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Formally Specified Dynamic Composition of Services in Pervasive Environments

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***Abstract*—Ubiquitous and pervasive applications may present critical requirements from the point of view of functional correctness, reliability, availability, security and safety. In contrast to the case of classic safety critical applications, the behavior of ubiquitous and pervasive applications is affected by the movements and location of users and resources.**

This paper presents a method for the formal specification and certification of the properties of services in a ubiquitous environment and their composition.

***Index Terms*—Software Certification, Ubiquitous Computing, Dynamic Composition of Services.**

I. Introduction

Nowadays, in the internet complex services are typically built start from simple "On the shelf" basic services sometimes even offered by different organizations. Composition of services has received much interest to support business-to-business and enterprise applications integration. The business world has developed a number of XML-based standards to formalize the specification of web services, their composition and their execution. On the other hand, the semantic web community focuses on reasoning about web resources by explicitly declaring their preconditions and effects with terms defined precisely in ontologies. Current service composition approaches range from practical languages aspiring to become industrial standards (e.g. BPEL and OWL-S) to more theoretical models and languages (e.g. automata, Petri nets, and process algebras) [1].

Some work has been done to provide formal descriptions and mechanisms for the composition of services in dynamic worlds.

In [2] authors give a formal description of a service architecture with Z notation, and then demonstrate an example of dynamic service composition based on the formal architecture.

In [3] authors designed a MAS structure named CSMWC(Collaborative Structure of MAS for the Web Services Composition)from a new view of the dynamic web service composition to remedy these shortcomings, They formally describe the constructed MAS system framework by using Spi calculus and reason the dynamic property, its adaptability, securities etc for the dynamic web service composition. Finally, we test and demonstrate our idea by the SPRITE tool based Spi calculus

In [4] authors argued that software architecture, esp. dynamic software architecture (DSA), should be used as a complement view for the commonly adopted workflow views in service composition. Furthermore, a novel reification mechanism for DSA is proposed to enable the runtime evolution of the architecture. A corresponding system named Artemis-ARC is implemented to support the development, execution and dynamic reconfiguration of service-oriented applications.

In this paper we present a formal methodology, which has been devices for pervasive and ubiquitous environments, adopted for the specification of properties of services, in a pervasive environment, and their composition. In particular, II introduces the formal method. Section III presents the approach. Section concludes the paper.

II. Bigraphical Reactive System

Bigraphical Reactive System (BRS) [5] is an emerging meta-model that derives from pi-calculus and -in addition to *Ambient Calculus*- deals with the interactions between mobile agents. A bigraph is a structure that enables the description of both the location of entities and their interactions. A bigraph includes two graphs, the *topograph* (or place graph) that describes locations of nodes and the *monograph* (or link graph) that describes their links.

An example of bigraph is reported in figure 1. In the picture, locations are represented by nodes of type r_i, v_j, and s_k. Nodes of type r_i are called roots and are part of the *outer face* of the bigraph, as well as names of type y_l. Nodes of type s_k, which are called sites, represent a sort of hole that can be replaced by other bigraph. Sites and inner names (x_m) form the *inner face* of the bigraph. The bigraph *B* has, then, an interface like *B*: $<3, \{x_0,x_1\}> \rightarrow <2, \{y_0,y_1,y_2\}>$, indicating that *B* has three sites and inner names x_0, x_1, and two roots and outer names y_0, y_1, and y_2. It is possible to compose the bigraph *B* with another bigraph *A* by nesting *A* into *B* (written *B*o*A*) if, and only if, the inner face of *B* matches the outer face of *A*. Other possible operations are parallel product and merge product, as shown in figure 2.

Such a model deals with static structures. For dynamics, there will be reaction rules that change the state of the system. A reaction rule is a pair of bigraphs called *redex* (or pre-condition) and *reactum* (or post-condition). An example of reaction rule is described in figure 3, which depicts the effect of the movement of the node v_2 into the node v_3.

This method, however, is still far to be mature and fully useful. As stated by the author himself, "*the model is only a proposal; it can only become foundational model for ubiquitous computing if it survives serious experimental application. For the latter, it must be seen to yield language for programming and simulation, and equipped with appropriate mechanized tools for analysis, such as model checking*" [5].

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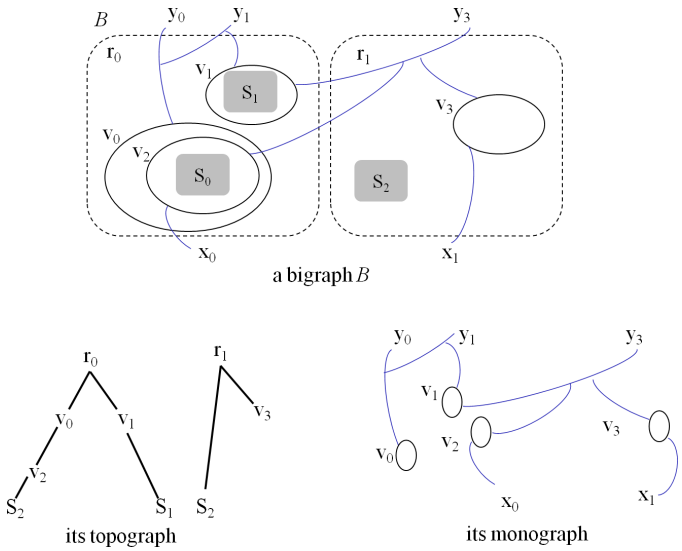

Fig. 1. BRS - Example of bigraph.

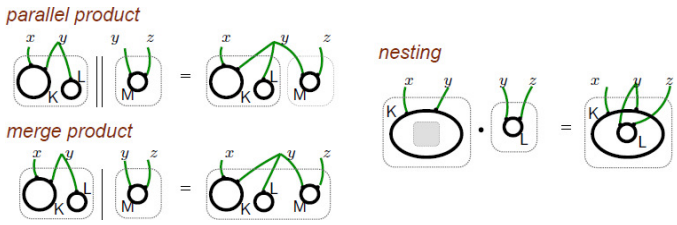

Fig. 2. Bigraph operations.

A. A simple case study

The case study is a smart Department of Nuclear Medicine. Within the Department, patients are injected with a small amount of a radioactive substance in order to undergo specific examinations (e.g. Blood Volume Study, Bone Scan, Brain Scan, etc.). Once injected, patients emit radiation (gamma rays) and have to stay in a specific room to wait for the examination to be performed. The time patients have to wait depends on the kind of examination that has to be performed and the time the radioactive substance takes to propagate -within the body- and to decay to the right level. In fact, examinations can be executed only if the radiation level is in a certain range. After the examination, patients return to the waiting room until the level of radiation becomes less than a specific threshold and, so, harmless. The department consists of the following rooms: 1) *Acceptance Room* -This is the room where patients are accepted within the department and wait for injection; 2) *Injection Room* -This is the room where patients receive the injection; 3) *Hot Waiting Room* - This is the room where patients wait for the examination after having been injected and until the radiation level reaches the correct range; and 4) *Diagnostic Room* -This is the room

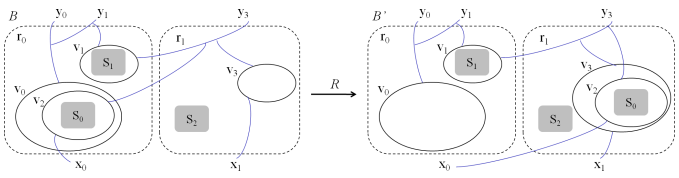

Fig. 3. BRS - Example of reaction.

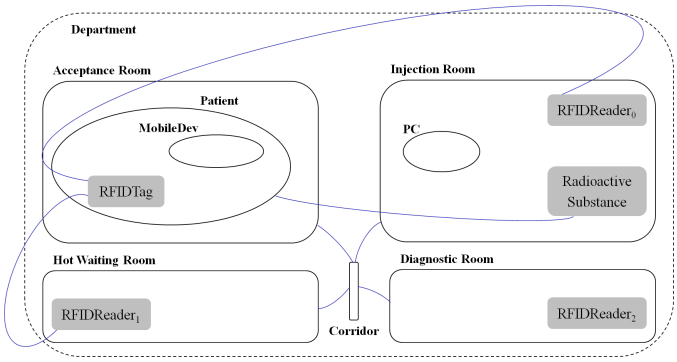

Fig. 4. Bigraph describing the department.

where examinations are performed.

The system will adopt RFID readers and tags to identify and locate patients within the department. Mobile devices will also be used to send messages to patients in order to invite them to move (e.g. "Move to the injection room", "exit the department", "you are not allowed to enter this room", etc.).

B. Using Bigraphical Reactive Systems to model interactions

In figure 4, a bigraph describing the static structure of the department with a patient inside is depicted. All the rooms are linked to a corridor, the patient RFID tag can be read by every RFID reader of the environment, and the radioactive substance can be injected within the body of the patient.

The patient is called into the injection room by means of a message sent by the PC into the injection room and received by the mobile device of the patient. The action of sending and receiving such a message is specified with the first reaction rule (namely *Call*) of figure 5. The figure also shows the change of location of the patient performed after having received the message. Thus, the final result of a call is to make the patient move into the injection room.

The second reaction rule described in the figure, instead, concerns the injection of a radioactive substance and represents the transfer of such a substance to the body of the patient.

III. Specification of Services

In this section, we use *Bigraphical Reactive System* to model some properties of services and their composition.

A. Example

Let's focus on the counter of inversions in a sequence of sensed data by a sensor. We consider two classes of services *Channel* and *Counter*. Let's suppose the following properties for any channel:

- $CONNECTION = (CONNECTION - LESS, CONNECTION - ORIENTED)$
- $RELIABILITY = (RELIABLE, UNRELIABLE)$
- $REAL - TYME = (REAL - TIME, NON\_REAL - TIME)$

and two actual channels

1) UDP=$(CONNECTION - LESS, UNRELIABLE, REAL - TIME)$
2) TCP=$(CONNECTION - ORIENTED, RELIABLE, NON\_REAL - TIME)$

In contrast, any counter presents one property, namely $ORDER=(REORDERED, RANDOM)$, concerning the ability to

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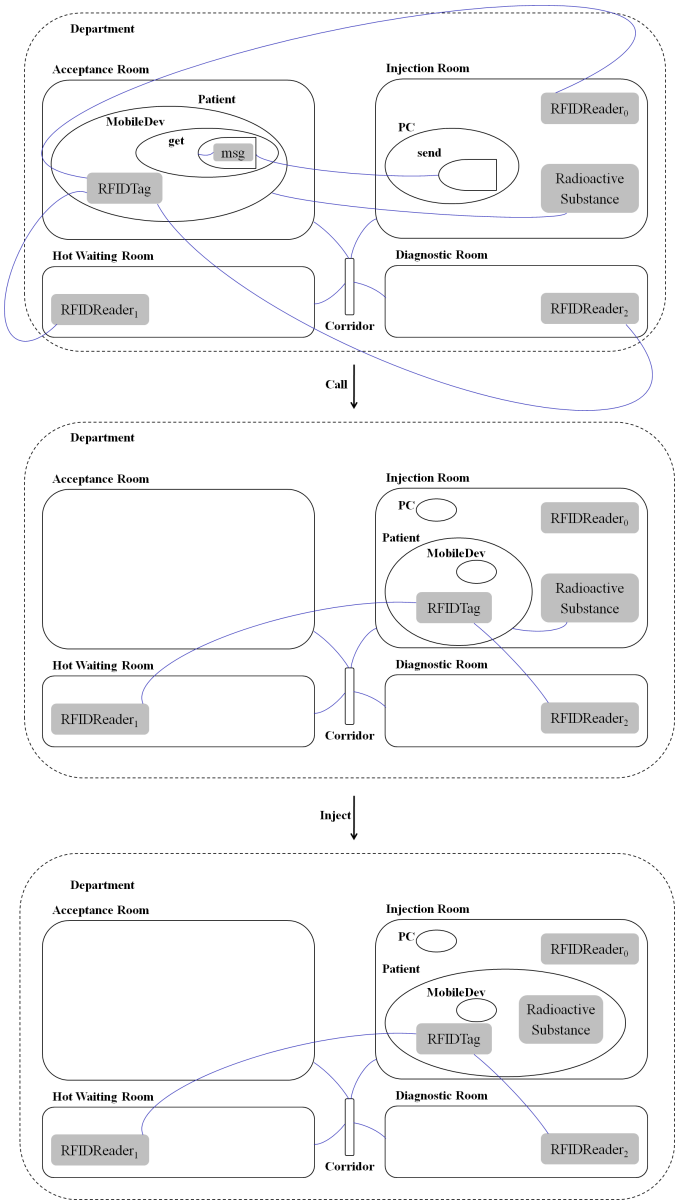

Fig. 5. A sequence of two reaction rules for the department.

reorder the sequence of received sensed data by means of temporal timestamps. The counter also ”includes” one channel to receive sensed data.

B. Using Bigraphical Reactive Systems to model service composition

Figure 6 shows the graphic representation of a certificate of properties for a counter. Specifically, the depicted service has one property indicating its inability to reorder the sequence of sensed data received from a channel that is represented as a site in the bigraph. The (bigraph) interface for the *Counter* is:

Counter: $<1, \{CONNECTION, RELIABILITY, REAL-TYME\}> \rightarrow <1, \{REORDER\}>$

In contrast, every channel could be represented by a bigraph with the interface

Channel: $\epsilon \rightarrow <1, \{CONNECTION, RELIABILITY, REAL-TYME\}>$

indicating that the *Channel* has no sites and inner names, but it has three outer names (exposed properties) $CONNECTION$, $RELIABILITY$, and $REAL-TYME$. Figure 7 reports the bigraphs for both UDP and TCP channels.

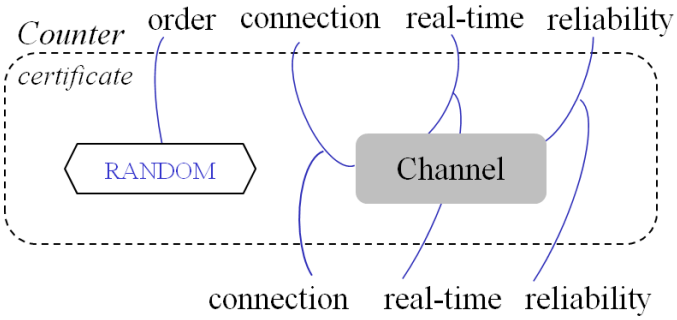

Fig. 6. Certificate for the service *Counter*.

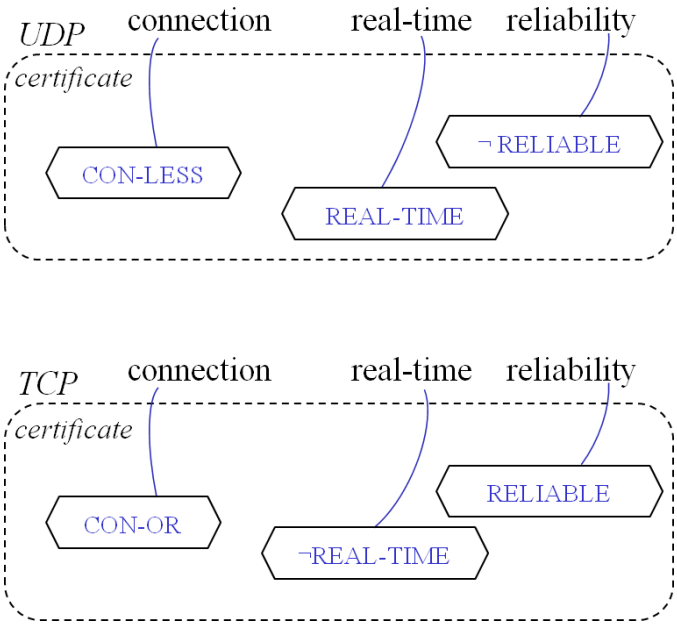

Fig. 7. Certificates for the services *UDP* and *TCP*.

Because of the structure of the interfaces specified so far, it is possible to compose the service *Counter* with any *Channel*. Figure 8 depicts the composition of the service *Counter* with the channel *TCP* and the resulting bigraph.

Finally, it is possible to describe formally the behavior of the counter by means of a set of parameterized reactions. In figure 9, the reaction *Count* is described. In this case, the reaction has the following set of controls:

Count = $\{V_{i+1}, V_i, T_{i+1}, T_i, C_{i+1}, C_i\}$ where T_j is 1 if the value of recent sensed data is increasing, and 0 viceversa.

This reaction is also described as it follows:

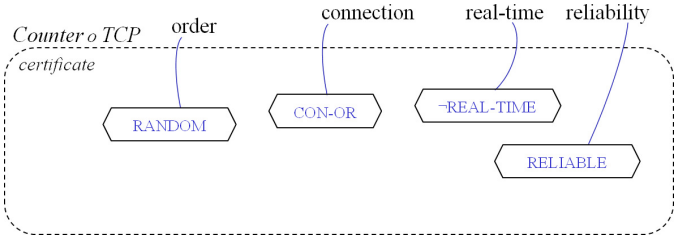

Fig. 8. Certificate for the composition of the services *Counter* and *TCP*.

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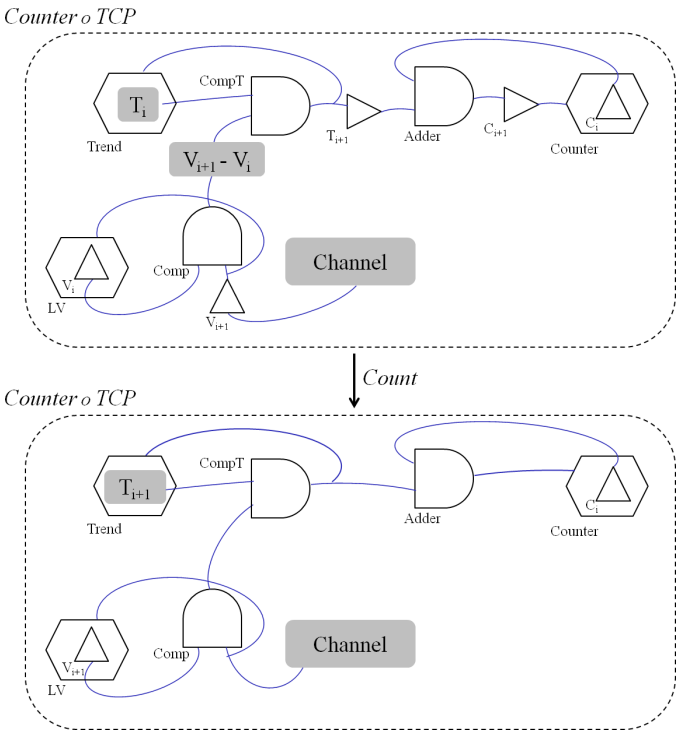

Fig. 9. Reaction rules for the service *Counter* over the channel *TCP*.

Count = $\{V_{i+1},V_i,T_{i+1},T_i,C_{i+1},C_i\} \rightarrow \{V_{i+1},T_{i+1},C_i\}$, iff $(((V_{i+1} - V_i) \geq 0) \wedge (T_i = 1)) \wedge ((V_{i+1} - V_i) \leq 0) \wedge (T_i = 0))$

meaning that the count (C_i) doesn't change if the trend is increasing and the current value (V_{i+1}) is greater than the last value (V_i), or viceversa.

IV. Conclusions

This paper has presented an approach to dynamic composition of service components and proposed a method for the formal certification of composed services properties. A composite service interface can be created using specific operators of the formal method, the Bigraphical Reactive System.

References

[1] M. Beek, A. Bucchiarone, and S. Gnesi, "A survey on service composition approaches: From industrial standards to formal methods," in *In Technical Report 2006TR-15, Istituto*. IEEE CS Press, 2006, pp. 15–20.

[2] J. Sun and H. Miao, "A formal architecture supporting dynamic composition of web services," in *Networking and Services, 2006. ICNS '06. International conference on*, july 2006, p. 48.

[3] D.-H. Xu, Y. Qi, D. Hou, Y. Chen, and L. Liu, "A formal model for dynamic web services composition mas-based and simple security analysis using spi calculus," in *Next Generation Web Services Practices, 2007. NWeSP 2007. Third International Conference on*, oct. 2007, pp. 69 –72.

[4] P. Yu, X. Ma, and J. Lu, "Dynamic software architecture oriented service composition and evolution," in *Computer and Information Technology, 2005. CIT 2005. The Fifth International Conference on*, sept. 2005, pp. 1123 – 1129.

[5] R. Milner, "Bigraphs and their algebra," *Electr. Notes Theor. Comput. Sci.*, vol. 209, pp. 5–19, 2008.

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