Smart Products: Integration Challenges

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1 Introduction

Smart Products (SPs) are elements for building ambient intelligent environments. AmI is considered to be a merger of Ubiquitous Computing (UC) with Social User Interfaces and refers to electronic environments that are sensitive and responsive to the presence of people [1].

Many visions of UC have already come to reality: Computers are "everywhere" and we have reached an n-to-1 relationship between computing devices and people. Devices are getting cheaper, become easier to use, and wireless network interfaces enable communications.

However, the "smartness", such as autonomic behavior, personalization and cooperation capabilities of these devices is still rather limited. Compared to the notion of *appliances* investigated in UC twenty years ago, which has brought several important base technologies, *Smart Products* aim to add such smart behavior.

2 Context-awareness of Smart Products

Most technological foundations needed to implement the vision of context-aware SPs are already available, such as powerful embedded systems, location tracking systems, sensors, and wireless networks.

SPs encompass three classes of knowledge: about themselves, about actual/potential environments, and about their users [2]. Self-aware SPs must be aware of their functions and components in order to share these capabilities with other devices and interaction partners. For offering more complex services, a smart environment (SE) collects and provides information about its attached SPs and users. As users and SPs can come, go and move, they constantly modify the *world model*.

The typical approach today is to model SEs in a *top-down* fashion: devices/sensors are deployed in the environment and then they manually modeled in the world model. In a world of SPs, it is more likely that SEs will be built in a *bottom-up* fashion. They will dynamically grow by bringing additional SPs into the environment. For reflecting the state of the real environment, the world model can be automatically adapted using location sensors of available products. While the bottom-up approach is beneficial for the user, allowing her to enhance the environment as needed, top-down modeling helps organizations to enforce global policies.

3 Personalized Services for Users

Today, we live in the age of "user-centered" computing: The user is in the center, surrounded by several carry-on or encountered devices. Because these devices do not directly talk to each other in a meaningful way, the user becomes a "mediator". For example, imagine a user who has to manually transfer an address entry from her cellphone to the car navigation system.

The more devices a user carries, the more functionality she will get. However, at the same time, the overall usability often decreases: e.g., a user who synchronizes the calendar of her desktop computer with a PDA and a cellphone will be notified three times - by each device separately - of upcoming appointments. It would be better if the devices would cooperate and determine which one can notify the user best and then inform others once the user has been successfully notified. Personalized communication requires the notion of *communication addressation of persons*, not devices.

For the above reasons, the user would greatly benefit

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from being removed from the center of this picture. Instead, a *personal trusted device* carried by the user can act as the mediator between the human and the digital world. Also, a personal device would be a good place to store personal information, authentication tokens, and process user-related information, such as location and other context, preferences, or recommendations.

Today, users have to directly authenticate with each computing device they wish to interact with. The personal device can introduce a two-stage authentication mechanism: When the user starts wearing the device, she has to authenticate once. Later on, the device will automatically authenticate the user with all encountered devices. This scheme drastically increases user convenience, while preserving security and privacy.

Personalized and proactive user interfaces require user profiles, task models, and context. For privacy reasons, context recognition and prediction should be primarily performed on users' personal devices. Recording context information in the environment might lead to major user acceptance problems. Users feel more comfortable with "smart" personal devices than with "smart" environments that capture information.

4 Communication and Services Integration

The integration of the services offered by SPs requires a new level of *openness* at the networking, communication, and services layers. Ad-hoc wireless networking and the support of hierarchical communication structures are vital infrastructural prerequisites for the interconnection of different smart devices (e.g., VCR, mobile phone and fridge). Therefore, compatible communication standards, support of various protocols and transparent interfaces are required.

Communication middleware is a means to abstract from concrete platforms and networking technologies. For SPs, such a middleware must support dynamic reconfiguration to fit on small devices, peer-to-peer overlays, automatic peer discovery, different communication paradigms (invocations, publish/subscribe, streaming) and different invocation protocols to serve as an integration platform. Today, several products and academic prototypes are available. However, as past experience has shown, the agreement on a single platform or middleware is very unlikely. Hence, standardization efforts should focus on inter-middleware protocols (e.g., SOAP, RMI, IIOP) and standardized APIs (e.g., JSR).

To integrate the services offered by several products into some higher functionality requires *service composition*. Manual composition approaches (e.g., Bluetooth pairing and SDP) are not flexible and dynamic enough and an increasing amount of devices, their services and the composition of complex services poses a cognitive overload to humans. Automatic composition methods are mostly based on *processes* or *goals*. Process-based composition is suitable for implementing fixed workflows where the service providers may vary (e.g., travel booking). Goal-based composition is mostly based on AI planing techniques and aims to reach a predefined end state (e.g., configuring a SE).

5 Security and Trust

The presented vision heavily depends on the seamless integration of the devices and services that are part of the SE. When developing SEs in a managed setting with only trusted participants security issues are usually not a major concern. Yet, in an omnipresent SE that is shared by entities with conflicting interests a reasonable level of security needs to be granted to all participants.

Security and trust may be supported by (1) deployment of Trusted Computing (TPM) for hardware and services platforms; (2) establishment of appropriate access control mechanisms (models & policies) that may be used across devices & products and allow for a fine-grained disclosure of personal information; (3) trust- & reputation-based selection of resources and services.

Although these concepts become more and more established, it is crucial to evaluate whether and how they scale in an environment with an unbound number of participants, limited computing capabilities and in absence of trusted third parties. The integration of security concepts in a non-intrusive but personalized way, as well as an intuitive announcement of the trustworthiness of an environment to the user are major challenges.

6 Ongoing Work

In our current work we center personalization aspects around the user's personal device, called Minimal Entity (ME) [4]. To integrate heterogeneous devices and services, we have developed the communication middleware MundoCore [5], which is available open-source. Further research areas include peer-to-peer, service composition (Theseus/TEXO) and trust (CertainTrust [3]).

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