Research on Context-Awareness Service Adaptation Mechanism in IMS under Ubiquitous Network

Wen'an Zhou, Jie Chang, Junde Song
Beijing University of Posts and Telecommunications, China
zhouwa@bupt.edu.cn, cjbupt@gmail.com, jdsong@bupt.edu.cn

Abstract—**The service adaptation mechanism is one of the key issues in ubiquitous network. However, most of the proposed approaches of service adaptation are either not context-aware or based on a specific definition of context in specific environment. This paper presents a context-aware service adaptation mechanism under ubiquitous network relying on user-to-object, space-time interaction patterns which helps to perform service adaptation according to user's contexts (such as preferences and habits), network context, service context and device context. The contribution of this paper is to propose: 1) importing user similarity into the service adaptation process and also considering users' trust value; 2) similar users-based service adaptation algorithm (SUSA) is proposed, by combining entropy theory and fuzzy analytic hierarchy process algorithm (FAHP). Evaluation results show that the service adaptation approach based on context-aware, user similarity and SUSA algorithm outperforms the traditional service adaptation algorithm in the accuracy aspect.**

Keywords- context-awareness; service adaptation; ubiquitous network

I. INTRODUCTION

In recent years, along with the steady advancement of pervasive technologies, the rapid spread of smart-phones, personal computers for interacting with networked objects in smart environments continue to proliferate, there's an unprecedented world of scattered pieces of contextualized information available to mobile users. The Wireless World Research Forum (WWRF) has set out a vision of the future where 7 trillion wireless devices will be serving 7 billion people by 2017 [1]. The future network is a convergent, heterogeneous, multi-device coordinated, mobile connectivity, ubiquitous network. Meanwhile, the future services are various being offered to meet user's preferences and needs. However, traditional services are usually designed in order to address a specific set of requirements within a specific characteristic of network environment, and also networks are increasingly complex and variable, variety of mobile devices dramatically exacerbating the issue. In ubiquitous network environments, how to select the best service for the user, how to allow devices to communicate with each other with minimum human involvement and how to provide better service experience have become some key questions to be solved for ubiquitous services to operate effectively and optimally. The increasing complexity of future services has to be supported to simplify the service development and deployment phases. In order to make further progress in future services, the IP Multimedia Subsystem (IMS) [2] [3] is specified by the 3rd Generation Partnership Project (3GPP) and 3rd Generation Partnership Project 2 (3GPP2) as a multi-service, multi-access, and multi-device control architecture relying on the IP networking infrastructure. IMS has been introduced with the objective to supply basic services in order to permit the adaption of services based on differentiated device context, user's context, service context and network context.

In this paper, our research focuses on how to improve ratio of satisfaction of service adaptation for users in ubiquitous network scenarios. We first import user similarity into the service adaptation process and also considering user's trust value, and then through the use of entropy theory [4] and fuzzy analytic hierarchy process algorithm (FAHP) [5], we propose a similar users-based service adaptation algorithm (SUSA) which helps to perform service adaptation in IMS. The essence of our approach is to improve the accuracy and reliability of service adaptation based on similar user's recommending, similar user's trust value and relative domain degrees.

The rest of the paper is organized as follows: Section II provides related works. Section III presents the adaptation framework. Then, user similarity is computed by using the Pearson correlation method and similar users-based service adaptation algorithm (SUSA) is proposed, by combining entropy theory and fuzzy analytic hierarchy process algorithm (FAHP) in Section IV. Simulation results and conclusions are respectively given in Section V and Section VI.

II. RELATED WORKS

Service adaptation has been investigated by several research efforts and its significance was established. Some of that address the problem of providing the user with an adaptive service from different viewpoints: device context, network context, etc. Moeiz et al. [6] proposed a context-aware dynamic service adaptation approach that the device dynamically collects contextual information by using its sensors in a pervasive computing system. However, this approach only considers device context and the form of its services. The upcoming networking environments are characterized by network heterogeneity and ubiquity where users should be encouraged to perform service by the best suited way. Their adaptation method is purely related to device context which contradict to the nature of ubiquitous network. The European IST VESPER project (Virtual Home

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Environment for Service Personalization and Roaming Users) [7] aims to define, demonstrate and promote a service architecture for provision of VHE across a multi-provider, heterogeneous network and system infrastructure. The context is often represented either by the network resources, or by the terminal capacity. There are also several researches efforts regarding service mobility.

III. Service Adaptation Architecture

In this Section, we present a service adaptation architecture that dynamically manage services to the device capability context (such as device type, device location and device capability), network parameter context (such as network type and network load), user preference context (such as user similarity and user's experience score) and service property context (such as service name, service resource and service cost). The proposed adaptation architecture (see Fig. 1) consists of Application Server (AS), Adaptation Manager (AM), Client Devices, and IMS network. Adaptation manager (AM) accumulates various kinds of profiles for each user registered on the system. User preference profile incorporate both data provided by the user explicitly and data inferred from the history of viewing behavior. Device capability profile is a database comprised of various kinds of device properties for each device of the user registered on the system. Network parameter profile is characterized by the bandwidth, delay, throughput of an internet connection. Service properties profile depends on service characteristics expressed in terms of the resources and cost. It is important that service management and negotiation module can provide necessary information for resource information for service. The dynamic decision and adaptation module is the key role in the architecture. The module helps to achieve better performance to users. It considers both the context information and the relation among user as it needs the contexts to select the services in AM that most adapting to the user's conditions. Therefore, the framework can provide better service to the user according to differentiated context information and the user's demands.

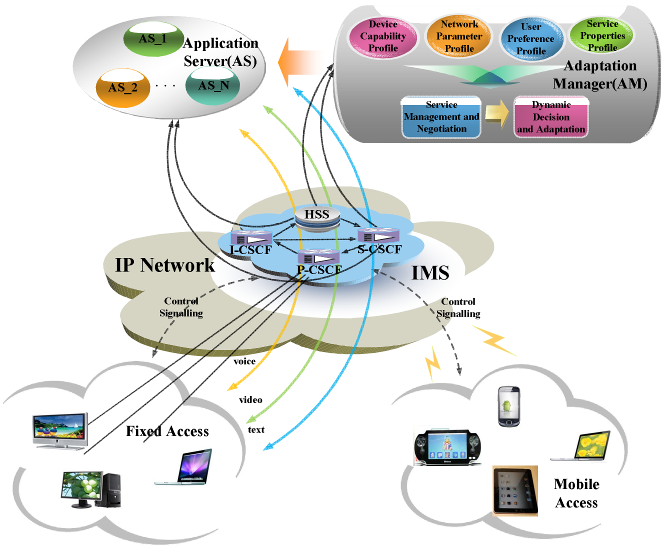

Figure 1. Service Adaptation framework.

IV. Similar Users Based on Space-Time Similarities

Traditional similar user selection mechanism did not consider information about where and when a particular user accesses a particular resource. Here, we focus on the value of such information as it makes the service adaptation more accurate, more reliable.

A. Compute User Similarity

Trying to predict a service's value to the user by aggregating similar user's ratings of that item is the main purpose of service adaptation. There are some main approaches for estimating user similarity, such as Pearson correlation, cosine vector similarity, adjusted cosine vector similarity, mean-squared difference and Spearman correlation. The below one is based on the Pearson correlation coefficient:

$$sim(i,j)=\frac{\sum_{s\in S_{i,j}}\left(R_{i,s}-\overline{R_i}\right)\left(R_{j,s}-\overline{R_j}\right)}{\sqrt{\sum_{s\in S_{i,j}}\left(R_{i,s}-\overline{R_i}\right)^2\sum_{s\in S_{i,j}}\left(R_{j,s}-\overline{R_j}\right)^2}}. \quad (1)$$

where $S_{i,j}$ are the services rated by both users i and j, and $sim(i,j)$ is the similarity function between i and j. where $\overline{R_i}$, $\overline{R_j}$ respectively denotes the mean value of the services rated by both users i and j, $R_{i,s}$ and $R_{j,s}$ respectively represents the service s rated by users i and j. From the equation we can known that the smaller the similarity value, the larger the similarity is, and $sim(i,j)\in[0,1]$.

However, the above equation does not consider Space-Time similarities under ubiquitous network environments. We can define similar equations for users and nomadic service by using location and interaction times to rate the services. We can therefore define the similarity function based on the Pearson correlation coefficient as:

$$sim(i,j)_L=\frac{\sum_{s\in S_{i,j}(L)}\left(T_{i,s}-\overline{T_i}\right)\left(T_{j,s}-\overline{T_j}\right)}{\sqrt{\sum_{s\in S_{i,j}(L)}\left(T_{i,s}-\overline{T_i}\right)^2\sum_{s\in S_{i,j}(L)}\left(T_{j,s}-\overline{T_j}\right)^2}}. \quad (2)$$

where $S_{i,j}(L)$ are the co-located services--that is, those in the same location--that are accessed by both users i and j, and $T_{i,s}$ and $T_{j,s}$ respectively denote user i and j access service s at this point. $\overline{T_i}$, $\overline{T_j}$ respectively denotes the mean value of the time at which user i, user j access service s. Equation 2 focuses on user's relative time patterns, independent of the mean time in which they access the same service s.

With these comparative evaluation values, the judgment matrix can be constructed, and is based on Pearson correlation. The judgment matrix is below:

$$sim_{user}\left(n,n\right)_L=\begin{bmatrix} s_{11(L)} & s_{12(L)} & \cdots & s_{1n(L)} \\ s_{21(L)} & s_{22(L)} & \cdots & s_{2n(L)} \\ \vdots & \vdots & \ddots & \vdots \\ s_{n1(L)} & s_{n2(L)} & \cdots & s_{nn(L)} \end{bmatrix}. \quad (3)$$

where $sim_{user}\left(n,n\right)_L$ is the matrix of user similarity in the same location L.

B. Computing User's Trust Value

There are not many trust relationships between users when they access the co-located services, so the judgment matrix is very sparse. Trust between users involves the subjective understanding to other users. Therefore trust cannot be described and handled using accurately conventional logic. This paper adopts an approach to define transmission characteristics of trust relationships which calculate the indirect trust relationship between users, so that user similarity in the original sparse matrix becomes relatively dense.

To determine whether or not a stranger who has no direct relationship is trustworthy, we choose the person who has the evaluation of strangers and is also the most trustful, regardless of the evaluation of our most trust person's is high or low.

C. Selection of Collaborative Users

The most accurate predictions can be obtained when using a combination of user similarity and user's trust value. The results from both are merged to produce unified ratings.

Collaborative users try to predict an item's value to the user by aggregating collaborative user's ratings of that item. To determine collaborative users for the user we take into account merge user similarity matrix and user's trust value. Using Equation 2 to measure the similarity between users account of the time and order pattern in which each user accesses different services. Equation 2 focuses on user's relative time patterns, independent of the mean time in which they consumed services. We select maximum of N users from neighbors as their collaborative users.

V. COLLABORATIVE USER-BASED SERVICE ADAPTATION MODEL

The focus of our work is to find an intelligent solution to the service adaptation problem based on collaborative users. In this model, the goal layer will rely heavily on the entropy theory and fuzzy analytic hierarchy process algorithm (FAHP), and the analysis hierarchy process employs the values to select services. The model is shown as Fig. 2. For collaborative users-based service adaptation, the goal layer (GL) is user satisfactory; the criterion layer consists of the influencing factors, which is divided into two sub-layers, the criteria layer (CL) and the sub-criteria layer (SCL); the alternative layer (AL) includes the service set of collaborative users in the heterogeneous wireless environment. It is shown in Fig. 2.

There are totally 4 kinds of contexts in CL and 9 kinds of sub-context in SCL. The CL includes collaborative user preference (UP), network parameter (NP), device capability (DC), service properties (SP). Particularly, collaborative user preference is the most subjective metric. The SCL includes collaborative user reputation (UR, integer 1-9), collaborative user experience score (EP, integer 1-9), network type (NT), network load (NL, %), device type (DT), device price (DP), device location (DL), the number of services (SN, integer 1-20), the resources required for the services (SR). Those are the influencing factors that they affiliate with CL.

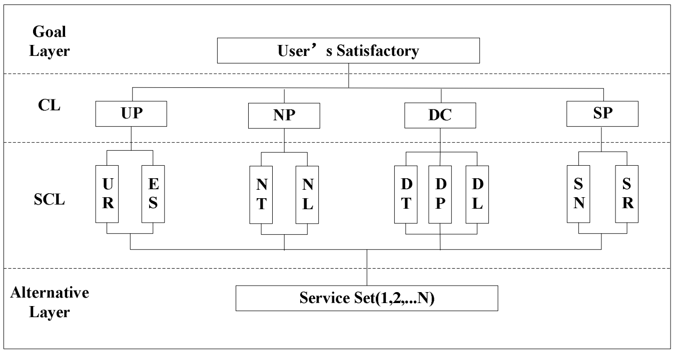

Figure 2. SS parameter hierarchy

This paper is mainly focused on the service adaptation mechanism according to the user's preference, device capability, network parameter and service properties, which should be based on collaborative user's service adaptation results. That means the services in this layer are what can satisfy the user's satisfactory. The current paper addresses the problem of uncertainty related to some of the major evaluation methods used in negotiations over service adaptation. The proposed approach is intended to overcome difficulties in ranking service offers, by using FAHP as an evaluation tool. The AHP is widely used for multi-criteria decision-making and has successfully been applied to many practical decision-making problems. In spite of its popularity, this method is often criticized for its inability to adequately handle the inherent uncertainty and imprecision associated with the mapping of the human preference's perception to exact numbers. FAHP is based on the AHP, which is an effective method for making decisions by fuzzy judgments, thinking. However, it is more superior to AHP as it is dynamic, considers the changes of the judgment matrix, and uses fuzzy evaluation which is better than the 1 to 9 ranked judgment matrixes. To decrease the subjective arbitrariness, we combine entropy theory and FAHP.

The weight value is the key to provide service adaptation satisfying different user preferences. Users with different preferences should have different metric weights so that different services can be selected out.

1) FAHP Weight

For the estimation of the importance of these criteria we used FAHP. Let us construct the fuzzy judgment matrix containing all pair-wise comparisons between elements i and j. First compute the normalized value of row sums (i.e. fuzzy synthetic extent) by fuzzy arithmetic operations:

$$S_i = \sum_{j=1}^{n} a_{ij} \otimes \left[\sum_{k=1}^{n} \sum_{j=1}^{n} a_{kj} \right]^{-1}. \tag{4}$$

Where $\otimes$ denotes the extended multiplication of two fuzzy numbers. Computing the degree of possibility of by following equation:

$$P\left(S_i \geq S_j\right) = \begin{cases} 1 & m_i \geq m_j \\ \dfrac{u_i - l_j}{\left(u_i - m_i\right) + \left(m_j - l_j\right)} & l_j \leq u_i \\ 0 & otherwise \end{cases}. \tag{5}$$

Calculating the degree of possibility of S_i to be greater than all the other $(n-1)$ convex fuzzy numbers S_j by $P\left(S_i \geq S_j \mid j = 1, 2, ..., n;\, j \neq i\right), i = 1, 2, ..., n$. Defining the priority vector $W = \left(w_1, ..., w_n\right)^{\mathrm{T}}$ of the fuzzy comparison matrix as:

$$w_i = \frac{P\left(S_i \geq S_j \mid j = 1, ..., n;\, j \neq i\right)}{\sum_{k=1}^{n} P\left(S_k \geq S_j \mid j = 1, ..., n;\, j \neq k\right)}, i = 1, ..., n \cdot \tag{6}$$

The weight of 9 kinds in SCL which are divided into 4 groups in CL should all be derived this way. The final weight of the j th to the goal given by FAHP is :

$$w_{FAHP,j} = w_i \times w_{i_j}, \left(i = 1, 2, 3, 4;\, j = 1, 2, ..., 9\right). \tag{7}$$

2) *Entropy Theory Weight*

According to entropy theory [8], the entropy of the i th SCL can be calculated from the normalized predicted experience matrix by:

$$H_j = -k \sum_{i=1}^{m} \left(\frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}} \ln \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}} \right), \left(j = 1, 2, ..., n\right) \cdot \tag{8}$$

where $k = 1/\left(\ln n\right)$, then the final weight to the goal given by entropy theory is given below:

$$w_{ET,j} = \frac{1 - H_j}{m - \sum_{j=1}^{m} H_j}, \left(j = 1, 2, ..., m\right) \cdot \tag{9}$$

3) *Comprehensive Weight*

To balance the fuzzy subjective judgment and objective service difference, we give the comprehensive weight as:

$$w_{CW,j} = \frac{w_{FAHP,j} \times \beta + w_{ET,j} \times \left(1 - \beta\right)}{\sum_{j=1}^{m} w_{FAHP,j} \times \beta + w_{ET,j} \times \left(1 - \beta\right)}. \tag{10}$$

Where β is the balancing factor between 0 and 1.

4) *Ratio of User's Satisfactory*

$$RS = \frac{\sum_{i=1}^{N} \left| p_i - q_i \right|}{N}. \tag{11}$$

Where RS represents the ratio of user's satisfactory and N denotes the number of services. p_i , q_i respectively denotes the evaluation value of user based recommendation, the evaluation value of user, the range is $[0,1]$. The smaller RS value is, the higher the accuracy of the service adaptation scheme is.

VI. IMPLEMENTATIONS AND PERFORMANCE EVALUATIONS

To verify the proposed context-aware service adaptation mechanism under ubiquitous network, we implemented the proposed system on PCs and a mobile phone (Client Device). The UCT IMS Client [9] is used in conjunction with the Open IMS Core [10], which is also an open source project. We use LIVE555 Streaming Media [11] as application server for multimedia streaming, which uses open standard protocols (RTP/RTCP, RTSP, SIP).

TABLE I. TRIANGULAR FUZZY NUMBERS

Linguistic variables	Triangular fuzzy numbers
Extremely important	**(7,9,9)**
Very important	**(5,7,9)**
Important	**(3,5,7)**
Moderately important	**(1,3,5)**
Equally important	**(1,1,3)**

TABLE II. TRIANGULAR FUZZY JUDGMENT MATRIX OF CLS

	UP	NP	DC	SP
UP	**(1,1,1)**	**(1/9, 1/9, 1/7)**	**(5,7,9)**	**(1/7, 1/5, 1/3)**
NP	**(7,9,9)**	**(1,1,1)**	**(1,3,5)**	**(1,3,5)**
DC	**(1/9, 1/7, 1/5)**	**(1/5,1/3,1)**	**(1,1,1)**	**(1,1,3)**
SP	**(3,5,7)**	**(1/5,1/3,1)**	**(1/3,1,1)**	**(1,1,1)**

Based on equation 4 we can calculate $w_1 = \left(0.271, 0.244, 0.229\right)$, $w_2 = \left(0.433, 0.469, 0.438\right)$, $w_3 = \left(0.100, 0.073, 0.114\right)$, $w_4 = \left(0.196, 0.215, 0.219\right)$, then triangular fuzzy judgment matrix of SCL are given below of Table III $\sim$ Table IV.

TABLE III. TRIANGULAR FUZZY JUDGMENT MATRIX OF SCL UNDER UP

		UP	
		UR	ES
UP	UR	(1,1,1)	(1/3,1,1)
	ES	(1,1,3)	(1,1,1)

TABLE IV. TRIANGULAR FUZZY JUDGMENT MATRIX OF SCL UNDER SP

		SP	
		SN	SR
SP	SN	(1,1,1)	(1/3,1,1)
	SR	(1,1,3)	(1,1,1)

TABLE V. TRIANGULAR FUZZY JUDGMENT MATRIX OF SCL UNDER DC

		DC		
		DT	DP	DL
DC	DT	(1,1,1)	(1,1,3)	(1/5,1/3,1)
	DP	(1/3,1,1)	(1,1,1)	(1/3,1,1)
	DL	(1,3,5)	(1,1,3)	(1,1,1)

TABLE VI. TRIANGULAR FUZZY JUDGMENT MATRIX OF SCL UNDER NP

		NP	
		NT	NL
NP	NT	(1,1,1)	(1/3,1,1)
	NL	(1,1,3)	(1,1,1)

Assume 150 users request for streaming service, and in the initial phase each user evaluate streaming service. Through the Global Positioning System (GPS) we can access location and time information of any user. The balancing factor is 0.85.

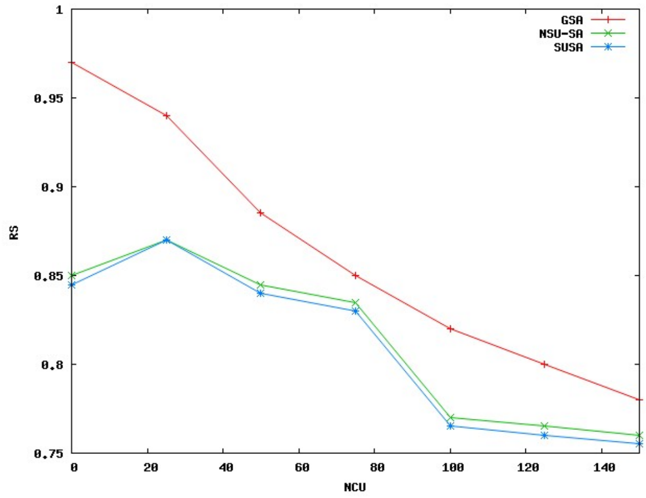

Figure 3. Comparison of Ratio of User's Satisfactory

Fig. 3 is the simulation result that comparison of ratio of user's satisfactory under three different strategies. As shown in Fig. 3, the proposed scheme (SUSA) manages to decrease the ratio of user's satisfactory. General Service Adaptation Scheme (GSA) is not consider context awareness and collaborative users so it cannot achieve the desired value, either for sparse collaborative users or dense collaborative users. This is one of the major reasons that the traditional context-awareness service adaptation scheme does not take into account collaborative users. Collaborative users decreases and the ratio of user's satisfactory changes accordingly, mostly getting worse. As our experiment shows, the proposed scheme has better performance than other schemes.

VII. CONCLUSION

The main idea of this paper takes into account user location and interaction time to context-aware service adaptation mechanism under ubiquitous network, and then proposes the similar users-based service adaptation algorithm (SUSA), by combining entropy theory and fuzzy analytic hierarchy process algorithm (FAHP). This can effectively increase the ratio of user satisfactory.

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