A MULTIMEDIA CONFERENCING ON A MOBILE AD-HOC NETWORK OVER VEHICLES

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ABSTRACT

This paper presents an implementation of a multimedia conferencing system on a mobile ad-hoc network over vehicles using SIP (Session Initiation Protocol) and Multicast. SIP and Multicast are applied to our multimedia conferencing system to manage inter-vehicle communication efficiently. In order to demonstrate the performance of our system, we have measured transmission characteristics such as throughput, delay and data loss rate on a test bed. A test-bed has been implemented to support multimedia conferencing system and to evaluate the feasibility of high-speed networking between vehicles for emergency notification. Through the experiment, we have used UDP and OLSR (Optimized Link State Routing) to measure transmission metrics. Our multimedia conferencing system operates well on a high-speed mobile ad-hoc network for inter-vehicle communication.

KEY WORDS
Multimedia over Wireless, Inter-vehicle Communications, Ad-hoc networks, SIP (Session Initiation Protocol)

1. Introduction

Due to the dynamic mobility of a car and limited wireless bandwidth, new telematics protocols and applications should be developed in a different manner compared with other wired network protocols. And even when they are carefully developed, most telematics companies may want to evaluate the performance of the protocol in real wireless environments before commercial release.

So, in the first place, we implemented multimedia conferencing system on a mobile ad-hoc network over vehicles. Then we went on experiment to demonstrate the performance of our system in real inter-vehicle communication. Our approach is to construct a real network test-bed following desired scenarios, and then run the applications or protocols in the test-bed. The proposed multimedia conferencing has been developed primarily to evaluate the feasibility of high-speed networking between vehicles for emergency notification and to support multimedia telematics applications.

In our system, users can make or join private group of vehicles. We have been developed using SIP (Session Initiation Protocol) and IP multicast to create or join group of vehicles. SIP is a well-known session control protocol. One vehicle of the group is act as both server and client. Server vehicle has a right to register and manage the list of vehicles. Because of the highly mobile environment in inter-vehicle communication, in the worst case, ad-hoc routing table can not be used immediately. So If SIP is used in multimedia conferencing application, even though group of vehicles is in highly mobile environment, group management can be achieved easily. And we chose IP multicast as a transfer mode to save the bandwidth and manage group of vehicles efficiently. With IP multicast, multi user is able to communicate each other simultaneously, while Hitachi's multimedia conferencing supports one-to-one communication. [1]

The focus of the test-bed is to develop and deploy a multi-hop wireless routing platform to facilitate on-road testing. Based on the network performance analysis and insights from the test-bed, a vehicular networking architecture is being developed across multiple networking layers targeted specifically for inter-vehicle communication

The rest of this paper is organized as follows. Section 2 gives a brief description of the related work and elaborates our contribution. Section 3 discusses inter-vehicle communication and some limitations of previous works. In section 4, we describe the design and implementation of the prototype. Section 5 shows our implementation of multimedia conferencing using SIP and multicast. In section 6, we present the measurement configurations that we have chosen. We also document the measurement results. Finally, section 7 concludes this paper confirming the suitability of WLAN-based access technologies for the vehicle network using Ad-hoc and pointing out next steps in our research.

2. Related Work

There are several implementations of multimedia conferencing, but research of multimedia conferencing on a mobile ad-hoc network is just started.

Due to the dynamic mobility of a car and limited wireless bandwidth, new multimedia conferencing protocols and applications should be developed in a different manner compared with other wired network protocols.

Recently, Hitachi, Japan Company, has been developed multimedia conferencing on a mobile ad-hoc network. [1] They use IEEE 802.11b based ad-hoc network for inter-vehicle communication. Unicast is used as a transfer mode, and one-to-one video conferencing is supported. Figure 1 shows Hitachi's multimedia conferencing application. Carnegie Mellon Univ. & GM also have been implemented test-bed for multimedia conferencing. [2] They used RoadMap tool [3] and H.323 standard libraries for multimedia conferencing.

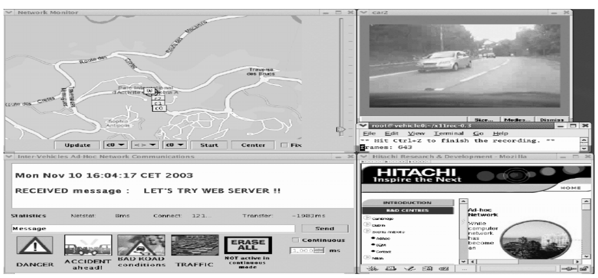


Fig. 1 Hitachi's multimedia conferencing system

However these approaches are at the proposal and demonstration stage. So these multimedia conferencing systems did not consider the multi-user communication, saving the bandwidth, group communication and real-time transmission. Due to the limited bandwidth of the inter-vehicle communication, saving bandwidth is very essential factor of multimedia conferencing on a MANET over vehicles. So we applied to Multicast in our multicast conferencing system to save the bandwidth. If a necessary condition of our multimedia conferencing is N, previous multimedia conferencing systems need N. We also use SIP to manage group communication efficiently.

The contributions of our proposed framework are shown at figure 2.

	Our multimedia conferencing system	Previous multimedia conferencing system
Transfer mode	1 : N (Multicast)	1 : 1 (Unicast)
Multimedia conferencing	Multi- user	1 : 1
Group communication	O	X
Real- time transmission	O (RTP)	X

Fig. 2 characteristics of our system

3. Background

<u>Inter-vehicle communication</u>

Inter-vehicle communication can be used to facilitate applications [7] improving driving safety and convenience. Potential uses of such applications are dynamic traffic routing, driver assistance and navigation, entertainment, co-operative driving, etc. The existing ad-hoc networking infrastructure can be leveraged and performance enhancement measures can be innovated for provisioning seamless inter-vehicle communication. As opposed to centralized service, and ad-hoc network is much better suited for vehicle-related applications that exchange data having local relevance. The existing 802.11 compliant devices can be used for providing wireless connectivity between moving vehicles. With the advent of 802.11a hardware, bandwidths of up to 54 Mbps have become realizable. However, Vehicular traffic scenarios pose greater challenges than the indoor WLAN applications, due to associated driving speeds, varying vehicular traffic patterns and driving environments. Performance measurements for 802.11 based wireless LANs have been done in indoor office and industrial environment [8]. These results do not provide performance indication for the more challenging vehicular scenarios. Through the test we conduct, we investigate the performance achievable by an 802.11b-based WLAN in vehicular scenarios.

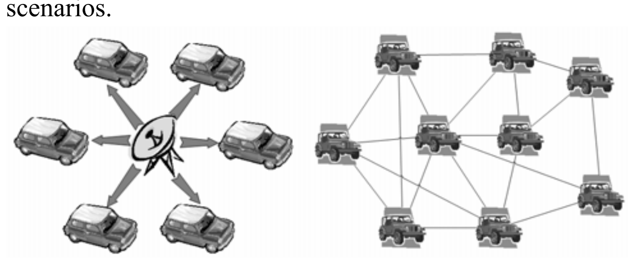


Fig. 3 The current network using access point vs ad-hoc network without access point

There are two types of inter-vehicle communication network using Ad-hoc [fig.3] One is Inter-vehicle communication supported by AP (Access Point), which has been discussed [9]. However, this approach is not cost-effective. It requires development of exclusive infrastructure. Access points may be provided at each street corner, co-located with traffic lights, or emergency phones, be placed in parking lots or in rest areas or may be co-located with gas stations or other shops in service areas. The other is inter-vehicle communication supported by ad-hoc routing algorithm [10]. In this approach, it is important that each mobile node can detect other's position and routing path continuously.

In this paper, we focus on plain WLAN connectivity and transport protocol behavior-and only briefly address implications on applications in the end. Our goal is to prove that WLAN technology is capable of enabling the vehicle network using ad-hoc in the first place and to document the communication characteristics we have observed with different measurement configurations using UDP and TCP as standard transport protocols. After simulation and measurement of transport protocol in ad-hoc mode, we describe the multi-hop mobile vehicular test-bed, our design decisions and driving experiences.

4. Our novel Multimedia conferencing on a MANET over vehicles

The overall architecture is shown at figure 4.

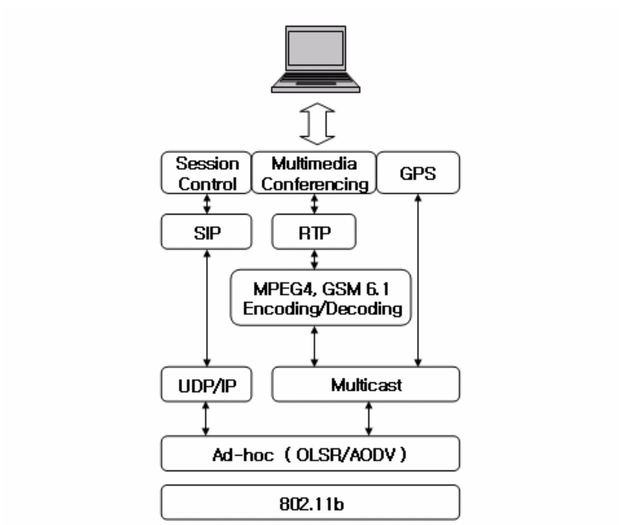


Fig. 4 Architecture of our multimedia conferencing system

A. SIP & Multicast

The Session Initiation Protocol (SIP) allows two or more participants to establish a session consisting of multiple media streams. The media streams can be audio, video or any other Internet-based communication mechanism. In our multimedia conferencing system, one vehicle of the group acts as both server and client. Server vehicle has a right to register and manage the list of vehicles. Because of highly mobile environment in inter-vehicle communication, in the worst case, ad-hoc routing table can not be used immediately. If SIP is used in multimedia conferencing system, even though group of vehicles is in a highly mobile environment, group management can be achieved easily.

IP multicasting provides delivery to multiple destinations. There are many applications that deliver information to multiple recipients: interactive conferencing and dissemination of mail or news to multiple recipients, for example. In many applications it is better than broadcasting, since multicasting imposes less overhead on hosts that are not participating in the communication. With multicast, multi-user is able to communicate each other simultaneously, while previous multimedia conferencing system supports only one to one communication.

B. Test-bed Hardware

We have used the cars with notebook as depicted in Figure 5.For the moving vehicles, we have equipped the

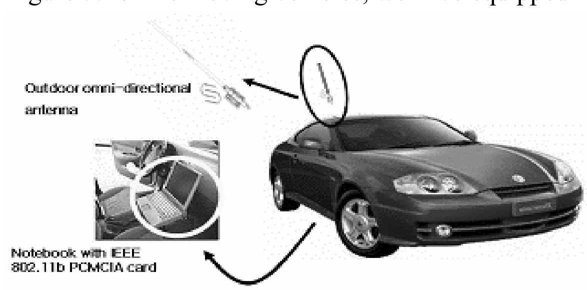


Fig. 5 Test-bed Hardware

PCMCIA card with an external antenna is placed at the right hand side of the vehicle. The PCMCIA card supports IEEE 802.11b, and the external antenna is outdoor omni-directional antenna. The range of the wireless link is approximately 300m for line-of-sight reception. The PCMCIA card was configured to use ad-hoc mode, so all the notebook has communicated with each other. We use the same ESSID, and WEP encryption has been deactivated, and we have used a beacon interval of one second which is the default settings for most access points. The mobile device had a statically assigned IP address. To facilitate multimedia applications, the test-bed includes a voice headset and a camera. All devices are powered by the vehicle's DC power system via the cigarette lighter, utilizing DC-DC power converters. Finally, GPS receiver is employed so that each vehicle can exchange its GPS information.

C. Test-bed Software

We primarily use three layers of software on the test-kit.

<Multimedia conferencing System>

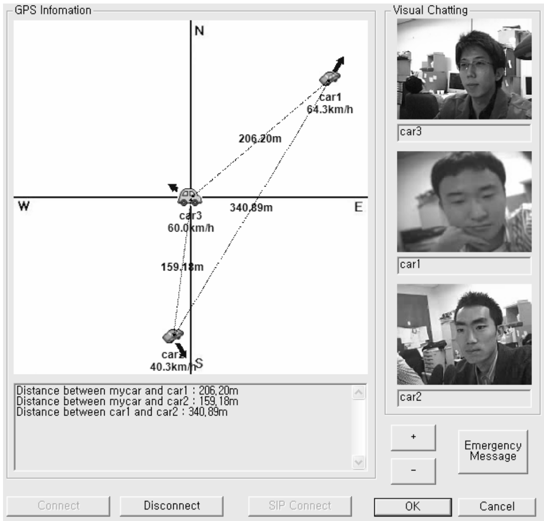


Fig. 6 Multimedia conferencing application

Interactive and well-defined applications such as inter-vehicle voice communication, video streaming and collaborative driving applications fall within the area of telematics. Using such applications, users can form or join private groups of vehicles. Our telematics application provides three major functions: Multimedia Conferencing system, Emergency Messaging and Location Information service. [Fig.6]

Audio and video streaming was performed using our implementations based on MPEG4, GSM 6.1 standard codec. To achieve the frequent and rapid transportation, buffering systems have been implemented separately: Audio buffer, video buffer. The reception of the audio and video codec was well-performed but when distance of the vehicle to vehicle is out of range, connection was broken.

Second, our telematics system supports Emergency Messaging [Fig 7]. Messages reporting vehicle accidents, sudden breaking and other critical events need to be spread promptly and for the duration of the event's life time, multimedia conferencing system has to be restricted. Such messages are multicast but within the scope of relevant vehicles approaching the event's location.

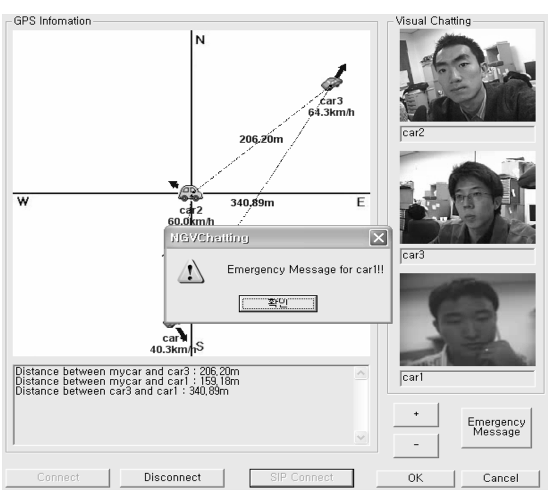


Fig. 7 Emergency Messaging

Finally, Location Information service is a part of our telematics application. To visualize the current position of the vehicles, distance of vehicle to vehicle and relative velocity (Hitachi only support current position of vehicle), we adapted GPS based Location information service for our test-bed. Because we used IP multicast to create group of vehicles, each vehicle exchanges its GPS information (position, velocity, direction…etc) every two second.

<Mobile Ad-hoc networking software>

We tested two existing mobile ad-hoc routing protocols such as AODV [11] and OLSR [12] kernel implementations. Though the protocols support connectivity across multiple hops, their performance in a mobile environment was unreliable. In a highly mobile environment such as inter-vehicle communication where connectivity changes often, these protocols were unable to reconstruct routes fast enough.

In order to improve performance, we fixed the driving situations. Our focus is to prove that mobile ad-hoc network can be employed to inter-vehicle communication, so vehicle to vehicle distances were maintained approximately 70m, and the velocity of the vehicle was fixed about 70km/h. And we have mainly employed the implementation of OLSR [13], which can be endure highly mobile environment

<Traffic generator>

We have measured both UDP and TCP performance in the same situation. For all UDP and TCP measurements, we have implemented two programs, one for configurable packet transmission and receiving tool sinking the received packets. We have transmitted packet size of 2500 bytes and used sending intervals of 2ms. It means that 500 packets per second. So, the nominal sending rate is 3Mbps and 5Mbps

5. Implementation

As we mentioned in section 4, our novel multimedia conferencing application has been implemented using SIP and multicast. SIP, the Session Initiation Protocol, is a signaling protocol for Internet conferencing, telephony, presence, events notification and instant messaging. It can run on any types of transport protocols (UDP, TCP) and can be called anytime during the multimedia session to modify parameters of session and even terminate session. . Because of the highly mobile environment in inter-vehicle communication, in the worst case, ad-hoc routing table can not be used immediately. So If SIP is used in multimedia conferencing application, even though group of vehicles is in highly mobile environment, group management can be achieved easily.

```
int CSIPMessage::SetInviteMsg(char* szMsg, UINT nSIPPort, char* strToID)
    {
            char* szInvite = szMsg;
            char strTmp[100];

            memset(strTmp, 0x00, sizeof(strTmp));
            sprintf(strTmp, "INVITE sip:%s@rti.biz SIP/2.0₩n", strToID);
            strcat(szInvite, strTmp);

            memset(strTmp, 0x00, sizeof(strTmp));
            sprintf(strTmp, "Via: SIP/2.0/UDP %s:%d₩n", m_strIP, nSIPPort);
            strcat(szInvite, strTmp);

            memset(strTmp, 0x00, sizeof(strTmp));
            sprintf(strTmp, "To: %s <sip:%s@rti.biz>₩n", strToID, strToID);
            strcat(szInvite, strTmp);

            memset(strTmp, 0x00, sizeof(strTmp));
            sprintf(strTmp, "From: %s <sip:%s@rti.biz>", m_strID, m_strID);
            strcat(szInvite, strTmp);

            return strlen(szInvite);
    }
```

Fig. 8 SIP message of client (INVITE)

In order to use SIP, a user registered into the system. In other words, client registered into the server to start session set up. Our implementation consists of the two parts: server and client. We have been developed our multimedia conferencing application for three cars. One of them plays a role in server and client, and others act as client only. Figure 8 shows the INVITE message which is sent by client. The INVITE message is used to establish media sessions between server and client. As shown in figure 8, SIP header (INVITE, Via, To, From…etc) is included in the message

```
int CSIPMessage::SetOKMsg(char* szMsg)
    {
            char strLine[200];

            memset(strLine, 0x00, sizeof(strLine));
            memset(m_strMsg, 0x00, sizeof(m_strMsg));

            strcpy(m_strMsg, "SIP/2.0 200 OK₩n");

            memset(strLine, 0x00, sizeof(strLine));
            strcpy(strLine, GetSplitString(szMsg, "₩n", 2));
            strcat(strLine, "₩n");
            strcat(m_strMsg, strLine);

            memset(strLine, 0x00, sizeof(strLine));
            strcpy(strLine, GetSplitString(szMsg, "₩n", 3));
            strcat(strLine, "₩n");
            strcat(m_strMsg, strLine);

            memset(strLine, 0x00, sizeof(strLine));
            strcpy(strLine, GetSplitString(szMsg, "₩n", 4));
            strcat(strLine, "₩n");
            strcat(m_strMsg, strLine);

            strcat(m_strMsg, "Subject: register success");

            return strlen(m_strMsg);
    }
```

Fig. 9 SIP message of server (200 OK)

Figure 9 shows the 200 OK message which is sent by server. It contains a message body containing the media properties of the server. The 200 OK is an example of a "success class" response.

```
BOOL CMulticastSocket::Create(char *pAddr, unsigned int uPort)

  {
    struct addrinfo *ai, *ab, hint;
    char pport[16];



    // For Multicast Address
    sprintf(pport, "%d", uPort);
    if( getaddrinfo(pAddr, pport, NULL, &ai) != 0 )
            return FALSE;

    // For binding
   memset(&hint, 0, sizeof(hint));
   hint.ai_family = ai->ai_family;
   hint.ai_socktype = SOCK_DGRAM;
   hint.ai_flags = AI_NUMERICHOST | AI_PASSIVE;

   if( getaddrinfo(NULL, pport, &hint, &ab) != 0 )
            return FALSE;


            else
            return FALSE;        // Not Supported Protocol

    memcpy((void*)m_ssAddr, (void*)ai->ai_addr, ai->ai_addrlen);
    m_iAddrlen = ai->ai_addrlen;

    if( pApi->Bind(s, (void*)ab->ai_addr, ab->ai_addrlen)==0 )
            return CreateThread();

            return FALSE;
      }
```

Fig. 10 Multicast

In addition, we have been implemented our multimedia conferencing application using multicast. In normal Internet packet routing, or unicast routing, a packet is routed to a single destination. In multicast routing, a single packet is routed to a set of destinations. Certain addresses have been defined for certain protocols and applications. With IP multicast, because

single packet is routed to several destinations, multi user is able to communicate each other simultaneously, while Hitachi's multimedia conferencing supports only one-to-one communication. Sample source code of multicast function is shown at figure 10.

6. Measurements

Three vehicles on which ad-hoc network nodes were installed drove on the street. Figure 11 shows the geometry of the experimental environment. The cars traversed the route repeatedly during the measurement.

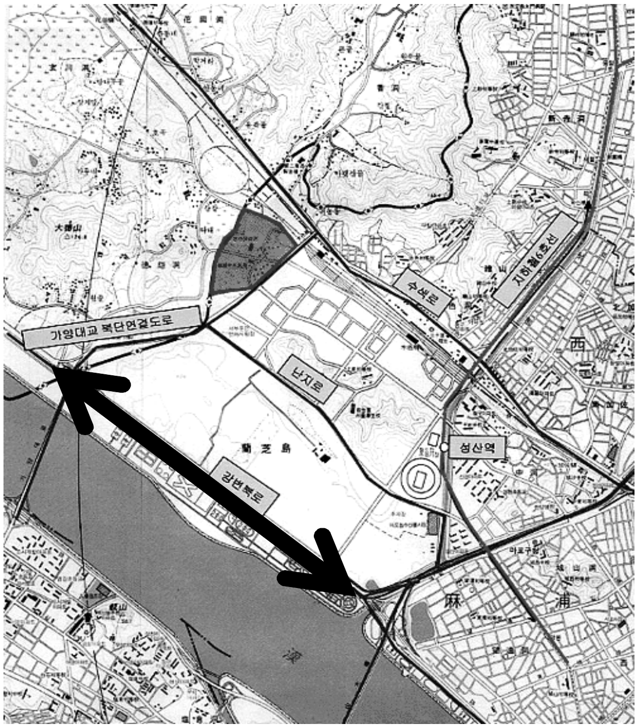
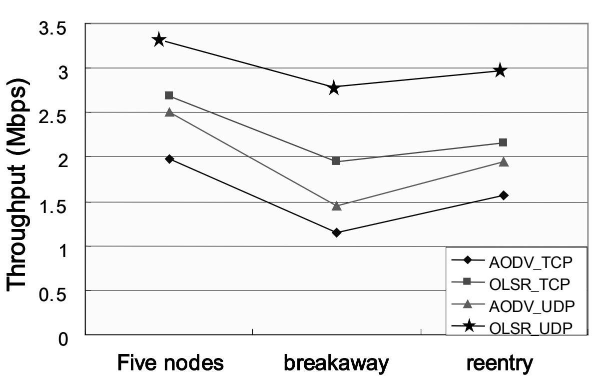
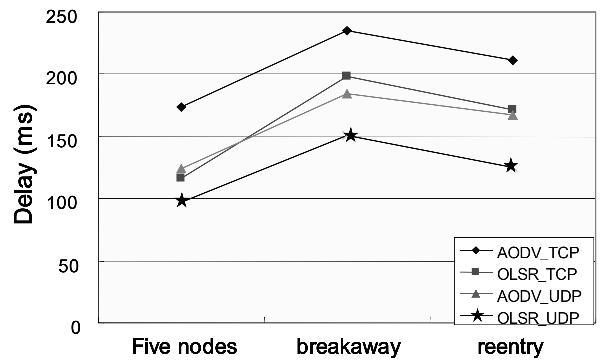


Fig. 11 Map of experimental environment

To demonstrate the performance of our multimedia conferencing system, we selected transport layer protocol and ad-hoc routing protocol firstly. In our experiment, we compare transmission protocols: TCP, UDP. And we also measure the transmission characteristics of two well-known ad-hoc routing protocols: AODV and OLSR. Figure 12 shows the results. In this experiment situation, we used five cars which are engaged in mobile ad-hoc network over vehicles. Velocity of cars is 30 km/h, and distance between vehicles is 50m. There are three steps in this experiment. First, five cars drive in a row. Second, 2 minutes later, one of the five cars is breakaway. Finally, another 2 minutes later, a car which was break away goes into mobile ad-hoc network. By doing this experiment, An aspect of route recovery time, we can see which ad-hoc routing protocol is better. And we also show that which transport layer protocol is suited for mobile ad-hoc network over vehicles in aspect of throughput and delay.



(a) Throughput

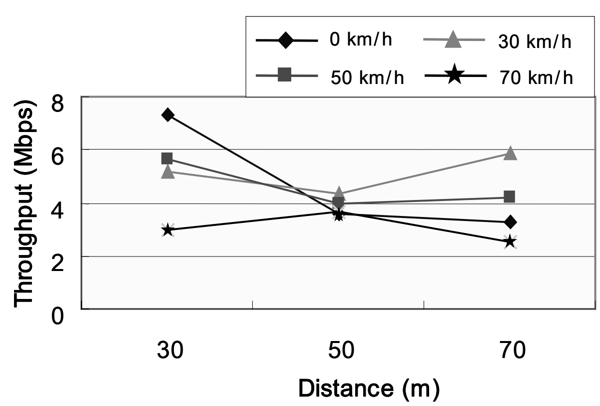


(b) Delay

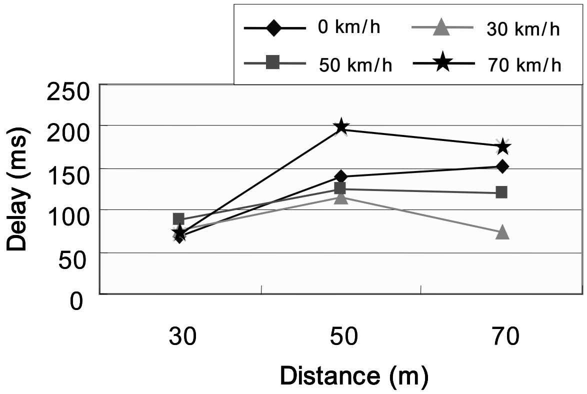
Fig. 12 Performance of Ad-hoc routing protocol with different transmission protocol

Figure 12-(a) shows that change of throughput in this experiment scenario. When we use both OLSR and UDP, we can get higher throughput than any other case. The minimum throughput in case of using OLSR and UDP is about 2.8 Mbps. Multimedia conferencing can be operated theoretically with this throughput. Figure 12-(b) shows the variation of delay. OLSR-UDP is also well performed. The highest delay time is about 150 ms when we use OLSR and UDP. In general, when delay is below 200 ms, user is not interrupted by the delay in multimedia conferencing.

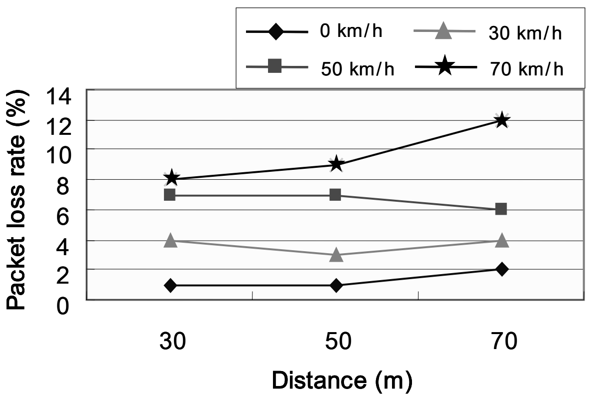
Then, we have measured transmission characteristics such as throughput, delay and data loss rate with a test bed. In these experiments, we use OLSR and UDP which is well performed combination on a MANET over three vehicles. Figure 13-(a) shows the variation of throughput when distance of each vehicle is 30m, 50m and 70m. We repeat this in case of increasing velocity of vehicles from 0 km/h to 70 km/h. In general, throughput is decreased when distance between vehicle is increased and velocity of vehicle is incremented. By the way, the minimum throughput is about 2.2 Mbps in case that distance between vehicles is 70 m and velocity is 70 km/h. In this environment, multimedia conferencing operates well.



(a) Throughput



(b) Delay



(c) Packet loss rate

Fig. 13 Performance of transmission characteristics: OLSR & UDP is used.

Figure 13-(b) shows the transition of delay in the experiment situation as mentioned in above. We show that delay is increased when distance between vehicle is increased and velocity of vehicle is incremented. Note that delay is beyond 200ms when velocity of vehicle is 70 km/h. In order to improve multimedia conferencing condition, performance of MANET should be reformed.

Finally, change of data loss rate is shown at figure 13-(c). Generally speaking, data loss rate is increased when distance between vehicle is increased and velocity of vehicle is incremented. Data loss rate should be checked when distance between vehicles is 70 m and velocity is 70 km/h. It means that multimedia conferencing system is falling off in quality.

After these experiments, we tested our novel multimedia conferencing system on a mobile ad-hoc network over three vehicles. As expected, our system operates well under same experiment environment. Because we applied multicast to our system, three vehicles are communicated successfully by saving bandwidth. And to join or leave the group is freely achieved as intended.

However, when velocity of vehicle is beyond 70 km/h and distance between vehicles is longer than 250m, our multimedia conferencing is cut off. Due to the limited bandwidth of wireless network, increased delay and data loss rate, inter-vehicle communication, network connectivity declined.

7. Conclusion

In this paper, we present a multimedia conferencing on a mobile ad-hoc network for inter-vehicle communication. Because our novel multimedia conferencing is implemented using SIP and multicast, group management and multi-user communication performs effectively in highly mobile environment such as mobile ad-hoc network for inter-vehicle communication.

Due to the limited bandwidth of inter-vehicle communication, multimedia conferencing is cut off when network mobility is extremely high and distance between vehicles is very long. We would like to investigate into this issue further in the future and improve this limitation of MANET over vehicles.

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