STANDARDS' DYNAMICS THROUGH AN INNOVATION LENS: NEXT GENERATION ETHERNET NETWORKS

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ABSTRACT

The inherent need for stable standards is difficult to reconcile with the ITU aim to develop state-of-the-art standards, and combine standardization with innovation. Standards' change is then inevitable; the consequence is that it increases transaction costs and calls prior interoperability into question.

In this paper we analyze the problem of standards change as a feature of innovation. We want to understand the role that standards' dynamics plays in processes associated with committee when the specifications and technologies co-evolve. To perform this study, we consider disruptions in the technology and/or the value chain simultaneously to classify innovations into four types. By identifying the type of innovation at hand, the innovation-specific issues of standards change that are likely to occur can be singled out. Tools can be devised to assist the various stakeholders in making their decisions. We illustrate this with the case of standards for the next Generation Ethernet networks.

Keywords—Innovation, NGN, standards, dynamics of standards, Ethernet

1. INTRODUCTION

The value of committee standards, i.e., of specifications developed by consensus and intended for repeated use and which is the focus of this paper, depends to a large extent on how stable they are. Standards make life easier because we can refer to them, and thus reduce what economists term the *informational transaction costs*. While stable standards reduce these transaction costs, changing standards increase them. Furthermore, the switching costs that might prevent moving among competing technologies also hinder standards upgrade or evolution in the field. Moreover, interoperability among different standard versions is no longer self-evident.

In this paper we address standards change as an inherent but problematic component of innovation, an area not yet addressed in a systematic way in the innovation literature. We focus on the following question: Given that technology innovation requires changes in standards, when and where are issues of change likely to occur and how can the various stakeholders deal with change? We use the case of the next generation Ethernet to illustrate our points.

We first discuss what we mean by standards' dynamics, introduce the categories change and identify two primary sets of causes of change. This is the subject of section 2. Because we view standards change as a potential problematic pocket in innovation, we then introduce the innovation framework in section 3. In particular, we discuss three elements and vantage points that have an immediately bearing on standards change, that is, the phases in the technology life-cycle, the timing of standardisation and the various classes of innovation. We then apply this framework to developments in next generation Ethernet standards in section 4 to illustrate issues where innovation and standards change could be at odds because their interactions have not been considered explicitly. Section 5 contains our attempt to systematize this area of intersection in order to help identify moments and situations in which the tension between standards' stability and innovation is likely to emerge. This section contains some useful tools that decision-makers can avail themselves of. In the conclusion, we summarize the main elements of the paper and propose future areas to be explored to further use studies on innovation to address the more difficult aspects of standards' change.

2. FUNDAMENTALS OF STANDARDS' DYNAMICS

Standards dynamics is a term which is reserved to refer to the changes to and interaction between standards, that is, to what happens to standards *once they have been set* [1]. It includes the changes that standards undergo, competition between standards, and the interaction and friction between complementary standards. We will be focusing, in particular, on two categories of standards' change, that is, maintenance and succession. *Standards maintenance* includes developing a new standard edition, a corrigendum, an amendment, or a revision; merging standards, splitting them, getting a standard accepted by another standards body, withdrawing a standard and re-instating it. *Standards succession* refers to the substitution of one standard or a generation of standards by another.

2.1. Drivers for change

There are two kinds of sources of standards change. Firstly, standards change which accompanies the evolving nature of the technology; and, secondly, changes which are standardization-specific. From the standardization angle, we refer to them as external and internal causes of change, respectively.

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Regarding the external causes, standardisation is an evident part of technology innovation, particularly for the information and communication technologies (ICT). In ICT applications, standards are subjected to the same forces as the technology itself, i.e., the pressures and dynamics of the market, regulatory context and, technological push. We can see this around us in the developments of the web-environment, the convergence and evolution of the grid and web standards towards the Web Service Resource Framework (WSRF) or the regulatory changes which triggered GSM: the scarce radio frequency bandwidth assigned within Europe for mobile use (around 900MHz), and the policy shift from national monopolies to regional industry coordination.

The internal causes of change are specific to the context in which standards are developed and applied. The aim is here to develop a stable standard as much as possible by avoiding unnecessary changes through a quality process. The source of change may be:

- A flaw in the concept or content of the standard, e.g., because the scope is too wide and standards become too comprehensive and unworkable;
- An aspect of the standards process, e.g., lack of consensus; absence of an important stakeholder;
- The quality of the standard specification, e.g., ambiguous terminology, errors or omissions; and
- The way the standard is implemented, e.g. partial implementation due to cost-constraints.

Table 1 – Drivers for standard change and their implications.

Drivers for Change	**External causes**	**Internal causes**
Source of change	Co-evolution with technology	Standardisation process
Characteristics of change	Inevitable	Consequence of a standardization management process (intentional or accidental)
Framework	Innovation	Management and business
Overall aim	Create up-to-date standard	Create a stable standard
Management objectives	Change control	Quality control

Sometimes standards change is a consequence of the committee strategy (e.g., laying an early claim on a market with a quick-and-dirty low quality standard; but also as a consequence of taking standards maintenance seriously). But usually, where internal causes are concerned, a new revision or replacement is an unintended by-product of flaws in the 'management' of the standards process - if one may speak in these terms where standards committees are concerned. For example, a standard which results from a low quality standards process, or one which is not based on testing and implementation experience is more likely to require a revision later on. Table 1 summarises the various drivers for changes in a standard specification.

Although the technology-evolution source of change has a more obvious and immediate relevance for the innovation angle taken in this paper, as we will point out in section 5, the internal causes are of importance because they may be under the control of the standardisation committee.

3. STANDARDISING INNOVATION

We focus now on the way the evolving nature of a technological innovation affects the standardisation process and the resulting standard. To do this we highlight some items for the literature on technological innovation, in particular, the technology life cycle and its relation to innovation and standardisation.

3.1. Technology life cycle

The literature on the management of technologies considers five main stages in the life of a technology: emergence, improvement, maturity, substitution and obsolescence. [2].

An emerging technology stimulates the consolidation of new functional areas and the accumulation of new types of knowledge through research and field experience. As the properties of this emerging technology become better understood, new designs ameliorate its performance and increase the efficiency of the production processes. If the technology moves to the mainstream, its market share expands until its performance saturates. At this point, any substantial performance improvement will require a switch to a new technology. Traditionally, standardisation takes place in the first three phases of a technology cycle but there are today vigorous attempts to consider the ecological impact of obsolete technologies, which will be reflected in new standardisation activities during the last two phases of the lifecycle [3].

Let us now consider the standardisation cycle.

3.2. Timing of standardization

Standardization as it relates to innovation can be anticipatory, enabling or responsive [4]. Early in the cycle, anticipatory standards are needed to specify the production system of the new technology. Enabling standards refine the production systems and improve the embodiment of the technology. Responsive standards are related to the manifestation of the technology and how it relates to a specific service environment or to extensions of the applications to new services [5]. We will now expand this discussion (see Figure 1).

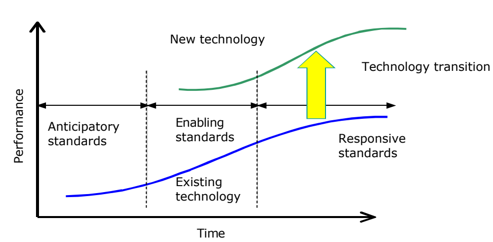

Figure 1 – Standardization and the technology S-curve.

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3.2.1. Anticipatory standards

Anticipatory standards are forward-looking answers to expected interoperability problems; accordingly, they are indispensable for the success of new networking systems. Their specification runs parallel to the production of prototypes, pilot services, and field trials to condense available theoretical and practical knowledge in a readily usable form. They also provide a way of sharing ideas through a systematic method of distilling investigations and experimental data into useful engineering knowledge. This is crucial when the risks are high because the collaboration with other competitors working on the sets of problems can increase the chances of success. Some examples of anticipatory standards are the X.25 packet interface, ISDN (Integrated Services Digital Network), the Secure Sockets Layer (SSL) for secure end-to-end transactions, Bluetooth, the initial IEEE 802.11 standard, etc. The UMTS (Universal Mobile Telecommunications Service) is an anticipatory standard for new services for voice and data.

Because of the lack of detailed experience with the field performance of the technology as well as definitive market conditions, anticipatory standards are highly susceptible to the problem of "scope creep." A restricted scope reduces the chance of over-specifications that could lead to onerous implementations. It avoids premature commercial conflicts that can stall the standardization, provided that it is clear what aspects are expected to evolve, when they will evolve, and how the feedback from pilots and early market entries could be used to write enabling standards. For example, the Open System Interconnection (OSI) transport and management protocols became hopelessly entangled in attempts to satisfy the requirements of all parties involved. Also, incorrect market assumptions may lead to a dead-end, such as in the case of Group 4 facsimile (facsimile on ISDN) or the Wireless Access Protocol (WAP). Ideally, therefore, anticipatory standards should offer a minimum set of features to allow interconnectivity, to stimulate the network externalities and to manage risks. Standards for flexible or modular common architecture allow partial changes to individual components without putting the whole edifice into question.

3.2.2. Enabling standards

The definition of enabling standards proceeds in parallel with market growth and enhancements to the technology and products to improve the agreed-upon designs by extending their robustness and their scale. The direction of the standards is affected by competitive forces and by the need to reduce production costs. This is why standards organizations feel the competitive market pressure to speed up the finalization of enabling standards [6].

From an information viewpoint, enabling standards diffuse technical knowledge and prevent market fragmentation. In addition, they signal that competition is shifting to areas not covered by the standards (cost, quality of implementation, service support, etc.).

One example of enabling standards is the V.90 Recommendation for modems at 56Kbit/s. There were some proprietary designs of modems operating at that rate; however, to avoid market fragmentation as well as increase the overall market size, chip manufacturers were forced by the rest of the value chain (modem manufacturers, computer manufacturers and Internet service provides) to collaborate in the standardization process at the ITU to come up with an implementation that would work independently of the chip set used.

Large standards are typically a mixture of anticipatory and enabling standards (which make their management difficult). For example, some area of the GSM (Groupe Spécial Mobile — Global System for Mobile communications) specifications were anticipatory in that they defined a platform for future growth both for service operators and for manufacturers, others were enabling because they were defined with feedback from the market.

3.2.3. Responsive standards

Responsive standards come at the end of technology development. Internal responsive standards are defined, once the dominant design has stabilized, to codify best practices into daily routines. External responsive standards, while backward looking from a technological viewpoint, improve efficiencies or reduce market uncertainties for auxiliary products or services. In that sense, they may be called "business standards" because they contribute to maximum returns associated with an established technology.

Examples of responsive standards abound in the areas of evaluation of voice quality through objective and subjective means, the measures for the overall quality of services, etc. TLS (Transport Layer Security) is a responsive standard following the establishment of SSL. In the world of information technology standards, the traditional role of ISO TC97 was to improve existing specifications and turn them into international standards. SGML (Standardized General Markup Language) was built on GML (Generalized Markup Language), while HDLC (High-level data link protocol) formalized the SDLC (Synchronous data link control) protocol that IBM had used in its System Network Architecture (SNA).

3.3. Classification of innovations

There is an endless debate on the impact of standardization on innovation. Some studies purport to show that standardization spurs innovations, while equally valid data support the opposing claim. We have seen earlier that technological advances could produce a technological discontinuity. C. M. Christensen [7] introduced the concept of discontinuities in a value network, i.e., the set of attributes used to rank products, services or technologies and determine their cost structures. The discontinuity arises when there are significant changes in the attributes or in their rankings. Factors that can cause a discontinuity include new legislation, emerging standards, evolution of the customer's profiles, etc. Such discontinuity opens opportunities to new entrants. For example, how to evaluate the subjective quality of speech communication depends on whether mobility is more important to the user than voice quality. Innovations that change the rank order are called disruptive, while those that preserve it are called sustaining. The marketing impact of a change in the value network can affect one or several of the following aspects: customer groups and markets, customer applications and channels of distribution and service delivery.

A disruptive innovation can be interpreted from the view of network externalities as follows. The benefits that accrue to the network participants increase with the number of interconnections until a saturation level, after which a subgroup would split to form their own network to satisfy unmet needs.

Depending on the degree of changes they introduce in the technology or in the existing value network, innovations can be grouped into four categories, as shown in Figure 2. These include incremental, architectural, platform and radical [5, 8, 9].

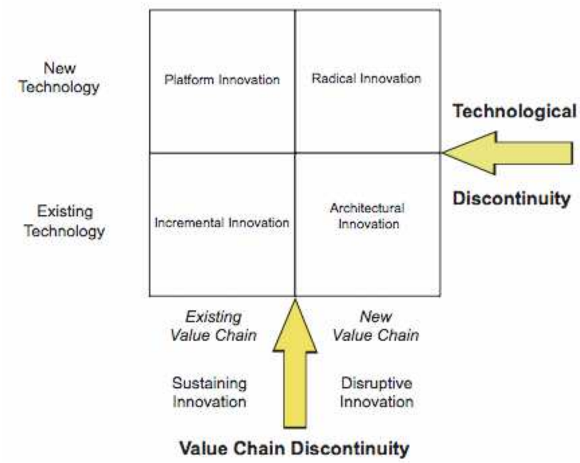

Figure 2 – Classification of innovation in terms of the value chain and the technological competencies.

3.3.1. Incremental innovations

Incremental (or process or modular) innovations build upon well-known technological capabilities to enhance an existing technology through improved performance, enhanced security, better quality and reduced cost, within the established value network. The purpose of the innovation is to enhance the competitive position through economies of scale to lower cost and improve productivity through automation. The objective of reduction in production and distribution costs requires extensive data collected from real experience. It is estimated that half of the economic benefit of a new technology comes from process improvements after the technology has been commercially established. This is why incremental innovations are typically process innovations that tend to reinforce the existing industrial order because they are more readily integrated within the firm's strategy both from the technological and financial viewpoints. This contrasts with other types of innovations that could alter the order and offer opportunities to new entrants.

Kuhn’s [10] description of the way “normal science” operates gives us some insight to the limits put on incremental innovations: they should be consistent with the established design, i.e., they should not rock the boat. By optimizing the operation, however, they increase the rigidity of processes and products, which decreases the overall ability to cope with changing markets or technical requirements. Also, such productive and efficient operation is less responsive to changes in regulations or customer tastes, breakdown in automatic processes, or disruptions in the outsourced functions.

3.3.2. Architectural innovations

Architectural innovations (sometimes called systems innovations) provide new functional capabilities by redefining the rearrangements of existing technology to satisfy unmet needs (simplicity, cost, reliability, efficiency, convenience, etc.) Architectural innovations result from a market pull: new uses of an existing technology. Camera phones are also an example of architectural innovation that add mobile telephony and handset ergonomics to the technology mix of digital photography such as image processing, miniaturized optics, and digital storage. By doing so, they changed the supply chains for both handsets as well as digital cameras, and created security issues for corporations and institutions.

Architectural innovations are articulations of latent patterns of demands that can be satisfied by blending incremental technical improvements from several previously separate fields of technology to create a new product or service. This category of innovation tends to modify the supply chain and to reorganize the market segments, ultimately forming one or more new value networks. The scope of architectural innovations is on new combinations of existing building blocks (e.g., technology, marketing channels, processes, etc.) to expand the market by satisfying unarticulated needs that are not met by existing products or services. This is why decentralization, deregulation and the opening up of markets stimulate mostly architectural innovations. When the number of potential players increases, improvements can extend to areas that were not even considered because of limited resources (time, money, personnel, etc.). The drawback is that entrepreneurial efforts will concentrate on exploiting existing technologies rather than on breakthrough activities.

As a consequence, market fragmentations are mostly associated with architectural innovations until coalescence around one or more new standard architectures. This can happen through several ways:

- The monopoly of a *de facto* standard based on one entity (Windows, iPod/iTunes, VHS, etc.)
- Several coalitions around competing standards, such as in the case of recordable DVD or the various IEEE 802.x standards

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- An industry-wide coalition around a unique standard, a rare event that happened in the case of Bluetooth
- A legislatively imposed standard, as in the case of the 2006 French legislation on digital music.

Note: Bluetooth (and the IEEE 802.x standards) is a marriage of local area networks (LAN) and wireless communications in the unlicensed part of the radio spectrum at 2.45 GHz reserved for industrial scientific medicine (ISM) band. Mastering this technology requires expertise in radio chip integration in addition to radio transmission, antenna design and protocol engineering to communicate with portable computers and personal digital assistants.

3.3.3. Platform innovations

Platform innovations correspond to a quantum leap in performance without changes to an existing value chain. These are complex programs that require large capital investments to upgrade the existing infrastructure. This technology transition demands the integration of sophisticated resources and the exploitation of expertise gained, which is usually beyond the reach of small- or medium-sized companies. New platforms change the technical competitive positions of larger firms by changing the technical criteria for competition and weaken smaller firms because they have less access to financing as well as technical and financial talent. Because a technology push is the main characteristic of platform innovations, technological considerations dictate business strategies to manage the development and diffusion, including licensing, training, etc.

While the digital coding of signals is a radical innovation, the introduction of digital transmission in the 1970s was a platform innovation. Similarly, frame relay and the asynchronous transfer mode (ATM) are platform innovations in the core technology of public networks. Both are based on packet switching along the "connection-oriented" paradigm.

3.3.4. Radical innovations

According to Kuhn [10], “a scientific revolution is a non-cumulative developmental episode in which an older paradigm is replaced in whole or in part by an incompatible new one.” Radical innovation, likewise, provide a totally new set of functional capabilities that are discontinuous with both existing technological capabilities and value networks. They are spaced in time and, when successful, lead to a new dominant design.

Radical innovations face four types of uncertainties: technical uncertainty, resource uncertainty, organizational uncertainty, and market uncertainty. Technical uncertainty arises from two factors: 1) many of the technical characteristics of the innovation are not well understood and 2) an even better technology may become available and displace the technology under development. In telecommunications, this is how optical transmission displaced the emerging waveguide technology. Resource uncertainties relate to the unknowns regarding the cost of development and implementation, as well as to maintaining the collaborative network of technical, managerial and marketing experts. Organizational uncertainties are due to the tension from simultaneous discontinuities in the technology and in the value network. Market acceptance is another unknown, because the more radical the technical innovation, the less likely that existing customers will be able to guide its development: market research methodologies typically focus on existing applications.

Relating the various innovation types to the technology life cycle and market acceptance [5], radical innovations are encountered first in proof of concept implementations. Once the innovation proves itself, successive platform and incremental innovations enhance the performance and allow the firm to gain market share. Architectural innovations are common when the technology has matured in pursuit of new markets.

When the performance improvement levels off, process (incremental) innovations increase the efficiency of operations or enhance some features to increase revenues. Incremental innovations target existing users; typical customers’ surveys provide useful guidance of their needs. Thus, incremental innovations follow a well-defined path from research to development, manufacturing and deployment. During each step, the responsibilities are well defined and the execution follows well-honed procedures. Thus, these innovations depend on the preservation, reproduction and maintenance of past data, learning from past experience and specialized knowledge, skills and capabilities.

We now try to apply this framework to understand and assess some of the aspects related to the current efforts for standardising the next generation Ethernet networks.

4. STANDARDISATION OF THE NEXT GENERATION ETHERNET NETWORKS

Over the past decades, the Ethernet hierarchy of bit rates was successfully increased from its originals 10 Mb/s to 100 Mb/s, 1Gb/s and finally to 10 Gb/s. Using the terminology of the previous framework, the first two extensions could be classified as incremental innovations to increase the access speed to a local area network (LAN) from desktop and laptop machines. The 10 Gb/s Ethernet, in contrast, was of a different nature. Its standardisation over twisted-pair cable (known as 10GBASE-T) required a sophisticated PHY layer and required more than 3 years of activities. Furthermore, current 10Gb/s Ethernet applications are mostly in wide area networks (WAN) and carrier networks. Within enterprises, they are used to interconnect servers in data centres. Their use in a LAN environment to connect workstations has been limited by the capabilities of disk drives to process high data rates [11]. Accordingly, we can view 10 Gb/s Ethernet as a platform innovation suitable to two distinct value chains: carrier networks and high-speed server interconnections.

As the number of services requiring packetized 10 Gb/s pipes increases (e.g., video distribution), it is anticipated that within the coming few years there will be a need for a comprehensive network solution to aggregate traffic at rates of Nx10 Gb/s. The current consensus is to standardize 2 such rates: N=4 and N=10 [12, 13]. The proposed standardization is not anticipatory, because there are already proprietary solutions operated at these rates, i.e., we are dealing with enabling standards where the speed of standardization is important [6]. In this case however, specifying the enabling standard starts before the expected market growth, and takes into account the time necessary for standards development and build upon the lessons learned from the pre-standard proprietary implementations. According to the framework, the corresponding innovation should be a platform innovation, with the explicit purpose of improving the performance of the technology to meet the expected scale of operations.

To enable Ethernet transmission at 100 Gb/s, new technologies must be used to increase the reach of 100 Gb/s over fibres for WAN applications and a higher speed copper Ethernet interface must be agreed [14-15]. For example, new multiplexing and line coding schemes are needed for transmission on copper links. In addition, new optical interfaces, including 100 Gb/s transceivers, opto-electronic modulators, higher performance network interface controllers (NIC), higher speed I/O buses, adapters, etc. need to be designed.

The standardization activities are taking place mostly in the ITU-T study group 15 and in the IEEE 802.3 Higher Speed Study Group (HSSG). The scope of activities in the ITU-T corresponds unequivocally to a platform innovation: definition of a new transport container for optical transport units (OTU)/optical data units (ODU) —denoted as OTU4/ODU4— for 100 Gb/s Ethernet, definition of the characteristics of the interface (e.g., the forward error control scheme), etc. The IEEE 802.3 is positioning the activity as an incremental innovation intended to extend the longevity of existing 10 Gb/s designs to 40 Gb/s and beyond. The intent is to reduce development risks through technology reuse. This would ensure backward compatibility as well by using the same frame format, same MAC (Media access control) layer, same physical coding sublayer (PCS) and same physical media attachment (PMA). However, it is well understood that IEEE's 40 Gb/s and ITU's 100 Gb/s Ethernet do not align gracefully and that the requirements for server interconnects are different than WAN requirements. In the first case, the links are typically 100 ms or shorter, while in the second they range from 10 to 40 km and have to be extremely reliable and maintain that reliability over the long term. Thus, because there are two value chains there is no pressure to merge efforts for achieving one common standard.

In this example, we can identify some of the forces that could affect the stability of a standard. In particular, we think that the IEEE 802.3 is trying to combine conflicting technical and business requirements and also in a short period of time. We propose that the incongruence between IEEE's scope of standardization (i.e. which includes aims that befit incremental innovation) and the technical challenge posed by platform innovation, may lead to unstable standards.

Of course, some conceptual or technological breakthroughs that could resolve the above difficulties cannot be excluded. However, if we extrapolate existing conditions and because enabling standardization faces time pressures, other possible solutions should also be explored. For example, the activities in the IEEE 802.3 HSSG could be repositioned as a platform innovation instead of being an incremental innovation. Another solution would be to decouple the 40 Gb/s activity from the 100 Gb/s by restricting the incremental innovation aspects to the first rate. However, this may be politically unpalatable, as this would mean accepting the ITU-T's total leadership in this regard. In any event, in planning the standardisation timeline, it would be wise to include an evaluation point where the above ideas are re-examined to see if they are still applicable. The two alternative trajectories for the next generation Ethernet networks are summarized in Table 2.

Table 2 – Two alternative standardisation trajectories in the new generation of Ethernet networks.

Standards setting	**ITU-T SG 15**	**IEEE 802.3**
Intended Rate	100 Gb/s	40/100 Gb/s
Value chain	Carrier networks (e.g., long distances; high reliability)	Server interconnects (e.g., short distances)
Technologies to be standardised	New container for OTU/ODU, new modulation schemes, optical interfaces, network interface controllers, etc.	Extending existing technologies
Characteristics of Innovation	Platform	Incremental
Characteristics of standards dynamics	Enabling standard (time pressure) Succession	Enabling standard (time pressure) Revision. Wide scope as cause for competing standards
Impact of standards change: compatibility	More effort needed to achieve backward compatibility	More straight-forward backward compatibility

5. INNOVATION AND STANDARDS' CHANGE

In this section we try to structure our insights to help identify moments and situations in which the tension between standards' stability and innovation is likely to emerge. We close again with a brief reflection on the Ethernet standards case.

5.1. Technology life-cycle and timing of standardization

First of all, let us not forget to mention the seemingly obvious: where a technology is mature and standardization more or less occurs ex post (responsive standardization), standardization will resemble a selection process. Knowledge about and experience with the technology will be readily available. Standard's implementation is already

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ensured. As a result, the standards committee's scope is likely to be focused and realistic. Those with a stake will be sitting at the negotiation table. Technical ambiguity is less likely to become part of the specification. In short, a more stable standard is likely to result.

Standards are less likely to be stable where emergent technologies are standardised (anticipatory standardization), since there is little certainty about how it will develop and be applied, there is no experience with the technology to fall back upon, etc. In the standards committee scope creep is more likely to occur. Because the future market and market positions are as yet unclear, economic interests may favour ambiguities in a standard. In short, anticipatory standards are much more likely to be revised at a later time than enabling and responsive standards. Moreover, the timing of standardization also determines the amount of pressure exerted on a committee process, and therefore on the quality of the process (e.g., amount of mistakes and ambiguities made, need to accept a bad compromise). From this perspective, the pressures of the various stakeholders on enabling standards (where the co-evolution of technology, markets and standards takes place) would be the highest. The impact of standardisation on the potential of changes in the specifications is shown in Table 3. In this table, typical external sources of change depend on the vantage point, whether that of the perspective of companies or of the application area (market sector).

5.2. Innovation type and standards change

We now take into account the combined effects of changes in the technology and the value chain on the expected changes of the underlying standards. For example, where incremental innovation occurs and a change of standard is necessary, standard revision will most likely include backward compatibility. Whereas the disruption that accompany radical innovation will require a new standard. In this case, the disruptions preclude compatibility. Table 4 illustrates how each type of innovation implies different characteristics of standards' change.

More specifically, the disruptions that define innovation categories also affect the actors participating in standardization and the area of standardization. To take the example of the 40/100 Gb/s Ethernet standardisation activities, because the effort is defined as an incremental one, the same actors will be sitting around the table as in earlier rounds of IEEE Ethernet standardization. The market shares between providers are likely to remain stable. However, in the ITU effort, where a platform innovation is aimed for, we hypothesize that largely the same actors will participate in standardization (i.e., because of same value chain), but that the stakes will be higher and the negotiation process harder than in the IEEE because of the technological disruption involved.

Table 5 summarizes the technical and market implications of the innovation disruptions on the standards, the actors participating in standardization, and the area of standardization.

6. CONCLUSIONS

Given that technology innovation requires standard change, our goal was to understand when and where issues of change are likely to occur and in what way standardisers can deal with change. We have relied on the innovation literature to derive some tools to help stakeholders assess the standards dynamics and chart courses of action. We attempted to use these tools to make predictions related to the current efforts to standardize the next generation Ethernet networks. One line of future research is to compare the predictions of these tools with the actual outcomes and improve them according to the results. Another activity would be to attempt to measure and quantify the elements discussed in Tables 3 and 4. In any event, we hope that this paper will convince the reader of the value of applying an innovation framework to understand and anticipate possible standards' change-related problems.

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Table 3 – Standardisation pressures.

Timing of standardization / **Standards Dynamics**	**Anticipatory Standards (Emergence)**	**Enabling Standards (Improvement)**	**Responsive Standards (Maturity)**
Amount of expected changes	+++	++	+
Required speed of standardization	++	+++	+
External causes of change – firm's perspective	Immaturity of technology	Technology & market uncertainty	Cost reduction; performance optimisation
External causes –application area perspective	Imprecise customer and supplier requirements	Market growth	Changes in market & regulations

Table 4 – Correlation of the type of innovation and the characteristics of standard's change.

Features / **Innovation**	**Technology disruption**	**Value chain disruption**	**Impact on standards**	
			Compatibility Preserved?	Type of change?
Incremental	N	N	Possible	Revision
Architectural	N	Y	N/A	New standard
Platform	Y	N	Unlikely	Revision/New standard
Radical	Y	Y	Almost impossible	Replace/Succession

Table 5 – Summary of the implication of innovations on standards.

Innovation	**Impact of (lack of) disruptions on standards**
Incremental	• More of same functionality, therefore technological continuity is assured and the market is stable • Revisions with backward compatibility are easy to achieve (parties' interests in existing technology coincide) • Same actors involved in standardization (we expect: stable and mature standards process)
Architectural	• Different functionality, system integration • New standards needed (architectural framework, interface) • New actors or actors diversifying in standards development • High competition among standards; possibly attempts to frustrate standardisation or lack of standards
Platform	• Different functionality, exponential increase in scale of performance • Same actors involved in standardization, but new/higher stakes than in incremental standards process
Radical	• Different functionality, different technological paradigm • Replacement/successor needed • Due to functional overlap with earlier standard competition arises, possibly preference for different standards body • Partly old and partly new actors in a different constellation

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