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▶ **To cite this version:**

Tim De Pauw, Filip De Turck, Veerle Ongenae. Autonomous Service Composition in Symbiotic Networks. 5th Autonomous Infrastructure, Management and Security (AIMS), Jun 2011, Nancy, France. pp.49-52, 10.1007/978-3-642-21484-4_5 . hal-01585865

HAL Id: hal-01585865

https://inria.hal.science/hal-01585865

Submitted on 12 Sep 2017

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Autonomous Service Composition in Symbiotic Networks

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Abstract. To cope with the ever-growing number of wired and wireless networks, we introduce the notion of so-called *symbiotic networks*. These networks seamlessly operate across layers and over network boundaries, resulting in improved scalability, dependability, and energy efficiency. This particular Ph.D. research focuses on software services operating in such symbiotic networks. When two or more networks merge, the services provided on them may be combined into a service composition that is much more than the sum of its parts. Driven by two distinct use cases, we aim to enable fully autonomous service composition and resource provisioning. For the first use case, an in-building over-the-top service platform, we describe a software architecture and a set of generic resource provisioning algorithms. The second use case, which focuses on wireless body area networks, will allow us to expand our research domain into highly dynamic symbiotic network environments, where services appear and disappear more frequently.

1 Introduction

In the future home and office, a large number of networks will be active simultaneously. There will be the public cellular networks used for voice and data services, competing with WiMAX. In addition to wired and wireless LANs, networks used in building automation, such as wireless sensor networks [1], will be commonplace. All in all, the growing number of mobile applications leads to an increasing density of colocated networks and devices.

We aim to bring these networks closer together through the introduction of the concept of *symbiotic networks*: independent, colocated, homogeneous and heterogeneous, wired and wireless networks, which operate across all layers and over network boundaries. This will be realized through advanced sharing of information, infrastructure and networking services. In this particular Ph.D. research, we aim to enable novel cross-network services through dynamic service composition in such symbiotic networks. This should ultimately contribute to networks with improved scalability, dependability and energy efficiency.

2 Research Questions

Establishing and maintaining symbiotic networks implies the exploitation and sharing of services that execute in different networks and with varying requirements. Our research focuses on forming symbioses between such services. We aim to answer the following research questions:

1. *How should resource and service parameters be modeled?*
   When a symbiotic network is formed, many parameters can be decisive toward collaboration at the application level. The identification and representation of these parameters is our first goal.
2. *How can the parameters' values be monitored?*
   Once key parameters have been identified, we need to determine how to measure them, how often they should be collected, andsoforth. Aggregation and caching may help reduce overhead, at the expense of some precision.
3. *How can an effective service composition be reached?*
   Based on parameters extracted from the environment, the actual symbiosis needs to be realized. The composition of services and the allocation of resources are subject to numerous constraints, calling for efficient algorithms.
4. *How should changes in the environment be handled?*
   The service composition should be dynamic. Changes in the environment must therefore be analyzed to see if the existing composition should be updated to reflect them. Ideally, this would be handled transparently.
5. *Which supporting components should enable the symbiosis?*
   To actually allow software components to operate in a symbiotic fashion, an enabling software platform must be available. The design of this platform forms another one of our goals.
6. *What makes a realistic test scenario?*
   For the validation of our findings, they need to be applied to representative scenarios. On one hand, random yet realistic scenarios can be generated. On the other hand, a real-life test case could also be interesting.

3 Approach

Our research focuses on two use cases for symbiotic networks. The first one emphasizes the case of static service composition, where new networks and services rarely appear. It serves as a stepping stone for the second case, where the symbiotic network and its service composition are highly dynamic in nature.

We envisage a context-aware **in-building** service platform to streamline day-to-day life in homes and offices. Context awareness means that the platform is driven by environment information such as the location of a user, his personal preferences, and his calendar, but also temperature measurements, cafeteria menus, andsoforth. The platform will help users find friends or coworkers, send them personalized recommendations, etc., and interact with their mobile devices, but also display information on wall-mounted screens, for instance.

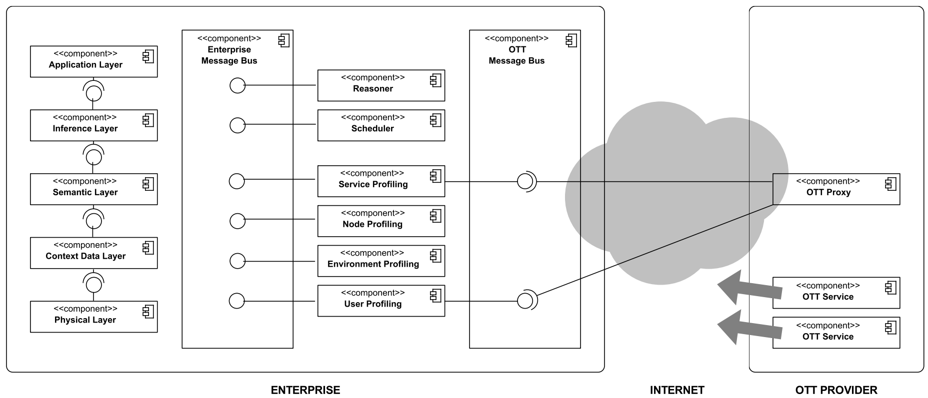

Fig. 1: Component diagram showing the in-building context-aware platform

The services supporting this platform's operation are quite diverse. Therefore, it is wise to delegate them to external service providers. By deploying the *over-the-top* paradigm, we allow these providers to inject their services into the platform and access its hard- and software components, while the platform itself remains in charge of monitoring and resource arbitration. Thus, implicitly, at least two symbiotic networks are formed. In [2], we described a software architecture to enable such a context-aware over-the-top service platform, thereby presenting initial steps toward answering research question 5. It is displayed in Fig. 1. On the left are five layers commonly found in context-aware applications. [3] Via the *Enterprise Message Bus*, they communicate with a number of enterprise services; among them are profiling services, which maintain context information about key parts of the operating environment. The *OTT Message Bus* allows for interaction with external service providers; via the *OTT Proxy*, a provider may inject his service components into the platform.

Resource provisioning is a core responsibility of symbiotic networks. In response to research question 1, we devised a generic resource model, which copes with the heterogeneity of the infrastructure. Building upon this model, we applied *bin packing* heuristics to the problem of scheduling tasks in heterogeneous environments, thereby providing a preliminary answer to research question 3. Both the model and the scheduling algorithms are detailed in [4].

In the case of in-building service provisioning, the service composition is expected to be rather static. Moving on to research question 4, regarding *dynamic* symbiotic networks, we will be paying attention to **wireless body area networks**. In such networks, sensors are placed on the human body to monitor physiological parameters like heartbeat, body temperature, motion, etc. A symbiotic body area network originates, for instance, when a driver's network merges with his vehicle's to prevent him from falling asleep. Furthermore, that symbiotic network could in turn merge with nearby cyclists', thereby again reducing the chance of accidents. Especially in this second scenario, additional networks appear and disappear quite frequently, calling for immediate response.

4 Validation

We aim to validate the in-building service platform through deployment on our test bed *WiLab*, composed of several hundred wireless mesh network nodes equipped with sensor boards. [5] This will allow us to conduct realistic experiments in a real-life office environment, with actual users.

In an attempt to answer research question 6, we will equip the service platform with an over-the-top service that analyzes context information to identify opportunities for public notices and advertisements, and subsequently broadcasts video streams to mobile devices and fixed displays. Initial benchmarks on WiLab have yielded favorable results, but further experimentation is needed. [2]

We are still in the early stages of researching *dynamic* service composition. The body area network scenario will therefore be addressed further when we have sufficiently researched the case of mostly static in-building services.

5 Conclusion

We introduced the concept of symbiotic networks, which operate across network boundaries to provide a more dependable infrastructure. Guided by the use cases of in-building over-the-top services and body area networks, we aspire to enable fully autonomous service composition in such network environments. Research is currently being carried out toward the first of these use cases. The second will provide insight into highly dynamic symbiotic network scenarios.

Acknowledgment

Tim De Pauw would like to thank the University College Ghent Research Fund for financial support through his Ph.D. grant. Part of this work has been funded by the IWT SBO SymbioNets project.

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