A Modular Reference Architecture Framework for Seamless Cross-Organizational Interoperation

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Abstract: The relentless march of improvements in the cost-performance ratio of information and communication technologies facilitates the emergence of an "Internet of Services" which allows for the easy provision and consumption of electronic services on a global scale. However, existing approaches for the realization of electronic interaction between organizations still exhibit significant weaknesses from both a managerial and a technological perspective. In this work, we propose a novel reference architecture framework for electronic business media which builds on the design principle of modularity. The framework aims to increase efficiency, flexibility, to reduce design and management complexity, to account for uncertainty and finally to enable a decentral evolution of business media for electronic, cross-organizational collaboration.

1. Motivation

Cross-organizational electronic collaboration is about to gain significant momentum, but still faces both managerial and technical challenges. On a **technical level**, existing e-business standards such as UN/EDIFACT, the RosettaNet framework or the UN/CEFACT e-business stack only represent building blocks of limited scope and are not yet implemented according to a structuring framework that allows for high operational agility (Schroth & Schmid, 2008b). On the basis of these focused technical standards, service providers already offer hosted environments providing integration functionality (Lheureux et al., 2007; Schroth, 2008). However, these services suffer from a focus on automation rather than business innovation, an inherent enterprise rather than multi-enterprise perspective, and are often setup as hard-wired, inflexible stand-alone island solutions (Lheureux et al., 2007). On a **managerial level**, existing enterprise architecture frameworks such as the Zachman Framework (Zachman, 1987), the U.S. Department of Defense Architecture Framework (DoDAF), the Federal Enterprise Architecture Framework (FEAF) and The Open Group Enterprise Architecture Framework (TOGAF) can be considered merely system-centric since they mainly focus on aspects within the boundaries of an enterprise and thus do not necessarily optimize the governance of federated information environments.

In this work, we propose a **modular reference framework** (Schroth & Schmid, 2008a) for distributed enterprise architectures which support the organization and implementation of seamless electronic interoperation. Based on the St. Gallen Media Reference Model (Schmid & Lindemann, 1998), this framework builds on the principle of modularity (Armstrong & Deborah, 2006). It encompasses the principle of modularity to increase efficiency, flexibility, extensibility, to reduce design and management complexity, to account for uncertainty and finally to enable a decentralized and collaborative evolution of business media for electronic, cross-organizational collaboration. **Modularity** encompasses "an important set of principles in design theory: design rules, independent task blocks, clean interfaces, nested hierarchies, and the separation of hidden and visible information. Taken as a whole, these principles provide the means for human beings to divide up the knowledge and the specific tasks involved in completing a complex design or constructing a complex artifact" (Baldwin & Clark, 2000, p. 90).

2. Reference Architecture Framework

According to Schmid (1998), media can be considered as enablers of interaction between agents. Agents can be represented by machines, individuals or whole organizations. Such interaction enablers can be structured into three main components: First, an organizational component (*O-Component*) defines a structural organization of agents, their roles, rules which impact the agents' behavior as well as the process-oriented organization of agents' interactions. Second, a logical component (*L-Component*) comprises a common "language", i.e. symbols used for the communication between agents and their semantics. Without such a common understanding, the exchange of data is possible, but not the exchange of knowledge. Third, a physical component (*C-Component*) supports the actual interaction of physical agents. This component can also be referred to as carrier medium or channel system (Schmid & Schroth, 2008). From a generic ("meta") perspective (Figure 1), the proposed reference architecture framework foresees the following **modular building blocks**: Media such as medium 1 (M1) enable the interaction between certain agents (A1.1, A1.2, A1.3 in Figure 1). Each medium is symbolized as a circle encompassing defined information objects (black symbols) to be exchanged between agents. Taken together, media and their directly connected agents are referred to as interaction modules in this work.

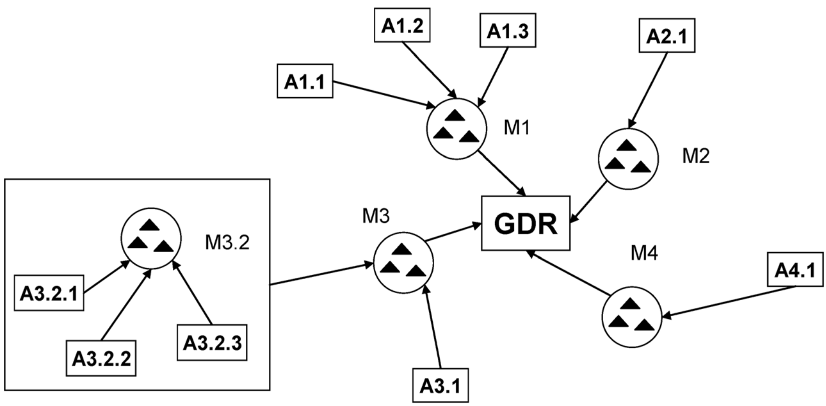

Figure 1: Meta View: Agents interoperating across diverse media

Design rules are of paramount importance for the modular design of a system comprising several media and agents. In general, by defining a set of design rules, modules can be designed and operated by separate, specialized groups working independently of one another. The autonomously designed modules then seamlessly work together and can even be substituted through other modules, amended, excluded, and split without redoing the whole. In compliance with Baldwin & Clark (2000), design rules are constituted of (1) the definition of the actual modules of a system, (2) their respective interfaces (required for information hiding), as well as (3) integration protocols, determining the interaction of the modules. Arrows in Figure 1 symbolize the visibility of such design rules for diverse modules. In this exemplary scenario, Global Design Rules (GDR) are visible for the designers of medium modules M1, M2, M3, and M4. The designers of agent modules aiming to interoperate via these media "see" the design rules imposed by the designers of the respective medium (e.g., A2.1 sees the design rules defined by M2). However, as the designers of M1 adhere to the GDR, the designers of its connected agent modules see these implicitly, too (this kind of design rule visibility can be compared with the inheritance operation in modular software programming). Through compliance with the global design rules, designers of business media (M1, M2, M3, and M4) ensure interoperability between their connected agents both on an organizational and a technical level. In the next sections, such design rules will be elaborated. A further important characteristic of our reference architecture framework is the inherent **recursivity**: Each agent can internally be organized as another multi-agent system, featuring a medium enabling the interaction of agents (for example, a firm may interact with other firms as one single agent, while the provision of its services is organized as an orchestration of numerous other agents (see the rectangle shown in Figure 1). The introduction of clear interfaces (as foreseen and defined as part of design rules) allows this encapsulated module to only expose some of its internal information and hide the rest. In case the module adheres to different design rules than the ones valid in its environment, additional adapter modules are required. These mediate between diverse organizational, logical, and infrastructural standards (Schroth & Schmid, 2008b).

2.1 Organizational View

The organizational view provides design rules of general validity which allow for the modular organization of electronic, cross-organizational interoperation. As a first step, the common interaction scenario has to be structured (**decomposed**) into **activities** or sub-tasks according to the general design guidelines for modular systems (Parnas, 1972). Rather than simply reflecting the business process, we analyze and structure the collaboration into ("public") sub-tasks. Secondly, we assign each of the sub-tasks specific **roles** to define the user who are allowed to perform these. Based on the roles which specific agents connected to the medium assume, they are allowed to perform only subset of the determined activities. As a third and final step, the diverse sub-tasks shall be decoupled by defining mutually independent, organizational "**interaction modules**" as argued above. Through this modularization, responsibilities for tasks and related information (data access rights) can be clearly separated and limited to those roles which are explicitly involved in a certain module. Also, in case of modifications (e.g., required by legal changes), the modules can be re-organized without affecting other modules. In order to exactly define these modules we need to examine and model the **process-oriented organization** of interaction in the respective context. The different activities performed by the agents are subject to diverse temporal interdependencies: Steward's task structure matrices (1981) represent an adequate methodological basis for the modularization of tasks: As visualized in Figure 2, all fine-granular pertinent activities which have been identified are assigned to both the x- and the y-axis of the matrix. The exemplary activities 3, 9, and 15 have been depicted in this figure. For each of these activities, all "predecessor" activities need to be determined in the next step (certain activities may only be performed after specific "preceding" activities have already been conducted). In order to visualize such temporal interdependencies, the following rule is applied: In case activity i precedes activity j, a mark (x) is put in column i and row j of the matrix. The resulting fields within the matrix which feature a high amount of marks mean highly interdependent groups of activities (representing the interaction modules discussed before). While high interdependencies exist between the activities which constitute an interaction module, no interdependencies are supposed to exist between activities which belong to different interaction modules. Each of the off-diagonal xs which are not included in one of the interaction modules basically represents an infringement (Baldwin & Clark, 2000) of the principle of information hiding and may be removed through the definition of design rules: In the task structure matrix shown in Figure 2, for example, activity 3 (part of interaction module 1) is required to be performed prior to activity 9 (part of interaction module 2). In case the outcome of activity A conducted by an agent as part of interaction module one, for example, constrains activity B performed as part of interaction module 2, a design rule is required to determine the outcome of activity A in a way that B does not depend on the actual outcome anymore. Figure 2 already shows the results of imposing organizational design rules: Points of interconnection between interaction modules disappear, leading to a comprehensive decoupling of modules.

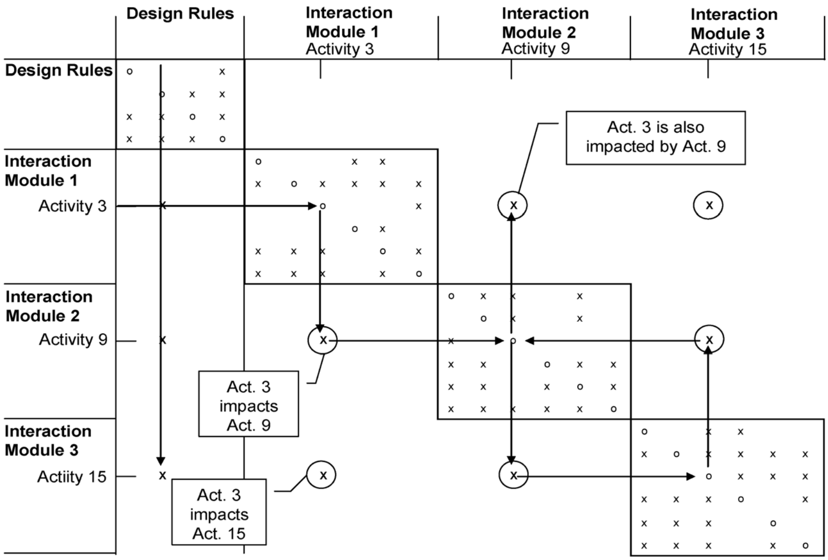

Figure 2: Task structure matrix for organizational modularization

Figure 3 depicts the resulting organizational view of the proposed reference architecture framework: After modularization, loosely coupled interaction modules emerge which consist of media and agents and are connected to each other via clear interfaces and possibly also adapter modules (in case of different design rules). As can be seen in Figure 3, each of the agent as well as the media modules comprises a dedicated structural organization (which can also be referred to as contract structure (Chandler, 1962)) and a process-oriented organization (also referred to as task structure (Baldwin & Clark, 2000)).

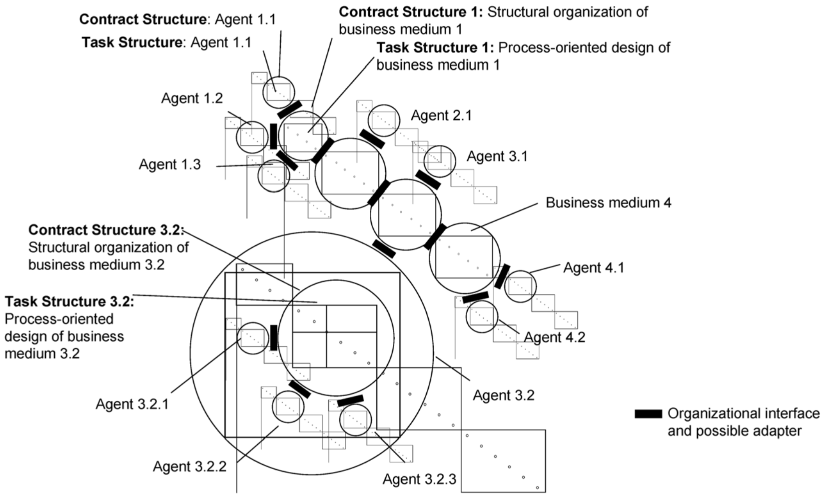

Figure 3: Organizational View

The principle of recursivity also concerns the organizational view: Agent 3.2 is internally organized as further multi-agent system. Business medium 3.2 as well as the connected agents (A3.2.1, A3.2.2, A3.2.3) feature individual contract and task structures. In case this internal organization of agent A 3.2 follows different design rules than those valid outside (GDR), organizational adapter modules are required (Schroth & Schmid, 2008b).

2.2 Infrastructural View

The infrastructural view of our reference architecture framework relies on and extends the recent Swiss governmental initiative “Event Bus Schweiz (EBS)” (Müller, 2007). Each medium can be considered as a sub-bus participating in a network of federated other bus-media. By adhering to a minimal set of technical design rules, all sub-buses and their respective connected agents are interoperable and still are provided a considerable individual design freedom. Figure 4 depicts such a set of buses which are connected to each other as well as to agents via interfaces. Only in case of different design, additional adapter modules are required. Again, one agent (e.g. A3.2) can be internally organized as multi-agent system featuring a medium and connected agents.

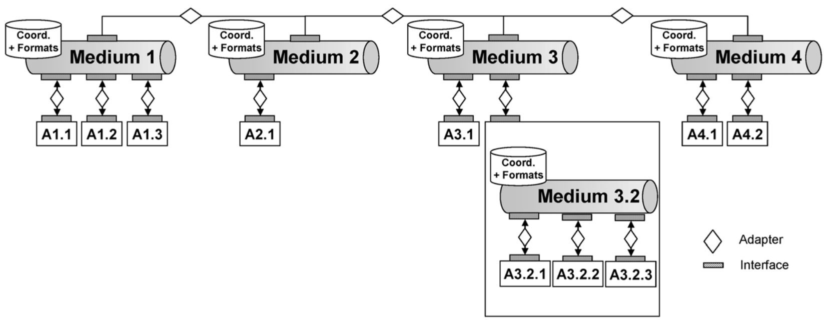

Figure 4: Infrastructural View

The design rules imposed by the EBS mainly determine a set of *operational services* which each compliant sub-bus needs to implement: abonnement services (supporting publish/subscribe message dissemination), directory services (allowing for publishing and retrieving business partners and their respective profiles), event catalogue services (documenting all messages which may be disseminated via the bus including the agent roles which may send/receive them), transformation services (accounting for mediation of electronic artifacts which adhere to different format standards), security services (encryption and decryption), operating services (for media administration purposes), error services (automatic failure detection and removal), routing services, and validation services (e.g. for evaluation of correctness and integrity of exchanged information). In order to account for the principle of modularity, the EBS specification allows for loosely coupling an arbitrary number of other buses which again may connect diverse agents. For cross-medium interoperability, each bus can incorporate an individual service design as long as it adheres to minimal "global design rules" which require the implementation of a standardized directory service, an event-catalogue service and the conformance to a specific message envelope standard (Müller, 2007). On this basis, events can be seamlessly exchanged between agents connected to different bus media. Within the modular bus media, additional *coordination services* can be deployed without impacting other buses (see the data base symbols in Figure 4): These may implement the individual contract and task structures as argued above. Due to space constraints, please refer to Schroth & Schmid (2008a, 2008b) for a detailed elaboration of these services.

3. Conclusion

In this work, we presented a modular reference architecture framework for electronic business media that overcome the drawbacks of today's B2B software products and services: On an organizational level, overall tasks need to be decomposed into fine-granular, modular sub-tasks. To define a process-oriented organization, task structure matrices can be used to define interdependencies between sub-tasks and thus define mutually independent interaction modules. On a physical level, the Event-Bus Schweiz concept represents an excellent basis for building electronic bus media which are seamlessly interoperable (a wide network of loosely coupled sub-buses is expected to emerge in Switzerland) and still allow for deploying rich and individual services (services which are only useful for one business ecosystem are exclusively implemented on the respective sub-bus and are shielded from the outside world). The framework is currently being applied to the context of corporate tax declarations in Switzerland. In (Schroth & Schmid, 2008a, 2008b), detailed elaborations on its real-world application as well as agility improvement potential are provided.

4. References

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