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A New Mobile Peer-to-Peer Architecture

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Abstract: - *With the increasing diversity and quantity of mobile terminals, the demand of new applications in the mobile networks has become increasingly high. However, due to the limitations of mobile devices, such as bandwidth, storage, and computation capability, and unpredictable connectivity, the development of new applications is restricted. In order to address this problem, we present a new scalable and reliable mobile P2P network architecture which is composed of cellular Ad Hoc network, wireless access network and 3G core network. Our objective is to emphasize both scalability and reliability issues of searching sharing resource index information in a cost effective way. In this system, an index server is connected with a GGSN in each PLMN to provide the sharing resource index information. We have evaluated the proposed system by comparing the index server searching mechanism with the general flooding searching mechanism. The results show that our design significantly improves the energy cost and the system scalability.*

Key-Words: -Peer-to-Peer; 3G Network; Ad Hoc Network; Distributed Hash Table; Flooding; Overlay

1 Introduction

With the increasing diversity and quantity of mobile devices, more and more users are seeking new applications derived from new technologies, and mobile data networks such as GPRS, UMTS enable the use of P2P technique. However, due to the limitation of devices, such as computation capability, bandwidth, storage, unpredictable connectivity, it maybe arise the phenomenon such as easy draining of the power and high costs to the user may arise as described in [1].

There are some papers that involve the architecture of mobile P2P. For instance, [2] describes a hybrid mobile P2P architecture, in which mobile devices share pressed data. This architecture can be accessed by other devices. Nevertheless it must provide the mechanism of publishing and broadcasting to improve the discovery of a semantic resource. In [3], MOTION access control system develops a service architecture for mobility collaboration. This architecture supports different devices and considers different connection patterns. The deficiency of these schemes along with the general infrastructure of resource discovery mechanism makes these schemes be unsuitable for the discovery of large dynamic P2P networks. Therefore, it is very necessary to present an effective discovering and locating resource mechanism in mobile P2P networks.

In this paper, we present a new architecture for mobile P2P, where an index server in each PLMN network stores resource index information provided by the peers who voluntarily provide the sharing resources in mobile P2P networks. The needed resources are located by the index server, and to some extent, it can effectively remedy the deficiency of mobile terminal devices and wireless network.

The rest of the paper is organized as follows.In section 2, the mobile P2P architecture is suggested. In section 3, Communication in the proposed system is discussed. The performance analysis is depicted in section 4, and the simulation results are given in section 5. Finally, conclusions are made in section 6.

2 The mobile P2P architecture

Fig.1 illustrates the suggested architecture of the mobile P2P system. This architecture is composed of three parts: (1) cellular Ad Hoc networks; (2) wireless access networks, which consist of several Node B, Iub interfaces and radio networks controller (RNC). They are used to process all functions relative with wireless access netwrok. (3) Core networks which are composed of SGSN and GGSN are in charge of processing all the voice and data connectivity in WCDMA system as well as switching and routing with outer networks.

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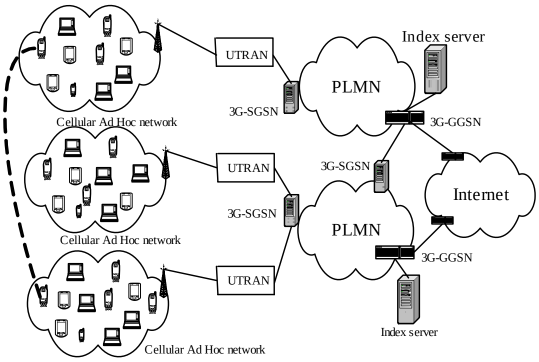

Fig.1 The architecture of mobile P2P system

The most important characteristic of this architecture is that an index server is connected with a certain GGSN in each PLMN network, which is used to maintain the sharing resource index information provided by the peers who voluntarily share resources with other peers. With structured P2P protocol, all index servers in all mobile networks can communicate with each other, therefore, resource index information needed by a peer can be found by its home index server.

2.1 Cellular Ad Hoc networks in mobile P2P system

In each cellular Ad Hoc network, we assume that the mobile devices use WLAN technique, e.g., 802.11g/b, to communicate with each other, and form a self-organized network. WLANs have higher data transmission rate. For example, the rate of IEEE 802.11b can reach 11 Mbps, more than 28 times higher than in W-CDMA networks for 3G service, where transmission rate is only 384 kbps. And the transmission rate of IEEE 802.11g can even reach 54 Mbps. It enables not only voice but also multi-media real-time transmission; and the pecuniary cost is lower, which is a very important factor for the downloading of files among large number of peers. Undoubtedly, it is very significant that the advantage of high transmission rate and low consumption in Ad Hoc network can be adopted to the applications that peers use to communicate with each other.

Nevertheless, Ad Hoc networks have also disadvantages of high mobility. Because the distance that peers can communicate with each other is very short, the frequent movement of peers causes unpredicted joining or leaving the Ad Hoc network, which may result in congestion inside Ad Hoc networks. Furthermore, Ad Hoc networks don’t have the ability of handover or roaming like cellular networks. In cellular networks, peers can have frequent mobility. And currently the cellular networks cover almost all areas where people can reach, but the data forwarding rate is very limited. Therefore, [4], [5] and [6] proposed some research on combining cellular networks with Ad Hoc networks. They mainly concentrate on how to improve the performance of cellular networks through Ad Hoc networks. However, as far as mobile P2P is concerned, its main applications are file sharing and multimedia service.

Due to the advantages and disadvantages of Ad Hoc and cellular networks, we design a reasonable mobile network to ensure that peers can communicate with each other. Due to the limitation of data forwarding rate in cellular networks, the multimedia and real-time communication service such as Video or Audio, which has a large amount of information, can directly run through Ad Hoc networks but not cellular networks. Therefore, the problem that the communications among peers must run through base stations, which may become communication bottleneck, is resolved.

In Fig.1, peers in mobile networks have two communication access techniques, one is the short distance communication interface (IEEE 802.11), and the other is the mobile network communication interface (3G).

The actions on the IEEE802.11g interface of each peer include as follows:

- To find the peers which can communicate with it, that is, the neighbor nodes;
- To establish a reliable communication connection with other peers, and form a self-organizing network. Therefore, the communications among peers can be progressed by multi hop in cellular Ad Hoc network.

The actions on the 3G interface of each peer include is as follows:

- To activate a PDP context request, designating that the type of PDP is IPv6, and notify the GGSN through the base station, and gain an IPv6 address from GGSN;
- To receive the request on the sharing resource index message broadcasted by index server in the home PLMN;
- To send the sharing resource index information provided voluntarily by the peers and their IP addresses (which is gained from GGSN in the home PLMN), as

well as their and their neighbors to the index server in the home PLMN;

- To send the requests on the sharing resource index information to the index server in the home PLMN;
- To receive the searching peers from the index server;
- To communicate with the peers in other cellular networks.

2.2 Index Server

The functions of Node B, Iub interface and radio networks controller (RNC) are presented in [7]. In the suggested architecture, we use an index server connecting with a certain GGSN in each PLMN network to maintain the relative index information of sharing resources provided by the peers in the PLMN network. Here, the index information includes the file names of resource sharing information, such as films, games, MP3, and even the documents, and the IP address and the ports belonging to the peers which voluntarily share resources, as well as the IP addresses of the peers' neighbor. The format of the index information in the index server can be seen from Fig.2, where MetaData i denotes the

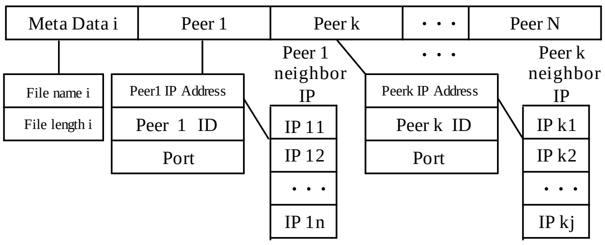

Fig.2 The format of the index information of Meta Data

name of the sharing resources, and peer 1, peer 2,⋯, peer N mean that they can provide the contents of MetaData i.

The communication process between the index server and the peers in the home PLMN network can be seen in Fig.3. As shown in Fig.3, firstly, peers can achieve an IPv6 address from GGSN by activating the PDP context. The Index server sends request to peers which are ready to provide the sharing resource index information in each Cellular Ad Hoc network of the home PLMN network. If peers would like to provide the sharing information, they will send responding information to the index server along with the resource index information which they would share. In 3G cellular Ad Hoc networks, because the range covered by the Base Station is very extensive, there may be a large number of

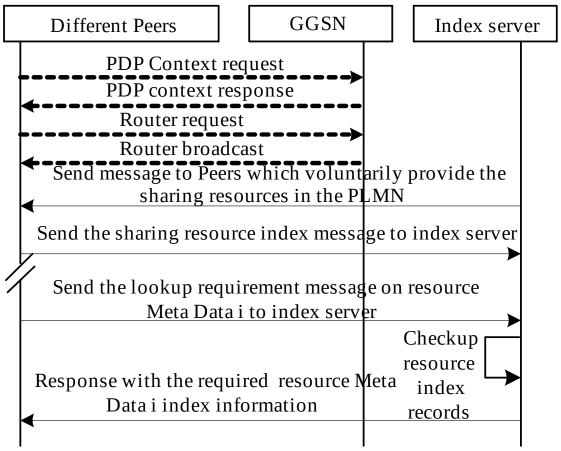

Fig.3 The communication process between the index server and peers in home PLMN network

peers, and these peers may offer a lot of different sharing resource index information. If these sharing index information are collected, the data would be enormous; furthermore, resource index information provided by peers may be fuzzy, such as the name of the resource is not integrated. To provide the resource index information for requesting peers, ideally the data mining technology [8] such as counting, clustering and prediction is needed to process the index information provided by peers.

At the same time, the index server classifies which cellular network peers belong to according to the IP address provided by each peer. This task needs the GGSN that assigns the IP address along with HSS to be completed. When a peer needs some information, it just sends a request to the index server, and the index server quickly searches the maintained list and returns the result. Therefore, the peer must not use the flooding mechanism to search other peers in the whole mobile network to get the relative resource index information just like other P2P file share applications. But enough memory space and process capability of the index server is essential to process all the information of peers in the PLMN network.

2.3 Structured P2P (index servers)

Just searching resource index information in a single PLMN network is not enough. When there are no resource index information records in a PLMN network, and if the index servers cannot communicate with each other, the peer can only search the information in the whole mobile network by using the flooding mechanism [9]. However, considering energy

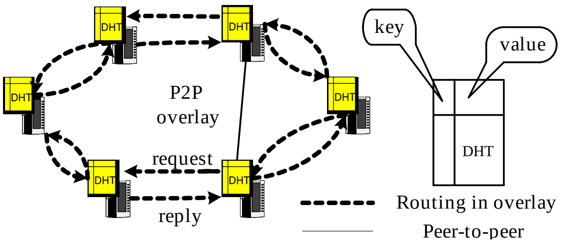

Fig.4 The relationship of index servers in the whole Mobile P2P network

efficiency, the cost of radio bandwidth, the fare that users should pay and the searching efficiency, this resource discovering mechanism is too expensive. Hence, index servers in the whole mobile network are self-organized by structured P2P Protocol such as Chord [10] to a P2P Overlay network. The index servers in the whole mobile network can communicate with each other by maintaining a DHT(Distributed Hash Table). The relationship of the index servers in the whole mobile network is shown by Fig.4. In this, each index server maintains a DHT to store a pair of (Key, Value), where, Key is the identifier of Meta Data used to search the sharing resource, and Value is the index information of the peer which voluntarily provides the sharing resource.

There are two operation processes between the index servers: Request (Key) and Reply (Key, Value). When the resource index information needed by a peer cannot be found in the local index server, this local server will send a Request message to other index servers. A certain index server who receives the Request message will search its lists, and if it has the index information, it will return the Reply message to the requesting index server; if not, it will transmit the Request message to its neighbor index server until the index information is found, and returns the results to the original index server.

3 Communication in the proposed system

In the mobile P2P system, because the target resource index information needed by a peer may situate in different PLMN networks, communication processes among peers should be considered in detail, along with the whole performance of the mobile network and the behavior of the users.

When the requesting resource peer is situated in the same cellular Ad Hoc network with the target peers returned by the local index server, they will communicate with each other inside the local cellular Ad Hoc network. Therefore, the bottleneck problem incurred between peers which run through the Node B is avoided, and it saves users' time and money.

Due to the unpredictable joining or leaving of mobile peers and the limit of the radio network bandwidth, communication delay between peers may be relatively long. For lots of multimedia and real-time services in the mobile P2P system, long delay is intolerable. In the mobile P2P system suggested in this paper, in case the requesting peer is situated in the same PLMN but in a different cellular Ad Hoc network with the target peers returned by the local index server, the SIP protocol is used to make a session control between the two peers before the data communication begins. The session control intends to reserve the communication resource to guarantee the bandwidth and the delay between the two peers. Fig.5 describes the process of the session control setup and the process of data communication between two peers in different PLMN network.

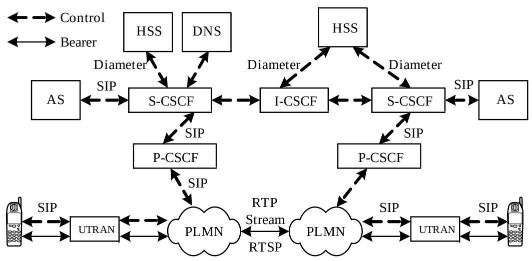

Fig.5 Session control setup and data communication between two peers in the different PLMNs

4 Performance Analysis

Since energy consumption of mobile terminals is one of the most important issues needed to be considered in designing mobile P2P networks, and it is widely regarded as the most important factor for assessing the superiority of the mobile P2P network, we analyze the energy consumption model in cellular networks, and compare the energy consumption using the index server searching in the proposed architecture with the flooding searching mechanism.

According to [11], the energy consumption which mobile terminals send, receive or discard data package is given by

$$Cost = m \times Size + b \qquad (1)$$

Where, $Size$ is the size of data package;

m is the additional energy consumption associated with the data package; and b is the indirect energy consumption of the data package; For data sending and receiving, parameters m , b can be chosen for variable values.

The energy consumption during the transmitting of data packages from one node to another can be given by

$$\omega(i, j) = Cost_{send} + Cost_{receive} \quad (2)$$

We analyze the energy consumption that a requesting data package consumes when the sharing resource exists in the same cellular network and two different cellular networks respectively. Here, we do not consider the energy consumption on the 3G core network.

(1) The energy consumption in the same cellular network

Assume that there are N peers in the cellular network, and M peers hold the resource which is needed by a certain peer. In addition, I is the number of intermediate transmitting nodes. $E_{flooding}$ and E_{server} denote the energy consumption on the flooding searching mechanism and the index server respectively, then:

$$E_{flooding} = I \times \omega(i, j) + (N - I - 1)Cost_{receive}$$
$$= ICost_{send} + (N - 1)Cost_{receive} \quad (3)$$

$$E_{server} = (M + 1)(Cost_{send} + Cost_{receive}) \quad (4)$$

(2) The energy consumption in the different cellular networks.

If the resource needed by a certain peer cannot be found in the home cellular network, the energy consumption using the flooding searching mechanism and the index server are $E_{flooding}$ and E_{server} respectively, then:

$$E_{flooding} = A[I \times \omega(i, j) + (N - I - 1)Cost_{receive}]$$
$$= A[ICost_{send} + (N - 1)Cost_{receive}] \quad (5)$$

$$E_{server} = (M + 1)(Cost_{send} + Cost_{receive}) \quad (6)$$

where, A is the number of the searched cellular networks.

5 Simulation Results

We have prepared a simulator based on the system description. It is assumed that there are *170* peers in each cellular network, and the area of each cellular network is *500m*500m*. The number of the intermediate transmitting nodes *I=1,8,16,24,32,40,50,60,70, 80,90, 100, 120, 140,160*, and the number of the holding resource nodes *M=1,8,16,24,32,40, 50,60, 70,80,90,100, 120,140,160*; when peers send a data package, the parameter *m=0.000405J/B, b=0.067594J*, when peers receive a data package, *m=0.000157J/B, b=0.037701J*. In addition, the number of cellular network *A=1,2*.

The experiment results are described as follows:

(1) Searching in the same cellular network

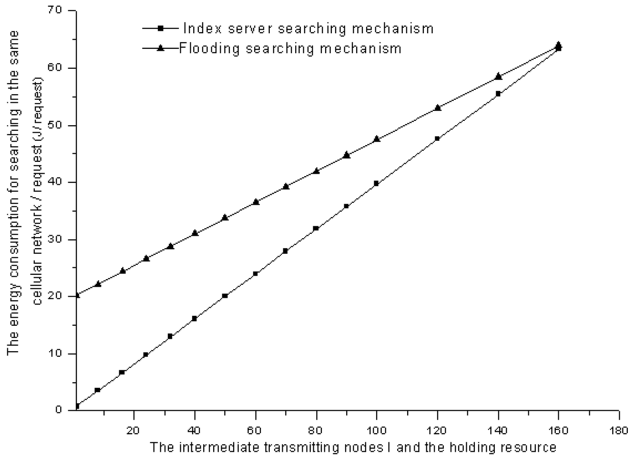

Fig.6 The energy consumption using two different searching mechanisms in the same cellular network

As shown in Fig.6, in the home cellular network, when the number of intermediate transmitting nodes I increases, $E_{flooding}$ increases too; when the number of the holding resource peers increases, E_{server} increases linearly too. When the index server mechanism is adopted, the energy consumption is less than that when the flooding searching mechanism is adopted; when M is close to the number of the total peers in the cellular network, for both searching mechanisms, the energy consumption is approximatively equal.

(2) Searching in the different cellular networks

As shown in Fig.7, when the resource needed by a certain peer cannot be found in the home cellular network, for the index server, the peer only sends a request to the index server in the PLMN, and receives the searching results returned by the index server, therefore, E_{server} is only correlative with the current cellular network which holds the resource needed by the peer. For the flooding mechanism, the searching process implements first in the home cellular network. When the needed resource is not in the home cellular network, the process continues in other cellular networks, until the needed resource is found, thus $E_{flooding}$ is correlative with the number of the searched cellular networks. If the searched cellular network number is *A*, then the energy consumption is *A* times the size of that of the home cellular network.

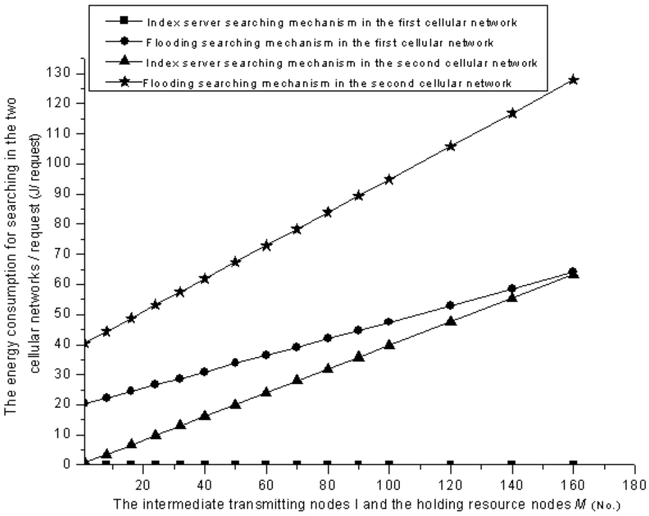

Fig.7 The energy consumption using two different searching mechanisms in two cellular networks

6 Conclusions

In this paper, a new architecture of mobile P2P system is presented, which is composed of Cellular Ad Hoc networks and 3G network. An index server manages the sharing resource index information provided by the peers voluntarily. At the same time, all index servers in the mobile P2P network can communicate with each other to search resource index information. The suggested sytem implements a simple and efficient searching method in the whole mobile network. Simulation results show that, comparing with the flooding mechanism, the index server searching method in the proposed system significantly improves the energy cost and the system scalability.

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