When and What to Standardize;

An Architecture Perspective.

Prof. Gerrit Muller
Buskerud University College and Embedded Systems Institute
Gerrit.muller@embeddedsystems.nl

Abstract. Many products today are developed for highly dynamic markets while the products and functions get more and more integrated. The product and service realization is based on fast changing technologies that come together in complex value chains. The challenge for modern companies in innovative domains is to survive in this dynamic world. In this paper we explore what the appropriate timing of product standardization is.

Introduction

The rationale of standardization depends on the position in the hierarchy of systems. Figure 1 shows four different viewpoints: component, system, system of systems, and complementing systems. We will take the position of system throughout this paper, but we should realize that suppliers, customers and complementers have their own specific interests in standardization. For an example of standardization in optical disks and the related stakeholders see [Shintaku 2006].

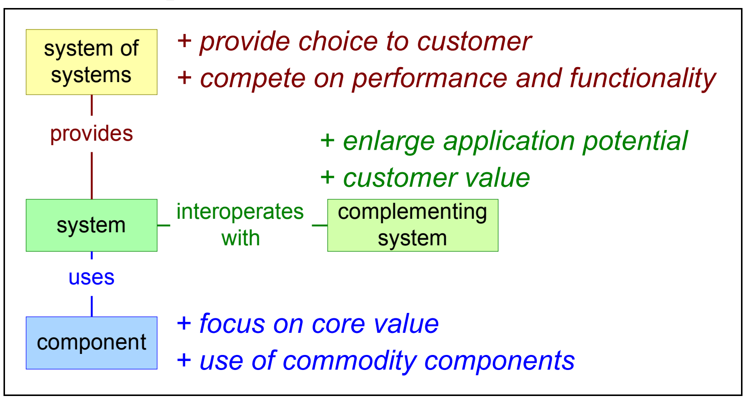

Figure 1, From system perspective different standardizations drivers apply for using, providing or interoperating functionality.

- **Suppliers** create and sell **components**. A system company needs to focus on its core business, hence it likes to standardize non-core components. If these standardized components become a commodity, then the system company benefits from cost reductions as well as ongoing innovations in these components.
- **System companies** create and sell **systems**. Note that this whole hierarchy is recursive; a component builder perceives itself as system company. For example, the camera provider for an X-ray imaging chain has component suppliers delivering lenses, CCD-chips et cetera.
- **Customers** create a **system-of-systems** to address their needs. Many individual

systems delivered by different system companies are integrated. One of the system companies is “our” company, the others are our complementers. Customers have a choice between competitors. Standardization of system interfaces adds value to customers by making systems interchangeable. As a consequence the competitive playground shifts to performance and functionality.

- **Complementers** create and sell **complementing systems**. For example in the Catherization Laboratory the injection system, the monitoring system, and the cardiology information system are complementary to the X-ray system. Standardization of interfaces to complementers improves interoperability between these systems. Interoperability enlarges the space of potential application. Interoperability in itself and more applications provide more customer value.

Note that the time scales of these different stakeholders can also vary widely. Infrastructure inherently has long time constants, due to the invested capital. Communications and computing technologies have had very short life cycles the last decades

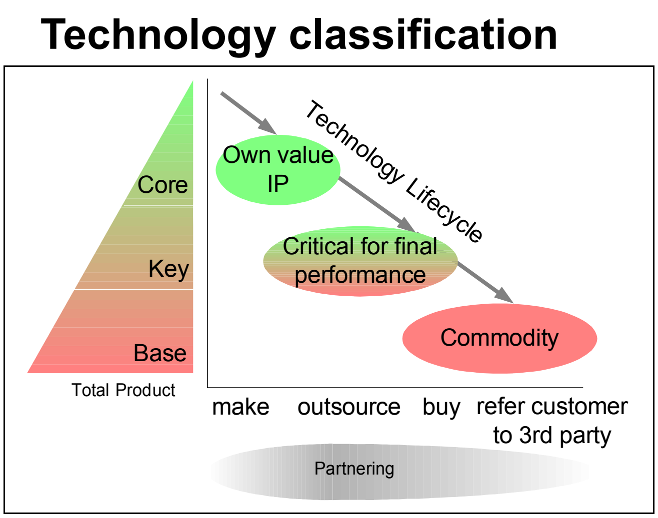

Figure 2, Focus on *Core* technology, not on *key* or *base* technology

A simple reference model to help in making make or buy decisions is based on core, key, and base technology, see figure 2.

- **Core technology** is technology where the company is adding value. In order to be able to add value, this technology should be developed by the company itself.
- **Key technology** is technology which is critical for the final system performance. If the system performance can not be reached by means of third party technology than the company must develop it themselves. Otherwise outsourcing or buying is attractive, in order to focus as much as possible on core technology added value. However when outsourcing or buying an intimate partnership is recommended to ensure the proper performance level.
- **Base technology** is technology which is available on the market and where the development is driven by other systems or applications. Care should be taken that these external developments can be followed. Own developments here are de-focusing the attention from the company’s core technology.

From the perspective of a system company there is a clear benefit to standardize interfaces to components in key and base technology areas. By such standardization the main focus of the company is on the core technology areas, where the company adds its specific value. An orthogonal classification question is the readiness level of the technology. For example, Technology Readiness Levels (TRL) by NASA can be used for this purpose, see [Mankins 1995].

The crucial timing question here is: where are specific technologies in their *technology lifecycle*?

When to Standardize

A crucial question for standardization is *when to standardize* [Elzinga 2005]. To standardize too early or too late can be rather damaging. Figure 5 shows characteristics and consequences of standardizing too early, at the right moment, and too late.

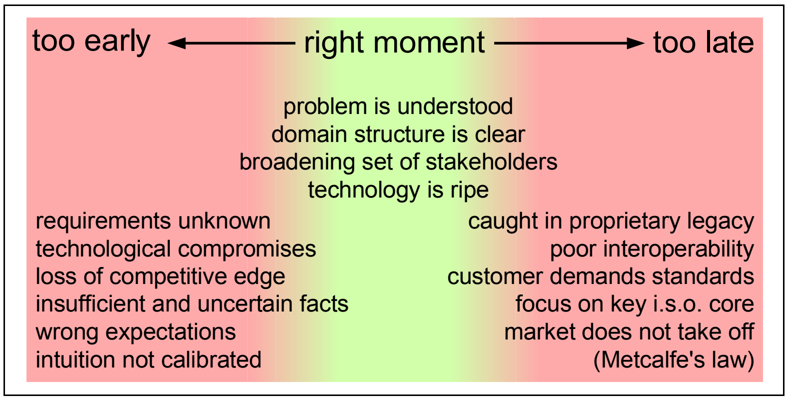

Figure 3, When to standardize?

Too early standardization often results in *technological compromises*; The right level of standardization is not realistic technological causing compromises in the standard to make the realization feasible. In the early phases too little is known about the application of the standard, the *requirements are unknown*. The early standard is based on *insufficient and uncertain facts*, while the *intuition is not calibrated*. The value in young markets is based on responsiveness to market needs and differentiation. Standardization can unify competitive products, causing *loss of competitive edge*. The combination of these factors causes a *mismatch of expectations*: customer expect the availability of reliable and interoperable solutions, while the involved parties are in fact still learning what is needed and how to realize it.

At the right moment to standardize the *problem is understood* and the *domain structure is clear*. A *broadening set of stakeholders* will benefit from the standardization. The *technology is ripe*, such that implementations are feasible within acceptable time, cost and effort constraints.

Too late standardization causes a company to be *caught in proprietary legacy*. The products depend heavily on the original solution and the realization is so much intertwined that migration to standard solution is costly and painful. For the customers the consequence is often *poor interoperability*, causing *customers to demand standards*. The *focus of the company is on key technology instead of core technology*. Some standards have to be in place to create sufficient market, if the standard is late, then *the market does not take off*. This is related to Metcalfe's law: "Metcalfe's law states that the value of a telecommunications network is proportional to the square of the number of users of the system"[1] The value of a standard also increases more than proportional with the number of involved stakeholders.

[1] source: wikipedia http://en.wikipedia.org/wiki/Metcalfe's_law.

Roadmapping

Roadmapping is one of the tools to develop a strategic view on the business dynamics [Phaal2001, Muller1999]. In essence roadmapping is a technique where trends and developments are mapped and visualized as function of time. A typical structure for a roadmap is shown in Figure 4. These trends are first of all external trends: what happens in the market (what are customer expectations and needs, what are domain specific trends in applications?), and what happens in technology (what are technological challenges, where are technological opportunities). With these inputs the strategic positioning of the company is translated in products (What products with what features and characteristics do we want to offer in the product portfolio). We need people and processes to realize these products and the technology used inside.

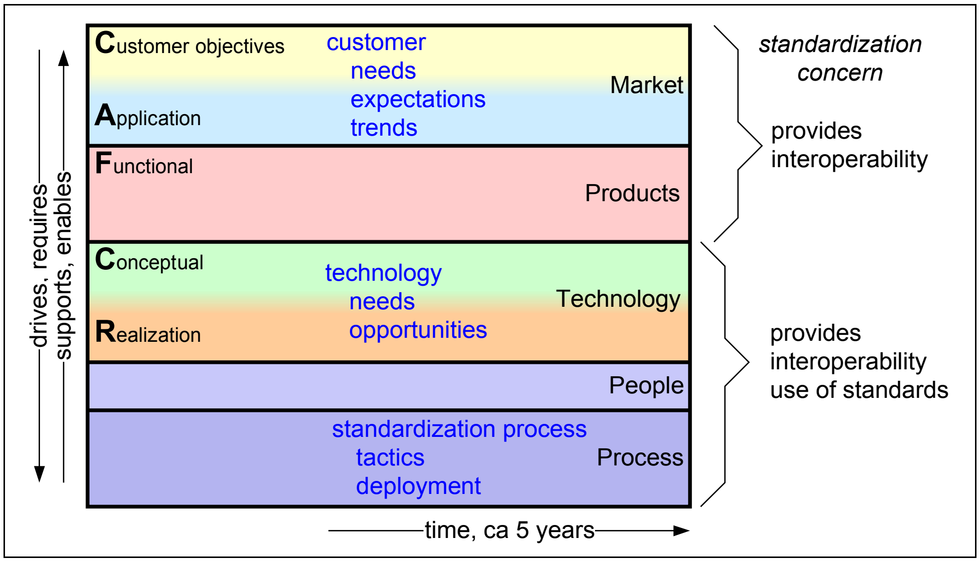

Figure 4, Roadmapping as tool.

Part of the processes will deal with the standardization itself, tactics as well as deployment. The standardization concern in the market and product roadmap is how to provide interoperability. The standardization concern in technology, people and process is two-sided: how to provide interoperability and how to harvest the use of standards.

Cost and benefit trends of *buying* or *outsourcing*

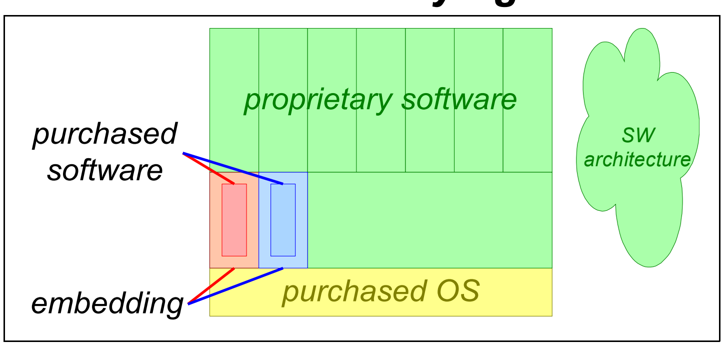

Figure 5, Purchased SW Requires Embedding

A complicating factor, from system creator perspective, is the use of COTS (Commercial Of The Shelf) software. Software developed as part of a platform follows the architecture guidelines of the platform. However, purchased software has been developed independent of the platform, using its own architecture guidelines. This same complication may occur when software is purchased as part of a standardization effort. Figure 5 shows that purchased software requires some kind of embedding to fit it into the desired architecture.

Figure 6 zooms in on the typical additional efforts to embed purchased software in a platform. Most embedding effort is required to ensure the desired system level behavior and qualities: configuration, installation, start-up and shutdown et cetera.

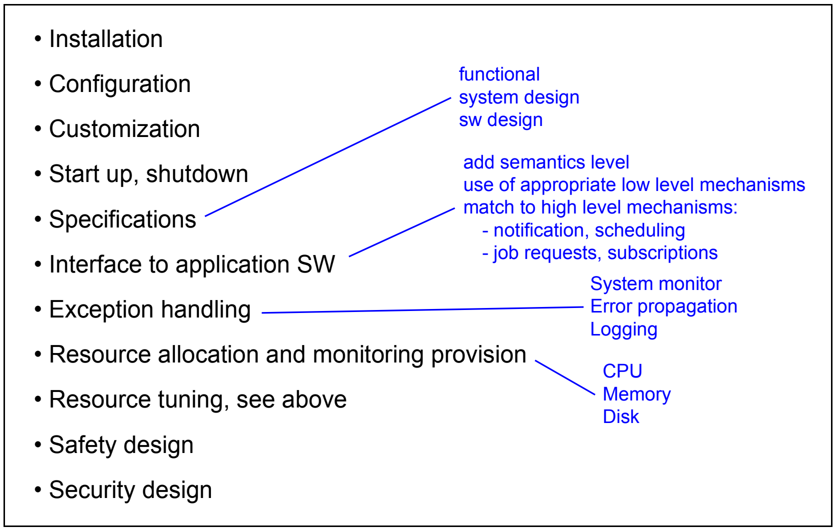

Figure 6, Embedding Costs of Purchased SW

Returning to the question *when to standardize*, we have to look at many considerations at the same time. Figure 7 shows a balance with pro and contra considerations for COTS. The figure is also annotated with the changes in time of these considerations. Some factors increase in weight (contra: integration effort, release propagation, required know how, and transition cost; pro: innovation from outside, focus on core technology, initial cost reduction, faster to market, interoperability, functional integration), some factors stay the same (flexibility, embedding), and some factors decrease in weight (license costs, performance, and resource use).

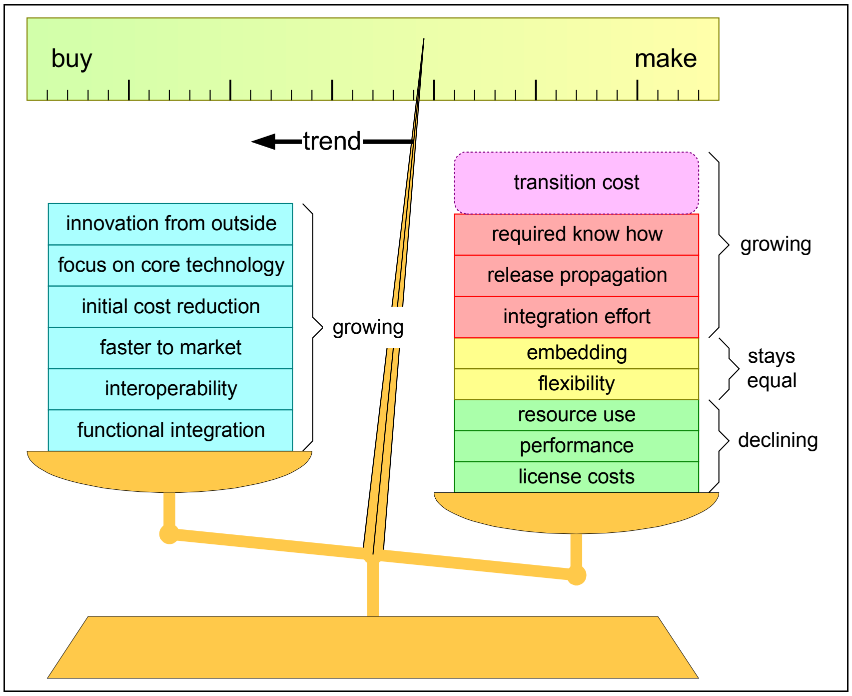

Figure 7, Balance of Considerations and Trends

The *contra* factors that increase are mostly increasing due to the ever increasing size and complexity of systems. The *pro* factors are in-line with the formulated reasons for standardization. The benefits will outweigh the disadvantages, unless the transition costs have become too high. In that case a company is caught in the legacy trap.

Reference Model.

Standardization is complicated due to the many involved stakeholders with their different interests and backgrounds. A *Reference Model* of the broader context can help to provide common ground for these different stakeholders. The Reference Model is also useful to understand the different time scales that are involved in the domain(s).

Figure 8 shows a Reference Model for image handling functions. This reference model is classifying application areas on the basis of those characteristics that have a great impact on design decisions, such as the degree of distribution, the degree and the cause of variation and life-cycle. Such a reference model is one of the means to cope with widely different life-cycles.

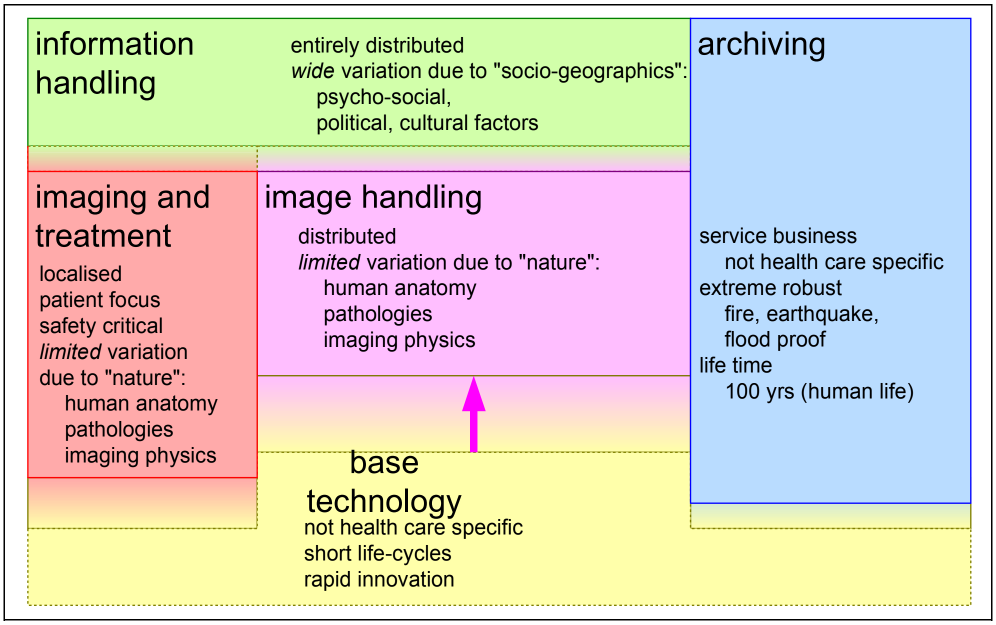

Figure 8, Reference Model for health care automation

Imaging and treatment functions are provided of modality systems with the focus on the patient. Safety plays an important role, in view of all kinds of hazards such as radiation, RF power, mechanical movements et cetera. The variation between systems is mostly determined by:

- the acquisition technology and its underlying physics principles.
- the anatomy to be imaged
- the pathology to be imaged

The complexity of these systems is mostly in the combination of many technologies at state-of-the-art level.

Image handling functions (where the medical imaging workstation belongs) are distributed over the hospital, with work-spots where needed. The safety related hazards are much more indirect (identification, left-right exchange). The variation is more or less the same as the modality systems: acquisition physics, anatomy and pathology.

The *information handling* systems are entirely distributed, information needs to be accessible from everywhere. A wide variation in functionality is caused by “social-geographic” factors:

- psycho-social factors
- political factors
- cultural factors
- language factors

These factors influence what information must be stored (liability), or must not be stored (privacy), how information is to be presented and exchanged, who may access that information, et cetera.

The *archiving* of images and information in a robust and reliable way is a highly specialized activity. The storage of information in such a way that it survives fires, floods, and earthquakes is not trivial[2]. Specialized service providers offer this kind of storage, where the service is location-independent thanks to the high-bandwidth networks.

[2] Today terrorist attacks need to be included in this list full of disasters, and secure needs to be added to the required qualities.

All of these application functions build on top of readily available IT components: the *base technology*. These IT components are innovated rapidly, resulting in short component life-cycles. Economic pressure from other domains stimulates the rapid innovation of these technologies. The amount of domain-specific technology that has to be developed is decreasing, and is replaced by base technology.

Stepwise development of standards

Standardization can be organized in an incremental way. Early on, when many uncertainties are present, a minimal set can be standardized to facilitate some interoperability and further development of standards. The standard is extended when feasibility of the extensions have been proven in practice. In more local scopes, for instance within a product group, uncertainties are less than in the more general global scope. Local standardization, within the product group for example, facilitates the feasibility work for more global standards. Such a leveled and incremental approach addresses a potential tension between standardization (keep interfaces stable) and innovation (break the current paradigms to create new value).

As an example we look at the standardization history in the health care industry. The health care industry is striving for interoperability by working on standard exchange formats and protocols. The driving force behind this standardization is the ACR/NEMA, in which equipment manufacturers participate in the standardization process.

Standardization and innovation are often opposing forces. The solution is often found in defining an extendable format and in standardization of the mature functionality. Figure 9 shows the approach as followed by the medical imaging product group within Philips around 1995. The communication infrastructure and the mature application information is standardized in DICOM. The, at that time, new auto-print functionality was standardized at vendor level. Further standardization of auto-print is pushed via participation in DICOM work groups.

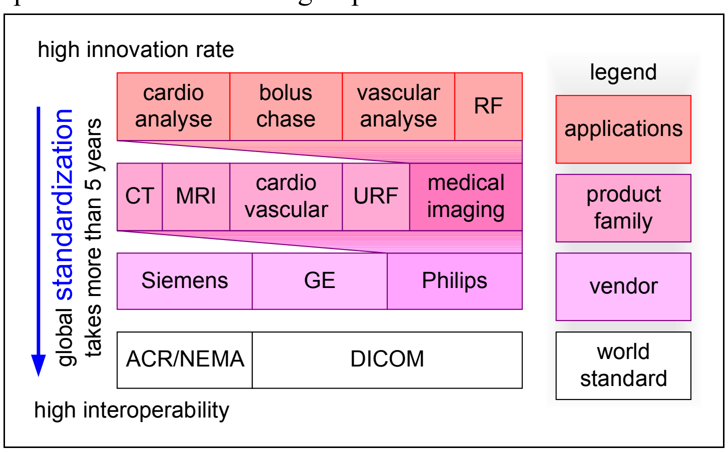

Figure 9, Information model, standardization for interoperability

A good strategy is to use the standard data formats as much as possible, and to build vendor specific extensions as long as the required functionality is not yet standardized. The tension between standardization and innovation is also present at many levels: between vendors, but also between product groups in the same company and also between applications within the same product. At all levels the same strategy is deployed. Product family specific extensions are made as long as no standard vendor solution is available.

This strategy serves both needs: interoperability for mature, well defined functionality and room for innovative exploration.

The information model used for import, export and storage on removable media is one of the most important interfaces of these systems. The functionality and the behavior of the system depend completely on the availability and correctness of this information. The specification of the information model and the level of adherence and the deviations is a significant part of the specification and the specification effort. A full time architect created and maintained this part of the specification.

The life cycle of standardization in this example from application specific feature to global standard took at least five years. This time constant is highly domain dependent. For example, in the optical disc storage this time constant is in the order of six to nine months.

Summary and Conclusion

The timing of standardization work is highly strategic and critical for business success. We discussed the different interests of the many involved stakeholders. We showed several methods and techniques to cope with this timing question: technology classification in *core, key,* and *base* technology, roadmapping, cost/benefit analysis, and reference models. Incremental standardization is an approach to cope with the potential tension between standardization and innovation.

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Author Biography

Gerrit Muller.

Gerrit Muller received his Master's degree in physics from the University of Amsterdam in 1979. He worked from 1980 until 1997 at Philips Medical Systems as a system architect, followed by two years at ASML as a manager of systems engineering, returning to Philips (Research) in 1999. Since 2003 he has worked as a senior research fellow at the Embedded Systems Institute in Eindhoven, focusing on developing system architecture methods and the education of new system architects, receiving his doctorate in 2004. In January 2008 he became a full professor of systems engineering at Buskerud University College in Kongsberg, Norway.

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