AUTONOMIC SERVICE CONFIGURATION BY A COMBINED STATE MACHINE AND REASONING ENGINE BASED ACTOR

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Abstract: Service systems constituted by service components are considered. Service components are executed as software components in nodes, which are physical processing units such as servers, routers, switches and user terminals. A capability is an inherent property of a node or a user, which defines the ability to do something. Status is a measure for the situation in a system. A service system has defined requirements to capabilities and status. Because of continuous changes in capabilities and status, dynamic service configuration with respect to capabilities and status is needed. Software components are generic components, denoted as actors. An actor is able to download, execute and move functionality, denoted as a role. Configuration is based on the matching between required capability and status of a role and the present executing capabilities and status of nodes. We propose an approach for role specification and execution based on a combination an Extended Finite State Machine and a rule based reasoning engine. Actor execution support consisting of a state machine interpreter and a reasoning engine has been implemented, and has also been applied for a service configuration example.

1. INTRODUCTION

Service systems constituted by *service components* are considered. Service components are executed as software components in *nodes*, which are physical processing units such as servers, routers, switches and user terminals such as phones, laptops, PCs, and PDAs. Traditionally, the nodes as well as the service components have a predefined functionality. However, changes are taking place. Nodes are getting more generic and can have any kind of capabilities such as MP3, camera and storage. The software components have been also changed from being static components to become more dynamic and be able to download and execute different functionality depending on the need. Such generic programs are from now on denoted as *actors*. The name actor is chosen because of the analogy with the actor in the theatre, which is able to play different *roles* play defined in different *plays*.

To utilize the flexibility potential, the attributes of services, service components, software components and nodes must be appropriately formalized, stored and made available. As a first further step towards this formalization, the concepts *status and capability* are introduced.

Status is a measure for the situation in a system with respect to the number of active entities, the traffic situation and the Quality of Service. A *capability* is an inherent property of a node or a user, which defines the ability to do something. A capability in a node is a feature available to implement services. A capability of a user is a property that makes the user capable of using services. An actor executes a program, which may need capabilities in the node. Capabilities can be classified into:

- *Resources:* physical hardware components with finite capacity,
- *Functions:* pure software or combined software/hardware component performing particular tasks,
- *Data:* just data, the interpretation, validity and life span of which depend on the context of the usage.

The functionality to be played by an actor participating in the constitution of a service is denoted as its role. We use the role-figure as a generic concept for the actor which is playing a role. So services and service components are realized by role-figures. *Service configuration* is here the configuration of services with respect to the required capability and status of the roles.

The Role of an actor is defined in a manuscript, which consists of an EFSM *(Extended Finite State Machine)* extended with rule-based policies. Using a local *rule-based reasoning* engine adds the ability to cope with various situations more flexible than is possible by the pure EFSM. Actors can locally take place in the configuration and reconfiguration of the services, in which they are a part of. The reasoning engine is based an XET (XML Equivalent Transformation) rule-based language.

The work presented in this paper has been related to the Telematics architecture for Play-based Adaptable System (TAPAS) [2]. Section 2 discusses related work. Section 3 presents the model used for the combined EFSM and reasoning engine based actor. Section 4 gives a short presentation of the TAPAS architecture with focus on the elements relevant for the autonomic service configuration. Section 5 presents the data model. Section 6 presents a simple scenario where an actor actively participates in service reconfiguration. Section 7 gives a summary and presents our conclusions.

2. RELATED WORK

The mobility of service components have been dealt within a number of approaches. An example is the Intelligent Agent, which is the most related to our work. DOSE [4] is an agent-based autonomic platform that uses Semantic Web to come up with response to failures. However, the behavior of each service component must be fixed along with the moving codes that cannot be downloaded or changed. A technique to overcome this shortcoming has been proposed using Java Reflection [5]. The behavior of server components can be downloaded or changed based up on a reasoning mechanism. However, the reasoning mechanism itself cannot be downloaded or altered. In our approach, the behavior of service components and the rules used in the reasoning mechanism are downloadable and can be changed upon needs.

3. THE ACTOR MODEL

The actor role is defined as an Extended Finite State Machine (EFSM) extended with policies. The mechanism interpreting the manuscript is an EFSM interpreter extended with a reasoning mechanism. The data structure applied for the representation of an EFSM is shown in Figure 1. An EFSM contains the EFSM name, initial state, data and variables and a set of states. The state structure defines the name of the state and a set of transition rules for this state. Each transition rule specifies that for each input, the actor will perform a number of actions, and/or send a number of outputs, and then go to the next state. Actions are functions and tasks performed during a specific state: computation on local data, role session initialization, message passing, etc. The structure of the <ACTIONS> list specifies the name, the parameters and the classification of an action.

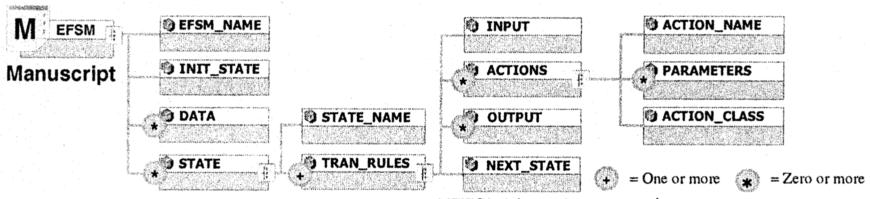


Figure 1. Data structure of EFSM-based manuscript

Rule-based reasoning is considered as a special type of EFSM action that executes policies. Policies are expresses in the XML Equivalent Transformation language (XET) [3]. The reasoning engine can directly operate and reason about XET descriptions.

The XET language is an XML-based knowledge representation, which extends ordinary, well-formed XML elements by incorporation of variables for an enhancement of expressive power and representation of implicit information into so-called XML expressions. Ordinary XML elements, XML expression without variables, are denoted as ground XML expressions. Every component of an XML expression can contain variables as shown in Table 1. Every variable is prefixed with '*T*var_' where *T* denotes its type.

Table 1. Types of XML variables

Type	Instantiation and examples
N	XML element or attribute names Ex: `<Nvar_X>…</Nvar_X>` can be instantiated to `<div>...</div>` or `<span>...</span>`
S	XML string Ex: `<a name='Svar_Y'/>` can be instantiated into `<a name='http://...'/>` or `<a name='ftp://...'/>`
P	Sequence of zero or more attribute-value pairs Ex: `<p Pvar_Z='NULL'/>` can be instantiated into `<p/>` or `<p style='...'/>`
E	Sequence of zero or more XML expressions Ex: `<p>Evar_P</p>` can be instantiated into `<p/>` or `<p><div>...</div><br/><br/></p>`
I	Part of XML expressions Ex: `<Ivar_X><hr/></IvarX>` can be instantiated into `<body><hr/></body>` or `<hr/>`

A rule is an XML clause of the form:

$$H, \{C_1, \ldots C_m\} \rightarrow B_1, \ldots B_n$$

where m, $n \geq 0$, H and B_i are XML expressions. And each of the C_i is a predefined XML condition used to limit the rule for a certain circumstances. This allows constraints modeling for a rule. Axioms are defined from one or more rule(s). The XML expression H is called the head of the clause. The B_i is a body atom of the clause. When the list of body atom is empty, such a clause is referred to an XML unit clause, and the symbol '$\rightarrow$' will be omitted. Hence ordinary XML elements or documents can be mapped directly onto a ground XML unit clause.

The reasoning process begins with an XML expression-based query. An XML clause will be formulated from the query in form:

$$Q \rightarrow Q$$

XML expression Q represents the constructer of the expected answer which can be derived if all the body atoms of the clause hold. However, if one or more XML expression body atoms still contain XML variables. These variables must be matched and resolved from other rules.

A body from the query clause will be matched with the head of each rule. At the beginning, there is only one body Q. Consider a rule R_1 in the form:

$$R_1: H, \{C_1\} \rightarrow B_1, B_2$$

If the XML structure of the body Q of the clause and the head H of the rule R_1 match without violating condition C_1, the body Q will be transformed into B_1 and B_2. All XML variables in the head Q and the new bodies B_1 and B_2 of the query clause will be instantiated. The query clause will be in the form:

$$Q^* \rightarrow B_1^*, B_2^*$$

Where X^* means the one or more variables in the XML expression X has been instantiated and removed.

The transformation process ends when either 1) the query clause has been transformed into a unit clause or 2) there is no rule that can transform the current bodies B_i of the query clause. If the constructor Q is transformed successfully into Q_f that contain no XML variable, the reasoning process ends and a desired answer is obtained.

4. TAPAS ARCHITECTURE

"Adaptable service systems" are service systems that adapts dynamic to changes in both time and position related to Users, Nodes, Capabilities, Status and Changed Service Requirements. Adaptability can be modeled as a property consisting of 3 property classes: 1) rearrangement flexibility, 2) failure robustness and survivability, and 3) QoS awareness and resource control. The Telematics Architecture for Play-based Adaptable System (TAPAS) intends to meet these properties [2]. In analogy with the TINA architecture [6], the TAPAS architecture is separated into a system management architecture and a computing architecture as follows:

- The system management architecture is an architecture showing the structure of services and services components.
- The computing architecture is a generic architecture for the modeling of any service software components.

These architectures are not independent and can be seen as architectures at different abstraction layers. The system management architecture, however, has focus on the functionality independent of implementation, and the computing architecture has focus on the modeling of functionality with respect to implementation, but independent of the nature of the functionality.

4.1 Computing architecture

TAPAS computing architecture has three layers: the service view, the play view and the network view as illustrated in Figure 2. For details see [1].

A service system consists of service components and the network system consists of nodes. *The play view* is the intended basis for designing functionality that can meet the adaptability properties as defined above. The play view is founded on the theater metaphor introduced in Sec.1. TAPAS actors are software components in nodes that can download manuscripts. An actor that does not have a role assigned is denoted as a *free actor.* An actor playing a role in a manuscript is denoted as a *role figure.* A service system is constituted by a play, and leaf service component are constituted by role figures. A *role session* is the dialog between two executing role figures. A role figure can move between nodes and its role sessions can be re-instantiated automatically. This mechanism, however, is not the focus of this paper. It is referred to [7].

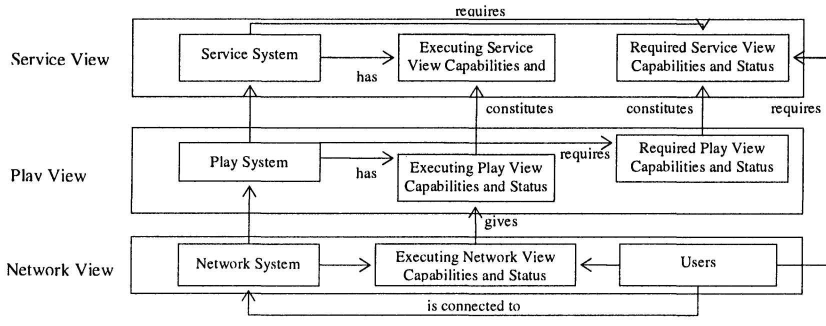

requires
Service View
Service System
has
Executing Service View Capabilities and
Required Service View Capabilities and Status
constitutes
constitutes
requires
Play View
Play System
has
Executing Play View Capabilities and Status
requires
Required Play View Capabilities and Status
gives
Network View
Network System
Executing Network View Capabilities and Status
Users
is connected to

Figure 2. The TAPAS computing architecture

4.2 System management architecture

The main functionality components of the system management architecture are illustrated in the Figure 3. The primary service providing functionality comprises the ordinary services offered to human users.

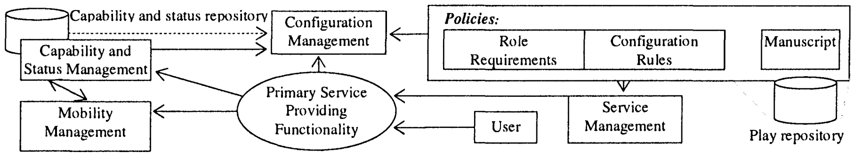


Figure 3. The TAPAS system management architecture

In addition, the architecture has two repositories: the Play repository and the capability and status repository and fours management components: Configuration, Service, Capability and status, and Mobility management.

The play repository stores *manuscripts* and *policies*, which are the required status and capability of a role as well as local configuration rules. Local configuration rules describe configuration and constraints of a role which must always be maintained. In addition, these rules define policies for handling of reconfiguration related events such as the decision of an actor to move a role when a failure happens. The capability and status repository stores *executing capability* and *status information.*

Configuration management makes the initial configuration and re-configures the service systems when needed. The Service management is responsible for deployment and invocation of services. Capability and status management registers, de-registers, updates and provide access to capability and status repository and the Mobility management handles the various mobility types.

To fulfill the failure robustness and survivability requirements, the architecture must be dependable and distributed. The proposed actor model creates a distributed configuration management by adding reasoning functionality to actors.

5. DATA MODEL

This section presents XML based approaches to the representation of the elements of the Play repository as well as the Capability and status repository.

5.1 Manuscript

A manuscript consists of EFSM-based behavior of individual roles. An XML-based EFSM given to an actor is executed by a state machine interpreter. A sample fragment of the XML-base manuscript is shown in Figure. 4.

```
<state name='ConnectionTimeout'>...</state>                %
<state name='ConnectionLost'>                              %
 <Transition name='RoleFigureMove'>                        %
  <input msg='RoleFigureMoveReq' source='*'/>              %
  <action class='Reasoning' name='SearchFreeActor'>        %
    <param name='role_name' value='role1'/>                %
  </action>                                                %
  <output><variable name='Dest_Variable'/></output>        %
  <action class='Communication' name='PluginActor'>        %
   <param name='actorList' value='Dest_Variable'/>         %
   <param name='role_name' value='role1'/>                 %
  </action>                                                %
  <next_state name='PlugoutPending'/>                      %
 </Transition>                                             %
 ...                                                       %
</state>
```

After the state *ConnectionTimeout* is visited infinitely often, the actor playing this manuscript will move to *ConnectionLost* state. If there is an incoming message *RoleFigureMoveReq*, the actor will execute the *RoleFigureMove* transition and perform two subsequent actions. The first action uses the built-in reasoning machine to find out a free actor where the role should be moved to. The second action installs the role to a free actor suggested by the first action. At the end of the transition, the actor moves to *PlugoutPending* state and wait for a plugout message from the newly instantiated role figure.

Figure 4. Fragment of an example XML manuscript showing a transition of state *ConnectionLost*

SMI interprets the downloaded manuscript. SMI uses *action libraries*. Policy related actions are platform independent constraints expressed in XET (see Section 2). For non-policy actions, the actions are platform-specific (such as C++) or platform-independent (such as Java) executable codes from the local action library cache to execute the actions in the transition. If the required action libraries cannot be found, SMI will download the actions from an action library database.

5.2 Executing Capability and Status

Nodes possess particular Network View Capabilities and Status, from now on abbreviated as NV-capabilities and -status. They are represented in a network information model such as Common Information Model (CIM) or Universal Plug-and-Play. We have chosen the XML representation of CIM (CIM-XML) to implement our test systems.

Actors have Play View capabilities and status abbreviated as PV-capabilities and -status. The idea is to hide the complexity of the network view. PV-capabilities and -status of an actor are derived from one or more NV-capabilities and -status. PV-capabilities and -status are represented in Resource Definition Framework (RDF) [9], which can be used to either define pointers to NV-capabilities and -status or define derived PV-capabilities and -status from NV-capabilities and -status [8].

5.3 Policies

The policies comprises: role requirements, local configuration rules. These are modeled by the XET language (See Section 3).

5.3.1 Role requirements

Role requirements consist of PV-capabilities and -status required by a role. These PV-capabilities and -status are represented in RDF and XML variables.

5.3.2 Local configuration rules

The heads of the XET clauses identify components of the outcome of the configuration or reconfiguration, while the body describes the configuration, composition and dependency conditions. A sample local configuration rule is illustrated in Fig. 5.

```
<xet:Rule name='SearchFreeActor' priority='3'>
  <xet:Head>
   <tapas:Actor rdf:resource='Svar_ActorID'/>
  </xet:Head>
  <xet:Body>
   <xfn:FactQuery xfn:uri='ds://PV-Repository' xfn:mode='Set'>
    <tapas:Actor rdf:about='Svar_ActorID'>
     <tapas:connectivity rdf:resource='dbServer'>
      <tapas:connStatus rdf:resource='Status_Active'/>
      <tapas:connType rdf:resource='Svar_connType'/>
      Evar_otherConnProps
     </tapas:connectivity>
     <tapas:actorStatus rdf:resource='Status_FreeActor'/>
     Evar_otherActorProps
    </tapas:Actor>                              Query Expression
   </xfn:FactQuery>
   <xfn:StringIsMember xfn:string='Svar_connType'
    xfn:list='Secured SecuredWireless'>
  </xet:Body>
</xet:Rule>
```

Intuitively, this rule looks for free actors that have a secured connection with *dbServer*, which is a database server providing sensitive information. The head of the rule will be derived as answer(s) if both body atoms can be successfully executed.

Namespace *xfn* refers to built-in atoms providing mathematic operations and database query, etc. These atoms will not be further matched with other rules. *FactQuery* queries actors from the capability and status repository. The query expression simply ignores the order of XML elements when it is working in mode *"set"*. Some irrelevant PV-capabilities and -status of actors are ignored by using two E-variables. *Evar_otherConnProperties* and *Evar_otherActorProps*.

The actors must have *Status_FreeActor* as specified in the query expression. They must have only *active secured* or *secured wireless connectivity* with *dbServer1*, which will be checked by the builtin atom, *StringIsMember*.

Figure 5. An example XET clause to search for free actors

6. DEMONSTRATION

A scenario of a secured database system is considered as an example. A database server contains sensitive information and will automatically blocks incoming requests from nodes that could possibly have malicious software such as viruses or trojans.

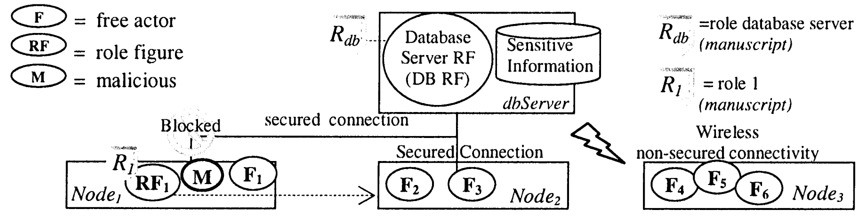


Figure 6. A sample scenario showing the survivability of a role figure.

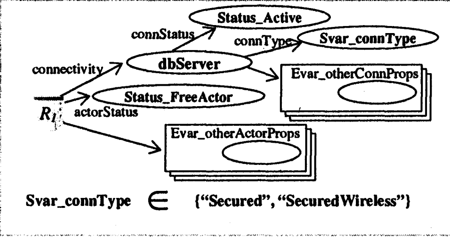
The goal of this demonstration is to show how a role figure in a blocked node can survive, move to other one other node, identified as harmless by the database server, and continue working with the database server. How the role figure proves itself as non-malicious software is not the focus and will not be further explained.

Fig. 6 illustrates a role figure RF_1 in Node 1, which is presently blocked by a database server role figure (*DB RF*). After RF_1 visits a state *ConnectionTimeout* infinitely often, it will move to *ConnectionLost* state. At *ConnectionLost*, *RoleFigureMove* transition will initiated by a

RoleFigureMoveReq message. The manuscript describing this transition has been presented in Figure 4.

6.1 R1 role requirement (required PV-capabilities and -status)

The PV-capabilities and -status required by the role R_1 are illustrated in Fig. 7. R_1 explicitly needs status *Status_FreeActor*. The connectivity between R_1 and *dbServer* must be a member of set {"Secured", "SecuredWireless"}. Actors trying to play R_1 may have other PV-capabilities and -status (as represented by *Evar_otherActorProps* and *Evar_otherConnProps*). These PV-capabilities and -status will be ignored by the reasoning engine.



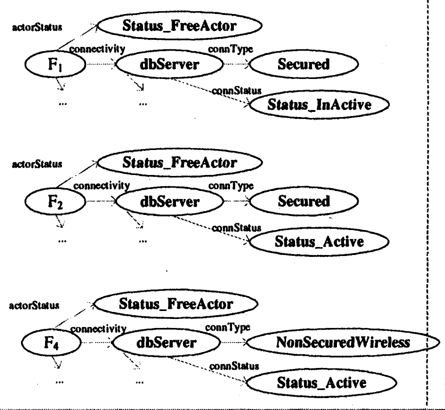
```
<tapas:Role rdf:about='R1'>
  <tapas:connectivity rdf:resource='dbServer'>
    <tapas:connStatus rdf:resource='Status_Active'/>
    <tapas:connType rdf:resource='Svar_connType'/>
    Evar_otherConnProps
  </tapas:connectivity>
  <tapas:actorStatus rdf:resource='Status_FreeActor'/>
  Evar_otherActorProps
  </tapas:Actor>

<xfn:StringIsMember xfn:string='Svar_connType'
                     xfn:list='Secured SecuredWireless'/>
```

Figure 7. The required PV-capabilities and -status of the role R1

6.2 Offered PV-capabilities and -status

Fig. 8 shows the offered PV-capabilities and -status of actor F_1, F_2 and F_4. The PV-capabilities and -status of F_3 are identical to F_2 while the capabilities and status of F_5 and F_6 are identical to F_4. For lack of space, they will not be presented.

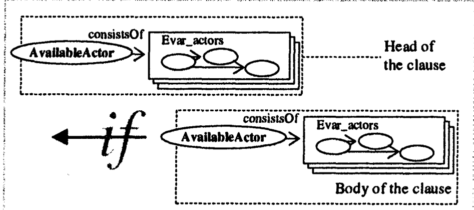


```
<tapas:Actor rdf:about='F1'>
  <tapas:connectivity rdf:resource='dbServer'>
    <tapas:connStatus rdf:resource='Status_Active'/>
    <tapas:connType rdf:resource='Secured'/>
    ...
  </tapas:connectivity>
  <tapas:actorStatus rdf:resource='Status_FreeActor'/>...
</tapas:Actor>
<tapas:Actor rdf:about='F2'>
  <tapas:connectivity rdf:resource='dbServer'>
    <tapas:connStatus rdf:resource='Status_Active'/>
    <tapas:connType rdf:resource='Secured'/>
    ...
  </tapas:connectivity>
  <tapas:actorStatus rdf:resource='Status_FreeActor'/>...
</tapas:Actor>
<tapas:Actor rdf:about='F4'>
  <tapas:connectivity rdf:resource='dbServer'>
    <tapas:connStatus rdf:resource='Status_Active'/>
    <tapas:connType rdf:resource='NonSecuredWireless'/>
    ...
  </tapas:connectivity>
  <tapas:actorStatus rdf:resource='Status_FreeActor'/>...
</tapas:Actor>
```

Figure 8. The offered PV-capabilities and -status of actor F1, F2 and F4

6.3 Query clause

The query clause in Fig. 9 is constructed from a query expression. As already explained in Section 3, the body of the clause will be initially matched with a configuration rule, which will be defined in the Section 5.4.



```
% The query clause explains that AvailableActors consisting an
% unknown set of actors will be derived if the reasoning engine can
% find a rule that matches the body of the clause.
```

```
<xet:Query>
 <xet:QueryClause>
   <xet:Head>
    <tapas:AvailableActors>
     <tapas:consistsOf rdf:parseType='Collection'>
      Evar_actors
     </tapas:consistsOf>
    </tapas:AvailableActors>
   </xet:Head>
   <xet:Body>
    <tapas:AvailableActors>
     <tapas:consistsOf rdf:parseType='Collection'>
      Evar_actors
     </tapas:consistsOf>
    </tapas:AvailableActors>
   </xet:Body>
 </xet:QueryClause>
</xet:Query>
```

Figure 9. Graphical notation of the query to search for available actors

6.4 Local configuration rules

Local configuration rules as illustrated in Fig. 10 indicate that the connection status and the connection type of the link between R_1 and *DB RF* must be maintained in a secured manner. The only QoS parameter defined here is *Svar_connType.*

6.5 The configuration result

The configuration result is shown in Fig 11. Based on the offered PV-capability and -status provided in Fig. 8 and the role requirement defined in Fig. 7, actors F_2 and F_3 are the most appropriate actors to play R_1.

The reasoning process is conducted by Native XML Equivalent Transformation reasoning engine (NxET) implemented as a Java-based action for the state machine interpreter (SMI). NxET is used by SMI to execute *SearchFreeActor* action defined in Fig. 5. The parameter *actorList* of the *PluginActor* action will be substituted with the available actors in Fig. 11. *PluginActor* will try to move R_1 to F_2 first. If the moving is not successful, *PluginActor* will try again with F_3. Subsequently, RF_1 will move to *PlugoutPending* state after R_1 has been successfully moved to either R_2 or R_3. At this state, R_1 will be plugged out from RF_1, which will become a new free actor.

```
<xet:Rule name='SearchFreeActor' priority='3'>
  <xet:Head>
   <tapas:AvailableActors>
    <tapas:consistsOf rdf:parseType='Collection'>
     Evar_actors
    </tapas:consistsOf>
   </tapas:AvailableActors>
  </xet:Head>
  <xet:Body>
   <xfn:SetOf xfn:mode='Set'>
    <xfn:Set>Evar_actors</xfn:Set>
    <xfn:Constructor>
     <tapas:Actor rdf:resource='Svar_ActorID'/>
    </xfn:Constructor>
    <xfn:Condition>
     <tapas:Actor rdf:resource='Svar_ActorID'/>
    </xfn:Condition>
   </xfn:SetOf>
  </xet:Body>
</xet:Rule>
<xet:Rule name='R1Requirement' priority='4'>
  <xet:Head>
   <tapas:Actor rdf:resource='Svar_ActorID'/>
  </xet:Head>
  <xet:Body>
   <xfn:FactQuery xfn:uri='ds://Play-Repository' xfn:mode='Set'>
    <tapas:Role rdf:about='Svar_RoleID'>
     Evar_properties
    </tapas:Role>
   </xfn:FactQuery>
   <xfn:FactQuery xfn:uri='ds://PV-Repository' xfn:mode='Set'>
    <tapas:Actor rdf:about='Svar_ActorID'>
     Evar_properties
    </tapas:Actor>
   </xfn:FactQuery>
   <xfn:MatchD xfn:mode='Set'>
    <Expression>
     <tapas:connectivity rdf:resource='Svar_resource'>
      <tapas:connType rdf:resource='Svar_connType'/>
      Evar_otherConnProps
     </tapas:connectivity>
     Evar_otherActorProps
    </Expression>
    <Expression>Evar_properties</Expression>
   </xfn:MatchD>
   <xfn:StringIsMember xfn:string='Svar_connType'
     xfn:list='Secured SecuredWireless'/>
  </xet:Body>
</xet:Rule>
```

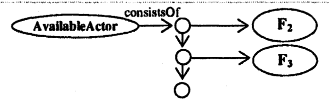
Rule *SearchFreeActor* will be matched with the body of the query clause defined in Section 5.3. After the matching, the body of the query clause will be re-written with *xfn:SetOf*, which is the only body atom of the rule. *xfn:SetOf* will to try to construct the list of available actors and add them into *Evar_actors* variable. Each members of *Evar_actors* will have the structure similar to the expression in *xfn:Constructor*. To actually instantiate the possible values for the constructor, the condition expression in *xfn:Condition* will be matched with other rules (clearly *R1Requirement*).

R1Requirement queries the R1 role requirement (required PV-capabilities and -status), which have been defined in Section 5.1. The rule again queries actors offering the same PV-capabilities and -status, which R_1 requires. The matching between required and offers PV-capabilities and -status are accomplished though the instantiation of variable *Evar_properties*. The actors queried from the capability and status repository needs *Status_Active* and *Status_FreeActor*. The actors can also have other PV-capabilities and -status because they are allowed by the role requirement.

The structure of PV-capabilities and -status of each actor will be matched with *xfn:MatchD* function so that PV-capability *connType* with a value *Svar_connType* can be inspected. Function *StringIsMember* verifies the instantiated value of *Svar_connType* to make sure that it is a member of the list *"Secured SecuredWireless"*. Actors that do not offer secured or secured wireless connection will be filtered out. Only qualified one will be selected. *R1Requirement* can return many answers.

The answers returned by *R1Requirement* will be aggregated and added to *Evar_actors* list in the rule *SearchFreeActor*. The value of *Evar_actors* will be instantiated to the head of the query clause, which will be the answer of the reasoning process.

Figure 10. Local configuration rules in XET



```
<tapas:AvailableActors>
 <tapas:consistsOf rdf:parseType='Collection'>
   <tapas:Actor rdf:resource='F2'/>
   <tapas:Actor rdf:resource='F3'/>
 </tapas:consistsOf>
</tapas:AvailableActors>
```

Figure 11. RDF-based graphical notation and XML-serialization of the configuration result

7. CONCLUSION

This paper presents an approach to model the behavior of service systems by actors playing roles defined in manuscripts. The actor is a combination of an Extended Finite State Machine (EFSM) and a rule based reasoning engine.

A service system has defined requirements to capabilities and status. Because of continuous changes in capabilities and status, dynamic service configuration with respect to capabilities and status is needed. Configuration is based on the matching between required capability and status of a role and the present executing capabilities and status. Roles are allowed to be moved to increase failure robustness and survivability of a service system. This role mobility can be achieved through EFSM behavior. However, using a rule-based reasoning mechanism allows actors to use local configuration rules to take decisions based on the current executing capabilities and status. The actor model improves actor functionality, increases survivability and makes the configuration management distributed.

Generic actor execution support consisting of a state machine interpreter and a reasoning engine has been implemented and applied for the presented example. All capability and status related data as well as actor behavior is based on XML representations, with exceptions of the EFSM actions. Normal EFSM actions are platform-specific (such as C++) or platform-independent (such as Java) executable codes while reasoning-based EFSM actions are XML-based. The reasoning engine is based on Native XML Equivalent Transformation.

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