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Context Management in Mobile Environment

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Abstract

This paper presents a context management framework in mobile environment together with a context representation and processing method. This includes a flexible procedure for context collection, update, exchange and processing for a mobile environment. This framework incorporates not only the dynamic context but also the static context distributed both in the network and mobile node. By compiling the context information and by context updates, support for context-aware decisions can be implemented effectively in the mobile environment.

1 Introduction

In mobile networks, applications have to cope with fragile and sometimes scarce wireless resources. Furthermore, future mobile environments will encompass heterogeneous networks and services. Context awareness is the ability of a particular service to adapt itself to a changing context. We show that the context information can be used for mobile users to improve their level of services. However, in the mobile environment, the context information is difficult to manage (the management of context information includes context collection, exchanging and processing), because:

- The context information is distributed in both network and mobile terminal. Therefore, it is difficult to be collected and need to be exchanged.
- Wireless link is the bottle neck for context exchange. Hence the information exchange between the mobile node and networks should be minimized.
- The context information can be either dynamic or static. The dynamic information needs to be updated frequently.
- The amount of context information can be enormous. For a specific service, some context information is relevant, some is not relevant. Therefore, we need a data structure to compile the relevant context information effectively.

The specific problem we discuss is network service decisions assisted by context information. In this example, we select a prospective access point which is most suitable for the services a mobile node may use. For this, we need to collect and compile the relevant context information. At the same time, we need to assure that the right information is available at the right point in time. Furthermore, the context information must be evaluated such that a decision can be taken. In the above case, this is the mobile node, which is in charge of making a decision depending on context information. Although there are several studies about context-aware applications [1], few exist about the need to enhance network services with context awareness. Our solution here introduces a complete framework for context collecting and processing. In particular, a matrix-based data structure is used for context-aware decisions.

There is some literature on using the context information to optimize the handover decision. [2] uses fuzzy logics in order to cope with the complexity of the information set retrieved from a heterogeneous mobile access network. However, the focus is on the algorithm used for the handover, and how to apply fuzzy logics to this problem. [3] provides a framework for a programmable handover. Our solution can extend this in order to adapt to context information. [4] gives a detailed analysis on different approaches to manage the context information. [5] implements the context management in programmable mobile network. This paper will focus on a flexible context data structure and context management based on our experience.

2 Classification of Context Information:

Before we present our context management framework, it is useful to analyze and classify the context information. In our solution, we distinguish four types of context information (Fig. 1):

1. Static context information in the network (e.g., User profile & history, network location, network capabilities & services, charging models). There is also some context information which is static with respect to a cell (e.g., potential next access points), which we consider them as static context information.
2. Dynamic context information in the network (e.g., network status, network load)
3. Static context information in the mobile node (e.g., user settings & profile, application settings, hardware capability of the terminal, supported services). Here the context information which is static with respect to a cell (e.g., current location) is also considered as static context information.
4. Dynamic context information in the mobile node (e.g., current required services, radio measurement, device status(battery, interface status, etc))

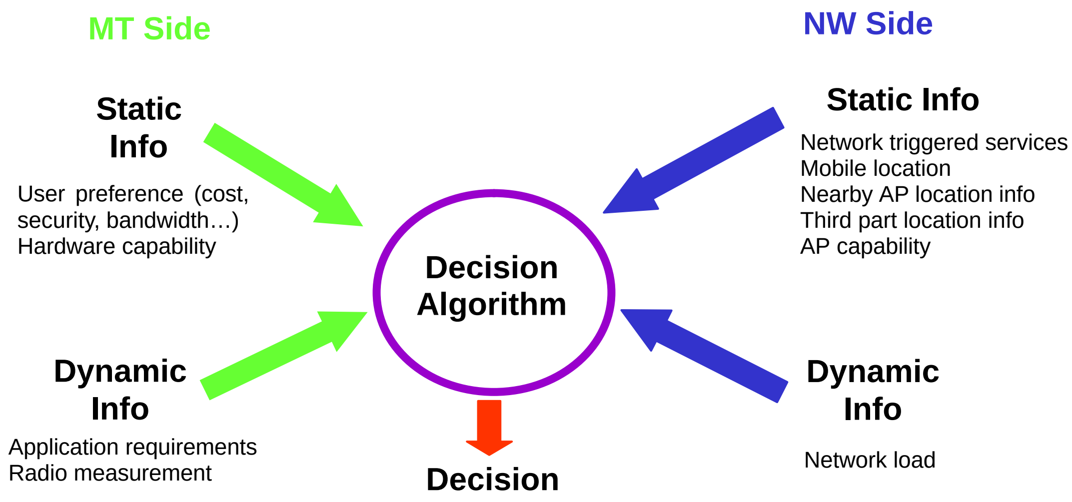

Fig. 1 Classification of context information

3 Context Management Framework:

Our framework, as presented in [4], is able to collect and process the relevant context information effectively. It defines the following types of entities (Fig. 2):

– *Various context repositories*, which are distributed in the networks and stores various context information

– *Context server*, which is located in the network to collect relevant context information from the context repositories. It also prepares the evaluation matrix in response to the equirement from the mobile context clients, as defined below.

– *Mobile context client* (e.g., mobile terminal). It evaluates the evaluation matrix for context processing. This evaluation matrix incorporates the static context. The evaluation matrix can be downloaded from the context server when the static context changes.

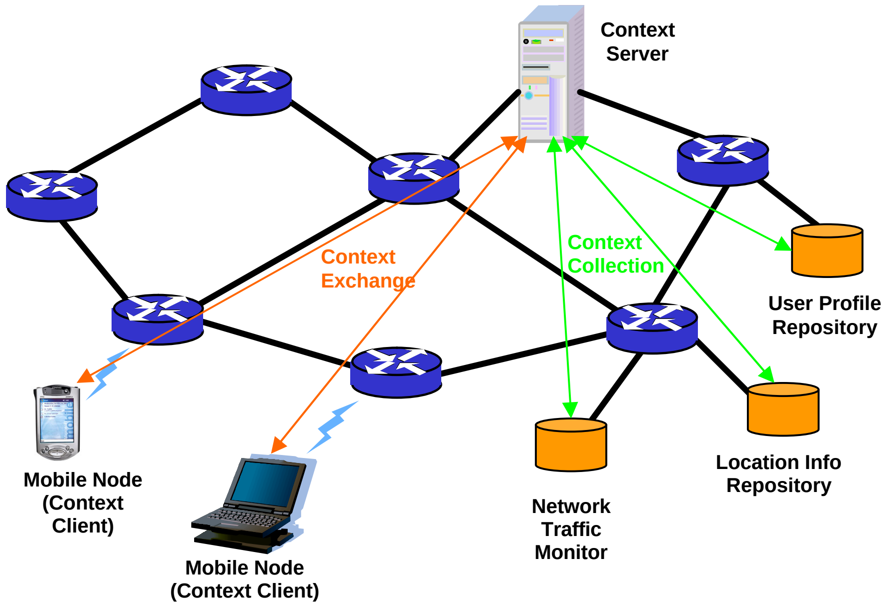

Fig. 2 Context management framework

4 Context Representation and Management

We show in the following how to make an optimal decision on services based on the context information for the case of hand-over decisions. More specifically, we need to select the right access point considering the changing nature of context information and rare wireless resources. As introduced above, this requires the following:

1 flexible data structure to express both user preferences and operator preferences;

2 a flexible context management to keep track of the context update from both the network side and mobile node side;

3 a robust mechanism to deal with partial data;

4 an efficient algorithm/procedure to minimize the context exchange on the wireless link.

To fulfill above requirements, we define a context evaluation matrix. It is flexible for updating (for both parameters and equations). Default values can be used in case that only partial data is available. Moreover, we also design an efficient context management procedure to update the context evaluation matrix and evaluate the matrix.

The evaluation matrix is a data structure which is defined to evaluate the possible access points with respect to the context information. In case of context-aware handover, the evaluation matrix can be as follows:

AP1 = S1* ((C1_1*P1+C2*P2)*Service1 + (C3_1 *P3 + …) * Service2 +…….)
AP2 = S2 *((C1_2*P1+C2*P2)*Service1 + (C3_2 *P3 + …) * Service2 +…….)
:

In this evaluation matrix, AP1, AP2… are the access points. Each AP is evaluated by some number which reflects the user and network preferences (based on context information) and the highest one is chosen. Service1, service2 … are the services which are both supported by the network and the mobile node. They can be 0 or 1 depending on the current required services by the mobile node. There are several kinds of parameters, where high values indicate positive service preference.

- P1, P2… are parameters which will affect the decision. For example, P1 can be the currently available bandwidth of different access points (APs), P2 can be the preference number based on the movement prediction of the mobile node, P3 could be the signal strength of different APs. For instance, services charges can be high in a network of one AP, hence the cost parameter will be low. Hence this AP will be evaluated less than others (not comparing other parameters) and hence other APs will be taken.

- C1_1, C2… are the coefficients of different parameters. These can be service specific (e.g. user preference) or service and operator specific (e.g. pricing). Such as C1_1, C1_2. These coefficients are the weight of different parameters.
- S1, S2, ... are coefficients which are service independent and concern only the AP, e.g. preferred operator

Such a linear data structure integrates many pieces of context information and expresses the feasibility or expected quality of an option (e.g., preference of an access point.) Then it is turned to a mathematic problem to find the right option by checking which equation has the maximum value.

In addition to the matrix, additional rules or conditions are considered which assign values to parameters. E.g., there can be some rules to set the upper or lower thresholds. For instance, the radio quality (P) must be above a value of 50, otherwise the value of the equation should be 0. Some parameters may also depend on each other. For instance, "if service1 = 0 then P3 = 0". This can express that service1 has an impact on other service parameters. These rules have to be evaluated before evaluating the matrix.

The procedure for context collecting and processing is as follows:

1. Mobile node sends a request, possibly together with the static context, to the context server to ask for evaluation matrix.
2. Based on the received static context information, the context server collects the relevant context information in the network from various context repositories.
3. The context server composes an evaluation matrix. The composition of the evaluation matrix consists of three steps:
   a) Compose the evaluation matrix. For example, in case of context-aware handover, the evaluation matrix can be as follows:

      AP1=S1*((C1*P1+C2*P2)*Service1+(C3*P3+…)*Service2+…….)
      AP2=S2*((C1*P1+C2*P2)*Service1+(C3*P3+…)*Service2+…….)
      :

      In this evaluation matrix, only the potential access points (i.e., AP1, AP2…) are included based on context information (e.g. mobile node's current position). Only the services which are both supported by the network and the mobile node (i.e., service1, service2…) are included.
   b) Decide which parameters to be used and the value of the coefficients. This depends on the static context information from the network and mobile node (e.g., user settings, charging models, user profile & history…).
   c) Fill in known values of the parameters which can be drawn from the static context information in the network. And evaluate the matrix as far as possible.
4. The context server sends the evaluation matrix to the mobile node.
5. The context server sends updates of the parameters for dynamic context information in the network to the mobile node.
6. The mobile node fills in the dynamic context information from the mobile node and calculates the evaluation matrix when a decision is needed.
7. The mobile node makes the decision based on the calculation results.

In this procedure, when the static context information in the mobile node changes (e.g., the user installs a new service, or the user change the profile), step 1 to step 7 should be repeated; when the static context information in the network changes (e.g., new access point available, network capabilities changes), step 2 to step 7 should be repeated; when the dynamic context information in the network changes (e.g., the change of traffic load in the AP exceeds some threshold), step 5 to step 7 should be repeated; and when the dynamic context information in the mobile node changes (e.g., mobile node switches from audio communication to video conference, the change of signal strength in the AP exceeds some threshold), step 6 to step 7 should be repeated.

In our solution, the decision matrix is minimized based on context information from both the network and mobile node, e.g. available services and neighboring access points (Step 3). At the same time the decision matrix is partially evaluated with available static context information (Step 3 c). By this the evaluation matrix is minimized before being sent to the mobile node.

Moreover, the dynamic context information from network can be sent separately with the matrix and is updated as needed (Step 5). The dynamic context information from MN is filled into the matrix by the mobile node before evaluating the matrix (Step 6). In this way, we can ensure that up-to-date context information is used for context evaluation. Hence, evaluation results can be more accurate.

If some parameters are not available when a decision is to be taken, default values can be taken for unknown parameters. This is difficult with some types of data structure, which base decisions on specific parameters and not on an overall evaluation of an access point.

5 Conclusions

This paper describes an effective context management framework which is able to optimize the services in mobile environment based on context information. Our solution ensures that the correct context information is available at the right place at the right time, and handles diverse, dynamic and distributed context information. We compile the context information into a decision matrix exploiting context information. In this way,, the context exchange through the wireless link can be minimized. Our context framework is implemented in a prototype [4][5], where different context formats and exchange algorithms are currently evaluated in detail.

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