Context-Aware Mobility Management in Heterogeneous Network Environments

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Abstract

Context-aware mobility management can provide major enhancements for future mobile communication systems. Not only it considers device mobility, but session mobility is also considered. Context-awareness is a key ingredient in any ubiquitous and pervasive system and provides intelligence to the system, allowing computing devices make appropriate and timely decisions on behalf of users. The use of contextual information is essential in optimizing services in a heterogeneous mobile network environment. Context awareness in mobile computing refers to internal and external adaptation of the environment and applications to the context state of each other. Such systems should adapt to the changes and variations of user's context such as location, device status and capabilities, network connectivity and etc. One of the important aspects of mobility management is the dynamic selection of the best access network for a multimodal device when there is a need to perform a handover. Multi Attribute Decision Making (MADM) is one of the successfully used methods in the literature to solve decision making problems. Weighted product method is an MADM method that penalizes the unreliable attributes in making a decision. WPM is a suitable candidate for decision making in more dynamic situations since the computational cost is low and does not suffer from ranking abnormalities as the alternatives change. In this paper, an algorithm for a context-aware network selection is proposed that is based on WPM. We argue that the quality of provided context data is an important factor in making decisions.

Keywords: Access network selection, Context-aware, MADM, Quality of Context, Weighted Product Method.

1 Introduction

Context-aware computing in mobile environment is interesting in that it paves the way for services and applications to take advantage of user's contextual information such as time, location, activities and etc.

Network services and application such as multimedia streaming, and other high-bandwidth services will be available via different access points in various ways. Therefore, it is essential to provide optimal services to the users according the user's situation.

Providing optimal services to the users will be challenging for several reasons [1]:

- Diversity and heterogeneity of radio access networks.
- Consideration for Quality of Service (QoS) guarantee, security, charging and roaming.
- Cope with the preferences of users and requirements of application while offering optimal support.
- Advanced location information and group mobility information.

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The Internet Engineering Task Force (IETF), has discussed the context in mobility related terminology [2] as transferring the current state of a routing-related service on re-establishing a new connection to a subnet for a similar service without having to perform the entire protocol exchange with the device. However, the new technology has enabled more information to be accessible with various context information providers and sensors. Beyond this, context awareness for mobility management purposes can be thought of services that a user often uses and features and requirements that those services demand, security requirements of services and the user, capability of the device, network related information, mobility information such as speed, coverage of available access networks.

In this paper, we propose a dynamic context-aware solution to the access network selection problem that is based on a modified weighted product method for access network selection for a mobile user. When a handover decision is made, it is important to choose the appropriate access network to continue the session with the existing context of the mobile user. In this method, the quality of context is utilized to penalize alternatives that have poor quality data. The proposed weight distribution method not only depends on the Quality of Context (QoC) parameters, but also on the fuzzy measure of the saliency of the context information that implies a truth value measure for a set of measurements for a predicate.

In this paper we make certain assumptions to limit the scope of this work. The first assumption is that where attributes are mentioned, we assume that attributes belong to independent axis of measurements. In any context-aware systems the issues of context information collection, processing and dissemination arises. We assume that data is collected and provided by users, applications, devices and other network entities.

This paper is organized as follows. A review of related work is provided in Section 2. Section 3 describes the system architecture that our proposed method is based on. In section 4 we provide the modelling and representation of contextual information that will be used in the paper. In section 5 we present our method that is based on the weighted product method and fuzzy measure of the saliency of the context data. Section 6 provides the evaluation and demonstration of the proposed solution. Finally, section 7 concludes the paper.

2 Related Work

Existing works in the literature [3][4] deal with the problem of access network selection and mobility management with several methods such as decision function based strategies, user-centric strategies and MADM methods [5] such as Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The scope of previously proposed work is mainly on the network selection prior to the connection establishment of the user terminal. One of the advantages of TOPSIS method is its accuracy and contrast in ranking the best alternative. However, it is computationally expensive and suffers from ranking abnormality as the alternatives are being removed or added. The ranking method is dependent to the other alternatives since this method is based of the shortest distance from the best alternative and longest distance from the worst alternative. Weighted Product Method (WPM) [5] is a more rigorous method in penalizing the alternatives with least significance, and computationally cheaper than TOPSIS method. It is dimensionless and ranking abnormality issue does not apply to WPM. The preference index of each alternative is independent of the other alternatives and one can set a threshold for an acceptable preference index to minimize the number of unnecessary handovers. Therefore, we recommend WPM as a better alternative than TOPSIS for dynamic decision making situations. In evaluating the decision making methods, there are two important evaluative criteria according to Triantaphyllou in [6]. The first one is that any accurate decision method for a multi-dimensional problem should also be accurate when applied to a single dimension problem and the second criterion is that the rank of the best alternative should not change when a worse alternative is replaced by another worse alternative, the so called ranking abnormality.

Context-aware services are investigated in the area of ubiquitous computing that aims at providing users with intelligent services. Mobility management, distributed context management architectures are also proposed in the literature. In the area of mobility management, a context-aware path planning approach and a handoff mechanism (UbiHandoff) is proposed by [7] that is based on MADM. The authors have implemented their context-aware handoff mechanism based on MADM approaches such as Genetic Algorithm (GA), Analytic Hierarchy Process (AHP) and TOPSIS and minimized the handoffs by finding the appropriate Access Point (AP) under QoS constraints.

A prediction based approach is presented in [8] that predicts user mobility, traveling trajectory and destination using knowledge of user's context such as preferences, goals, and analyzes spatial information to avoid imposing any assumptions about the availability of users' movements history. Prediction of future context [9] of users significantly expands the possibilities of context-aware computing applications. However, the accuracy of the prediction is also important because an incorrect prediction may also mislead the application and may result in inappropriate application behaviour. In another work [10], a context-aware vertical handover decision algorithm multimode mobile terminals in heterogeneous wireless networks is proposed that is based on the AHP method for MADM. Other related works address the mobile service adaptation with context discovery and propose a context discovery mechanism [11].

Another work focused on energy efficiency is proposed for network selection in heterogeneous wireless networks [12]. In that paper user preferences, network conditions, QoS requirements and energy consumption is taken into account for optimal access network selection. Their proposed method is based on a fuzzy TOPSIS approach. There are other related works with a focus on energy efficiency and power consumption [13][14][15][16].

3 Proposed Context-aware System Architecture

For the purpose of this work we simplify the representation of a context-aware Service Delivery Platform (SDP) to a typical Service Oriented Architecture (SOA) [17] as shown in figure 1.

The role of SDP is to abstract the complexity of the underlying network's infrastructure from the applications and service enablers [18]. Service enablers perform tasks common to multiple applications necessary to deliver a service and context providers are in charge of delivering the requested information to the services and applications via the APIs.

Based on this framework, we assume that Services, and applications can also initiate the handover for the case of a M2M interaction. In order to ensure the availability of contextual information that can be utilized to support the operation of heterogeneous context-aware services, one can realize the need for a context management plane in such a service platform to be in charge of the following tasks:

- Context sensing and collection: consists of collecting the required contextual information from different context sources such as device, network, and other sensors.
- Context processing: is the inference of a situation from raw data that are collected from different entities. It requires reasoning and inference methods to infer higher level information from lower level contextual information.
- Inter-domain context handling and aggregation: is the process of managing and aggregating the context information collected from various sources and representing that in an easy to use and understand to be shared with other entities.
- Context distribution: is the process of disseminating and publishing the context information to applications and services based on the QoC agreement level.

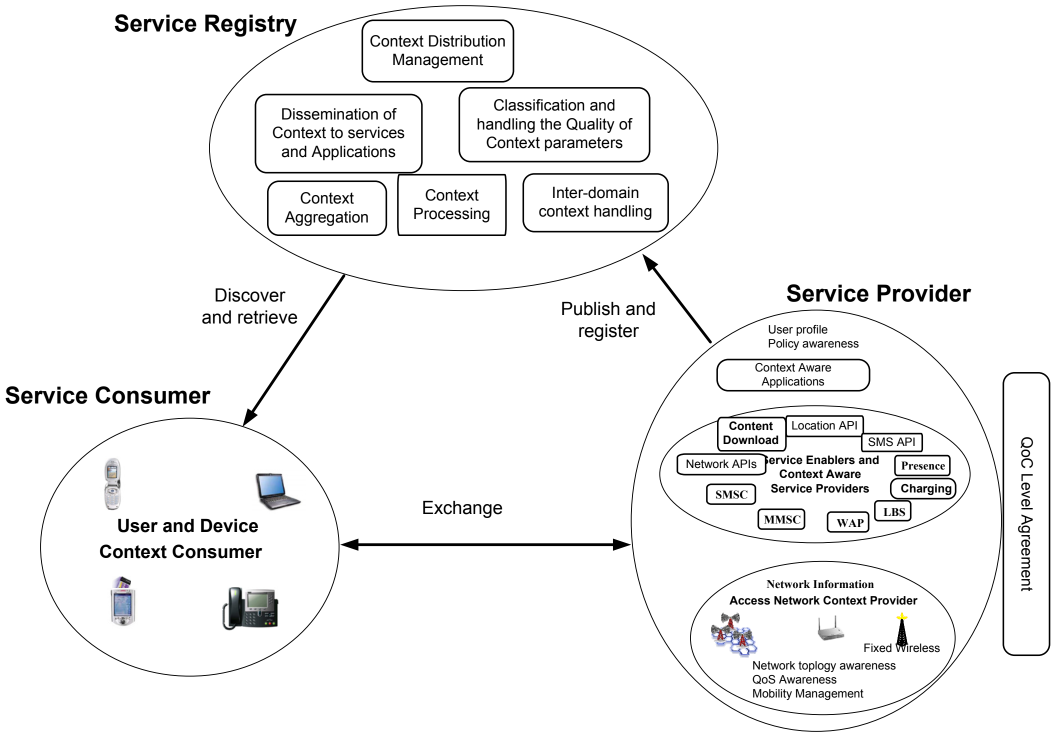

Figure 1: SOA based framework for the context-aware system

- QoC mapping function: is in charge of managing and provisioning the QoC parameters to ensure the required QoS and Quality of Experience (QoE) expected.

4 Representation and Modelling of Contextual Information

With the complexity of context-aware applications and heterogeneity of contextual data with different quality of information, it is important that context-aware applications are supported by appropriate model and reasoning of context. [19].

Context reasoning also involves a trade-off between complexity of reasoning and expressiveness, and description logic have emerged among other logic based representation [19][20]. Some of the benefits of ontologies are capability to automatically infer new knowledge about the current context, and detect possible inconsistencies in the context data [19]. Ontology based models of context information is widely used in various application domains. Ontologies are descriptions of concepts and their relationships. SOUPA is one of the proposals for modelling context in pervasive environments [21].

Inference of situation can be performed based on the user specified information or by automatic learning and recognition by means of machine learning techniques. The learning based approach however requires a certain training period. Examples of the learning based approaches can be found in [22, 23, 24, 25]

Definition Context (C) is the user related information that is used to describe the state of a user, entity or system in a specific situation [26]. An entity can be a person, location, or any object relevant to a user and/or the application. Authors in [26] have defined context as an N dimension vector in the form of:

$$C = (a_1^V, a_2^V, ..., a_N^V) \tag{1}$$

Where C is the context state and each component a_i^V of the context vector is an attribute that can be divided into several types either low level context like bandwidth, delay, access network type or higher level context, such as location, time, behaviour, etc. We show each context attribute as a triple to describe a context component. A context component $a_i = (w_a, t_a, v_a)$ where w_a is the weight of the context attribute a_i as an indication of its relevance , t_a is the type of a_i , and v_a is the value of a_i if applicable.

Definition Context attribute a_i^t is the i^{th} attribute of a context state at time t and is defined as any type of data that can help us in inferring a situation [27].

For notation simplicity we use the following notation to indicate the context state of the user at any given time t as an N-dimensional vector:

$$C^t = (a_1^t, a_2^t, ..., a_N^t) \tag{2}$$

Context space $R_i = (a_1^R, a_2^R, ...a_N^R)$ is the domain of acceptable values that are allowed for a specific context attribute. An acceptable region a_i^R is defined as a set of elements V that satisfies a predicate P such that $a_i^R = \{V|P(V)\}$ [26][27]. For the scope of this work the context space is defined as follows.

Definition Context space $R_i = (a_1^R, a_2^R, ...a_N^R)$ is the predefined region of acceptable operating modes or states that a user terminal or application can be in that state. It is the range of acceptable values that are allowed for a specific context attribute. An acceptable region a_i^R is defined as a set of elements V that satisfies a predicate P such that $a_i^R = \{V|P(V)\}$.

For the purpose of this paper, we define the regions as predefined modes (profiles)

Mode 1	Low BW profile
Mode 2	High BW profile
Mode 3	Low cost profile
...	...
Mode N	Low battery profile

Any of the modes or profiles will be inferred with the assumption that the attributes are independent from each other. However, this assumption may not be realistic as the collected contextual information will not be independent in many cases. We therefore develop the following as a representation of the state of a user based on the collected contextual information:

$$S^t = (\overline{a}_1^t, \overline{a}_2^t, ...\overline{a}_N^t)$$

where $\overline{a}$ is a collection of dependent features that are included in an attribute.

Definition Essential attributes are those that may have a negative influence in inferring a situation if missing or their value is not within the acceptable region of a predefined situation.

Definition Optional attributes are the attributes that are complementary in inferring a situation. In other words, optional attributes can assist in a more accurate inference of a situation.

Contextual information can also be classified into user centric and access network centric context. User centric, as mentioned earlier, determines the location, time, identity, activity of a user and other user related information whether dynamic or static. The network centric context is a lower level type of contextual data, can be dynamics of network (delay, bandwidth, etc), access network technology, interface, and mobile device information and capabilities [28].

Modelling and representation of the contextual information also depends on different properties of contexts. Different (heterogeneous) systems may model the contextual information in different ways. A survey by G. Chen et. al. [29] discusses various approaches in different context-aware systems (mainly those that are focused on location). For exchange of context information and interworking of systems, data structures are important. In that survey [29] they have briefly introduced four data structures namely, key-value pairs, tagged encoding, object-oriented model, and logic-based model. Schilit in his PhD thesis [30] takes into account the underlying access network technology and presents a context-aware service delivery architecture that is aware of changes in the dynamics of the user's communication environment.

It is important to develop a data format that can be used across different domains for communicating the context of users. One possible format is the Presence Information Data Format (PIDF) that is standardized by IETF in RFC 3863 [31]. The PIDF data format is not tied to any protocol for transporting it. In IETF and IMS, PIDF can typically be transported using the SIP protocol, or other protocols such as HTTP or SOAP.

4.1 Quality of Context and Uncertainty of Information

In developing context-aware services and provisioning of services, the availability and reliability of contextual information is of great importance. The QoC is any information related to the quality of contextual information that are involved in making context-aware decisions [32, 33, 34, 19]. Since context information can often be uncertain and incomplete in nature, it is important to provision the enforced actions based on the QoC to ensure the effective utilization of provided context information that leads to efficient context management solutions. Uncertain information can lead to uncertain reasoning and inference. Models of context uncertainty are proposed in [35] based on Gaia [36] that is a prototype pervasive computing infrastructure. Entities in Gaia can use probabilistic logic, fuzzy logic, or Bayesian networks to reason about uncertainty and author of [35] have described various ways of reasoning about uncertain contexts that are used in Gaia.

Authors in [32] and [33] have proposed a quantification approach of QoC. Furthermore, an algorithm for evaluation of QoC is also presented in [33] and the following parameters of QoC are evaluated.

1. Precision: refers to the level of accuracy. For example, a GPS receiver can locate a user with the precision of less than 10 meters, while positioning a user via a GSM cellular network may have a precision of up to 500 meters.

2. Probability of correctness: refers to the probability of correctness for any given contextual information. For the previously mentioned example, there is no guarantee that the precision is true since it may depend on various other factors such as the density of the base stations in a specific area.

3. Completeness: is a representation of the degree of support that a set of attributes provide for inferring a context. Let $C(a_i)$ denote the completeness of attribute i, then the ratio of the sum the weights of all features that support a context information with respect to all the features representing that context information.

4. Trust-worthiness: is an indication of the likeliness that the provided information is correct. It is analogous to the notion of *rating* in the context of sellers and customers. Let $T(q)$ denote

the trustworthiness of the i^{th} attribute and it can be measured in terms of the accuracy of the information, the previous history of collected data and statistical estimation techniques.

5. Resolution: refers to the granularity of the provided information.

6. Up to datedness and time validity of information: refers to the age of the collected and provided information. For many applications, the events are time stamped and the age of the provided data play a major role. Denoting $U(a_i)$ as the time validity of a context information, it is represented in terms of the difference of the current time and most recent measurement time.

There are other factors that are application dependent like the previously mentioned factor of *up to datedness*. Other measures for QoC are also presented in [37]. In that paper in addition to above mentioned measures, the following dimensions are listed: Accessibility, completeness, ease of manipulation, objectivity, security, and more. While QoC is very different from QoS and QoE, they are interdependent. In order to make use of the above mentioned parameters, it is important to quantify the QoC parameters in a usable manner.

For the purpose of this paper we define a measure of saliency for a context information. It is an indication of the containment of attributes for inferring a predicate and the truth value of that predicate is based on the QoC parameters. The truth value function for a set of attributes on a predicate returns a truth value $\in [0,1]$.

$$\mu : R^m \rightarrow [0,1]$$

for m dimensions such as precision, trust-worthiness, completeness, timeliness, etc. The truth value of a predicate or a context information a is $\mu(a)$ and it is a function of the aforementioned QoC parameters. i.e.

$$\mu_i(a) = F(P(a_i), PrC(a_i), C(a_i), T(a_i), R(a_i), U(a_i))$$

where $i = 1,2,...N$ and $\mu_i(a)$ represents the truth value of context attribute a collected from source i, $P(a_i)$ is the precision, $PrC(a_i)$ is the probability of correctness, $C(a_i)$ denotes completeness, $T(a_i)$ is trustworthiness, $R(a_i)$ refers to resolution, and $U(a_i)$ is up to dateness.

Analogous to Service Level Agreements (SLA) QoC agreements also negotiated between the context-aware service providers and context providers. Such an agreement can also be defined among the context providers that use low level context to provide higher level context to users or service providers.

The impact of QoC on the QoS and the quality of underlying technology or hardware is discussed in details in [34].

4.2 The Problem of Context-aware Access Network Selection

We intend to develop a utility based data fusion method for the purpose of access network selection in a heterogeneous environment based on a multi attribute decision making approach. In this section the structure of contextual information for the purpose of this work is explained. For the purpose of developing the appropriate data fusion model, we need to develop our model of context. The following issues are important in modelling of contextual information:

- Relevance and impact of an attribute.
- Data structure and representation of context.
- Cost of capturing the contextual information.
- Quality of context

5 Weighted Product Method

WPM [5] is a compensatory MADM technique that penalizes the alternatives that have unreliable or poor attribute values by assigning appropriate weights. Each row A_i in the decision matrix DM corresponds to an access network alternative. A typical procedure for WPM is as follows:

1. Determine the weight of each attribute for a given context vector and normalize weights such that

$$\sum_{j=1}^{n} w_j = 1$$

   where w_j is the weight of j^{th} attribute.

2. For each alternative A_i in the decision matrix DM, raise each element to the power equal to the weight of each attribute.

$$DM = \begin{bmatrix} (a_{11})^{w_1} & \dots & (a_{1j})^{w_j} & \dots & (a_{1n})^{w_n} \\ (a_{21})^{w_1} & \dots & (a_{2j})^{w_j} & \dots & (a_{2n})^{w_n} \\ \dots & \dots & \dots & \dots & \dots \\ (a_{m1})^{w_1} & \dots & (a_{mj})^{w_j} & \dots & (a_{mn})^{w_n} \end{bmatrix}$$

3. The best alternative is the row with the highest product of elements:

$$DM^* = \{A_i | \max_i (\prod_{j=1}^{n} (a_{ij})^{w_j}\}$$

5.1 Determining the Weights of Attributes in Making Decisions

Deploying any compensatory MADM, requires an appropriate weight assignment mechanism. The proposed mechanism in the work is based on the types of attributes as discussed above and the QoC parameters. In the scope of this work, weights of attributes are relevant from two perspectives:

1. Having known the state of a user at any given time t, we want to rank the access network alternatives and make the optimal access network selection.

2. Having collected the contextual information from various sources, we need to infer the state of the user.

The State of the user is chosen among a set of predefined modes or profiles.

Definition Influence function I is a function that maps the QoC parameters (that is a subset of Q) of an attribute $a_i \in S^t$ to its corresponding weight $w_i \in [0,1]$ such that $\sum_{i=1}^{N} w_i = 1$. It also represents the relative importance of an attribute among the alternative modes (profiles) that our decision algorithm takes into consideration.

$$I : Q \to [0,1]$$

5.2 Weight Assignment Based on The Most Critical Attribute

As mentioned in the previous sections, the context information vector can represent either the state of the user or the context of the candidate access network alternatives. In the decision making approach proposed in this paper a context-aware choice of access network based on the context information vector of the user and the aggregated context of access network and available services is made. In making such decisions, there are attributes that are critical in making decisions based on the current status (profile) of the user and the application or services that the user is intending to access. On the other hand, it is important to eliminate the unnecessary changes in access network (handover) to reduce the cost of unnecessary signalling that can lead to degradation of QoE by the user in many use case scenarios such as multimedia streaming, or voice/video calls. This is to ensure that the most critical attribute has the most significant effect in ranking of the alternatives. In our proposed algorithm we deploy a weight distribution method that is based on the degree of criticality of attributes relevant to a specific situation (profile).

Let $\delta_{k,i,j}$ denote the threshold value of the ratio of change (can also be in %) in the weight of the k^{th} attribute, w_k (after normalization) that can enforce a change in ranking of the access network alternatives i and j, DM_i and DM_j. The threshhold value is given as follows[38]:

$$\begin{array}{ll} \delta_{k,i,j} > R & if \quad R \geq 0 \\ \delta_{k,i,j} < R & otherwise \end{array}$$

The R is defined as follows:

$$R = \frac{\log \prod_{y=1}^{N} (\frac{a_{i,y}}{a_{j,y}})^{w_y}}{\log(\frac{a_{i,k}}{a_{j,k}})} \times \frac{100}{w_k}$$

where $\delta \leq 100$.

5.3 Weighted Product Method with Interval Data

Since the collected contextual information are fuzzy in nature, one possible approach is to show them in the form of interval data. The acceptable region or possible modes of operation can also be characterized with interval data. Attributes and characteristics of each mode can have lowest acceptable value, or a range of acceptable values or if it is cost or delay, the highest acceptable value would be applicable. For convenience of notation, we represent the attributes of each operation mode as an interval of lowest to highest possible values. The following matrix $\widetilde{DM}$ shows the decision making matrix in the form of interval data where columns are the attributes and rows are the access network alternatives:

$$\widetilde{DM} = \begin{bmatrix} (\underline{a}_{11}, \overline{a}_{11}) & \dots & (\underline{a}_{1j}, \overline{a}_{1j}) & \dots & (\underline{a}_{1n}, \overline{a}_{1n}) \\ \dots & \dots & \dots & \dots & \dots \\ (\underline{a}_{i1}, \overline{a}_{i1}) & \dots & (\underline{a}_{ij}, \overline{a}_{1j}) & \dots & (\underline{a}_{in}, \overline{a}_{in}) \\ \dots & \dots & \dots & \dots & \dots \\ (\underline{a}_{m1}, \overline{a}_{m1}) & \dots & (\underline{a}_{mj}, \overline{a}_{mj}) & \dots & (\underline{a}_{mn}, \overline{a}_{mn}) \end{bmatrix}$$

and each normalize attributes can be shown as:

$$\widehat{a}_{ij} = \frac{a_{ij}}{\underline{a}_j}$$

for monotonically increasing attributes and

$$\widehat{a}_{ij} = \frac{\overline{a}_j}{a_{ij}}$$

for monotonically decreasing attributes, where $\underline{a}_j$ and $\overline{a}_j$ are lowest possible and highest possible value for the j^{th} attribute respectively. The resulting normalized decision matrix $\widehat{DM}$ is shown below:

$$\widehat{DM} = \begin{bmatrix} (\hat{a}_{11})^{w_1} & (\hat{a}_{12})^{w_2} & \dots & (\hat{a}_{1n})^{w_n} \\ (\hat{a}_{21})^{w_1} & (\hat{a}_{22})^{w_2} & \dots & (\hat{a}_{2n})^{w_n} \\ \dots & \dots & \dots & \dots \\ (\hat{a}_{m1})^{w_1} & (\hat{a}_{m2})^{w_2} & \dots & (\hat{a}_{mn})^{w_n} \end{bmatrix}$$

5.4 The Proposed Method of Network Selection Based on the Inferred Context of the User

Below is the summary of the proposed method:

1. Context aggregation.
2. Inferring the state of the user in terms of the predefined modes of operations (profile).
3. Determine the weight of each attribute in the inferred mode using the truth value function.
4. Use the modified weighted product method to rank the alternatives.
5. The alternative with the greatest preference number is chosen.

6 Numerical Examples

The purpose of this evaluation is first to validate our method against a well known decision making approach. The second objective is to demonstrate our method in a real use case example. For the purpose of demonstration, we have used a typical example for five access network alternatives. The attributes are assumed to be inferred by some context reasoning method. The numerical example demonstrates the result of the WPM and TOPSIS approach for typical usage profiles such as high bandwidth, low cost, and low power.

Profile	BW	Delay	Power	Packet loss	Cost	Security	Jitter
High BW	0.77	0.08	0.04	0.05	0.02	0.04	0.01
Low cost	0.09	0.06	0.10	0.20	0.51	0.02	0.01
Low power	0.03	0.09	0.74	0.06	0.04	0.03	0.01
Multimedia	0.45	0.22	0.07	0.07	0.02	0.01	0.15
Secure	0.06	0.10	0.04	0.10	0.04	0.60	0.08

Table 1: Weight distribution among attributes for different usage profiles

In this example we have considered five access network alternatives. For simplicity of presentation, we have limited the alternatives to five network alternatives which characteristics are listed under n number of attributes such as delay, bandwidth, cost, jitter, security, packet loss ratio and power constraints. It is assumed that the attributes determining the state of user are inferred based on some context reasoning method.

In order to make the TOPSIS approach valid, one of the assumptions in this example is that attributes belong to independent axis of measurements. The weight distribution is calculated based on the QoC for each attribute. For the purpose of comparison, the same weights are assigned to attributes for the case of TOPSIS.

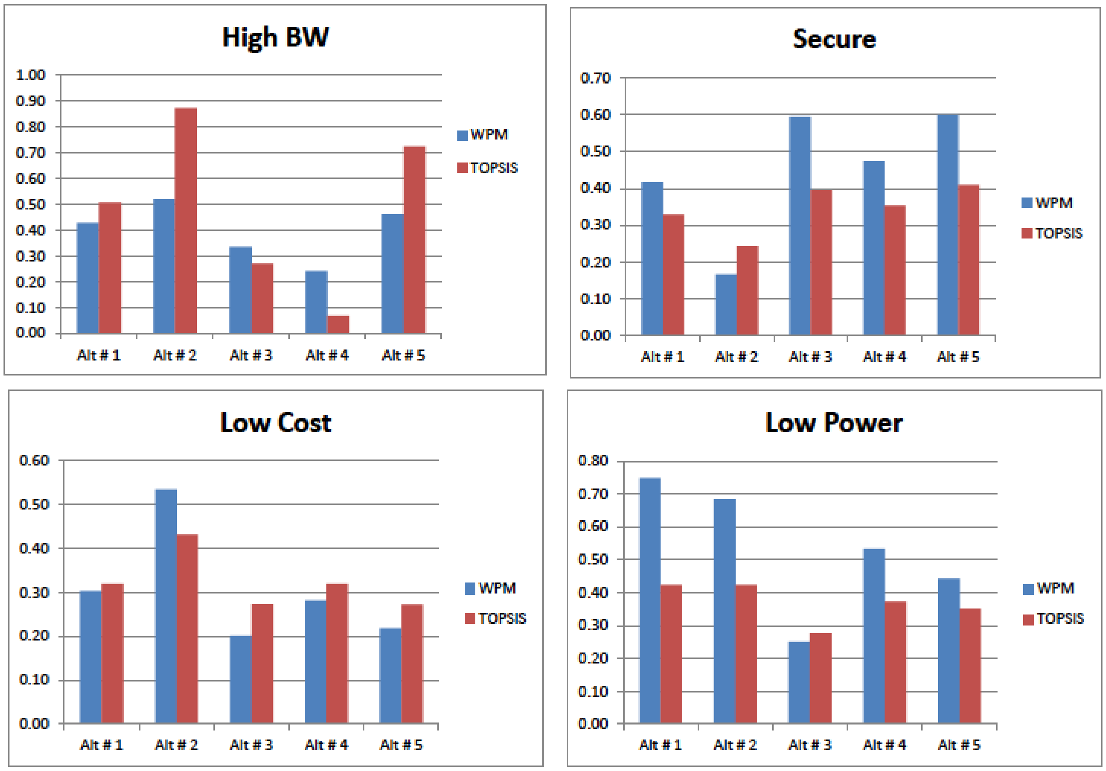

Figure 2: Result of the network selection considering each usage profile

Access Networks	BW	Delay	Power	Packet loss	Cost	Security	Jitter
Alt# 1	0.4	1	0.9	0.3	0.2	0.4	0.3
Alt# 2	0.6	0.2	0.9	0.8	0.5	0.1	0.1
Alt# 3	0.3	0.9	0.2	0.5	0.1	0.7	0.8
Alt# 4	0.2	0.5	0.6	0.4	0.2	0.5	0.9
Alt# 5	0.5	0.2	0.5	0.6	0.1	0.8	0.7

Table 2: Characteristics of each access network alternative. Attribute values of alternatives scaled on [0,1] on the level of desirability

The status of the user is inferred based on the aggregated context from various sources and assigning weights to each attribute based on the QoC and containment of that attribute (criterion) in inferred status or profile. Table 1 shows the weight distributions. For each profile the features that have the highest impact are weighted more. Table 2 shows the five network alternatives under consideration and their features and attributes. For the purpose of the WPM, we eliminated the units by mapping each attribute to the scale range of $(0,1]$ where a scale of 1 represents superior choice. Ranking of alternatives are shown in table 3 in terms of preference value of each alternative for each usage profile. A graphical representation of the preference index derived by TOPSIS and WPM are shown in Figure2.

Access Networks	High BW Profile	Low Cost Profile	Low Power Profile	Multimedia Streaming	Secure Profile
Alt# 1	0.43	0.30	0.75	0.48	0.42
Alt# 2	0.52	0.53	0.68	0.37	0.17
Alt# 3	0.33	0.20	0.25	0.44	0.60
Alt# 4	0.24	0.28	0.53	0.35	0.47
Alt# 5	0.46	0.22	0.44	0.42	0.60

Table 3: Preference value for ranking of each alternative for different profiles

7 Summary and Conclusion

Context-aware computing in mobile environment is interesting in that it paves the way for services and applications to take advantage of user contextual information such as time, location, activities and etc. We have shown our proposed SOA based system architecture for a context management framework. In this work we addressed the problem of dynamic access network selection for handover in heterogeneous network environments. Our proposed method is based on WPM method of decision making and weight assignment procedure is based on a sensitivity analysis for the most influential criteria based on the state of user at a given time. The weighted product method of MADM is a more robust approach for dynamic decision making and it penalizes the attributes with poor quality to a greater extent. Furthermore, we take into account the QoC parameters for fuzzy saliency measure of the context information to facilitate the distribution of weights for attributes in the MADM. QoC parameters are important since they can play a major role in determining the truth value of a context information. The numerical example and use case of our method is shown are section 6.

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