An Agent-based Framework for Multi-domain Service Networks
Eduroam Case Study

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Abstract: This paper introduces a methodology for the acquisition of the computational model of a service provider group and its transformation into agent-based model. The methodology is as follows. First, we analyze the case at the signal layer, i.e. the message exchange between actors, and model them with the components of "belief, desire and intention (BDI)" agent architecture. In the next step, we identify the implicit actions, intentions, and conditions which are necessary for the story to occur. These steps correspond to descriptions of agent-roles observed in the case study. As a concrete result, a preliminary implementation of the framework has been developed with Groovy.

1 INTRODUCTION

A priori identification of benefits and risks to stakeholders that collaborate to provide a service across multiple service domains is a problem that depends on the goals, benefits and capabilities of multiple service providers. In this paper, we will explore the feasibility of Agent Based Modeling(ABM) use as a first step to identify the benefits and risk in such an open domain system. ABM has been introduced to model an open domain where agents are self-governed autonomous entities that pursue their own individual goals based only on their own beliefs and capabilities (Abdelkader, 2003). Open domain systems have an intuitive mapping onto an ABM. An open domain system consists of smart, cooperative and autonomous agents where each of them has its own goal to achieve. Agents present specific roles in this system and interact with others as a means to accomplish their goals. Modeling such systems receives considerable attention from both the Artificial Intelligence (AI) and the communications network communities (Abdelkader, 2003; Dignum et al., 2005). ABM provides a way to investigate the benefits of collaborating autonomous agents. A service network is an example of an open system. Service networks are composed of competitive service providers that see the benefit in collaboration. It is important to note that in such networks, each member cannot provide a service on its own and collaboration provides benefits such as reduced cost or increased revenue. For instance, providing authenticated Eduroam WiFi access to visiting students is an example of a campus IT service that a single university is unable to provide on its own without having a collaboration with other universities. The Service Provide Group (SPG) (Gommans et al., 2015) is a way to describe such collaboration. The SPG framework provides a way to organize thinking about multi-domain service network and can be used to describe the structure of such a collaboration. Eduroam is a good example of such collaborations. In this paper, we take the Eduroam confederation as an example of open domain system which consists of multiple autonomous agents, where each of them have their own goal and intent to collaborate.

ABM is an effective platform for the SPG because they provide mechanisms to allow organizations to advertise their goal, negotiate their terms, exchange rich information, and synchronize processes at a high-level of abstraction (Preece et al., 1999). A comprehensive model for ABM must be able to express the global goal and the requirements of the domain in a distributed way by considering the autonomy behavior of the SPG.

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This paper aims at presenting an ABM for multi-domain service network. We demonstrate the transformation of a sequence of inter-agent interactions into intra-agent characterizations. The paper is organized as follows. The methodology is introduced in section 2. In section 3, we present our SPG case study. We present it at the signal layer, defining the topology and the story line. In the following we show how to enrich the previous representations with an intentional layer, integrating institutional concepts as well. In section 4 we provide elements for the transformation of the previous models into scripts for cognitive agents. Discussion and further steps will be presented at the end.

2 METHODOLOGY

The method we used to provide an ABM model of a SPG is as follows: the case was analyzed at the signal layer, i.e.we identified all the events and their messages; then we visualized them by using a message sequences chart (MSC). Next, we integrated the previous layer with an internal behavioral characterization, a specification and we constructed an agentic layer where we addressed intentions of agents. For this purpose, we defined the mental objects and events from a BDI perspective, maintaining the relationship between components. Finally, we embedded an institutional layer to consider the normative aspect. It should be noted that our conceptual framework covers several realities: physical (message exchange), mental (social network), institutional and story line.

3 Eduroam AS A SERVICE PROVIDER GROUP

This study has been motivated by Leon Gommanse (Gommans, 2014), who is a researcher on multi domain authorization frameworks. His SPG research considers the role of trust and power to authorize a service delivery by multiple autonomous service provider. In general terms, Eduroam [EDUR] allows students, researchers and staff from participating institutions to obtain Internet connectivity (WiFi) across campus and when visiting other participating institutions by simply opening their laptop. Eduroam allows participating research and education institutions, known as an eduroam SPG, to provide internet access for students from any other participating institute that acts as Identity Provider (IdP). To reduce the complexity of case study, we only consider one SP

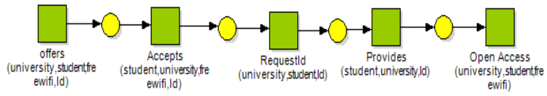

Figure 1: Example of occurrence: a WiFi connection instance.

(university) and students who are willing to use this free service. In the following section, we describe the story of Eduroam[1] Eduroam network is an example of a SPG and works as follows:

> A university offers a WiFi access to students and staff who are registered in the Eduroam identity database. The student accepts the term and condition of this free service. The university requests an identity from the students. The student provides a valid identity. Finally, the university will deliver the service (free WiFi).

A successful WiFi connection is a fundamental cross domain transaction. Consequently, what the case describes is a collaboration among the SPG (university) and their users (students) which is just one of many other possible scenarios. Figure 1 shows a successful Eduroam connection process.

3.1 Signal Layer

In order to initiate the modeling, first we look at the speech acts of agents and all the events to illustrate the first layer of our framework (called signal layer). As a first definition, we may consider a story as a chain of events which act as functions to bring the story from a set of initial conditions to a certain conclusion (from this perspective, we can consider all of them as acts of communication, as messages going from a sender to a receiver entity). In addition, each action is coupled with the acknowledgment by the other party. The Eduroam service delivery process is basically characterized by the actions offer, accept, request, provide and open access, performed by one of the parties as represented in Figure 1. This process is protected by an Eduroam confederation agreement, when a mandatory action is not executed, the party who was expected to benefit from the act can enforce on a failed performance. In order to trigger the performance of the reported acts, there might be other con-

[1]Eduroam is a federated roaming service that provides such secure network access by authenticating a user with their own credentials issued by their IdP. A group of National Research and Education Networks (NRENs) are in essence providing this service for their participating educational institutes under the eduroam brand arranged by TERENA (López et al., 2008; Wierenga and Florio, 2005; Gommans et al., 2015).

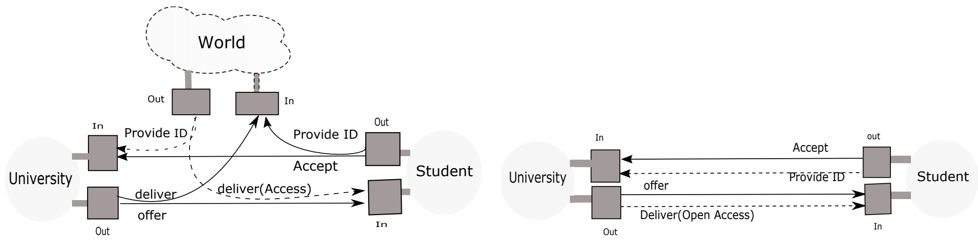

Figure 3: Topology of an Eduroam story: direct and indirect communications.

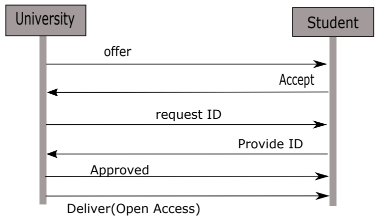

Figure 2: Message sequence chart of a story about an Eduroam WiFi service.

ditions or hidden acts to be taken into account. Thus, the story can be illustrated in Figure 2. A student usually accepts a term and condition only if he/she holds a valid identity and physically presents at the Eduroam WiFi range. To be Registered as a student is a precondition for successfully perform the authorization steps. Both physically presents and holds a valid Id are examples of critical conditions for completing the process by this story. Such critical conditions are in general associated to the ability or, more in general, to the power of the agent, in a specific context "agent+environment". They identify the propositions that should be true in the story-system, so that the agent is successful in the performance of the associated action.

3.2 Topology

The topology is drawn based on the collection of messages. The topology serves as a still picture of the whole story-system, and shows how signals are distributed over the agent-roles (Boer and Van Engers, 2011). In our approach, topology helps to identify an agent in a certain agent-role which is shown by the MSC (e.g. Figure 2). This part of the research has been inspired by an "actor model" of (Hewitt et al., 1973). For simplicity, we only consider two possible representations of the topology (direct and indirect communication), which has been illustrated in Figure 3. The figure's right side, the little boxes are messages queues and lines are communication channels. Also, all messages have a specific propositional content. On the left figure, the dashed lines refer to actions that have relevant outcomes besides the direct communication. In order to take eventual side-

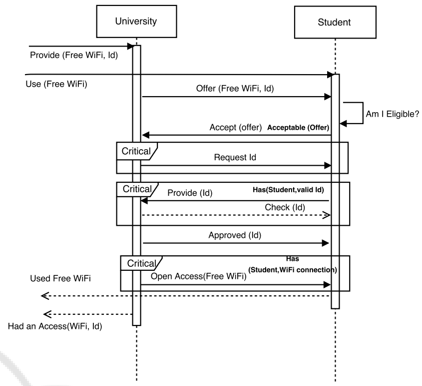

Figure 4: MSC with intentions and critical conditions.

effects into account, we introduced an explicit world actor, dis-joining the sender from the receiver (which is presented in the right figure). The world would play as intermediary entity also in case of broadcast messages. In the Eduroam case, world plays as a role of an IdP.

4 AGENT PERSPECTIVE

In the previous section we referred to the message exchange in this story (Eduroam WiFi access). When we discover such messages, however, we apply an intentional stance introduced by Dennett (Dennett, 1989). We started from a representation of the Eduroam WiFi access story on the MSC chart and we refined it with Petri nets patterns. Beside that we want to extract agent-role descriptions from this representation. Therefore, we write down typical scenarios (e.g. Figure 1) with the typical roles that agents play. Such roles are associated with certain beliefs, plans (resulting in actual actions) and goals. An agent is able to play simultaneously several roles and vice-versa. From the agent point of view, the precondition and ex-post intentional interpretation of the story results in a decomposition of the plans followed by the agents. A possible result of the interpretation is presented in Figure 4. In order to do so, first externalized intents have been considered as the events triggering the processes of offer/open access between a university and a student. The final results of those actions are then reported with output messages at the end of the chart. In the next step, we consider the possible hidden acts. In this case, we know that the university usually accepts student's requests for using the WiFi, once their identities have been approved by the IdP. And finally, we use the critical grouping to highlight conditions (in addition to sequential constraints), which are necessary for the production of that message. To sum up, we assume that: (a) the student performs an evaluation of the offer (evaluation action), (b) the student accepts the offer if it is acceptable for him/her (term and acceptability condition), and (c) the student provides the ID (the university provides access) if he owns the requested information (valid identity or ownership condition). The MSC diagram in Figure 4 depicts a good conclusion for the story; the inputs/outputs provide an intentional characterization. The vertical bars indicate the ongoing activities, while the messages refer to successful acts of emission and reception, whose occurrence is constrained by the critical conditions. In the following sections we will introduce some patterns to be attached to the flow of the story. Instead of using just one visualization, we provide alternative representational models. In our model, we refer to four layers, each of which addresses specific components:

- the signal layer—acts, side-effects and failures (e.g. technical failure,user abuse): outcomes of actions,
- the action layer—actions (or activities): performances intended to bring about a certain result,
- the intentional layer—intentions: commitments to actions, or to build up intentions,
- the motivational—motives: events triggering the creation of intentions.

The last three layers compose the agentic layer. The closure of the sensing-acting cycle of the agent is guaranteed by the fact that certain signals, when perceived by agents, becomes motives for action. In our framework, motivation refers to conditions that makes the agent sensitive to a certain fact, which becomes the motive for starting an action. As we observed before, obligations are prototypical reason for actions. Despite of that, not all obligations are followed by a performance. People comply with obligations when they have some motivation due to habit, convenience, respect for authority, or in our case to use WiFi. Motivations however often remain implicit in the story (Sileno et al., 2013).

4.1 Institutions

In general, we can say that an institution is an intentional social collective entity (Boer, 2009), defined by certain rules and some institutional facts. It is collective and intentional, simply because a group of people recognizes its existence. A complementary perspective on institutions has been introduced by Searle (Searle, 1969), and more recently by (Searle, 2009), as an outgrowth of his study. This concept of institution unifies games, (social) informal norms and legal norms. Terms like ”university” and ”student” denote agents acting within the free WiFi institution. However, there is an intrinsic difference between the actual participants and the role that they play. An institution concerns persons, but not whole persons: each one enters via an adequately trained and specialized part of himself. These parts are embodying specific institutional roles.

Agent-role model were first introduced by Boer and Van Engers (Boer and Van Engers, 2011) with the purpose of representing scenarios of compliance and non-compliance elicited from legal experts. In this work, an agent-role links the concepts of institutional role, and intentional agent. In practice, we add characteristics to the role that are important factors according to the constructed normative theory, and we describe its behavior by using an intentional approach. We start considering only the core functions (events, acts) related to our character. This process proceeds by using a common knowledge interpretation to define each agent's intention. Then, the analysis of intentions allows us to reconstruct the goal reduction process. Rationality is usually defined as the ability of an agent to construct plans of actions to reach the goal. Differently from objects (and actors), however, agent-roles are entities associated also to motivational and cognitive elements like desires, intents, plans, and beliefs.

Institutional roles are defined with certain abilities (equivalently, powers), obligations and expectations about the other roles. Following the description given by the Eduroam WiFi agreement, if a student accepts an offer, and if he/she does that, he/she has to provide a valid ID, to expect an access to the WiFi from any other participating institute (universities) that acts as an IdP provider. Therefore, institutional roles are defined in the first place by actions that may be taken, in an adequate institutional setting, in order to achieve certain goals. Furthermore, we observe that the possibility of WiFi connection exists because there is a university who has offered and received acceptance and finally delivers the service. Both roles are strictly necessary: there cannot be a student without a univer-

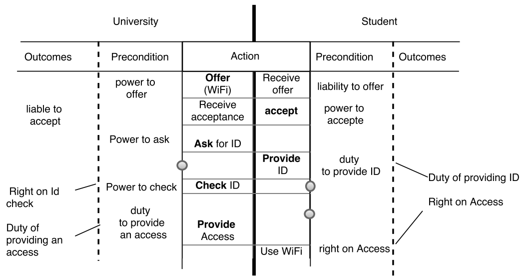

Figure 5: A WiFi connection transaction illustrated in terms of actions, with pre- and post conditions.

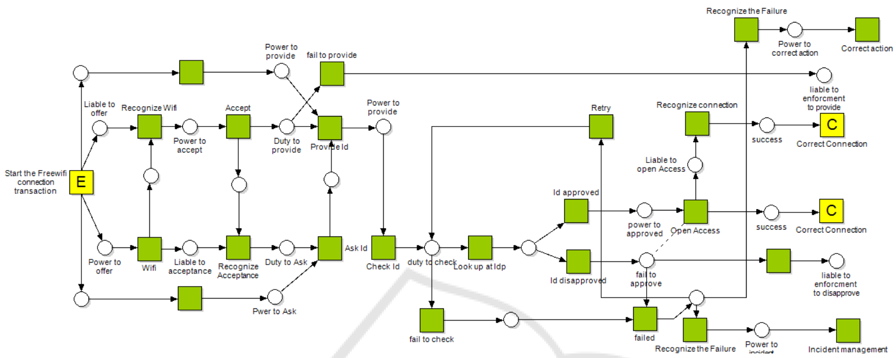

Figure 6: Full action pattern associated to an Eduroam WiFi connection.

sity in case of free WiFi. In this line of thought, WiFi connection does not concern only one university with its own students. Eduroam connection is a free WiFi for all students all over the world and composed by several competing actors (e.g. campuses). Although, it is not explicitly present in the formal description of the internet connection institution, the presence of IdP and technical partners is obviously not negligible for the institutional role. These relations are involved in the evaluation of the offer (having a power to offer as a university) and action which meant to judge the acceptability of the offer (being in the WiFi range and holds a valid ID). Evaluation however, is not made explicit in the definition of the free WiFi process. A complete scheme about the process can be drawn unifying procedural and institutional descriptions which have been shown in Figures 5, 6. The university acts as offeror and student acts as offeree. The gray circle in Figure 5 shows that the performance of the action is not sufficient to proceed, but it has to return a positive result.

4.2 Visualization

We use Petri nets to visualize the flow of the story (Fehling, 1993). The choice of Petri nets as representational model has positive outcomes in itself. First, allowing for descriptions in terms of localized states rather than a global state comparable to Kripke models(Esakia, 1974). Next, exploiting their topological characterization, can easily model the institutional dynamic, i.e. timing/synchronization aspects. Finally, Petri nets offer a direct visualization both of the local structure and of the behavior of the system, which can be useful for validation purposes.

4.3 Preliminary Implementation

For the model discussed in Figure 6 we have implemented a generic framework in Groovy. Groovy is a recent extension of Java which compiles on the Java virtual machine (JVM). The language is suitable for fast prototyping, and differently from Java, is a dynamic language, and can be used for scripting. It provides the libraries implementing the actor computational model as described by Hewitt *et al.* (Hewitt et al., 1973). This framework is able to take care of all the parallel and concurrent actions that need to be done in the case study. The Default-Actor class was provided to be the base for our agent class. This Agent class can be used to further implement different agent roles and the interaction between them. For space reasons, we are not able to present further examples of their use with Petri net models and source code, but the interested readers can find some other models on our website[2] and more information about the project on our website[3].

[2] https://sarnet.uvalight.net/

[3] http://delaat.net/sarnet/index.html

5 DISCUSSION AND FURTHER DEVELOPMENTS

Our research is intended to model normative reasoning in a complete distributed environment. In particular, we are interested in how to model the SPG from the normative perspective to observe the agent behavior and identify the benefits and risks. In the current approach, typical strategy decision problems for a given game do not take explicitly into account the possibility of the player to behave avoiding a rule, or forcing the interpretation of the rule toward its interest, if the regulator (consciously or not) left some ambiguity. Using our framework, agents models or roles involved in a social scenario, outlined from a story can be described. As an operative result, such a simulation can help to understand the social (institutional) dynamics: validating the domain of conceptualization of the experts, making predictions, suggesting improvements to regulations for the SPG framework and spotting normative weaknesses and vulnerabilities. This model is an essential step to provide an ABM of cross domain framework which is one of the directions of our future research. Along with this work, a preliminary implementation has been developed, using an existing ABM platform. The current ABM implementation was expressive enough to build a first version of the generic ABM framework of SPG. However, we have experienced some shortcomings in expressivity, which are left outside the scope of this paper, and we will address these issues as next steps and present in a separate publication.

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