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Autonomous Cooperation Technique to Achieve Fault Tolerance in Service Oriented Community System

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Abstract

The advancement of mobile telecommunication and wireless technologies is required to provide local but familiar services in daily life, which has not been satisfied through the global services on the Internet. In retail business under evolving market, users request access to unknown but appropriate services based on their preference and situation, and retailers need to be aware of the current requirements of the majority of consumers in specific local trade areas. Because of the transience of the requirements of the users in their trade-areas, the services require being temporary and having the time limit. Therefore the areas of the services need to become narrower with the time.

The concept of the Service Oriented Community has been proposed to satisfy both the users and the retailers requirements. It consists of members in the specified area based on services, and they cooperate with each other in order to get mutual benefits. For realization of the service oriented community, the systems require flexibility for the effective provision of the services and fault tolerance for the stable service.

In the Service Oriented Community System, the Time Distance has been introduced as the efficient measure of the distance between the users and the retailers. The Time Distance Oriented Service System architecture has been proposed to satisfy these requirements for flexible and stable services, where the nodes are autonomously distribute services and reduce the service area based on the time distance. Here autonomous cooperation technique for achieving fault tolerance is proposed in order to satisfy the requirement of high service availability.

1. Introduction

The advancement of mobile telecommunication and wireless communication technology has made mobile commerce possible. More than 50 people access the Internet with mobile phones such as I-mode in Japan.

In retail business under the evolving market, the requirements for not only location aware but also timely services for daily life have been increasing even more, which cannot be satisfied through the global services such as e-commerce on the Internet. The users require the utilization of unknown but appropriate services at each precise moment. It has been almost impossible for the retailers to provide effective services based on each user's preference and situation under such environment.

Systems using a service accelerator (SEA) system and an autonomous decentralized service system (ADSS) to provide personal services have been reported[1, 2]. These systems mediate between service providers and users, and provide individual users with services based on their profiles. Location awareness systems using mobile terminal have been developed for provision services based on the users' location[3, 4, 5]. These papers describe a basic concept of service mediation platform. However, the flexibility of service for effective provision has not been discussed.

The Service Oriented Community System [7] based on Autonomous Decentralized System (ADS) [6] has been proposed to achieve the assurance of both the users and the retailers requirements for the local but familiar services in daily life. Time Distance is introduced as the efficient measure of the distance between the users and the retailers. The Time Distance Oriented Service System architecture has been defined to satisfy flexibility for the local services, where the users and the retailers have cooperative roles both for the provision and utilization of the services under the evolving situations.

This paper is divided into five main sections. Section 2 clarifies application requirements for location and situation awareness services in retail business, the Service Oriented Community concepts to satisfy the requirements of both the users and the retailers, and system requirements for flexibility and fault tolerance. Section 3 presents the Service Oriented Community System. It explains the Time Distance and then introduces the architecture of the Time Distance Oriented Service System. It also describes the process of service provision in the System. Section 4 exposes a technique to avoid fault propagations by autonomous cooperation among nodes. Section 5 finally draws the conclusion.

2. Requirements

2.1. Application Requirements

In the retail business under the evolving market, the users with mobile terminals move around and have different preferences for local services in daily life. They require unknown but the appropriate services based on their preference and location, which are provided by the retailers within accessible area.

They tend to buy daily necessities near their houses. On the other hand, they tend to buy expensive products at a department store that is situated far from their houses. Figure 1 shows a user's preference. He wants some bread, a teacup, and a PC. He would buy each product at the bakery nearby, at the super market down the road and at the electronics store on the other side of town, respectively. The services provided by retailers are required to reflect these preferences of the users in their trade-areas.

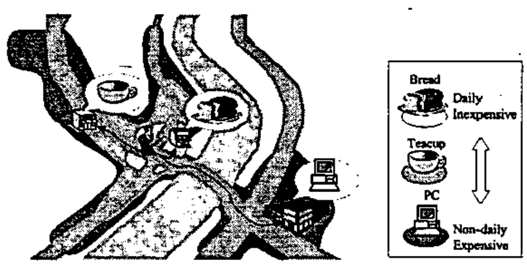

Figure 1. User preference

On the other hand, it is difficult for the retailers to provide appropriate services to each user under the evolving situation. The retailers need to grasp the current requirements in their own vicinity trade-areas in order to determine appropriate services. They also require providing services to the users effectively. The services based on the current requirements are effective only for a restricted time because the users are constantly on the move and the requirement changes dynamically. Therefore the areas of the services need to become narrower as time passes by to achieve effective service provision. Figure 2 shows a time-sale service area as a example of time-limited services.

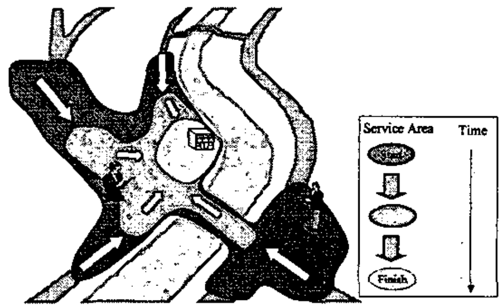

Figure 2. Time-sale service area

The users and the retailers require the stability of utilization and provision of the services.

2.2. Service Oriented Community

The Service Oriented Community is proposed in order to satisfy both the requirements of the users and that of the retailers. The Community consists of members such as the users and the retailers in the specified area based on services. For example, the area is represented as local trade-area in retail business.

In the community, the members cooperate with each other in order to get mutual benefits like social community. The users provide their requirements to the retailers as well as utilize the services, and the retailers utilize the users preference as well as provide the services.

As the result, the retailers can grasp the current majority requirement in the community by collecting the requirements of the users, and determine the most appropriate service based on it. Then, the users can utilize the appropriate services based on their preference and location.

2.3. System Requirements

For realization of the Service Oriented Community, the systems are asked for the following requirements.

Flexibility

The requirements of the users in the service community areas should be transmitted to the retailers in appropriate areas. The services also should be distributed to the users in the service-based community areas, which becomes narrower as time passes by. Therefore the flexibility is required of the system to realize the Service Oriented Community.

Fault tolerance

Both the users and the retailers require the stable utilization and provision of the services. As the network becomes large under the changing environment, it may include the failure. Therefore fault tolerance is necessary to achieve high service availability for both users and the retailers.

3. Service Oriented Community Systems

Time Distance Oriented Service System architecture has been proposed to achieve flexibility for the Service Oriented Community.

3.1. Time Distance

The time distance is logical distance that is defined by user's physical moving time, and an efficient measure to determine the appropriate service areas. It is important for the users that the services provided by the retailers are available certainly. The retailers have to provide the services to the users in the available area. For example, even if the straight distance between a consumer and a store is equal, the time distance may differ greatly when he has to get across a river (Figure 3). Therefore the provision of the services based on the time distance is effective for the retail business.

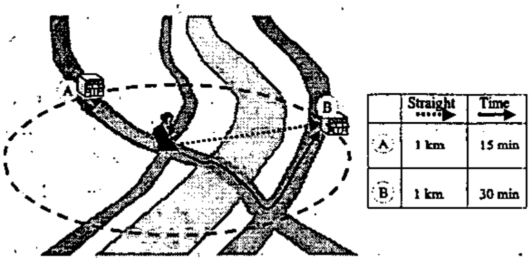

Figure 3. Time Distance

3.2. Architecture

The system consists of the nodes such as a base station of the mobile network, which are connected by the network and transmit data among neighboring nodes. The users and the retailers connected to the closest nodes. Each node has a time distance table, in which time distances from neighboring nodes are registered.

The services are supplied and transmitted to the closest nodes by the retailers. Then the services are distributed to other nodes in the service areas determined by the time distance, and broadcasted to the users within the coverage of the nodes.

Figure 4 shows the architecture of the Time Distance Oriented Service System.

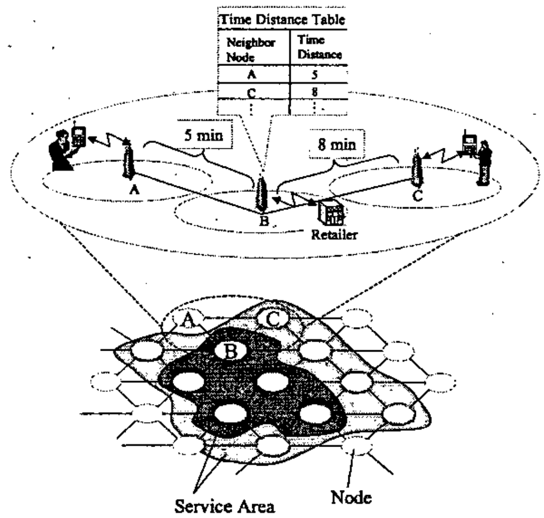

Figure 4. System Architecture

3.3. Time Distance Measuring

The nodes autonomously distribute each message based on the time distance between the nodes. The time distance measuring is realized by autonomous background processing of the nodes and the users' mobile terminal. Figure 5 shows the sequence of the time distance measuring. Each node broadcasts its ID to the users in its own cell. The mobile terminals of the users record the ID and received time. The mobile terminals detect the movement from a node to another by comparing the IDs. If the mobile terminals receive the ID from node A at time T_A and node B at time T_B, the time distance $T_{A \to B}$ between node A and node B is calculated by the formula (1).

$$T_{A \to B} = T_B - T_A \tag{1}$$

The mobile terminals send $T_{A \to B}$ to the node B as the time distance from the node A based on the message format. The node B records $T_{A \to B}$ in its time distance table. Thus each node measures the time distance from neighboring nodes by the users' migration.

If every user in the cell sends the time distance information to the node at each movement between cells, network congestion might occur, and some mechanism to avoid congestion is necessary. For example, nodes select some mobile terminal in the cell randomly at regular time intervals, and avarage each time distance. However the traffic depends on the width of the cell. If the cell is small, users move across cells frequently. On the other hand, if the cell is large, users migration seldom occurs.

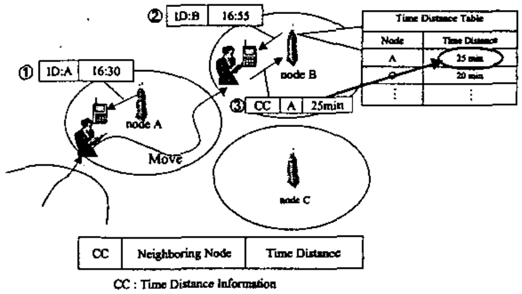

Figure 5. Time Distance Measuring

3.4. Autonomous Service Provision

The initial service areas in the community are determined by the time limit of each service. If it is 15 minutes, the service is propagated to only the users who can get to the retailer within 15 minutes. Thus the users can utilize the services provided by the accessible retailers, and the retailers can provide the services effectively. This service provision is achieved by the autonomous communication among the nodes based on the time distance. The services are sent out to the network as the messages. Each of these messages includes Content Code (CC), time limit of the service (TL) and Cumulative Time Distance (CTD) (Figure 6).

Content Code	Sender ID	Service ID	Service Contents	Service Life Time	Cumulative Time Distance

Figure 6. Message Format

The CC corresponds to the content of the service. The users mobile terminals autonomously judge by the CC whether the message should be stored or disposed based on the users preference.

The LT shows that the service is provided during the period.

The CTD presents the time distance from the retailer at each node. Each node judges whether it is included in the service area or not by comparing the TL and the CTD.

The retailers transmit the services to the neighbor nodes. At each node, the node adds the time distance from former node and the CTD. CTD_n of the time distance at the Nth node is expressed with the following formulas (2).

$$CTD_n = \sum_{k=2}^{n} T_{k \rightarrow k-1} \quad (n \geq 2) \tag{2}$$

The node judges whether the service is disposed there or not. If the CTD is larger than the LT, the node disposes of it. Nodes comply with the following algorithm (3).

$$Action_{node} = \begin{cases} Nothing & \text{if } CTD \leq TL \\ Dispose & \text{if } CTD > TL \end{cases} \tag{3}$$

Thus the services are distributed based on the time distance (Figure 7).

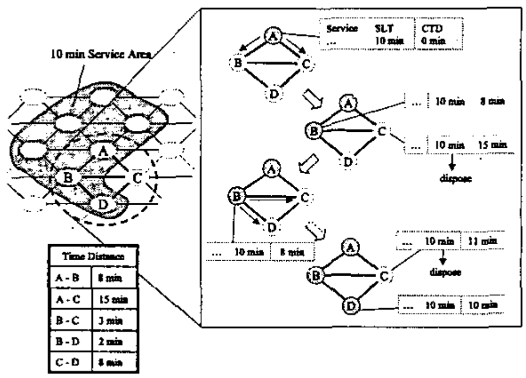

Figure 7. Service Provision

3.5. Autonomous Information Shrinking

To achieve effective provision of the time limited services, the nodes included the service areas autonomously judge whether they stop sending the service to the users or not because the service areas become narrower with time. Each node in the service area continuously calculates the rest time of the service (RT) based on the LT. The nodes judge whether the announcement to users should be kept or stopped according to the following algorithm (4).

$$Action_{node} = \begin{cases} keep & \text{if } CTD \leq RT \\ stop & \text{if } CTD > RT \end{cases} \tag{4}$$

As the result, the service is distributed only to the users in the service area available. Figure 8 shows the example of a time sale that LT is 10 min. Node A, B and C broadcast to the users in their cell at the start of the service. 2 minutes later, node C stops broadcasting because CTD (= 9 minutes) is larger than the RT (=8 minutes). Further more 5 minutes later, node B stops broadcasting because CTD (= 4 minutes) is larger than the RT (= 3 minutes). Thus service area available shrinks and the effective service provision is achieved.

4. Autonomous Cooperation Technique

4.1. Autonomous Cooperation Technique

Autonomous Cooperation Technique is proposed to achieve fault tolerance in the provision of the services. Fig-

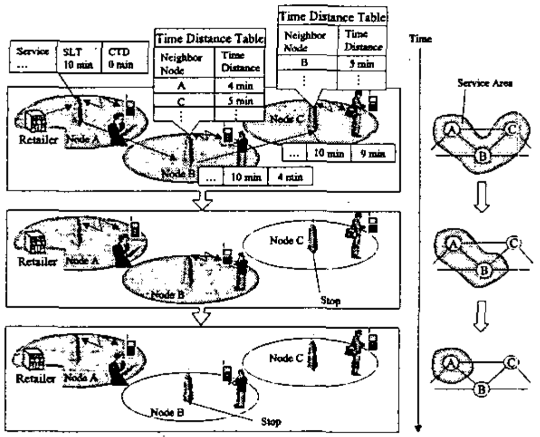

Figure 8. Autonomous Informaiton Shrinking

ure 9 shows an example of fault propagation. Normal case shows the service flow when all the nodes in the service area are operating correctly. When node C has failed, node E and F cannot receive the service. In this case, fault propagation occurs, and the node failure causes the decrease of the reliability of the service distribution. Therefore techniques for achieving fault tolerance in the provision of the services are necessary.

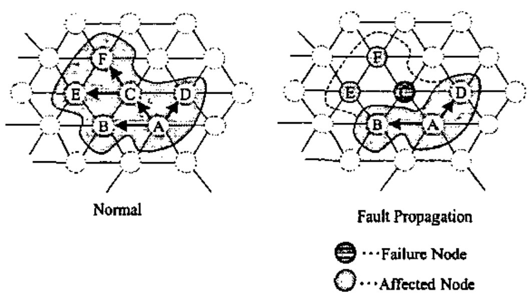

Figure 9. Fault Propagation

Each node sends a signal to neighboring nodes at regular time intervals T. When a certain node is down, the signal is stopped. The neighboring nodes can detect the node's down by watching the signal. If the signal does not come even if it passes over the time T, the node is judged as a failure node. When the neighboring nodes of the failure node send the message, they attach the urgent header containing urgent flag, failure node ID and sender node ID to the normal message, and send to every neighboring node except the failure node. Nodes, which receive the urgent message, judge whether the message should be sent to the neighboring or disposed. If the failure node is the neighboring, the node sent every neighboring node unconditionally and checks the message history and judge whether the cumulative time can be restored. If the cumulative time is restored, the urgent header is removed and the message is sent as a normal message. If the failure node is not neighboring, the urgent message is disposed. Thus, information is surely distributed except failure nodes (Figure 10).

During this process, all of the other nodes -as well as the fault detecting node- continues normal operation.

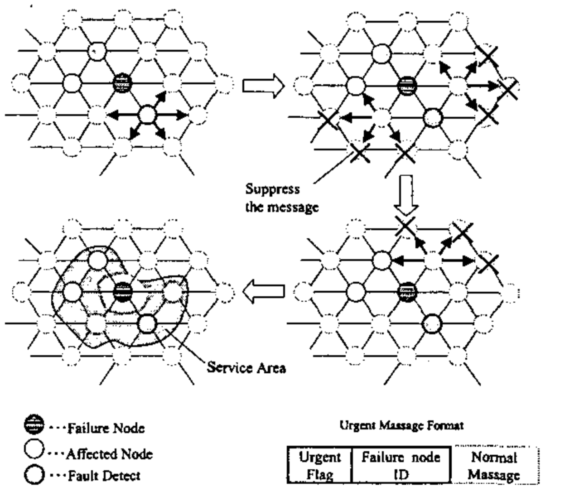

Figure 10. Autonomous Cooperation Technique

4.2. Evaluation

The reliability of the service distribution S_N is given as

$$S_N = \frac{n}{N}$$

where N is the total number of nodes, and n is the number of nodes which is possible to transmit the messages to users in the service area.

We can now compare the service availability of the proposed system with the centralized management systems. For simplicity, and to clarify the difference in their reliability of the service distribution, we will assume that the reliability of the centralized server is R_s with a value of 0.95, and of every node is R_n with a value of 0.90. We will also assume that the reliability of the centralized server decrease with the increase of the total number of the node N because of the load congestion. These ratio are T_s with a value of 1.1 and T_n with a value of 1.01 respectively. $R_s(N)$ represents the reliability of the centralized server with N nodes, and $R_n(N)$ shows the reliability of the nodes.

For the Centralized system, S_N is given by the following equation:

$$S_N = R_s(N) \sum_{k=0}^{N} {}_N C_k (1 - R_n(N))^k (R_n(N))^{(N-k)} \quad (5)$$

The number of the working nodes N for the proposed system is given by the following equation:

$$S_N = \sum_{k=0}^{N} {}_N C_k (1 - R_n(N))^k (R_n(N))^{(N-k)} \quad (6)$$

Figure 11 represent the reliability of the service distribution. The result shows that the reliability of the centralized system is high rate when the system consists of few nodes, but the reliability of the proposed system is high rate when the number of the nodes increases.

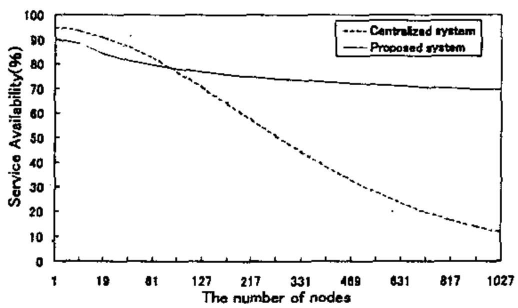

Figure 11. Evaluation: Reliability of the service distribution

5. Conclusions

The requirements for obtaining local but familiar information services, which cannot be achieved by the Internet global information service system, have been clarified. Under the evolving market of the retail business, the users requirements of accessible and desirable services change dynamically. The retailers have to grasp the majority requirements of the trade areas in order to provide the most preferable services, and distribute time-limited services to only the users who can access during the period.

Here, Time Distance is introduced as the effective measure for the utilization and provision of the services in mobile commerce. The Time Distance Oriented Service System is proposed, where the users and the retailers have cooperative roles both for the utilization and provision of the services under the evolving situations. Each node has autonomy for not only interactive communication but also processing of the distribution to achieve flexible and stable services in the local trade area.

It is shown that this architecture and technologies realize the flexibility and fault tolerance and achieve effectiveness in mobile commerce.

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