THE BIM COLLABORATION HUB: A MODEL SERVER BASED ON IFC AND PLCS FOR VIRTUAL ENTERPRISE COLLABORATION

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ABSTRACT

For a long lasting effort and collaboration among several actors, there is a need for integration and consolidation of the building information in a common information hub, a model server. A standardized exchange format, like IFC today, in its own is not enough. If the standardized format is only used in point to point exchange situations, the project and building information will not be integrated neither consolidated.

The IFC standard can manage snap-shots of the information, but to manage the whole life cycle, there is a need for a standard like PLCS, Product Life Cycle Support, ISO 10303-239, www.plcs-resources.org, which supports some critical business needs faced by companies as they seek to implement Product Lifecycle Management (PLM) and other broad enterprise-based initiatives. The model servers shall secure collaboration both within an organization as well as throughout an extended enterprise and its various participants. One implementation of an open BIM based model server is the BIM Collaboration Hub based on the model server Share-A-space from Eurostep. The BIM Collaboration Hub was the foundation for the web-based Open ICT Platform in InPro, a 4 year European R&D project which finished in November 2010.

At its core, Share-A-space is a standards-based data consolidation and exchange solution. It is built on PLCS, a standard which promises to become a key enabler for process improvements in several service-focused industries such as aerospace and defense.

This paper presents the BIM Collaboration Hub, the technologies and how it was used as the web-based Open ICT platform in the InPro project. It presents the next paradigm in virtual collaboration in construction, where the full lifecycle is supported. The discipline specific definitions of objects and relations of the IFC standard are put into this framework and related to the extended functionality of PLCS.

Keywords: IFC, Collaboration, Model Server, PLCS, BIM Collaboration Hub

1. INTRODUCTION

The limited integration of information and automation systems supported by BIM applications of today are described in the CIB white paper on IDDS, Integrated Design & Delivery Solutions (Owen (ed.), 2009). To implement IDDS requires improvements in work processes, technologies and people's capabilities to span the entire lifecycle of the building creation related processes including environmental issues (Owen (ed.), 2009).

For a long lasting effort and collaboration among several actors, there is a need for integration and consolidation of the building information available for all stakeholders in the processes. One emerging solution is to base the information sharing on a common information collaboration hub, a model server (Eastman et al., 2011). The benefits using a collaboration hub to facilitate the implementation of a predictive Life cycle Management System (LMS) and by that improve the feasibility for adopting long-term and dynamic maintenance strategy in the FM process is discussed by Hallberg and Tarandi (2011).

A standardized exchange format like IFC today in its own is not enough. If the standardized format is only used in point to point exchange situations, the project and building information will not be integrated neither consolidated. Through life support requires a collaboration hub.

This paper presents the BIM Collaboration Hub, the technologies and how it was used as the web-based Open ICT platform, OIP, in the EU 6th framework project InPro (Sebastien et al., 2011). It presents the next paradigm in virtual collaboration in construction, where the full lifecycle is supported, based on the ISO standard PLCS (ISO, 2008). The discipline specific definitions of objects and relations of the IFC standard are put into this framework and related to the extended functionality of PLCS. For other taxonomies and ontologies than the IFC standard, dedicated mappings to the PLCS framework has to be done, as presented in chapter 4 in the mapping section.

This paper is structured in four parts:

- The InPro project – the project specific parts
- The Technologies – the IFC and PLCS standards
- The BIM Collaboration Hub – the functionality and architecture of the hub
- Conclusions

2. THE INPRO PROJECT

The four year industry-led research project InPro – Open Information Environment for Knowledge-based Collaborative Processes throughout the Lifecycle of a Building – was a project within the 6th framework of the European Commission ending in November 2010 (Sebastian et al., 2011). The main objective was to develop a model-based and collaborative way of working with a through life support.

To support this collaborative work, the InPro Open Information Environment, OIE, was defined and developed with the BIM Collaboration Hub as the basis platform, the web-based Open ICT Platform, OIP (Tarandi and Houbaux, 2010). The implementation of the BIM Collaboration Hub was based on the model server Share-A-space from Eurostep (2011).

To demonstrate the use of the OIP in early project phases, seven key processes where studied and documented in process model diagrams. As all work processes are to be requested, accepted, performed, accepted and ended, the concept of Coordination Process has been defined. All the key processes are broken down into a number of Coordination processes. In Figure 1, one coordination process interacting with the hub is shown.

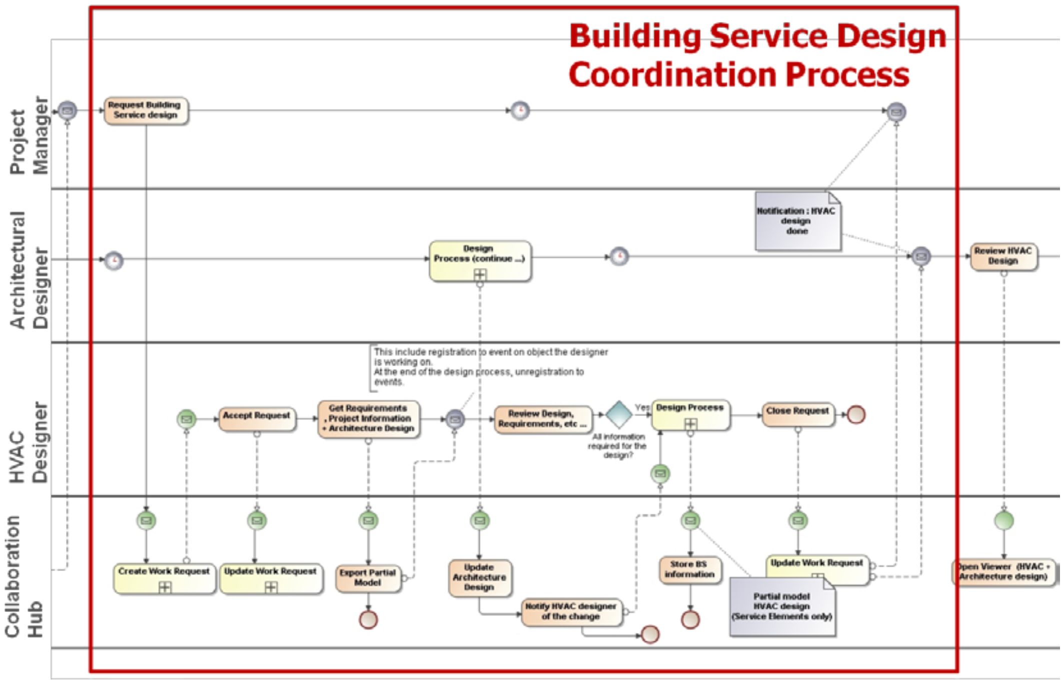

Figure 1 A coordination process for a Key Process

These key processes, focusing on early project phases, were demonstrated at the final public demonstration in Nyborg, Denmark, in September 2010 (InPro, 2010). They were: Integration of architecture design and building services design, Approval workflow, Energy analysis, Construction scheduling, Model reference definition, Client requirements management, and Cost management.

The architecture of the OIP, (Dumoulin, Benning, Tulke,2011), see Figure 2, where the BIM Collaboration Hub has been inserted for the OIP, was designed for a collaboration hub supporting the following:

- The complete object model
- Aggregating models provided by different disciplines
- Exporting and importing partial models
- Managing workflows and changes
- Exchanging information with the hub using a neutral exchange format – based on IFC

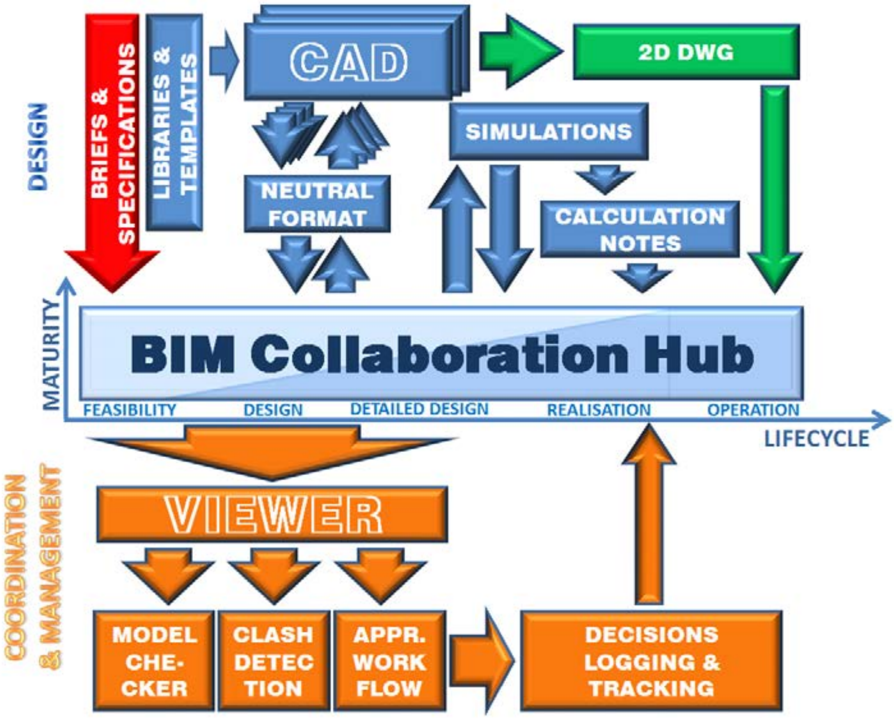

Figure 2 The architecture of the OIP

In the implementation of the BIM Collaboration Hub, in addition to the neutral exchange format IFC, the PLCS, Product Life Cycle Support, ISO 10303-239 (ISO, 2008) exchange and sharing format was added to support information exchanges not covered by IFC. Structured requirements, documents and information from other data models than IFC needed support and linking to the building information. The need to extend the scope of BIM has also been identified in the development of the IDDS white paper, where it is described as the next step in the evolution (Owen (ed.), 2009).

One of the achievements regarding BIM provided by InPro is the ability of managing changes at building element level. The decision to base the through life support on PLCS led to the need of a mapping of the IFC model into the PLCS model. The most important business demands are supported by the technologies implemented in the frame of the InPro project (Dumoulin, et al., 2011):

- **Holistic approach facilitating coordination:** the whole model created partially by different authoring tools related to different disciplines can be viewed and analyzed
- **Data sharable and reusable without retyping:** quality management of the data. This quality is depending on the input data, on the quality of the IFC translator and on the quality of the Building Breakdown Structure selected for the project.

- **Support of discipline specific point of view:** ability of managing partial models, using discipline-based configurations.
- **Support of collision detection, decision making and follow-up actions traceability:** collision detection has been successfully tested in InPro, and can provide reports stored in the collaborative hub in order to trace decision making and follow-up activities.
- **Change management including associated coordination action tracking:** stakeholders acting in the collaborative hub are stored; request for information, request order are traced by the hub.
- **Global model management:** 4D models are supported for visualization of the building and its construction processes.
- **Support of private knowledge:** the collaborative hub is the repository of the shared data of the project. The authoring tool or the expert tool can manipulate private and shared knowledge. The necessary filter to protect private knowledge is implemented at discipline level.

3. THE TECHNOLOGIES

The BIM Collaboration Hub is based on two major standards, IFC and PLCS. They together cover the semantics of the construction industry and the industrial view on life cycle management, see Figure 3.

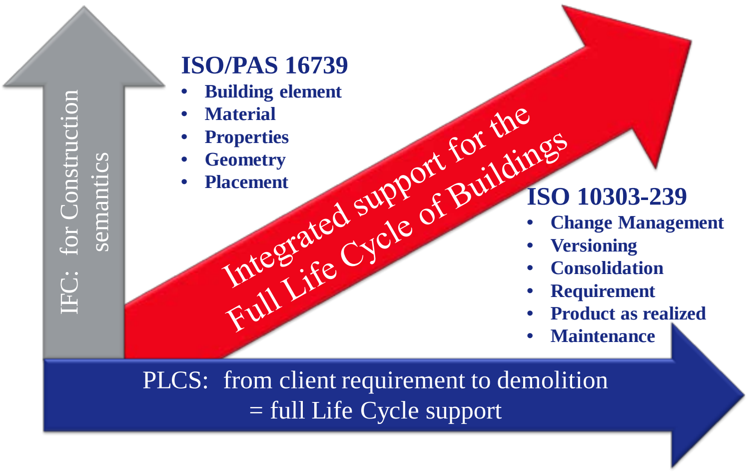

Figure 3 Relation between the basic standards used in the BIM Collaboration Hub

The IFC standard IFC2x3, ISO/PAS 16739 (buildingSMART, 2011a & 2011b) is used for the semantics, and the PLCS (ISO, 2008) is used for the life cycle related structuring and definitions.

The IFC standard can manage snap-shots of the information, but to manage the whole life cycle, there is a need for a standard like PLCS, which supports some critical business needs faced by companies as they seek to implement Product Lifecycle Management, PLM, and other broad enterprise-based initiatives.

The model servers shall secure collaboration both within an organization as well as throughout an extended or virtual enterprise and its various participants

IFC: The IFC2x3 standard is described on http://buildingsmart.com (buildingSMART, 2011a). The standard is now partly an ISO standard (buildingSMART, 2011b). The IFC data model consists of data representations of building information for exchange of AEC models (Eastman, 2011). It covers building design, engineering and production information today, but is continuously increasing the scope also with infrastructure as a possible domain.

PLCS: The business objects in PLCS cover the whole life cycle for products, with the goal to support the maintenance, influence the design, development and production for maintainability and finally influence the requirement improvements for the coming projects.
In Figure 4 these main business objects are illustrated, as well as the objects for change management, where Work requests, Change proposals, and Change orders are linked to design and products to

support configuration control. Finally a Work order will link physical changes to the product with serial number, the Product-as-realized.

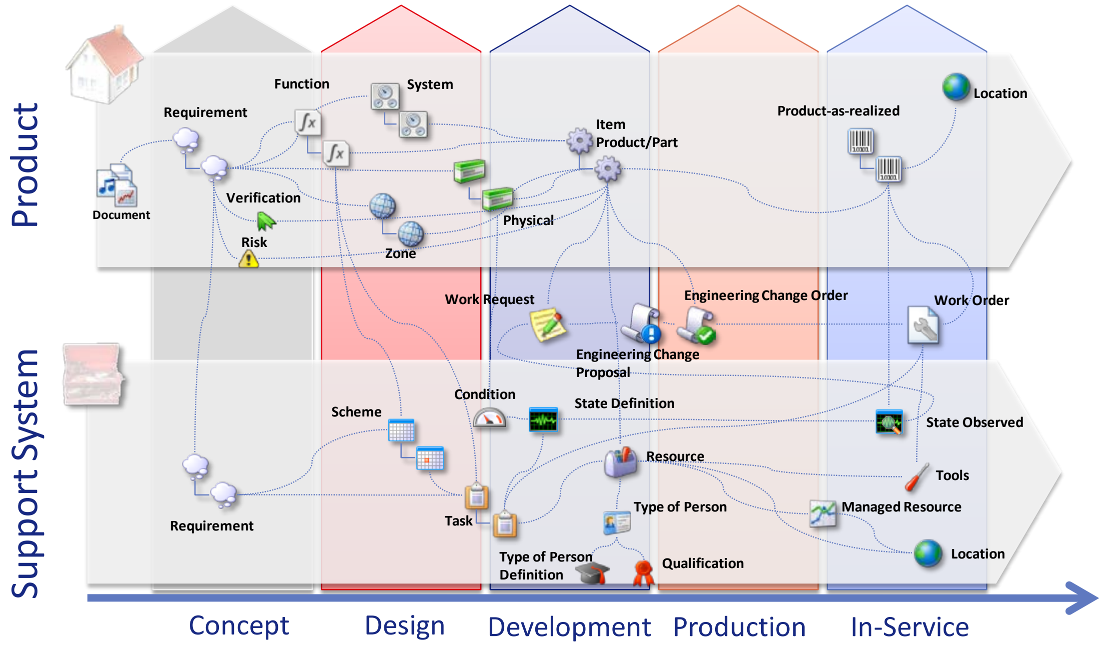

Figure 4 Main Business Objects of the PLCS standard.

Scheme with related Tasks can be linked to State definitions, to be carried out for defined states. Condition based maintenance can be governed based on the state definitions.

In Figure 5 the key elements of PLCS are shown. The elements for plans, schedules, work request and work order are highlighted to illustrate which parts of the whole information model that are used for those activities.

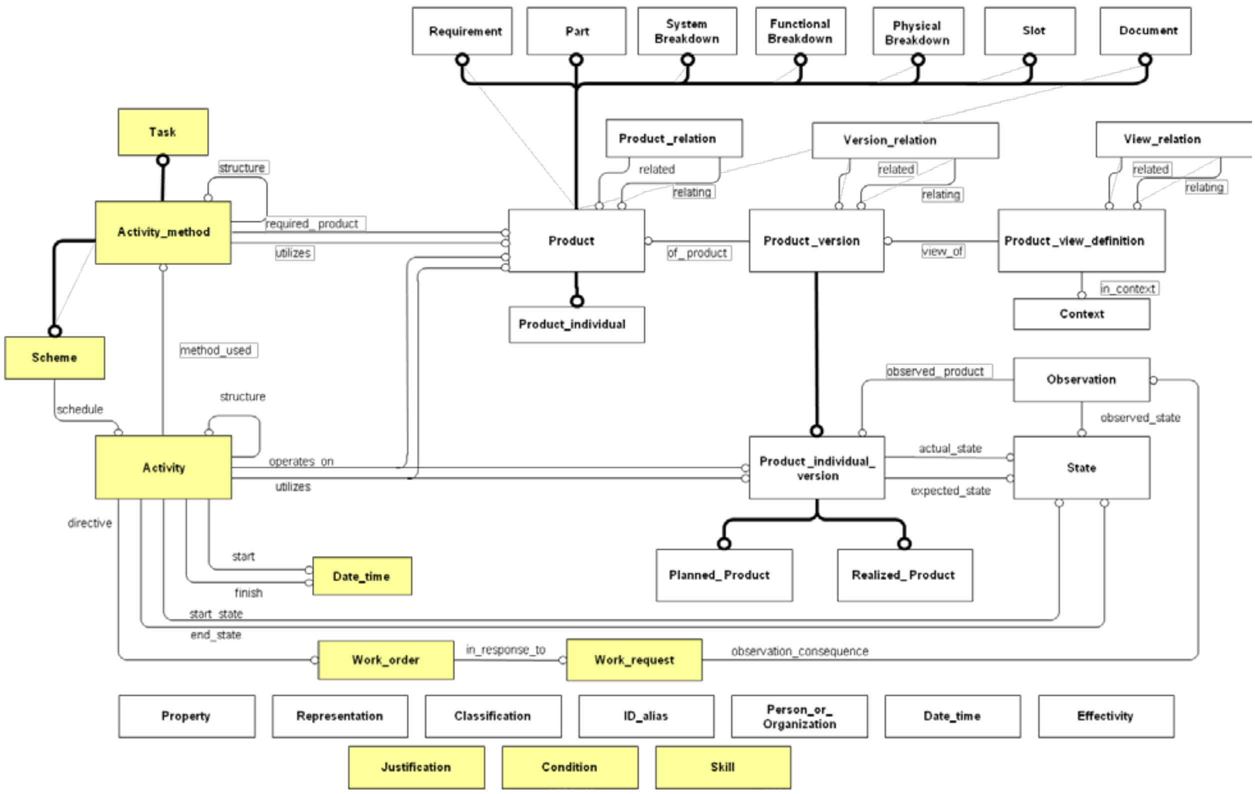

Figure 5 High level view of the scope of PLCS, showing key elements (Express-G notation)

The PLCS standard is built as a number of modules to enable extension and re-use of other already defined and developed or coming modules. The Product concept is central. It can be sub-classed into parts, requirements, documents and more, and can have relations for versioning in several ways. The relations can be in parallel as well as sequential. The relationship is an object in its own. It allows the relationship to have properties and allows many to many relationships if necessary. To the product versions, multiple representations can be linked. The versions can also have several views related for different contexts – discipline and project phase. The concept of effectivity gives the possibility to store and retrieve base lines, base configuration, and views at specific points in time. Effectivity is linked to the relationships in the structures between parents and children. Effectivity has starting date, but end date is optional.

4. THE BIM COLLABORATION HUB

The main part of the OIP, for InPro is the BIM Collaboration Hub, which is based on the model server Share-A-space (Eurostep, 2011)). For viewing and linking the Solibri Model Viewer is used, and for model checking the Solibri Model Checker (Solibri, 2011). Share-A-space is a commercial software in use at a number of industries and organizations. It has all the functions required for the manufacturing industry for PDM and PLM collaboration and information consolidation. With the InPro additions and modifications, these generic functions are now available also for the construction industry.

The BIM Collaboration Hub is using PLCS as a backbone for the life cycle management of model objects. It is supporting open BIM objects represented by IFC semantics where the IFC objects are mapped to the PLCS data model and stored in the Hub as PLCS objects. Data exchange is typically based on check-out/check-in operations using partial models or even the full dataset. Access control and versioning on object level is part of the services provided by the Hub. Viewing and checking of requirements and rules linked to objects is enabled with the Solibri Viewer and Model Checker services built into the Hub. The BIM Collaboration Hub is supporting Network-based integration.

InPro requirements on the BIM Collaboration Hub were to handle both structured data, unstructured data, and all the relevant Meta-data for the collaboration:

- **Object models** (like ”Building Information Model” data): The BIM Collaboration Hub is supporting open BIM objects, represented by IFC semantics. The objects are mapped to the PLCS data model and stored in the Hub as PLCS objects, relations and characteristics.
- **Representation models** (like 2D/3D drawings, documents, etc.): The BIM Collaboration Hub is supporting multiple representations for objects based on the PLCS standard. Documents with physical files for the representations can be linked to the BIM objects in the Hub.
- **Meta information** (like collaboration information related to basic data): The BIM Collaboration Hub is based on PLCS with object versioning, access control and collaboration information linked to relations and objects.

In Figure 6 the high level functional view of the current Hub is shown. The BIM Collaboration Hub manages the life cycle process starting with requirements and continuing with functions, systems, zones/spaces, physical elements and types, ending with individuals (product_as_realized) with serial numbers.

Functionality of the hub

The systems engineering work is illustrated by linking requirements to functions and then defining proper system solutions. The links between the individual objects in the Hub are created in the web user-interface or via special clients built for that purpose. They can also be imported as PLCS files or as IFC files, which then are mapped to system objects for relevant parts in the structure of IFC systems.

CAD defined BIM in IFC format is imported in parallel with the documents. When mapping from IFC to PLCS the type objects are automatically (rule based) or manually created if missing in the import file, and then linked to the typed objects, which can be physical elements or zones.

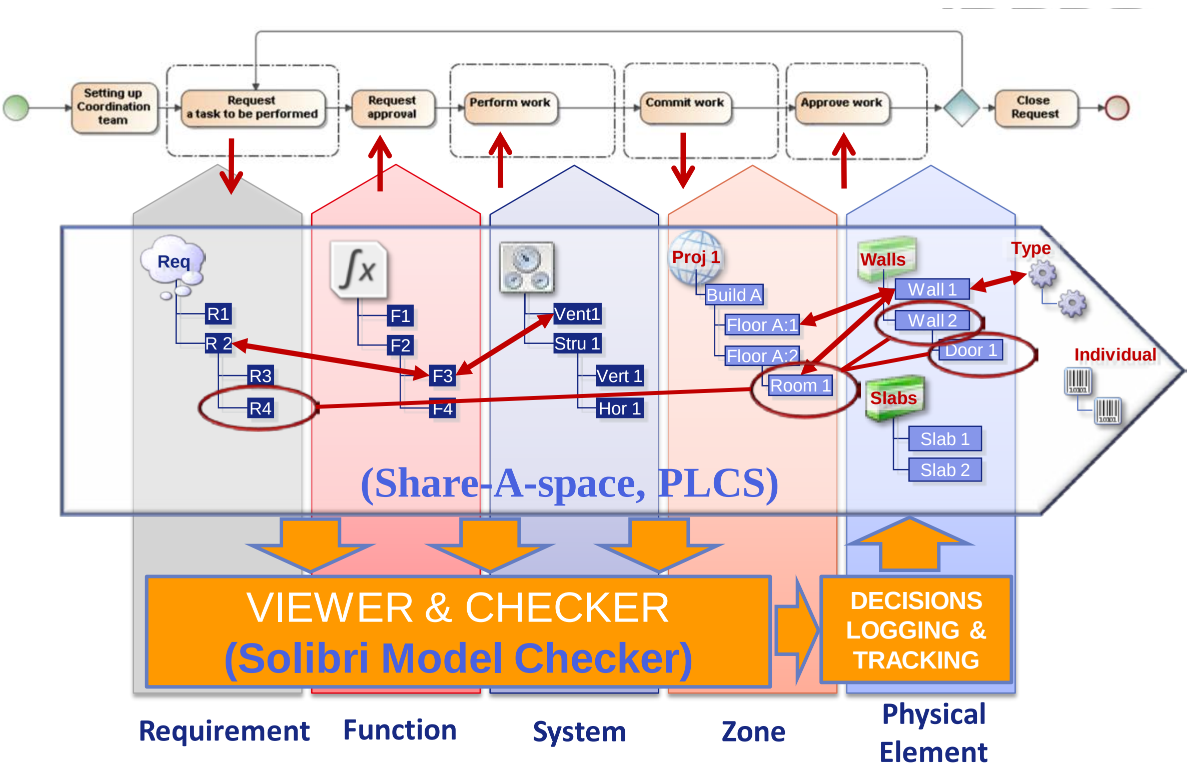

Figure 6 Overview of functions in the Collaborative Hub

The requirements are linked to the design – spaces and physical elements. Validation of a simulation result is done based on the requirement linked to the space (Room 1). The Solibri Model Viewer is integrated and the Solibri Model Checker is present as a service to call from the Hub.

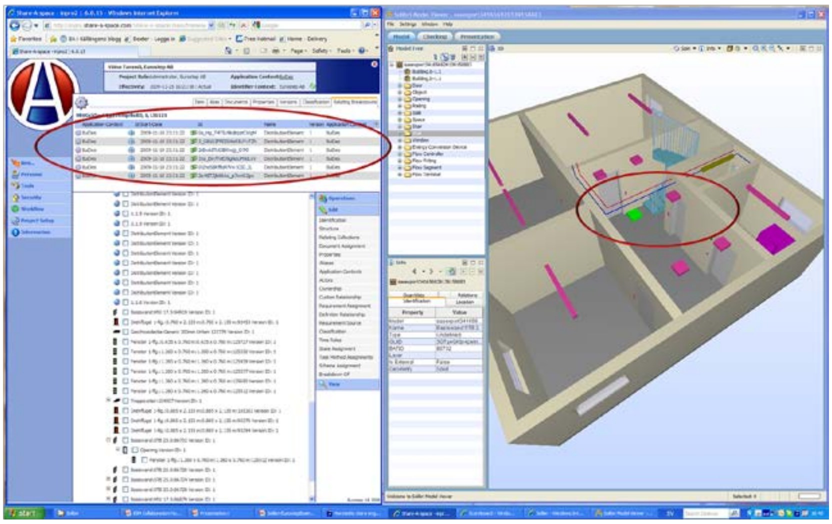

Figure 7 An individual object can be traced to all the other occurrences of its type

The graphical user interface of the BIM Collaboration Hub is presented in Figure 7, where the Share-A-space view is in the left window and the Solibri view is in the right one. Both views are linked when navigating in one of them. From the BIM Collaboration Hub the Solibri Model Checker can be started/triggered as a service. The rule set used is selected from an archive, and the service can also use e.g. a requirement with its stated value – max, min etc. – to define limitations for the checking. The results of the checking are linked to the scoped object – the building, a floor, a space etc. They are then distributed to different actors in the project, and a work request is issued with links to the Solibri information about the conflict, together with the identities of the involved objects. The document illustrating the conflict is available under the work request.

The BIM Collaboration Hub is based on the results of the European VIVACE project 2004-2007 for the aerospace industry, where one result was the Virtual Enterprise Collaboration Hub (Ahlmyren et al., 2007), which was based on PLCS.

Share-A-space opens up the full industrial tool kit for the construction and facility management sector. All the functions traditionally used in the manufacturing industry are now available for the Open BIM as the IFC-objects are mapped to PLCS and imported and stored in Share-A-space. The IFC standard is supporting building elements, material, properties, geometry and placements. In addition, documents can be imported and exported linked to building elements and other object types. From the BIM Collaboration Hub, exports can be defined based on several different selection criteria like storey, space, classification and discipline. The architecture of the Hub is presented in Figure 8.

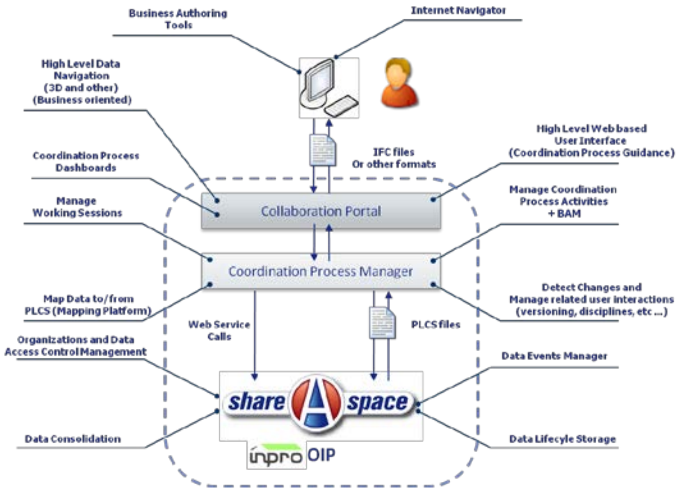

Figure 8 The global architecture of the BIM Collaboration Hub

Combining IFC with PLCS adds change management, versioning, consolidation, requirement, product as realized, and maintenance to the IFC model. The BIM Collaboration Hub addresses the whole domain for infrastructure constructions, not only buildings as IFC.

Mappings from IFC data models to the BIM Collaboration Hub

The mapping of IFC to PLCS is the central function of the BIM Collaboration Hub. The typical IFC structure is shown in Figure 9 to the left. To the right is the corresponding high level structure mapping.

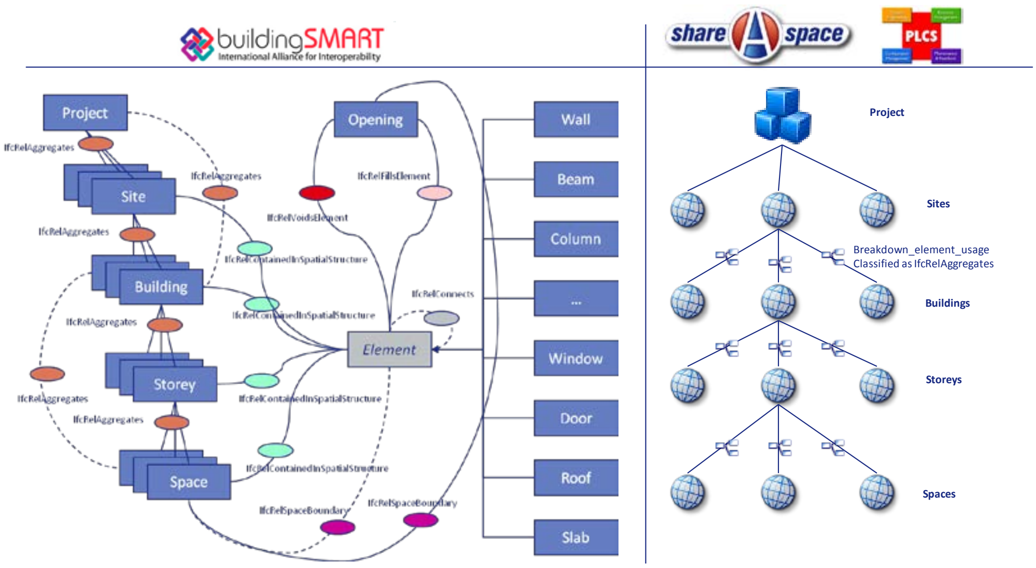

Figure 9 Typical IFC data exchange file structure and high level structure mapping

The concepts of IFC are mapped to corresponding generic concepts of PLCS, see Figure 10.

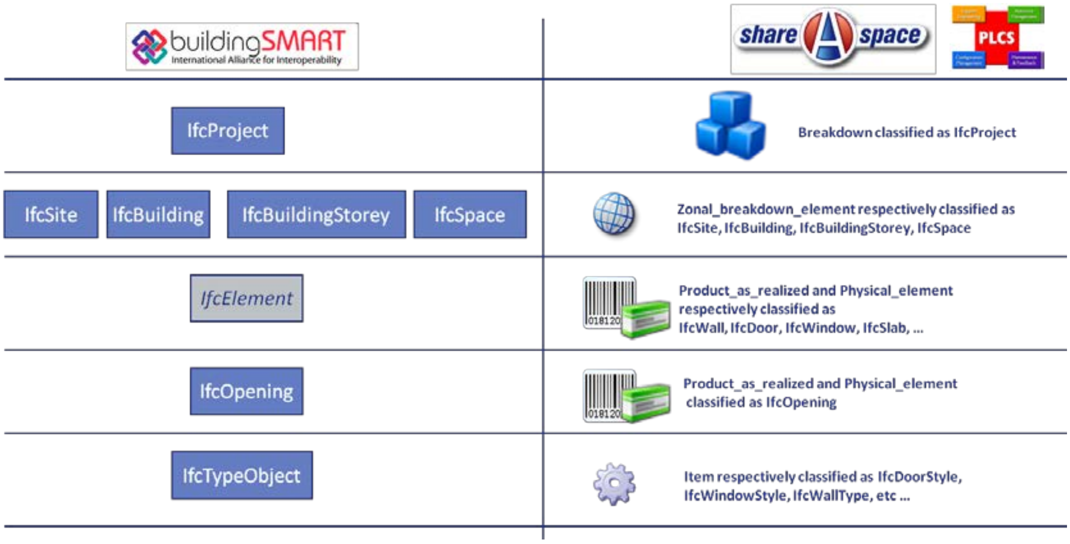

Figure 10 High level mapping from IFC to PLCS/SAs

Mapping from heterogeneous sources with different taxonomies/ontologies

In Inpro the mapping was done between the IFC data model and the PLCS generic breakdown structures for zonal and physical breakdown elements. IfcSite, IfcBuilding, IfcBuildingStorey and IfcSpace are all mapped to zonal_breakdown elements. For another type of construction, like roads with their specific spaces like lane spaces etc., the mappings can also be done to zonal_breakdown elements with their specific classifications attached. In the PLCS data model these different object structures can then be linked using the View_definition_relationship, classified for specific usages.

Share-A-space

Share-A-space (Eurostep, 2011) provides all needed functionalities for managing the information of a building (product) across its life-cycle and therefore provides an information orchestration platform which is process agnostic and complementary to any Enterprise Service Bus (ESB) such as MS-Biztalk, IBM Web-Sphere or any other process orchestration tool to fit different Business Processes.

At its core, Share-A-space is a standards-based data consolidation and exchange solution. It complements many existing solutions like CAD, Computer Aided Engineering (CAE), Product Data Management (PDM), Enterprise Resource Planning (ERP), and others, and provides the possibility for these solutions to add information and functionality to the enterprise and its business partners. Share-A-space is built on PLCS, a standard which promises to become a key enabler for process improvements in several service-focused industries such as aerospace and defense.

Consolidation rules are guidelines to the importer. They define how the importer should use the comparison between information in the import file and what is in the Share-A-space database to update the database. Consolidation rules have to be defined by the projects, as there are different principles used in industry for versioning and changes.

5. CONCLUSIONS

This paper describes the web-based Open ICT Platform, the BIM Collaboration Hub available for the industry as a test environment. It was used for the Key Process demonstrations during the last year of the InPro project, and is now further developed in pilot projects in industry and research.

Most of the requirements and specifications in the InPro project were fulfilled for the short term goals of the project. For the integration and communication with client applications used in the demonstrations and in new pilot projects, development of mapping and conversion of file formats have to be carried out to stream line the information flows. The definition of the Exchange Requirement for the information exchanges have to be further defined to be the basis for importers and exporters with their mappings for the BIM Collaboration Hub.

A near future development for the OIP is to integrate the Coordination Processes with the BIM Collaboration Hub. The Model View Definitions, MVDs, have to be developed and implemented in them. The high level API of the BIM Collaboration Hub, in combination with the Exchange Requirements definitions in the remaining MVDs for InPro long term goals, have to be defined and developed in parallel to build an efficient collaboration environment. This has to be done in close collaboration with the buildingSMART initiatives for IDM, MVD and IFD (buildingSMART, 2011). The experience of limitations in the IFC standard for collaboration support in the BIM Collaboration Hub were documented in the InPro project. These have to be complemented with input from other initiatives regarding collaboration through life, and brought to the standardization bodies, mainly buildingSMART. To get industry input, the BIM Collaboration Hub has to be tested in a multi-disciplinary collaboration environment in real projects.

ACKNOWLEDGMENTS

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