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This section summarizes related work on technical integration, semantic integration with semantic web services, and service matchmaking with multi-objective optimization.

**Technical Integration**

Technical system integration is the task to combine networked systems that use heterogeneous technologies to appear as one big system. There are several levels at which system integration could be performed [1], but there is so far no standardization process that explains how to integrate in general.

Need for integration over heterogeneous middleware with different APIs, transport capabilities, and architecture styles implies either solutions like SOA [14] or the development of static and structure wrappers between each combination of middleware, and thus increases the complexity of the integration.

**Integration with Semantic Web Services**

Integration is solving problems originating from data across disparate and semantically heterogeneous sources [6]. These problems include the description of inconsistencies, and the model specifications in different sources [18]. One of the largest problems is a problem in semantic web services, making semantic correspondence (or equivalences of different data sources) [3] a foundation for a solution to semantic integration problem has been added to OWL. Other ontologies promise to provide machine-understandable information, while allowing human-readable formats as well as the derivation of ontologies based on the model.

In this paper, we describe the semantic mappings of BP and SS and the utilization of the integration with respect to the available network capabilities. We demonstrate the machine-understandable description of BP and SS requirements at the point of view of understanding and the availability of the integration infrastructure.

**Related Work**

This section discusses related work on technical integration, semantic integration with semantic web services, and service matchmaking with multi-objective optimization.

**Technical Integration**

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**C. Service Matching Approaches**

Semantic matchmaking can be seen as a major feature of semantic integration, which supports designers and system integrators by providing sets of possible integration partners according to structural and semantic attributes. However, the relevant semantic concepts are hard to define unambiguously for general domains, thus the focus on the well-defined domain like ATOM provides semantic clarity.

Other approaches are using a mapping of WS-Policy to OWL. WS-Policy provides a general purpose model and syntax to describe the policies of a Web service. It specifies a base set of constructs that can be used for other Web service specifications to describe a broad range of service requirements and capabilities. The main advantage of representing Web Service policies using OWL is that it is much more machine-readable than WS-Policy and that provides a framework for exploring richer policy language. Verma et al. [20] present an approach for matching the non-functional properties of Web Services requests using WS-Addressing. Oldham et al. [19] present a framework for the matching of providers and consumers based on WS-Agreement. The WS-Agreement specification defines a language and protocol for capturing relationships with agreements between two parties.

Both WS-Policy and WS-Agreement define a generic framework for the representation of standard Web Service policies. To map both frameworks to semantic service description languages, they are being developed language approaches for so-called Semantic Web services [13]. The Ontology Language for Web Services (OWL-S), which seeks to provide the building blocks for encoding rich semantic service descriptions in a way that builds upon the Web Ontology Language (OWL), supplies Web Service providers with a clear set of markup language-constructs for describing the properties and capabilities of their Web Services in unambiguous, computer-interpretable form [4]. WS-DL-S [15] is another approach for annotating current Web Service standards with semantic descriptions. The Web Service Modeling Ontology (WSMO) [10] is a framework for Semantic Web Services which defines a rich conceptual model for the development and the description of Web Services based on two main requirements: maximal decoupling and strong mediation. All three approaches, OWL-S, WS-DL-S and WSMO, provide mechanism for semantically describing Web Services, with the major goal of allowing generic description of service functionality as well adding semantics to general service descriptions like provided/consumed messages or service bindings. This ambitious goal seems very useful for generic service descriptions; however its usage is limited in specific domains like in the ATOM domain, since too specific features would complicate a generic approach too much. Therefore, we defined our own ontology-based architecture for describing the properties and features of the ATAM services [17].
III. RESEARCH ISSUES

Recent projects with industry partners from the ATM domain raised the need for semi-automated BP integration support in technology-driven integration environments. Recently, we developed a data-driven approach [16] that explicitly models the semantics of the problem space, i.e., BP integration requirements and existing infrastructure capabilities [17]; the solution space, i.e., the connectors, and data transformation between SSs. Finally, we provide a process to bridge problem and solution spaces, i.e., identify feasible BP and SSs pairs while fulfilling business requirements and optimizing the chosen integration solution according to multiple objectives.

IV. ATM SCENARIO DESCRIPTION

This section describes the integration scenario ATM domain used throughout this paper. The ATM (Figure 1) represents an infrastructure layer in which static attacks on ATM infrastructure (e.g., denial of service) and dynamic attacks on ATM infrastructures (e.g., by changing the state of the infrastructure). The system integrators choose the most promising scenarios, the so-called collaboration sets. SM2: The selected collaboration sets are then optimized regarding the original infrastructure requirements of both the business BPs and the SSs, as well as the available limited capabilities of the infrastructure's nodes and links. The outcome of SM2 is an optimized configuration of the integration solution, consisting of the selected collaboration sets as well as their grounding to the underlying integration network infrastructure.

Figure 2: A Typical ATM Domain Integration Node

As shown in Figure 2, the integration network of business services connected to integration networks between these nodes, there may exist different kinds of work links using different transmission technologies (radio or wired transmission) as well as different secure technologies for communication purposes. The nodes and links, like throughput, availability, reliability, and security are explicitly modeled in order to be capable of generating suitable communication paths for particular requirements, e.g., the communication link between ATMIS Node and the Red Node 12 represents a relatively secured communication path which may be requested by the ATMIS business service.

V. SEMANTIC SERVICE MATCHMAKING

This section describes the semantic service matchmaking as well as the multi-objective optimization of the collaboration services candidates.

A. Specification of Possible Collaboration Candidate Sets

A possible collaboration candidate set is defined as a behavioral algorithm that, using dynamic & static SQA solution results, will provide a set of candidate sets reduced by applying the allowed to the possible collaboration candidate sets. If the rules are met, the set of candidate sets is reduced by applying the allowed to the possible collaboration candidate sets. This section describes the reduction rules.

B. Validity-Check and Optimization of Collaborations

Once all collaborations have been specified a Scenario is derived. A Scenario contains beside all collaborations a specification of collaboration behaviors that must be satisfied by the roles of the network infrastructure, so that the solution is optimized according to the given objectives. The following process steps needed to optimize the scenario is explained.

1. Preliminary Check. The process step checks whether there is at least one single network route for each collaboration satisfying all required network and infrastructure specific policies. If this step cannot be completely satisfied by the process raises an exception. The system integrator either updates or removes the collaborations which cannot be mapped to a network route, and restarts the process step, or adapts the semantic infrastructure model, by adding additional nodes and links.

2. Route Derivation. Once it has been verified that each collaboration can be mapped to at least one route in the network, the process step derives every possible route for each collaboration. The only restrictions are that no node is allowed to appear twice within the same route and all policies have to be satisfied. The valid ones are retained; the others violating the restrictions are removed. At the end of this process step, each collaboration will have either a single route or a set of valid routes to choose from.

3. Creating Scenarios. The processing step combines each route of each collaboration with each other. This means that a scenario consists of a set of collaborations where each collaboration is exactly once in each scenario. The more scenarios are created, the higher the probability to find a scenario that is well suited for achieving the stated optimization objectives.

4. Evaluation. The process iterates through all scenarios and calculates their fitness according to the optimization objectives. The fitness of a scenario is the fitness of all its containing collaborations, and represents the real values (e.g., the time to message needs and the costs along the chosen route) of the objectives. The fitness represents the trade-off of the configuration, the routes of each collaboration predetermining the set of fitness values is then analyzed according to the Pareto Front approach [8]. The Pareto Front contains either a single Scenario or a set of Scenarios. In the latter case, there may be several "nearly equivalent" configurations as optimization solutions.

5. Multi-Objective Optimization. We have accomplished the process of optimizing collaborations by implementing a Java nPOEMS approach into the SWISS framework. nPOEMS is an evolutionary algorithm using the concept of dominance for multi-objective optimization. The results and explanations of the approach can be found in [9].
In this section, we evaluate the SWIS framework using a clear and comprehensive example to show the principles of our approach.

by the two provider services, so the system has to find the suitable information that match with the consumer service's needs. Additionally, the service ATMS_TransRegIs defines a policy for the underlying integration network, stating that only secure network links may be used for the communication.

From the domain knowledge description, we know that Flight.ID is a synonym for Flight Number, that Departure and Arrival are combinations of the airport code and country code of departure/arrival, and that the FlightStatus arrived or departed, can be derived by checking the occurrence of either TimeOfArrival or TimeOfDeparture.

Next, we calculate the network resources needed for sending messages from the SFDP Node to the PPF Node with less capacity. From the integration network description, we can see several nodes connected by links. Each link contains information regarding source node and target node, support for secure transmissions and the transmission delay. The communication between ATMS to PPF needs to be done using secure connections only. There are two possible connections, either via Node Y or via Node Z. The system will choose connection via Node Y because it has less delay (6) than connection via Node Z (7).

VII. DISCUSSION

The example shows that even for small problems the solution space is typically large. However, large BP and SS integration networks consist of hundreds of integration nodes, and changing or adding new domains and capabilities make the correct and efficient identification of feasible BP and SS pairs a recurring complex and error-prone task. By providing only sets of feasible service-provider and consumer candidates, semantic matchmaking supports designers in identifying possibly usable BP and SS pairs as well as SS and network capabilities to provide SSAs for each BP. Out of all the possible integration pairs, designers need to choose the wanted sets. These sets may be optimized with multiple objectives (e.g., representing the capabilities of the underlying integration network infrastructure, with its limited and specific as possible).

CONCLUSION AND FURTHER WORK

We presented an approach for semantic service matchmaking for software services (SSAs), the "System Information Sharing (SWIS) Business Process (BP) Framework. The SWIS framework is an integration framework for understandable SWIS models to describe BP pairs as well as SS networked capabilities to provide SSAs for each BP. Out of all the possible integration pairs, designers need to choose the wanted sets. These sets may be optimized with multiple objectives (e.g., representing the capabilities of the underlying integration network infrastructure, with its limited and specific as possible).

The feasibility of the SWIS approach in an ATM domain. The example shows that the solution space is typically large for large BP and SS integration networks. A tool supporting the process of BP identification can provide assistance with a set of promising Service Providers strongly reduces the human effort on mapping a much smaller space of matching candidates to determine the best fitting service pairs.

We have developed a data-driven approach [1] that detects the semantic similarity of the service space, i.e., the solution universe, i.e., the connectedness and interactions between SSAs. In this paper, we describe the bridge problem and solution spaces, i.e., the BP and SS pairings that we use to optimize the chosen integration solution approach.

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REFERENCES