I4.0 Component Models based on IEC/EN 62264

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Abstract: *Laying the foundations on which to build the cyber-physical world of the Fourth Industrial Revolution comes down to creating a unified platform for transforming existing information solutions to ones, that meet the requirements and capabilities of the new integrated world. The RAMI 4.0 standard aims to introduce the concept of "asset" as part of the cyber-physical world, as well as to describe the hierarchical structure of assets in an industrial enterprise during their life-cycle. A similar purpose has another standard - IEC/EN 62264, which describes the operations resources as objects for integration of information between information systems of different hierarchical levels, as well as models of operational activities for definitions, planning, execution and collecting and analyzing information on these resources.*

Keywords: *CYBER-PHYSICAL SYSTEMS, RAMI 4.0, IEC/EN 62264, ASSET, B2MML, WEB SERVICE*

1. Introduction

In the field of industrial solutions, the building foundation of the Fourth Industrial Revolution was released in 2016, in the form of the DIN SPEC 91345 standard - Reference Architectural Model for Industry 4.0 (RAMI 4.0) [1]. Its main purpose is to present a complete description of cyber-physical entities' (assets) architecture as a standardized reference model built on three fundamental standards [2,3,4] and referring four others [5,6,7,8], all of them, either in the field of industry or ICT, or interdisciplinary, in the area between the two. This is why the presumption in this article is that the aim of the RAMI 4.0 standard is to encompass, summarize and enhance the knowledge covered by the mentioned standards in a different perspective. The novel part in the model is introduced with the Architecture axis, describing the role of on asset or entity, hence the name. The standard RAMI 4.0 explicitly states that the layers in the Architecture axis should not be confused with information systems hierarchy layers, rather than describe structural properties of asset or assets. Layers also do not always have to have content. [1]

Second assumption given in the article is that the structure of the administration shell of an I4.0 component may be implemented by the use of standardized industrial models, such as the ones presented in the IEC/EN 62264, along with the B2MML XML Schema Definition (XSD) that accompany the standard. This common statement is used in cases where the asset does not posses embedded intelligence.

2. Reference Architecture Model for Industry 4.0

According to RAMI 4.0, the term "asset" means anything, physical or logical, that has value for the company. The asset can be part of the physical or information world, be tangible (sensor, engine, device, installation, etc.) or not (idea, service, software program). Depending on its role in the organization, the asset can perform a certain function of the "Architectural Axis" - Asset (the artifact itself, represented in the physical world); Integration function (the means by which the physical world cooperates with the information world); Communication function (represents who-where-when information through which the asset is represented in the information world); Information function (represents data processing modified by the event / model and verification of information); Functionality (describes the function of an activity in terms of its role in the 4.0 system); Business function (describes the commercial perspective of the asset).

The remaining "Life cycle and value flow" "represents the lifetime of the active and the value-added process based on the IEC 62890 standard. In this axis, the asset is secured with its condition at a certain point in time. [2]

The levels of the "Hierarchy" axis in the Reference Architectural Model Industry 4.0 (Fig. 2) is a modification of the model of the hierarchy of equipment from the standard IEC / EN 62264 (ANSI / ISA-95), thus suitable for defining assets compatible with I4.0. [3]

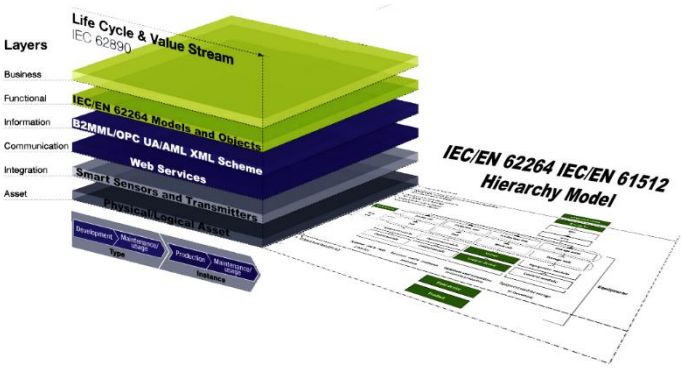

Fig. 1 *Hierarchy Model in the scope of RAMI 4.0.*

Another important aspect addressed in the RAMI 4.0 standard is the presentation and communication capabilities of the assets from the point of view of Industry 4.0. The presentation capacity of an asset refers to the extent to which it is represented and administered in an information system. From this point of view, the assets can be: Unrepresented; Anonymously submitted; Individually presented; Administered as an object.

From the communication point of view, the capabilities of the assets, may be: No communication capabilities; Passive; Active; I4.0 compatible. Assets of this type have an Administrative Shell, which contains a Manifest and a "Component Manager". Through the Administrative Shell accompanying the asset, the information system can access and request information about various functions and states of the I4.0 component (Fig.2).

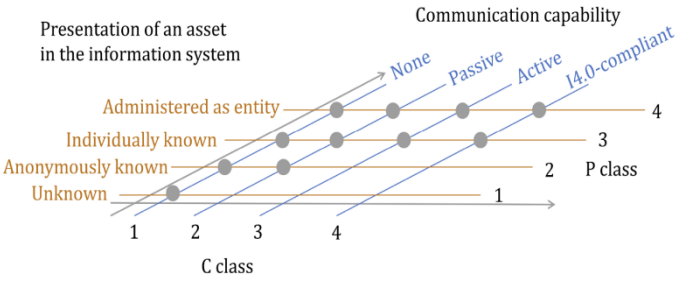

Fig. 2 *Communication and Presentation capabilities of an asset.* [1]

3. IEC/EN 62264

The main purpose of the standard is to provide a framework for integrating information from information systems at different hierarchical levels. This is necessary for several reasons: the different goals that systems at different levels have; the complexity of the tasks that the systems perform; time period or frequency of transactions execution and data aggregation. The information incompatibility may be overcome by defining the models and objects for transmission and aggregation of information between the different information levels.

The standard describes the models of the main resources used at operational level of management, on which information is collected and aggregated: Equipment Model, Materials Model Personnel Model and the logical union of personnel, equipment and materials – the model of Process Segment (workplace). These resources are the basis of the models of the definition of operation, in the sense of a series of operational activities (product production, maintenance, quality management or inventory), Production Capacity, Planning and Response.

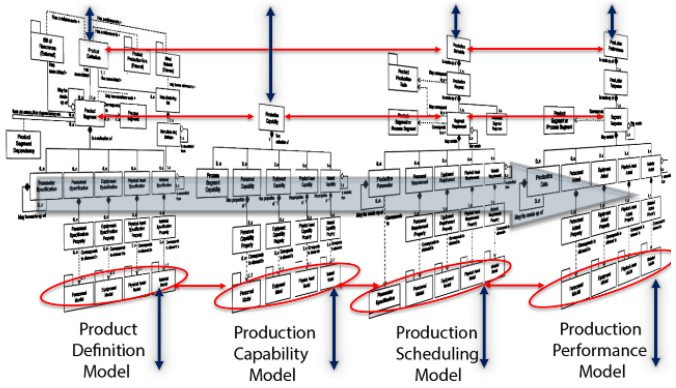

Fig. 3 *Manufacturing life-cycle and information integration in IEC/EN 62264*

The Operations Definition model introduces the term Operations Segment (or Operation) which represents a logical union of Equipment, Material and Personnel Specifications (specifies what type of Equipment, Material and Personnel that should be involved in the operation). The Operations Definition is associated with a list of Operations Segments (list of Operations). The Operations Segment corresponds to a Process Segment i.e., a given Operations should be executed on a particular workplace. Similar to the Operations Segment Specifications, there are Process Segment Specifications i.e., there must be a specific Equipment, Material with some characteristics and Personnel with particular qualification on a given workplace. The Operations Schedule, made up of Operations Requests consists of Requirements for each Operation – Equipment Requirement, Material Requirement and Personnel Requirement. Operations Capability Model is defined by the capabilities of Equipment, Material and Personnel, which corresponds to their availability in a particular time interval. The Operations Response Model is made up of responses of the scheduled operations and contain the Actual Equipment, Actual Material Consumed, Produced and/or Consumables and the Actual Personnel involved. These four models refer to Production, Maintenance, Quality and Inventory Management operations.

Figure 3 represents the four Production models as an example. The upper red arrow in the figure represent transition between production manufacturing operations of Definition of a product, Production scheduling and Production response. The lower red arrow aims to present that the Product Segment (respectively Process Segment) is related to Production Capability, Production Requirements and Production Response. The drilldown relation is expressed as Product / Process Segment Personnel / Equipment / Material Specification – Personnel / Equipment / Material Requirements – Personnel / Equipment / Material Capabilities – Personnel / Equipment / Material Actual used. The last ones from the four manufacturing models refer to same Personnel / Equipment / Material Information Models (the red ellipses). The blue arrows aim to pinpoint the objects, for which information may be transferred between different hierarchy level information systems.

Transferring of information through the use of the IEC/EN 62264 framework of models and objects allows tracking and tracing throughout the life-cycle of operational activities related not only with the product production, but to maintenance, quality and inventory operations (Fig. 4). [10].

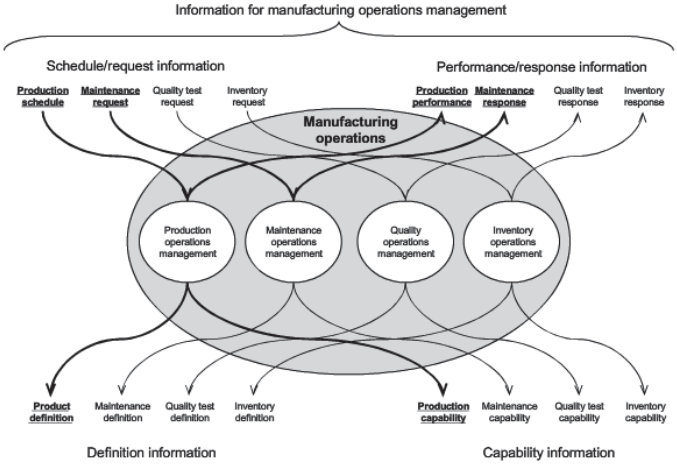

Fig. 4 *Information model of manufacturing operations.[10]*

4. I4.0 Component Models based on IEC/EN 62264

I4.0 compatible assets or I4.0 components are assets that have at least passive communication capabilities and are administered as an entity in an information system by an administration shell. There are a number of requirements for the administration shell, that are as follows:

a) The administration shell consists of the body and the header.
b) The body contains information on the asset in question.
c) The header contains information on how the asset is used.
d) The administration shell contains the key elements, the manifest and the component manager.
e) The information in the administration shell must be accessible using service-oriented architecture (SOA) and must take the corresponding security requirements into account.
f) The administration shell represents information on application aspects.
g) The administration shell is structured using views.
h) The administration has a unique ID.
i) The asset has a unique ID.
j) Even a factory can be an asset that has an administration shell and can be addressed using its ID. It should be possible to apply the concept of nesting.
k) Types and instances must be indicated as such.
l) The administration shell can contain references to other administration shells or I4.0 information.
m) Additional properties, such as manufacturer-specific ones, must be possible.
n) A reliable minimum set of properties must be defined for each administration shell. [1, 11, 12]

MES/MOM systems are industrial information systems that handles the models described in the standard IEC/EN 62264 and administer the whole information about manufacturing resources throughout their operations life-cycle. Following the standard objects allows the ease of integration with other information systems. Figure 5 presents a UML structural class diagram of the IEC/EN 62264 material model used in the MES/MOM system MOM4. Each class contains attributes from [9] and basic functionality applied with the help of methods: OnCreate(); OnRerieve(); OnUpdate(); OnDelete();

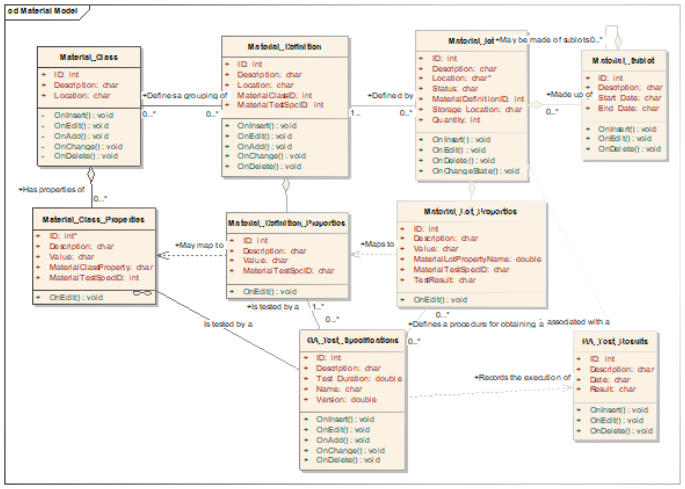

Fig. 5 *UML Class Diagram of the IEC/EN 62264 Material Model*

The Material Model represents a form of classification of materials used for the purpose of defining, scheduling and execution of manufacturing activities. All tangible piece of material is presented and described by the object Material Lot. The Material Lot is defined by a Material Definition, which describes the lot in all aspects needed. The Material Lot consists attributes as: ID, Location, a reference to a Material Definition ID, State, Storage Location and Quantity. The Material Lot has properties, the restriction count of which may depend e.g., on maximum capacity specification of a table in SQL Server [17].

Material Definitions have properties that describe them uniquely. A logical grouping of Material Definitions with similar characteristics for the purpose of scheduling is referred as Material Class. The Material Class has properties that describe it. Both the Material Class and Material Definition properties may be tested by a QA Test Specification which has to define a procedure for the Material Lot to obtain a property. Every QA Test Specification made creates a Material Lot Quality Test Result, which may have relation to the Material Lot current quality state. The Material Model is referred from every operations model in the form of Specifications, Requirements, Capabilities or as Actual Consumed, Produced or Consumable materials.

The information integration between industrial systems from different or same informational layer is made with the use of common XSD (XML Schema Definition), which represents a formal description of elements in an XML document. This formal description may refer models, as it is in B2MML (Fig. 6) [13] referring IEC/EN 62264 models (Fig), OPC UA [14,15] and AutomationML (AML) [16].

As shown in Figure 1, the meanings of communications function, as described in the RAMI 4.0 standard are performed in the form of web services. The web service technologies allow platform-independent communication through World Wide Web in a standard data format, such as plain text, HTML, JSON (REST) or XML (REST or SOAP services).[18]

The following piece of code is presented as a functional illustration in WSDL (Web Service Definition Language) of the web service operation “Create”:

```
<wsdl:portType name="IB2MMLService">

<wsdl:operation name="Create">

<wsdl:input
wsaw:Action="http://tempuri.org/IB2MMLService/Create"
message="tns:IB2MMLService_Create_InputMessage"/>

<wsdl:output
wsaw:Action="http://tempuri.org/IB2MMLService/CreateResponse
" message="tns:IB2MMLService_Create_OutputMessage"/>

<wsdl:fault
wsaw:Action="http://tempuri.org/IB2MMLService/CreateWCFServ
iceExceptionFormFault" name="WCFServiceExceptionFormFault"

message="tns:IB2MMLService_Create_WCFServiceException
FormFault_FaultMessage"/>

</wsdl:operation>
```

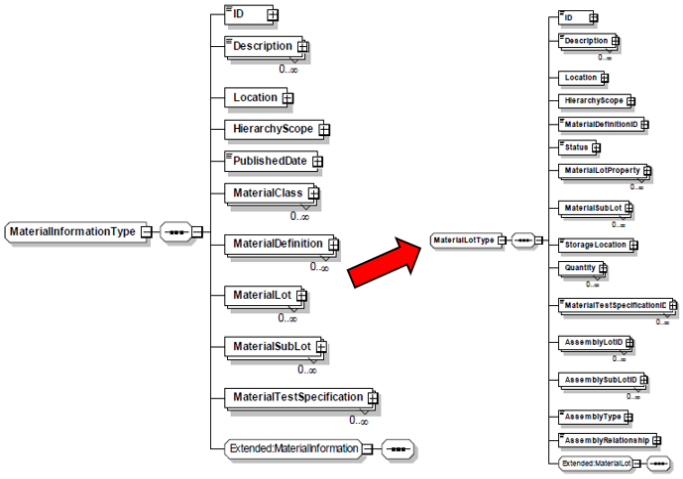

Fig. 6 *B2MML Material Information and Material Lot Schema [13]*

All the models described above have the following characteristics while interacting with each other:

a) The combination of all models is used for establishment of a logical, virtual representation of a given resource in an administrating information system.

b) The resource is described in all necessary aspects by properties.

c) Involving the resource in activities, covered by the models of definition, scheduling, capability and performance represents information of the usage of a resource.

d) The models define a meta-information of properties of the resource and description of operations that can be invoked through external interface.

e) The information described in the models is accessible using service-oriented architecture (SOA) [18] and take the corresponding security requirements into account.

f) The models represent information on application aspects.

g) The models are structured using views.

h) The models have a unique ID.

i) The resources have unique ID.

j) The Equipment hierarchy model is native to IEC/EN 62264 and comprise Enterprise, Site and Area, all of which may refer to a Factory.

k) Each resource is an instance of its class or definition.

l) Operations Models refer to resource models.

m) Additional properties, such as manufacturer-specific ones, are possible through Property classes.

n) A reliable minimum set of properties must be defined for each resource (attributes).

These fourteen assumptions, along with the definitions of the Manifest and Component Manager substantiate that IEC/EN 62264 standard models, B2MML XML Schema Definition and web services may be used as a suitable solution for building Administration shell for assets – I4.0 Components, when no embedded intelligence is applicable.

5. *Conclusions*

The Fourth Industrial Revolution is yet in its beginning and there are still many concepts to be clarified. The DIN SPEC 91345 standard - Reference Architectural Model for Industry 4.0 (RAMI 4.0) is a basis for future science and industry development. Although there are every day examples of Cyber - Physical Systems

that include assets with embedded intelligence, most of the assets in manufacturing production don't have any presentation capabilities at all. A small part of all assets is being administered as an entity by information systems and has Communication capabilities – I4.0 Components. The meanings by which the Administration shell of an I4.0 Component may be realized, must be standardized model-based descriptions of structure and behavior that follow all stages during the asset's life cycle.

Among others, IEC/EN 62264 standard models and objects may be used as a functional, information and communication architecture structure, together with the accompanying B2MML XML Schema Definition and the use of Web Service technologies.

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