PLATTFORM INDUSTRIE4.0

DISCUSSION PAPER

Interaction Model for Industrie 4.0 Components

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1. Motivation and starting point

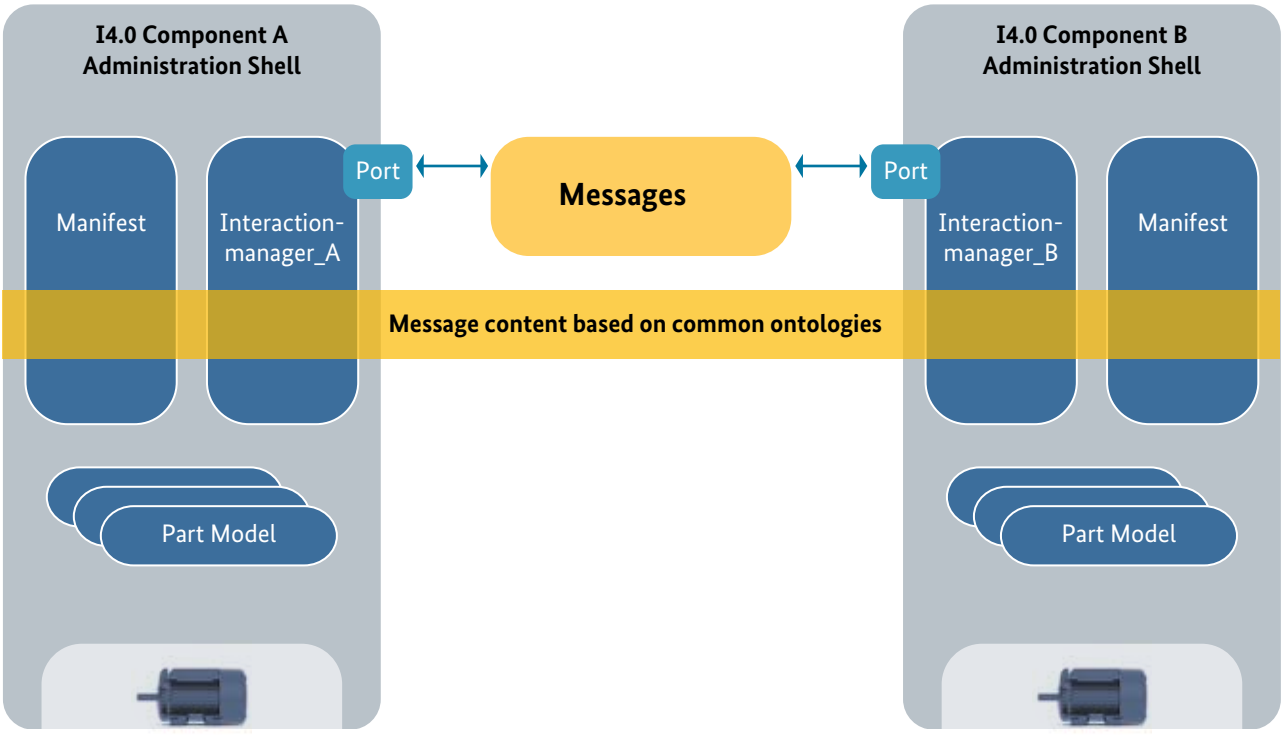
One of the essential characteristics of I40 systems is that assets are represented as I40 components and come directly into contact with each other to execute tasks in value chains. For this purpose special interaction patterns are required.

The fundamental concept is that I40 components exchange messages (Fig. 1) that are handled by an interaction manager. The message elements are configurations of properties. These are represented in the manifest of the Administration Shell. The properties are known and unique in the I40 system. The properties can originate from property catalogues, for example as they are given by eCl@ss. The use of other technological concepts such as ontologies is also possible.

Messages are sent by the Administration Shells of I40 components by means of a series of services which make domain-specific submodels of the I40 components available to external users (Fig. 2). For this purpose wide-ranging services are necessary which provide infrastructure measures for access to the submodels. Generic and basic services are worthy of mention.

Generic services make it possible to investigate properties from the manifest of the Administration Shell. Administration Shells are the means of providing assets with the desired flexibility. The assets should no longer be usable based on a configuration planned in advance. Instead it should be possible that the partners agree at the runtime about the functionality suitable for the task at the appropriate point in time and with the parameterisation and configuration appropriate for the special case. It must therefore be possible to negotiate these agreements during operational running. Corresponding services must be provided in the I40 component.

Fig. 1: Exchange of messages between I40 components



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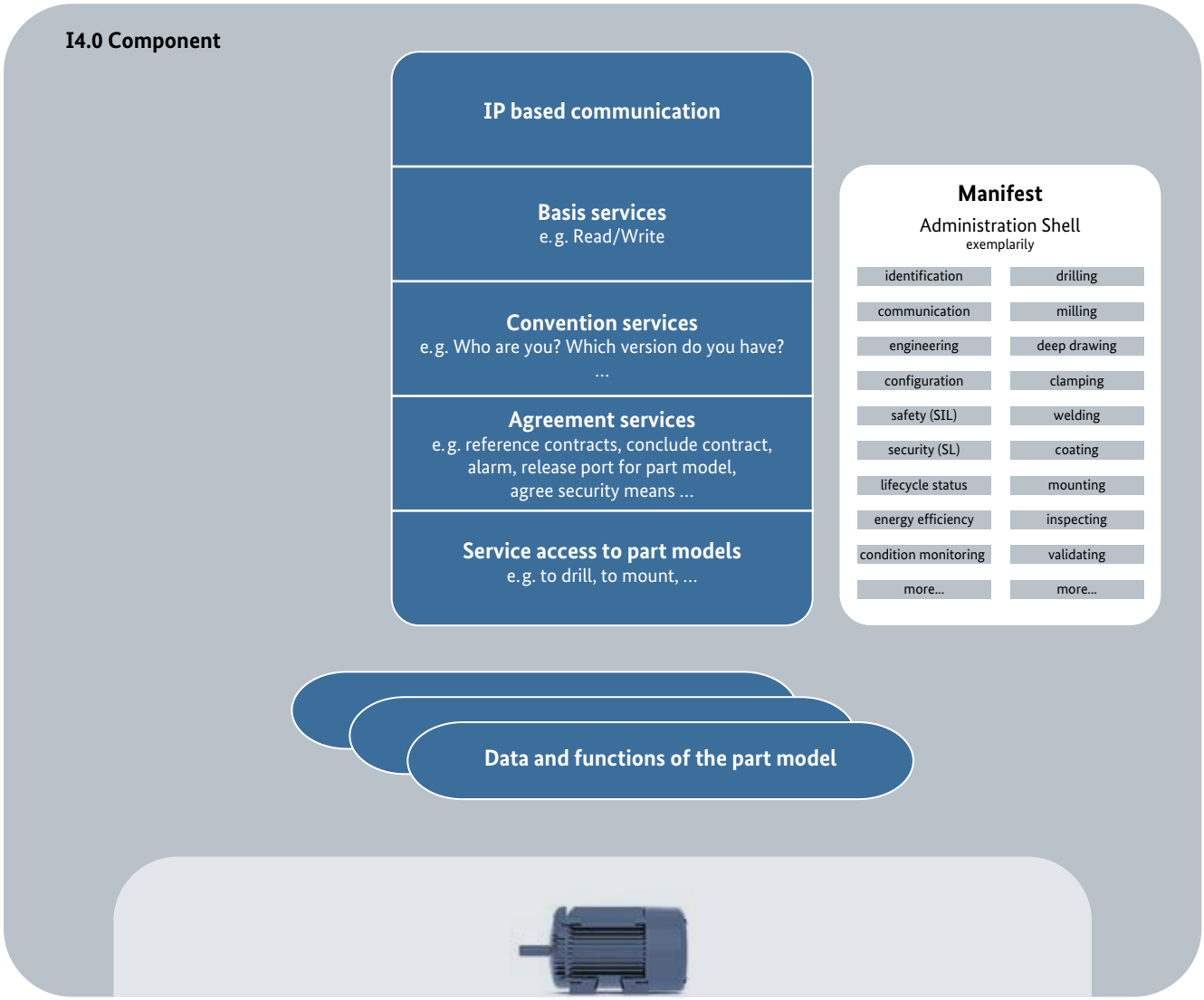
The basic services provide access to the IP-based communication system and derive from the various communication technologies. In principle services are accessible through ports. The interaction manager receives the messages through a standard port and organises interaction with the manifest and the submodels. In the simplest case there is only one port (e.g. Port 80 for http usage) if only one service may be activated. Otherwise a session model is required, which allocates a suitable port for each service processing.

The "Ontology" sub-working group (UAG) of AG1 "Reference Architecture, Standards and Standardisation" is responsible for the agreement services and the interaction model required for the latter.

Fig. 2: Services of I40 components



Source: Plattform Industrie 4.0

2. Patterns of interactions between I40 components

The scenarios of I40 systems always feature a high degree of flexibility and adaptability during operational running for current tasks of the value chains. In addition to the processing of the productive task, such as the completion of a drilling task, it must be established in advance whether the I40 component can execute the task functionally, with the required non-functional features (e.g. quality) and at the required point in time. One can also imagine inclusion of non-functional features from the "business" aspect, such as the price. This requires interaction patterns which, for example (here just a selection, which is not exhaustive), can fulfil the following tasks.

- Ascertainment of the identity and agreement on the security measures – before starting the reciprocal activities the security aspects must be clarified
- Initiation of a task in a value chain – reference to an existing agreement
- Initiation of a task in a value chain – request for a collaboration
- Negotiation of a task in a value chain – negotiation of the details (functional and non-functional features) for a collaboration
- Commissioning of a task in a value chain – authorisation of a collaboration (in the simplest case the task starts immediately, though the task can be placed in a batch buffer (job list))
- Execution of a task – the collaboration is processed between the principal and the corresponding submodels
- Termination of a task in a value chain – termination of the job relationship after fulfilment
- Report of malfunctions during negotiation and job processing – during the overall initiation and processing of a task undesirable or unforeseen events can occur which must be dealt with

Each I40 component contains a specific set of these interaction patterns which corresponds to its purpose, i.e. the functional content and the position in a value chain and the life cycle phase. It can be assumed that all I40 components check and adjust security aspects before it is possible to start the cooperation. Single I40 components will make use of pre-prepared agreements which must be uniquely identifiable and thus verifiable and can activate the submodels offered in sequence. Through a wide range of combinations and expansion stages one can also imagine I40 components (e.g. a processing centre in production engineering or a modular station in process engineering) which can negotiate the content and processing of a job. For example, these I40 components could offer batch functions, which are nowadays typically contained in MES systems, as submodels.

3. Interaction model for the agreements between I40 components

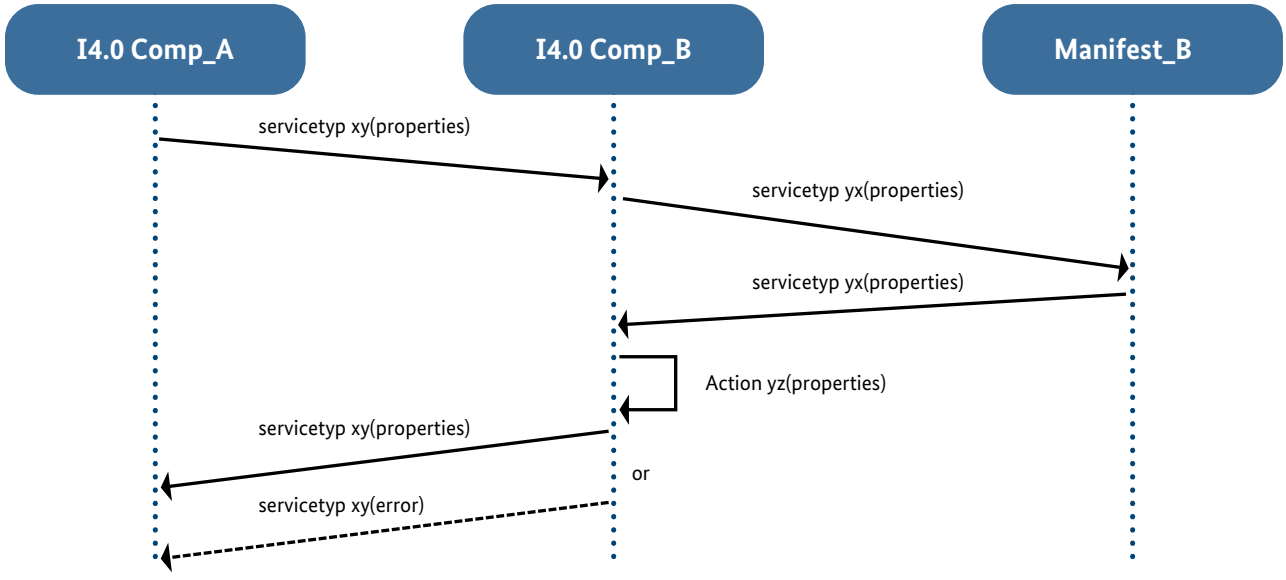
Interactions consist of messages exchanged between I40 components, interaction between the latter results. The purpose of an interaction is that the acting participants, i. e. the I40 components, impact on each other in order to jointly carry out a task. The detailed description of the messages and the participants, the sequence of the messages for fulfilment of the interaction pattern and the triggering of actions and of other behaviour-activating processes must be mutually agreed upon.

An example should briefly illustrate this. The example is only given for the purpose of understanding in principle, the specifications being still under discussion. In the event of initiation of a task based on an existing agreement, an I40 component sends a request to the desired I40 component (Fig. 3). The corresponding interaction manager of the component to which the request has been sent checks the entry in the manifest to make sure that this agreement exists and may be activated. The properties relevant to this pattern are deposited in the manifest. If this is the case a corresponding positive answer is given together with the data required for the task. If this is not the case a corresponding negative response is given with indication of an error tag. The UAG will state the corresponding specifications in detail for all patterns.

The properties in the request and the properties deposited in the manifest are the same. They are designated by means of unique identifiers. The values of the properties in the request represent requirements and the values deposited in the manifest are assurances. Thus properties with the same identifier can have different configuration statements. This must be taken into account in a check, to the extent that rules exist which check fulfilment of the requirement by means of the assurance. In the simplest case equality must be established. However, cases are also conceivable in which validity ranges are checked or, indeed, logical and mathematical relationships between different properties have to be evaluated. The results of the rule processing control the concrete configuration of the interaction patterns.

When the designated examples are abstracted the pattern consists of the definition of interacting partners (here I40 components, manifest and submodel), the message contents (e. g. IDs and properties of agreements, and jobs), the processes (represented here by a sequence diagram) and additional rules, for example for checking requirement and assurance. The result is a language in the message contents whose sequences (interaction patterns) and rules are defined for the controlling of alternatives in the process. For this purpose, formal and semi-formal models and methods are used, such as class diagrams, sequence diagrams, state machines, classifications and property catalogues.

Fig. 3: Typical interaction patterns



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4. Classification of the terms language, semantics, ontologies and grammar in the concept

These terms are used in a parrot-like manner, that is as brightly and colourfully as a parrot. They most certainly also represent different aspects, depending on whether one uses them as a linguist, a philosopher, a computer specialist or an engineer. I40 systems are technical systems and therefore the viewpoint of the computer specialists and engineers should be used.

Language in the wider sense is the set of things/entities and rules which serves for mutual understanding in the systems. This includes alphabets, rules regarding the structure of terms, vocabulary groups, rules regarding the structure of phrases, etc. Material actions can also be included. Once speaks of language in the narrower sense if the characters exchanged exhibit an internal structure in the sense of a grammar.

The specification of a language does not determine the totality of the meanings. Instead the meaning of formal language is on the whole strictly compositional, i. e. the meaning of the combined entities. For example, the meaning in sentences, results entirely from the meaning of their parts in conjunction with the rules of their composition. For determination of the meaning of the entities of natural languages, as a rule additional knowledge about the usage context is necessary.

Grammar is the set of all rules whose application produces the set of all valid character strings/ messages which can be found in the language of Industry 4.0. The grammar describes the legitimacy of the construction of a language.

Interaction semantics: The data exchanged in the framework of an interaction are given their meaning by the actions/transformations of the recipients initiated by them, thus by means of understanding and processing. Indeed, the condition of the recipient can at the same time play a role. A distinction thus needs to be made between formal (the action at the recipient is formally defined) and informal semantics. Formality can be achieved if allocation of meanings to the transitions is carried out in machines on the recipient's side.

Ontologies are formal descriptions of relationships between terms expressed by means of a language (see above). At this point we would refer the reader to a very well written and informative publication [1].

What does this now mean for the interaction model of I40 components? I40 components must speak a common language for their co-operative tasks. The message types and the content must respectively be unambiguously known to the co-operation partners. For this properties are used which are anchored in the manifest. Properties are terms, i. e. they have an unambiguous identifier (ID) and additional features, such as designation, definition, value range, unit of measure, and references to a standard. For this the definitions based on IEC 61360 can be used. For structural aspects class diagrams can be used. The rules are described with the sequence diagrams and the indicated controlling of the co-operative interaction. They form part of the grammar of the language. If automata are defined for the interaction partners (e. g. for the behaviour of the interaction managers), then one increases the degree of formality and obtains clearer semantics. If relationships exist between the properties and if these are utilised mechanically, ontologies can be used for this.

5. Current work and outlook of the UAG

Strictly speaking, the UAG defines a language for I40 components with particular focus on the conclusion of agreements and activation of the interactions with the submodels. The content of the tasks can thus be negotiated and activated. Negative cases are viewed as malfunctions.

The UAG is working on an example in which all designated aspects are dealt with in order to be able to take into account these experiences during the specification phase. At the same time the designated models are used.

References

[1] **J. Busse, B. Humm, Ch. Lübbert, F. Moelter, A. Reibold, M. Rewald, V. Schlüter, B. Seiler, E. Tegtmeier, Th. Zeh:** *Was bedeutet eigentlich Ontologie? Informatik Spektrum 37 4.2014.*

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