Service-Oriented Research Opportunities in the World of Appliances

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1 Introduction

There is a rapid growth in the number of ways that appliances are being put to use. New and novel services are being created, personalized, and then delivered by exploiting e-services and appliances. Appliances are being used not only as service clients but also as interfaces to personal agents that help users make better decisions. On the other end, technologies such as Bluetooth are enabling appliances to communicate over adhoc networks and to act as service providers for a new class of services.

Building, deploying, and using such services requires interplay between a number of technologies – service composition, registration, brokers, discovery, introspection, binding, agents, wired and wireless protocols, personalization, and context-awareness to name a few. Emerging high-level middleware platforms such as the XML stack in HP Netaction/Bluestone [1], Biztalk in .NET [2], and place managers in CoolTown [3] are aimed at providing some of these features.

While the addition of appliances brings a whole new class of services into place, the problem of managing these appliances and end-to-end services becomes more challenging. For example, service providers of these new services will be faced with the problem of having to manage a very heterogeneous environment consisting of multiple networks, protocols, and devices. Users of appliances will need additional utilities such a profile management, global login, and security.

This document is a collection of thoughts, interesting technical problems, and opportunities for service-oriented research in the world of appliances. Services in this world could mean (Figure 1):

(a) Network and Infrastructure services that would enable the creation, deployment, operation, management, optimization, and evolution of business services. These are horizontal services that would cut across and would be used in multiple domains.

(b) Vertical business services (domain-specific) that are built for specific markets.

This document focuses on two very broad areas of research:

1. What are the new types of business services that are enabled by appliances, or by a combination of appliances and other existing technologies such as e-services?
2. What are the network and infrastructure services that would enable the creation, deployment, operation, management, optimization, and evolution of such business services?

The rest of this paper is organized as follows: Sections 2 and 3 provide some groundwork to get to a common understanding on appliances, their trends, usage scenarios, and characteristics. Sections 4 and 5 discuss opportunities for research in the two areas listed above.

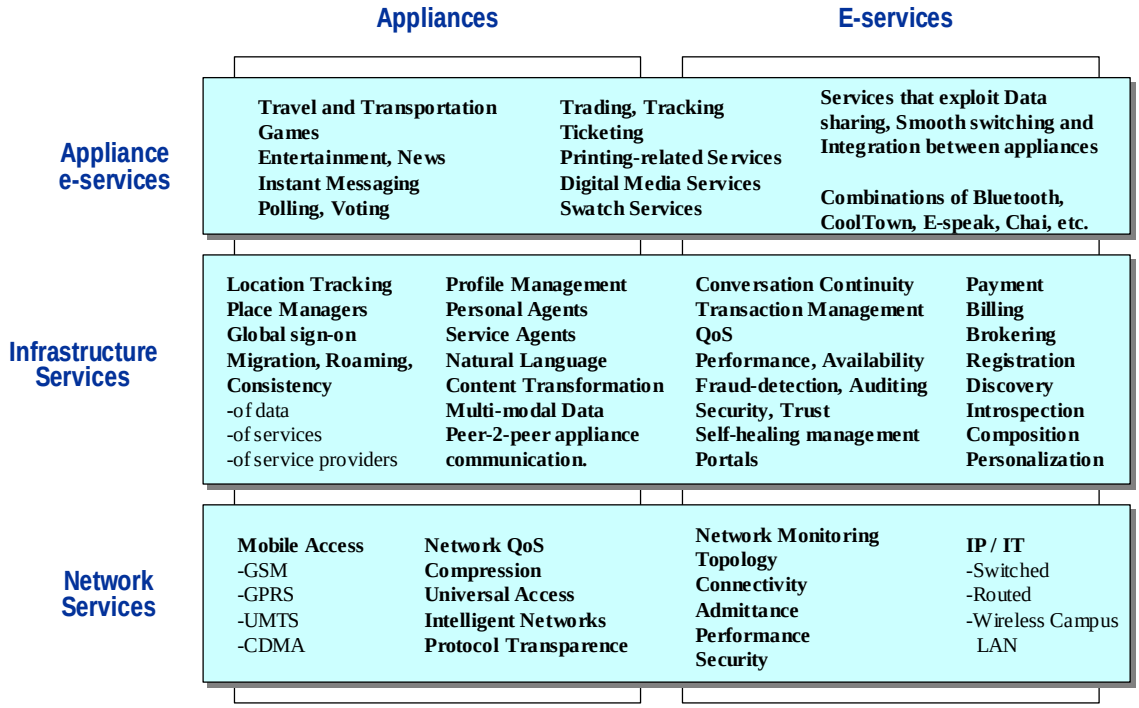

Figure 1. Appliances and Services

2 Appliance Scenarios

This section provides some scenarios that demonstrate how appliances are being used or are anticipated to be used. Understanding these scenarios would help in the rest of the discussion.

1. **Personal utility:** Appliances such as the earlier versions of Palm® and notebook computers have personal utilities such as address and phone book, notepad, etc for assisting users in managing their day to day activities.

2. **Thin service client:** This is a popular way that appliances such as cell-phones and Palm handhelds are being used today. They act as simple browsers that connect to special services on the Internet. For example, many cellular service providers offer (or contract other service providers to offer) stock trading or banking services to their customers. In all these cases, the appliance displays a simple browser (a general purpose software) or a special-purpose user interface to provide access to the service's functionality. In other cases (e.g., games), the appliance may download special-purpose software from the Internet.

3. **Interface to personal agent:** It is anticipated that the world in the future will comprise of a sea of agents – some of which collaborate to provide services (e-commerce agents), and others which act on behalf of end users (personal agents). These agents communicate with other agents and with existing resources on the Internet to accomplish their tasks (Figure 2). For example a personal agent may help the user in selecting the best service by discovering and negotiating with a broker agent. Similarly, a personal agent may interact with the shopping mall agents and with the store agents (in a shopping scenario) to provide the best options and deals to the end user. In all these cases, where pervasive access to the personal agent is required, an appliance acts as the interface to the personal agent. This scenario is not very different from the "thin service client" scenario above from the appliance's perspective. But, it stresses the new class of services that could be offered when appliances are combined with agents and services.

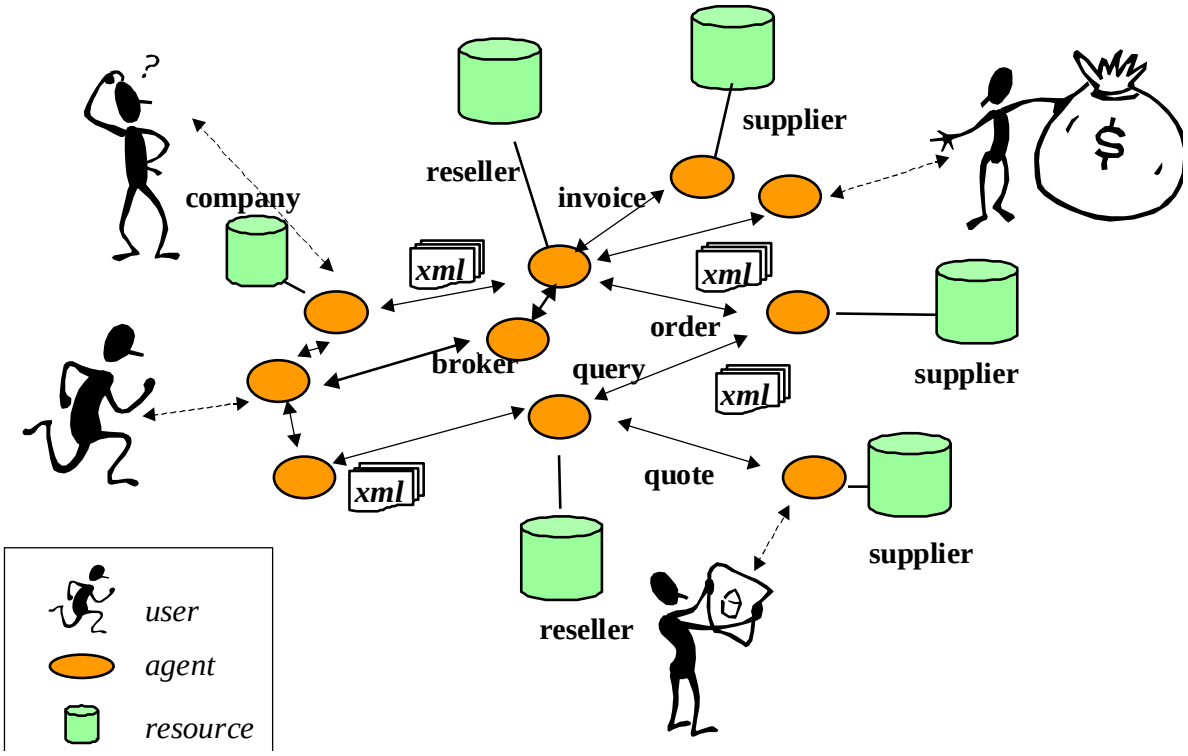

Figure 2. E-commerce agents, personal agents, and users interact with each other.

4. **Embedded web server, identifiable:** Some of the appliances (including those that are fixed) may host embedded software such as a web server. In other cases, these appliances may just provide a unique URL (either using a barcode mechanism or by squirting) to another appliance, which can then be used to connect to a web server located elsewhere. In the simplest case, this enables web pages to be served by the appliance. These web pages could provide basic information about the appliance or even expose some configuration interfaces. In the more advanced case, the web server could host complex objects or agents (e.g., Chai Web Server), thus allowing appliances to download new features or to support complex conversational interfaces.

5. **Network of appliances:** Appliances can communicate with each other. For example, a handheld can beam a document to be printed to a printer. An appliance may use a cellular link to download the profile of its user. In all these cases, appliances exploit the network to provide a new service to their users. In other cases, appliances communicating on a network may offer a new class of services to other customers thereby bringing new sources of revenue for the appliance users. For example, appliances on a adhoc network can exploit each others' unused resources (memory, CPU, connections) etc to perform a better job at what they do. An appliance downloading a huge movie on a cellular link could take a long time to finish the job. But, if the same appliance could exploit the cellular connections of the proximate appliances, it could easily speed up the download process. The fast adhoc network could then be exploited to bring all the pieces of the downloaded movie into one appliance. In examples such as these, there should be payment mechanisms between the borrowers of the appliance resources and the providers of such resources.

3 Characteristics of Appliances

- **Heterogeneity**: Appliances have widely varied capabilities and configurations. Differences exist in terms of appliances' form factors, functionality, mobility, user interface capabilities, connectivity, and protocols used. Further, a device's capabilities are subject to frequent change, yielding frequent change in interfaces and communication protocols.
- **Special purpose vs. generic:** Most of the appliances are made to be special purpose (e.g., toasters, cell phones, etc). Some of them are intended to be general-purpose clients (e.g., handheld browsers).
- **Large number:** A feature that makes appliances so different is that there could be so many of them in use. If we consider the number of special purpose appliances and those that are mobile, we can imagine how many of these there could be.
- **Mobility**: Some of the appliances are mobile with the user (e.g., watches, handhelds, etc.). Some of them may be mobile in other ways (e.g., with the user's car).
- **Intermittent connectivity**: Some of the appliances (e.g., PC) are always connected. Others are intermittently connected. For example, a handheld may be connected when it is plugged in. The rest of the time, it is disconnected. Some of the appliances may have multiple connections. For instance, an appliance may have a cellular link, a Bluetooth link, and a traditional IP link. These connections differ widely in their characteristics. Cellular links are long-range, low bandwidth, and expensive. Bluetooth links are short-range, high bandwidth, and cheap. IP links are medium-range, high bandwidth, and cheap as well. Cellular links and IP links are more pervasive than the Bluetooth links.
- **Adhoc networks**: The networks that appliances participate in may be adhoc in nature. Networks are dynamically created and broken based on the proximity and locations of devices. The only people who can see this network are the users of the appliances. It should be possible to manage these networks and applications built on the top of these networks without the need for additional operators, or even better, make them self-manageable.
- **Context dependence**: The functionality offered by an appliance may change based on the context in which it is used. For example, based on who is using the appliance (user-dependence) the appliance may load different profiles. Based on the location in which it is used (location-dependence), the appliance may access new services.

The services that are built around appliances also exhibit unique characteristics:

- **Heterogeneous networks**: In the end-to-end case, the service may have to pass through various network infrastructures such as IP-based, telco-based, wireless, and adhoc networks.
- **Heterogeneous middleware**: Components of the service will be implemented on various middleware platforms such as Bluestone and .NET for composed e-services and agents, CoolTown for bringing context awareness, and appliances for clients.
- **Intermittently connected providers and consumers:** Because of the intermittent nature of connectivity of the appliances, providers and consumers of services may not always be connected to each other.
- **Context-dependent access, functionality, QoS, and performance:** Based on the context (location, user, etc), a whole new set of services may be offered. Non-functional characteristics of the service such as QoS and performance may also vary widely based on the context.
- **Security and Access:** Providing secure communication and access to services will be even more challenging with the large number of appliances, some of which could be mobile. There are various issues surrounding authentication, authorization, access control, and trust when appliances are used to connect to services.

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