RNA-inspired Framework for Situated Federation of Smart Objects

Yuzuru Tanaka
Meme Media Laboratory, Hokkaido University

Information system environments today are rapidly expanding their scope of subject resources, their geographical distribution, their reorganization, and their advanced utilization. Currently, this expansion is understood only through its several similar but different aspects, and referred to by several different stereotyped terms such as ubiquitous computing, pervasive computing, mobile computing, and sensor networks. No one has clearly defined this expansion as a whole. Recently it is often pointed out that the lack of a formal computation model capable of context modeling to cover this diversity as a whole is the main reason why most applications of ubiquitous computing are still within the scope of the two stereotyped scenarios, i.e., the location-transparent service continuation, and the location- and/or situation-aware service provision.

In expanding information environments of ubiquitous and/or pervasive computing, some resources are accessible through the Web, while others are accessible only through peer-to-peer ad hoc networks. Any advanced utilization of some of these resources needs a way to select them, and a way to make them interoperable with each other to perform a desired function. Here we use the term 'federation' to denote the definition and execution of interoperation among resources that are accessible either through the Internet or through peer-to-peer *ad hoc* communication. Federation is different from integration in which member resource objects involved are assumed to have previously designed standard interoperation interface. The current author has already proposed federation architectures for resources over the Web, and extended their targets to cover sensor networks using ZigBee Protocol, and mobile phone applications. These architectures are, however, still within the framework of Web-based federation.

This paper will focus on the proximity-based federation of intellectual resources on smart objects. Proximity-based federation denotes federation that is autonomously activated by the proximity among smart objects. Smart objects denote computing devices such as RFID tag chips, smart chips with sensors and/or actuators, mobile phones, mobile PDAs, intelligent electronic appliances, embedded computers, and access points with network servers.

This paper will propose three new formal models of autonomic proximity-based federation among smart objects including both physical smart objects with wireless network connectivity and software smart objects such as services on the Web. These three formal models focus on different levels, i.e., federation and interoperation mechanisms, dynamic change of federation structures, and complex application scenarios with mutually related more than one federation. Our first-level formal modeling focuses on the federation interface of smart objects, hiding any details on how functions of each smart object are implemented. Each smart object is modeled as a set of ports, each of which represents an I/O interface of a service provided by this smart object. We consider the matching of a service-requesting query and a service-providing capability as the matching of a service-requesting port and a service-providing port. In the preceding research studies, federation mechanisms were based on the matching of a service-requesting message with a service-providing message, and used either a centralized repository-and-lookup service. In these architectures, messages to be matched are issued by program codes, and therefore the dynamic change of federation structures by message matching cannot be discussed independently from the codes defining the behavior of the smart objects. Our first-level formal modeling allows us to discuss applications from the view point of their federation structures. This enables us to extract a common substructure from similar applications as an application framework. Our second-level formal modeling based on graph rewriting rules focuses on developing application frameworks each of which uses a dynamically changing single federation, while our third-level formal modeling focuses on developing complex application scenarios in which many smart objects are involved in mutually related more than one federation, and describes them as collectively autocatalytic sets proposed by Start Kauffman in the context of complex systems.

This paper will show how our three formal models of federation enable us to describe application frameworks not only for stereotyped applications, but also novel applications including those inspired by molecular-biological mechanisms.