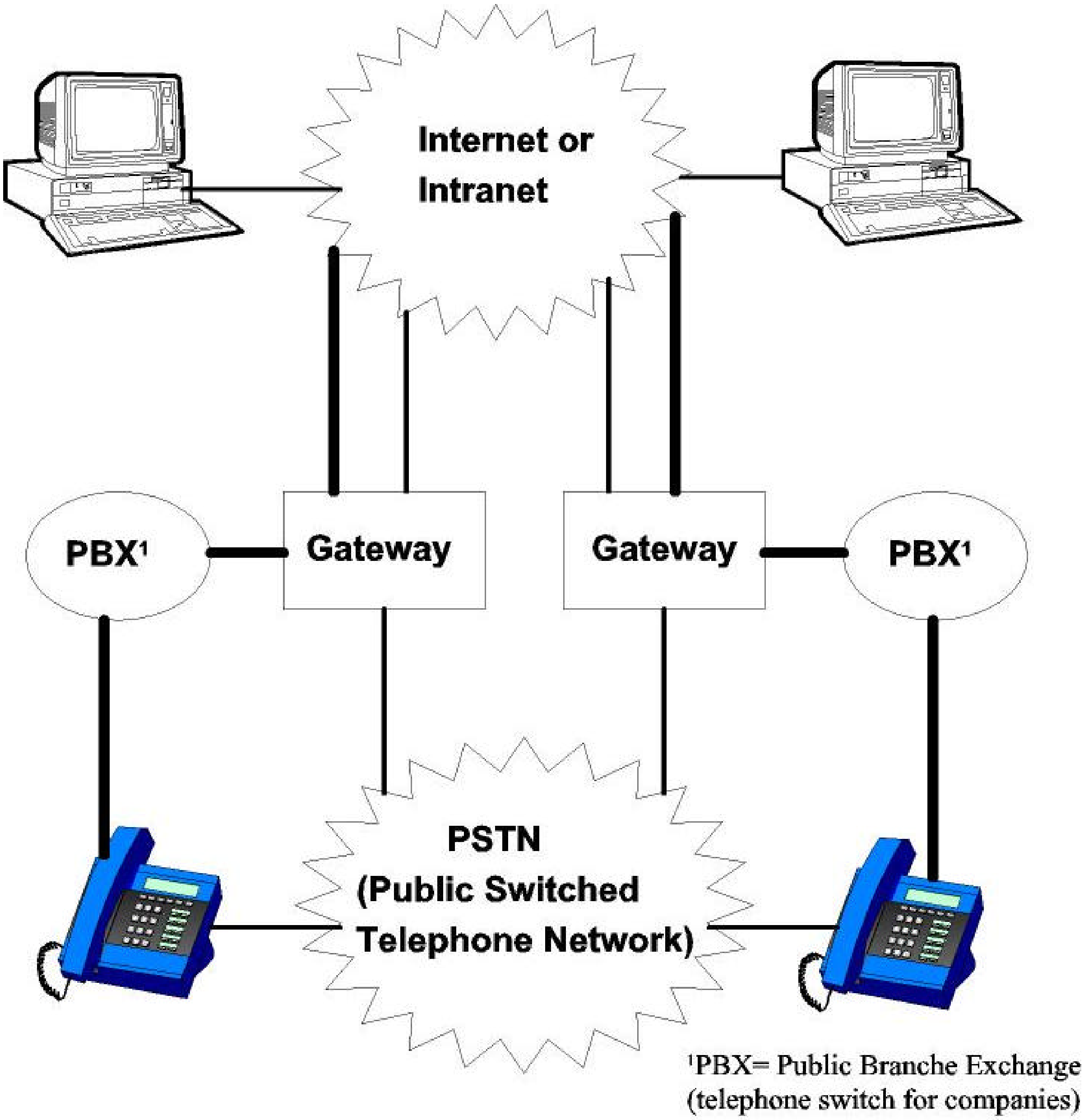

Figure 3. Possible ways to realize Internet telephony