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A Service Transmission and Recovery Strategy Based on Cluster in Mobile Social Network Service Environment

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Abstract: In mobile social network service (MSNS) environment, users can establish a group relying on some relationships and share services within a group or among different groups. When the mobile devices provide services for a user, some service transmission paths will fail because of device movement or failure, and the user cannot receive required services. Recovering the service quickly and efficiently is the main problem of this paper. This paper presents a new service transmission and recovery strategy based on cluster in MSNS. Establishment mechanism of recovery point is adopted in the strategy. The recovery point is able to save and maintain the service data received from the service provider. When the service transmission fails, the upstream recovery point can directly resend the service data to its downstream recovery point. Simulation results show that this strategy can save the transmission time and improve the probability of successful transmission.

Keywords: Cluster, communication, group, mobile social network service, recovery, transmission.

1. INTRODUCTION

Mobile social network service (MSNS) has changed personal communication way [1-3]. In the past, the communications between users are based on some network protocols. In MSNS, users can establish a group relying on some relationships which include families, friends, interests and activities. These users can communicate and share services within a group or among different groups [4-7]. How to maintain the communication paths for the group users is one of the important research areas in MSNS.

In general, there are several mobile devices in a group. When the mobile devices provide services for a user, some service transmission paths will fail because of device movement or failure, and the user cannot receive required services. To address this problem, this paper presents a new service transmission and recovery strategy based on cluster in mobile social network service environment. The simulation experiments demonstrate that our strategy can decrease the service transmission time and increase the successful request ratio, which makes the transmission process more reliable.

2. BACKGROUND AND RELATED WORK

When the service path fails, the existing recovery strategies include local recovery [8-12] and global recovery strategies [13-15]. About the local recovery strategy, Imran *et al.* [8] put forward a method applied to single node or multiple nodes failure in WSAN. First, the method determines which node should be a key node according to some rules. Second, these key nodes select backup nodes for themselves in one hop scope. When a backup node detects that its corresponding key node fails, it will replace the key node. The reference supposes that the failed node will be certainly recovered in one hop range, which is not fit for real network circumstance sometimes.

Mi *et al.* [9] put forward a failure detection mechanism in MANETs. If a cut-vertice fails, the mechanism will allocate the best candidate to replace it. The selection of the best candidate is based on the information of K-hop neighbors. The reference presents many supposed conditions. For example, there is a path between two nodes at anytime, and there is a suitable candidate in K-hop neighbors for the failed cut-vertice undoubtedly. The mechanism can work well upon the supposed conditions and does not consider other unexpected situations.

Jeon *et al.* [10] propose a fast route recovery mechanism for dense network environment, which utilizes node mobility and implements the route recovery process implicitly. To reduce control messages and ensure service efficiency and reliability, this reference adopts local route recovery. The description of the recovery process is simple, which results in the whole mechanism unclear.

Li *et al.* [11] present a reliable route transmission protocol about missing packets in vehicular ad hoc network (VANET). Through forecasting the link state of the network, the protocol can deploy intermittently connected points in the transmission path. But the method of forecasting the link state of the network is not very reliable and accurate.

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Chen *et al.* [12] combine the forward error correction (FEC) technology and recovery point scheme to increase the transmission reliability and avoid excessive control cost. The reference describes how to use the FEC technology in multicast. FEC technology, however, is not fit for the device service recovery in MSNS environment.

About global recovery strategy, Ouyang *et al.* [13] explain that the receiver is responsible for detecting the loss of data packet and notifying the sender to retransmit. The reference requires that the sender should save all the state information of the receivers. Whenever the receiver requires retransmission, it must send an acknowledgement (ACK) message first. The sender deals with all the ACK messages, presenting a large burden for the sender. The method often forms transmission bottlenecks for the sender and influences the expansibility.

Chen *et al.* [14] suppose there are several mobile devices providing services for a user at the same time. When a device fails, the user could let his/her mobile device resend a service request and select a new device serving for him/her. Based on [14], Chen *et al.* [15] add some other function. It adopts dynamic monitors which can supervise and control the devices providing service. The requester cannot control the service device. But the network topology is unstable, and the service provided by some devices will not be used. If the requester is always waiting for a service, it will increase the network load and service execution time.

Based on the above references, this paper studies the service scenario and system model and describes the establishment mechanism of recovery point in detail. According to the presented problem, this paper gives a service transmission and recovery strategy based on cluster or group in MSNS.

3. SYSTEM MODEL

In this section, suppose there is a service scenario of traveling group in MSNS. We design a system model for this scenario.

3.1. Scenario and Problem Description

In such a scenario, some travelers (for example, classmates of several classes of a college) take bus by group or form several groups based on interests. All the travelers carry some mobile devices including mobile phone, laptop or tablet computer. There are several dynamic groups, and the members of a group travel together. All kinds of services provided by mobile devices can be shared within a group. Several groups can also connect through some of the mobile devices, so there are many mobile ad hoc travel groups in the scenario.

In each group, there is a mobile leader responsible for managing and saving the service for its group members. A group is called cluster, a leader of a group is called cluster head, and the mobile devices of a group are called cluster members. Service discovery for a group is done by the cluster head who can establish relationships among groups. In this way, the services are shared by all the group members. The cluster head is responsible for cluster formulation, member enrollment and exit, service registration and network topology maintenance. Because the power and processing ability of a mobile device is limited, cluster structure makes the mobile device need not to save the whole network topology. In a large-scale dynamic network, cluster structure is conducive to effectively guiding the network traffic and saving service discovery time. As such, it is suitable for the scenario of group travel in MSNS. The selection of the cluster head and formation of the cluster is out of scope of this paper and will not be described here.

Mobile ad-hoc network (MANET) is a kind of typical network mode applied to the cluster structure. MANET is a peer-to-peer infrastructureless communication network formed by short-range wireless enabled mobile devices. In a cluster based on MANET, a user first sends a service request to the cluster head, and the cluster head discovers if there are required services. If there are no such services or not all the services are in its cluster, the cluster head will send the service request to other cluster heads. This process is repeated until all the required services are discovered. A cluster member can directly send service data to the requester within a cluster. The service provider outside the cluster of requester will send service data to the requester according to the request path, and the process perhaps experience transmission by more than one cluster head and relaying node.

In MANET, node mobility or power limitation may cause node failure, and the network topology will change with the node failure. Service data in the process of transmission will fail due to the change of network topology, which seriously affect the user's service sharing experience. This paper mainly studies how to transmit and recovery services data quickly and efficiently under the condition of service provider is far from the service requester.

3.2. System Model

System model is illustrated in (Fig. **1**), four kinds of nodes with oblique line shadow represent that they can provide four kinds of services. For example, nodes 1and 11 provide service S_1, nodes 2, 12 and 18 provide service S_2, node 9 provides service S_3, nodes 4, 10 and 15 provide service S_4. The nodes without shadows are relaying nodes which do not provide service and only relay data. The nodes with dot shadows are cluster heads including nodes 3, 7, 8, 13 and 17. The service requester is represented by node R.

This paper supposes that all the services provided for a user do not need order. That is, several services can send the service data to the requester concurrently, which uses multicast. When data flow through each node, the node will perform some operations, such as data processing or relaying.

Figure **1** explains the whole process of providing services for a user. Suppose a service requester R in the cluster is supervised by cluster head 17. First, R needs services S_1, S_2 and S_3 and sends a service request to cluster head 17. Second, cluster head 17 checks its service list and finds that node 18 can provide S_2. Node 18 is the neighbor of R and sends S_2 data to R. At the same time, cluster head 17 sends the service request to its neighbor cluster head 13 through relaying nodes 16, 14. Cluster head 13 also checks its service list and finds that node 11 can provide S_1. Node 11 will be required to send S_1 data to cluster head 13. Third, S_1 data can be return to R by node 13, 17. In the same way, S_3 can be discovered and transmitted to R by cluster head 8. Finally, R will receive all the services S_1, S_2 and S_3.

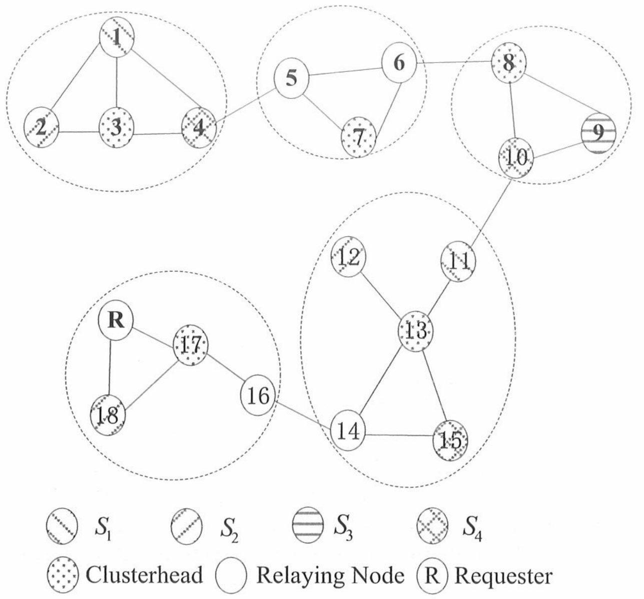


Fig. (1). System model.

4. ESTABLISHMENT MECHANISM OF RECOVERY POINT

In the above scenario of a user asking for several services, mobile devices may move out of the range of the service transmission path, or the power of devices may be exhausted. These situations will cause some mobile devices to fail to provide services or forward data, which will lead to the service path interruption. The network topological structure of MANET cannot guarantee reliable end-to-end transmission. So we need a recovery mechanism to deal with interruption of service transmission path and data loss problems. To improve the reliability of multicast, this paper proposes a recovery point mechanism.

4.1. Description of Establishing Recovery Point

Recovery points are nodes deployed in the service transmission path. A recovery point is responsible for the maintenance of the service data from the source node (service provider). Recovery point has the function of saving and forwarding service data: as soon as it receives all of the service data, it will send an acknowledgement message to its upstream recovery point or source node. After receiving acknowledgement message, the upstream recovery point deletes the service data from its memory. When the transmission of service data fails, this recovery point will retransmit the lost data for its downstream recovery point. The distance from the recovery point to the requester is less than the distance from the source (service provider) to the requester. Therefore the transmission time of the recovery point retransmission mechanism may be shorter than source retransmission. How to select and deploy recovery points in a service transmission path needs to be studied and discussed.

After establishing the service transmission paths, each mobile device acts as a different role during data transmission process. These roles include the cluster head, service provider, service requester and relaying node. Deciding which role should be the recovery point is critical. In a network based on cluster, the cluster head has more information about service registration and network topology than the other roles, so the cluster head can act as recovery point. In the whole network, however, there are many cluster heads, and not every cluster head can be a recovery point. The cost for saving service data and sending acknowledge messages is large, so we need to design a mechanism to decide which cluster head is the service recovery point.

The establishment mechanism of recovery point is described as follows.

1) Suppose that the distance between two adjacent cluster heads is one logical hop. Here the meaning of adjacent cluster head is not necessarily a link between the two cluster heads. Maybe there are multiple network links between adjacent cluster heads. That is, one logical hop consists of several network links. A logical hop field n (initial value is 0) is used to append to a service request.
2) The cluster head of a service requester finds if there are no required services or not all the services are in its cluster, the cluster head adds 1 to n and sends the service request to its first adjacent cluster head. On the path of transmitting the service request, every cluster head will adds 1 to n.
3) Suppose a parameter range [a, b], called window, is set for the logical hop field (a, b are positive integers). If a cluster head finds there are required services in its service list, it will let the service provider send service data. If there are no required services or not all the services are in its cluster, the cluster head adds 1 to n. Then it checks whether n is within the range of the window [a, b]. If n is not in this range, the service request will be transmitted.
4) If the cluster head find that n is within [a, b], we will see whether it is suitable for a recovery point. If the cluster head meets the criterion for a recovery point, it will be marked as recovery point. It will set logical hop field n to 0 and forward the service request to adjacent cluster head. If the cluster head does not meet the criterion, it only adds 1 to n and forwards the request.

To evaluate a cluster head, we can measure some performance values of cluster head i which can be used to determine if i is qualified to be a recovery point. Then the cluster head i can be evaluated quantitatively. These performance values include computing ability c, remaining power p, storage capacity s and failure rate f. A performance expression formula of a cluster head can be represented in (1).

$$F(i) = w_1 * c_i + w_2 * p_i + w_3 * s_i + w_4 * \frac{1}{f_i} \tag{1}$$

Ordinary mobile devices include laptop or tablet computer and mobile phone, *et al.* The devices' handling speed and ability are different. It is necessary to take computing ability as an evaluation index. Remaining power reflects how long the device will persist, which can be directly measured with storage capacity. Failure rate is recorded according to the previous failure of a cluster head. An evaluation value of cluster head i is obtained by computing formula (1). The bigger the value is, the better the performance of the node is. w is the weight of every performance parameter and satisfies formula (2).

$$\sum_{j=1}^{4} w_j = 1 \quad (2)$$

A threshold value (TH) is set in this paper. If we compute formula (1) and $F(i) \geq TH$, cluster head i can be marked as a recovery point. At this time, logical hop field n of the service request is set as 0, and the service request can be transmitted to adjacent cluster head.

5) When n increases and is equal to b, no recovery point has been found, that is, no cluster head meets the threshold within the range of the window [a, b]. Finding a recovery point is failed in this circle, we will wait to find until n is up to a next time. At this time, n is set as 0, the service request is transmitted to adjacent cluster head, and the next circle of finding recovery point begins. In this way, the service transmission path between service requesters and service providers will regularly produce multiple recovery points.

Please note that the value of window [a, b] determines the logical hop interval of establishing recovery point. The value should not be too large nor too small. For example, if [a, b]=[1, 2], a recovery point should be established every 1 or 2 logical hops, which will greatly increase the cost of the mechanism. If the values of a and b are too big, only a few recovery points should be established, which will decrease the reliability and efficiency of service recovery. So we set constraints for the value of window which is expressed as formula (3).

$$b - a < a$$
$$a > 0, b > 0, a \leq b \quad (3)$$

The goal of formula (3) is to make the value of the window more reasonable and to only find one recovery point in a window [a, b]. It does not increase much burden to the network.

Because the recovery point deployed in the network is movable and not static, it has an ability to work in any position flexibly. The recovery point can control the service data received from the service provider. In other words, once the recovery point receives from its upstream recovery point or the service provider, it assumes that it is responsible for transmitting the service data to the requester. So the recovery point is more intelligent than the traditional relaying node.

4.2. Process of Establishing Recovery Point

In order to understand the recovery point mechanism explicitly, (Fig. **2**) is used to illustrate the process of establishing recovery point.

5. SERVICE TRANSMISSION AND RECOVERY ALGORITHM

The service transmission and recovery process based on cluster in MSNS can be divided into two processes which include service request and service transmission and recovery. The two processes will be explained as follows.

5.1. Service Request

A service requester sends a service request to its cluster head requiring multiple services. This paper mainly studies the relationship among these required multiple services which is parallel rather than sequential. For example, a user asks for music files or electronic books stored in different mobile devices. Each of these music files or electronic books are independent and there are no requirement for them to reach the requester by sequence. Then these documents will be separately transmitted to the requester through multiple transmission paths.

Assume that the cluster members periodically register their services in the service lists of their cluster head. After receiving the service request, the cluster head of the service requester first checks whether there are required services in its service list. If there are required services in its cluster, the cluster head will let the corresponding service providers send service data to the requester. If there are no such services or not all the services are in its cluster, the cluster head will send the service request to adjacent cluster head. All the cluster heads receiving this request will do the same work until all the required services are discovered. Finally, several service transmission paths may be established. According to the description of section 4.1, multiple recovery points are established in a service path between the service provider and the service requester.

5.2. Service Transmission and Recovery

During the process of the service provider (source) sends back the service data along the service transmission path, the service data will encounter multiple recovery points. When the source's first downstream recovery point receives and stores the complete service data, it will send an acknowledgement message to its upstream source node. The message includes service ID, receiving time, data size, source and destination addresses, and so on. Then the current recovery point is responsible for maintaining, controlling and restoring the service data. When the current recovery point sends the service data to its downstream recovery point, if the downstream recovery point receives the entire service data successfully, it will also send an acknowledgement message to the current recovery point. After receiving the message, the current recovery point deletes the service data from its memory immediately.

When the current recovery point sends the service data to its downstream recovery point in a service path, the trans-

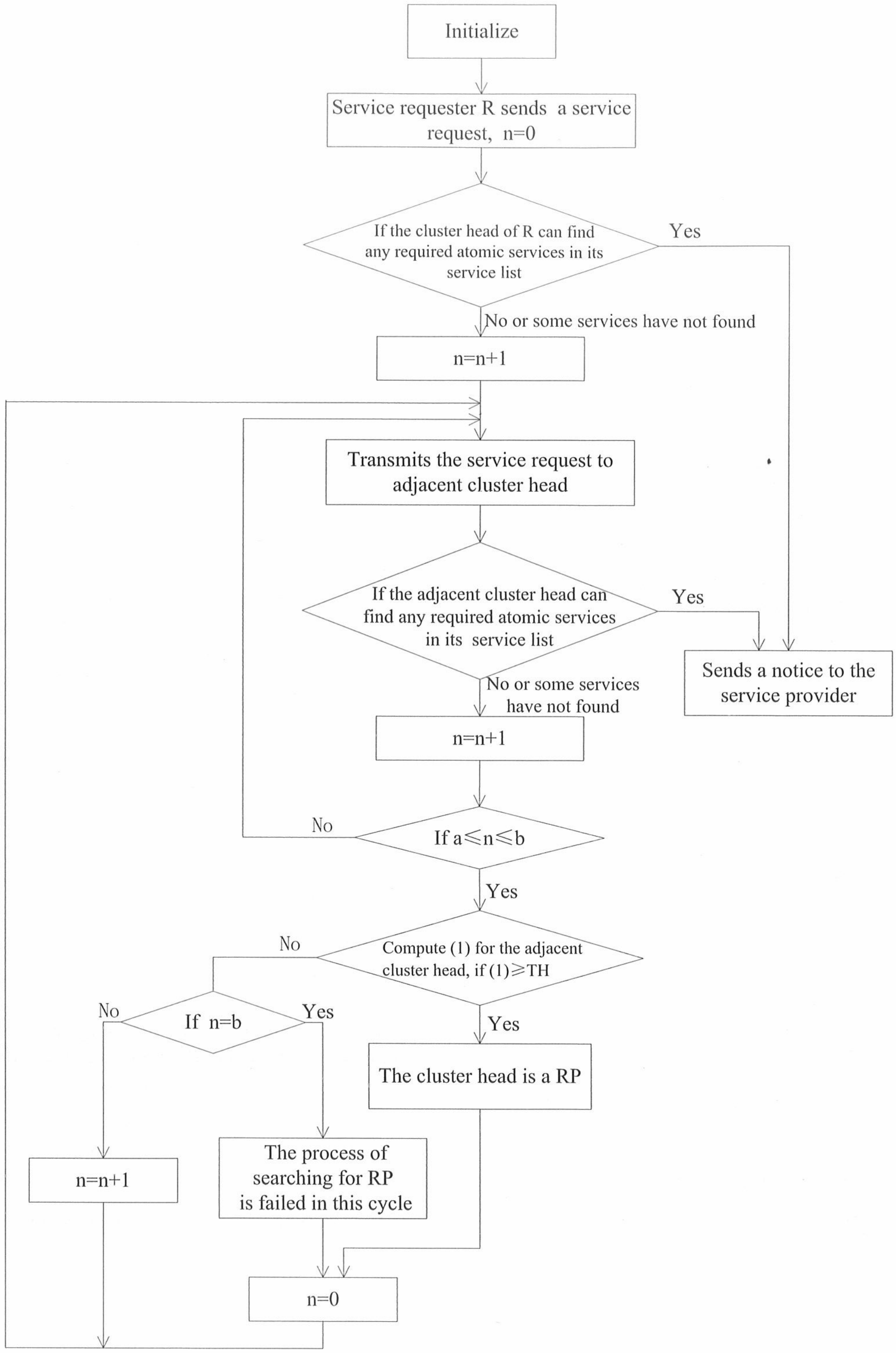


Fig. (2). Process of establishing recovery point.

mission is failed or the data is lost. The failure can be detected by setting a timer for the recovery point. If it does not receive the acknowledgement from its downstream recovery point in a specified period of time, it will directly recover the service data for the downstream. That is, it retransmits the service data immediately and does not inform the service provider.

Then, every recovery point transmits and recovers the service data to its downstream recovery point as described. Finally, the service requester receives the complete service data and sends the acknowledgment message to its upstream recovery point. At this time, this upstream recovery point deletes the service data, and a service transmission and recovery process ends.

The algorithm flow of service transmission and recovery is show in (Fig. 3).

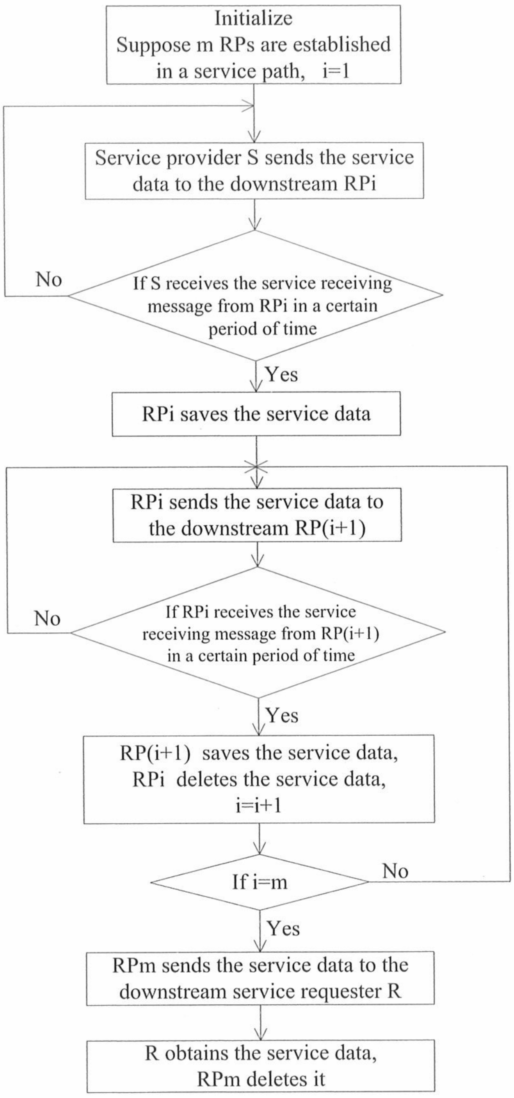


Fig. (3). Algorithm flow of service transmission and recovery.

5.3. Algorithm Analysis

The selection of recovery point is based on the performance of the cluster head. These points are more reliable. In the event of other situations, for example, if some of the recovery points fail or move in the process of forwarding service data, the requester does not receive a service for a long time. So the service requester also starts a timer after sending a service request. If the requester does not receive a service for a long time exceeding the timer, it will resend its cluster head a service request.

In a service path, the distance from the recovery point to the requester is less than the distance from the source (service provider) to the requester. When a transmission is failed, the service data is retransmitted by the recovery point rather than source. This method greatly reduces the transmission time and increases the probability of successful transmission, which is verified in the simulation experiments of this paper.

In some cases, several devices providing the same service satisfy a service request, and the first one to be found is the service provider. A recovery point may be on several service paths and serves different requesters and providers. These recovery points will distinguish the service data according to service ID, source and destination information, and so on.

6. SIMULATION EXPERIMENTS

6.1. Simulation Setup

In our simulation experiments, C++ language is adopted to program in VC++6.0. The moving range of nodes is $120\times120(m^2)$. The simulation experiments are executed in two kinds of networks which are sparse network (40 nodes) and dense network (80 nodes). All the nodes follow the random way mobility model (RWP) [16], and the requested services are random too. The transmission of a node is 30m. There are 10 kinds of services distributed in the nodes. For each service, there are 4 or 8 nodes as the providers in the two kinds of networks. The speed range of a node is from 1 m/s to 20 m/s. After a node moves for 2s, it will pause for 4s. Assume that the time of executing a service is 2s, the number of the concurrent requests to a node is 4. We use ad hoc on-demand distance vector routing (AODV) protocol. The simulation time is 300s. The parameter range [a, b] is set as [3, 5].

6.2. Simulation Process

The description of simulation process is as follows.

Step 1: initialize parameters and set the serial numbers for the 40 or 80 nodes, the coordinate value of each node includes X and Y value, the range is from 0 to 120. All the nodes are distributed evenly in the area. Node belongs to which cluster is based on its location distribution.

Step 2: utilize random function to generate random numbers. These numbers are used to generate the values of moving direction, speed and needing services.

Step 3: when a node sends a service request, set a time threshold value according to the requested service number. If the transmission time exceeds the time threshold value, the service request fails.

Step 4: if a service transmission interrupts, recovery begins based on the algorithm described in section 5.

Step 5: whether or not the recovery process succeeds, we should record the data result for each service request. The data include the serial number of each requester, the interruption number and transmission time. We mark the success or failure with 0 and 1, which are recorded too. When an experiment ends, we can get a data form.

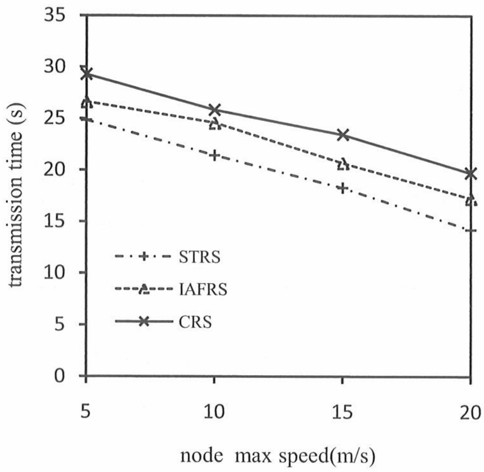
Step 6: revise the parameters and execute the experiment again.

6.3. Simulation Results

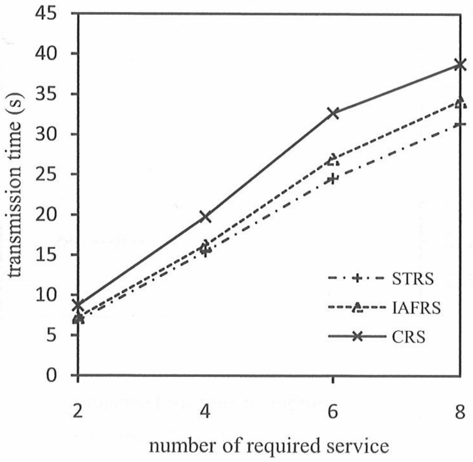
We compare the service transmission and recovery strategy (STRS) based on cluster with intelligent adjustment forwarding and recovery strategy (IAFRS) [11] and connectivity restoration strategy (CRS) [9]. Two aspects will be compared in the sparse and dense network separately for these strategies.

1) Transmission time

Service transmission time is a period from the requester sends a request to receive all the services successfully. Figure **4** is the simulation results of transmission time in the sparse network (40 nodes).



(1) node max peed change

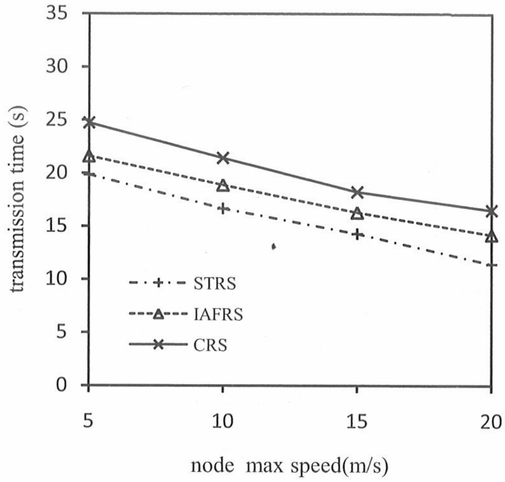


(2) Number of required service change

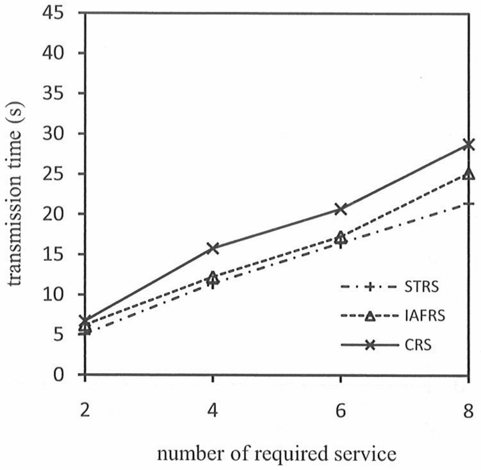
Fig. (4). Transmission time in sparse network.

Figure **4(1)** illustrates when the service requester demands 5 services, the service transmission time of three strategies change with the increase of node max speed. The transmission time of STRS is lower than IAFRS at ~6-18% and lower than CRS at ~15-28%. Figure **4(2)** shows the service transmission time of three strategies change with the increase of number of required service, in the case of node max speed is 15m/s. The transmission time of STRS is lower than IAFRS at ~5-10% and lower than CRS at ~19-25%.

Figure **5** is the simulation results of transmission time in the dense network (80 nodes). Figure **5(1)** is the service transmission time of three strategies change with the increase of node max speed when the service requester demands 5 services. The transmission time of STRS is lower than IAFRS at ~8-20% and lower than CRS at ~19-31%. Figure **5 (2)** is the service transmission time of three strategies change with the increase of number of required service, in the case of node max speed is 15m/s. The transmission time of STRS is lower than IAFRS at ~5-18% and lower than CRS at ~20-28%.



(1) node max peed change



(2) Number of required service change

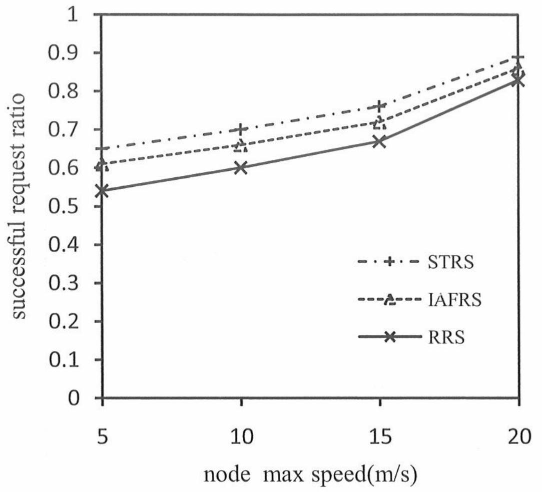
Fig. (5). Transmission time in dense network.

In general, under the same condition, the transmission time of Fig. **5**(1) is little less than that of Fig. **4(1)** and the transmission time of Fig. **5(2)** is little less than that of Fig. **4** (**2**). The reason is that in the same area, node density increasing leads to the service providers for each service increasing, and the service node can be discovered more quickly.

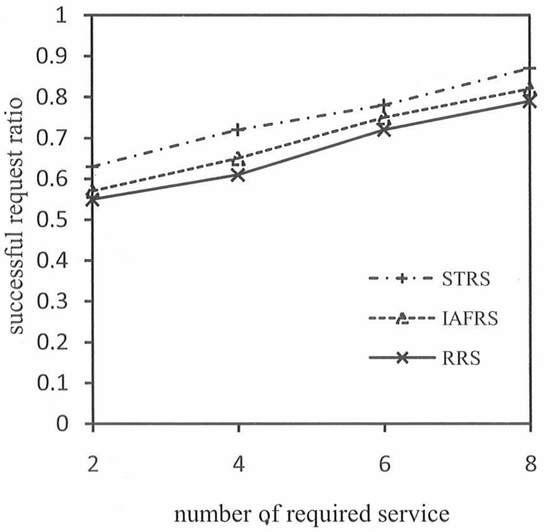
2) Successful request ratio

Successful request ratio is the ratio of successful requests number to all of the requests number in an experiment. (Fig. **6**) is the simulation results of successful request ratio in the sparse network (40 nodes).

Figure **6(1)** shows when the service requester demands 5 services, the successful request ratio of three strategies change with the increase of node max speed. The successful request ratio of STRS is higher than IAFRS at ~3-7% and higher than CRS at ~7-20%. Figure **6(2)** illustrates when the node max speed is 15m/s, the successful request ratio of three strategies change with the increase of number of required service. The successful request ratio of STRS is higher than IAFRS at ~4-11% and higher than CRS at ~8-18%.



(1) node max peed change



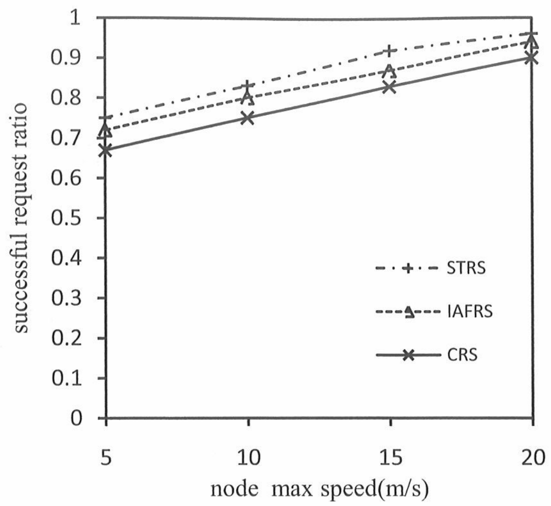
(2) number of required service change

Fig. (6). Successful request ratio in sparse network.

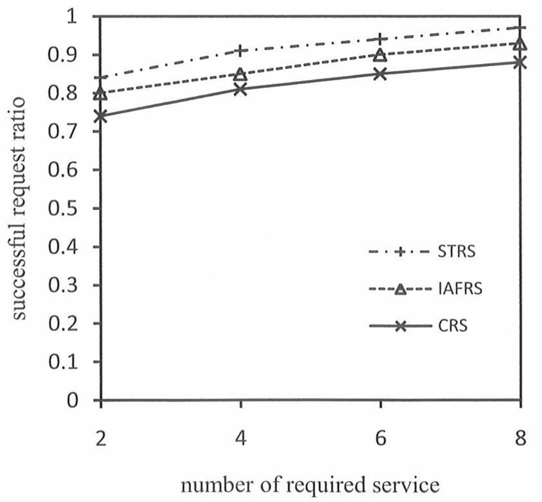
Figure **7** is the simulation results of successful request ratio in the dense network (80 nodes). Figure **7(1)** is the successful request ratio of three strategies change with the increase of node max speed when the service requester demands 5 services. The successful request ratio of STRS is higher than IAFRS at ~2-6% and higher than CRS at ~7-12%. Figure 7(2) is the successful request ratio of three strategies change with the increase of number of required service, in the case of node max speed is 15m/s. The successful request ratio of STRS is higher than IAFRS at ~4-7% and higher than CRS at ~10-14%.

The successful request ratio of Fig. **7(1)** is little higher than that of Fig. 6(**1**) and the successful request ratio of Fig. **7(2)** is little higher than that of Fig. **6(2)** under the same condition. In dense network environment, the probability of finding service provider is easier, and the service transmission paths increase. So the successful request ratio is enhanced in dense network.

From the above simulation results, we can see that the transmission time of STRS is less than other two strategies, and the successful request ratio of STRS is higher than others. The performance of STRS is the best among the three service transmission and recovery strategies.



(1) node max peed change



(2) number of required service change

Fig. (7). Successful request ratio in dense network.

CONCLUSION

During the process of service transmission and recovery based on cluster in MSNS, there are many causes of failures of forwarding service data. These causes include node movement, power exhaustion and other failures. Service retransmission method leads to high latency and reduces the efficiency of the network. Traditional local recovery service method involves a great deal of control messages. This paper presents the recovery point which is responsible for retransmitting the lost service data received from the service provider. The recovery point is able to save and maintain the service data flexibly. When the service transmission fails, the upstream recovery point can resend the service data to the downstream recovery point. This strategy saves transmission time and improves the probability of successful transmission. It is able to provide effective, low cost and stable services for users.

CONFLICT OF INTEREST

The author(s) confirm that this article content has no conflicts of interest.

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