BIONETS: Self Evolving Services in Opportunistic Networking Environments

Iacopo Carreras[1], Louay Bassbouss[2], David Linner[2], Heiko Pfeffer[2], Vilmos Simon[3], Endre Varga[3], Daniel Schreckling[4], Jyrki Huusko[5], and Helena Rivas[5]

[1] CREATE-NET, Trento, Italy
[2] TUB, Berlin, Germany
[3] BUTE, Budapest, Hungary
[4] Univ. of Passau, Passau, Germany
[5] VTT, Finland

Abstract. This paper presents the *BIONETS* opportunistic service evolution platform. The proposed platform allows pervasive services to evolve over time by exploiting opportunistic communications among mobile nodes on the one hand, and evolutionary computation techniques on the other. We present the main components of the platform, describing their functionalities and technical implementation. Finally, we present the hardware–in–the–loop approach we have followed to evaluate it, where a simulation platform, in charge or reproducing a large number of mobile nodes communicating wirelessly, is integrated with a real software prototype.

Keywords: evolutionary services, opportunistic networking, hardware–in–the–loop, demonstrator, BIONETS.

1 Introduction

Opportunistic communication systems [1] have gained a significant attention from the research community. This is mostly due to the proliferation of mobile devices such as smartphones, equipped with short-range wireless connectivity (e.g., Bluetooth and WiFi) that have encouraged the development of applications which allow users to produce, access and share digital resources without the support of a fixed infrastructure. This includes not only digital content, but also mobile pervasive services residing on users portable devices. In particular, services become now able to interact with each other simply as the consequence of users co-location. This is enabling innovative execution models where services are able to share/exchange components, data and evolve over time in order to adapt their behavior to a specific situation or context.

Starting from this socio-technological trend, the *BIONETS* project [2] developed the concept of *opportunistic evolutionary services*, which consists in pervasive services evolving as the consequence of $P2P$ localized interactions among mobile nodes. The reference scenario is constituted by mobile services, running on users' portable devices, and able to evolve as the result of (i) service execution by users (ii) interactions among different services running on various user devices. Evolutionary principles are applied to different generations of *composite services*, which are complex services resulting by

E. Altman et al. (Eds.): Bionetics 2009, LNICST 39, pp. 88–94, 2010.
© Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering 2010

the interwinding of atomic ones. The evolution process takes place by first evaluating the fitness of a given service composition, and then applying genetic operators to create new ones.

In this paper we will describe the BIONETS platform, which is the combination of an opportunistic content distribution framework and a distributed service execution engine based on the concept of portable services. The platform has been evaluated following a hardware–in–the–loop approach, where a simulation platform reproducing mobile nodes moving and exchanging data is integrated with a prototype of the application being provided to users.

The reminder of this paper is organized as follows. In Sec. 2 we will briefly describe the opportunistic service evolution concept. In Sec. 3 we will describe the demonstrated platform and the hardware–in–the–loop approach. Finally, in Sec. 4 we will conclude the paper, pointing out current research activities.

2 Evolutionary Opportunistic Services

The reference application scenario of the BIONETS project [2] is that of future computing environments: smart ambients characterized by a halo of heterogeneous mobile devices embedded in the environment and by mobile nodes exchanging data through localized interactions whenever in close proximity. Due to the mobility of nodes, disconnected operations represent the rule, rather than the exception, and information is diffused similarly to the spreading of an epidemic. *Opportunistic evolutionary services* refer then to mobile services being executed over such an opportunistic networking infrastructure, and evolving over time as the consequence of a distributed evolutionary process.

2.1 Epidemic Data Spreading

Starting from the considered application scenario, the BIONETS project developed the "disappearing networking" concept, which is a networking framework addressing the problems of scale (in terms of number of devices) and heterogeneity (in terms of different features supported by the different nodes). In particular, it provides a novel network architecture, centered around the concept of "epidemic spreading" of information: similarly to the spreading of an epidemic, data is diffused by means of localized interactions among mobile nodes. Data exchanges are regulated by a dissemination scheme, which determines the rules according to which data is forwarded from one node to another. Refer to [3] for a comprehensive overview of the different data forwarding schemes that can be used in order to deliver messages in an opportunistic communication environment. We have then designed and evaluated various data dissemination schemes, and studied how different message forwarding algorithms can co-exist on the basis of natural selection principles [4].

Various security mechanisms were also investigated to ensure classical security characteristics in such a non-classical environment. In particular availability, reliability, and trustworthiness of the information spread are critical aspects to be considered. For this purpose, we developed a so called *barter-based-approach* [5] which has the characteristic that the only beneficial behaviour for an attacker, such as a selfish-node, is beneficial for all nodes in the network.

This mechanism can be complemented by a *fair exchange protocol* which also allows the fair exchange of valueable information even though no central trusted third party is present. Here again, the characteristic of the disappearing network is exploited by defining a transient trusted third party formed by the surrounding nodes. Finally, the quality (or trustworthiness) of the information spread in BIONETS is evaluated by a trust and reputation management system. This is done by assessing the trust of the node the information originates from.

2.2 Evolutionary Mobile Services

Evolutionary services are expected to run on top of such "disappearing networking" infrastructure, and to be subjected to a specific service life-cycle which describes their creation, lifetime and possible deprecation. Traditional service life-cycles are rather static and do not possess abilities to dynamically respond to environmental changes. Differently, in BIONETS we are focusing on highly dynamic environments, which required the realization of a novel bio-inspired life-cycle, which features service compositions that can evolve over time to remain adapted to the environmental context and can support the security requirements therein [6].

The bio-inspired service life-cycle has been realized on top of the BIONETS *SerWorks* framework [7], which is depicted in Fig. 1. It consists of four loosely coupled containers. An *Application Container* holds atomic services as well as service compositions; a *Network Container* encompasses services providing networking functionalities. Both types of services are not extended to provide a certain autonomic behavior. Instead, a third container contains a set of *Mediators*, which realize basic functionalities such as service discovery/recovery, as well as complex operations such as the modification

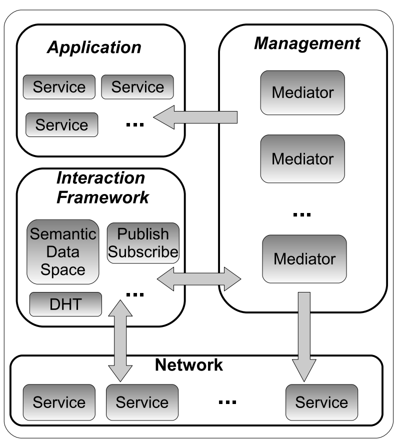

Fig. 1. The BIONETS Serworks system architecture

of service compositions by means of genetic operators. Interactions among elements of these containers are handled by the Interaction Framework, which implements various interaction models. As an example, in Fig. 1 a DHT, Puslish/Subscribe and Semantic Data Space interaction models are considered.

The interaction model includes also the support for service migration, a key element to support service evolution and to increase the service penetration in a dynamic environment. Service migration can be interpreted as a special case of a wider service mobility concept, where the running service, or set of services, are transferred from one node to another, while keeping all the user and network associations alive during the procedure. In the BIONETS platform, the service mobility and migration is handled by a specific software entity, which makes the decision and triggers the movement of the service over the existing network. In order to realize such procedure, such component needs to gather information also from the other containers (including e.g. the networks status information from the network container) and to interact with the other Mediators.

In this paper's scope, the BIONETS service migration is defined as node's capability to exchange service descriptions with other nodes over the network and within the connectivity range, and to execute the service with either the service's original preference set or if necessary with modified preference set corresponding the special requirements of the new platform, such as new user credentials etc. In this migration scenario, we do not assume multi-hop network and the migration happens over the point-to-point link.

Evolving Service Compositions. One of key objectives of the BIONETS project is to define innovative solutions for enabling the adaptation of service compositions during runtime. The many existing solutions are based on the simple replacement of services based on certain additional information. For instance, in [8] genetic operators are used to enable a QoS-aware creation of service compositions by selecting the single services within the composition based on their quality. However, they did not revise the structure of the service composition itself and thus did not address the problem of related semantic service descriptions. In [9], authors proposed a policy specification language and respective hierarchical policy model to incorporate the users context during the binding phase of a service compositions creation and thereby also provide a solution to adapt services based on a changing user context. Again, this solution focuses on an optimal replacement of single services, but cannot provide an alternative solution in case the service cannot be replaced by exactly one other service.

In BIONETS, we aim to overcome the limitations of information driven adaptation and replacement algorithms towards an autonomic evolution of applications, where underlying service compositions are continuously evolving over time in order to fit into the continuously changing environment. This is achieved through a service composition model where a workflow graph based on modified timed automata and a dataflow graph serve as the basis for evolutionary applications [10]. By applying genetic operators we are able to evolve service compositions in order to substitute parts of the application that have dropped out and to provide an equivalent functionality with a different set of services [11]. Equivalently, we developed mechanisms [12] which modify the service composition model in order to guarantee security requirements of the user, of the user's data the service uses to operate, or the device the service is running on.

3 The BIONETS Platform Demonstrator

The BIONETS platform is a practical implementation of a mobile framework supporting the execution of *evolutionary opportunistic services*. It consists of (i) a software prototype of the platform (ii) a simulation environment, which is used to reproduce a very large number of mobile nodes exchanging data over time. The software prototype and the simulator are integrated following a *hardware–in–the–loop* approach, where the scale of a very large number of mobile nodes is delegated to a simulation environment, and the user interactions of the developed application is implemented in a real prototype (Fig. 2). More in detail, this consists of a server simulating a mobile network containing a large number of virtual nodes. The prototype connects to this server and participates in the simulated network, just like it was a real one. This allows to stress test the prototype in a much larger environment that is not practically possible by using real devices. In this setting, the prototype is represented in the simulation through a *delegate* node, which is a simulated node implementing all the networking functions and interacting with the Service Framework that is running in the prototype.

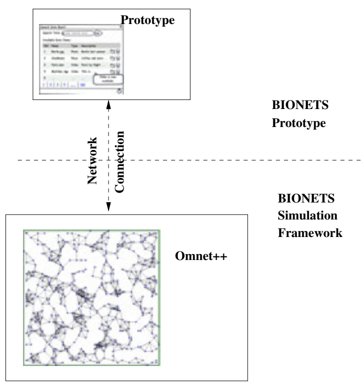

Fig. 2. The hardware–in–the–loop demonstrator architecture

3.1 Simulating an Opportunistic Network

To verify and benchmark the system properties of BIONETS, a special purpose simulation platform was implemented. This was based on $OMNeT++$ [13], a C++ simulation library which includes the support for simulating a mobile network. The focus of the simulator is the implementation of the networking functions of the SerWorks architecture Fig. 1, which specifies a service oriented dynamically configurable networking solution. This module encapsulates all of the opportunistic networking and epidemic spreading related protocols, as well as many of the security solutions (e.g., trust and reputation management, fair exchange and barter based protocols). The challenges related to the development of this platform mostly relate to the (i) implementation of a platform that was able to scale up to a very large number of nodes (ii) support of a wide range of different data dissemination schemes that could be selected at runtime.

3.2 Evolving Service Compositions

In BIONETS, composed applications are modeled by means of service compositions that are represented as timed automata [14]. This formal notion constitutes a formal link to mature research areas such as semi-group or category theory, making existent algorithms applicable to the BIONETS service composition notion. In addition, the special consideration of real-time aspects makes the composed application responsive to timeout and delays, such that services can by dynamically exchanged during runtime in case a service or its host device is no longer responding.

A runtime environment has been developed that supports the execution of these timed automata based service compositions. An implementation is available both for services as well as for smaller mobile devices. The latter version is implemented in pure JavaScript, such that it can be initially transferred to the client device and run on every user device featuring a Web browser with a JavaScript interpreter; changes on client devices are thus not necessary.

Services are labeled with semantic descriptions specifying their inputs, outputs, preconditions, and effects, so-called IOPE descriptions [15]. Based on these annotations, algorithms have been created to automatically create a service composition for a requested set of effects and outputs. Within the scope of our demonstration environment, variants of these algorithms are used to dynamically create service compositions and to evolve them over time in order to remain adapted to the continuously changing environmental context. Here, a user can initially subscribe to a set of services or functions. Appropriate services are discovered and offered to the user. In case a service is considered as suitable, it is automatically integrated into the user's current service composition. Every time new services become available within the network, services are offered to the user and optionally integrated during runtime. Thereby, the application evolves over time, offering an adapted application to the user given the current landscape of available services. To achieve a mapping from service compositions underlying evolvable Web applications, we developed a mapping from the service compositions to a graphical presentation. Here, services are classified according to the resources they generate. For instance, there are services operating on map, others on locations, and others on images. The resource allows us -in the style of the Web- to derive a representation of the current state of the service composition. Every time a resource is modified by means of a service execution, the accordingly modified resource is pushed to the frontend such that its presentation can be updated.

4 Current Research Work

In this paper we have introduced the concept of evolving opportunistic services, we have described their practical implementation over the BIONETS platform. Current research activities are currently concerned with the implementation of *MyDirector*, an application that loosely combines mobile services for the presentation of location-based data. The application supports the geo-referenced capturing and sharing (via opportunistic networking) of video snapshots in an urban environment. This use-case will be used as a driver for the evaluation of opportunistic evolvable services in a concrete application scenario, providing a valuable feedback on the developed platform and a benchmark for the implemented algorithms and solutions.

Acknoledgements

This work has been supported by the European Commission within the framework of the BIONETS project ISTFET-SAC-FP6-027748, www.bionets.eu.

References

1. Pelusi, L., Passarella, A., Conti, M.: Opportunistic networking: data forwarding in disconnected mobile ad hoc networks. IEEE Comm. Mag. 44(11) (November 2006)
2. BIONETS: Bio-inspired evolution for the pervasive age, http://www.bionets.eu
3. Hanbali, A.A., Ibrahim, M., Simon, V., Varga, E., Carreras, I.: A survey of message delivery protocols in mobile ad hoc networks. In: Proc. of INTERPERF, Athens, Greece (October 2008)
4. Simon, V., Bérces, M., Varga, E., Bacsardi, L.: Natural selection of message forwarding algorithms in multihop wireless networks. In: Proc. of IEEE WiOpt, Seoul, Korea (June 2009)
5. Buttyan, L., Dora, L., Felegyhazi, M., Vajda, I.: Barter-based cooperation in delay-tolerant personal wireless networks. In: Proc. of WoWMoM (2007)
6. Pfeffer, H., Linner, D., Radusch, I., Steglich, S.: The bio-inspired service life-cycle: An overview. In: Proc. of ICAS, Athens, Greece (June 2007)
7. Pellegrini, F.D., Miorandi, D., Linner, D., Bacszardi, L., Moiso, C.: Bionets: from networks to serworks. In: Proc. of SAC, Budapest, Hungary (December 2007)
8. Canfora, G., Penta, M.D., Esposito, R., Villani, M.L.: An approach for qos-aware service composition based on genetic algorithms. In: Proc. of ACM GECCO, New York, NY, USA (July 2005)
9. Zhang, B., Shi, Y., Xiao, X.: A policy-driven service composition method for adaptation in pervasive computing environment (2008)
10. Pfeffer, H., Linner, D., Steglich, S.: Modeling and controlling dynamic service compositions. In: Proc. of IEEE ICCGI, Washington, DC, USA (August 2008)
11. Linner, D., Pfeffer, H., Steglich, S.: A genetic algorithm for the adaptation of service compositions. In: Proc. of SAC, Budapest, Hungary (December 2007)
12. Schreckling, D.: Adaptive Security in BIONETS. BIONETS (IST-2004-2.3.4 FP6-027748), Deliverable D4.4 (Feburary 2009)
13. OMNeT++: Discrete event simulation system, http://www.omnetpp.org
14. Pfeffer, H., Linner, D., Steglich, S.: Modeling and controlling dynamic service compositions. In: Proc. of ICCGI, Washington, DC, US (July 2008)
15. Jaeger, M., Engel, L., Geihs, K.: A methodology for developing owl-s descriptions. In: Proc. of INTEROP-ESA, Geneva, Switzerland (February 2005)