Advertisement Data Management and Application Design in WBCs

Zhanlin Ji
College of Computer and Automatic Control, Hebei United University, P.R.China
Email: zhanlin.ji@ieee.org

Ivan Ganchev, Máirtín O'Droma
Telecommunications Research Centre, University of Limerick, Ireland
Email: {Ivan.Ganchev, Mairtin.ODroma}@ul.ie

***Abstract*— This paper describes the design and implementation of the advertisement data management and corresponding intelligent application for use in wireless billboard channels (WBCs) services in the emerging ubiquitous consumer wireless world (UCWW). Running at the application enabler sub-layer of a WBC service provider (WBC-SP)'s node the advertisement data is formatted by using the abstract syntax notation (ASN.1) and organized into segments to reduce the access time, and thus minimizing the mobile terminal's (MT) energy consumption on this service. The intelligent application is implemented within three tiers of the WBC service layer: a service discovery and maintenance tier acting as a client-server distributed system for data collection and organization; an intelligent application tier holding all business logic and common application programming interfaces (APIs); and a multi-agent system (MAS) tier maintaining the advertisement, discovery and association (ADA) agents' lifecycle, and supplying directory facilitator services and message transport services. The performance evaluation of the proposed data management scheme is performed. Details of the application's architecture are also provided.**

***Index Terms*— Ubiquitous Consumer Wireless World (UCWW); Wireless Billboard Channel (WBC); Advertisement, Discovery and Association (ADA); Software Architecture; Multi-Agent System (MAS)**

I. Introduction

Wireless billboard channels (WBCs) [1] are novel UCWW infrastructural components for facilitating direct service advertisement of service providers wireless service offerings, and their discovery by MTs together with the means to associate with them for service purchase - the service advertisement, discovery and association functions (ADA), [2-3]. The UCWW mobile user (MU) is a consumer, not constrained to use, or bounded to, any particular access network provider (ANP). He/she may access teleservices through any available and suitable access network, and pay for the use of services through a trusted third-party authentication, authorization and accounting service provider. The consumer is free to choose what s/he perceives as 'best' for her/him, i.e. the teleservice and access network (AN) s/he considers best matches her/his needs at any time or place (Figure 1). Since today's long-term subscriber-like contracts are optional in UCWW and are unlikely to be the norm, maximizing the consumer wireless transactions, rather than subscriber contracts, becomes the main business driver for UCWW service providers. Service providers therefore need to be able to have a non-intrusive but direct 'push advertisements' channel to advertise their mix of service offerings to consumers (including access networks' communication service, ANCSs, and teleservices) [2]. Likewise consumers need to continually receive updates of the wireless services on offer in their local or in general. WBC advertisements enable them (i.e., WBC client-specific software application operating in the background of the MTS) to discover all services available/deployed in a given area/location and associate with the 'best' of them. This direct wireless ADA of wireless services over WBCs is thus a key aspect of the UCWW [1]. Corresponding to this foreseen demand, design of an efficient and easy mechanisms for wireless services ADA adapted to the mobile terminal (MT) capabilities, MU preference and location, is a clear research priority.

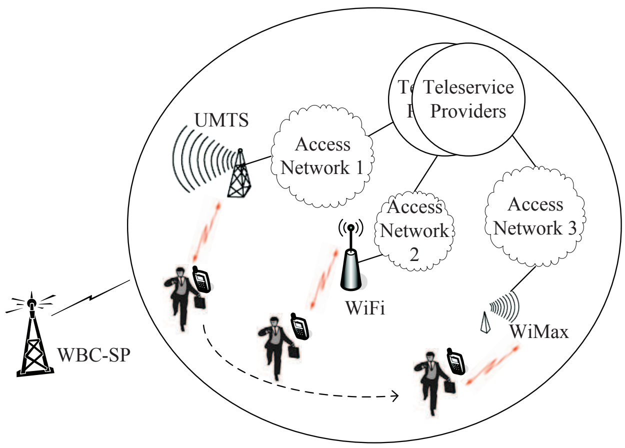

Figure 1. The WBC in the UCWW environment.

The newly conceived WBC infrastructural component

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of the UCWW is shown in Figure 1. There can be several WBC service providers -competing in many instances, and operating over different platform types. For all, the unidirectional broadcast communication between the WBC-service provider's (WBC-SP) node and the users' nodes satisfies the push-based WBC requirements of this service. Each node contains three logical layers. The physical layer is represented by a transmitting system in the WBC-SP node and a receiving system in the user node. The link layer is concerned with typical frame processing issues. The service layer describes the service discovery model and data management schemes. The service layer consists of two sub-layers: a service-enabler sub-layer and an application-enabler sub-layer. Both these sub-layers need significant wide-ranging design [2], and it may take some time before the final format of components crystallize in a satisfactory way to contribute to and meet global standardisation requirements.

This paper focuses on the advertisement data management performed at the application-enabler sub-layer of WBC.

II. WBC ADVERTISEMENT DATA DISCOVERY

A. WBC Service Description Model

Service discovery allows MTs to automatically find all available services in the current location. A number of well-established service discovery protocols exist, such as Jini, Service Location Protocol (SLP), Salutation, etc. Their basic service discovery model follows this message flow sequence, Figure 2(a):

1. xSPs register their services with a register centre;
2. The MU sends a request to the centre querying the desired service;
3. The register centre returns relevant service information to the MU;
4. The MU uses the service.

This request/reply mechanisms, however, is not efficient for WBCs. A broadcasting scheme was proposed in [1] that is independent of the client population, 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 bandwidth is more efficiently used. Moreover, the MTs only passively listen to the channel thus consuming less battery power. The push-based WBCs services discovery model could be summarized as follows, Figure 2(b):

1. The xSPs register their services with a WBC-SP's central registry using some external methods, e.g. via a web portal;
2. The WBC-SP broadcasts all SDs repeatedly on a WBC (service advertisement);
3. The MU/MT tunes to WBC and listens to broadcasts to receive desired SDs (service discovery);
4. The MU/MT associates with the chosen service provider to use the 'best' services it has discovered (association).

To describe the wireless service advertisement, a service description (SD) format was defined for storing and

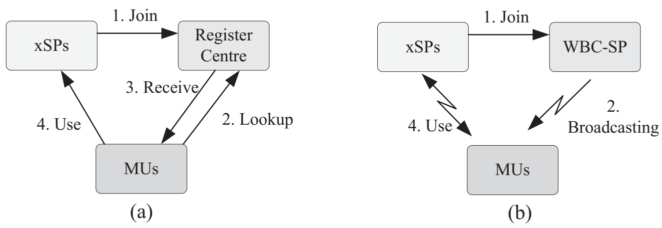


Figure 2. The Service Discovery Model used by: (a) Jini, SLP, Salutation and (b) WBC.

exchanging the services' ADA information in WBCs. A SD consists of a number of fields, such as a service type, length, scope list, composite capability / preference profiles (CC/PP) [4], QoS and attribute list.

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

Efficient structure description languages, such as the XML schema definition (XSD) and the abstract syntax notation (ASN.l) [5], have been considered as candidates for the description and storage of SDs. While XSD describes and stores data structures with eXtensible markup language (XML), ASN.l describes data structures with Backus-Naur form (BNF) but stores and transmits data using a compressed octets stream. The latter ASN.l property allows reducing the SD size. Also, ASN.l can describe more complex data structures than XSD. Since using as little bandwidth as possible is one of the WBC desired properties, ASN.1 was chosen for describing the WBC SDs.

The ASN.1, published by the International Telecommunications Union - Telecommunications sector (ITU-T), is well known as a reliable description language, which uses compactable encoding rules for specifying data in telecommunications protocols and is well-tied to the Java programming language. An example of a SD template (WBCAService) in ASN.1 is shown below.

```
WBCAService DEFINITIONS IMPLICIT TAGS  ::=
BEGIN  IMPORTS  WBCAService FROM WBC;
AWBCTSASMS ::= SEQUENCE {
    service-Type  Service-Type,
    ccpp          CCPP,
    length        SDLength OPTIONAL,
    attributes    Attributes }
Service-Type ::= SEQUENCE {
    division    OCTET STRING(SIZE(1..16)),
    category    OCTET STRING(SIZE(1..16)),
    type        OCTET STRING(SIZE(1..16)),
    version     OCTET STRING(SIZE(1..16)) }
CCPP ::= CHOICE{
    defaultCCPP    [0] SEQUENCE OF CCPPProperty,
    notDefaultCCPP [1] SEQUENCE OF CCPPProperty }
Attributes ::= aWBCAService
END
```

To integrate the ASN.1 Packed Encoding Rules (PER) scheme into the WBC service layer, all SD templates were compiled into Java classes with an ASN.1 Java compiler.

The encoding of the SD example (above) into a Java code is shown below:

```
Wbc.initialize();
Coder coder = Wbc.getPERCoder();
ByteArrayOutputStream sink
        = new ByteArrayOutputStream();
SampleWBCAService Sample
        = new SampleWBCAService();
coder.encode(Sample.valueWBCAService, sink);
byte[] encoding = sink.toByteArray();
sink.close();
```

B. *WBC SD Management*

The use of efficient power saving schemes is a key issue for mobile terminals. In this regard, reducing the access time needed to get information about a service is of paramount importance in WBCs. However, the classic algorithms used to reduce the access time, such as [6], cannot be applied directly in WBCs, because the unpopular SDs will be broadcast too many times. Our novel WBC solution uses intelligent agent-based schemes for efficient SD management.

The WBC broadcasting cycle is shown in Figure 3. SDs are grouped into fixed-size segments for broadcasting over the WBCs. Each segment is made up of a number of SDs of the same type. This facilitates the MT filtering, caching, comparing and selecting the favorite SDs. Considering the fact that the client access pattern for SDs does not follow the uniform distribution, to minimize the access time the segment / SDs broadcasting times should follow the client access pattern [6].

Table I lists the notations used further in the paper.

TABLE I. THE GENERAL WBC SYSTEM PARAMETERS.

Parameters	*Details*
M	*Total number of distinct segments in a broadcasting cycle.*
N	*Total number of data segments in a broadcasting cycle.*
F_n	*Broadcasting frequency of n-th segment* ($1 \le n \le M$)*, i.e. the number of instances of n-th segment in a broadcasting cycle.*
$I_{g,n}$	*Inter-arrival gaps for n-th segment,* $1 \le g \le F_n - 1$.
p_n	*Current access probability of n-th segment.*
T_n	*Expected value of access time[2] for n-th segment.*
T	*Expected value of mean segment access time.*

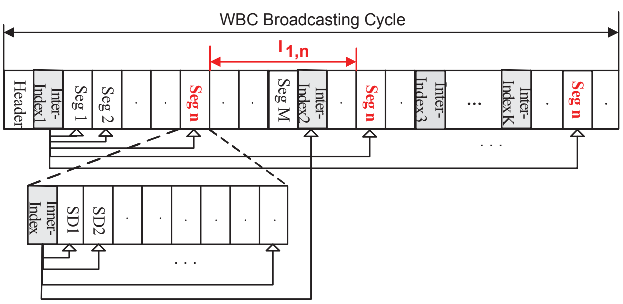


Figure 3. The WBC Broadcasting Cycle.

The minimization of T_n is a key goal in WBCs.

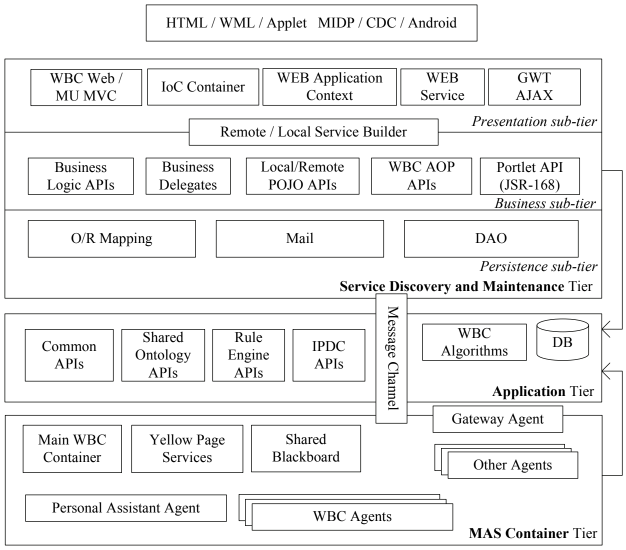


Figure 4. The WBC Application Enabler Sub-Layer's Architecture (WBC-SP Side) .

T_n can be calculated as:

$$T_n = \frac{1}{N}\sum_{s=1}^{F_n}\left(\sum_{z=0}^{I_{g,n}}\left(\frac{1}{2}+I_{g,n}\right)-\sum_{x=0}^{I_{g,n}}x\right) = \frac{1}{2N}\sum_{s=1}^{F_n}(I_{g,n}+1)^2 \qquad (1)$$

It can be shown that T_n is minimal when the inter-arrival gaps between all consecutive instances of the n-th segment in the broadcasting cycle are equal, i.e. if for each $1 \le g \le F_n - 2$:

$$I_{g,n} = I_{g+1,n} = I_n = \left\lfloor \frac{N}{F_n} \right\rfloor \qquad (2)$$

then:

$$Min(T_n) = \frac{F_n}{2N}\left\lfloor \frac{N}{F_n} \right\rfloor^2 \approx \frac{N}{2F_n} \qquad (3)$$

Now, assuming that all p_n are independent, for T we have:

$$T = \sum_{n=1}^{M}\frac{p_n N}{2F_n}. \qquad (4)$$

where $\sum_{n=1}^{M} F_n = N$

The minimum value of T is reached, when for every independent F_n:

$$F_n = \frac{N\sqrt{p_n}}{\sum_{j=1}^{M}\sqrt{p_j}}. \qquad (5)$$

From (4) and (5), we can obtain the minimum value of T:

$$Min(T) = \sum_{n=1}^{M}\left(p_n\frac{\sum_{j=1}^{M}\sqrt{p_j}}{2\sqrt{p_n}}\right) = \frac{1}{2}\sum_{n=1}^{M}\left(\sqrt{p_n}\right)^2 \qquad (6)$$

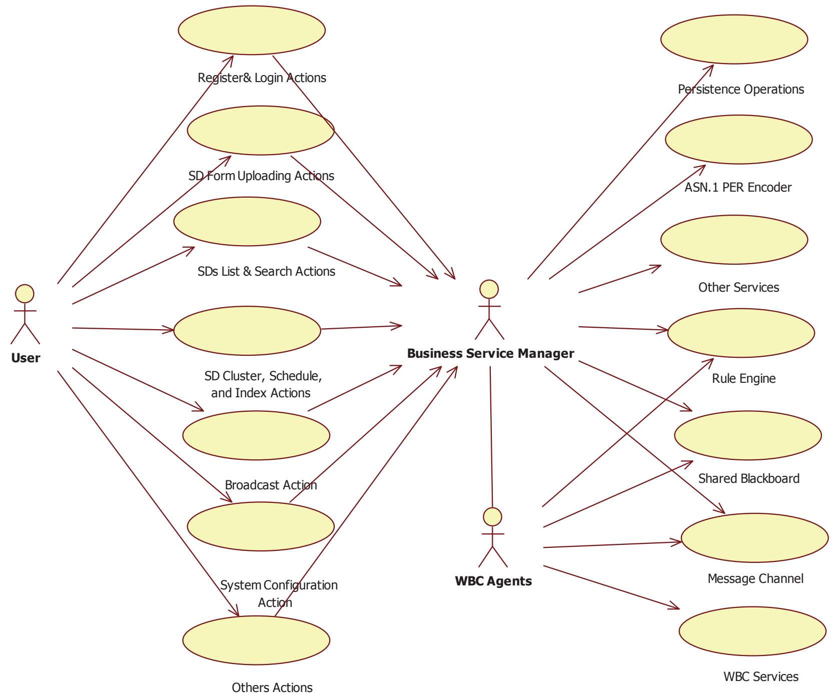


Figure 5. The Use Case View of the Service Discovery and Maintenance Tier.

To enable an efficient and intelligent WBC advertisement data management, a novel architecture is proposed and corresponding implementation is described in the next two sections.

III. WBC Application Enabler Sub-layer's Architecture

The architecture of the WBC application enabler sub-layer consists of three tiers (Figure 4):

1) The service discovery and maintenance tier is a web tier with two main types of actors: service providers (xSPs; 'x' signifies anyone of the wide range of SPs operating in the wireless communications market) who submit/publish and manage the SDs of their services via the WBC-SP portal application, and the WBC-SP who monitors the status of xSPs' SDs and maintains the WBC center's (WBCC) server;

2) The application tier contains common application programming interfaces (APIs), such as the shared ontology API, common APIs, Drools/Jess API and SDs clustering, scheduling, and indexing APIs. This tier is shared by the other two tiers;

3) The multi-agent system (MAS) container tier provides an agent run-time environment. The WBCC controls the life cycle of all agents. A special gateway agent is used for communication with the service discovery and maintenance tier via a shared message channel.

The design and implementation of the WBC application enabler sub-layer follow the personal software process (PSP) methodology [7]. An experience repository database is used to store all development experiences. The test driven development (TDD) [8] and feature driven development (FDD) [9] methods were selected for the design of this PSP project. With these two methodologies, the three-tier heterogeneous WBC application enabler sub-layer's architecture is plotted into a set of functional unit modules (features). For each unit module, from bottom to top tier, a unified modeling language (UML) diagram for the corresponding interface was first designed. Then the interface was fully implemented and a unit testing was performed. The WBC application enabler sub-layer is built with a number of open-source integrated development environments (IDEs)/APIs/frameworks. The benefits of using open-source software include public collaboration, not bounding to a single development company, auditability, flexibility and freedom. The details of each tier's design and implementation are presented in the following section.

IV. Design and Implementation

A. Service Discovery and Maintenance Tier

To design and implement the service discovery and maintenance tier quickly and efficiently, a project skeleton as well as a number of build/test/deploy schemes was first developed. To describe the requirements for analysis, design, implementation and documentation, a use case diagram was first designed as shown in Figure 5. It includes a number of modules, such as login, SD uploading, search, configuration, etc. For each unit module, the design and implementation followed these steps:

Step 1: Create the corresponding Plain Old Java Object (POJO) *aentity* and add Java Persistence API's (JPA) annotations. Implement the *toString()*, *equals()* and *hashCode()* methods. Then run the command *mvn test-compile hibernate3:hbm2ddl* to create the *aentity* database table.

Step 2: Create the *aentity*'s data access object (DAO) bean *aentityDao* for database's Create, Read, Update and Delete (CRUD) operations. Configure the *aentityDao* with the class *org.wbc.dao.hibernate.GenericDaoHibernate* in the context file *wbcContext.xml*. Once the *aentityDao* is being defined, add the setter method with parameter of *GenericDao* in order to use this bean as a dependency of the object.

Step 3: Create the *aentityManager* to act as a service facade to *aentityDao*. Configure the *aentityManager* with the class *org.wbc.service.impl.GenericManagerImpl* in the context file *wbcContext.xml*. Similarly to step 2, add the setter method with a parameter of *GenericManager* in order to use this bean as a dependency of the object.

Step 4: Create the web tier using *xwork*. Implement an *aentity* action to process the request and response operations.

The WBC-SP user interface (UI) of the service discovery and maintenance tier was implemented as a Java desktop portal application. It integrates several applications, such as a MAS application, WBC portal initial application, WBC web viewer application, and WBC broadcasting application. The WBC-SP UI application provides the environment variables for running the native libraries and executable files, i.e., a URL-based application, C++ application, Applet, Java EE container, etc. Figure 6 shows the UI Java class dependencies' UML diagram.

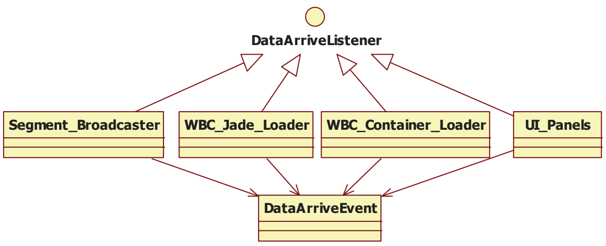


Figure 6. The UI Java Class Dependencies' UML Diagram.

There are two parameters in the *DataArriveEvent* - the string data and the Java source object. The *DataArriveListener* listens to the arrived events and notifies the relevant processing application about the event. Figure 7 shows sample UI panels of the service discovery and maintenance tier.

The portal UI includes four tabs: (i) a MAS tab for maintaining the WBC-JADE environment; (ii) the portal tab for starting/stopping the Java EE distributed environment, and recording log-information of the system; (iii) a WBC APP tab as an entrance to the WBC-portal (it mainly includes the WBC SD collecting, clustering, scheduling, indexing and broadcasting section); (iv) a send tab as a remote control panel used to control the advertisements delivery protocol (ADP) server to broadcast WBC segments/SDs in a carousel way.

B. Application Tier

To achieve a loose-coupling system and enable the WBC advertisements-processing to run in an intelligent

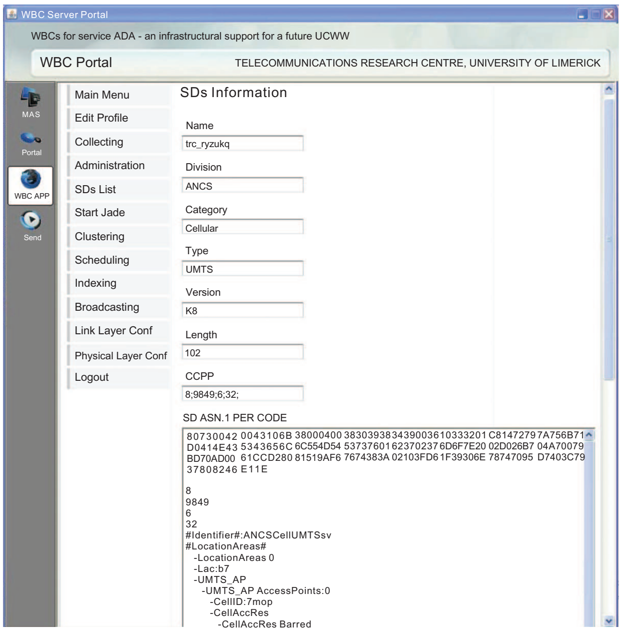


Figure 7. The WBC-SP UI Portal.

way, the WBC APIs, rule engine and database are integrated in this tier. Considering that the programming to an interface is the key principle of the reusable object-oriented design [10], all APIs of the application tier are extract interfaces to other tiers. Figure 8 shows the interface design of the application tier.

A rule-based expert system operates at this tier for facilitating the data broadcasting on the WBC-SP node. The Drools was selected as the rule engine in WBC. All the .drl configuration files are stored in a database, which can be accessed and updated via the portal application. Figure 9 shows the UML diagram of the Drools main recommendation classes. The *RecomendCmD* class implements the recommended interface and gets the recommended SDs via a sorting interface. With this interface design pattern, when a new rule is added to the system, the system does not need to be recompiled thus ensuring loose-coupling.

C. MAS Container Tier

A lightweight MAS, called WBC-JADE, was designed based on JADE (c.f. the popup UI in Figure 11). In addition to the WBC collecting agents, clustering agents, scheduling agents, indexing agents, broadcasting agents and personal assistance agent (PAA), a gateway agent, message channel and blackboard were also developed. Figure 10 depicts the diagram of the main UML classes for MAS communication with the Java EE environment. The *MyGateWayAgent* verifies the received blackboard object and forwards it to the proper agent, and vice versa; the *DirectoryServlet* links the MAS to the Java EE environment; the Interaction exchanges HTTP requests and responses between the *DirectoryServlet* and *ProxyAgent*; the Synchronizer synchronizes the blackboard between the *DirectoryServlet* and *ProxyAgent*; and the *ProxyAgent* accepts objects through the communication channel and

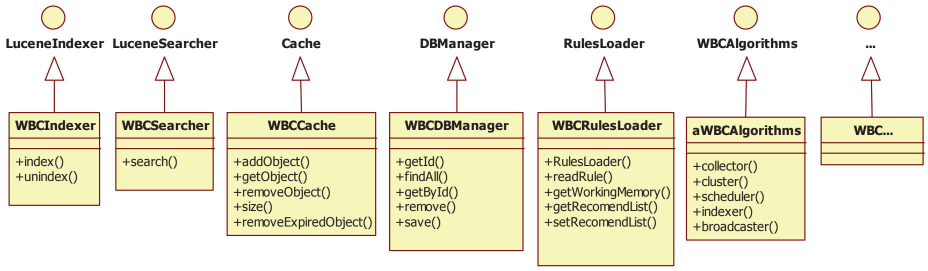


Figure 8. The Interface Design of the Application Tier.

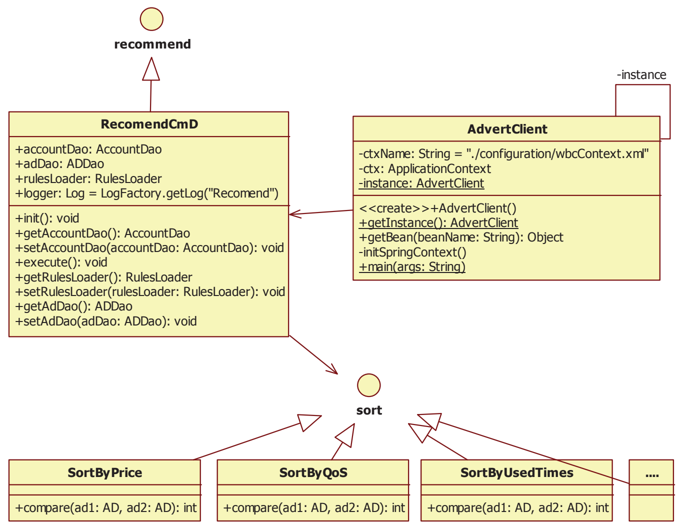


Figure 9. The UML Diagram of Drools Main Recommendation Classes.

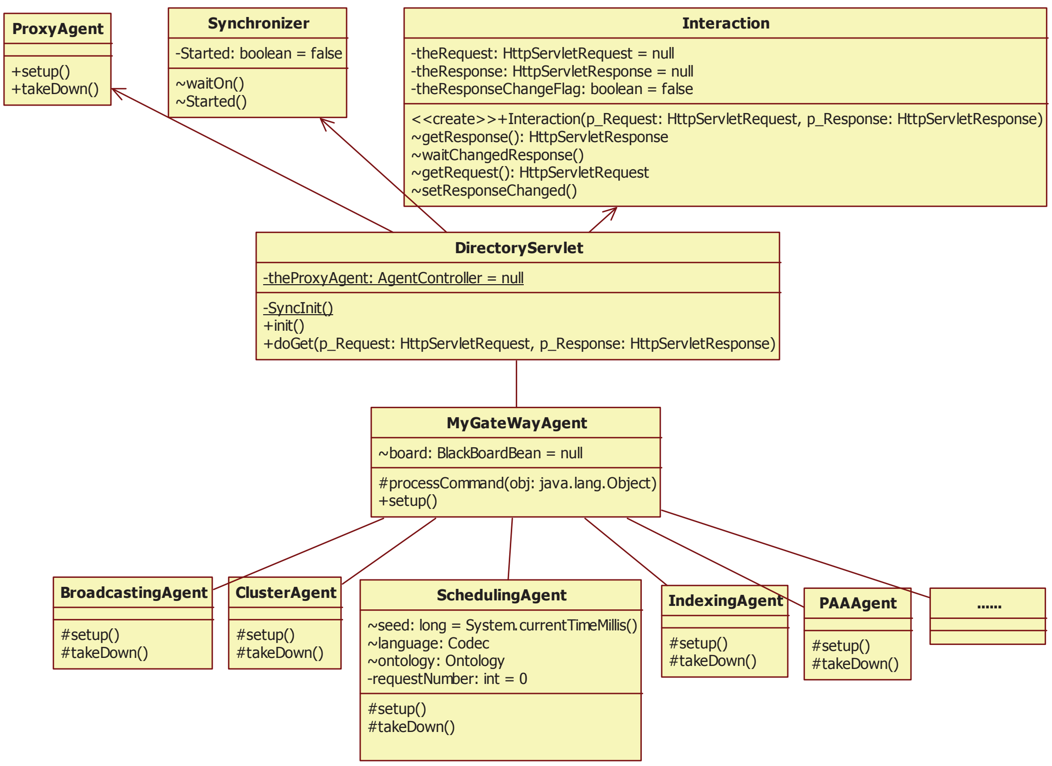


Figure 10. The UML Diagram of MAS and Java EE Main Communication Classes.

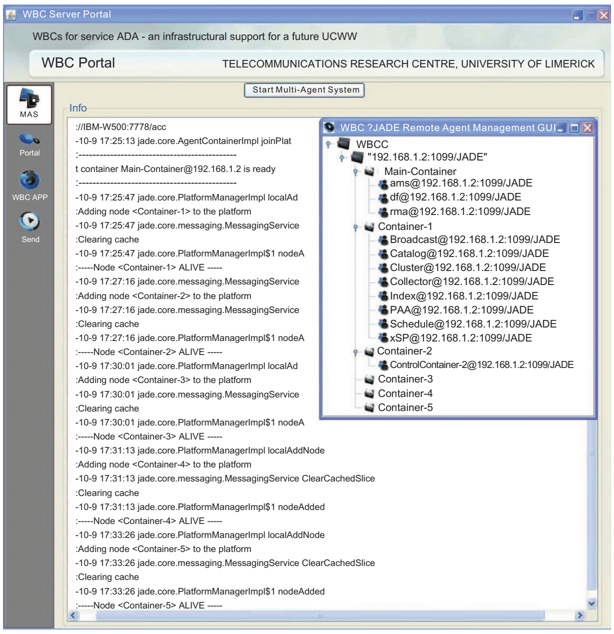


Figure 11. The WBC-SP MAS Portal.

provides behaviours that deal with requests.

The developed UI of the MAS portal is depicted in Figure 11.

V. Performance Evaluation

In this section, we evaluate our overall WBC data organization and management algorithm presented in Section II.B, which runs at the application enabler sub-layer to decrease the mean segment access time (T).

In the simulation tests, we used a 32-kbps ideal channel for broadcasting. The segment length was set to 8 kB. The segments sequence follows the geometric distribution with *P=0.4945*:

$$R_n = (1-p)^{n-1}P \tag{7}$$

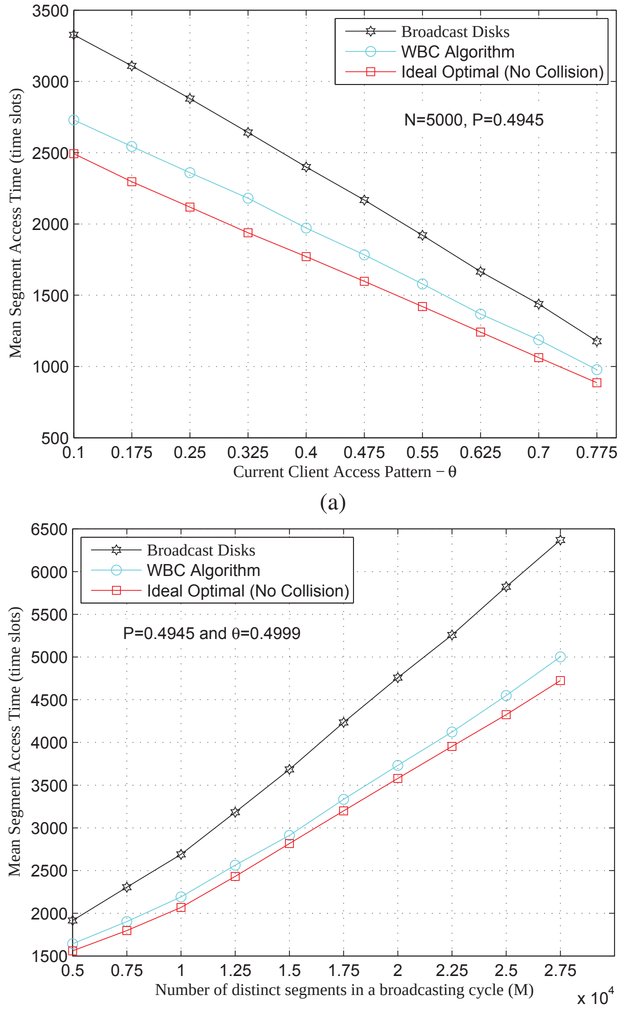
where $1 \leq n \leq M$

To test the relationship between T and p_n, we assume that the current client access pattern θ follows the *zipf* distribution:

$$p_\sigma = \frac{\frac{1}{\sigma^\theta}}{\sum_{j=1}^{M}\frac{1}{j^\theta}} \tag{8}$$

where $\sum_{\sigma=1}^{M} p_\sigma = 1$

Figure 12(a) shows the obtained simulation results. It is clear that T is reduced when the current client access pattern became more skewed, i.e., when the value of θ is increased. The WBC algorithm is more efficient comparing to the broadcast disks algorithm [6] due to the intelligent WBC solutions used for collision resolving. For example, in the case of having a number of segments satisfying the necessary conditions for inserting into the broadcasting sequence, the broadcast disks algorithm selects one of them in arbitrary way, whereas the WBC



(b)

Figure 12. The Mean Segment Access Time: (a) for different θ; (b) for different M.

algorithm uses a number of intelligent decision rules to decide which exactly segment should be inserted into the sequence.

Figure 12(b) shows that T increases with the increase of M. Similarly to Figure 12(a), it shows that the value of T achieved by the WBC algorithm is closer to the optimal value (no collisions), which proves that the WBC algorithm outperforms the broadcast disks algorithm.

VI. Conclusion

A novel wireless billboard channel data management scheme and its corresponding intelligent application's design and implementation have been proposed in this paper. An efficient data management algorithm was elaborated for minimizing the access time. The corresponding application was implemented in a three tier architecture within the WBC's Service Layer. These tiers are a service discovery and maintenance tier that maintains the client requests and server responses, supports the service discovery model, and serializes objects to the persistence subtier; a rule-based expert system running in the intelligent application tier and providing WBC common services; and a peer-to-peer multi-agent system (MAS) tier running a set of agents for the management of advertisement service descriptions, SDs.

The performance evaluation of the proposed WBC data organization and management application shows that the mean segment access time achieved is pretty close to optimal.

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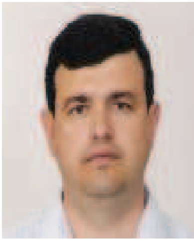
Zhanlin Ji received his MEng, M.Sc and PhD degree from Dublin City University, Beijing University of Posts and Telecommunications, and University of Limerick in 2005, 2006 and 2010, respectively. His Ph.D research was focused on the Wireless Billboard Channels' (WBC) design, development and testing for use in the Ubiquitous Consumer Wireless World (UCWW). Since 2010, he is a lecturer at the Hebei United University, China. His research interests include UCWW, WBCs, Software Engineering, Mobile and Ubiquitous Computing, Information Retrieval and Management, Content awareness, Personalization, Multi-agents systems, Java EE architectures, Medical image analysis and processing, Machine Vision, Broadcasting.



Ivan Ganchev received his DipEng and PhD degrees from the Saint-Petersburg State University of Telecommunications in 1989 and 1994, respectively. He is an Associate Professor from the University of Plovdiv and an ITU-T Invited Expert. Currently he is lecturing in the University of Limerick (Ireland), where he also acts as a Deputy Director of the Telecommunications Research Centre. Previously Dr Ganchev served as a member of the Academic Network for Wireless Internet Research in Europe (ANWIRE) and two European Science Foundation 'COoperation in the field of Science and Technology research' Actions: 'Modelling and Simulation Tools for Research in Emerging Multi-service Telecommunications', and "Traffic and QoS Management in Wireless Multimedia Networks", (COST 285 & 290). Currently he is a member of the COST Action IC0906, "Wireless Networking for Moving Objects" (WiNeMO). His research interests include: simulation and modeling of complex telecommunication systems, new communications paradigms for wireless next generation networks (NGN), always best connected & best served (ABC&S), third-party authentication, authorization and accounting (3P-AAA), wireless billboard channels (WBC), Internet tomography. Dr Ganchev served on the Technical Program Committee of a number of prestigious international conferences, including IEEE Globecom (2006), IEEE VTC (2007-2010), and IEEE ISWCS (2006-2010).

Máirtín O'Droma received his BE and PhD degrees from the National University of Ireland in 1973 and 1978, respectively. He is a Senior Academic and Director of the Telecommunications Research Centre at the University of Limerick, Ireland. He is an IEEE Subject Matter Expert, an ITU-T Invited Expert, a Fellow of the IET and Chair of Ireland's Royal Irish Academy's Communications and Radio Science Committee. His previous activities include: founding partner and steering committee member, TARGET -Top Amplifier Research Groups in a European Team-, the EU FP6 Network of Excellence IST-507893, 2004-2008, and section head of the RF power linearization and amplifier modeling research strand; founding partner and steering committee member, ANWIRE -Academic Network for Wireless Internet Research in Europe, the EU FP5 Thematic Network of Excellence IST-38835, 2002-2004; member of two European Science Foundation 'COoperation in the field of Science and Technology research' Actions: 'Modelling and Simulation Tools for Research in Emerging Multi-service Telecommunications', and "Traffic and QoS Management in Wireless Multimedia Networks", (COST 285 & 290). Currently he is delegate (Ireland) to the COST Action IC0906, "Wireless Networking for Moving Objects" (WiNeMO). His research interests include: wireless NGN infrastructural innovations and new paradigms; complex wireless telecommunication systems simulation and behavioral modeling, linearization & efficiency techniques in multimode, multicarrier broadband nonlinear microwave and mm-wave transmit power amplifiers; smart antenna and MIMO channels. Dr O'Droma served on the Technical Program Committee of numerous IEEE and other international conferences and workshops.