國立交通大學

網路工程研究所

碩 士 論 文

一個無線隨意網路上支援 P2P 即時多媒體系統之跨層機制研究

A Cross-Layer Scheme Supporting P2P Real-time Multimedia System over Wireless Ad-Hoc Networks

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摘要

P2P網路和無線隨意網路是近年來流行的技術。將擁有P2P應用程式的終端系統應用在隨意網路，已經被深入的研討了一段時間。然而，一開始大多數的研討都著重在無線網路上的檔案分享應用，近幾年來許多的研究轉移到多媒體在無線網路上之即時應用這個有趣的議題。這種應用包括支援群體通話，所以擁有此應用程式的使用者可以跟彼此互相溝通。此應用程式是設置在無線終端系統，因此，使用者除了群體通話外並且可同時做其它線上活動。

即使使用者可以藉由此種應用讓生活更方便有趣，但是讓應用層協定與網路層協定互相合作是顯著的阻礙。我們提出跨層的機制讓屬於上層的串流應用可以和下層的網路協定互相合作，並且架構無線點對點系統。我們所提出的方法中，P2P串流應用是具有對延遲敏銳、可擴展的、穩定的特性。因此，這個串流應用能讓使用者感受到良好的 Quality of Experience（藉由使用者接受度當成效能評估的準則）效能。

A Cross-Layer Scheme supporting P2P Real-time Multimedia System over Wireless Ad-Hoc Networks

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Abstract

Peer-to-Peer (P2P) and wireless ad-hoc networks are popular technologies in recent years. End system with P2P application deployed on ad-hoc wireless networks has been the subject of intensive studies for researchers for a while. However, most of studies before were concerned with file sharing application over wireless networks. Applying real-time streaming application on wireless P2P ad-hoc networks is an interesting issue that is noticed by researchers in recent years. This application system can support group communications, so users who are running the application can communicate with others in the group. Since the application is applied on wireless end system, users can do another online activity with the mobile devices while they are communicating with others.

Application protocol cooperating with network protocol is a big obstruction even if the application makes users living simple and convenience. Streaming application on the upper layer can cooperate with the lower layer protocol in a cross-layer scheme. In our proposed scheme, the P2P streaming application has the characteristics of delay-sensitivity, scalability, and good stability. As a result, the streaming application is really user sensitive with a good performance of quality of experience (QoE).

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Contents

Table List

Figure List

Chapter1 Introduction

Peer-to-Peer (P2P) computing or networking system is a distributed application architecture that partitions tasks or bandwidth between peers. Any peer in this system is equitable with each others. P2P shares resource (like computing power, network bandwidth, data, etc) among a great deal of users without assistance of definite servers. Thanks to the popularity of file-sharing applications on the Internet, such as Napster [1] and Gnutella [16], more and more researchers in recent years have been attracted by P2P systems. Moreover, several P2P applications, such as Skype [2], have been deployed in the Internet, especially in wireless network.

MANET is a shortened form of "mobile ad hoc network" [3]. MANET is a kind of wireless ad hoc networks that usually has a routing table in network environment of a link layer ad hoc network. A MANET is a type of ad hoc network that configure itself in wireless network. MANET is an infrastructure-less mobile wireless network, therefore any two nodes in the system communicates with each other through intermediate nodes. There is no central server, so every node with mobility has to work independently and automatically. Each node in MANET moves independently in any direction, and changes its links to the most suitable node periodically. The most importance in building a MANET is how to maintain the routing table and how the routing works, we'll speak about it later.

1.1 Background

Computer networking, simply referred to as network, is one of the most interesting and important technique in recent three decades. The Internet interconnects and shares the resources and information among computers and devices, and provides a global communication, storage, and computation infrastructure. There is more and more people need the Internet, hence, the number of the end systems grows exponentially. Thus it can be seen that the Internet is important for people.

People nowadays live a more and more hurried life style. It is such busy that people have little time to communicate with others face to face, not mention to make person to person social activity. Nevertheless, more and more people communicate with each other by the mobile devices through the Internet. Hence, the Internet is now being integrated with mobile devices and wireless technology. As a result people socialize when they take public transportation, walk on the street, and so on. They can virtually go anywhere with the Internet, because wireless network provides anywhere access for people. Wireless network has become a essential Internet access technology around the world.

Thanks to the explosive growth in the wireless network and mobile devices, real-time multimedia service is developed extremely quickly. This service makes people's life convenient. You can watch the live World Cup through Live streaming. You play interactive games with your friends on Face book or Twitter. You listen to new song of your favorite singer through Internet radio. These services are based on the well developed real-time multimedia application systems. Nowadays the multimedia application is an important part of our daily life and it makes us live more convenient.

1.2 Issues

Conference application on P2P has been very popular since year 2000 [5, 8], especially applying these kinds of applications on MANET. The impressively progress in wireless communication technology and the popular of mobile end systems helps deploying wireless networks widely. Although real-time streaming application over P2P applied to conference, relief system, and the other application is our main idea in the beginning, the main topic of this thesis is to develop a real-time streaming application based on Ring overlay, a P2P overlay we proposed in our scheme, over mobile ad hoc network (MANET).

Mobility is a characteristic of the end hosts in MANET. Mobile end hosts in MANET provide people another communication method. Sufficient bandwidth, good time sensitivity, and low packet loss rate are main issues when developing P2P real-time streaming application. Comparing with the wide area cellular data networks, such as 3G network, MANET features higher bandwidth and lower cost. As a result, real-time streaming application applied in MANET provides much better quality than in the wide area cellular data networks when transmitting data [6].

P2P networks and MANETs have been developed by different communities. On one hand, P2P networks are application-oriented overlays and have primarily developed over the wired network since then. On the other hand, MANETs are self-organization and infrastructure-less networks. Moreover, the basic elements of MANETs are user's mobile end systems. However, decentralized, autonomous (self-organization) and highly dynamic are in a quite similar way to MANETs and P2P networks [9]. To make our application performing easy and smooth, we take a good advantage of these characteristics from both networks.

Here is a scenario that shows the concept of real-time streaming application. A big earthquake just occurred and caused a disaster to the area. Rescue crews have to search the survivors while they have to communicate with each other when they work separately. However, there is neither cellular system nor Internet in the damaged area, due to the crash of the system. To overcome the challenge, every rescue worker may carry a mobile device that is equipped with P2P real-time streaming application. Therefore they can communicate with each others if they need any help or share some information during the rescue mission.

1.3 Motivation

P2P real-time conference streaming application over MANETs has a potential to simplify and facilitate people's daily activity, according to the advantages we mention above. It is also the motivation of our study. The major characteristic of our streaming application is the group collaboration. Everyone using the application in the network can talk to each other. User makes use of Skype [2] after connecting via end system with the Internet and logging in with an account.

Deployment of P2P application on wireless networks introduces several challenges. Though the application in our scheme is deployed on MANET, maintaining the node mobility is an important issue [7]. Since the structure of mobile devices is quite different with personal computers, power consumption is the weak point of the mobile devices. The limited memory and less powerful processor may affect the fluency of real-time streaming. Moreover, P2P technique and MANETs are infrastructure less nature, this is the challenge we first meet.

In our scheme, delay-sensitivity and loss-tolerance is concerned with the quality of real-time application, because real-time applications are based on user's sense. However, high-performance handheld mobile devices have had a great advance nowadays, limited memory and scare of batter power is no longer an important problem.

The basic concept of ring is to make peers form a logical ring overlay, so the distance between any two nearest peers (these two peers are mutually neighbors) can be shortened as small as possible. However, in reality the physical topology is usually not a round shape, because mobile devices move causing highly dynamic topology and it is another challenge to develop real-time streaming application on top of MANETs.

As a result, Ring overlay based on P2P structure over MANETs in cross layer scheme can conquer the challenges and solve the above problems. Reducing packet loss and shorten the transmitting delay of real-time data make the streaming application work smoothly. Ring overlay maintains the mobile peers being formed in a logical round shape by cross layer technique. Overcoming the challenges can make the performance of the application high as well as keep mobility efficient for the users. Additionally, it helps the users work effectively with mobile device. As a result, we use Ring overlay to manage peers in the application and use MANET to connect with nodes for routing.

1.4 Goal

In this thesis, when we refer end systems in application layer and network layer as *peers* and *nodes* respectively. In a cross layer scheme, round-trip delay time (RTT) value in network layer is passed through the other layers to application layer. RTT value is a key factor for peer management.

A cross layer technique is advantageous to Ring overlay in application layer, because we use peers to mange nodes in MANET. Moreover, P2P system is popular with scalability, fault-tolerance, and self-organization, similar with ad hoc network. Every peer receives some useful information from network and MAC layer so that peers only keep the information of the front peer and rear peer. We form Ring overlay into a logical circle shape that makes the data transmission efficient and smooth.

Though we want to combine two layers (network layer and application layer) technique so as to work together, these two layers have quite different capability. There are three layers between application and network layer, so we make these two layers communicate with each other directly in an effective way by designing a cross layer scheme. As a result, the management of peer is simple and efficient, and also streaming application can be a true real-time when transmitting data across the MANET. The contribution of this thesis is to develop a quality (user's sense) real-time streaming application in MANET completely.

According to the introduction of our scheme, we expect to achieve some important goals as follows:

1. Reducing the rate of packet loss and shortening the data transmitting delay make users senseless of this drawback.
2. Analyze the suitable number of peers that move in a fixed area or building.
3. Decide the best moment of processing the "maintaining Ring overlay" procedure.

Chapter2 Related Work

When it comes to streaming, Skype [2] is a quality P2P application comparing with other protocols. A number of studies have been devoted to bringing P2P file sharing protocols into ad hoc networks. Many of these studies are mainly conceptual, presenting architectural proposals but not evaluating them [28, 32, 34, 35, 36, 42]. Majority of studies tried to evaluate the performance of P2P file sharing over MANETs using Gnutella, Chord, Pastry, Free pastry and BitTorrent, respectively [27, 29, 36, 38, 39, 40] or proposed their own P2P file sharing algorithms [4, 30, 31, 33, 37, 41]. Minority of studies have been aware of P2P streaming over MANET.

In [9], P2P streaming over MANET really makes the streaming application efficient. Nevertheless, mesh is a kind of existing basic P2P overlay. Many characters, advantages, and techniques are quite similar with our scheme. The applications both based on P2P networks though the users are distributed. Streaming application is applied on MANET for user's mobility. Moreover, cross layer scheme is used in managing the network in our scheme. To produce a quality streaming with smooth mobility is the most important common interest.

Recently, the synergy between MANETs and P2P networks was very popular. P2P network has been researched widely, and many P2P systems are applied for researchers to share files [10, 11] or multimedia live streaming [12, 13] over the Internet. P2P can be classified into two kinds of applications as follows:

1. P2P file sharing, for example：Gnutella [16], BitTorrent [10], Chord [17], Pastry [18], Free-Pastry [19], KaZaA [20], and Tapestry [21]
2. P2P streaming application, for example：PPlive [12], Sopcast [22], Joost [23],

Coolstreaming [24], Peercast [25], and Zattoo [26]

Thus it can be seen that P2P network protocol has been studied intensively by many researchers. On the other hand, wireless network is also a active topic that attracts quite a bit of researchers to work on. Ad hoc network is one of a representative work of wireless network protocols. The routing protocol in ad hoc networks can be probably classified into the following types:

1. Proactive (table-driven) protocol periodically distributes routing table to maintain the routing paths of node and new lists of destinations. For instance, Destination Sequenced Distance Vector Routing (DSDV), Cluster-Head Gateway Switch Routing (CGSR), and Wireless Routing Protocol (WRP) belong to this type of protocol.
2. Reactive (on-demand) protocol finds a routing path on demand by flooding Route Request packets in the networks. For example, Ad hoc On-Demand Distance Vector Routing (AODV), Dynamic Source Routing (DSR), Temporally Ordered Routing Algorithm (TORA), Associativity Based Routing (ABR), and Single Stability Routing (SSR) are classified to this type protocol.
3. Hybrid (both proactive and reactive) Protocol combines the advantages of proactive and reactive routing protocol. Zone Routing Protocol (ZRP) and Zone-Based Hierarchical Link State Routing, and Dynamic Group Routing Protocol (DGRP) are this kind of protocol, for instance.

Although there so many variations in these protocols, no matter in P2P overlay or ad hoc routing, all of them have advantages and disadvantages in different opinions. Using the appropriate ad hoc routing protocol for the suitable P2P application is the most important issue. Table.2-1 and Table.2-2 show the classification of P2P applications and ad hoc route, respectively.

Table 2-1 The classification of P2P application

Application	File sharing	Streaming application
Operation mode	Download, Upload	Audio, Video
Instance	Napster, Gnutella, Bit torrent, Chord, Pastry, Free-Pastry, KaZaA, and Tapestry	Skype, PPlive, Sopcast, Joost, Coolstreaming, Peercast, and Zattoo

Table 2-2 Different routing protocol in MANET

Protocol	Proactive	Reactive	Hybrid
Operation mode	Periodically distributes routing table	Flooding with request packets	Combination of them
Disadvantage	1. Respective amount of data for maintenance 2. Slow reactive on restructuring and failures	1. High latency time in route finding 2. Excessive flooding can lead to network clogging	Chapter1 Advantage depends on number of nodes activated Chapter2 Reaction to traffic demand depends on gradient of traffic volume
Instance	DSDV、CGSR、WRP	AOVE、DSR、TORA、ABR、SSR	ZRP、DGRP

Chapter3 Proposed Scheme

We propose a new cross-layer scheme to overcome the difficulty of media streaming for P2P network over MANET. In our scheme, all peers self-organize a ring overlay structure to simplify the maintenance of the overlay. We apply the ring scheme to integrate the P2P overlay with the MANET topology. Due to the cross-layer integration, an immediate forwarding with proximity can achieve the low traffic overhead and fasten the in-time data delivery. The ring scheme loads less overhead, every peer in the network just needs to keep the information of the front peer and the rear peer. To construct the ring overlay, the underlay network dynamics, such as the topology and available bandwidth, must be known, such that the cross-layer information can be used for promoting the efficiency of the network. The value of round-trip time (RTT) is passed from the MAC layer to the application layer. The integration of the ring overlay and cross-layer scheme not only makes the system efficient, but also reduces the traffic overhead. As shown in Figure 3-1, we illustrate the fundamental structure to show the up-down stack, and then propose the followings in detail successively.

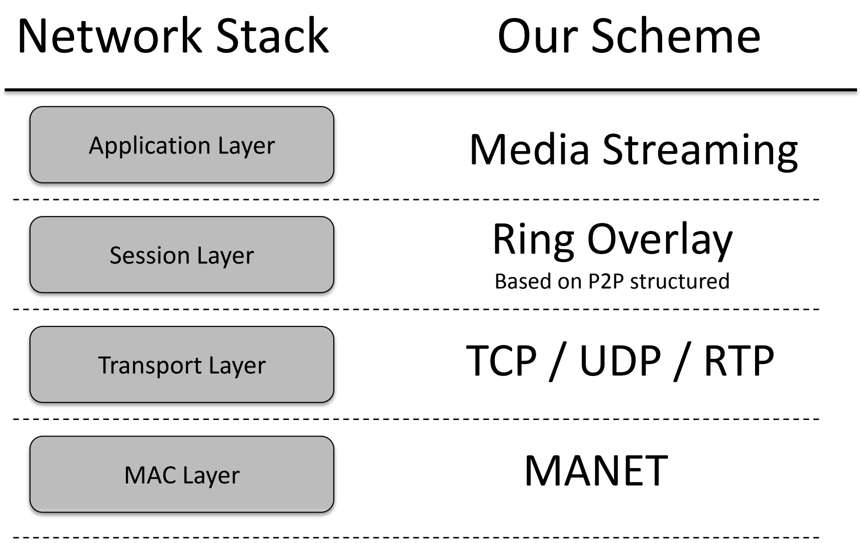

Figure 3-1 Frame structure of our scheme

3.1 System Stack

3.1.1 Application layer

The real-time multimedia service over wireless network is the major application of our proposed scheme. How to provide the smooth and live voice or video streaming in this wireless application is our main challenge. In general, the good quality of network can improve the playback smoothness. However, quality of service (QoS) usually reflects the network condition, while the users may prefer better quality of experience (QoE). QoS is consisted of network parameters, which are measured objectively, such as throughput, packet loss, and latency, but QoE is evaluated subjectively by real humans. To make the application perform easily and smoothly in wireless network, QoE is more important than QoS. To ensure acceptable of QoE when transmitting real-time data in wire network is easy whereas it is difficult in wireless network. As a result, transmitting the data in our scheme would be the bottleneck due to applying the application in wireless network.

With considerations mentioned above, a real-time streaming transmitted smoothly over wireless network is the major concern of our application. Users can hold the devices with our application to speak with each other whenever they move. Since the movement of the users is unpredictable, making a progress in such application is extremely difficult. The major challenge for P2P streaming is to offer users satisfactory QoE in terms of playback smoothness and average packet delay. In the proposed scheme, we keep the acceptable QoE instead of QoS.

3.1.2 Session layer

As we introduced above, P2P overlay management is quite suitable for streaming application. With scalability there is no limitation for the number of users in the network, because the more the user, the more peers able to forward data. As the number of peers grows, the messages sent or received by the peers grows significantly, decentralizing the messages is a strong point of P2P. Thanks to mobile devices that make inter-person communication more convenient, wireless network is getting more and more poplar in recent years. As a result, we use ad hoc mode instead of infrastructure mode in Wi-Fi or Wi-Max (we'll mention soon), and self-organization is one of the characteristic in P2P that really takes a good advantage of ad hoc mode. A reliable P2P overlay is created by a set of good peers so as to reduce the number of messages sent in the network and the number of request by peers. A load balanced P2P application equally divides the overhead of the network. Owing to these characteristic of P2P, we design a Ring overlay that tries to feature these good points every minute of dripping.

The main idea of our scheme is simple and efficient. The characteristic of the scheme we proposed is that all peers only keep the information of two peers, the front peer and the rear peer, in the P2P overlay. The streaming data can be forwarded in a short time, and the management of peers joining and leaving is performed as usual. In general, the simpler protocol is suitable for Internet. The complexity of maintenance for every peer is O(1) approximately in our scheme so the complexity of the system is O(n) approximately, while n peers are in the system. Since the real-time streaming application is applied on MANET, the number of users is limited by the size of network topology in MANET. On the other hand, the distance of every user in MANET is only several microsecond, the end-to-end delay won't be long and can be acceptable by users for real-time applications. Therefore, the P2P overlay we proposed can be deployed on the ad hoc network that we will explain later.

3.1.3 Transport layer

In our scheme, UDP and RTP are more suitable than TCP for forwarding streaming data immediately. In UDP and RTP packet loss happens more often than in TCP, consequently out-of-date information is not the issue we concern of in the live streaming. Using UDP and RTP not only shortens the transmission time, but also reduces the overhead of the traffic in routing. Though UDP and RTP provides real-time data transmission, sometimes TCP can be applied owing to the rate of packet loss in wireless network is higher than in wired network.

3.1.4 MAC (network) layer

As previously stated in the session layer, the ring overlay based on P2P structure we proposed is quite simple and easy to maintain and create. Because of these advantages, the routing in the ad hoc as well as the routing table of the nodes that involved in the Ring overlay in the network layer can be simply constructed. Hence, the routing of the data can be speeded up, and the routing table will be easily managed in the whole topology. To save costs, every node broadcasts once instead of floods recursively the data to other nodes. As a result, the cost of network traffic, system overhead, and the message loading is significantly low.

The scheme we proposed is robust and available because it makes not too much difference to deal with the MAC layer whether it is in WiFi ad hoc mode or WiMAX ad hoc mode. The two possible differences in these two modes may be transmission speed and transmission range. Nevertheless, our routing is in ad hoc mode, the transmission range of WiFi is limited; the data forwarding of the voice streaming doesn't need too much bandwidth, hence the speed of WiMAX (802.16e offers 128/56 Mbit/s) in ad hoc mode wouldn't be the bottleneck.

Both 802.11 (which includes WiFi) and 802.16 (which includes WiMAX) define Peer-to-Peer (P2P) and ad hoc networks, where an end user communicates to users or servers on another Local Area Network (LAN) through its access point or base station. Though there is just a little difference between using WiFi and using WiMAX, adapting different IP address schemes to the Ring overlay is quite different, such as IPv4 and IPv6. VoIPv6 provides better QoS, scalability, reachability, end-to-end interworking, and security than VoIPv4. Implementing QoS with the assistance of classification and marking, IPv6 provides a reliable VoIP infrastructure. IPv6 prioritizes packets better than IPv4 and scales up the network topology. IPv6 with the redesigned header can speed up their path through the router therefore it performs the real "end to end" delivery. Due to these advantages in IPv6, traffic flow of live real-time application is more efficient and system overhead is reduced for VoIP.

3.2 Cross-layer scheme

3.2.1 Overlay construction

In the beginning, there must be at least one peer in the topology and initiate the P2P application in our proposed scheme. If another new peer joins and contacts the peer that is already in the network, then the next process would be the same as the "peer join" steps that we mentioned in the next part. Once the new peer joins in, there are only two peers in the network, and these two peers would establish a ring overlay and are mutually the front and the rear peer. As the new arriving peers join one by one, every peer would connect to two nearest peers that it could attach to. All peers periodically broadcast a message that is the measured RTT (round trip time) of the nearest peers. For example, as shown in Figure 3-2, assuming that there are 8 peers in the topology, peer 1 connects to peer 2 and peer 8, the rear and the front peer, respectively. The data from the sender is forwarded all the way down to its rear peers until the sender receives it again. For example, peer 8 speaks firstly and delivers the dialogue to peer1, peer2, peer3, peer4, peer5, peer6, and peer7 one by one. Once peer7 receives the dialogue and delivers it back to peer8, peer8 recognizes the data that is sent by itself and drops the data immediately.

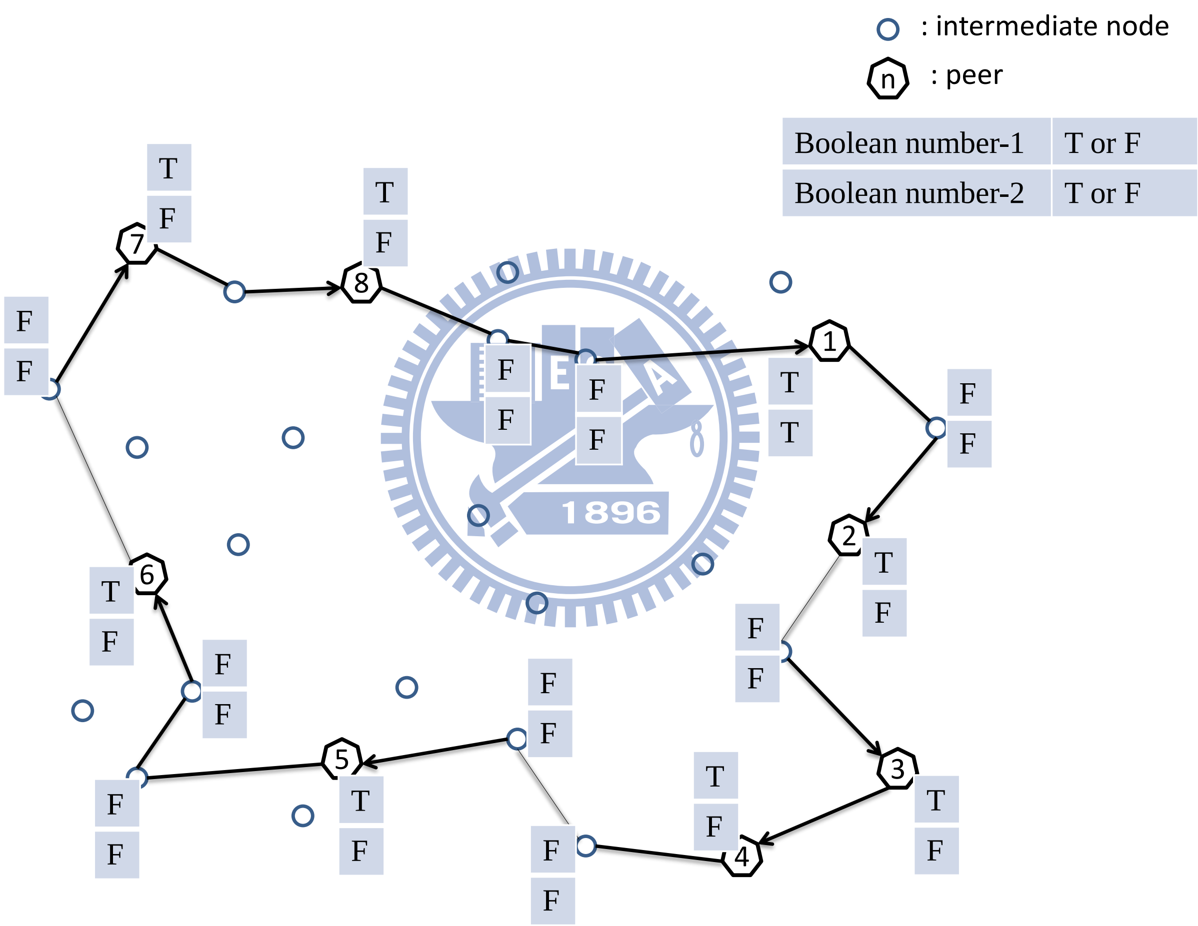

Figure 3-2 Ring overlay in our scheme

Every peer that joins ring overlay in the beginning generates automatically an 8-bits random number. It is the identification of peers in the system. We use a true or false Boolean number-1 to distinguish whether an end system is a peer in Ring overlay or just a node in the mobile ad hoc topology. If a peer joins in ring overlay firstly, it tries to find other peers nearby. Once it can't find any one, it floods request messages to all the nodes in the network topology to find peers nearby. If it can't still find any peer in the whole network topology, it means this peer is the first peer in the Ring overlay. We recognize that this peer is the builder of Ring overlay, and use a Boolean number-2 of true to represent it. This mechanism can avoid building two Ring overlays in a mobile ad hoc network. Moreover, once an end system joins in Ring overlay successfully, it changes the Boolean number-2 from false to true. It tells other end systems that it is a peer in ring overlay now. The Boolean numbers in every peer are shown as below：

Boolean number-1：If it is true, it is a peer. Otherwise, it is just a node.

Boolean number-2：If it is true, it is a ring overlay builder.

As figure 3-2 shown, peer1 is the first peer in the system, so it is a Ring overlay builder and the Boolean number-2 is true in peer1. However, peer2, peer3, peer4, peer5, peer6, peer7 and peer8 are not peer builder in the beginning but they are normal peers in the system. The Boolean number-1 of peer2, peer3, peer4, peer5, peer6, peer7 and peer8 is true but the Boolean number-2 of peer2, peer3, peer4, peer5, peer6, peer7 and peer8 is false. Both Boolean number-1 and Boolean number-2 of intermediate node are false, since they are neither peer builder nor normal peers.

3.2.2 Peer join

3.2.2.1 Normal example

If a new peer wants to join the ring overlay, (1) it broadcasts *Request Message* to all peers that it could reach in one hop. Once these peers receive the *Request Message* and respond with *ACK Message*, then new peer knows the amount of peers that it may connect to. Hence, (2) new peer unicasts a *Measure Message* to each of these peers for measuring RTTs of each peer. As a result, the new peer gets the information (i.e. RTT) of its neighbor peers and determines the smallest value of these RTTs. At the moment of getting the information, (3) *Update Message* is passed from transport layer to application layer through the cross-layer message. The new peer connects to the Ring overlay firstly by (4) sending a *Join Message* to Receiver1 and receives a *Reply Message* from Receiver1. This is the first connection in the Ring overlay for the new peer. The (5) *Reply Message* responds the information about Receiver1's front and rear peer, and we assume Rear peer is Receiver1's later as Figure 3-3 shows.

The new peer determines the smallest RTT value of the two peers in (6) *Algo1*, and decides to build the second connection to the smaller one. At the moment, the new peer also knows the direction of the data streaming. As Figure 3-4 shows that the direction of the data streaming is clockwise now. After the new peer sends a *Connect Message* to Receiver1, the *Connect Message* is forwarded to the rear peer by Receiver1. Whenever Rear peer receives *Connect Message*, the new peer also recognizes Receiver1 and Rear peer as its front peer and rear peer respectively. Finally, the new peer can join the Ring overlay successfully.

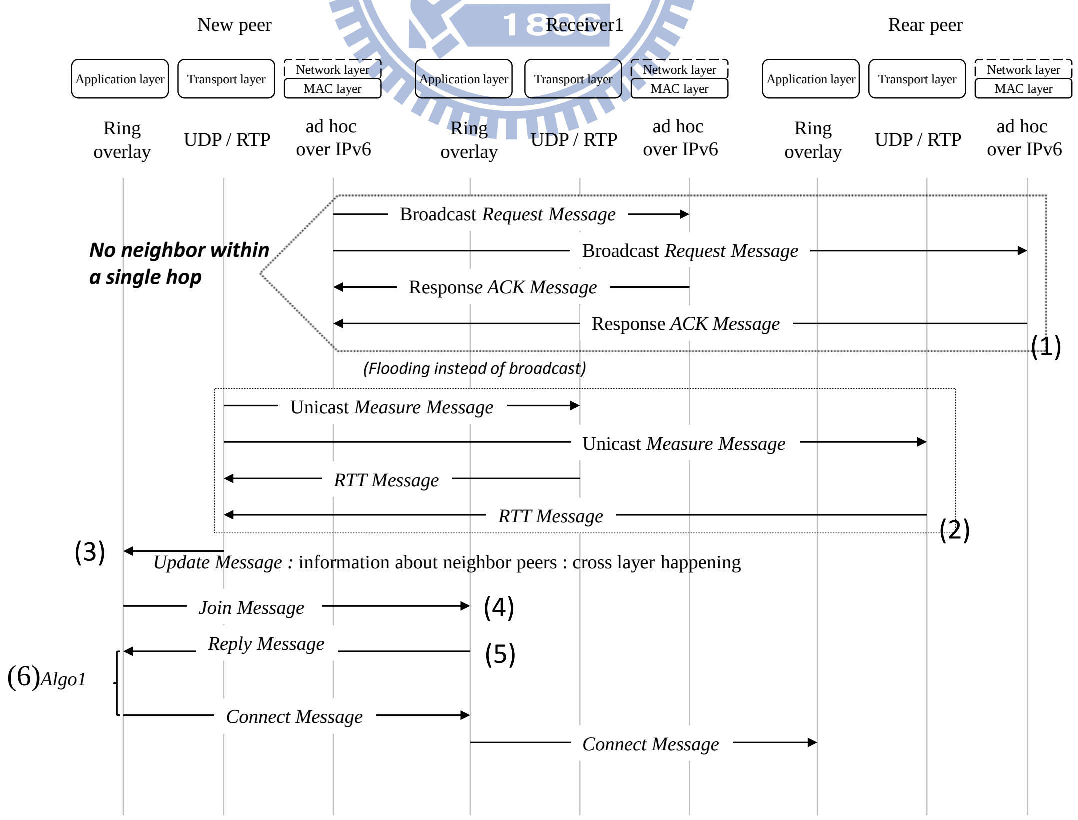

Figure 3-3 Message flow chart of peer joining

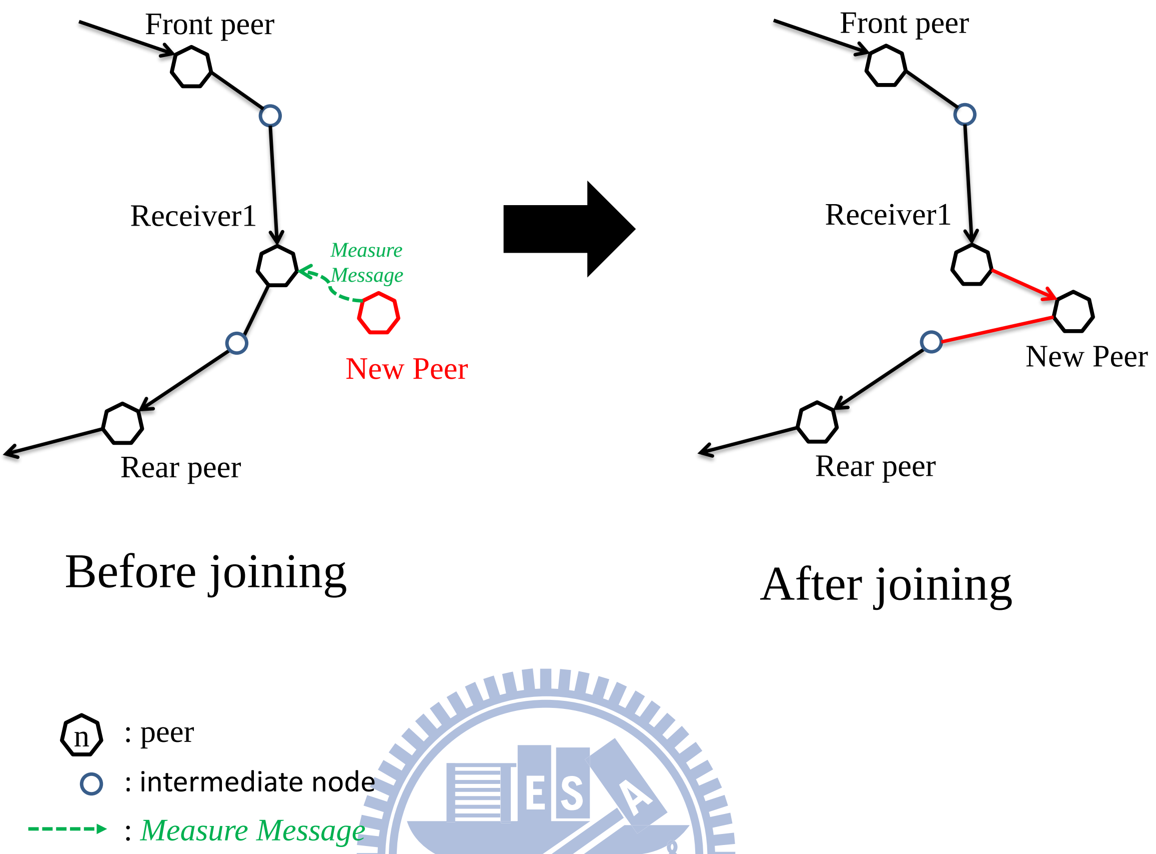

Figure 3-4 Diagram of peer joining

3.2.2.2 Abnormal example

Sometimes there would be an accident, just like the following case. A New Peer wants to join in, but there are not any peer could be attached by only one hop. The New Peer would terribly flood the *Request Message* to all peers in the whole network just for finding the nearest peer as shown in Figure 3-3 with the dotted line.

Figure 3-5 shows that a new joining peer couldn't attach to the existing peer with one hop. The new peer could not connect to the existing peer because there are not enough intermediate-nodes for the new peer to join in the Ring overlay. Peer A and B are the existing peers in the Ring overlay, however peer C is the new peer that couldn't attach to peer B by any intermediate-nodes. This would be the worst case of the peer joining because the overhead of sending the *Request Message* is large.

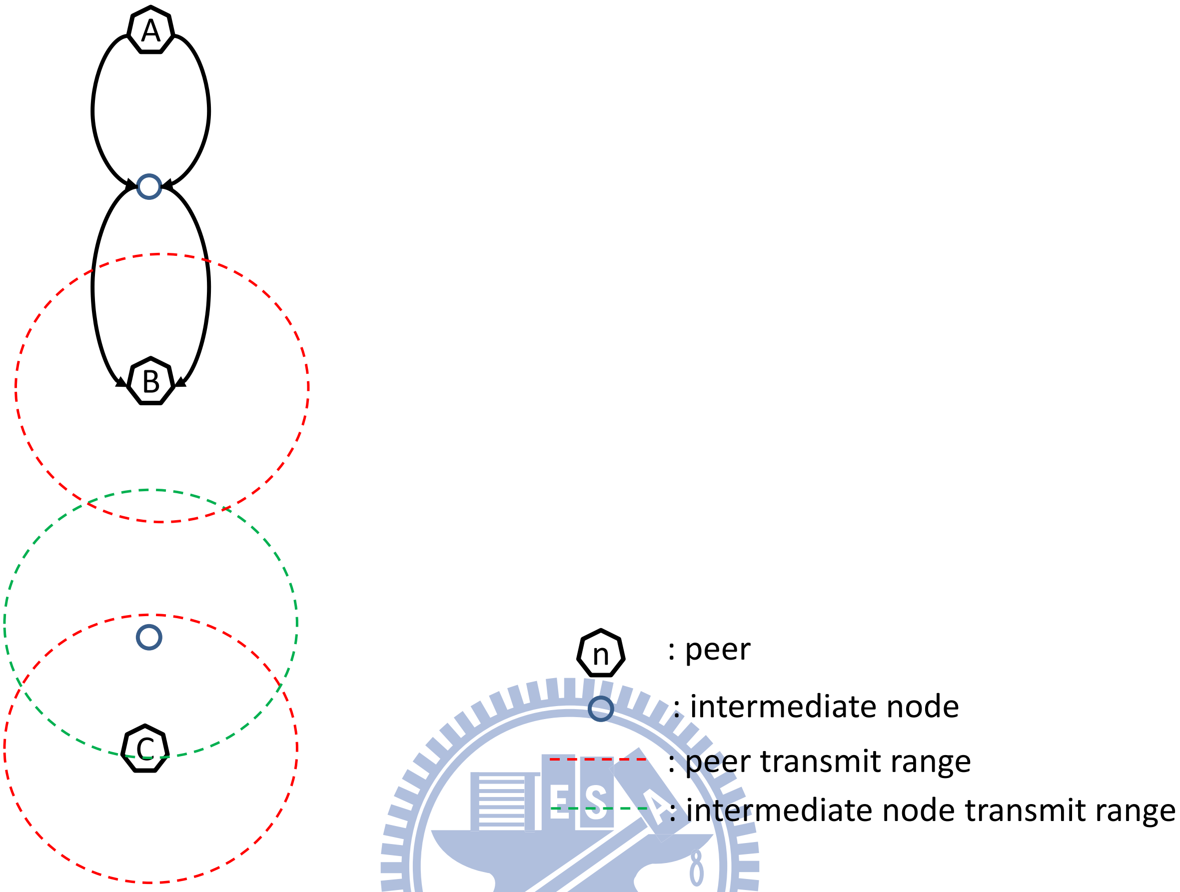

Figure 3-5 Diagram of remote peer joining

3.2.3 Peer leave

3.2.3.1 Normal example

When the time "a peer leaves gracefully" the ring overlay, it will (1) send a *Leave Message* to its' Front Peer and Rear Peer as shown in Figure 3-6. A user turning off the P2P application or computer normally is called "a peer leaves out gracefully". The *Leave Message* toward Front Peer tells Front Peer about Rear Peer's ID. And the *Leave Message* toward Rear Peer tells Rear Peer about Front Peer's ID. The purpose of these two messages is to let Front Peer and Rear Peer can find each other quickly if they can connect to each other. To make sure that Front Peer and Rear Peer have the information of each other, they both (2) reply an *ACK Message* to the Leaving Peer. Then Leaving Peer disconnects with Front Peer and Rear Peer, and Front Peer and Rear Peer try to find the new Rear and Front peer respectively. Usually Leaving Peer's Front and Rear peer would mutually be neighbors of each other. As usual, (3) Front peer and Rear peer send a *Request Connect* Message to each other for being neighbors, and then (4) also receive *Response* Message from each other. As shown in Figure 3-7, they repair the Ring overlay, and the streaming application is still going on. But, sometimes there is always an exceptional case we will explain it in the following section.

Our scheme is deployed in MANET, which is often a small size network, so there are only a small amount of peers in the system (assuming 100 peers in our scheme). Hence, the end to end delay of peers is around 200ms. If a peer leave, its' rear peer waits for 20ms for it. It can reduce packet loss, since rear peer may find new joining peer in 20ms. As a result, it is worthy to wait for 20ms, because 200ms is 10 times larger than 20ms.

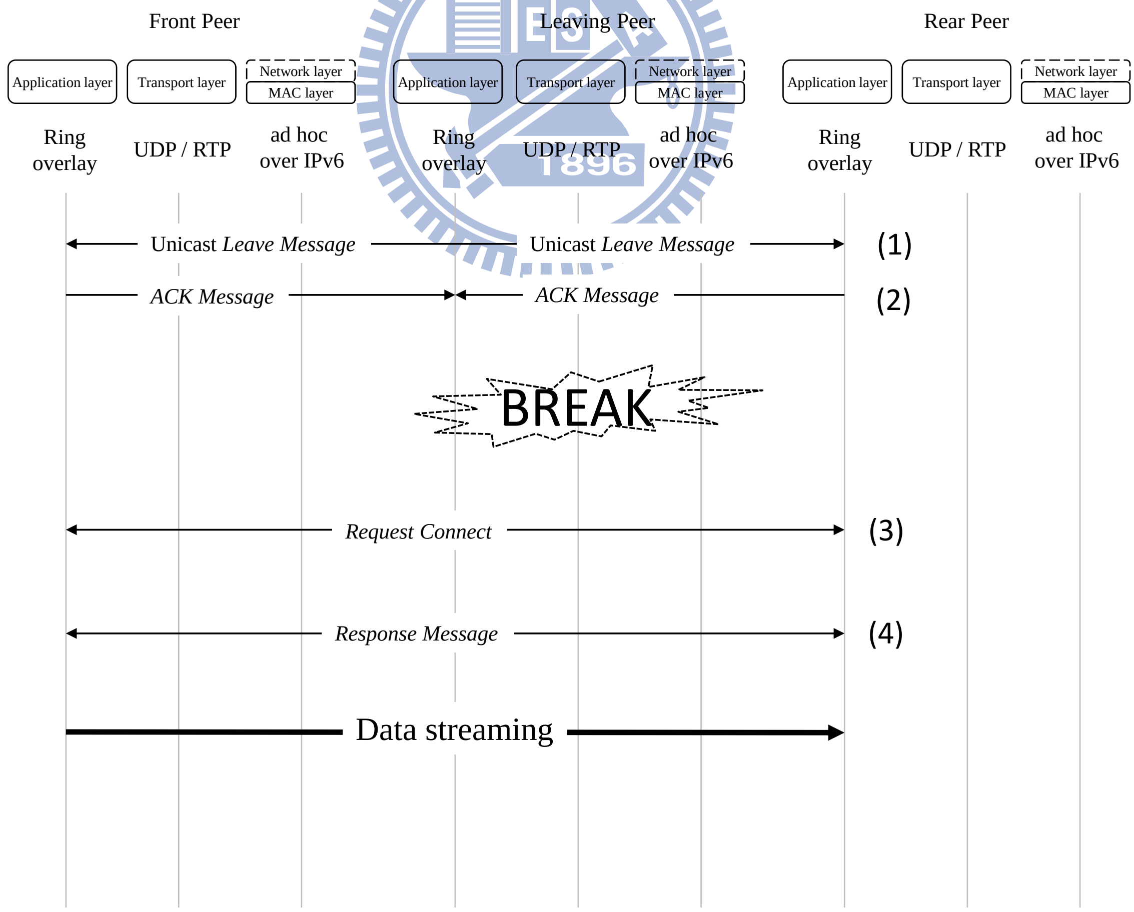

Figure 3-6 Message flow chart of peer leaving

3.2.3.2 Abnormal example

A peer quickly and unexpectedly disconnects due to power failure or abnormally turning off that causes a sudden system status change. As illustrated in Figure 3-8, (1) after data steaming, (2) Leaving Peer suddenly encounters power failure, but (3) Front Peer keeps sending message to it and causing packet loss. There is a recovery mechanism in our scheme, every peer periodically send a *Keep Alive Message* to its' Front Peer. At the moment, (4) Rear Peer sends a *Keep Alive Message* to Leaving Peer (its' Front peer) and finds out that Leaving Peer has disappeared for. (Once a peer receives a *Keep Alive Message* they must reply an ACK to their Rear Peer.) As a result, (5) Rear Peer floods *Finding Messages*, which includes Leaving Peer's ID, to all the peers in the network.

It keeps the Ring overlay working; nevertheless, it could cause a large amount of unnecessary message overhead in our scheme. If (6) Front Peer receives *Finding Message*, it connects to Rear Peer actively. Because Leaving Peer is the only peer that keeps the information of Front Peer and Rear Peer, Leaving Peer's ID is only known by Front Peer and Rear Peer. As a result, Rear Peer sends *Finding Message* (which includes Leaving Peer's ID), Front Peer must know it. Once (7) Front Peer sends a *Request Connect* to Rear Peer then Rear Peer receives it and (8) makes a response back to Front Peer. Finally they repair the Ring overlay and (9) the streaming application keeps on working. Flooding messages wastes time and the bandwidth for sending messages as well as increases the overhead of the system.

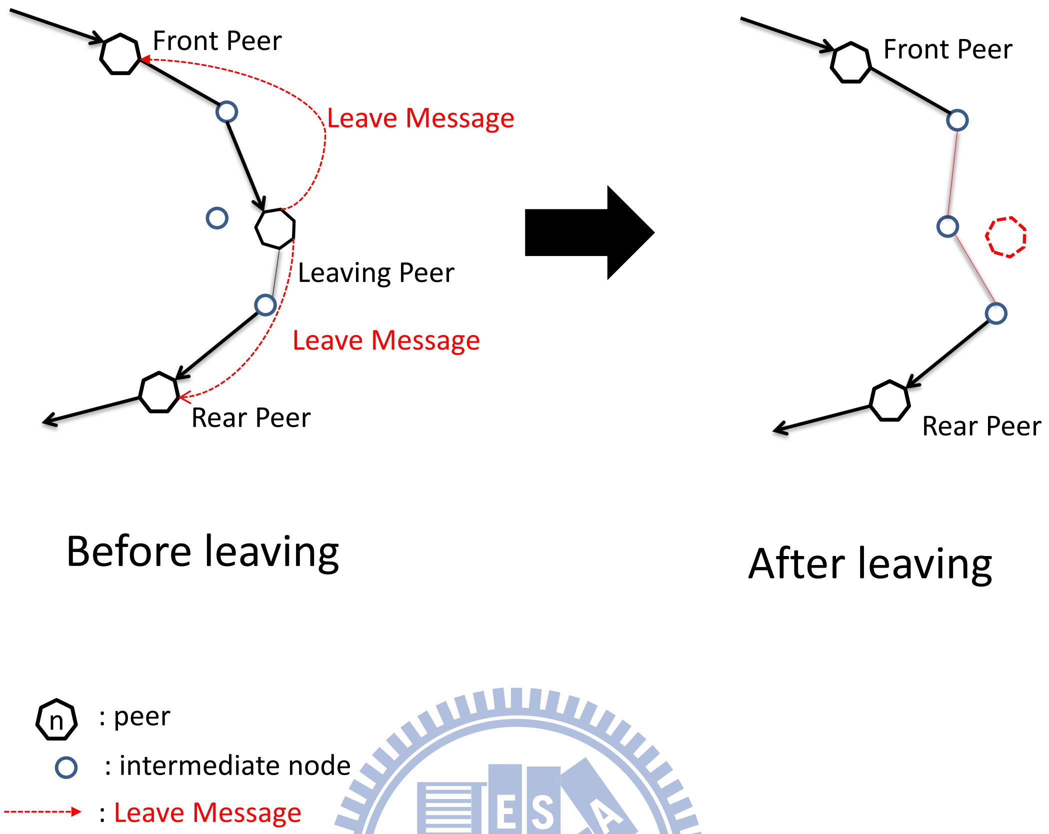

Figure 3-7 Diagram of peer leaving

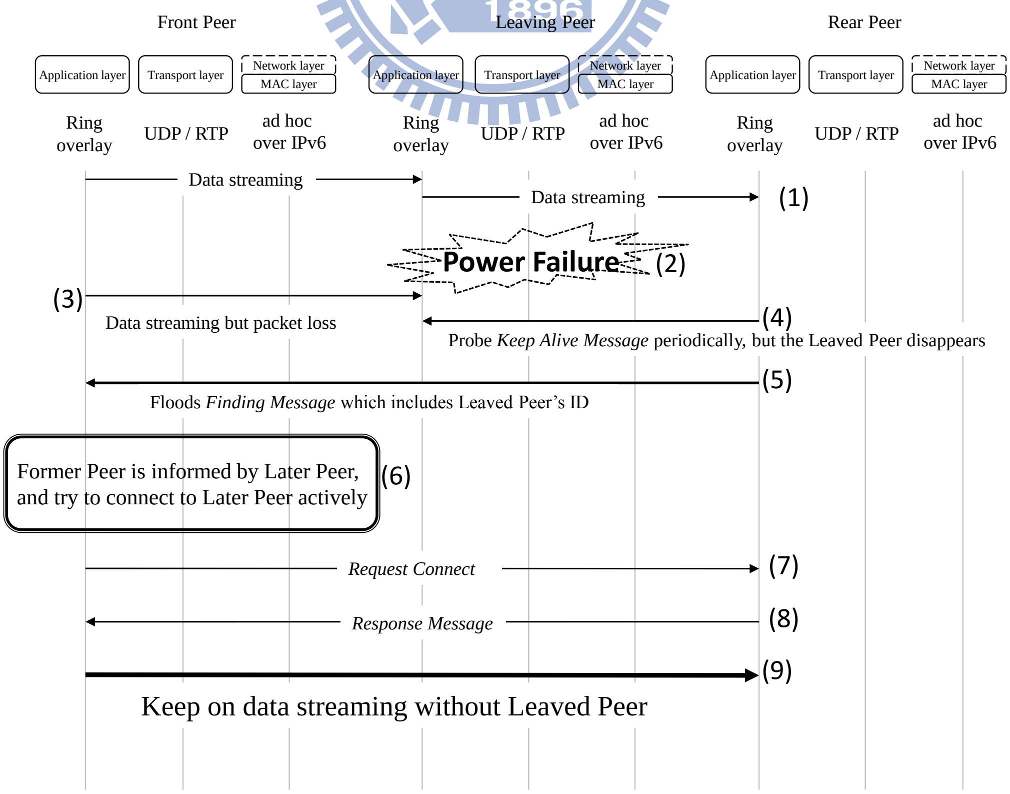

Figure 3-8 Message flow chart of peer leaving abnormally

3.2.4 Peer with mobility

3.2.4.1 Normal example

One of the features to be supported by our scheme is live streaming with mobility. Peers in the network could move as the users want to, so every peer broadcast the *Measure Message* which carries the measured RTT. The *Measure Message* tells peers that the distance to the other peers it could attach to by broadcasting. When RTT value of any two peers increases, it means that the distance of these two peers becomes larger. For example, see Figure 3-9.

Peer 5 is moving toward the direction of Peer 8 and Peer 1. Since Peer 5 broadcasts the *Measure Message* periodically, it detects that Peer 8 is more and more close to itself. Peer 5 chooses the larger value of RTT between its front and rear peer. (We assume RTT value between Peer 5 and Peer 6 is larger than RTT value between Peer 5 and Peer 4 so that Peer 5 chooses RTT value between itself and Peer 6 to compare with the other RTT.) If RTT value between Peer 5 and Peer 8 is K (K is one of the simulation result) times larger than RTT value between Peer 5 and Peer 6, then Peer 5 would tries to connect to Peer 8 and disconnects with Peer 6 and Peer 4. The procedure of Peer 5 connecting to Peer 8 is like a new peer, say New Peer 5, joining the Ring overlay. And the procedure of Peer 5 breaking with Peer 6 and Peer 4 is like Leaved Peer, Peer 5, leaving from the Ring overlay, as Figure 3-10 shows. To maintain the mobility of the Ring overlay, peers have to send messages periodically. However, it is worth. Sending these messages makes the overhead increasing, but maintaining the mobility reduces the network traffic flow and makes real-time live streaming work efficiently.

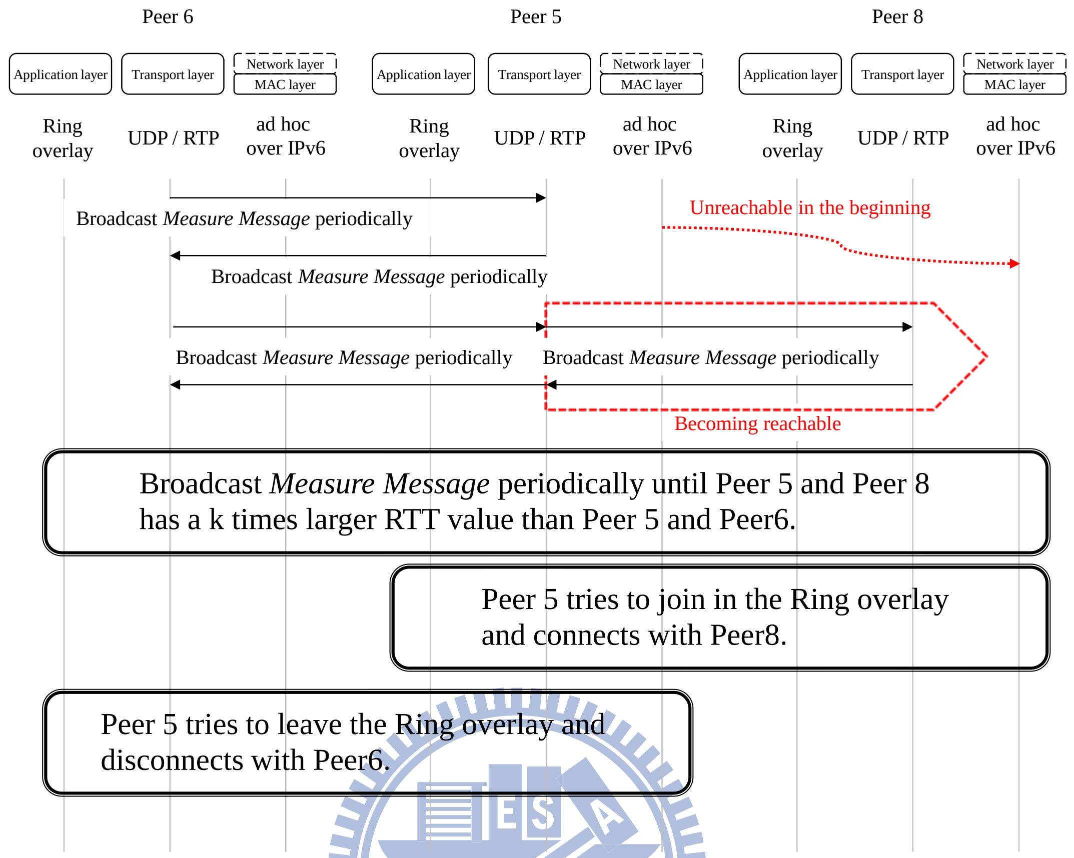

Figure 3-9 Message flow chart of peer moving

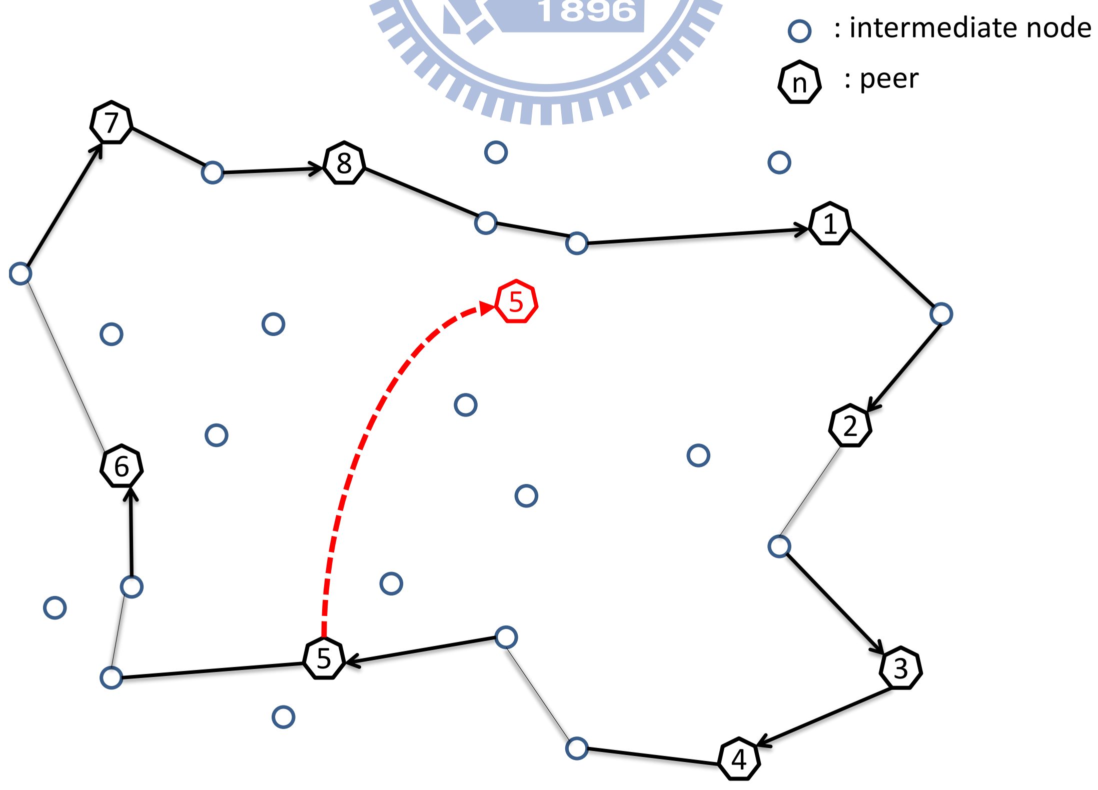

Figure 3-10 Diagram of peer moving

3.2.4.2 Abnormal example

The mobility provided in our scheme would be limited, because sometimes user moves in an unreasonable manner. The K value we mentioned above is the key issue when maintaining the ring with the mobility. If a peer moves too abnormally fast so that it couldn't correctly measure the RTT concerned with the K value, the route of the ring overlay may not be the shortest path. Once there are too much redundant paths in the ring overlay, the overhead of traffic flow and the amount of messages would be heavy.

3.3 Two Examples

3.3.1 Case1 (Ring overlay)

Here is a scenario about the application in our scheme. There is a group of colleagues working for the same company. They have a conference about a topic for an hour during the lunch. Since they don't have too much time, after they start the conference, they want to finish the meeting on time and get back to their workplace. For example in Figure 3-11, the colleagues of the company can still moves around in their company while in lunch. They can have some tea or coffee in the café, or chat with other colleagues in the lounge.

The only thing they must have is a device with the support of Wi-Fi or Wi-Max service and the application in our scheme. Though our scheme is deployed in the ad hoc mode, it is not a burden for these workers holding a device with mobility. Since most of the device with mobility supports wireless and they are quite light weight nowadays. (For example, iPhone 4, HTC sensation, iPad, and Samsung GALAXY.) The purpose of our scheme is to form the P2P ring overlay that supports live real-time streaming. The users can communicate with each other while they are moving around inside the company's complex.

If colleague 1 in the ring overlay talks, the voice message will be passed to its rear peer, colleague 2. And then colleague 2 passes the voice message to colleague 3, and so on. After the message is passed to colleague 7, the message is still passed from colleague 7 to colleague 1. Once colleague 1 receives the message, which is sent by colleague 1 originally, colleague 1 will drop the message.

All the dialogues can be heard by everyone in the ring overlay. In addition, we use a P2P application that makes the quality of the conversation clear because the network size is limited. Our P2P application could function effectively under the ad hoc environment which usually consists of not too many end hosts. However, MSN and Skype don't support multiple users using a streaming application but our application do. Our application has a better data transmitting technique than MSN so that the system is stable. As we mentioned before, that's the reason why we use the P2P Ring in our scheme instead of other topology.

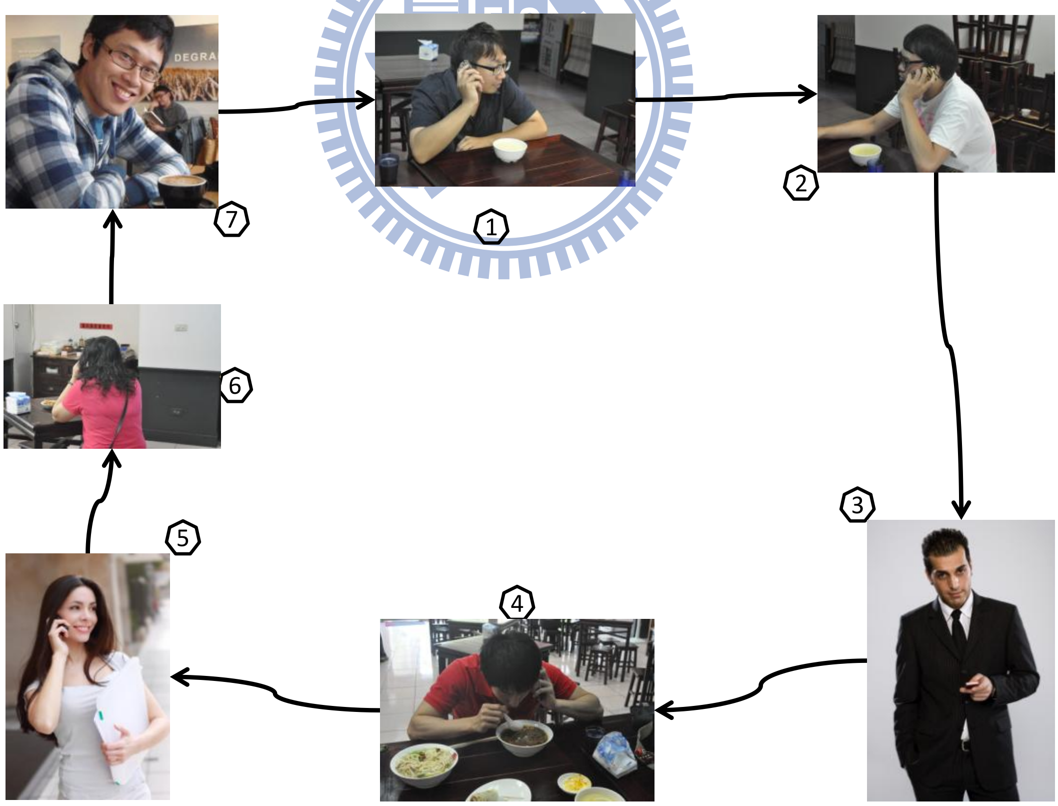

Figure 3-11 Diagram of example1

3.3.2 Case2 (Line overlay)

Nowadays bicycle riding is very popular exercise. Especially, riding in a group is very common. When riding on the road, it's not easy to talk with each other. You have to stop and wait for the other to come up, or catch up the other in front of you. Since communicating with others during the journey is more fun when riding trip is long. As illustrated in Figure 3-12, the first bike rider sees the nice scenery and he wants to stop to take a rest and take picture. Then he tells the following members behind him, and finally they make a decision whether to stop or not through the mobile device carried on the bike.

The bike team is always in a line. If the first rider speaks firstly and passes the message to the second rider, then passes it to the third one and so on. The last rider will drop the message and pass the ACK message back to the first rider.

Generally, the first rider is often the first speaker, but not always be. If the first rider speaks (the route of the message is mentioned above), all the riders except the speaker receive the message very soon. However the delay for sending from the last rider back to the first rider is longer. But it is really not important for the users, because all the users get the message they want as soon as it can. In other words, it is inefficient in view of the system since it is user sense. Although the application in this example is not sufficient to demostrate all the scenarios, it makes their journey fun and saves a lot of stop and waiting time in the bike riding trip.

Figure 3-12 Diagram of example2

Chapter4 Simulation and Numerical Results

OMNeT++ is a component-based, modular and open-architecture discrete event network simulation framework. The most common use of OMNeT++ is its use as a structure for simulation of computer networks. It is also used for queuing network simulations, and other areas as well. OMNeT++ is popular in academia for its extensibility and plentiful online documentation. On one hand, OMNeT++ supports GUI interface that help us simulating a P2P overlay. On the other hand, it explicitly defines the network components as OSI model of computer networking.

4.1 Simulation environment

Since we propose a real-time application, user's sense is the most important concern. Propagation delay is the amount of time it takes for the source of the signal to travel from the sender to the receiver over a medium path. Transmission delay which influence the smoothness of streaming is the amount of time required to deliver all of the packet's bits into the medium through an interface. In other words, this is the delay caused by the data-rate of the link. The simulation environment is in a 1000*1000 square meters area, the transmission range of the end device is 100 meters, and the Keep Alive message is periodically sent in every 3.33s. Every peer can join in or leave from the P2P network. Peer may disappear due to power failure or may move far away. The other parameters are recognized as variables and changed by different situations.

4.2 Simulation performance

We consider three basic kinds of wireless topologies to discuss how our proposed scheme can manage the P2P Ring for live streaming. First, wireless nodes are distributed in a straight line configuration; second, wireless nodes are distribute in a circle configuration; and third, wireless nodes are distributed in a grid configuration. We evaluate the time delay of voice delivery (between initialization of voice data to playback of this data in the most far peer), standard deviation of delay, and traffic overhead. The short time delay of voice reflects a successful real-time service and affects QoE. The small standard deviation of delay represents the slight jitter and also an important factor for high QoE. The low traffic overhead leads to the sufficient network capacity and impacts QoS.

4.2.1 Line type

At the beginning, the network topology is constructed in a straight line which is considered as the worst case in our expectation before the simulation. After the simulation, we can discover that P2P overlay forms a chain to manage this linear topology. This can demonstrate that our proposed overlay is suitable for different type of topologies of MANET proximity to deliver the streaming data efficiently. The delay time of packet transmission grows as the number of peers in the network increases, as shown in Figure 4-1. The average delay time, in the blue curve, increases lightly as the number of peers grow from 4 to 32, since Ring overlay becomes larger with more peers. The tail of the chain must wait for long time when the number of peers increases to a large value. Then the minimum delay time, in the green line, grows gently with network size increasing, because the minimum delay time is constrained by transmission delay and propagation delay. However, the Maximum delay time, in the red curve, goes up when the number of peers increases. There is an obvious correlation between maximum delay and network size, because the maximum delay time is affected by some other factors which we can’t calculate precisely. For example, the queue delay time of the end system affects the maximum delay time very much. If there are 5 end systems in the network, the maximum delay time will certainly be over 5 times of the queue delay time, since the data is passing through all of these 5 end systems.

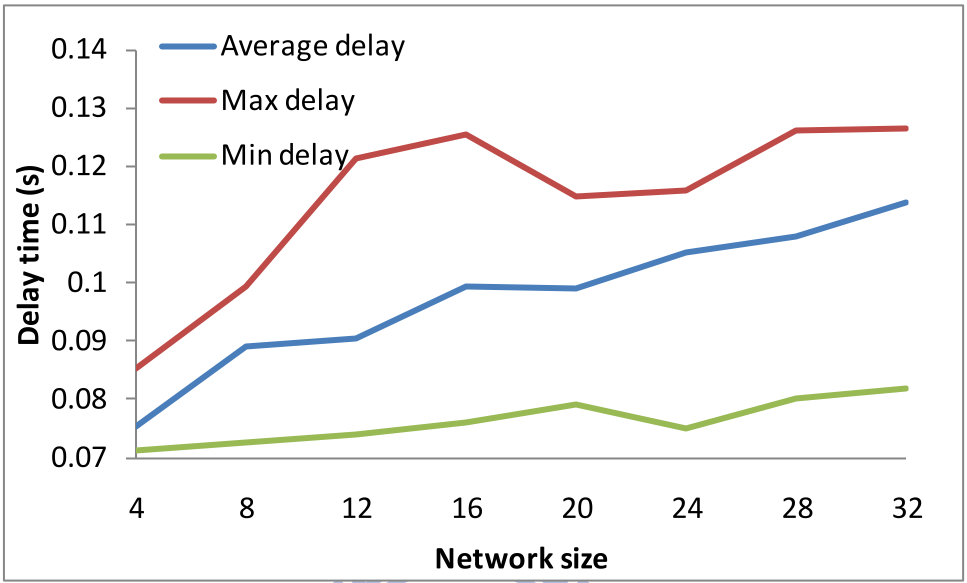

Figure 4-1 Packet delay in line type

Figure 4-2 shows the standard deviation of delay. The value of the standard deviation grows when the network size increases. For example, the standard deviation of the average delay grows from 0.002875 to 0.009605 as the number of peer increases from 4 to 32. However, the increasing curve, the blue line, is not growing exponentially. Ignoring the end-to-end delay, it is a scalable load balancing scheme, the standard deviation grows linearly and steadily. The standard deviation is still small when the network size is large, and this explains that a stable streaming can be delivered in our proposed approach.

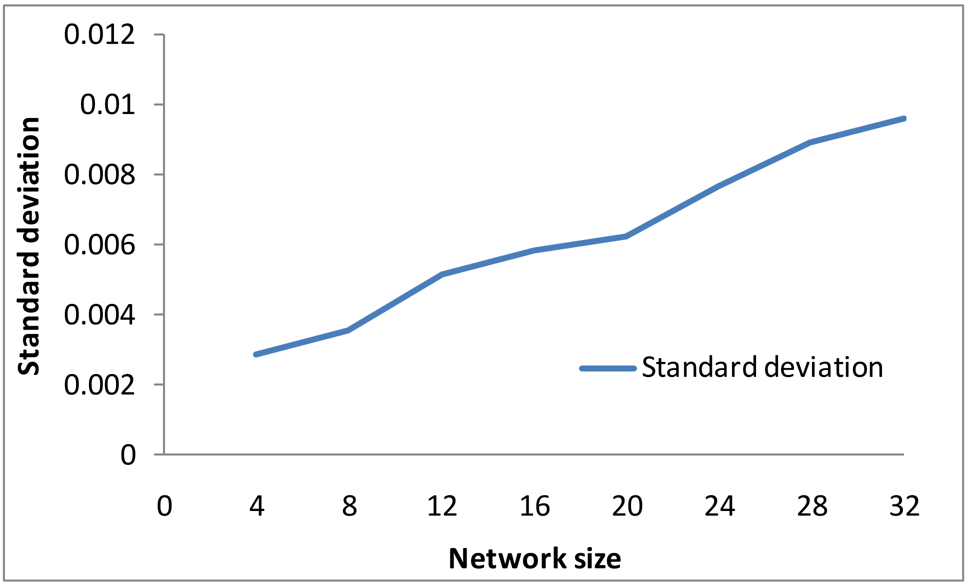

Figure 4-2 Standard deviation of delay in line type

We define the *overhead index* as the number of non-data packets sent per peer per second. The overhead means the amount of all kinds of messages instead of chunk data in P2P. The chunk data in our scheme is the streaming data which is encoded in data of voice. In Figure 4-3, the overhead only grows slightly when the total number of users increases. Because our application is Ring P2P overlay and it makes all peer almost receive the same amount of messages. It means the system is load balance.

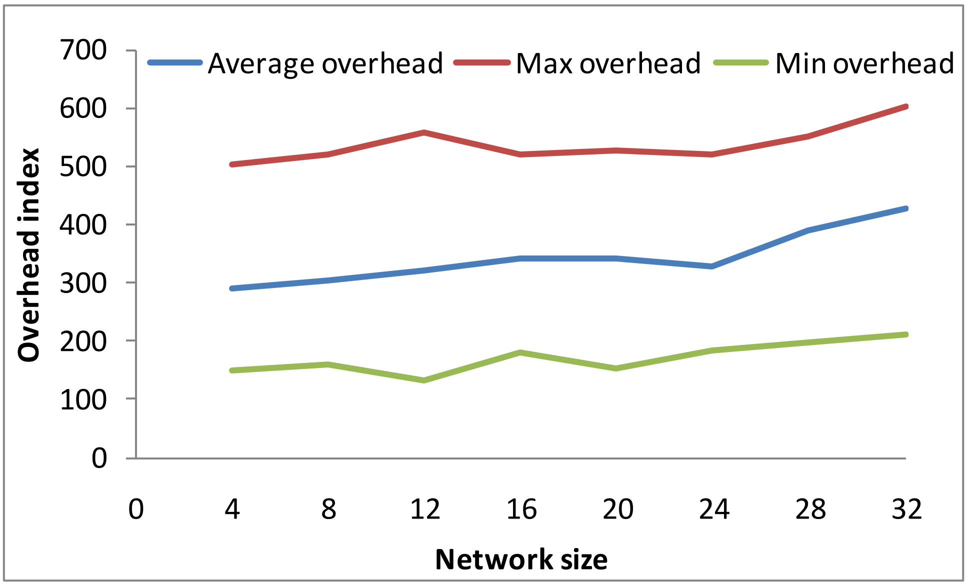

Figure 4-3 Overhead in line type

4.2.2 Ring type

As shown in Figure 4-4, in the ring type network topology which is the best case in our expectation before the simulation. Actually, the simulation result shows that the average delay time of transmitting packets grows as the number of peers in the network increases, as shown in blue line in Figure 4-4. It is evident that the growth rate of blue line is much lower than that in the line type. The system in Ring type is scalable.

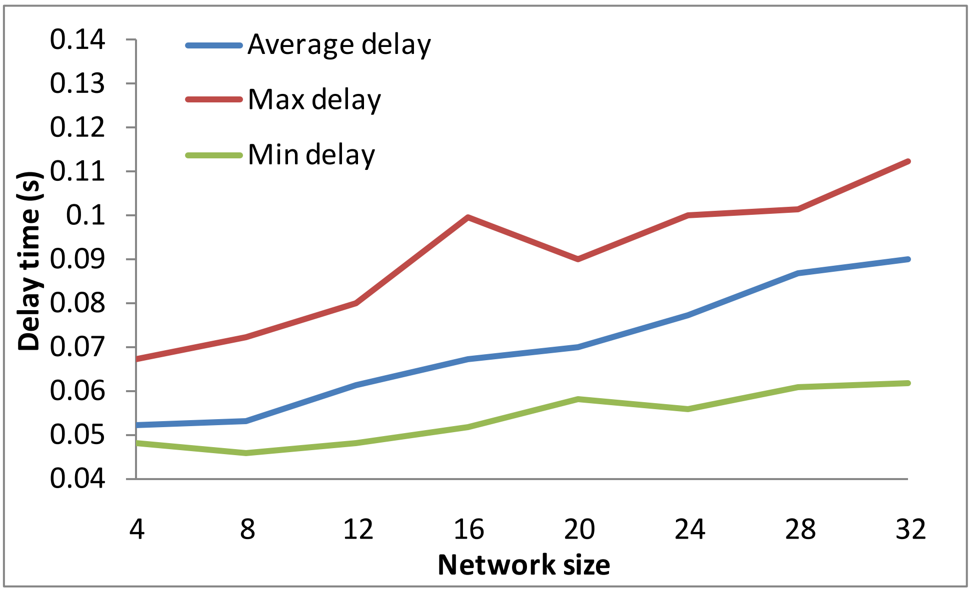

Figure 4-4 Packet delay in ring type

Figure 4-5 shows that the value of the standard deviation grows slowly when the size of network increases, and the blue increasing line grows gently. Since our application is load balancing, so performance of QoE is good. Hence, the standard deviation grows linearly and gently. The growth scope rate of the standard deviation in ring type topology is similar to the straight line. It means that our scheme make the streaming application stable.

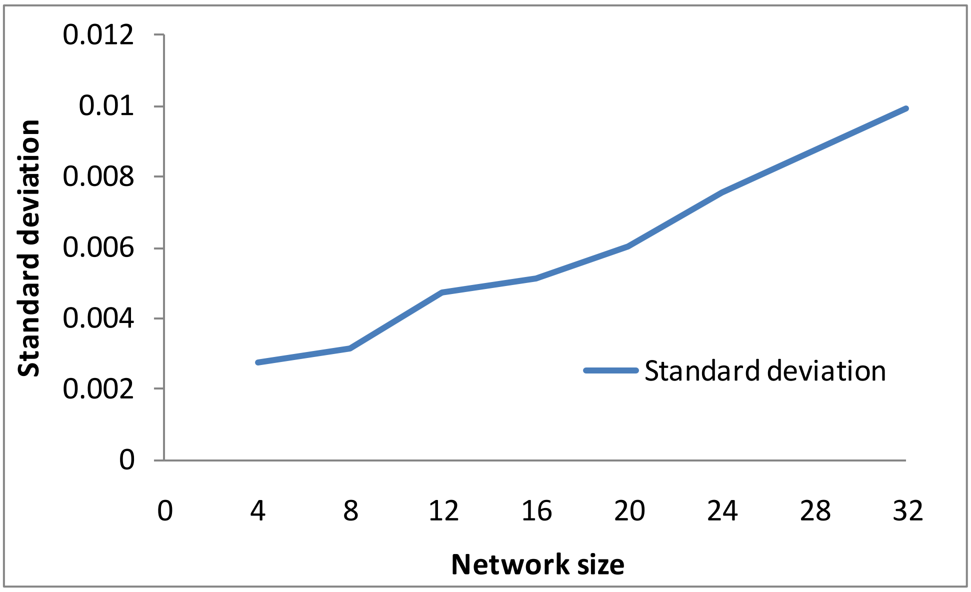

Figure 4-5 Standard deviation of delay in ring type

As we can see in Figure 4-6, the average overhead and the minimum overhead just grow slightly and gently if the total number of users increases. It shows that ring overlay is a load balanced, and scalable P2P system once again. However, the interval between the red line, blue line and green line in this type of topology is quite similar to that in line topology. It represents that the application in our scheme is load balanced.

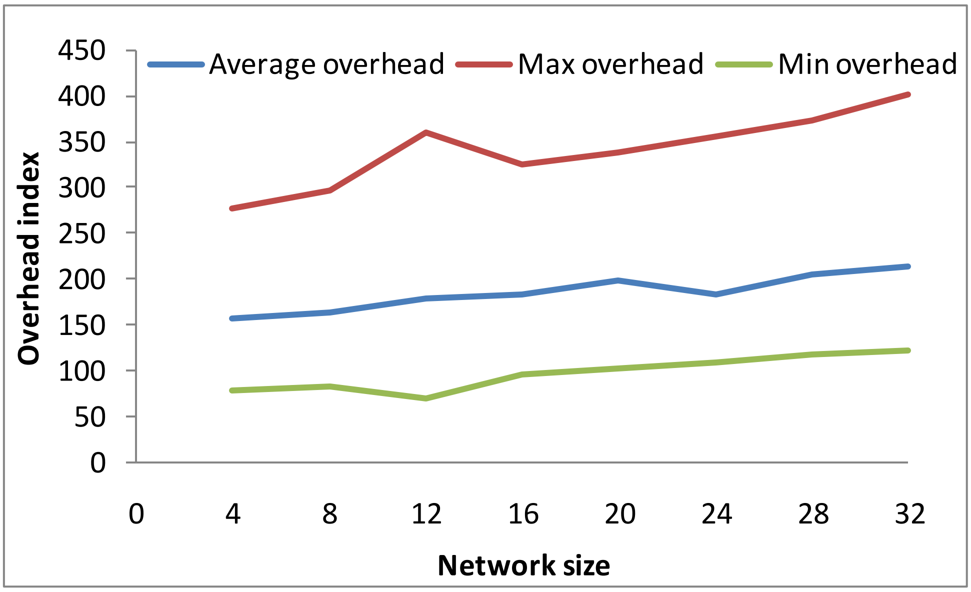

Figure 4-6 Overhead in ring type

4.2.3 Mesh type

As Figure 4-7 shown, the performance in the average delay of the grid type is better than that of the line type but is worse than the circle type. It explains that the network topology and P2P overlay in the real world, in which peers may be distributed randomly within an area, so the average propagation delay of any peer between itself and its rear peer is shorter than in the line type but longer than in circle type. Moreover, the growth ratio of the minimum delay time still increases gently while the number of peers grows. As a result, the minimum delay time of three different type topology, ring, line and mesh, are limited by the minimal of transmission delay and propagation delay. On the other hand, the Maximum delay time is still affected by queuing delay. Hence, the growth ratio of the maximum delay time is extremely unstable.

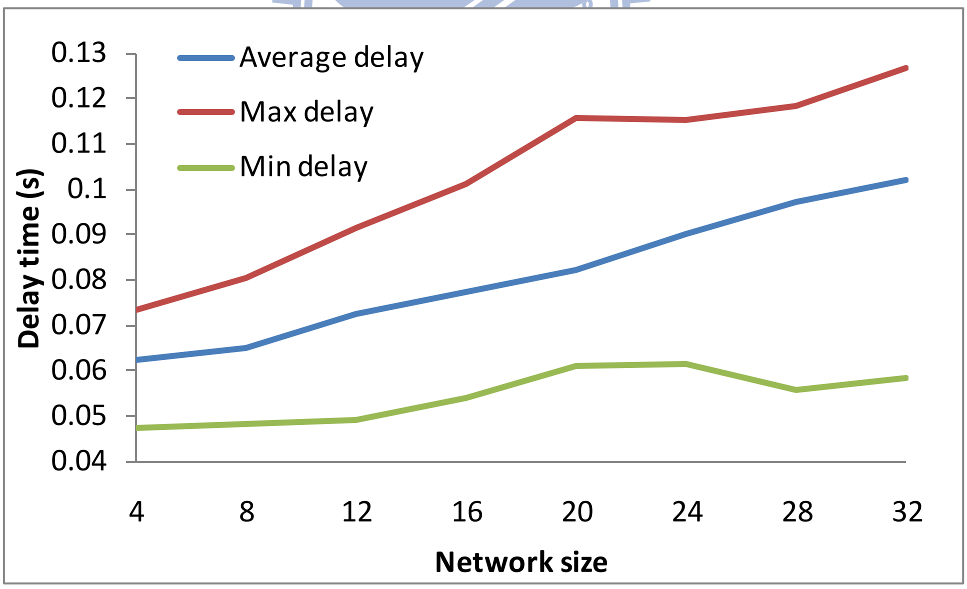

Figure 4-7 Packet delay in mesh type

In Figure 4-8, we demonstrate that the system is stable, because the standard deviation grows linearly and gently when the network size increases, as shown in the blue line.

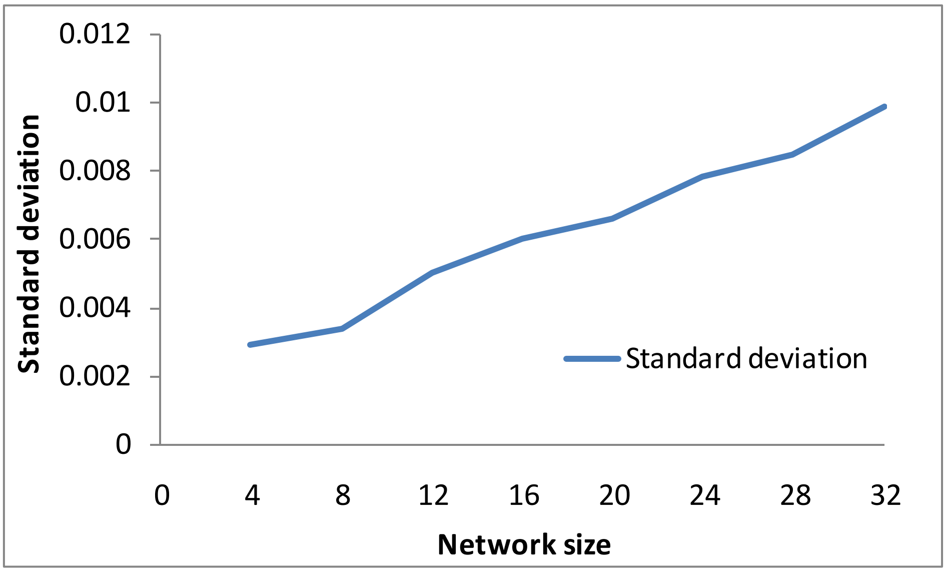

Figure 4-8 Standard deviation of delay in mesh type

Figure 4-9 shows the average, maximum, and minimum overheads in the mesh type topology. The interval between the average, maximum, and minimum overhead is close to the line topology and the ring topology. The average overhead ranges only from 200 to 350 messages as network size from 4 to 32. It explains that our system is a load balanced application even if the application is deployed in different types of topology.

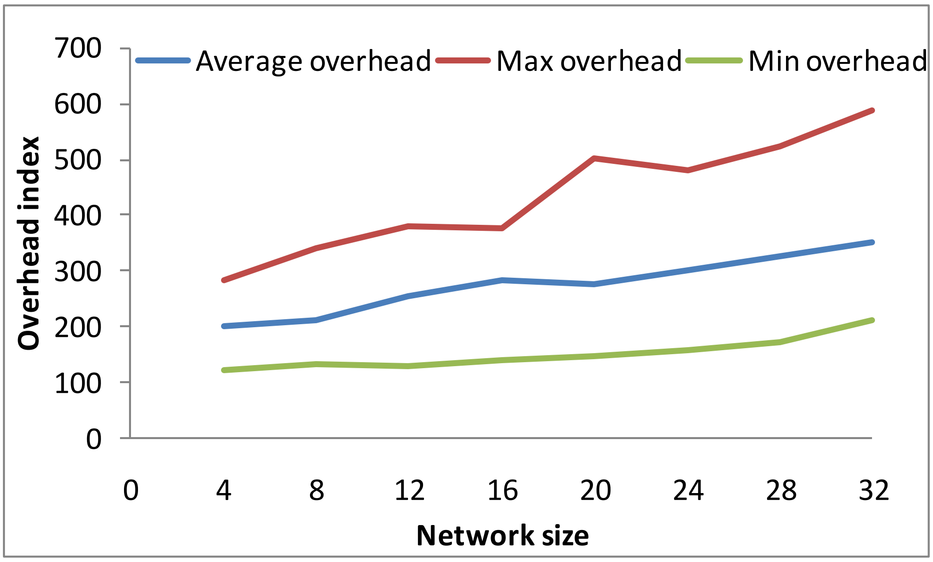

Figure 4-9 Overhead in mesh type

Chapter5 Conclusion

Our proposed protocol is simple, easy and suitable for real-time streaming application over wireless ad hoc network. Our proposed protocol constructs ring-based P2P overlay to deliver the real-time message and to manage the overlay. The simulation results show that the system overhead increases very slowly, and conclude that our P2P system is load balance, scalable, and stable. Our application considers really user experience, because transmission delay and standard deviation is short.

The simulation results also show that different ad hoc topologies cause a little different outcome. For ring type, mesh type, line type from our experiments, although the ring type shows the best performance of these three types, it doesn't conform to the present situation. However, the mesh type is similar to network in the real world even if the ring type has the better performance.

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