3rd URSI AT-AP-RASC, Gran Canaria, 29 May – 3 June 2022

Intelligent System for Recommendation of Mobile Services to Consumers

Ivan Ganchev*(1)(2)(3), Zhanlin Ji(3)(4), and Máirtín O'Droma(3)
(1) Department of Computer Systems, University of Plovdiv "Paisii Hilendarski", Plovdiv, Bulgaria
(2) Institute of Mathematics and Informatics – Bulgarian Academy of Sciences (IMI-BAS), Sofia, Bulgaria
(3) Telecommunications Research Centre (TRC), University of Limerick (UL), Limerick, Ireland
(4) College of Artificial Intelligence, North China University of Science and Technology, P. R. China

Abstract

This paper presents an intelligent system for recommendation of services to mobile users (consumers) by considering the current context. The system builds up and dynamically manages personal profiles of consumers, aiming to facilitate and optimize the service discovery and recommendation process, in support of consumers' choices for getting the best 'cost / quality of experience (QoE)' ratio when utilizing different mobile services.

1. Introduction

In the modern 'Big Data' era, recommendation systems have become the essential tools for both the providers and consumers for addressing the problem of information overload and assisting the latter. This process is highly dynamic with the increasing number of: (i) *items*, available for online buying, watching, etc.; (ii) *mobile applications* (*apps*) available for downloading from the corresponding app stores; and (iii) *mobile services* of different types. The goal of recommendation systems, in general, is to provide consumers with accurate timely recommendations [1]. So far, the efforts in this direction have been mostly focused on *item* recommendations, whereas *app* recommendations and *service* recommendations are left behind. The aim of this paper is to set out some new research contributions which begin to address the identified research gap in the use of recommendation systems, in particular for the benefit of mobile users (consumers). In doing this, the authors recognize they are pushing a new research and development (R&D) horizon in the "*service* recommendation" sub-area, and one that could become quite extensive taking into account that consumers today seek more freedom of choice in using the 'best' instances of their desired mobile services. However, the increased freedom should not be a burden for the consumers trying to navigate through the vast 'information seas' in order to find the information, product, item, or service needed. Therefore, facilitating the consumers with automatic discovery of the 'best' service instances available for use through the 'best' mobile access network, following the consumer-oriented, consumer-friendly, and consumer-driven *Always Best Connected and best Served* (*ABC&S*) wireless communications paradigm, is of paramount importance. Such recommendations provision should cover a myriad of services already deployed, ranging from typical telecommunication services (e.g., texting) to Internet services (e.g., multimedia streaming) and to more sophisticated Internet of Things (IoT) services such as those helping the consumer's health and security needs, an example being the search (with subsequent dynamic change, if required) of the most 'healthy' or 'secure' driving/biking/jogging/walking route to follow so as to avoid areas posing particular, consumer-specific, health or safety risk. Assisting consumers in discovering what they may need could be done through the receipt of timely personalized recommendations, or supplied data in support of that to be used by an onboard recommendation app on their mobile device, working in cooperation with an intelligent service recommendation system.

This paper presents such system, hosted by a third party located in the cloud, which can automatically identify the usefulness and applicability of mobile services for each engaged consumer, and discover and recommend the 'best' instance of each service identified as useful for him/her. The recommendation of service instances is not only based on the current *consumer context* but also takes into consideration the current *network context* and *service context* [2].

Faced with the vast dynamically-changing information (consumer-, network-, and service-related), the elaborated intelligent recommendation system provides a scalable, efficient, and effective solution for real-time, cloud-based service recommendations, helped by 'big data' analytics [4]. This paper describes a refined structure of this system, based on the initial work[5], which is able to manage sematic 'big data' in real-time for highly contextualized, customized, and personalized service recommendations. Information about services and consumers is stored and managed in the form of a heterogeneous service network (HSN), in order to suggest most suitable and 'best' service instances. By exploiting context-aware recommendation approaches and semantic web technologies, the system first collects and extracts service information, and dynamically models an HSN, based on the elaborated network schema. Then, profile kernels, referring to the minimal set of features describing

the consumers' preferences, are extracted for modelling of the consumers profiles. The discovery of consumers' features is performed, as proposed in [6], by utilizing the 'betweenness centrality' concept [7] within the scope of the HSN, which is a novel approach for consumers profiles' generation based on the meta-paths concept.

The rest of the paper is organized as follows. Section 2 describes an application example of intelligent service recommendations using "texting" as a service example. The design of the elaborated intelligent service recommendation system is briefly presented in Section 3. Section 4 concludes the paper and sets future direction for research.

2. Application Example

The application example in Figure 1, based on the "instant messaging" (texting) service, briefly illustrates the idea. Consumer *A* wants to send instant messages to *B* always in the 'best' possible way, e.g., based on the integral 'cost/QoE' criterion. The cheapest option, presented in green color in Figure 1, would be to utilize the VoIP technology, e.g., by using (for instant messaging) the mobile app of some VoIP provider, over a (free or paid) Wi-Fi connection. This app, however, must be installed on the device(s) and used by both consumers, which is a major constraint. The Wi-Fi/VoIP option will be the preferable one when consumer *B* is a friend or a family member, as this involves a minimum cost even though the QoE guarantees and supports will be the lowest. The QoE here relates mostly to the timeliness of the messages appearing on the screen of the device of consumer *B*, as the VoIP app itself may not be set properly (either by the consumer due to lack of knowledge or by the app developers due to some design choices) to send timely notifications to its consumer about messages coming from other consumers. However, in doing this, consumer *A* could miss an opportunity of using another/better VoIP service provider, who guarantees better QoE for texting to *B* at that moment. The elaborated intelligent service recommendation system, presented in this paper, can find such an opportunity, i.e., the existence of a better VoIP service instance, and recommend it to consumer *A*.

The second option, presented in red color in Figure 1, would be to use the regular short messaging (SMS) cellular service. This higher-QoE / higher-cost option will be the preferable one in certain contexts, e.g., when *B* is the *A*'s manager, business partner, important client, etc. The situation, however, may change drastically when one (or both) of these consumers is currently in a foreign country due to the associated extra roaming cost. In this case, additional and more attractive option, presented in orange color in Figure 1, is to use a (e)SIM card of some local cellular operator which is on sale in the corresponding foreign country, instead of the (e)SIM card provided by the home cellular operator. This is the preferable option for texting abroad, especially in countries where the home operator was unable to negotiate better/lower roaming SMS costs for its subscribers. Yet, the best option in terms of the integral 'cost/QoE' criterion, would be the use of a global (e)SIM card, which in many cases could result in the lowest cost. However, this comes with difficulties in finding if that card provides indeed competitive cost for texting to *B*, as this depends also on the consumer's current location (the country where s/he is at the moment of the call).

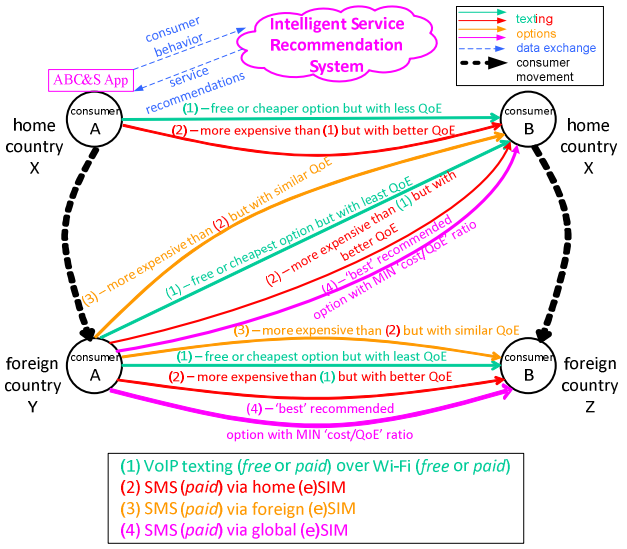

Figure 1. An application example of intelligent recommendations for using the 'best' instance of the *texting* service.

All these scenarios can be easily served by the intelligent service recommendation system, presented in Section 3, which can find the 'best' option for *A* to text *B* in each case, depending on the current context. For this, the system works in cooperation with an ABC&S app, operating on the mobile device of each consumer, e.g., for recommending to *A* the 'best' texting option in the presented application example. Moreover, a more sophisticated version of such app can automatically select the 'best' texting instance, depending on the current context, allowing the consumer to focus on the actual text without thinking of the associated cost/QoE particulars, knowing that this will be done by the app itself.

3. Intelligent Service Recommendation System

The elaborated intelligent system provides two main types of recommendations in relation to: (i) ***service popularization***, by supplying a *global* ranked list of popular services to *all* engaged consumers; and (ii) ***service personalization***, by supplying a *personalized* ranked list of top-*N* service instances to a *particular* consumer.

A *cascade hybrid* context-aware recommendation approach, utilizing both pre-filtering and post-filtering stages, and considering different contextual information (of the consumer, network, and service) in the middle,

was elaborated initially in [8]. Later, it was enriched with *weighted* and *mixed hybridization*. By applying *mixed hybridization* first, it presents recommendations from several different recommendation models at the same time. This is followed by *weighted hybridization* as to come up with the final ranking of service instances, whereby the scores of several recommendation models are combined in a single formula with weighted coefficients to produce a single recommendation.

Service recommendations depend greatly on the current context as being the key element in the mobile space along with the proactive nature of mobile services (and their recommendations) needed for facilitating the consumer input and effective interaction with services. In addition, taking the context into account has really a substantial impact on the recommendation performance [10]. The elaborated service recommendation system supports real *context-awareness*, by utilizing a diverse range of (explicit and implicit) data available in a rapid and scalable manner. Deciding on which service instance is the 'best' one in each case is based on a set of context parameter values, categorized in three groups – consumer-related ***(c)***, service-related ***(s)***, and (access) network-related ***(n)***, forming a 3D ***(c, s, n)*** context space (Figure 2). This way, Moreover, the utilized concept of context allows making intelligent decisions based on mining of data, stored in cloud repositories. It was proposed in [2] the context to include both the data sensed from the environment (as in a typical context-aware system), and the individual and collective consumer behavior history.

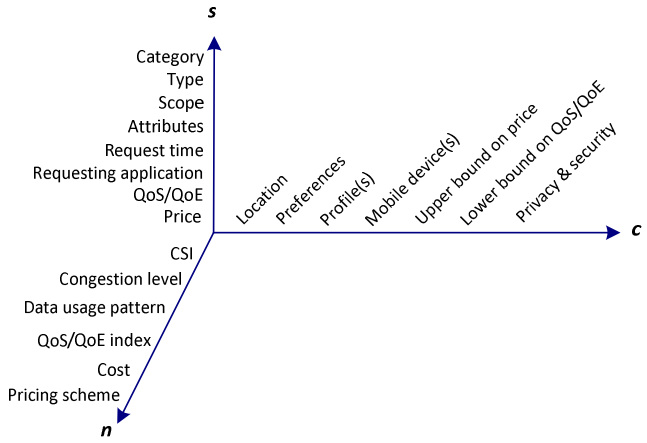

Figure 2. The 3D context space.

For service personalization, the developed intelligent service recommendation system continuously updates consumer behavior profiles, consumer interests and requirement tendencies, and sends an up-to-date ranked list of 'best' service instances to each engaged consumer, by utilizing relevant recommendation models [11] [12] and updated recommendation rules. A modular system structure has been adopted with three domains, related to the *consumer*, *web*, and *cloud*, as depicted in Figure 3 [5].

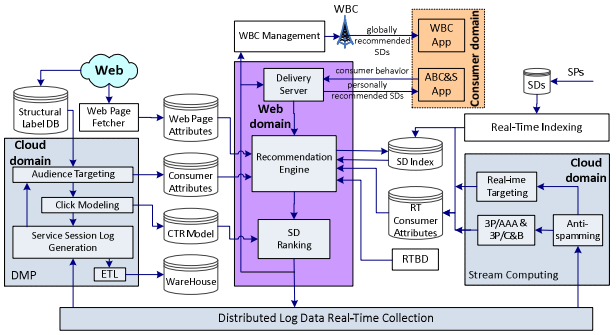

Figure 3. The modular structure of the intelligent service recommendation system.

4. Conclusion and Future Work

The presented intelligent service recommendation system can assist providers of mobile services to reach valuable consumers, by recommending up-to-date lists of ranked 'best' service instances to choose from. For a truly consumer-driven ABC&S wireless communications paradigm realization, additional information may be also supplied in regard to the 'best' available wireless access network that should be used for availing of a particular service.

The presented intelligent service recommendation system facilitates the storage of data harvested from consumers' mobile devices and third parties, such as social media platforms, and based on the 'big data' analytics offers predictions as to applicability (and ABC&S suitability) of services to each engaged consumer. Over time, the collected filtered data can produce an accurate view of consumer cohorts, based on their common interests and the repetitive access to and usage of services. By using this information, the system can accurately predict the types of services most applicable to a particular consumer, and in turn, recommend these to him/her in real-time manner. Furthermore, efficient artificial intelligence algorithms are utilized by the system to obtain better service predictions in the cloud. The collaboration option of this cloud with wireless billboard channels' (WBC) [13] [14] service providers holds potential. Through it, consumers may have their information distilled by the cloud, relevant to their current context, delivered to them in a personalized frame through an appropriate WBC. The full elaboration of this interesting approach needs, however, further research.

In addition, research and development will be carried out on a wireless mobile based 'independent, autonomous service recommender app' which works in combination with geo-location dependent data received through WBC, which is mediated by mobile services marketing/sales-booster providers who operate this element of WBC push-data-to-mobiles, harvesting and gathering all the mobile-services data from the geo-location-dependent mobile services' providers and streaming this data to mobile users (consumers) in a structured way . The WBC service

providers would be offering this service at a subscription to both sides, to the service providers and likewise to the consumers.

Another more practical work will be focused on integrating different components of the presented system into the IoT platform EMULSION [15].

6. Acknowledgements

This publication has emanated from joint research conducted with the financial support of the Bulgarian National Science Fund (BNSF) under the Grant No. КП-06-ИП-КИТАЙ/1 (KP-06-IP-CHINA/1) and the S&T Major Project of the Science and Technology Ministry of China, Grant No. 2017YFE0135700.

References

[1] M. Jalili, S. Ahmadian, M. Izadi, P. Moradi, and M. Salehi, "Evaluating Collaborative Filtering Recommender Algorithms: A Survey," (in English), *IEEE Access,* vol. 6, pp. 74003-74024, 2018, DOI: 10.1109/Access.2018.2883742.

[2] I. Ganchev, M. O'Droma, N. Nikolov, Z. Ji, "A UCWW Cloud System for Increased Service Contextualization in Future Wireless Networks," presented at the 2nd International Conference on Telecommunications and Remote Sensing (ICTRS'13), Noordwijkerhout, The Netherlands. 11-12 July 2013.

[3] I. Witten, E. Frank, and M. Hall, *Data Mining: Practical Machine Learning Tools and Techniques*, 3rd ed. Morgan Kaufmann, 2011, p. 664.

[4] H. Zhang, I. Ganchev, N. S. Nikolov, and M. O'Droma, "A Service Recommendation System for UCWW," presented at the 4th UL-NUIG Alliance Postgraduate Research Day 2014, Limerick, Ireland, 20 May 2014.

[5] I. Ganchev, Z. Ji, M. O'Droma, and L. Zhao, "Smart recommendation of mobile services to consumers," *IEEE Transactions on Consumer Electronics,* Article vol. 63, no. 4, pp. 499-508, 2017, Art no. 8246829, DOI: 10.1109/TCE.2017.015115.

[6] H. Zhang, I. Ganchev, N. S. Nikolov, and M. O. Droma, "A service recommendation model for the Ubiquitous Consumer Wireless World," in *2016 IEEE 8th International Conference on Intelligent Systems (IS)*, 4-6 Sept. 2016, pp. 290-294, DOI: 10.1109/IS.2016.7737436.

[7] M. Barthélemy, "Betweenness centrality in large complex networks," *The European Physical Journal B - Condensed Matter and Complex Systems,* vol. 38, pp. 163-168, 2004.

[8] H. Zhang, N. S. Nikolov, and I. Ganchev, "UCWW semantic-based service recommendation framework," in *2015 IEEE International Symposium on Technology and Society (ISTAS)*, 11-12 Nov. 2015, pp. 1-6, DOI: 10.1109/ISTAS.2015.7439435.

[9] R. Burke, "Hybrid Recommender Systems: Survey and Experiments," *User Modeling and User-Adapted Interaction,* vol. 12, no. 4, pp. 331-370, 2002/11/01 2002, DOI: 10.1023/a:1021240730564.

[10] A. Karatzoglou, L. Baltrunas, K. Church, and M. Böhmer, "Climbing the app wall: enabling mobile app discovery through context-aware recommendations," presented at the Proceedings of the 21st ACM international conference on Information and knowledge management - CIKM '12, Maui, Hawaii, USA, 2012.

[11] H. Zhang, I. Ganchev, N. S. Nikolov, Z. Ji, and M. O'Droma, "FeatureMF: An Item Feature Enriched Matrix Factorization Model for Item Recommendation," *IEEE Access,* vol. 9, pp. 65266-65276, 2021, DOI: 10.1109/access.2021.3074365.

[12] D. Zhou *et al.*, "Novel SDDM Rating Prediction Models for Recommendation Systems," (in English), *IEEE Access,* vol. 9, pp. 101197-101206, 2021, DOI: 10.1109/Access.2021.3097207.

[13] P. Flynn, I. Ganchev, and M. O'Droma, "WBCs - ADA vehicle and infrastructural support in a UCWW," in *2006 IEEE Tenth International Symposium on Consumer Electronics (ISCE'06)*, St. Petersburg, Russian Federation., 2006, pp. 351-356.

[14] Z. Ji, I. Ganchev, and M. O'Droma, "Advertisement Data Management and Application Design in WBCs," *Journal of Software,* Article vol. 6, no. 6, pp. 1001-1008, 2011, DOI: 10.4304/jsw.6.6.1001-1008.

[15] I. Ganchev, Z. Ji, and M. O'Droma, "A Generic Multi-Service Cloud-Based IoT Operational Platform - EMULSION," in *2019 International Conference on Control, Artificial Intelligence, Robotics & Optimization (ICCAIRO)*, 8-10 Dec. 2019, pp. 100-105, DOI: 10.1109/ICCAIRO47923.2019.00024.