Review of standardization opportunities in smart industrial components

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***Abstract* — Smart Components in manufacturing are defined as components which incorporate functions of self-description, communication, sensing and control in order to cooperate with other smart components, analyse a situation, make decisions based on the available data and modify their behaviour through feedback. These smart components are made up with a variety of parts with various roles: sensors for signal acquisition, elements transmitting the information, control units that take decisions and give instructions based on the available information, components transmitting decisions and instructions, and actuators that perform or trigger the required actions.**

The absence of standards in certain areas and the lack of critical mass to effectively drive such standards is currently one of the identified barriers to widespread adoption of smart components by industry. There is also a need to clearly define the new business models and regulatory frameworks in which these smart components will operate.

This paper presents a review of needs and opportunities for standardisation for smart components identified within the scope of the Co-FACTOR project.

Keywords — industrial smart components; advanced manufacturing systems; factories of the future; standardisation;

I. INTRODUCTION

Co-FACTOR [1] intends to bring together those actors who contribute to enabling "smart components". At the core of Co-FACTOR are six running FoF (Factories of the Future) projects: I-RAMP³ [2], ReBorn [3], SelSus [4], T-Rex [5], INTEFIX [6] and Power-OM [7]. This paper summarizes and analyses the findings of a study on standardisation opportunities conducted by the the project, and reviews the current status and needs, in terms of standardisation, as perceived by this community.

Although the main focus is on the need for standardization, the study started by building a common view of what are smart components, derived from the expertise and experience present in the six core projects represented in Co-FACTOR initiative. During this effort, not only a definition for Smart Industrial Components was established but also the main topics of interest for the smart component community were identified. Standardisation was clearly identified as one of these topics of interest, with the experts involved pointing several standardisation opportunities and reference models like RAMI4.0 [8] as already existing efforts in this area.

Consolidating the results of the activities, major topics for which standards are needed emerged: "management shells" for the smart components, their definition, functionality (i.e. self-description capability); communication/integration and content (syntaxes and semantics) for the exchange of information between the different components and layers; the integration of web and Internet of Things and common standards for vertical and horizontal integration. The discussion has shown that the need for standardization is evident but not to be handled just by a small group of people. Although there are other valid efforts, both EU and world-wide, the RAMI4.0 reference architecture is positioned as a good starting point to tackle standardisation in this context. Not only because of its current state of development but also due to the fact that large enterprises already committed themselves towards this reference architecture model. Results from the study also highlight and emphasise that industrial showcases and demonstrators, open innovation and cluster activities are very promising approaches for bottom up (grassroots and needs based) standards.

The paper is structured as follows. After the presentation of the motivation and objectives in this section, section two gives an overview of the methodology, actors and activities involved in the study. Whilst section three presents the main contributions for the discussion, including the understanding of smart component and a first review of standardization opportunities, section four goes deeper in the discussion of the standardisation opportunities identified in the study. Section 5 concludes this paper with a discussion on the main findings and presenting opportunities for future work.

II. METHODOLOGY AND ACTIVITIES

At the core of the Project Co-FACTOR are six running FoF projects: I-RAMP³, ReBorn, SelSus, T-Rex, INTEFIX and Power-OM. The methodology followed in this study was based on the task forces, led by experts coming from the Co-FACTOR consortium and with members coming from the core project consortia. The activities were organised around 3 Task Forces assuming that smart components are relevant to all

however, partly with overlapping, partly with specifically different challenges: 1. smart sub-machine parts, 2. smart production equipment and 3. smart production systems/lines. Each Task force carries out activities to tackle the challenges in the three different application areas, which are relevant for industrial application and deployment of smart components. The three task force groups reflect the focus on 3 application areas for "smart components", as such smart production lines and systems, smart production cells and equipment, and smart sub-machine parts and components.

Task Forces consist of a limited number of flexible and agile experts, still confining a critical mass of experts per Task Force. Task Force leaders are acting as drivers and moderators of activities highly focused on three smart components application areas. The following table presents this organisation and identifies the task force leader.

Application area	Task force	Task force leader
smart production lines & systems	smart production systems	Roland Wertz, FhG IPA
smart production cells & equipment	smart production equipment	Dr. Niels Lohse, Lboro
smart sub-machine parts & components	smart sub-machine parts	Gil Gonçalves

Figure 1: Task Force areas and leaders

The methodology followed in the study started with a survey that has been answered by members of the task forces. The survey included general questions on smart components but also specific questions related with the different task forces. The answers were collected and analysed, and further information was collected for specific issues as standardization and barriers to the adoption of smart components in industry.

The information collected in this survey was first used to define what "smart" is in the context of each task force, to understand the potential and requirements of smart components for industrial deployment, to assess horizontal issues like standardization, and to identify future needs of R&D program support.

On a second step the 3 task forces jointly elaborated on the availability, features and maturity of smart components currently being developed. The aim was twofold: first, to learn and define if and how different smart components can be exploited (and to which degree) in different applications as represented by the 3 focus areas. Secondly, to assess the current and expected technology readiness level to the "smart technology" results of the core projects and to compare the chosen technological implementation approach.

The third step of the methodology extended the discussion to a wider scope and involved the preparation of a position paper on smart components and the organization of an expert panel, involving internal experts from the task forces as well as external experts from industry, consultancy and representatives from standardization bodies (CENCENELEC, DIN, ETSI). The main objective of the expert panel was to explore the prevalent standardization needs and opportunities for smart components within the 3 application areas.

The expert panel counted with the involvement of 15 top-ranked international experts with broad experience in the EU manufacturing landscape. The expert panel was organised as a half-day event consisting of a general session and 3 parallel workshops around the 3 focus areas. The general session included a keynote speech on the need for standardization and certification of products and processes, "quality labels" and current obstacles and needs. In the 3 parallel workshops, concrete information exchange on standardization issues, definition of the required focus, action plans and strategies to convince the wider community were elaborated using a roadmapping template prepared beforehand (see Figure 2).

III. MAIN CONTRIBUTIONS

The common view emerging from the first interactions between the task force members helped to shape a common definition of Smart Components. Smart Components in manufacturing are components which incorporate functions of self-description, communication, sensing and control in order to collaborate with other smart components, analyse a situation, make decisions based on the available data and modify their behaviour through feedback. These smart components are made up with a variety of parts with various roles: sensors for signal acquisition, elements transmitting the information, control units that take decisions and give instructions based on the available information, components transmitting decisions and instructions, and actuators that perform or trigger the required actions. In a smart factory of the future, the normal hierarchical structure of the famous automation pyramid will be replaced by horizontal and vertical integration. These new complex systems will be composed of networked smart components, with the ability to collaborate across all previous boundaries. Different technologies are being used in the development of smart components, in order to be able to achieve several benefits such as improved reliability, better performances, and higher quality.

As a result of these first interactions with the task force members and the analysis of the survey results [9], not only the common definition of Industrial Smart Component was established but also the main topics of interest for the smart component community were identified. Amongst these topics of interest are also identified several standardisation opportunities and reference models.

The topics identified by the task force members are closely related with the standardisation opportunities. In this respect, the experts identified several standardisation opportunities and reference models like RAMI4.0 (which has been stated explicitly) as already existing efforts in this area.

Within the task forces the priority on the needs for standardisation are clearly related with interoperability, security and protocols for data communication flexible, reliable and platform independent interfaces on all levels. In general, the members of the task forces stated their interest in the new technologies related to "smartness". Data handling and security is one of, if not the, major concerns common to all task forces.

Consolidating the results from the discussion, several major topics for which standards are needed emerged from the three task forces:

i) Definition and functionality (i.e. self-description capability) of smart components.

ii) Communication/integration and content (syntaxes and semantics).

iii) Integration of web and Internet of Things and common standards for vertical and horizontal integration.

One of the main functionalities to have in a smart component, is the ability of auto-diagnosis and the ability of adapt to new operation conditions. As implementation has to be performed by utilizing and accepting different integration technologies and protocols, safety and security is a pre-condition to all further developments, no matter if aggregation of data and information will be performed on components or machine level or via big data analysis as service in the cloud.

From the technological point of view, prevalent discussion points are architectures issues and interoperability. Researchers are more concerned about the harmonization of their individual components but no so aware of the standardisation needs. This could be due to the limitations of existing standards and approaches to identifying lacks. Considering the answers received from some of the Task Force members, it seems there is no knowledge about how standards can influence in the exploitation strategy of the results. The main non-technological discussions are about opportunities coming from new business models and strategies for its implementation. Common exploitation discussions are always there, but on top of them, what prevails is the strategy and market segment for individual companies.

The interaction with the task forces and discussion around the definition of "smartness" led to the identification of a set of technologies that are central in the implementation of smart components. From these interactions it was clear that Research and Technological Development (RTD) activities for the realisation of Smart Components should be based on already existing standards.

Different technologies are being used in the development of smart components, in order to be able to achieve several benefits such as improved reliability, better performances, and higher quality and in order to comply with the "smart functionality" requirements. One of the main functionalities smart component have to provide, identified through the interaction with the task forces, are communication and of (self-)adaptation to new operation conditions.

It was clear that knowledge and awareness about these areas exist in the community but the meaning of specific terms and expectations related to them were not always very consensual. Furthermore, the different technology trends and buzzwords are causing some confusion.

IV. STANDARDISATION OPPORTUNITIES

This section is a summary of the main findings regarding standardization opportunities from the discussions carried out within the different Task Forces and with the expert panel.

The discussions within the task forces and the roadmapping exercise in the expert panel have shown that the need for standardization is evident but not to be handled just by a small group of people. Whilst, each expert was capable to name examples in his field of application, the overall picture could not be sketched from the individual inputs. RAMI4.0 seems to be a good way of tackling it, providing a solid reference model. Also, as an initial experiment during the expert panel one exercise was the positioning of various smart components (coming from the 3 application areas) within the RAMI4.0 model, thereby exploring whether such an approach might help smart components providers to identify potential gaps in the standardization landscape.

Overall, there was a consensus that integration of information across devices was very important. The main barrier currently is a lack of a current standard(s) and the lack of critical mass to effectively drive such standard. Technologically networked, integrated, smart equipment solutions are possible but due to the lack of integration standards and security, most of the analytical and cognitive potential of such devices is currently not being used and development is very limited outside academia.

Data already is and furthermore will become highly available, and data security is an issue that needs to be guaranteed by design. If this is the case, the level of smart production systems will highly benefit from the addition information being aggregated on lower levels (provided by smart equipment and sub-machine parts). Smart sub-machine parts are clearly the building blocks for the introduction "smartness" in manufacturing. From the discussion during the expert panel, the consensus around needs and approaches emerged naturally along with the feeling that these building blocks have to be in place to make "smartness" in the other levels a reality.

The discussion in the expert panel clearly demonstrated that the need for standardization exists and that industrial uptake of smart components is hampered by the limitations of existing standards. It was also clear from the discussion that no individual or "top-down" initiatives could promote the needed developments and that clustering or community initiatives were the preferred way forward. Open innovation platforms and bottom up standardisation through communities of practice and cluster formation were highlighted as promising direction to overcome these current barriers.

Approaches that were identified and discussed favoured the creation of communities involving users, developers and researchers, along with the use of open frameworks and platforms. The RAMI4.0 reference architecture was identified as a good tool to build upon, also due to the fact that large enterprises already committed themselves towards this reference architecture model and involved in many activities around it. The use of demonstration and cluster activities were also identified as very promising approaches to for the

development of bottom up (grassroots and needs based) standards as opposed to the typical top down approach.

Overall, standardization is considered a relevant topic for the exploitation of results but not so relevant for project development. Technology harmonization prevails over standardization issues. Some of the Task Force members attend regularly working groups meetings linked with standardization organisations as CEN and VDMA, but without clear objectives. Major topics for which standards are needed emerged from the three task forces: "management shells", their definition, functionality (i.e. self-description capability); communication/integration and content (syntaxes and semantics) for the exchange of information between the different components and layers; the integration of web and Internet of Things and common standards for vertical and horizontal integration.

Task force members and experts coming from research are more concerned about the harmonization of their individual components but no so much involved on standards. This could be due to the limitations of existing standards. For the members coming from industry, the main concern seems to be the conformance to standards being relevant for future exploitation, although sometimes is not considered in the project implementation because the extra costs it could require. On the other hand, all members agree that standardisation is a long term process that it is worthwhile when the technology has been proven as successful. The need for standardization is evident but not to be handled just by a small group of people.

Barriers to wider market uptake were also highlighted. As data already is and will further become available, data security is an issue. If this can be guaranteed, the level of smart production systems will highly benefit from the addition information being aggregated on lower levels (provided by smart equipment and sub-machine parts). The main barrier currently is a lack of a current standard(s) and the lack of critical mass to effectively drive such standardisation processes.

These findings led to the development of a simple standardisation roadmap that is presented below in the roadmap chart. It summarises the main results from the perspective of standardisation needs and opportunities for smart industrial components. This roadmap, resulting from the discussion in the wide yet limited scope of the task forces and expert panel, will be used to bootstrap a wider discussion within the smart components community. As a final remark, although this roadmapping work was conducted individually by the three task forces, common trends emerged in the discussion and following analysis thus leading to the integrated roadmap conflating the individual conclusions.

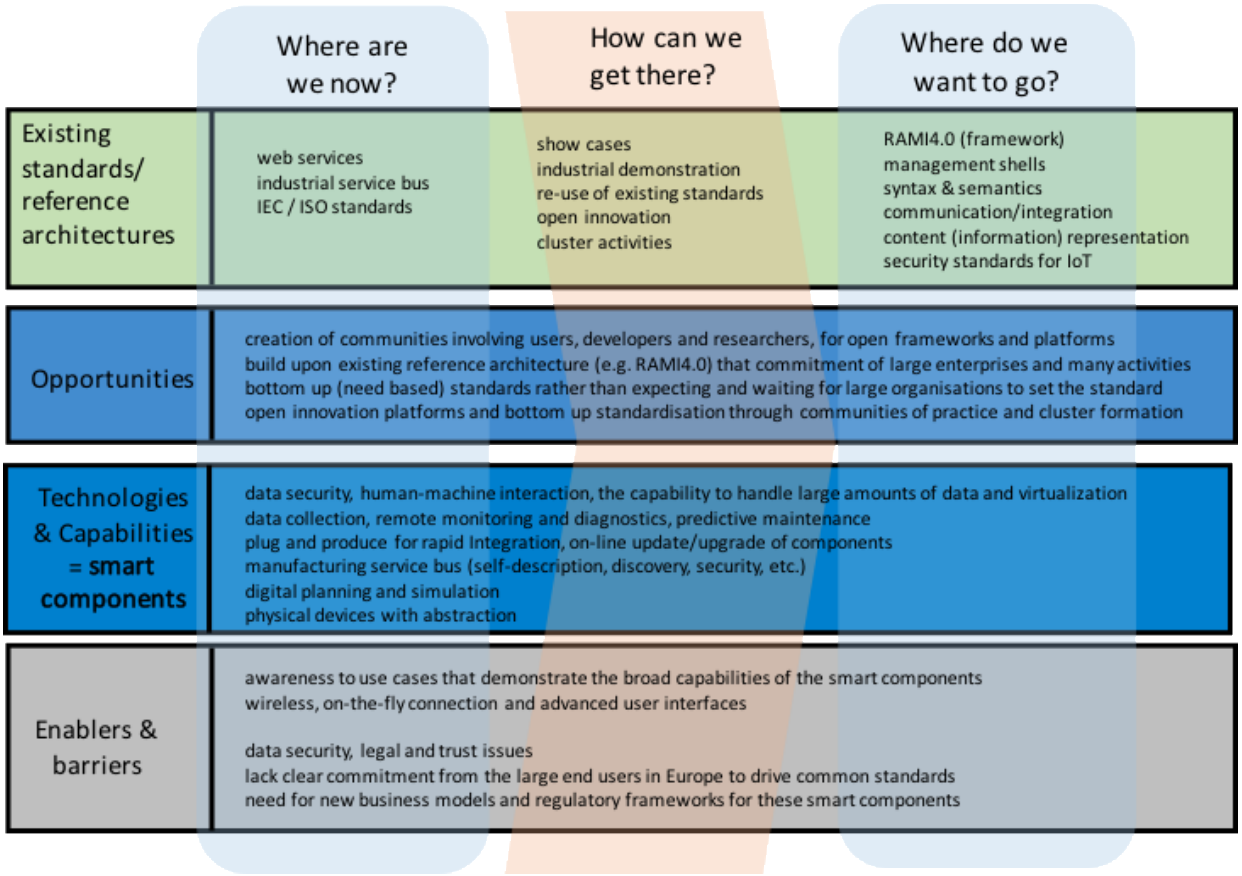

Figure 2: Simple Roadmap for Smart Component standardisation

V. Discussion and Future Work

From the discussion it is possible to conclude that step by step, key players in the field of the smart components are taking shape. Basically, the actors can be divided into three groups: tech-oriented solution providers, service producers and process developers and, finally, end users. They all see the future possibilities and challenges from a different perspective. For the moment, market uptake is taking place mainly among the first group. It consists of the developers of digital solutions, which provide the solid technological foundation for the smart component community. But there is a growing market for technological solutions and the machine builders are becoming more and more involved. The second group of companies take advantage of recent digital solutions, and they are aiming for boosting their own performance or providing more rationalized services to their customers. Companies in the second category are few, but the emerging front runners will be able to convince end users of the benefits of data collection, analysis and automated actions.

The proposed standardisation roadmap identifies the current status ("Were we are now?"), the desired progress ("Where we want to be in 5 years?") and how this progress can be achieved ("How can we get there?"). At the same time it identifies the main opportunities, drivers and barriers to this evolution.

As recognised by the experts, relevant but isolated standards already exist. These standards need to be articulated, made interoperable and complemented in a few areas accounting for the ever increasing cross-application of technologies and emerging solutions. This can be achieved by piggy backing in existing frameworks, like RAMI 4.0, which can be used for positioning of existing standards across business and factory domains as well as the need and potential for new ones. Promoting industrial demonstration programs to clearly show the advantages of smart components in industry. This effort should be clustered around ecosystem and communities and should build on open innovation practices.

From this study it is clear that the lack of a current standard(s) in different areas and the lack of critical mass to effectively drive such standards it the main barrier to a wider adoption of smart components in industry. The need to clearly define the new business models and regulatory frameworks for these smart components was also highlighted as the one of the main barriers. Questions like "Who owns the data/knowledge collected?" and "How to regulate 'in-use' buys?" are just to examples of many other question that need to be addressed and regulated to ease the introduction of smart components in the market.

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