INTELLIGENT FRAMEWORK FOR RECOMMENDATION OF MOBILE SERVICES TO CONSUMERS

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***Abstract**: This paper describes an intelligent framework for the recommendation of mobile services to users, based on a combination of two different approaches. The first one utilizes Wireless Billboard Channels (WBCs) to push (by broadcasting) service advertisements to mobile users/devices in order to enable them to discover and associate with the 'best' service instances under the Always Best Connected and best Served (ABC&S) communications paradigm. The second approach uses a dedicated service recommendation system, which finds and suggests to each individual user the 'best' service instances, depending on the current user-, network-, and service context. The main parts of the proposed framework are explained and the key technological solutions required to support it are outlined.*

***Keywords**: Ubiquitous Consumer Wireless World (UCWW), Always Best Connected and best Served (ABC&S), Wireless Billboard Channels (WBCs), Advertisement, Discovery and Association (ADA), mobile services, service recommendation system, intelligent framework.*

***ACM Classification Keywords**: C.0 GENERAL – System architectures, C.2.1 Network Architecture and Design – Wireless communication, C.2.4 Distributed Systems – Client/server, D.2.2 Design Tools and Techniques – Evolutionary prototyping.*

1. Introduction

In the near future, a next generation network (NGN) wireless environment, called the Ubiquitous Consumer Wireless World (UCWW) [O'Droma, 2007, O'Droma, 2010], will emerge, where users will act more like consumers of mobile services rather than subscribers as nowadays. In the UCWW, services will be available anywhere-anytime-anyhow, will be customized to the user's needs and adapted to the current user- and network context, in the best possible way, independent of the user's movement across heterogeneous access networks, e.g. 3G/4G, Wi-Fi, WiMAX, etc., according to his/her own criteria (e.g. on the basis of price/performance offerings), while maintaining active service sessions, i.e. without service interrupting, restarting applications, or losing data. This new communications paradigm, called the Always Best Connected and best Served (ABC&S) [O'Droma, 2006], will be facilitated by a novel

Consumer-Based techno-business model (CBM), which will enable a loose dynamic (even casual) consumer-type association between mobile users and access network providers (ANPs).

The UCWW could be considered as a global communications environment, which brings a different approach to the wireless communications business. It will provide greater flexibility and freedom to mobile users, full user mobility among participating access networks, and a greater degree of service choice. Besides these new benefits for users, the UCWW has the potential to stimulate the creation of a number of new interesting business opportunities and to create a more liberal, more open and fairer wireless marketplace for existing and new ANPs and (mobile) service providers (xSPs), allowing their primary business success indicator to shift from subscriber numbers to the volume of consumer transactions. In the future, this will increase the range of competitive price/performance and price/quality offerings, specialist and niche service offerings, and so forth, all of which will drive forward innovation in the wireless communications and mobile services market.

To enable this user-oriented, user-friendly, and user-driven ABC&S wireless communication environment, the mobile user should be made aware of the presence of communications services and mobile services around him/her. One possibility to accomplish this is to use Wireless Billboard Channels (WBCs) to solely push (by means of broadcasting) service advertisements to mobile users/devices in order to enable them to discover and associate with 'best' service instances under the ABC&S paradigm. This technological solution along with the supplementary procedure for services' Advertisement, Discovery and Association (ADA) is described in greater detail in the next section.

Another option is to use a dedicated service recommendation system, which to do the same without a need for additional infrastructural network elements, simply by utilizing the (mobile) Internet connection of users. Details about this option are provided in Section 3. The building of an intelligent framework for recommending mobile services to users, by combining these two approaches, is described in Section 4. Conclusions and future research work are presented in Section 5.

2. Wireless Billboard Channels (WBCs) and Advertisement, Discovery and Association (ADA)

Wireless Billboard Channels (WBCs) are simplex push-based channels, used for pro-active broadcasting of service advertisements to mobile devices (in a particular coverage area) in order to enable mobile users to discover and associate with 'best' service instances (in a background mode of operation) under the ABC&S communications paradigm (Figure 1). If needed, they can operate also as down-link (DL) out-band Cognitive Pilot Channels (CPCs).

At first glance, the WBCs may look as a form of CPCs. However, the WBC concept was elaborated in 2004 by two researchers (O'Droma and Ganchev) at the University of Limerick, Ireland [O'Droma, 2004a], i.e. a few years before the CPC concept [Bourse, 2007]. The CPC idea was promoted by the

European Telecommunications Standards Institute (ETSI) [ETSI, 2009] in order to provide collaboration between networks and mobile devices as to enable the information transfer to mobile devices of available knowledge of the wireless network environment, including available radio access networks (RANs), radio access technologies (RATs), corresponding coverage areas and frequency bands, network policies, etc. CPCs are used mostly in relation to the wireless communications services' provision, whereas WBCs provide also (advertisement) information about the (most appropriate to the user) mobile services, which makes them much richer solution as regards the functionality.

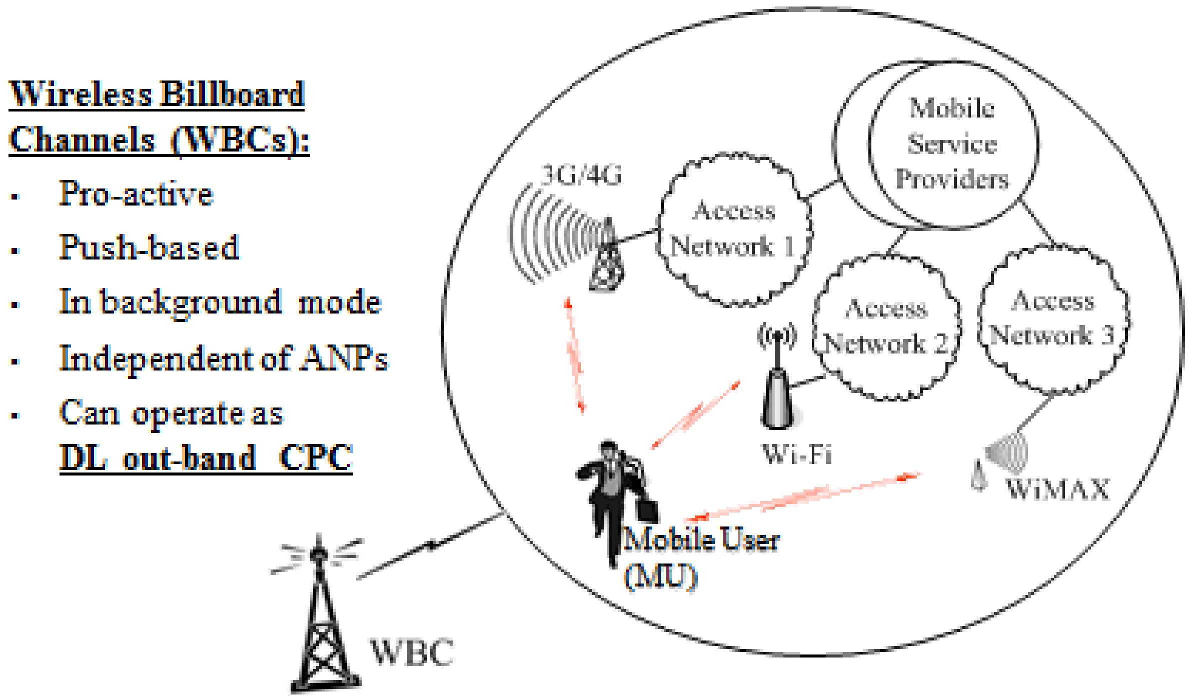

Fig. 1. The use of WBCs for the ABC&S realization (adapted from [Ji, 2010a])

If the user (acting as a consumer) is located in the footprints of several wireless access networks, first thing s/he needs is to discover these networks well enough to make ABC&S decisions in respect of the various services s/he may wish to access. Second, the user needs to know supplementary information about the services provided by these networks along with corresponding price policies. Third, s/he needs to find out what network is best for use for each particular (mobile) service (instance). Information about all these is provided via the WBC deployed in the area of presence. The user's mobile device can than compare this information with its own capabilities, the current user profile's preferences, the current location, and other contextual information such as the time of day, day of the week, etc. to select (in a background mode) the ‘best’ services (instances) for use to achieve a particular goal (e.g. to make a phone call). As well as advertising the service, the WBC will also provide information to help with the process of discovering and associating with that service (e.g. access networks’ physical layer information), [Flynn, 2006]. All this is referred to as the Advertisement, Discovery and Association (ADA) procedure, which could be (almost) fully automated and completed transparently to the user.

WBCs are wireless equivalent of roadside advertisement billboards and as such could be used as ‘push’ advertisements means for providers (ANPs and xSPs) to let users know about their presence and current service offerings. After receiving this information in the form of WBC broadcasts, the user’s mobile device would be able to dynamically compile information about available services in the current location and to match these service offerings against ABC&S criteria under different user/device roles/profiles, all in all facilitating the ABC&S network-service match decisions and proposing ABC&S solutions to the user through (optional) device reconfigurability and application service adaptability functionalities. The user then, according to one of his/her roles, e.g. family parent, will select the available ‘best’ access network for a particular service and the ‘best’ service instance, using criteria such as price/performance ratio and current location. For instance, different mobile service and access network will be selected to call a family member (i.e. VoIP over Wi-Fi) than to call a business partner (i.e. an ordinary phone call via a 3G/4G cellular network), based on time/day/week/location configuration.

In the future, mobile devices will be able to select any access network they consider being the ‘best’ among all available access networks in the current area, even those whose communications technologies, protocols, etc. are not supported (by default) by the device itself. This is because mobile devices will become more and more reconfigurable, and eventually be able to access any and all existing and new access networks, and because users will more and more want autonomy in availing of access networks’ communications services as with any other consumerist services [O’Droma, 2004b]. Through the Software-Defined Networking (SDN) technology, networks will also become more reconfigurable in order to match users’ (individual and collective – groups’, communities’) variable mobile wireless service needs and desires thus achieving the ABC&S reconfigurability goal.

The following are the main WBC characteristics and related attributes [Flynn, 2006]:

- *Point-to-multipoint (broadcast)*

  A WBC, deployed in a particular area, will deliver service advertisements to multiple (all active) mobile devices, currently located in the same area.

Simplex

The simplex (i.e. unidirectional) attribute has the additional benefit of easing WBC physical deployment and operation. If the channel were duplex, then bandwidth-spectrum allocation will become a much more significant issue, closer to the complexities involved in existing cellular spectrum allocations.

- *Limited bandwidth*

  Given the proposed usage – point-to-multipoint, unidirectional service of advertisements –, bandwidth requirements will be relatively narrow. This has the added advantage of enhancing WBC likely success, e.g. of global agreements on spectrum allocations for WBC.

- *Maximum coverage area*

  The WBCs should ideally be available anywhere-anytime. No matter where it is, a mobile device should have the ability to discover what services are available to it from local to regional and international service providers. Device mobility should not affect the ability to receive information on the channel.

- *Different versions for different areas*

  The number and types of WBCs could eventually correspond to the local, regional, national, and international interests of advertisers and users. For instance, there could be one national WBC channel, advertising all the services that are relevant on a national level, which could include advertisements of local, regional or interregional significance, and then separate regional WBC channels, advertising the services available in that particular region (Figure 2).

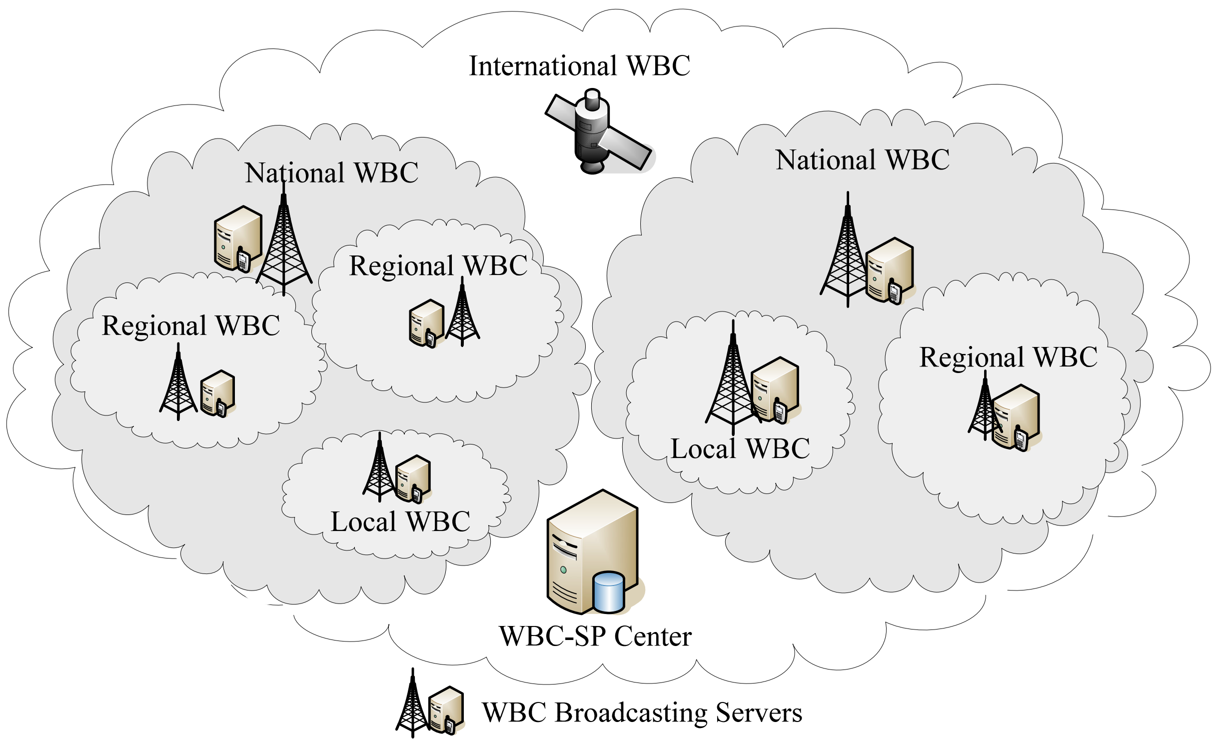

Fig. 2. Different WBC versions (adapted from [Ji, 2007])

- *Operated by non-ANP service providers*
  WBCs will need to be regulated and be fully independent and physically separate from ANPs and their access networks. This is needed to ensure fair competition and equity of access to WBC advertisement space, i.e. equally open to all ANPs. For this it is better that they be operated by non-ANP service providers, e.g. by existing radio and TV broadcasters.
- *Carrier technologies*
  There are several seemingly suitable broadcast technologies to consider, which fall into two main categories – terrestrial and satellite. Terrestrial examples include Digital Audio Broadcast (DAB), Terrestrial Digital Multimedia Broadcast (T-DMB), Digital Radio Mondiale (DRM), Digital Video Broadcast Handheld (DVB-H), Multimedia Broadcast / Multicast Service (MBMS). Satellite examples include Satellite DMB (S-DMB) or the Digital Audio Radio Satellite technologies being used by, for example, the WorldSpace system, XM Radio and Sirius.

The main WBC purpose is to allow services[1] to be discovered by mobile users/devices. The standard approach used by service discovery protocols, such as Jini, SLP, and Salutation, relies on a central registry of service descriptions (SDs). Service providers register their SDs with that registry. Clients query the central registry about available services, based on service attributes. The central registry responds to the clients with SDs that match their queries. The clients then can start using the services they discovered.

A modified version of this model was elaborated for use in the WBC by taking into account its specifics [Flynn, 2006]. As the WBC is a simplex "push" channel which does not facilitate queries to a registry, the solution was to broadcast all SDs in turn on the channel and the mobile device just to wait for the required SD to be broadcast. The WBC service discovery model is shown in Figure 3 and described below:

A. All service providers (ANPs and xSPs) register the SDs of their services with the WBC service provider's (WBC-SP's) central registry.

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[1] The term 'service' here means both access networks' communications services and mobile services. The former are the actual access networks through which mobile devices connect. The latter is an encompassing term for all non-access-network services, e.g. from e-learning, e-government portals to on-line Internet shopping, e-mail, web-browsing, peer-to-peer services, etc. To use a mobile service, a mobile device will utilize an access networks' communications service.

B. The WBC-SP broadcasts all collected (and paid) advertisements / SDs, repeatedly, on a WBC. The advertisement structure should be flexible enough to include all, or at least all relevant, SDs. Advertisements should be streamed cyclically with frequency dictated by the WBC-SP's business model.

C. Each mobile device (MD) tunes to the channel and collects all SDs that the mobile user (MU) is interested in.

D. The MU/MT may seek further information (e.g. following a URL in the advertisement), makes a choice of the 'best' ANP for a service it requires, associates with that ANP, and begins to use the 'best' instance of that service.

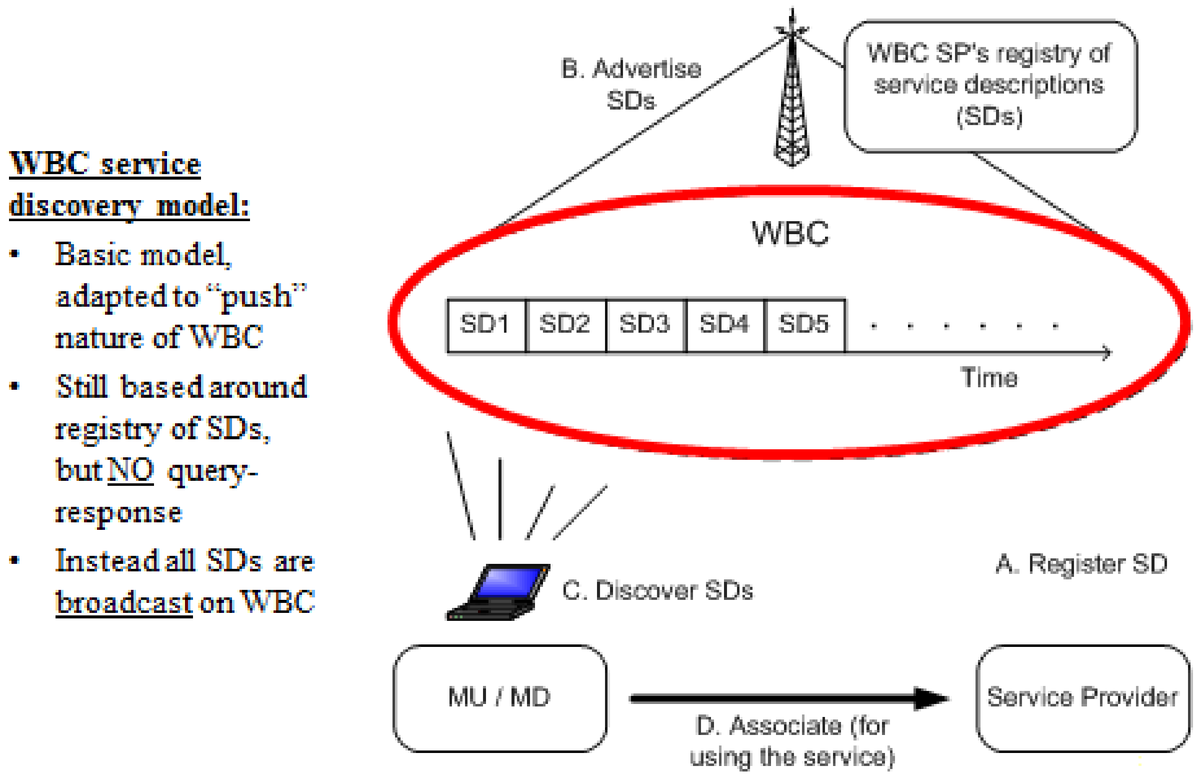

Fig. 3. The WBC service discovery model (adapted from [O'Droma, 2012])

The service advertisements, which are broadcast on the WBC, are composed of SDs. A three-part design of the SD was adopted in [Flynn, 2006]:

Service Type

The purpose of this field is to group together similar services, making the advertised services (and their SD) easier to find in the WBC streaming. Every service to be advertised has an assigned *Service Type*. Each *Service Type* has a template, which SDs follow. These templates are managed by the WBC-SP and published for all providers to follow.

Scope List

This field identifies which scopes a particular service belongs to. Scopes are a way to group services together. For example, a service provider may offer a number of news alert services to mobile users who pay a monthly subscription. All these services can then be assigned the same scope. The users, when discovering services using the WBC, will see their scope and will know they have access to them. Non-subscribing users will see that these services have a scope, which they have not been assigned, and can ignore any such SDs.

Attribute List

This field carries structured information on a service being advertised. For ANP's wireless access services, sufficient information to enable a mobile user/device to associate with the access network should be present in these SD attributes. To this end, SD templates, with relevant attribute lists, for different service types are formulated in [Flynn, 2006]. The format of the *Attribute List* in a SD depends upon the *Service Type* of that SD. Each *Service Type* has a service template specifying the format of the *Attribute List*. Templates are managed by the WBC-SP.

Making decisions between different service instances is semi-automatic. The mobile device reads the SDs from the WBC and provides relevant information to the user. For a given service type, that the user is interested in, the device will show all available service instances (sorted in order of preference based on attributes such as cost, quality, and supported features specified in the service profile) and among these the user will choose the 'best' service instance for the desired service. After that, the mobile device will need to know how to associate with that service (instance). The first thing needed is the client-side software to be installed on the mobile device (if not already installed/pre-loaded). For this, an attribute is envisaged, which to tell the device how to download this software. Another attribute specifies the software itself and its version so that the device can see if it needs to be updated. It could be better to have one software-download service (which would also be advertised as any other service on the WBC), which allows for downloading of all additional software needed for the use of services advertised on the WBC (this could be used for software defined radio, SDR, downloads as well). Having installed the software, there are some attributes specific to a particular service (e.g. IP addresses and port numbers) that need to be known as well.

For the SD encoding, the use of the Abstract Syntax Notation (ASN.1) was proposed in [Flynn, 2006]. ASN.1 offers various different encoding rules, among which the Packed Encoding Rules (PER) are the most efficient that can yield encoding close to optimal. This is important for the WBC as bandwidth is a big issue.

An efficient system for SD advertisement, collecting, clustering, scheduling, indexing, discovery, and association was elaborated in [Ji, 2008a] along with a novel Advertisements Delivery Protocol (ADP) [Ji, 2008b]. In addition to collecting SDs from service providers, the other goal of *collecting* is to provide information about the user demand for a particular service and the advertisement cost paid by the corresponding service provider, which has to be taken into account when generating the SD broadcasting frequencies. The goal of *clustering* is to group SDs into WBC segments in an optimal way so as to reduce the user's access time and tuning time. The goal of *scheduling* is to apply a reasonable scheduling scheme for minimizing the access time of the entire system. Scheduling could be based on a push-based non-flat broadcasting, which will broadcast the more popular SDs more often. To achieve this, the WBC segments could be divided into two groups – *hot segments*, which are broadcast more frequently depending on the current user demand (i.e. several times per broadcast cycle), and *cold segments*, which are inserted equally into the scheduling cache by filling the remaining gaps (i.e. ones per broadcast cycle). A modified Broadcast Disks algorithm was developed to accomplish this goal more efficiently than the classic Broadcast Disks algorithm [Ji, 2008a].

Tuning time could be reduced by employing an *indexing* scheme because without it, a mobile device would have to tune into the WBC and listen to the broadcast continuously until the required SD is transmitted. By adding indexing data to the broadcast, mobile devices can tune in, find out when the required SD will be transmitted, then tune out and wait until that time to tune back in again. By adding redundant data to the broadcast, however, the average access time will be increased. Suitable indexing schemes, providing a good trade-off between the tuning time and access time, were investigated in

[Flynn, 2006] and an indexing scheme adjusted to the WBC specifics was proposed in [Ji, 2008a], based on the *(1, m)* indexing algorithm.

The goal of *discovery* and *association* is to discover and associate with the 'best' service instance by utilizing the information stored in various user's profiles, such as an identification/authentication profile, an advertisement profile, a discovery profile, an association profile, a rules profile, a history profile, etc.

To smooth the SD processing in the WBC, a new reliable and scalable ADP protocol was elaborated, based on the standard Asynchronous Layered Coding (ALC) protocol, to convert WBC segments into IP packets. The designed ADP protocol includes Building Blocks (BBs) and Protocol Instantiation (PI). Four modified BBs (i.e. Layered Coding Transport BB, Forward Error Correction / FEC BB, Congestion Control BB, and authentication BB) and two types of PIs (i.e. ALC using FEC) and NACK Oriented Reliable Multicast (NORM) relying on FEC with ARQ) were developed for the ADP in [Ji, 2008b].

A pilot 'WBC over DVB-H' prototype system, based on a 3-layer architecture and utilizing novel algorithms, schemes, and protocols, was developed, evaluated, and tested [Ji, 2010b]. Besides the design and implementation of a layered, distributed, intelligent, and heterogeneous WBC system prototype, the research work to date included the proofing and refining of different aspects of the design. Also completed is the operational testing, performance evaluation, and scalability evaluation of the core WBCs elements.

Information about the WBC has appeared in a recent International Telecommunication Union Radiocommunication Sector (ITU-R) report [ITU-R, 2015] as a realization of a coverage-area out-band CPC, piggybacked on a broadcast digital platform.

3. Service Recommendation System

Another possibility to recommend (mobile) services to consumers-users is to use a dedicated service recommendation system, like the one described in [Ganchev, 2013] as a means for users matching their need to discover the 'best' service instances, and facilitating, and supporting, the association with them by following a user-driven ABC&S paradigm.

The area of service recommendations has attracted great attention in the last few years. For instance, [Lee, 2010] proposes a personalized digital TV program recommendation system, working within a cloud computing environment, which is able to analyze and use the viewing pattern of consumers in order to personalize the TV program recommendations. A personal photo recommendation system is proposed in [Tian, 2013] by fusing contextual and textual features on mobile devices. A music recommendation system, based on analysis of users' sentiments extracted from sentences posted on social networks is presented in [Rosa, 2015]. In [Songhui, 2012], a context-aware architecture of a car navigation recommendation system is described, which computes and dynamically adjusts the optimal travel path(s), based on real-time traffic information. [Wu, 2014] describes an intelligent urban car parking recommendation system for facilitating drivers with fully efficient, real-time and precise parking lot guiding suggestions. [Zhang, 2015] applies a semi-automated, extensible, and ontology-based approach for the discovery and selection of Infrastructure-as-a-Service (IaaS) cloud offers, by utilizing a multi-criteria decision-making technique, based on real-time end-to-end quality of service (QoS) parameters, for meeting service-level agreements (SLAs). [Nagarathna, 2012] proposes a service recommendation system, based on trust, reputation, and QoS requirements, for use in a Service Oriented Grid (SOG) by utilizing a mechanism of similarity computation and ranking of service providers based on users' feedback. [Pääkkö, 2012] applies knowledge-based recommendation techniques for dynamic, runtime, proximity-based service compositions for mobile devices.

However, the service recommendation system presented here is considered as a global solution applicable to all types of mobile services and also to many other Internet services. Taking into account the 'big data' aspect of information about (and gathered from) consumers, networks, and services, a cloud-based version of such a recommendation system is envisaged as being more capable for facilitating the delivery of increasingly contextualized mobile services to support the consumer-choice optimization process.

A UCWW mobile application [Ganchev, 2015a], installed on the user's mobile device and associated with such a system, could be used for finding and recommending to users, or even automatically selecting if the user's profile settings are so set, the 'best' mobile services, depending on the current context, including in that decision process the user's personal profile requirements. The complex functional requirements of such application make for a demanding app design, testing, and validation. A possible design solution, realized through a structured composition of three tiers – a mobile application tier, a web tier, and a cloud tier, is presented in [Ganchev, 2014a].

On the back-end, a UCWW cloud is envisaged to facilitate the storage of user data harvested via mobile devices, and based on the analysis of this data, to offer predictions as to the applicability and ABC&S

suitability of services to particular users, and to enable ever-enhanced contextualization and personalization functionalities. Over time the data collected relating to particular users can give an accurate view of particular cohorts, based on common interests, repetitive access of particular services, etc. By monitoring this information, the system then can accurately predict the types of services most applicable to individuals, and in turn, recommend these to them. Furthermore, efficient algorithms must be applied to facilitate service utilization predictions locally on the mobile devices or as part of the UCWW cloud as an alternative to mining the stored data [Ganchev, 2015b]. For instance, [Zhang, 2016] proposes a hybrid method that integrates user trust relations with item-based collaborative filtering. This is achieved by incorporating user social similarities into the computation of item similarities. Performance evaluation results demonstrate that the proposed approach achieves better accuracy than the traditional item-based collaborative filtering.

The UCWW cloud could be established to operate as a middleware. At the lowest layer, the user's mobile device collects context data from the environment, and at the highest layer the UCWW client application makes use of this data. Between them operates the middleware of the system, which could be entirely implemented as cloud services. [Ganchev, 2013] describes the flow of context data between a mobile device and the UCWW cloud as well as the mechanism of sending requests and receiving responses from the decision support subsystem, i.e. providing ratings (ranking) of the service providers available for a particular type of service requested by the user.

This service recommendation system could be deployed as an 'anywhere-anytime-anyhow' oriented component, supplemented by a Data Management Platform (DMP) [Ganchev, 2016b] that acts as a machine learning platform for turning raw data into actionable analytic dataset, i.e., user behavior profiles, including user preferences, content consumption preferences, shopping preferences, interest preferences, app usage, etc., abiding by the user-privacy principles. More specifically, the DMP provides data collecting, processing, analyzing, and consumer targeting operations. It could be used for managing consumer identification and generating audience segments, in order to target consumers with most appropriate / 'best' (mobile) services. For this, it utilizes real-time user's profiling algorithms and off-time data processing algorithms [Ganchev, 2016a], and could be implemented with the Publish/Subscribe design pattern [Ganchev, 2016b].

The service recommendation system communicates with the DMP, keeps updating the user behavior profiles, user interests and requirement tendencies, and sends a personalized list of 'best' recommended service instances to each user in a real-time manner by utilizing relevant recommendation algorithms and updated recommendation rules. A recommendation engine acts a central element in this system. It allows uploading the recommendation algorithms to the system and defining/updating the recommendation rules. This engine can be built with a Lambda Architecture for providing real-time recommendations (at the speed layer) and off-time analytical operations (at the batch layer) [Ganchev, 2016a].

The service recommendations, provided by such a system, will depend greatly on the current context. Besides the context that relates to the mobile *services* available on offer (i.e. the category, type, scope and attributes of the service, the request time, the application initiating the request, the current Quality of Service / Quality of Experience (QoS/QoE) index of the service, price, etc.), the context data may relate to the *user* (e.g., the user location, the user preferences and profiles, current battery charge and other operational characteristics of the user's mobile device, type of activity, intentions, social interests, the upper bound on the price and the lower bound on QoS/QoE accepted by the user for each particular service, privacy and security requirements, etc.), and/or relate to the constraints of the wireless access *network* currently utilized by the user (e.g., the communication channel state information (CSI), network congestion level, the current data usage pattern, the current QoS/QoE index, the cost of using the network, pricing scheme, etc.). Then determining the 'best' service instance at any moment for a particular user is based on a set of context parameter values, categorized in three groups – user-related ***(u)***, service-related ***(s)***, and (access) network-related ***(n)***, forming a 3D ***(u,s,n)*** context space, as illustrated in Figure 4. The selection of the 'best' service instance ***s*** for user ***u*** in the network context ***n*** is based on finding the following maximum value [Ganchev, 2014b]:

$$Max_{s_1 \dots x} \sum_{i=1}^{n} Best(\mathrm{u}_i, \mathrm{s}_i, \mathrm{n}_i)$$

The concept of context allows making smart decisions based on mining of data stored in cloud repositories. [Ganchev, 2013] proposes context to include both the data sensed in the environment (as in a typical context-aware system), and the history of the user and the collective history of users who have acted in a similar environment. This constitutes a novel approach in providing context-aware services with elements of community-based personalized information retrieval (PIR), applied to mobile network environments.

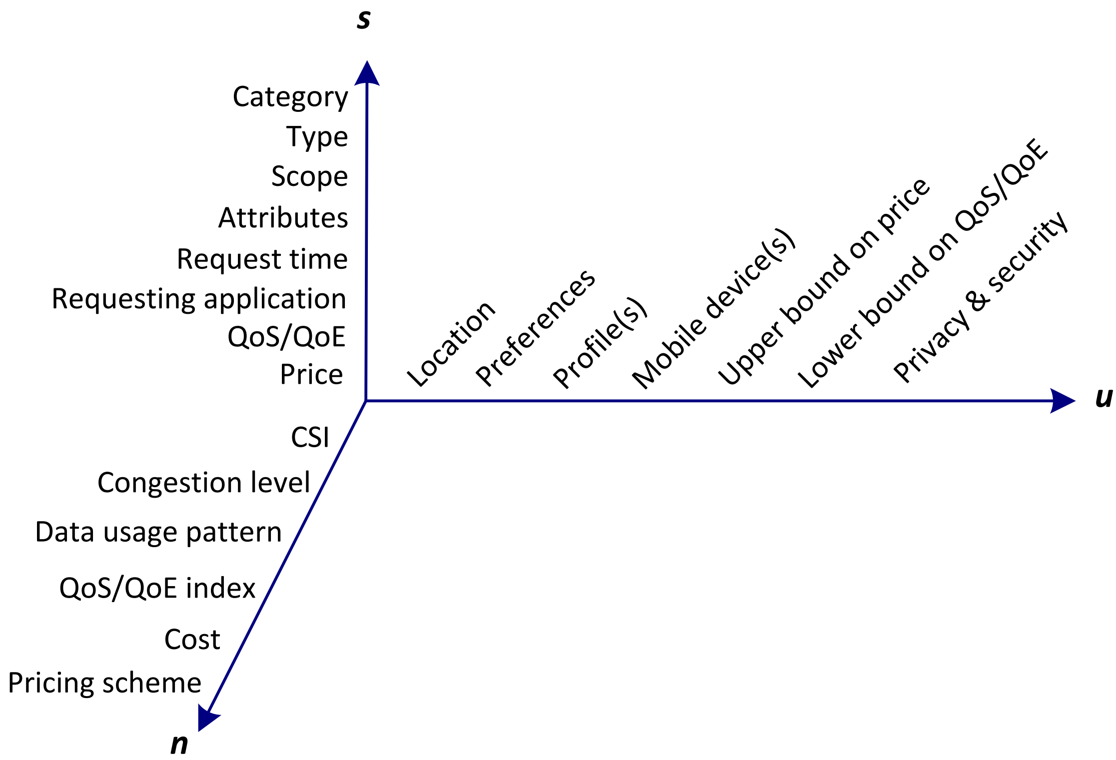

Fig. 4. The 3D context space.

4. Intelligent Framework for Recommendation of Mobile Services to Consumers

By combining the two aforementioned service advertisement approaches, an intelligent framework could be built with a modular structure consisting of four main parts, used for stream computing, SD server hosting, cloud-based data mining, and distributed log collection, respectively (Figure 5), [Ganchev, 2014b].

Among these, the SD server is the main part. It collects aggregated user behavior monitored by the UCWW client app installed on the user's mobile device. The monitored behavior includes user's searching for services, user's associations with services, actual service usage, etc. In the first step, the SD retrieval module searches for the relevant keyword in the SD index database, facilitated by the user's profile, web page attributes database, and real-time bidding system for demand (RTBD), and as a result an initial service recommendation list is generated. The list is then pushed to SD ranking module and, after computing with the click-through rate (CTR) module, a final list is generated. The WBC management module collects the list, sends it back to the user (via the UCWW server), and pushes it to the log data real-time collection part. If SDs are for new/popular/emerging services, these SDs will be cached in the WBC management module for broadcasting on the WBC. The memory key-value NoSQL database Redis (http://redis.io) could be used to provide persistence operation and the Ngnix (http://nginx.org) – for load-balancing services in the web tier [Ganchev, 2014b].

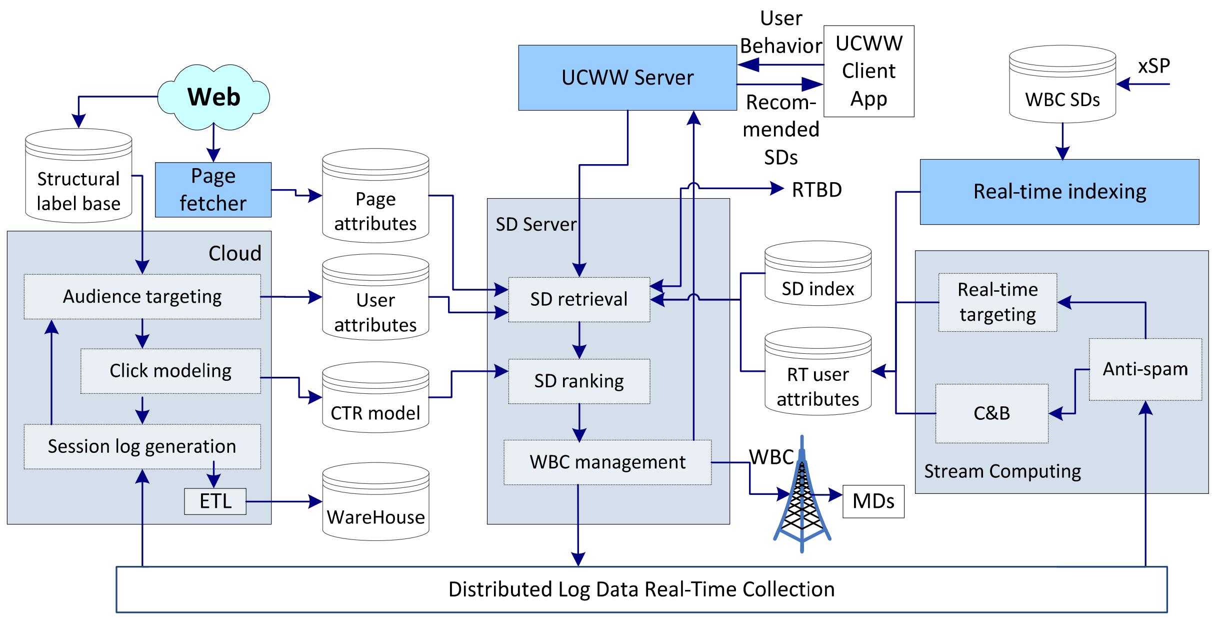

Fig. 5. The intelligent service recommendation framework [Ganchev, 2014b].

The distributed log data real-time collecting part utilizes a producer-consumer paradigm to exchange data, i.e., the SD server is a producer, and the cloud and the stream computing parts are consumers. The Apache Flume (http://flume.apache.org/) could be used to implement this part [Ganchev, 2014b].

In the cloud, the corresponding session data is generated with a unique user ID and serialized to the data warehouse by the extraction transformation loading (ETL) module. Then the audience targeting function collects the behavior and updates it to the user attributes key-value database and CTR model database. Besides collecting the log data from the ad server, the cloud also fetches the corresponding service's web page, updates it to a page attributes database, labels the keywords, and saves the new information to a structural label database. A Hadoop environment could be utilized to provide input/output, remote procedure call (RPC), and Map/Reduce functions [Ganchev, 2014b].

The stream computing part is a real-time computing system, which uses an anti-spam function to filter user's behavior, integrates a charging and billing (C&B) function for services, and updates the behavior to the real-time user attributes Redis database.

4. Conclusion

This paper has reported on the development of a cloud-based next generation networking (NGN) conceptual framework for the supply of service recommendations to consumers (mobile users), built on the revolutionary concept for the realization of the next phase of a NGN-based consumer-oriented wireless networking, founded on the key attributes of the Ubiquitous Consumer Wireless World (UCWW).

The described cloud-based framework provides a personalized data collecting, processing, analyzing, and consumer targeting functions. It could be used to manage consumer identification and generate audience segments in the UCWW, in order to target consumers with the 'best' suitable mobile services they might be interested in, thus facilitating the realization of a truly consumer-centric Always Best Connected and best Served (ABC&S) 'anywhere-anytime-anyhow' provision.

The framework has a modular structure and as such contains a supplementary module for feeding with updated information a Wireless Billboard Channel (WBC), proposed as a global solution for services' Advertisement, Discovery and Association (ADA) in the UCWW.

The integration of such semantic-based recommendation framework into the UCWW has the potential of creating an infrastructure in which consumers-users will have access to (mobile) services with a radically improved contextualization. As a consequence, the framework is expected to radically empower individual consumers in their decision making and thus positively impact the society as a whole by facilitating and enabling direct consumer–service provider relationships. Besides benefitting the consumers, this will open up the opportunity for stronger competition between providers, therefore creating a more liberal, more open, and fairer marketplace for existing and new providers, in which they can deliver a new level of services that are both much more specialized and reaching a much larger number of consumers (mobile users).

Future research work will seek further elaboration of the design, followed by implementation, testing, and evaluation of a fully operational system prototype, employing an efficient and effective relevance measurement approach for the UCWW heterogeneous service network, along with an effective graph-based feature extraction method for building the consumer profiles for facilitating real-time service recommendations, supplied to consumers in order to discover and choose the 'best' (mobile) service instances, under the ABC&S communications paradigm. With this design, the resultant framework will be flexible, scalable, and could be easily integrated into the UCWW cloud.

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