A Local WBC System Operating Across a University Campus

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***Abstract*—A local wireless billboard channel (WBC) system, operating across a university campus and supporting contextualized advertisement of services to students and staff members for subsequent service discovery and association, is proposed in this paper. A description of the main wireless services available on campus is provided. Design and implementation aspects of the system's software architecture are outlined.**

***Keywords*—wireless billboard channel (WBC), InfoStation, multi-agent system (MAS), software architecture, Java, JADE**

I. Introduction

The continuing evolution of mobile devices has, in recent years, precipitated a change in the roles they play in the everyday lives of people around the world. Just as mobile devices transformed how people communicate over distance, they are now being utilised to evolve the way in which people interact with their surroundings and local environments. Indeed today, with rapidly developing smart phone technology, mobile devices are taking on many roles in the service of their owners. The contribution to this that we make in this paper is to propose a new localized system to facilitate a minimally intrusive service advertisement, discovery and association (ADA) for mobile users within a university campus environment. As opposed to the alternative, more intrusive, unsolicited, text-based messaging schemes, this scheme would work in the background and interact with relevant applications in the mobile device. Services and service outputs would then be delivered –presented– to the user in accordance with their personal profile settings. This system builds on the work carried out as part of the Ubiquitous Consumer Wireless World (UCWW) project [1], [2] and the InfoStation-based mLearning initiative [3]-[5]. Building on the advances made through both of these projects, the system detailed in this paper seeks to facilitate a more effective, in-obtrusive, personalized and pervasive service awareness and usage.

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The paper is organised as follows. Section II provides some background of the wireless billboard channels (WBCs). Section III presents the proposed local WBC system infrastructure, identifying the main actors and elements. Section IV presents some of the wireless services supported by this system, identifying the benefits these services can offer to users within the university domain. Section V identifies various design aspects of the system's software architecture, both for the server- and the client side, and the tools involved in their implementation. Finally, section VI concludes the paper.

II. Wireless Billboard Channels (WBCs)

WBCs are infrastructural components used for ADA of wireless services in the UCWW. UCWW is the University of Limerick's vision of the wireless Next Generation Network (NGN) environment. The UCWW is based on the classic Internet Protocol (IP) infrastructure and encompasses all existing mobile and fixed wireless networks, providing wireless services which are independent of any transport-related technologies, both terrestrial and satellite. From the mobile user (MU) viewpoint, the mobile devices can be reconfigured to use many different access technologies to discover and associate with 'best' services - including teleservices and access networks (ANs)' communications services, thus giving rise to the concept of an always best connected and best served (ABC&S) communication paradigm [6]. In UCWW environment, the user - identified by a personal, network-independent and location-independent IPv6 address [7] - is not constrained to any particular AN provider (ANP) and may use any available service through any available AN, and pay for the use of services through a trusted Third-Party Authentication, Authorization and Accounting Service Provider (3P-AAA-SP) [8]. The consumers are free to choose what is 'best' for them, i.e., the service and the access network that they consider best matches their needs at any time or place. In the UCWW environment, the WBC infrastructural component aims to 'push' advertisements of new wireless services and updating information about existing wireless services to potential consumers. Indeed, it is quite apt to develop a local WBC based on the InfoStation system operating within a university campus.

The WBC broadcasting scheme was proposed in [9], where the streaming of service advertisements is available simultaneously to a large number of clients. With this push-based WBC data delivery system, the wireless channel bandwidth is efficiently used. Moreover, mobile devices only passively listen to the channel thus consuming less battery power.

The ADA procedure consists of the following three phases:

--*Advertisement*: The WBC service provider (WBC-SP) broadcasts the service descriptions (SDs) of all registered services repeatedly on the channel.

--*Discovery*: The mobile device tunes to the channel and listens to broadcasts to receive only SDs of those services that are desired by the user.

--*Association*: The mobile device associates with the chosen server(s) to use the wireless services it has discovered.

The number and types of WBCs could correspond to the local, national, and international interests of advertisers and users. In practice there would be growth; perhaps a start-up situation would be one national WBC channel, advertizing all the services that are relevant on a national level, which could include also advertisements of local, regional or inter-regional significance. And then separate local WBCs channels, advertizing the services available in that region (Figure 1).

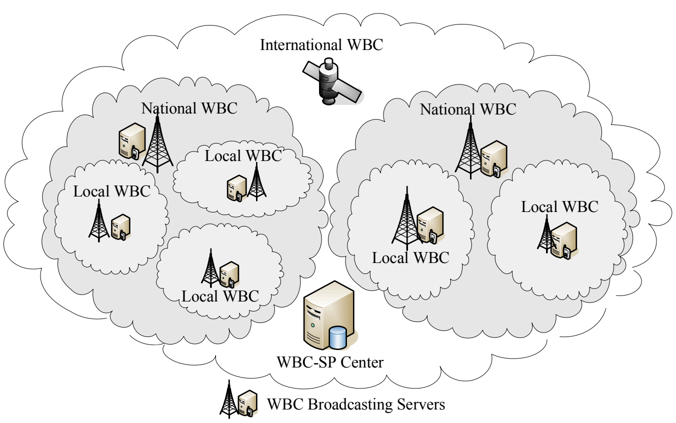

Fig. 1. The main WBC types: international, national, and local.

III. Local WBC System Infrastructure

For the realization of a local WBC system for operation across a university campus we propose to utilize a distributed network of intelligent wireless access points (InfoStations), situated at key locations throughout the campus (e.g., in library, lecture halls, laboratory spaces, cafeteria, car parking area, etc). These InfoStations can essentially be thought of as portals through which the mobile devices can receive information about available services and communicate with a variety of servers.

While InfoStation systems were, in the past, designed with cellular technologies in mind, the first iteration of this system sought to incorporate widely available computer networking wireless standards, such as IEEE 802.11 WLAN (WiFi), IEEE 802.15 WPAN (Bluetooth), and IEEE 802.16 WMAN (WiMax), as illustrated in Figure 2. The former two are particularly useful, especially when considering the fact that practically every mobile device available today supports one, or both of these standards. The incorporation of the local WBC system into the current iteration of the InfoStation-based system infrastructure can serve to greatly enhance the effectiveness of the system in delivering services.

The placement of this array of InfoStations at key points throughout the campus also has a bearing on which services are accessible. At certain locations, the InfoStations may be specialised to provide specific location-based services. This is an idea which is particularly applicable to educational institutions, whereby mLearning services can be offered through InfoStations operating within lecture halls, facilitating the enhancement of the teaching and learning experience of both the students and the lecturers. This approach to the delivery of localised services is also applicable to spaces beyond the lecture hall. The InfoStation-based system also demonstrates great potential for deployment within libraries or within specific departmental areas within an institution, supporting services tailored to that environment. Within the library domain for example, services can be deployed which enhance the existing service infrastructure, whether facilitating mobile access to catalogues of resources, or recommending resources based on the users previous interactions with the system.

Local service providers (xSPs) submit/publish SDs of their services (c.f. section IV) to the WBC-SP over the Internet through a web portal (Figure 2). To reduce the mobile device's *access time* [1] and *tuning time* [2], a number of intelligent algorithms - running on the WBC Centre (WBCC) server - for SD collecting, clustering, scheduling, indexing and broadcasting were developed. Finally, the WBC advertisements delivery protocol (ADP) [10] server produces ADP messages that are encapsulated into UDP/IP datagrams for sending them over the university intranet to various types of InfoStations, which broadcast these to the mobile devices currently located in their service areas. Finally, each mobile device filters out the received SDs (based on information stored in the user profile) and records only the desired SDs to a database for subsequent selection and use by the mobile user (MU).

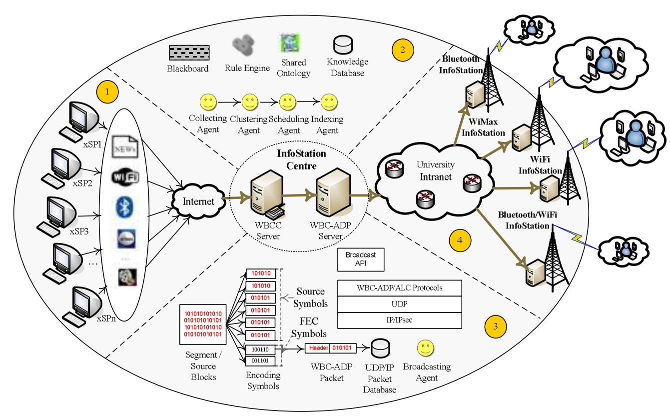

Fig. 2. The local WBC system infrastructure, consisting of an InfoStation Centre, InfoStations, and user mobile devices.

[1] ***Access time:*** The total amount of time from the moment when a mobile device first tunes in the WBC channel, until that the device receives the needed data.

[2] ***Tuning time:*** The time that a mobile device keeps active mode for listening to the WBC and receiving the needed data.

Table I describes the elements of the main WBC actors, i.e., the WBC-SP, xSPs, and MUs.

A major obstacle to the development of this system, and in particular ensuring the system achieves the stated goals, has been the facilitation of sufficient flexibility and adaptability in order to overcome several issues related to the delivery of services within heterogeneous wireless deployment environments. There are a number of challenges which must be overcome, in particular, those stemming from the very nature of the InfoStation-based network. In particular, the provision of effective mechanisms for system control and management, while operating within mobile environments.

TABLE I
THE WBC ACTORS AND ELEMENTS

Node	Element	Description
WBC-SP / xSP	Portal application	This provides interfaces to: (i) the WBC-SP administrator - for defining the WBC parameters; (ii) the xSPs - for submitting their SDs to WBCC.
WBC-SP	Data organization schemes	These are used for SDs' collection, clustering, scheduling, and indexing with WBC rules for data organization, prior to broadcasting of the SDs.
WBC-SP	WBCC	A server used for running the WBC portal application and providing a Multi-Agent System (MAS) runtime environment.
WBC-SP / MUs	MAS	A self-organized system consisting of a number of agents, which communicate to each other in order to solve a particular problem.
WBC-SP / MUs	Rule engine	A rules-based and facts-based pattern matching tool used for separation of the business logic from data.
WBC-SP / MUs	WBC-ADP	An API for converting the WBC segments into IP datagrams on the WBC-SP side and vice versa on the client side.
MUs	WBC receiver application	Running on mobile devices, this could be a Mobile Information Device Profile (MIDP) Midlet application, a Connected Device Configuration (CDC) Xlet application, a Google Android application, a GWT application, etc.
MUs	User profiles	These help the WBC user application discover and associate with the desired SDs.

This includes possibilities for a change in the mobile device and/or the serving InfoStation due to the geographically intermittent nature of the communication. One approach which emerged to tackle these issues involved the utilization of autonomous programs, called agents, which could gather information and accomplish tasks without the need for human interaction. In groups these agents could coordinate themselves, working together in order to effectively complete various network management tasks. Within their own immediate environment, they can function autonomously to complete their own objectives. This agent-oriented approach was adopted because it offers many benefits towards the implementation of the InfoStation-based system. Due to the target audience of this system, which is designed to cater for (predominantly mobile users), as well as the spatially discontinuous nature of the connectivity to the InfoStations, agents will operate not just onboard the InfoStations, but also within the users mobile devices [11], [12]. These agents, acting as personal assistants (PAs), function autonomously in order to satisfy any user service requests they may encounter, while in or out of contact with other agents (e.g., installed on the InfoStations). The agent autonomy facilitates the most efficient utilization of the InfoStation's high-rate yet often intermittent coverage.

The utilised InfoStation-based system architecture is organised into a 3-tier structure consisting of mobile devices, InfoStations, and an InfoStation Centre. Each user's mobile device houses a lightweight PA, which facilitates the user's interactions with the system and their access to the various services. The InfoStations house a community of interoperating agents, which coordinate themselves to facilitate any service requests which might be encountered. Also housed is a cache of recently accessed service content. As has been discussed, certain InfoStations can be utilised to access particular services based on the location of the InfoStation (e.g., library-based InfoStations offering access to the library catalogue service). For this reason it is necessary for the InfoStations to cache and maintain a repository of the most up-to-date content for those specific services in order to be able to deliver it to users as quickly as possible. The InfoStation Centre, which stands at the core of the system (Figure 2), is concerned with the update and synchronization of service content throughout the system. From this central point, service updates can be propagated across the system.

In order to build this system as a multi-agent one, a proper development framework was required, preferably as part of an open-source initiative. The Java Agent DEvelopment (JADE) framework developed by the Telecom Italia LABoratories (TILAB) [13], one of the most widespread middleware systems in use today [14], was chosen as the basis for this system. The JADE framework [15] aids the development of complete agent-based applications through the facilitation of a run-time environment implementing simple, yet effective life-cycle support features required by agents, the core logic of agents themselves, and a rich suite of graphical tools, as well as full compliance with the Foundation for Intelligent Physical Agents (FIPA) specifications [14]. Another major merit of utilizing the JADE platform is its abstraction over the object-oriented language, Java, providing a set of APIs completely independent of the underlying network or the Java version. To support the running of JADE-based agents within the mobile environment (i.e., onboard the user's mobile device), the Lightweight Extensible Agent Platform (LEAP) module [16] can be deployed, which replaces various parts of the JADE kernel providing a modified lightweight run-time environment, which enables FIPA agents to execute on a wide range of Java-enabled mobile devices. It also allows for the optimization of communication mechanisms when dealing with devices with limited resources, connected through wireless networks. A JADE platform is comprised of a number of agent containers, which may be distributed throughout the network. Each container facilitates run-time environment support for a number of JADE agents. A group of active containers, coupled together, form a platform. Within each platform, a single main container must always remain active. The first container to become active on a platform assumes this role, and all other containers must register with this main container as soon as they are initialized on the platform. For deployment of JADE-LEAP runtime environments on mobile devices, the container is split into two separate sections, a FrontEnd which runs within the mobile device itself, and the BackEnd which runs within a fixed network entity - or mediator, as illustrated in Figure 3. This mediator is charged with instantiating and maintaining the BackEnds. Within this system, the InfoStations deployed throughout the university campus take on this mediator role. The splitting of the containers into two separate, yet connected, entities is particularly useful when deploying agents within resource constrained devices, as the FrontEnd of the container is far more lightweight in terms of the required memory and processing power than the entire container.

The PA agents operating within the FrontEnd of the JADE-LEAP container harness contextual information from the mobile user, which can be utilised to filter out the service ads received from the local WBC system, and personalize and contextualize them to suit the particular user.

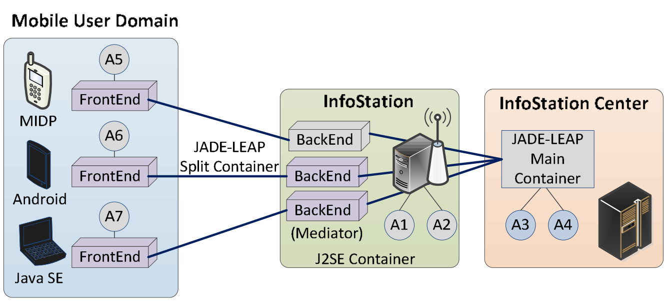

Fig. 3. The JADE-LEAP split-container execution.

IV. Local Services in University Campus

The wireless services in a university campus include educational-, library-, notification-, advertisement-, car parking services etc. To describe the wireless service advertisement, a SD format was defined for storing and exchanging the service's ADA information over the WBC. A SD consists of a number of fields, e.g., service type, scope list, length, composite capability / preference profiles (CC/PP), QoS, and attribute list. The full SD format is as follows:

```
ServiceDescription ::= SEQUENCE
{
        serviceType    Service-Type,
        length         Length,
        scopeList      ScopeList,
        ccpp           CCPP,
        qos            QoS,
        attrList       ServiceTemplate.
}
```

The *serviceType* is a field that indicates the basic function performed by the service which allows the SDs of similar services to be grouped together to generate a WBC segment. The length field indicates the *length* of the SD in bytes. The *scopeList*, *ccpp* and *qos* act as filters for the service. The *attrList* field is the main field, which carries the ADA information. Each service type has its own attribute template. The SDs are described by the ASN.1 notation language [17] and encoded to octet streams by an ANS.1-PER encoder [10], [18].

This local WBC system has been designed to cater for a number of different types of services as briefly described below.

1) Automated Library Recommendations Service

This service recommends relevant library resources to the users, based on their current educational context. By harnessing information relating to the utilization of resources by particular cohorts of students, patterns can be identified. These patterns can then be utilised to recommend resources to students in the future which might be of significant interest. This automated process would develop and evolve as more and more students from various cohorts avail of the service.

2) Notifications Service (to large groups of users)

This service sends notification messages to selected groups of users or whole class groups. This can be used, for example, to notify students of changes to the class timetable. This is an especially useful tool as the lecturer knows all the recipients will receive the message in a timely manner wherever they might be.

3) Local Advertisements Service

This service offers the opportunity to advertize information pertaining to local events within the vicinity of the user. Through the WBC, the user is presented with information relating to food and restaurant offers, tours or cultural events within their environs. Within an educational domain, this service facilitates the delivery of information relating to advertisements for classes and seminars on offer. This service can also be immensely useful in advertizing information about the local environment of the system user. For example within the departmental domain within which the user finds themselves, information relating to the office hours of lectures, the departmental offices, departmental procedures etc. are all advertised through this service. Beyond educational environments, this service could be utilised to enhance a wide variety of environments. Shopping districts could use this service to advertize information on deals within certain shops and restaurants. Within sporting arenas, such a service could be utilised to provide information to fans about the stadium itself (e.g., fire & safety information and procedures) or indeed relating to the event (e.g., team-line ups). In essence, this service facilitates the enrichment of the local informational environment of the user.

4) Parking Locator Service

Within educational and industrial campuses throughout the world, the issue of locating parking spaces each day can become quite difficult and troublesome. This service seeks to alleviate such issues by allowing registered mobile users to gain access to information regarding the availability of parking spaces on the university campus and subsequently reserve a space that best suits them when approaching/entering the campus. By utilizing information harnessed from sensor networks based throughout the campus parking structures, as well as information pertaining to the users themselves, such as the location of their office, their desired destination on campus, or in the case of a student, the location of their next class, the service delivery can be effectively tailored. This ensures that the user is directed to the most apt parking location depending on their personal requirements. Visitors to the campus may also gain access to this service for the duration of their stay. On accessing the service, these visitors would be directed to a visitor's car park.

V. Software Architecture

A. Server Side

The local WBC system's software architecture (server side) is built on three tiers (Figure 4):

Service discovery and maintenance tier: The Java Platform, Enterprise Edition (Java EE) is well suited for building the service layer application. There are two actors in this tier: service providers (xSPs), who submit their SDs to the WBC content database in a competitive way via the WBC-SP web portal; and WBC-SP, who maintains the roles and databases, and defines the WBC broadcasting parameters, etc.

Application tier: To simplify the system design and enable the system decoupling, this tier is implemented as an expert system for maintaining the business logic and WBC algorithms. A set of Application Programming Interfaces (APIs), such as common APIs, ontology APIs, SD's processing APIs, intelligent rule-engine APIs etc, are shared with the other two tiers.

MAS container tier: This tier is an agent run-time environment for facilitating the SDs' collection, clustering, scheduling, indexing, and broadcasting. A shared blackboard and gateway agent are used for agent's communication and tier's communication, respectively.

A Message Channel (MC) is shared by the three tiers as shown in Figure 4.

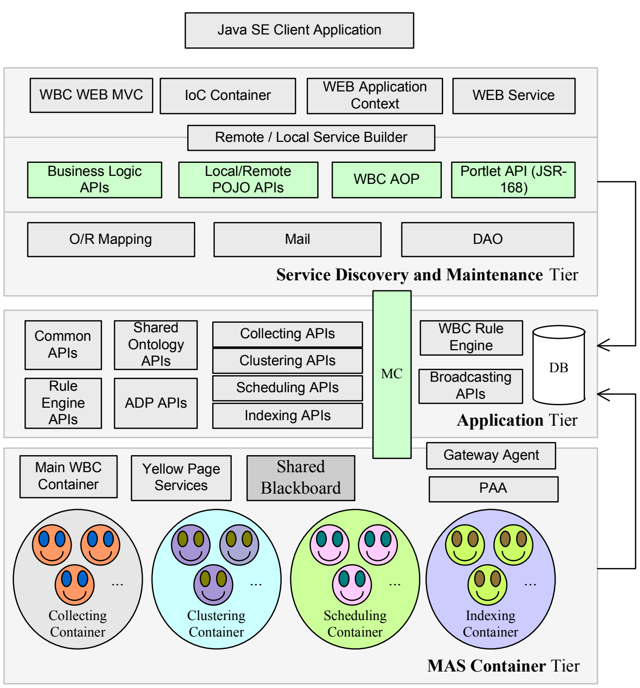

Fig. 4. The WBC server-side software architecture.

B. Client Side

To achieve a portable and efficient structure on the client side, similarly to the server side, the software architecture consists of three tiers as depicted in Figure 5.

Comparing with the architecture on the WBC-SP side, the client architecture is a lightweight one. The client user interface (UI) component includes mobile information device profile (MIDP), Android and Google web toolkit (GWT) Java applications. In the application tier, the WBC wireless service advertisement APIs are changed to discovery and association APIs. In the MAS container tier, the wireless service advertisement agents are divided into two groups:

(i) The SDs agent, DVB-H agent, iWBC agent, and dispatcher agent that run in a iWBC content provider for discovering and processing the SDs;

(ii) The personal assistance agent (PAA) and monitor agent that run in an iWBC UI to facilitate the association with discovered services.

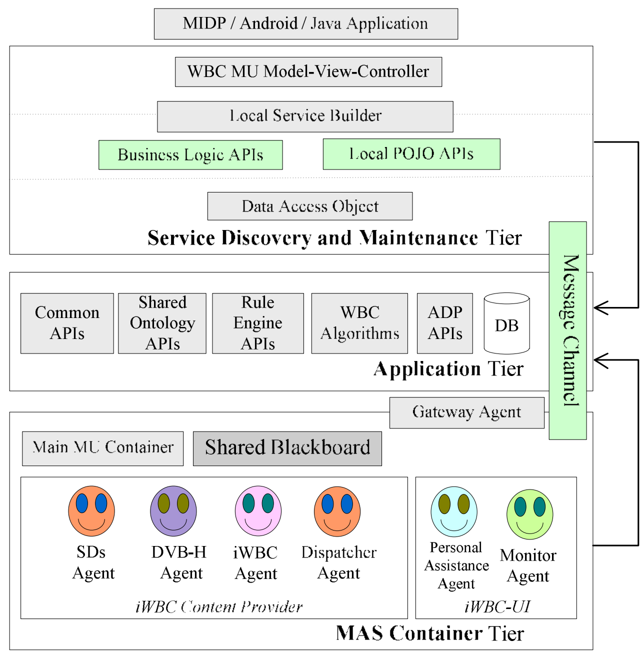

Fig. 5. The WBC client-side software architecture.

C. Implementation

To design and implement the system quickly and efficiently, a project skeleton as well as a number of build/test/deploy schemes was first developed based on the open-source Integrated Development Environments (IDEs) and APIs described in Table II.

VI. Conclusion

A local wireless billboard channel (WBC) system operating across a university campus for broadcasting advertisements of campus wireless services to mobile users in a 'push' mode, which is minimally intrusive, has been proposed in this paper. As opposed to the alternative, more intrusive, unsolicited, text-based messaging schemes, this system works in the background and interacts with relevant applications installed on the user mobile devices. Services and service outputs are then delivered and presented to the user in accordance with their personal profile settings. Various wireless services, proposed for delivery through this system, have been described along with their generic description. The system software architecture has been outlined along with the main IDEs and APIs used for its implementation.

TABLE II
THE MAIN IDES/APIS USED IN THE SYSTEM

Name	Description
Eclipse	An open-source Java IDE platform (http://www.eclipse.org).
DB4O	A high-performance, embeddable, open-source OO database (http://www.db4o.com).
MySQL	A popular open-source relational database (http://www.mysql.com).
JUnit	A simple framework to write repeatable tests for Java classes (http://www.junit.org).
Mock	A Java object behaviour simulation tool (http://ant.apache.org).
ANT	A Java building tool (http://ant.apache.org).
Maven	A software project management and comprehension tool (http://maven.apache.org).
Hibernate	An object/relational persistence and query service mapping framework (https://www.hibernate.org).
Lucene	A high-performance and full-text Java search engine (https:// lucene.apache.org).
XDoclet	A Java code generation engine (https://xdoclet.sourceforge.net).
XWork	A Java IoC container (https://www.opensymphony.com/xwork).
Spring	An AOP framework (http://www.springsource.org).
JBoss	A Java EE container (https:// www.jboss.org).
Jena	A semantic web framework API for reading and writing CC/PP RDF files (http://jena.sourceforge.net).
JADE	A software framework fully implemented in Java with the FIPA specifications (http://jade.tilab.com/).
Drools	A rule-engine-based expert systems (http://www.jboss.org/drools/).

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