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# RING: A Cross-Layer P2P Group Conferencing Mechanism over Mobile Ad-Hoc Networks

**Jun-Li KUO**[†], ***Nonmember***, **Chen-Hua SHIH**[†a)], ***Student Member***, **Cheng-Yuan HO**[†], **Ming-Ching WANG**[†], ***and*** **Yaw-Chung CHEN**[†], ***Nonmembers***

**SUMMARY** In the infrastructure-less disaster environment, the application of the peer-to-peer (P2P) group conference over mobile ad hoc network (MANET) can be used to communicate with each other when the rescue crews search the survivors but work separately. However, there still are several problems of in-time multimedia delivery in P2P-MANET: (1) MANET mobility influences the maintenance of P2P overlay. (2) P2P overlay is not proximal to MANET topology, this leads to the inefficient streaming delivery. (3) The unreliable wireless connection leads to the difficulty of multi-source P2P group conferencing. Therefore, P2P conferencing cannot work well on MANET. To overcome the above disadvantages, in this paper, we present a cross-layer P2P group conferencing mechanism over MANET, called RING (Real-time Intercommunication Network Gossip). The RING uses the ring overlay to manage peers and utilizes the cross-layer mechanism to force the ring overlay to be proximal to MANET topology. Therefore, RING can lead efficient in-time multimedia streaming delivery. On the other hand, the ring overlay can deal with peer joining/leaving fast and simply, and improves the delivery efficiency with the minimum signaling overhead. Through mathematical theory and a series of experiments, we demonstrate that RING is workable and it can shorten the source-to-end delay with minimal signaling overhead.
***key words:*** *group conference, P2P-MANET, cross-layer design, wireless ad hoc, P2P live streaming, real-time multimedia service*

## 1. Introduction

Multimedia conferencing system becomes important on commercial industry and academic fields. Most of the existing systems can build the virtual conferencing room through the wired network or Internet. However in many situations, the communications between mobile hosts neither rely on any fixed infrastructure nor access Internet. For example, the high cost or long setup time of a system installation may be unacceptable in the disaster areas and battle fields. It motivates mobile ad hoc network (MANET) which can be expected to operate in the infrastructure-less and wireless environment. For example, after a heavy earthquake or tsunami caused a disaster, the rescue crews have to search the survivors and communicate with each other when they work separately. However, there is neither cellular system nor Internet in the damaged area. The group conference over MANET is necessary to overcome the challenge.

In MANET, two mobile nodes can communicate with each other through other intermediate nodes over wireless infrastructure-less network without the centralized administration. Users can hold a simple conference through MANET via network-layer flooding. However, the flooding in MANET is too inefficient to deliver real-time data. The one-to-many flooding cannot support the many-to-many conference, so a decentralized approach like peer-to-peer (P2P) technology can be an appropriate solution to manage MANET[†1].

There are some similarities between MANET and P2P, so the development and integration of P2P is suitable for MANET. (1) Both peers and mobile nodes[†2] collaborate with each other without the centralized server. (2) Both peers and mobile nodes operate as hosts and routing nodes[†3]. (3) Both the MANET topology and the P2P overlay[†4] changes frequently due to the high churn rate. (4) Both ad hoc network and P2P network self-organize with scalability and need the efficient route.

In recent years, more and more P2P applications have been implemented in MANET, and P2P-MANET (P2P over MANET) [1] has appeared to this network architecture. However, there still are several problems of in-time multimedia delivery in P2P-MANET: (1) MANET mobility influences the maintenance of P2P overlay. (2) P2P overlay is not proximal to MANET topology, this leads to the inefficient streaming delivery. (3) The unreliable wireless connection leads to the difficulty of multi-source P2P group conferencing. Therefore, P2P conferencing cannot work well on MANET so far [2].

To overcome the above disadvantages, in this paper, we present a cross-layer approach for P2P conferencing tailored to MANET, called RING (Real-time Intercommunication Network Gossip). It motivates real-time multimedia streaming for time sensitivity on P2P-MANET. The goal of RING is to achieve a low latency and overhead wireless group conference without through Internet. RING uses the *ring* overlay to manage peers and is proximal to MANET topology. The ring overlay can deal with peer joining/leaving fast and simply, and improves the delivery efficiency with the mini-

[†1]P2P solution can establish the many-to-many connections without any central control.

[†2]In the paper, a peer means a member of P2P network, and a node means a member of MANET. The peer is a node with P2P application.

[†3]Each peer acts both as a client and a server, or called servent.

[†4]The topology means the distribution of nodes in MANET physically, and the overlay means the distribution of peers on P2P logically.

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[†]The authors are with Computer Science, National Chiao Tung University, Taiwan.
a) E-mail: chshih.cs@gmail.com
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mum signaling overhead.

## 2. Related Works

The applications of P2P-MANET consider the integration of a P2P overlay and an ad hoc routing protocol. The P2P overlay handles the application layer multicast and manages the relationship of mobile nodes. The ad hoc routing protocol deals with the packet forwarding through the physical topology. We focus on two tiers for the group conferencing application.

### 2.1 P2P Overlay

The traditional P2P computing uses the *distributed hash table* (DHT) to apply for file sharing. The fast and accurate searching ability of DHT-based algorithms is workable attractively in wired networks. Chord [3] is a famous example of ring-based DHT[†1], which is used to index peers and files[†2]. Chord uses the consistent hashing function to map peers in the static domain, and every peer can locate itself or query any peer depending on the *hashing key*. However, DHT is unstable for MANET due to the mobility and the locality [4][†3]. Therefore, DHT scheme is modified for the cross-layer integration of P2P overlay and ad hoc routing protocol to improve the delivery efficiency in MANET [5].

For group conferencing, three models of overlay have been developed on MANET:

- *Flooding model*: The application connection is established via Session Initiation Protocol (SIP) based on flooding-based multicast. A peer always floods the received data to other peers immediately. The hierarchy-based [6] or cluster-based [7] architecture is used to improve the efficiency of flooding delivery.
- *Leader model*: Skype [8] can hold the group conference through Internet[†4]. Skype classifies peers into two types: *super peer*[†5] and *ordinary peer*. The super peer is responsible to build P2P overlay and optimize the routing path. Hence, a super peer is like as the leader of group conference, and it synchronizes voice data then multicasts to ordinary peers.
- *Multi-tree model*: Audio conferencing testbed (ACT) [9] allows that a group of people sets up a meeting in WiFi MANET. ACT uses the minimum spanning tree[†6] to minimize the latency of audio dissemination to the whole network[†7]. Every peer must maintain its minimum spanning tree to deliver data by itself.

In general, a lack of the efficient delivery leads to data duplications in the flooding model. This leads to a large consumption of bandwidth and an unbalanced traffic. The global overlay must be required in the leader model and multi-tree model. The signaling overhead is increased for the recovery optimization when the overlay changes (peer joining/leaving/moving). Three models all face the scalability problem.

### 2.2 Ad Hoc Routing Protocol

The ad hoc routing protocol must be considered to complete a specific purpose of P2P application [10], and the protocols can be classified into *reactive* and *proactive* routing. In proactive or *table-driven* routing protocols, such as destination sequenced distance vector (DSDV) [11] and optimized link state routing (OLSR) [12], every mobile node maintains a routing table with the global information of network topology. The reactive or *on-demand* routing protocols, such as dynamic source routing (DSR) [13] and ad hoc on demand distance vector (AODV) [14], every mobile node finds a routing path only when it is necessary.

Virtual Ring Routing (VRR) [15] is inspired by DHT and adopts the ring-based routing[†8] to shorten the end-to-end delay and reduce the message overhead. VRR organizes the mobile nodes in a unique *virtual ring*, which is independent of physical location. Each node maintains a small number of routing paths to its neighbors in the ring without any flooding scheme. However, its virtual ring is not proximal to the physical topology, this leads to the far routing path and is unsuitable for real-time group communication.

Several multicast routing protocols[†9] have been newly proposed for the simultaneous transmission from one sender to multiple receivers. Most of these protocols adopt the hybrid routing for integration with the advantages of reactive and proactive protocols, such as optimized polymorphic hybrid multicast routing (OPHMR) [16] and power-controlled hybrid multicast routing (PCHMR) [17]. However, these routing protocols are unstable for the real-time service with high data rate due to long delay and high overhead[†10].

We can comprehend that the off-the-shelf combination of P2P overlay and ad hoc routing protocol is unstable for the mobile group conferencing. Therefore, a cross-layer design is proposed for P2P-MANET in the paper.

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[†1] Chord uses ring-based DHT to achieve multi-hop querying; our proposed scheme, RING, uses ring-based overlay to achieve one-by-one real-time delivery. They are entirely different.

[†2] Each peer has a link to its predecessor and successor according to the DHT of Chord called *finger table*.

[†3] DHT is used for static peers in large-scale wired network; the topology of MANET is dynamic and small.

[†4] Skype cannot work if MANET cannot access Internet.

[†5] Any peer with a public IP address having sufficient CPU, memory, and network bandwidth is a candidate to become a super peer.

[†6] *Broadcast tree* is the buzzword in ACT.

[†7] ACT also uses distributed TDMA scheme and circuit-switch type to guarantee the acceptable quality of service. In addition, ACT can predict the disconnection and mobility to shorten the service interruption time.

[†8] VRR uses ring-based routing in network layer; RING, uses ring-based overlay in application layer. They are entirely different.

[†9] Multicast routing protocols usually is designed for the content multicast or distributed database management.

[†10] A lot of computing cost and bandwidth is required to maintain the dynamic routing tables in proactive routing; the larger delivery delay is inefficient for heavy traffic in reactive routing.

## 3. Our Proposed Scheme

For overcoming the difficulty of multimedia streaming for P2P network over MANET and improving the latency and overhead in the previous works, we propose a new cross-layer scheme, RING. In our scheme, RING, all peers self-organize a ring overlay to simplify the maintenance of P2P overlay. Due to the cross-layer integration, an immediate forwarding with proximity can achieve the low traffic and fasten the in-time delivery. To construct the ring overlay, the underlay network dynamics must be known, such that the cross-layer information can be used for promoting the efficiency of the network.

### 3.1 Overview

We illustrate the establishment of RING as shown in Fig. 1. First, the mobile nodes self-organize an ad hoc network, and each mobile node maintains a routing table to know its neighboring topology and establish the point-to-point connections[†1]. The users in a group must coordinate a *Peer ID* and a *Group ID* to login the application, thus RING groups users via the Group ID. A peer is the mobile nodes using RING application with the same Group ID.

Next, the peers organize themselves via a ring-based overlay to deliver live voice. Unlike other existing P2P overlays, every peer is unnecessary to know its all neighbors. Every peer only knows its *front peer* and *rear peer* in RING. Whenever a peer joins or leaves, it notices its front peer and rear peer actively. Every peer sends *Probe Message* to its front peer and rear peer periodically to do the estimation of *round trip time* (RTT), which can also indicate the peers' movement, available bandwidth, and absence. As a result, the P2P overlay can be mapped to the physical ad hoc topology in our proposed scheme without an additional global positioning system (GPS). Every peer is just responsible to forward data to its rear peer without handling data scheduling, peer adaptation, nor multiple sources, so the algorithm complexity and the signaling overhead can be reduced.

Third, the peer creates voice data and delivers it on demand instead of maintaining a connection for VoIP. The peer derives the routing path and considers the hidden terminal problem to delivers data best effort. As Fig. 1 shown, once the new arriving peer joins one by one via the same Group ID, every peer should connect to two nearest peers and forwards voice data. When user A speaks, the voice data with peer A's ID is forwarded to every peer in order. Every peer checks the Peer ID to decide whether the voice data is forwarded. When peer C receives the voice data, peer C does not forward the data to peer A, because peer C knows that peer A is its rear peer and the source.

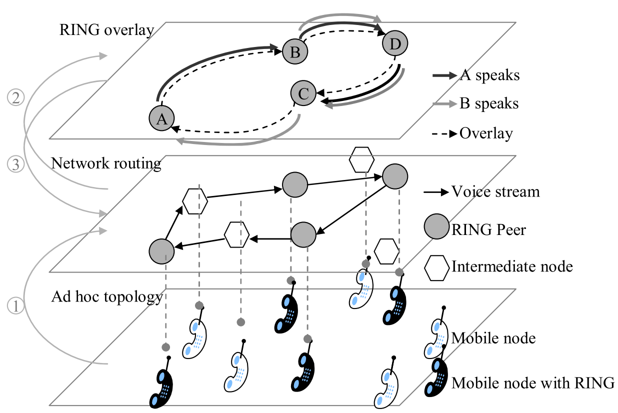



**Fig. 1** Relationship between the ring overlay and the physical topology.

### 3.2 Peer Joining

A diagram of new peer joining is shown in Fig. 2, and a new peer does not know any P2P overlay and friendship[†2] initially. We give a detailed explanation to clarify the process of new peer joining as Fig. 3 and Algorithm 1 illustrated:

(1) The direction of voice stream is F → L → R. Peer L only keeps the information about peer F and peer R.
(2) The new peer (peer N) searches the peers who have the same group ID via *Request Message* and *Response*

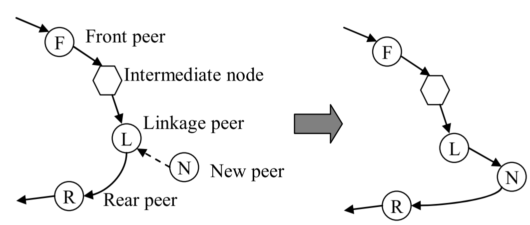



**Fig. 2** Diagram of new peer joining.

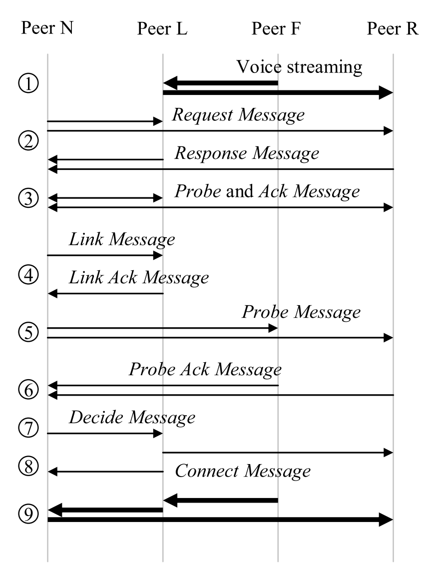



**Fig. 3** Message flow of new peer joining.

[†1]The streaming can be delivered via a point-to-point connection through multi-hop routing in an *opportunistic* network [18].

[†2]Two peers have the friendship that they know each other.

**Algorithm 1:** Message handling in each peer

```
let rank, temp be initially 0;
while a Request Message is received do
    check the source address of received message;
    if source address is reachable†1 then
        send a Response Message back;
    else
        drop the request;
    end if
end while
while a Response Message is received do
    send a pair of Probe Messages back;
    rank = 0;
end while
while a Probe Message is received do
    send a Probe Ack Messages back;
end while
while a pair of Probe Ack Message is received do
    rank ++ ;
    if rank == 1 then
        check the source address of received message;
        send a Link Message back;
        this→linkage = source address;
    else
        temp ++ ;
        if temp == 1 then
            check the source address of received message;
            Decide Message (dmsg)→next = source address;
            send the dmsg to this→linkage;
        else
            drop the ack;
        end if
    end if
end while
while a Link Message is received do
    Link Ack Message (lmsg)→candidates = this→front;
    lmsg→candidates = this→rear;
    send the la back;
end while
while a Link Ack Message is received do
    check the candidates of received message;
    send Probe Messages to the candidates;
end while
while a Decide Message is received do
    check the source address of received message;
    if source address is addable then
        check the next of received message;
        modify this→front or this→rear;
        send a Connect Message to this→front;
        send a Connect Message to this→rear;
    else
        drop the ack;
    end if
end while
while a Connect Message is received do
    check the source address of received message;
    modify this→front or this→rear;
    bind the socket and open data stream;
end while
```

*Message*[†2] .

(3) Peer N selects its linkage peer via *Probe Message* and *Probe Ack Message* depending on RTT and *signal to noise ratio* (SNR)[†3].
(4) Peer N contacts to peer L as its linkage peer via *Link Message* and *Link Ack Message*. *Link Ack Message* brings the information about the candidates (i.e. the front peer and the rear peer of the linkage peer).
(5) Peer N sends *Probe Message* to the candidates (peer F, peer R) to ensure that the candidates are connectable.
(6) Peer F and peer R return *Probe Ack Message* to peer N. We assume that peer N receives *Probe Ack Message* from peer R earlier than the message from peer F.
(7) Peer N decides to connect peer R due to the short time interval between *Probe* and *Ack*. Peer N sends *Decide Message* to peer L to insert the path.
(8) The linkage peer resets its front peer or rear peer, and sends *Connect Message* to peer N and peer R to set or reset their front peers and rear peers.
(9) The direction of voice stream is F → L → N → R. The joining process is completed.

As Fig. 4 shown, we illustrate the detailed message flow between the new peer and the linkage peer during the joining process. There are several required parameters in each signaling message, such as, source Peer ID, target Peer

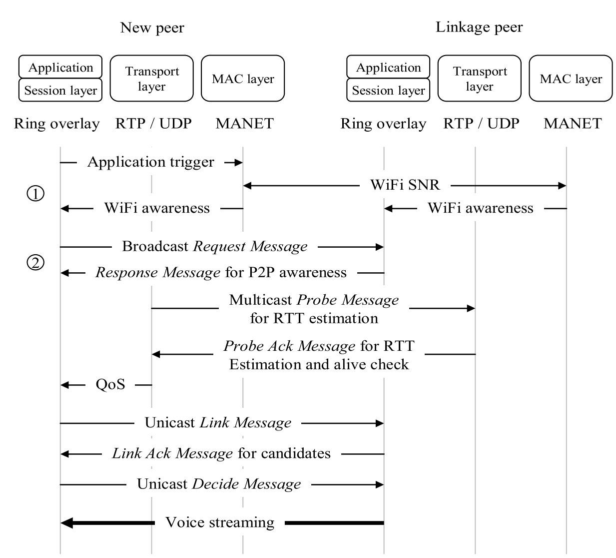
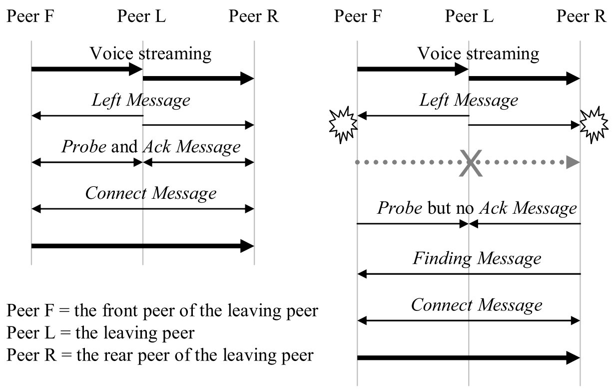



**Fig. 4** Cross-layer message flow of new peer joining.

†1 The reachable address means that two peers know routing information including multi-hop path each other.

†2 We assume that peer L and peer R are in the transmission range of peer N and can receive *Request Message*, and then they return *Response Message* back. Peer N can know how to route to peer L and peer R via *Response Message*.

†3 If a peer can detect its neighbor within the transmission range, the SNR is evaluated via the link layer. The RTT is evaluated via the interval between *Probe Message* and *Probe Ack Message*. The SNR indicates the quality of one-hop physical link and the RTT indicates the quality of multiple-hops logical link.




(a) Graceful leaving (b) Reactive leaving

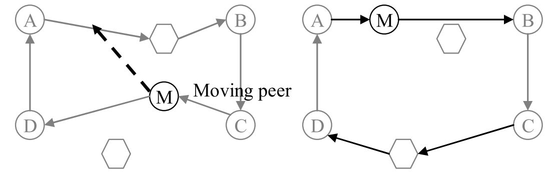
**Fig. 5** Message flow of peer leaving.

ID, Group ID, and created time[†1]. In position 1, if two nodes detect each other, a WiFi[†2] awareness is updated; otherwise, the new node is indicated to join the ring overlay through intermediate hops. In position 2, if the new node gets a WiFi awareness, it sends *Request Message* in its transmission range; otherwise, the new node floods *Request Message* cross the entire ad-hoc network. The new node receives *Response Message* for P2P awareness, and this means there are other nodes using the same group ID in the ad-hoc network. Next, the new peer multicasts *Probe Message* to the nodes who return *Response Message*, and the linkage peer is selected. Finally the new peer joins successfully after the completeness of *Link Message* and *Decide Message*.

### 3.3 Peer Leaving and Moving

When a peer leaves the P2P network, it voluntarily informs its front peer and rear peer via a *Left Message* so that they can recover the ring overlay. The purpose of *Left Message* is to let the front peer and the rear peer can find each other quickly[†3]. After receiving *Left Message*, the peers send *Connect Message* to each other for the confirmation of connectivity. When the original delivery path is broken due to peer leaving, the new delivery path is established as Fig. 5(a) shown. However, *Left Message* may be lost, or the peer leaves before exchanging *Connect Message*, so the original delivery path is broken as Fig. 5(b) shown. Therefore, in our proposed scheme, every peer multicasts periodically *Probe Message*s to maintain indirectly P2P overlay and monitor the neighbors' movements. When the rear peer (peer R) finds out the disappearance of its front peer (peer L), it floods *Finding Message*, which includes the peer L's ID, to all peers in the ad hoc network. Peer F receives *Finding Message* and knows that the peer L is its rear peer, and then Peer F exchanges with peer R for *Connect Message* to establish a new delivery path.

Because every peer only knows its front peer and rear peer, it cannot gain the neighboring information like GPS. Therefore, a peer indicates its neighbor moving via the reactive leaving. As Fig. 6(a) shown, after peer M starts to move, neither peer C nor peer D probes to peer M gradually.




(a) Moving as reactive leaving (b) Renew joining

**Fig. 6** Diagram of peer moving.

Peer C and peer D think that peer M should leave or move, peer D disconnects from peer M and then connects to peer C as Fig. 6(b). Thus peer M becomes an orphan and then finds a linkage peer as Fig. 2. As Fig. 6(b) shown, peer M finds peer A as a linkage peer and joins into the overlay.

## 4. Analysis

In our proposed ring-based forwarding scheme, we can assume a probability that the $i$th peer creates a voice packet in a given time $t$ is $p$. The event $b_i$ represents the process among $n$ peers, and a sequence $b_1, b_2, b_3, \ldots$ can be defined via Bernoulli formula:

$$\begin{aligned} &\mathrm{P}(b_i = 1) = \mathrm{P}(i\text{th peer speaks}) = p, \forall\ \ i \text{ and } i \in n \\ &\mathrm{P}(b_i = 0) = \mathrm{P}(i\text{th peer calms}) = 1 - p \end{aligned} \tag{1}$$

At some time $t$, the probability that $k$ peers create voice packets simultaneously is $\mathrm{P_K}$.

$$\mathrm{P_K}(k) = C_k^n p^k (1-p)^{n-k} \tag{2}$$

Therefore, the probability that a peer creates $h$ packets in $m$ time slots is $\mathrm{P_H}$ is similar with Eq. (2) theoretically.

$$\mathrm{P_H}(h) = C_h^m p^h (1-p)^{m-h} \tag{3}$$

For one peer, $t_j$ can be defined that $j$th packet is created in an inter-arrival time. Then the probability that a peer creates $h$ packets in a given time $t$ is $\mathrm{P_T}$.

$$\begin{aligned} \mathrm{P_T}(t) &= \mathrm{P}(b_i \text{ is true AND } h-1 \text{ packets are created} \\ &\qquad \text{in the first } t-1), \text{ for each } i \\ &= \mathrm{P}(b_i = 1) \cdot \mathrm{P_H}(h-1), \text{ while based on } t-1 \\ &\qquad \text{for } t \geq h \\ &= p \cdot C_{h-1}^{t-1} p^{h-1} (1-p)^{t-h} \\ &= C_{h-1}^{t-1} p^h (1-p)^{t-h} \end{aligned} \tag{4}$$

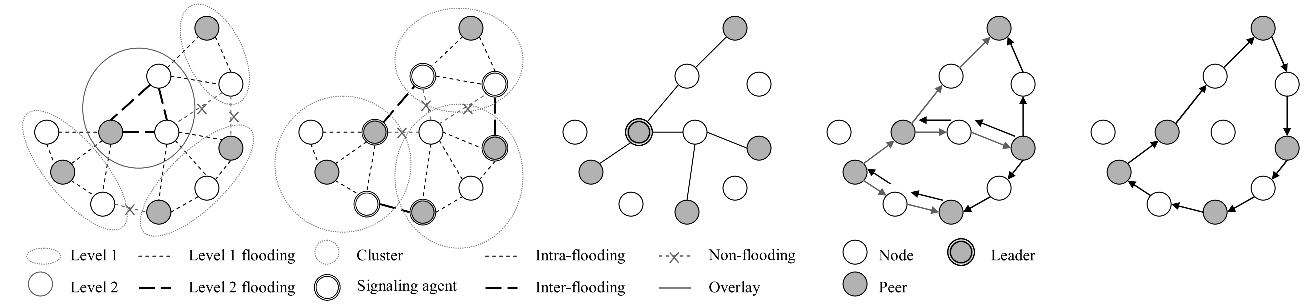
And the expected time of $h$ packets is $\mathrm{E_H}(h)$.

$$\mathrm{E_H}(h) = \mathrm{E}(t_1) + \mathrm{E}(t_2) + \ldots + \mathrm{E}(t_h),$$

[†1]When a peer moves, it may receive a duplicated message because the delivery path is changed. The duplication can be detected via the created time of message.

[†2]We implement RING on WiFi ad hoc network due to its popularity in wireless LAN.

[†3]*Left Message* toward the front peer tells the front peer about the rear peer's ID. And *Left Message* toward the rear peer tells the rear peer about the front peer's ID.




(a) Hierarchy flooding model (b) Cluster flooding model (c) Leader model (d) Multi-tree model (e) RING

**Fig. 7** The signaling architectures of compared models.

E is expected function

$$= 1/p + 1/p + \ldots + 1/p = h/p \quad (5)$$

The Bernoulli formal can be applied to an analog of Poisson process in a continuous time. We can define that the rate of packet created is $\lambda$ in a given time $t$. The probability that $k$ peers create packets in $t$ is $\mathrm{P_N}(k, t)$.

$$\mathrm{P_N}(k, t) = e^{-\lambda t}(\lambda t)^k/k!, \text{ while } \lambda t = h = \mathrm{E_H}(h) \times p \quad (6)$$

Therefore, the expected value of duplicated packets is simplified as $\mathrm{E_N}$.

$$\mathrm{E_N}(n) = \Sigma_k P_N(k, t) \times k \times n \quad (7)$$

The fixed $\lambda$, $t$, $n$ can derive the $\mathrm{E_N}(n)$ for the low bound of packet duplications in the proposed ring-based forwarding scheme.

## 5. Simulation Results

We simulate the group conference via many-to-many delivery. We compare RING with other delivery models introduced in the Relative Works. The signaling architectures of compared models are shown in Fig. 7[†1]. We implement the compared models on the reactive AODV and the proactive DSDV routing protocols, and implement the RTS/CTS mechanism to avoid the hidden node problem. We consider the propagation delay and the number of intermediate hops as the *link cost*.

We use INETMANET [19][†2] on OMNet++ [20] to simulate the voice streaming delivery. There are 4 ∼ 40 peers among 60 mobile nodes in an ad hoc area 1 km × 1 km. We define every wireless node with parameters ($x$, $y$, $\pi$, $v$, $s$) in a simulation environment as Fig. 8 shown. The descriptions of parameters are represented in the Table 1. The parameters ($x$, $y$) represent the coordinate of a node in the simulation square. $\pi$ represents the moving angle of each node. If a node moves beyond the simulated boundary, $\pi$ becomes a reflective angle as node $b$ to ensure that every node moves in the simulation square. $v$ represents the moving speed of each node[†3]. $s$ represents whether a node is the peer or not[†4]. The transmission range of node is 150 m and the probability that peers speak is 0.6.

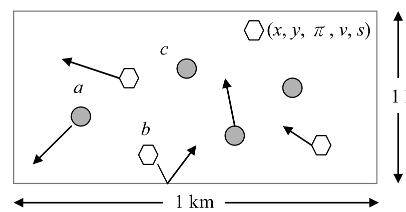



**Fig. 8** The simulation environment.

**Table 1** The parameters of simulation.

| Parameter | Type | Range | Description |
|---|---|---|---|
| x | natural number | 0 ~ 1000 m | x-axis |
| y | natural number | 0 ~ 1000 m | y-axis |
| π | decimal | | moving angle |
| v | natural number | 0 ~ 128 km/hr | moving speed |
| s | binary number | true of false | turn on or not |

### 5.1 Scalability

Scalability is an essential characteristic for group conferencing on both P2P network and MANET. We sum up the amount of copies of voice data which are transmitted through the ad hoc network as Fig. 9 illustrated. We can find out the exponential increase of voice traffic with the number of peers in the flooding model. The enormous duplication in the flooding model is intimidating, even if the hierarchy and cluster base can reduce redundancy. The flooding model paralyzes ad hoc network. However, our proposed RING, the leader model, and the multi-tree model use P2P overlay to manage MANET, such that the amount of voice copies can be approximated to an ideal $\mathrm{E_N}(n)$. Especially, RING has the best performance among the compared models, because every peer only copies once for its rear peer, and every

[†1]There is no overlay in the flooding models including of hierarchy and cluster models.

[†2]We need the source codes of AODV and DSDV from INETMANET.

[†3]When $v$ is 0, it means the node is static as node $c$.

[†4]If $s$ is true, node $a$ is a member in P2P overlay; otherwise, node $b$ is just a member in MANET topology.

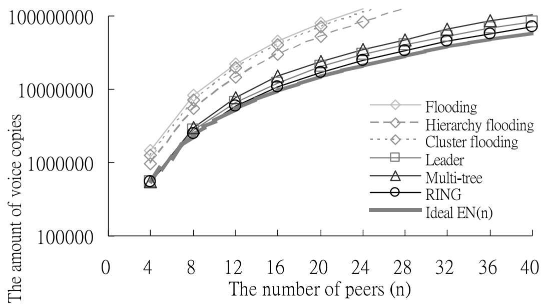



**Fig. 9** The amount of voice copies increases with the number of peers.

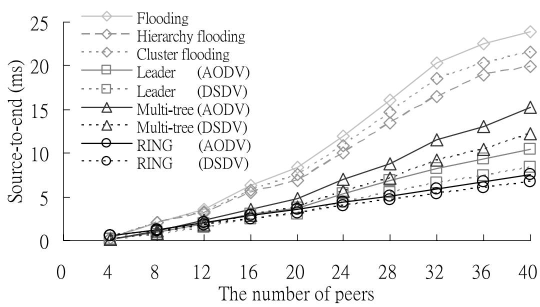



**Fig. 10** The source-to-end delay increases with the number of peers.

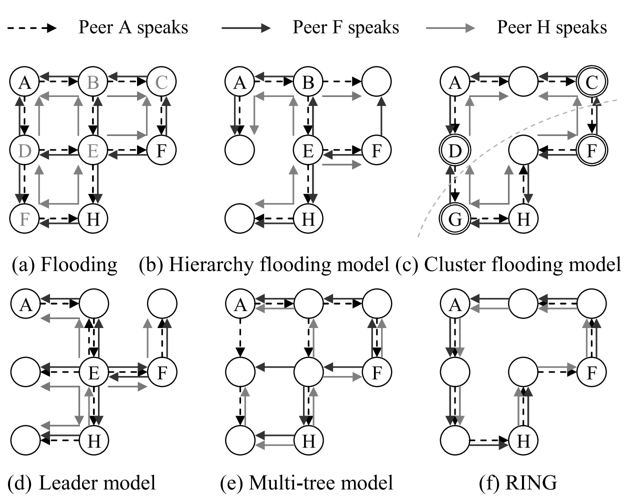



**Fig. 11** A simulation example for the compared models.

intermediate node only copies once for the destination.

The source-to-end delay is defined by the time from the creating time of packet at source to the arriving time of packet at destination. The average delay of voice packet can be discussed in Fig. 10. We can find that RING has the shortest delay among all compared models. The overlay proximity and the low probability of hidden terminal collision[†1] minimize the delay. A part of overlay in simulation is shown in Fig. 11, and we use the figure to explain the effectiveness of compared models.

- The flooding model is illustrated as Fig. 11(a), there is no overlay in such model. Every peer always floods its data through the whole network. If two peers speak simultaneously, someone must wait for the flooding completion of another peer via RTS/CTS mechanism. The more peers create and deliver the voice data, more duplication leads to more hidden terminal collision.
- The hierarchy-based flooding model [6] is illustrated as Fig. 11(b), there is a two-level architecture in such model. Every level-1 peer attaches one level-2 peer, and every peer floods its data through its level. The hierarchy architecture limits the packet flooding rather than whole flooding. However, the hidden terminal collision is serious when many peers speak simultaneously due to the innate flooding.
- The cluster-based flooding model [7] is illustrated as Fig. 11(c), every peer floods its data within its cluster, and only *signaling agent* can flood beyond its cluster. Peer A, B, C, D group a cluster, and peer E, F, G, H group a cluster. Peer C, D, G, F are the signaling agents. The reason of serious hidden terminal collision is similar with the reason in the hierarchy-based flooding model.
- The leader model is illustrated as Fig. 11(d), every peer delivers its data through the leader (peer E) because the unique overlay managed by a leader. If peer F and peer H speak simultaneously, they must compete the communication capacity for peer E. The more peers create and deliver the voice data, the hidden terminal collision is more serious (the probability of collision is higher). The major reason of collision is that the overlay and delivery is dominated by the leader. Besides, there is a traffic bottleneck in the leader.
- The multi-tree model is illustrated as Fig. 11(e), every peer delivers its data via its minimum spanning tree. The delivery path of peer A is different from the delivery path of peer F or peer H. When peers speak simultaneously, the peers on a cross have the high probability of hidden terminal collision. For example, if peer A and peer H speak simultaneously, the voice streaming meets a collision in peer C and peer E, and then the streaming is multicast via waiting by turns. The major reason of collision is that the directions of streaming are collided each other.
- The proposed RING is illustrated as Fig. 11(f), every peer delivers its data through the unique ring overlay. Because the directions of streaming are always identical, RING is suitable for the wireless half-duplex links to alleviate the hidden terminal collision. If peer F or peer H speaks, peer A still sends its data simultaneously. Even if many peers speak simultaneously, the probability of collision is low because the streaming is stored and forwarded hop by hop in a unique direction.

In addition, the on-demand routing discovery and routing path selection are always executed before an establishment of multi-hop connection on AODV. Hence AODV requires

[†1]The hidden terminal problem is avoided by RTS/CTS mechanism. Every peer must compete for the free band at random interval. The sender and receiver occupy the band within their transmission range. The problem that the peer cannot send out its data immediately is generally called as the hidden terminal collision.

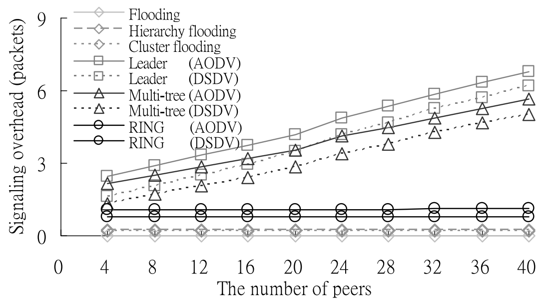



**Fig. 12** The signaling overhead relates to the number of peers.

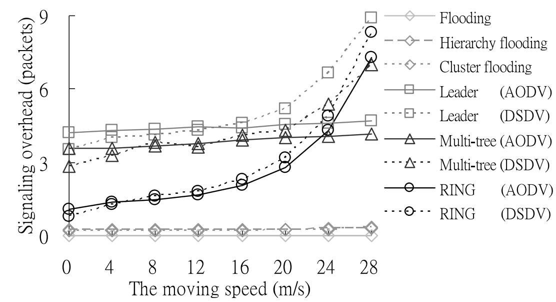



**Fig. 14** The signaling overhead relates to the moving speed of peers.

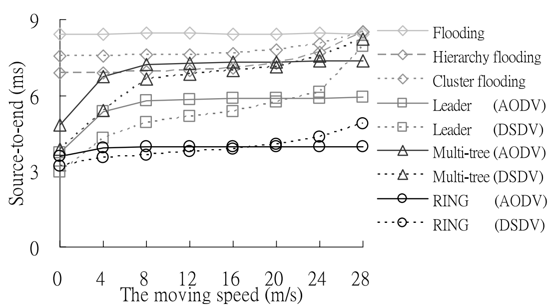



**Fig. 13** The source-to-end delay relates to the moving speed of peers.

the more traffic time than DSDV does.

We define the signaling overhead as the number of non-data packets sent per peer per second. The signaling overhead includes the control messages of *overlay maintenance* and *routing discovery*. As Fig. 12 illustrated, we can find out some observations:

- In the flooding models (including of hierarchy and cluster base), a peer does not keep any overlay information[†1]. And a peer always floods the voice data without any control message. Therefore, flooding model has the minimum overhead among the compared models.
- In RING, a peer only keeps its front peer and rear peer on the overlay via periodical probing. DSDV and AODV also bring the signaling overhead when executing ad hoc routing[†2].
- A peer has more signaling overhead when the overlay is larger in the multi-tree model, because the spanning tree grows with the scalability.
- The super peer costs much overhead in the leader model due to the same reason as above. Besides, the super peer needs an additional overhead to communicate with the ordinary peers.
- From Figs. 9 and 12, the three flooding models, leader model, and multi-tree model is not scalable for MANET.

## 5.2 Mobility

Mobility is an essential characteristic for group conferencing on MANET. We set 20 peers, randomize $\pi$ and increase $\upsilon$ to simulate the peer moving. The simulation result is curved in Fig. 13, and we can discover that RING isn't influenced by the moving speed and has the best quality among the compared models.

- RING can detect peer moving and modifies its ring-based overlay to avoid the far routing path. However, peer's movement changes the network topology, so the leader model and the multi-tree model meet the inefficient routing. The performance of multi-tree model is serious because no leader dominates the changed overlay.
- Because the routing table is maintained periodically on DSDV, the instantaneous movement of node is difficult to detect immediately. The high moving speed leads to the extreme change of ad hoc topology, so the far routing may result in the long source-to-end delay on DSDV. However, the routing path is selected on demand on AODV, so the mobility influences the AODV slightly.
- The three flooding models neither maintain overlay nor use multi-hop ad hoc routing, so the mobility does not degrade the performance.

Figure 14 illustrates the relationship between the moving speed and the signaling overhead. Because the peer's movement can be detected in RING, this leads to the increasing signaling overhead. Even if the ring-based overlay changes, the moving peer always influences only two neighbors (its front peer and its rear peer). Therefore, the low speed does not cause the heavy overhead. Because the peer just changes two neighbors no matter what the global topology is changed, there is a little difference between AODV and DSDV.

However, there is a large difference between AODV and DSDV in the leader model and multi-tree model. AODV always decides the routing path on demand, so the changed topology cannot increase the routing overhead on AODV. In general, the routing table is updated periodically on DSDV. However, the routing table is updated reactively when the link interruption due to the high mobility. In leader model and multi-tree model, although the overhead of overlay maintenance is not increased with the moving speed, the

[†1]A node must advertise the hierarchy and cluster information in the hierarchy-based and cluster-based flooding models, thus the overhead of both models is slightly more than the overhead of flooding model.

[†2]Proactive routing floods on topology change; reactive routing floods to discover routes. The flooding scheme leads to the major overhead.

control overhead of routing recovery is increased with the high mobility on DSDV. The signaling overhead of flooding models (including of hierarchy and cluster base) is negligible with scalability and mobility due to a lack of overlay and ad hoc protocol.

In summary, the performance of RING is better than other compared models:

- Every peer always forwards data to its rear peer with one duplication. The routing traffic can be reduced.
- Every peer always transmits along the unidirectional one-by-one delivery on the unique ring. The source-to-end delay can be shortened.
- Every peer only keeps its front peer and rear peer. The algorithm complexity can be simplified, and the signaling overhead can be decreased.
- The source-to-end delay can be shortened and the signaling overhead can be decreased due to the overlay proximity.

## 6. Conclusion

In this paper, we design an application for group conferencing over mobile ad hoc network. And we present a cross-layer scheme to integrate the ring-based overlay and mesh-based topology. The implement shows that our proposed scheme, RING (Real-time Intercommunication Network Gossip), is simple to work and suitable for small-scale conference. The simulation results show that RING reduces the packet duplication, source-to-end delay, and signaling overhead, that demonstrates RING is suitable for the real-time high-rate delivery in the multiple users. The logical overlay of RING can be proximal to the physical topology based on cross-layer design. Hence, the combination of algorithms for peer joining/leaving/moving can provide a stable routing path in dynamic ad hoc network. From simulation results, RING is suitable for the wireless half-duplex connections to alleviate the hidden node problem. In the future, we consider the *double-ring* overlay and the admission control to save energy and shorten latency.

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**Jun-Li Kuo** received his M.S. degree in Computer Science and Information Engineering from National Central University, Taiwan in 2006. He is a Ph.D. student in Computer Science at National Chiao Tung University, Taiwan. His research interests include peer-to-peer network, mobile ad hoc network, cloud computing, and wireless multimedia.

**Chen-Hua Shih** is currently a Ph.D. candidate in computer science at National Chiao Tung University, Hsinchu City, Taiwan. He received his B.S. degree in computer science and information engineering at National Central University, Jhongli City, Taiwan. His research interests include QoS, mobile IP, wireless networks, and network protocols.

**Cheng-Yuan Ho** received his Ph.D. degree in computer science at National Chiao Tung University, Hsinchu City, Taiwan in 2008. He also works with the Wireless and Networking Group of Microsoft Research Asia, Beijing, China since Dec., 2005. His research interests include the design, analysis, and modelling of the congestion control algorithms, high speed networking, QoS, and mobile and wireless networks.

**Ming-Ching Wang** received his M.S. degree in computer science at National Chiao Tung University, Hsinchu City, Taiwan in 2011. His research interests include peer-to-peer network, mobile ad hoc network, and wireless multimedia.

**Yaw-Chung Chen** received his Ph.D. degree in computer science from Northwestern University, Evanston, Illionis, USA in 1987. During 1987–1990, he worked at AT&T Bell Laboratories. Now he is a professor in the department of computer science of National Chiao Tung University. His research interests include multimedia communications, high speed networking, and wireless networks. He is a member of ACM and a senior member of IEEE.