AN ADAPTIVE LOCATION DATA MANAGEMENT STRATEGY FOR CONTEXT-AWARENESS IN THE UBIQUITOUS COMPUTING ENVIRONMENT[†]

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ABSTRACT:

Recently, a location based system(or middleware) is usually based on the distributed architecture to manage a large-volume of location data efficiently and supports a variety of spatio-temporal queries. Especially, in the ubiquitous computing environment, location data is generally considered to be an important context which changes continuously. Despite some works on an adaptive query or adaptive data filtering engine, most ubiquitous computing systems typically manage location data in a non-adaptive or non-scalable manner.

In this paper, we propose an adaptive location data management strategy in order to support adaptivity and scalability of the location based system using a variety of contexts which can be accessed in the ubiquitous computing environment. The proposed strategy enables the location based system to address problems related to heterogeneity and enormousness of location sensors or clients, enormousness of location data, and multiplicity of location queries based on a variety of context data including location, time and so on. Therefore, the location based system can be adapted to any environment, and the ubiquitous computing system can efficiently process location queries.

1. INTRODUCTION

The location is considered as the most important context in the ubiquitous computing environment. The critical issue in the ubiquitous computing environment is the efficiency of location management including update and search for the location data of user or device because of the mobility, one of the major characteristics of the ubiquitous computing environment.

Despite some works on an adaptive query and adaptive filtering engine, most previous works on the location data management of the ubiquitous computing environment don't sufficiently consider a variety of characteristics in the ubiquitous computing environment. Moreover, the adaptive and scalable data management has been not considered in overall processes from the collection to the application of location data.

This paper suggests the context-aware location data management using the context especially to support the context-awareness and heterogeneity in the ubiquitous computing environment. The adaptive location data management using the context mainly aims to reduce the complexity in a large-volume of location data management using the context data continuously changed and to minimize the location update cost. And the key goals of scalable location data management using the context are to support the heterogeneity of diverse location sensors and devices and the scalability in the distribution management of location data.

The remainder of the paper is organized as follows. Chapter 2 examines the profile-driven data managing and context managing as the related works. Chapter 3 looks through the context-awareness of the ubiquitous computing environment. The adaptive location data management suggested is explained in Chapter 4. Finally, Chapter 5 concludes the paper.

2. RELATED WORK

The data management researches in the ubiquitous computing environment have been conducted largely in two directions up to now; data managing on the basis of the user-related context called the profile; context managing related to the classification and architecture of context.

2.1 Profile-driven Data Managing

According to Perich(Perich, 2004), certain entities shall work without definite human intervention in the ad-hoc environment and the current and future actions of entities are determined using such profiles. The user profiles such as "beliefs", "desires" and "intention" are used to create the standing query or determine the utility of cache information. The device uses these queries to contact other devices in its vicinity in the hope of obtaining information that the user may require in near future. The adaptive cache replacement strategy applies the utility values of all cached and incoming information to manage the limited cache size.

Perich tried to enable more effective data management using the context such as user intention. However, the studies on the expression and application of various context data except the user-related context were not sufficiently conducted. Thus, a variety of context data are not flexibly utilized. In particular, the previous studies didn't consider on using a variety of dynamic context information in the data management that is

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relatively frequently changed as compared to the user context, the static context that is not frequently changed.

2.2 Context Managing

Schmidt(Schmidt, 1999) defined the context as the key issue for the interaction between human being and computer that describes the surrounding facts enhancing the meaning and suggested the context model for the context-aware mobile computing. The context conceptually describes the environment or situation where the devices or users were included and is identified by the unique name. Schmidt classified the context largely into the context related to human factor and the context related to the physical environment in his context model. Each context model is hierarchically structured into three categories.
Hegering(Hegering, 2003) explained the process that the context data was used for the context-aware service as shown in Figure 1.

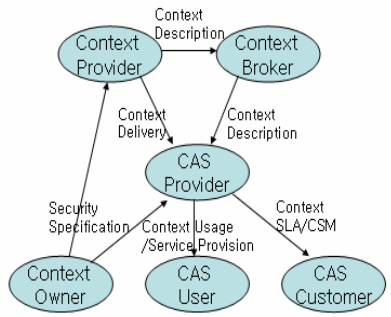

Figure 1. Role Model for the Context-Aware Service

In Figure 1, the Context Provider captures and provides the context and the CAS Provider supplies the context-aware service through the service contextualization. Moreover, the Context Broker supplies the description information related to the Context Provider to the CAS Provider. The Context Owner supplies the specification related to the security to the Context Provider and the CAS User uses the context-aware service. The CAS Customer controls the customer service management related to the context-aware service.

Despite such researches, there is no detailed definition on the context model in the ubiquitous computing environment until now. Furthermore, the studies on the contextualization for adapting the data around the service contextualization have been not actively performed.

Buchholz(Buchholz, 2003) defined QoC(Quality of Context) as the quality related to context and demonstrated that the content(i.e., context data set) could be used for the adaptation. QoC is any information describing the quality of information used as the context information. The parameters of QoC include the “precision” describing how exactly the provided context information mirrors the reality, “probability of correctness” showing the probability that a piece of context information is correct, and “up-to-date” indicating the age of context data. Buchholz suggested the adaptive application of cache strategy according to the predefined agreement of QoC parameters and QoS(Quality of Service) in order to effectively distribute and store the context data.

However, this study failed to apply the potential relevancy of various context data in the actual ubiquitous computing environment to the data adaptation and accordingly couldn’t fully reduce the complexity through the automatic data management.

Therefore, this paper suggests the adaptive and scalable location data management using the context data that is managed for the context-aware service in the ubiquitous computing environment requiring the processing of a large-volume of heterogeneous data.

3. CONTEXT-AWARENESS IN THE UBIQUITOUS COMPUITNG ENVIRONMENT

3.1 Context in the Ubiquitous Computing Environment

According to Dey(Dey, 2001), the context means any information that can be used to characterize the situation of an entity such as person, place or object. The context-aware system is the system to provide the context-related information or service using such context. The context data in the ubiquitous computing environment is collected from sensors, databases or devices and can be used to adapt automatically certain behaviours in the context-aware service.

The step-wise processes from collection of context data to utilization for service, that is, sensing, refinement, aggregation and contextualization, are required(Hegering, 2003). Sensing is a step to collect the data from the context source and refinement is a step to convert the low-level context data acquired from the sensing step to the high-level context data required in the context-aware service. Aggregation is a step to allocate the context data related to a specific entity and context-aware service and contextualization is the last step to conceptualize the service using the integrated context.

3.2 Location in the Ubiquitous Computing Environment

The location plays the very critical roles in a variety of context-aware system in the ubiquitous computing environment. The location of users, devices and services is a context and simultaneously the important source of context(Schmidt, 1999). Since the location data can be used as a large-volume of data for a variety of purposes as well as acquired from diverse sources in the ubiquitous computing environment, collecting and managing the location data become very complicated(Kim, 2005). The following issues need to be addressed by the system for the collection and management of location data.

1) Processing of various location types acquired from a variety of sources:
The types and characteristics of locations in the ubiquitous computing environment have been gradually diversified according to the requirements on higher accuracy and development of smaller and more diverse sensors. The location data from GPS devices, the most frequently used and traditional device in the LBS(Location Based Service), is just one of locations with the lowest accuracy now. Accordingly, it is required to find out the methods to support the diversity of location from various sources in the ubiquitous computing environment.

2) Effective processing of a large-volume of location data:
A number of various devices from the laptop computer system to tiny and compact home appliances will play the roles of computing system for communication in the ubiquitous computing environment. Thus, more location data for more people or more systems shall be processed in far wider range.

The storage strategy such as indexing and distributed system architecture technology in the previous studies for more effectively processing a large-volume of location data need to be developed to the location data management technologies in the broader distribution environment on the basis of the Grid computing technology in the ubiquitous computing environment.

3) Processing of uncertainty related to location:
The location data in the ubiquitous computing environment always contains the errors from the measurement. Such errors are caused by the hardware or software of devices used for measurement or measurement interval. For supporting a variety of location types mentioned above, the uncertainty processing related to the errors is important. Moreover, more effective LBS will be realized by utilizing the fundamental uncertainty characteristics of location data in the aspects of the location system and the data management.

4) Integration of location data management with context management:
The location is a key context that has continuously changed data value in the ubiquitous computing environment. The acquisition and management of location data mentioned above are included in the general context data acquisition and management in the ubiquitous computing environment. Therefore, more intelligent conceptualisation can be achieved through the context reasoning(using or for location data) by expanding the location data management to the context data management in the ubiquitous computing environment and integrating and managing the location data with other context data.

3.3 Context-Awareness in the Ubiquitous Computing Environment

This section explains the context-aware service, the context-aware resource management, and the context-aware data management.

1) Context-aware Service:
Most services in the ubiquitous computing environment need to recognize a variety of location or context data and provide the service depending on such context data(Kaasinen, 2003; Franklin, 2001). As illustrated below, there is an example of context-aware services.

‘David gets on his car as leaving his office in the Saturday afternoon. The music that David frequently enjoys in his car in the Saturday afternoon is automatically played. David calls his friend to make the appointment. He checks the location of his friend using the terminal on his car and goes to that location indicated by the navigation system along the optimum path. His friend also checks the location of David using his mobile phone in real time.

On the way to his friend’s location, the travel information system provides the information on the recommended destinations where he can travel for one day or two days from the current time based on his preference, current weather and so on. The information is ordered by the distance between the current location and each recommended destination. When David meets the friend, he selects one of recommended destinations with his friend and the navigation system provides the optimum path from the current location to the selected destination. On the way home, when his friend starts to doze off, the car audio system will automatically reduce the volume of music.’
The types of context information used in the service scenario above are time, user preference, location, traffic, weather and so on.

2) Context-aware Resource Management for Autonomous Resource Discovery:
Beyond the automatic adaptation of service to the users as explained above, the context data can be used for management and discovery of resources used for the service(Bellavista, 2003). The ubiquitous computing environment includes a variety of device types such as the device with sensing capability, device with computing capability, or device with communication capability. This feature and the mobility of device itself may be very useful for the context-aware resource management. In other words, the autonomous resource discovery and service provisioning can be effectively carried out using the dynamic context such as the client location and access control as well as the static context such as the characteristics of users or devices.

3) Context-aware Data Management for Adaptive and Scalable Data Management:

The context data can be used for the automatic adaptation of a large-volume of data in the ubiquitous computing environment like the automatic adaptation of services for users(Buchholz, 2003). In the context data processing, we can acquire the new context data through the analysis and conversion in the refinement and aggregation steps with the context data acquired from the sensing step. Such context data is stored or updated as the new data or delivered to other devices(or servers) according to a policy.

This paper describes the context-aware data management that automatically changes the data management policies depending on the dynamic context data in all steps for the adaptive data management: refinement, aggregation and contextualization steps. Since the adaptive data management approach is basically based on the context, it supports the scalability in the ubiquitous computing environment with the characteristics of the distributed computing environment to process and manage a large-volume of data.

4. ADAPTIVE LOCATION DATA MANAGEMENT

4.1 Data Access and Management

The data access is the basic requirement for the services in the ubiquitous computing environment or pervasive computing environment, the computing environment that flexibly provides the services required by users even in the anywhere, anytime, anyplace, anydevice and anynetwork environment(Weiser, 1994). Thus, the ubiquitous computing can’t be considered more valuable without the ubiquitous data access and the consistent access to the storage and effective data management technique are essential.

The general issues related to the data access and management in the ubiquitous computing environment include the mobility, context-awareness, heterogeneity, and collaboration. The data management strategy supporting the context-awareness and heterogeneity will be discussed in this paper.

1) Support for Context-awareness:
The devices shall be continuously used as recognizing and using the information on the changes of situation. In other words, the ubiquitous device system needs to recognize the works that the users are currently performing or will perform in the near future and automatically supply the services. Moreover, the data management for a variety of context data shall be automatically and effectively carried out for enabling the system in the ubiquitous computing environment to provide a large-volume of data in the timely manner.
The support for such context-awareness requires the approach to share the context knowledge between a large number of diverse devices widely distributed on the network.

2) Support for Heterogeneity:
Since the ubiquitous computing environment needs to support a variety of heterogeneous sensors, devices, client systems, and networks, it shall support the heterogeneity for the sensor data such as location data and query. In other words, data from different sensors shall be processed by the client queries for diverse purposes through the different networks of different devices. This objective requires the abstraction of data and query transferred as well as the network technologies.

4.2 Adaptive Location Data Management

This section describes the adaptive location data management suggested in this paper in terms of the relevant context.

1) Context for Data Management:
What is important in the data management policy to automatically perform the location data management using the context is that the policy shall be changed as the relevant context is continuously changed. The context attributes influencing on the changes of data management policies include the update cycle, request cycle and transfer cycle. Like the condition-and-action in the database trigger, data with certain context ID is updated, requested or transferred according to the specific cycles of update, request or transfer.

All cycles of update, request and transfer have the values that are dynamically changed. The context attributes changing such values include the precision, probability of correctness, up-to-date, and number of requests. In other words, the values of update, request and transfer cycles are changed depending on the precision, probability of correctness, up-to-date or number of requests of certain context ID and the values are automatically applied to the actual data management policies.

All context data can be related to other context data in the ubiquitous computing environment. For example, the location context has the relevancy to the time context indicating the time when the location data is acquired or place context indicating the meaning place of that location. The structure of context type including the relevancy among context types can be defined and applied using the context ontology.

2) Adaptive Location Data Management:
The adaptive location data management is automatically performed as the values of context attributes are changed by the relevancy among context types defined in the ontology as well as the values of other relevant context attributes.
Figure 2 illustrates the role model on the context data management for the context-based location data management policy.

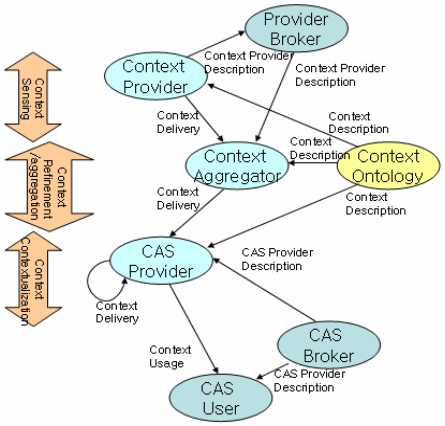

Figure 2. Role Model for the Context Data Management

The Context Provider acquires the context data from the sensors and the Context Aggregator refines and aggregates the context data from the Context Provider. The CAS Provider provides the context-aware services to the CAS Users. The context may be the location type or other context types. The Context Provider, Context Aggregator and CAS Provider are the conceptual components performing the roles explained above and can mean a single or multiple systems. Thus, the CAS Broker provides the description on the CAS Provider and the Provider Broker provides the description on the Context Provider for supporting the interoperability and scalability among systems. In other words, the information on the CAS Provider is delivered to the CAS Users and the CAS Provider description is supplied to the CAS Providers using the CAS Brokers. Then, the context can be delivered to several CAS Providers.

The adaptive location data management strategy in this paper changes the update strategy on the location data on the basis of several context attributes and QoS as described below.

(1) The Context Provider assigns ID to each location context and sets the attributes such as update cycle, request cycle, transfer cycle, precision, probability of correctness, up-to-date and number of requests to each predefined default values.

(2) The Context Provider delivers ID, update cycle, request cycle, transfer cycle, precision and probability of correctness according to the request from the Provider Broker.

(3) The Provider Broker delivers the description on the Context Provider including ID, update cycle, request cycle, transfer cycle, precision and probability of correctness according to the request from the Context Aggregator.

(4) The Context Aggregator sets its request cycle on the basis of the description and requests the location data to the Context Provider.

(5) The Context Aggregator updates the location data from the Context Provider according to the update cycle.

(6) The Context Aggregator resets the update cycle on the basis of the precision, probability of correctness, up-to-date and number of requests. For example, if the number of requests and up-to-date are smaller than a specific threshold value and up-to-date is a relatively latest one, the Context Aggregator resets the update cycle of relevant location or other context data longer.

(7) The Context Aggregator refines and aggregates the location data from the Context Provider on the basis of the precision, the probability of correctness and the update cycle, creates the new location data or context data and sets the update cycle of it.

(8) The CAS Provider sets its update, request and transfer cycle on the basis of the QoS, request or request cycle of CAS User.

(9) The Context Aggregator sets its transfer cycle according to the request or request cycle of the CAS Provider and delivers the relevant location or other context data.

(10) The CAS Provider delivers the relevant location or other context data to the CAS User according to the transfer cycle.

(11) The CAS Provider resets the update cycle of relevant location or other context data longer if the number of requests is smaller than a specific threshold value and up-to-date is a relatively latest one.

Moreover, the components change the update strategies of other relevant context using the context ontology as described below.

(1) The Context Provider, Context Aggregator and CAS Provider request the description on the contents related to IDs of other context or specific location from the Context Ontology.

(2) The Context Ontology delivers the description on the context related to the relevant context.

(3) Each component changes the update cycle of relevant context data on the basis of the relevancy of delivered context data and context attributes that it already knew. For example, if the time context meaning the time stamp acquiring the location related to the location context is the child, the Context Aggregator can resets the update cycle of time data simultaneously as resetting the update cycle of location data.

Such policies reduce the interaction of person(such as administrator) and the complexity of a large-volume of location data management through the automatic data management and minimize the location update cost by dynamically changing and applying the data management policies. Moreover, the heterogeneity for a variety of location sensors and devices is supported using the context attributes such as precision and probability of correctness and the scalability is supported in the distributed management of location data. In other words, the data management policy can be flexibly changed and applied when adding new context types or relevancy among context types.

5. CONCLUSIONS

Ubiquitous computing pursues the environment that all users ideally get the easy-to-use services while they don't recognize the computers. For realizing this goal, a number of technologies such as human interface, convergence network, human sensibility engineering, security and contextual service technologies are required. However, it is firstly required to recognize the ubiquitous data management technology as the fundamental technology for all kinds of ubiquitous technologies, overcome the restrictions of the ubiquitous computing environment and then enable the effective data access through the self-tuning or self-optimization in data management.

In particular, in the processing and management of spatio-temporal data or location data that have been widely researched in the GIS or LBS field up to now, the location shall be considered as key context for the ubiquitous computing environment and the location data shall be managed in terms of the ubiquitous data management.

This paper concentrated especially on the support for context-awareness and heterogeneity among major issues in the ubiquitous computing environment and suggested the context-aware location data management using the context in terms of the location data management as well as the location data processing for the context-awareness in the ubiquitous computing environment. The goals of adaptive data management using the context is to reduce the interaction of person(such as administrator) using the continuously changing context data as maximum as possible and the complexity of a large-volume of location data management in the ubiquitous computing environment through the automatic data management and to minimize the location update cost by dynamically changing and applying the data management policies in the timely manner. The adaptive data management also aims to support the heterogeneity of various location sensors and devices using the context and the scalability in the distributed management of location data.

The further study needs to concentrate on the data access performance in consideration of the mobility and collaboration for more effective location data management in the ubiquitous computing environment.

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