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Media - A Formal Model of Communities and Platforms

(Extended Abstract)

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1 Introduction and Motivation

Internet provides the means to transport information over space and time, and world wide web has established itself as a universal service for representing and communicating information. While there are protocols, languages, tools and standards for transportation and representation of information on a basic level, there is a distinctive lack of well established, general concepts and standards, interoperable services for information processing or Electronic Commerce. Moreover, there is no language to describe rules and protocols guiding the interaction between agents, e.g. business partners, as well as the interfaces to the services which would allow autonomous agents to access the platform and act in behalf of human agents.

We suggest two models for an organized “Web of services” accessible to autonomous agents: media and the media reference model (Schmid, 1999). Thus, we address two issues here (1) the design of platforms with powerful, well integrated services which are accessible to agents and (2) the design of those agents capable of understanding and accessing those platforms.

Media are envisioned as spheres for communities of agents and they are modeled as channel systems of multi-agent systems. Media are characterized by (1) a logical space to determine syntax and semantics of the information represented on them, (2) a channel system to transport information over space and time and (3) an organization with roles and protocols to describe the behavior expected from agents and admissible interactions. Those organized channel systems are inhabited by communities of agents.

The media reference model describes the components and relevant aspects of media. It distinguishes four views and phases. In the community view, logical space and organization of the medium are determined. The process view implements transactions and processes according to the protocols by employing the services of the transaction view. The infrastructure view provides the means to transport information. The four phases are supported by dedicated services for information processing. We distinguish information phase, intention phase, negotiation phase and settlement phase.

We formalize those models employing Rewrite Logic (Meseguer, 1998), Maude (Clavel et al. 1999), Labelled Deductive Systems (Gabbay, 1996) and Modal Logic. This formalization is outlined in this paper. We present the general structure of the specification – a media architecture.

The formal model of media that we obtain is (1) a description according to which the channel system can be implemented as well as (2) a description of the structure and knowledge of artificial agents capable of navigating on such a channel system. Herein, the formalization with the means of logic distinguishes our approach. Such a formalization is prerequisite for agents to understand and access their environment - the platform.

2 The Media Model

Media are spheres for communities of agents. We think of media as platforms for open, distributed systems of communicating agents (s Figure 1).

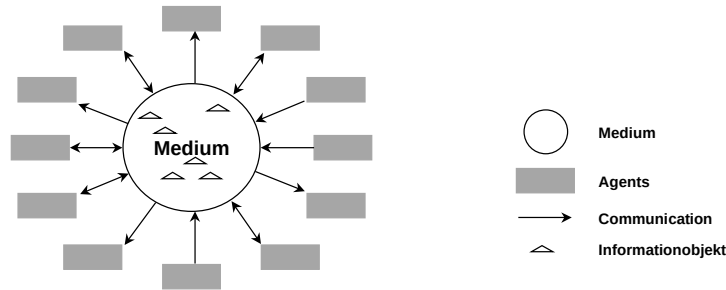


Figure 1 Medium as Sphere for Agents

We suggest a general model for media – the computational media metaphor. Media are characterized through three components (Schmid, 1997):

- a *logical space*, which determines syntax and semantics of the information represented on the platform.
- a *channel system* to transport information over space and time and to facilitate communication of information.
- an *organization* which determines with *roles* the behavior expected from agents and with *protocols* the admissible interactions.

This organized channel system is utilized by a community of

- agents, which communicate information represented as sentences of the syntax of the logical space according to the organization in the channel system.

Subsequently, we outline the formalization of the components logical space, channel system, organization together with the formalization of a medium and agents.

2.1 The Logical Space

The logical space determines syntax and semantics of the information represented on the medium. The logical space is common to the agents employing a platform.

To formalize the logical space with syntax and semantic we use the concept of a logic according to Meseguer (Meseguer, 1996). A logic L is a tuple $(\text{Sign}, \text{sen}, \text{Mod}, \vdash, \models)$ where Sign is a category whose objects are called *signatures*, $\text{sen}: \text{Sign} \rightarrow \text{Set}$ is a functor associating to each signature Σ a set of Σ -sentences, called the Σ -language, $\text{Mod}: \text{Sign} \rightarrow \text{Cat}^{\text{op}}$ is a functor that assigns each signature Σ a category whose objects are called Σ -models, $\vdash$ is a function associating to each $\Sigma \in |\text{Sign}|$ a binary relation $\vdash_{\Sigma} \subseteq \mathcal{P}(\text{sen}(\Sigma)) \times \text{sen}(\Sigma)$ called Σ -*entailment* such that reflexivity, monotonicity, transitivity and $\vdash$ -translation are satisfied, and $\models$ is a function associating to each $\Sigma \in |\text{Sign}|$ a binary relation $\models_{\Sigma} \subseteq |\text{Mod}(\Sigma)| \times \text{sen}(\Sigma)$ called the Σ -*satisfaction* satisfying the following satisfaction condition for each $H: \Sigma \rightarrow \Sigma' \in |\text{Sign}|$, for all $M' \in |\text{Mod}(\Sigma')|$ and $\phi \in \text{sen}(\Sigma)$, $M' \in \models_{\Sigma'} \text{sen}(H)(\phi) \Leftrightarrow \text{Mod}(H)(M') \models_{\Sigma} \phi$ and the following soundness condition is satisfied: for any $\Sigma \in |\text{Sign}|$, $\Gamma \subseteq \text{sen}(\Sigma)$, and $\phi \in \text{sen}(\Sigma)$ $\Gamma \vdash_{\Sigma} \phi \Rightarrow \Gamma \models_{\Sigma} \phi$, where, by definition, the relation $\Gamma \models_{\Sigma} \phi$ holds if and only if $M \models_{\Sigma} \phi$ holds for any model M that satisfies all the sentences in Γ .

Note that $(\text{Sign}, \text{sen}, \text{Mod}, |=)$ is called an *institution* and $(\text{Sign}, \text{sen}, |-)$ is called an *entailment system* (Meseguer and Marti-Oliet, 1995).

The logic defines syntax and semantics of information represented on the platform. The syntax is realized with Sign , sen and $|-$, the semantics is given by Mod . The satisfaction relates syntax and semantics, it formalizes the notion of a *view* from where the world is reflected.

Note, that this concept of a logical space provides not a single language, or a single entailment relation or a single model. Instead, it provides an organized collection of languages, entailment relations and models. Later, we explore the number of languages as well as the relations among them that coexist on a medium and the general structure of a medium and motivate, why such a “collection of logic” is essential.

2.2 The Channel System

Channels transport information over space and time. They distinguish agents, distribute them over space and time, connect them, facilitating co-ordination among agents.

To formalize the channel system for a distributed community of agents, we utilize the concept of Labelled Deductive System (Gabbay, 1996; Gabbay, 1994).

A Labelled Deductive System is a structure based on three components: A , L , F where

- A is an Σ_A -algebra with elements denoting labels and relations between labels. Labels denote and distinguish agents; the relations model connections among labeled agents.
- L is a logic presented as $(\text{Sign}, \text{sen}, \text{Mod}, |-, |=)$. This logic formalizes the agents with their knowledge and capability of processing information.
- $F: A \rightarrow P(\text{sen}(\Sigma))$ for some Σ in $|\text{Sign}|$ is a family of mappings assigning elements of the algebra to sentences of the logic. F models the relation of agents to the channel system.

Note, that Labelled Deductive Systems with those three components provide a conceptual clear distinction between agents and their knowledge and the channel system relating those agents.

An agent-channel system is described as a so-called database, the behavior of an agent-channel system is given in terms of an entailment relation between databases.

Let us explain the formalism in more detail. A database is a collection of algebraic elements, called labels and a special label, the distinguished “name” of the database as well as a mapping relating labels with sentences of the logic. Thus, a database is a labeled agent channel configuration. The axioms of a Labelled Deductive System define the relations between databases. They describe typically in a declarative way, how agents communicate and co-operate and evolve over time –provided the entailment relation is interpreted as computational progress over time in the sense of (Meseguer, 1998). Note, that the format of the rule provides the means to include the channel system and the knowledge of agents to decide whether and how agent coordinate and communicate. Moreover, agents may contain as their knowledge the channel system, providing them hereby with the knowledge to act as mobile agents on the platform.

2.3 The Organization

The organization describes with roles the configuration of a community of agents and the behavior expected from agents within this community. With protocols, the organization describes admissible interactions among agents through channels.

Roles model the behavior of a (kind of) agent or the behavior expected from an agent in a community. Protocols model the (admissible) interactions among agents via channels.

Roles are descriptions of behavior of agents. This may comprise, e.g., liabilities and assets of agents within a community. Protocols are descriptions of interactions among agents. Roles and protocols are typically not descriptions of agents, but of classes or types of agents.

Agents are expected to perform according to roles and protocols. However, roles and protocols have to be part of the medium, and the agent-channel configurations and the knowledge agents dispose of. This facilitates reasoning of agents about themselves and other agents as well as about their further behavior and the behavior of the whole community. Thus, it enables them to compute the behavior expected from them and useful to them.

In a formal model of an agent-channel system (in Rewrite Logic, or Labelled Deductive Systems), roles and protocols can be implemented in the axioms and meta-rules of the logic. The entailment relation has to be correct with respect to the formalization of roles and protocols.

2.4 A Medium

Finally, we give the formalization of a medium - a platform for communication of an organized community of agents. The description of a medium consists of

- a logical space formalized as a logic (Sign, *sen*, Mod, $\vdash$, $\models$)
- a channel system presented as an algebra and a Labelled Deductive System with a Σ -algebra A , a logic L and a relation among elements of this algebra and sets of theorems of the logic.
- an organization, with roles and protocols describing behavior of agents and agent channel configurations.

Let us discuss the notion of logic and the information to be represented on a medium. Media are designed to represent, process and communicate information about some domain of discourse. However, this domain of discourse constitutes just one small part of the logic, of the information that has to be formalized, and of the agents' knowledge. The model distinguishes channels, agents, description of agents in roles and protocols and suggests to formalize all those components. There are several reasons for this. First, not only the knowledge about some the domain of discourse but also roles, protocols and channel system may change over time. This has to be described in the model and therefore be captured by the formalism. Second, agents have to reason about themselves and other agents on the platform to be able to act autonomously and to navigate autonomously on those platforms. Thus, agents have to have knowledge about channels, about the behavior expected from agents, about the admissible interactions and about the possible changes on the platform. Such a formalization enables them to act on this platform – thus, the formal model allows them to reason.

2.5 Agents

The information which is transported in channels is activated as knowledge by agents.

Agents are capable of acting on this platform according to their knowledge. The information they dispose of contains facts and procedural information as well as the knowledge how to apply facts and procedural information on the platform. Agents are machines capable of processing information in general and of computing the entailment relation from axioms.

Agents can be formalized as specifications with a signature, a set of axioms, meta-rules how to apply the axioms, and a strategy, how to proceed in computation.

Let $L = (\text{Sign}, \text{sen}, \text{Mod}, |-, |=)$ be a logic. Let Σ be an element of $|\text{Sign}|$. An agent is given as a tuple $(\Sigma, \text{sen}, \text{Ax}, S)$, where Σ is an object in Sign , $\text{sen}(\Sigma)$ is the language, Ax a set of axioms and S a strategy how to apply those axioms.

Typically, one requires the specification to be correct not necessarily complete w.r.t. the entailment relation $|-$.

Let us discuss the notion of “knowledge of agents”. Agents may have more knowledge than the knowledge about some domain represented on the platform. They may have knowledge about the channel system, about other agents (description of agents as roles), about interactions among agents, about the knowledge of other agents. Thus, their knowledge may comprise the medium description of the actual medium they are part of.

3 The Media Reference Model

The media model describes *how* to envision and model media. Media are modeled as channel systems of multi-agent systems. Media are open distributed systems, described by a logical space, channel system and organization. The media reference model details generic components and issues to be modeled and the relations among those generic components and issues (see Figure 2). The media reference model describes *what* to model.

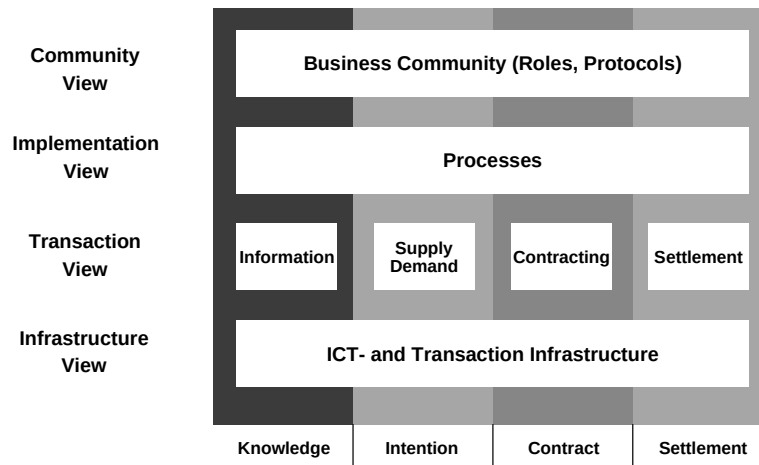


Figure 2: Business Media Framework

It details a medium in four phases and four views. Subsequently, we give a short description of the phases and views: (Schmid and Lindemann, 1998; Schmid, 1999; Schmid, 1997):

- The community layer represents the normative aspects of a medium. Here, logical space and organization of the community are given and formalized. The community of agents is described with their language, the semantics of the language, the view (given in the logical space), common interest and values. The organization describes assets and liabilities in terms of roles. The protocols infer the transaction to be allowed on the channel system of the medium.
- The process layer defines the processes of information processing according to the organization and the use of the services of the transaction layer.
- The transaction layer provides the services for information processing available in the medium. We envision those services as artificial agents enhancing the natural agents ability to process information. Thus, the means for information processing are provided by artificial agents.

- The information- and communication infrastructure implements the transport of data among services and agents and provides the adequate soft- and hardware. In this view, the channel system is being represented.

The phases of the medium are each supported by a particular service. The relation or temporal ordering of the phases is established in the process view according to the protocols.

- The logical space is established by the services of the information phase. Agents gather the common knowledge from this service that enables them to communicate or exchange information or goods in the later phases.
- The service of the intention phase support the agents in formalizing and externalizing their intention, i.e., to determine supply and state demand. The information is connected with the desire of the agents as well as the knowledge of the agents and processed internally to gain the intention.
- In the contracting phase, the agents communicate their individual intentions and negotiate a common intention: The individual intentions have to be matched, i.e., they have to be compared and altered according to the agents desires. Finally, the common intention, agreed upon, is being externalized to a contract. That contract is - as a protocol - part of the organization and determines and formalizes the organization of the settlement phase
- In the settlement phase, the agents act according to the contract. Here, payment and logistics are typically handled by the service.

The media model describes the generic components and the relations among the components of a medium. Note, that the information represented on a medium as well as the agents, their knowledge, organization and means for settlement may change during the lifetime of a medium. For a discussion on how the communities evolve with the organization see (Lechner et al. 1998).

Let us discuss how this media model is connected to the media reference model: The components of the media model are assigned to the views of the reference model which themselves correspond to the steps of a design process for domain-specific reference models. (Klose et al. 1999).

The phases and their services provide various means to process information. They establish contexts in which information about the domain of discourse is being represented, processed and interpreted, and determine how pieces of information are being related. This distinction of context and domain is formalized in a modal logic with

- Propositions as sentences of a logic to represent the information on the domain of discourse.
- Modalities to formalize the context in which propositions are to be interpreted.

According to the structure of the media model, we distinguish four different modalities for each of the phases and give the relations between those modalities in the protocols.

4 Agents and Media

According to the BDI architecture of agents (Huhns and Singh, 1998; Jennings and Wooldridge, 1995; Müller, 1996), agents consist of the knowledge (or belief), desire, intention, plan and schedule. Note, that we may establish a correspondence between components of an agent and services of the medium: belief corresponds to information, intention to intention, plan to contract, schedule to settlement. The desire of an agent corresponds to the protocols implementing, how the common goal should be achieved.

Thus, the services of a medium are external “organs” of knowledge processing which correspond to the internal “organs” of knowledge processing of agents. Moreover, this correspondence allows to think of media as agents and agents as media.

5 Architecture for Media

Let us conclude with the overall structure of the formalization of media – our architecture for media. We distinguish (1) the concepts to structure a medium in the small, (2) the concepts to structure a medium in the large and (3) a design method.

For modeling a medium (medium in the small) we distinguish three dimensions.:

- The domain represented on the medium vs. the contexts in which this domain specific information is implemented. Domain and context are distinguished as propositions and modalities of a modal logic.
- Phases and services each imposing the context for information to be represented and their means for structuring a specification. – The phases are distinguished as modal logics – each one particular for a phase and a service.
- Logics, Channels and Organization (roles and protocols) as components of a platform - distinguished by the structure of Labelled Deductive Systems.

For modeling the media net – the medium in a large- we identify two concepts:

- Media as agents and agents as media. Services correspond to the components of media and the desire corresponds to the protocols. Thus, media can be considered as agents which are themselves again part of media – Hereby, a hierarchy of media is formed.
- A logical space is part of a category of logic, algebras can be an object in a category of algebras, channels, agents and organizations can be shared among media. Hereby, a media Web is being formed.

The views of the media reference model are relevant for the design of media. (Klose et al. 1999)

- First, the relevant community is determined and the characteristics of (virtual) communities, as, e.g., common language, common view, trust and goal of the community are described.
- The community and its characteristics are formalized as logical space and organization in the community view of the media reference model.
- Then, services and IKT-Infrastructure are modeled and processes combine those services according to the requirement of the medium.

6 Discussion and Further Work

With the models and the outline of the formalization we propose a new quality for information systems as well as a new generation of services. The models can be used twofold: (1) as a description of the platform to be built and (2) as a description of the knowledge of agents. The model we propose are general and generic. However, such general metaphors, and models are prerequisite for interoperable, integrated information services and systems.

Our approach distinguishes itself also by its comprehensiveness. New structures as, e.g., Value Webs or Economic models can be studied within this model and the design method clarifies the interdependencies of the (virtual) communities with the social and economic models on the one hand and the platform with its services constituting the community on the other hand. A special

focus lies here in those aspects that distinguish new media from mere virtual counterparts of real institutions.

Our concept of Media expands present Internet and WWW. Alike the Web it envisions distributed, open, flat structures. However, it provides more organization and stronger semantic foundation of the information to be represented. By modeling platforms for agents and artificial agents, our approach envisions a new kind of universal information system – a MediaWeb for agents.

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