Research on the Performance of Protocols and the Evaluation Metric for VIDEO Transmissions in an Ad Hoc Network

Ruey-Shin Chen[1], Louis R. Chao[2], Ching-Piao Chen[3] and Chih-Hung Tsai[3†]

[1]Department of Information Management National Kinmen University of Science and Technology No. 1, University Rd., Kinmen, Taiwan

[2]Department of Computer Science and Information Engineering Tamkang University, Taipei, Taiwan

[3]Department of Industrial Engineering and Management Ta-Hwa Institute of Technology 1 Ta-Hwa Road, Chung-Lin Hsin-Chu, Taiwan, ROC
Tel: +886-3-5927700~2953 E-mail: ietch@thit.edu.tw

Abstract

Video transmission effectiveness in the Ad Hoc network is becoming important recently, if different routing protocols are applied. Some researchers conclude that the reactive protocols are better for file transfer protocol (FTP) and constant bit rate (CBR) or hypertext transfer protocol (HTTP) transmission in an Ad Hoc wireless network but the performance report of video transmission is not much. This study adopts Qualnet (Network Simulator) as a simulation tool for environmental designing and performance testing, and employs an experimental design with eight groups. Our experiment shows that: (1) The performance of AODV (reactive) protocol is better than DSDV, ZRP and DSR when the transmission load has only one video stream; (2) Proactive (DSDV) and Hybrid protocols (ZRP) are better for a smaller Ad Hoc network when it transmits a video stream with some applications (VoIP, FTP and CBR). We conclude that packet loss rate is sensitive to the quality of video transmission and it has negative relationship with Peak Signal-to-Noise Ratio (PSNR) value. In addition, our experiment also shows that PSNR is a simple Metric for the performance evaluation of video transmission.

Key Words: Ad Hoc Network, Proactive, Reactive, Protocol, Video Transmission

1. Introduction

In the field of wild area rescue or military combat, the Ad Hoc network is one of the important modes for an independent audio or video transmission in the region without using any

† Corresponding Author

pre-installed network infrastructure. Several studies have highlighted the file transfer protocol (FTP) or hypertext transfer protocol (HTTP) transmission played by different protocols. But, VIDEO transmission is becoming important recently, and these protocols may be doing good or bad communication at different VIDEO application backgrounds. Thus, the effectiveness with different protocols (proactive, hybrid or proactive) appears a crucial issue to examine. Mobile-phone is one of networks having a fixed infrastructure, and its global market for the premium content is expected to expand to more than $43 billion by 2010 (i-wisdom, 2007). Another mobile network, having no stationary infrastructure, is a new but highly valuable and promising type of network. It can be explained as a network of mobile computers, in which they create or destroy links each other, and therefore is called a mobile ad hoc network (MANET) (Pandey and Fujinoki, 2005). MANET devices are becoming more and more important in this computer and communication era due to their non stationary, high mobility, and rapid installation at wild area which does not need to construct a fixed stationary before mobile network communication. However, users are not always satisfied by the simple transmission of traditional information on MANET. In fact, the efficiency of multimedia transmission is not as good as it is seen in a fixed infrastructure network. Therefore, the selection of a suitable protocol becomes of great importance for a user in a MANET wireless network.

Multimedia transmission, such as video packet transmission, results in more packets loss and delay in mobile ad hoc networks because of users' dynamic channel changes. In Ad Hoc networks, fixed stations do not exist and every local broadcast will transfer a packet to multiple nodes within the communication range of a transmitting node at the same time. Good routing performance is needed when global broadcasts transmit copies of each packet to the destination. Bad performance of a routing protocol not only reduces the quality of a video transmission but also wastes battery power of intermediate nodes for transmitting duplicated copies of packets. In recent years, some researches have been reported that Dynamic Source Routing (DSR) performs better than Ad hoc On-Demand Distance Vector (AODV) on the transmission of FTP or HTTP in conditions where the node density and/or node mobility are low. On the contrary, AODV performs better when both of them are high (Cordeiro and Agrawal, 2002; Hong *et al.*, 2002). However, it seems that there isn't any published work to reveal how much better performance of video transmission is on these MANET routing protocols. Thus, in order to know the performance of a video transmission under different protocols in a small network (nodes < 50), two evaluation experiments are performed in this study for simulating the transmission of video streaming through different ad hoc protocols.

2. Overview of Ad Hoc Routing Protocols

There are some famous Ad Hoc routing protocols which have been prepared for mobile networks. They can be classified as proactive protocols, reactive protocols and the hybrid protocols (Pandey and Fujinoki, 2005). A classification of the well-known ad hoc routing protocols is shown in Figure 1.

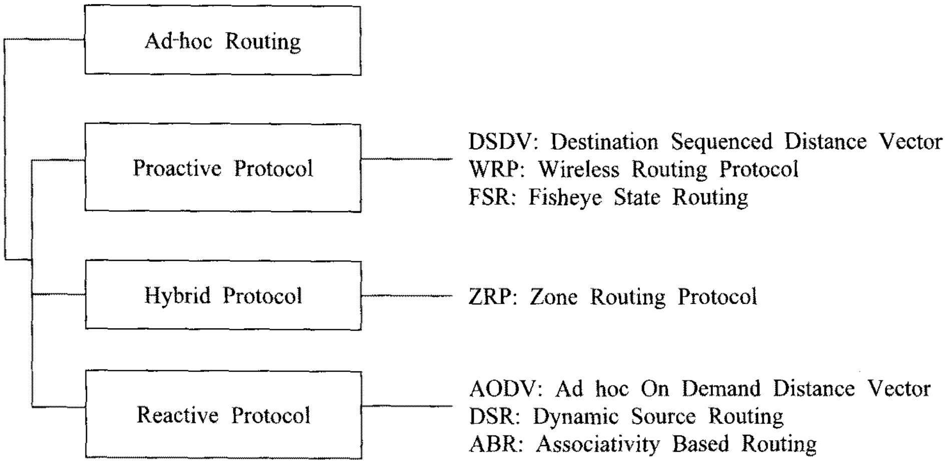

Figure 1. Reactive and proactive protocols

The two major types of mobile ad-hoc routing protocols are proactive protocol and reactive protocol. Proactive protocol establishes any two nodes path in its routing table and refreshes it at certain time intervals, even if no communication is needed. It is also called a table-driven routing protocol. Destination Sequenced Distance Vector (DSDV) is one of the more famous proactive routing protocols (Perkins *et al.*, 2003a; Perkins and Royer, 1999). Reactive protocol searches and establishes any two nodes path in its routing list when communication is requested. It is also called a source-initiated or demand-driven routing protocol; AODV and DSR are the two most famous reactive routing protocols (Perkins *et al.*, 2003b; Broch *et al.*, 1999). Zone Routing Protocol (ZRP) is one hybrid of the reactive and proactive protocols. It may be a better video transmission solution for MANETs as it uses the best characteristics of both reactive and proactive protocols (Pandey and Fujinoki, 2005; Perkins *et al.*, 2003a; Johnson *et al.*, 2004). As a proactive protocol, DSDV, WRP or FSR establishes its route before any transmission is started. When a proactive protocol is used for MANETs, the node will frequently update its neighbors with the routing information. The fast changes in network topology might crush the network with excess overhead and control messages (Perkins and Bhagwat, 1994; Johnson and Maltz, 1996).

The procedure for most reactive protocols includes route discovery and route maintenance. In the practice of reactive protocols, a starting node performs a route discovery process when a node wants to send information to a target node in a network. Once a path is found, the route is kept in the temporary cache at a starting node until it expires or another route is discovered after an event occurs. Compared to proactive protocols, the advantages of a reactive protocol include: (1) Each node has less routing information; (2) The node needs not obtain and maintain the routing information for all the nodes in a network; (3) The midway nodes do not have to make routing decisions. The disadvantages of a reactive protocol include: (1) Route acquisition may be delayed by route discovery; (2) Compared with a proactive protocol, excess volume of overhead messages might occur due to frequent changes of the MANET's nodes (Pandey and Fujinoki, 2005). Reactive protocols (AODV, DSR, and ABR) have a more dynamic approach. They search for and setup a new route only when communication is required. Because it could reduce vast processing and control overhead, which is caused by routing maintenance and the periodic updating, previous research argues that reactive protocols are more suitable for large wireless networks (Perkins *et al.*, 2003a; Tran and Raghavendra, 2006; Klaue *et al.*, 2003; Corson and Park, 1999; Lu *et al.*, 2003). In order to know whether the performance of Reactive protocol is still better for Video transmissions in a small Ad Hoc Network, this study will address the performance of proactive, reactive and hybrid protocols such as DSDV, ADODV, DSR and ZRP in a small (less than 50 nodes) Ad Hoc Network.

3. Evaluation Framework

For an experiment of performance evaluation, it is difficult to create a large physical Ad Hoc network system. In this study, we adopt the Qualnet Network Simulator for simulating the entire experiment and obtaining the result data. We test an MPEG4 video transmission performance with different Ad Hoc protocols (DSDV, AODV, DSR and ZRP). The area is limited to 500m × 500m with a different nodes number (15, 30 and 45) for each protocol experiment. The fast shift rapid is set to 200 m/sec while the slow rapid is set to 40m/sec, 80m/sec and 120m/sec. The total experiment time is set to 1,000 seconds as shown in Table 1.

Table 1. Parameter for experiment environment

Experiment Area	500m × 500m
Node Numbers	15, 30 and 45
Node Allocation	Random
Move style	Random Waypoint
High speed	200 m/sec
Low speed	40, 80 or 120 m/sec
Experiment Time	1000 sec

The experiment includes two groups. There is only one video stream in the packet transmission of first experiment. The second experiment includes constant bit rate (CBR), voice over IP (VoIP), file transfer protocol (FTP) and video stream. For example, when the nodes numbers are 15, it links with 2 CBRs, 1 VoIP, 2 FTPs, and one video stream. The linkage applications are doubled when nodes are doubled (30 nodes link with 4 CBRs, 2 VoIP, 4 FTPs, and two video streams).

3.1 Video generating

The Qualnet provides traffic trace for an application in multimedia transmission. It can read user provided sample information and generates corresponding packets. The sample information is shown as the Table 2. In order to get an objective traffic trace, as shown in Figure 2, we transfer the video using the EvalVid tool. At the start of the procedure, it transfers a YUV format to a traffic trace format (YUV to MP4, MP4 to the format of Qualnet trace file). During

Table 2. the format of Trace file for MPEG4

Frame no	Frame type	Length (byte)	No of cut	Time (ms)
804	P	536	1	26.770
805	P	601	1	26.801
806	P	820	1	26.834
807	P	773	1	26.879
808	P	549	1	26.911
809	P	813	1	26.942
810	P	606	1	26.973
811	H	6,457	7	27.005

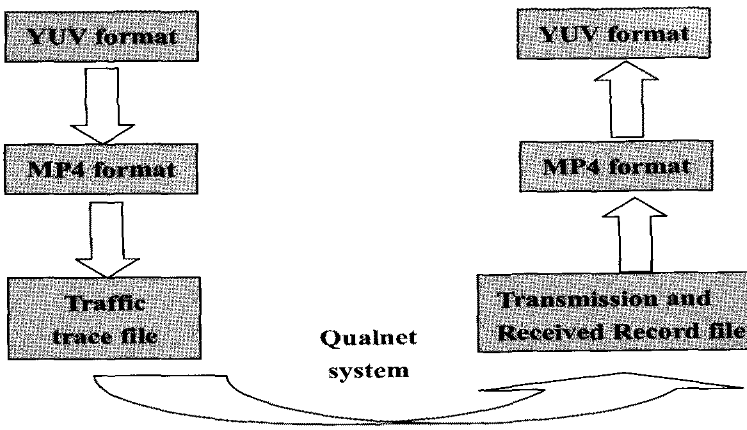

Figure 2. The procedure of generating and transmitting a Traffic Trace File

the middle of the procedure, Qualnet simulates the transmission of an Ad Hoc network. At the end of the procedure, it combines data between the receipt point and the Qualnet simulator and generates a new YUV format for evaluating the performance of received video.

4. Simulating Measurements

Many researchers constrain themselves by using the packet loss rate, packet delay or packet jitter and consider those measures as sufficient to characterize the quality of the resulting video transmission. It is, however, well known that the above mentioned parameters can not be easily evaluated. Beside these traditional metrics, this study will adopt EvalVid as one of the tools, and PSNR and MOS as metrics for a video transmission experiment. EvalVid presents a complete framework and tool-set for the evaluation of the quality of video transmitted over a real or simulated communication network (Klaue *et al.*, 2003).

In this experiment, we use 5 metrics to evaluate 4 protocols (DSDV, AODV, DSR and ZRP). These metrics include end-to-end delay, end-to-end jitter, packet loss rate, PSNR and MOS. PSNR is one of the most common metrics for assessing application-level QoS of video transmissions. Equation (1) shows the definition of the Peak Signal-to-Noise Ratio (PSNR) between the luminance component Y of source image S and destination. The difference between the qualities of the encoded video at the source and the received one can be used as an objective QoS metric to assess the transmission impact on video quality at the application level. PSNR can reflect the most realistic video quality rather than decodable frame rate or other metrics. It is suitably used to assess the quality of video transmission in comparing the protocols. The following is the PSNR equation: where Vpeak = 2^k-1 and k = number of bits per pixel (luminance component) (Ohm, 1999).

$$PSNR(n)_{dB} = \frac{20\log_{10} V_{peak}}{\sqrt{\frac{1}{N_c N_r}\sum_{i=0}^{N_c}\sum_{j=0}^{N_r}[Y_s(n,i,j) - Y_D(n,i,j)]^2}} \quad \text{Equation} \quad (1)$$

Table 3. Possible PSNR to MOS conversion

PSNR [dB]	MOS
> 37	5 (Excellent)
31~37	4 (Good)
25~31	3 (Fair)
20~25	2 (Poor)
< 20	1 (Bad)

Comparing PSNR at the application level, Mean Opinion Score (MOS) is a subjective metric to assess the quality of digital video. People are used to rank the quality of a function from 1 (bad) to 5 (excellent) in reflecting their impression of service or payment. The PSNR of every single frame can be weighed against the MOS scale in this outlined measurement as Table 3 (Ohm, 1999).

5. Analysis and Discussion

5.1 Transmission Analysis for MPEG4 in Ad Hoc network

This section analyzes two group experiments of Transmission results of MPEG4s in an Ad Hoc network.

5.2 Experiment 1: One video stream in Ad Hoc network

The following figures show the simulation result in Packet loss rate (Figure 3), End-to-end delay (Figure 4) and End-to-end jitter (Figure 5) with different protocols. From the comparison of these metrics, the performance of Reactive (AODV) protocol is obviously better than DSDV, ZRP and DSR when the transmission load has only one video stream in an Ad Hoc

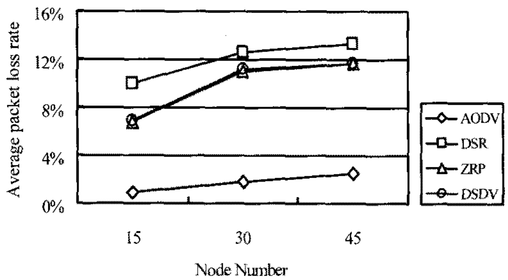

Figure 3. Packet loss rate

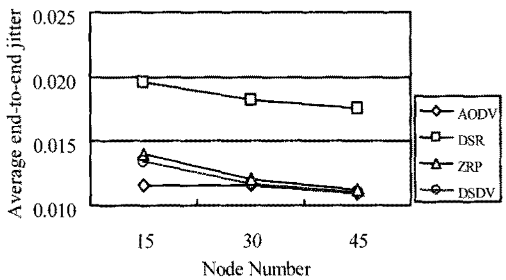

Figure 4. End-to-end delay

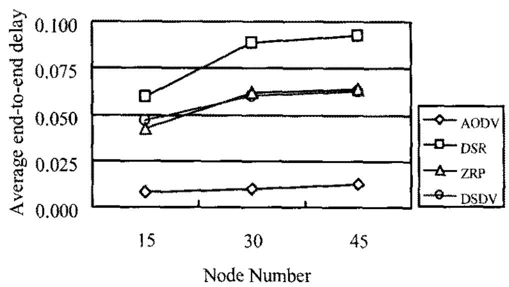

Figure 5. End-to-end jitter

Table 4. PSNR values

Nodes	AODV	DSDV	DSR	ZRP
15	35.5370	35.1874	35.0984	35.2099
30	35.4502	34.8879	34.9857	34.9036
45	35.4360	34.6500	34.7844	34.6858

Table 5. loss rate vs. PSNR values

Node = 15	AODV	ZRP	DSDV	DSR
Loss rate %	1	6.3	7	10
PSNR	35.54	35.21	35.19	35.10

Table 6. loss rate vs. PSNR values

Node = 30	AODV	ZRP	DSDV	DSR
Loss rate %	2	10.2	11	12.5
PSNR	35.45	34.90	34.89	34.99

Table 7. loss rate vs. PSNR values

Node = 45	AODV	ZRP	DSDV	DSR
Loss rate %	3	11.4	11.6	13.5
PSNR	35.44	34.69	34.65	34.78

Table 8. Regression of experiment one

Independent: Loss Rate, Dependent: PSNR					
Mth	Rsq	Sigf	b0	b1	b2
LIN	.863	.000	35.6088	-.0651	
QUA	.863	.000	35.6191	-.0697	.0003

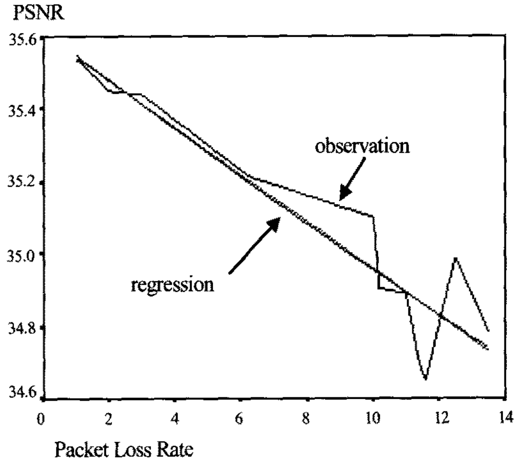

Figure 6. Packet Loss Rate VS PSNR

network due to AODV having low Packet loss rate, low End-to-end delay and low End-to-end jitter. As Table 4 shows, it can also be verified by the average of PSNR values. The PSNR values of AODV are greater than 35.4, which are better than the value of all other protocols tested.

From these measurements listed above, we confirm that packet loss rate is sensitive to the quality of video transmission and it has negative relationship with PSNR value. According to Table 5, Table 6, Table 7, and Figure 6, both R square of linear and quadratic regression are high at 0.863. Based on the regression analysis, we found that all variable loadings were highly significant at 0.00 (Table 8, $^{**}p < 0.01$) which shows that the experiment values are good to fit these regression lines. The PSNR value can be predicted by Packet loss rate.

5.3 Experiment 2: Video stream combines with some applications in Ad Hoc network

The following figures show the simulation result in Packet loss rate (Figure 7), End-to-end delay (Figure 8) and End-to-end jitter (Figure 9) with different protocols. From the comparison of these metrics, the packet loss rate and End-to-end delay of ZRP is better than the rate and delay of other protocols when nodes are less or equal to 15. As the PSNR Table 9 shows, it can also be confirmed by the average of PSNR values. The PSNR average values of DSDV and ZRP (node = 15) are greater than 35.2, better than the value of other

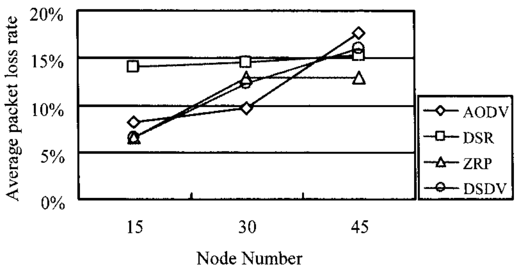

Figure 7. Packet loss rate

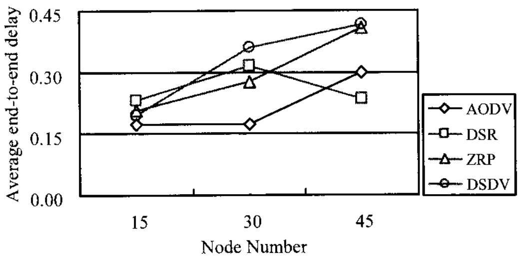

Figure 8. End-to-end delay

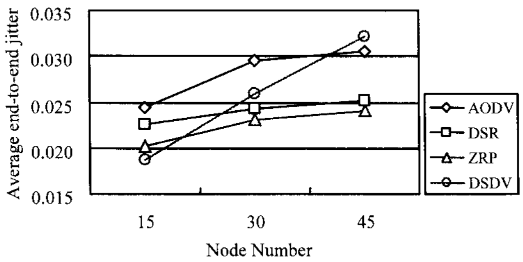

Figure 9. End-to-end jitter

Table 9. PSNR values

Nodes	AODV	DSDV	DSR	ZRP
15	35.1030	35.2153	34.7778	35.2352
30	35.0673	34.8140	34.7014	34.7590
45	33.9170	34.7333	34.6243	34.6744

Table 10. Loss rate vs. PSNR values

Node = 15	ZRP	DSDV	AODV	DSR
Loss rate %	6.2	6.5	8	14
PSNR	35.24	35.22	35.10	34.78

Table 11. Loss rate vs. PSNR values

Node = 30	AODV	DSDV	ZRP	DSR
Loss rate %	10	12.5	13	14.5
PSNR	35.07	34.81	34.76	34.70

Table 12. Loss rate vs. PSNR values

Node = 45	ZRP	DSR	DSDV	AODV
Loss rate %	12.5	15	16.2	17.5
PSNR	34.67	34.62	34.73	33.92

Table 13. Regression of experiment one

Independent: Loss Rate, Dependent: PSNR					
Mth	Rsq	Sigf	b0	b1	b2
LIN	.764	.000	35.8015	-.0819	
QUA	.863	.000	35.0164	-.00704	.0003

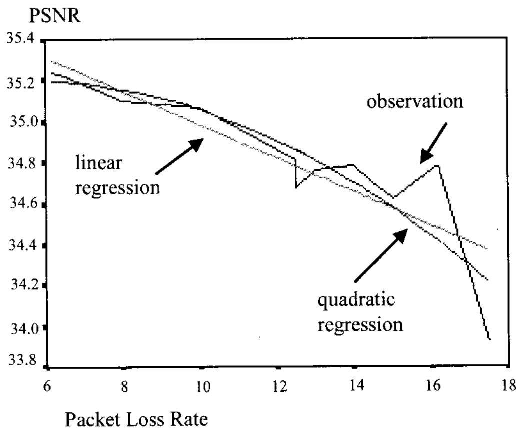

Figure 10. Packet loss rate vs. PSNR values

protocols. The packet loss rate and End-to-end delay of AODV is better than the rate and delay of other protocols when nodes are between 15 and 30 though its jitter is slightly higher than that of the others. As the following PSNR table shows, it can also be confirmed by the average of PSNR values. The PSNR average values of AODV (node = 30) are greater than 35.06, which is better than the value of other protocols (DSDV = 34.8, DSR= 34.70 and ZRP = 34.75). AODV is still better than other protocols when nodes are at 30. It shows that end to end delay is sensitive in video transmission and it has negative relationship with PSNR. When nodes are at 45, the packet loss rate of AODV (18%) is higher than the rate of DSDV (16%), DSR (15.5%) and ZRP (13%), the performance of AODV (PSNR = 33.91) is worse than other protocols when nodes' transmission combine video stream with some other applications in a lager Ad Hoc network.

As experiment one shows, it also clear that packet loss rate is sensitive to the quality of video transmission and has negative relationship with PSNR value. According to Table 10, Table 11, Table 12, and Figure 10, the R square of linear regression is 0.764 and the quadratic regression is 0.863. Based on this regression analysis, we found that all variable loadings were highly significant at 0.00 (Table 13, $^{**}p < 0.01$), which shows that the experiment values are good to fit these regression lines.

6. Conclusion

According to the first experiment, The PSNR values of AODV are greater than 35.4, which are better than the values of all other protocols tested when the nodes are 15, 30, or 45. The performance of reactive protocol (AODV) is better than other protocols in a transmission with only one video stream in Ad Hoc network. It shows that reactive protocol (AODV) is also better than other protocols when the video transmission is simple. In the second experiment, an Ad Hoc network transmission with a video stream and some applications, reactive protocols (DSR) are more suitable for larger wireless networks (nodes = 45). The PSNR average values of proactive (DSDV) and hybrid protocol (ZRP) are greater than 35.2 (when nodes = 15) which clearly is better than the value of other protocols (DSR 34.8, AODV 35.1). It shows that proactive (DSDV) and hybrid protocols (ZRP) are also suitable for small wireless networks of wild area rescue or military combat team in a network transmission with a video stream and some applications. Though packet loss rate is sensitive in the performance of a video transmission and it has negative relationship with PSNR, as shown in Figure 6 and Figure 10, there are different slopes of lines in different application environment; we can't predict the PSNR value of a protocol performance with packet loss rate for experiment two from experiment one which implies that it is not easy to predict the video performance with packet loss rate. Therefore, we conclude that PSNR is currently a good metric for the video performance evaluation. The simulation experiment of video transmission is complicated and is especially time-consuming in larger networks. Therefore, a new metric or some novel experiment models should be focused in the future study in order to get an easy way for user application.

References

1. Broch, J., Johnson, D. B., and Maltz, D. A.(1999), "The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks," IETF Internet Draft.
2. Cordeiro, C. M. and Agrawal, D. P.(2002), "Mobile ad hoc networking," In proceedings of the 20th Brazilian Symposium on Computer Networks, pp. 125-186.
3. Corson, S. M. and Park, V. D.(1999), "Temporally-Ordered Routing Algorithm (TORA) Version 1 Functional Specification," Mobile Ad Hoc Network (MANET) Working Group, IETF.
4. Hong, X., Xu, K., and Gerla, M.(2002), "Scalable Routing Protocols for Mobile Ad Hoc Networks," *IEEE Network*, Vol. 16, No. 4, pp. 11-21.
5. i-wisdom(2007). i-wisdom.typepad.com/iwisdom/mobile/index.html.
6. Johnson, D. B. and Maltz, D. A.(1996), "Dynamic Source Routing in Ad-Hoc Wireless Networking, Mobile Computing," Kluwer: New York.
7. Johnson, D. B., Maltz, D. A., and Hu Y. C.(2004), "The dynamic source routing protocol for mobile ad hoc networks (dsr)," Draft-ietf-manet-dsr-10.txt, Internet-draft.
8. Klaue, J., Rathke, B., and Wolisz, A.(2003), "EvalVid- A Framework for Video Transmission and Quality Evaluation," The 13th International Conference on Modeling Techniques and Tools for Computer Performance Evaluation, Urbana, Illinois, USA.
9. Lu, Y., Wang, W., Zhong, Y., and Bhargava, B.(2003), "Study of Distance Vector Routing Protocols for Mobile Ad Hoc Networks," Proc. IEEE Int'l Conf. Pervasive Computing and Comm. (PerCom), pp. 187-194.
10. Ohm, J. R.(1999), "Bildsignalverarbeitung fuer multimedia-systeme," Skript.
11. Pandey, A. K. and Fujinoki, H.(2005), "Study of MANET routing protocols by GloMoSim simulator," *International Journal of Network Management*, Vol. 15, No. 6, pp. 393-410.
12. Perkins, C., Belding-Royer, E. M., and Chakeres, I.(2003a), "Ad Hoc on Demand Distance Vector (AODV) Routing," IETF Internet Draft.
13. Perkins, C., Belding-Royer, E., and Das, S.(2003b), "Ad hoc on demand distance vector (aodv) routing," RFC 3561.
14. Perkins, C. and Royer, E.(1999), "Ad-hoc on-demand distance vector routing," Proc. of 2nd IEEE Workshop on Mobile Computing Systems and Applications, New Orleans, LA, pp. 90-100.
15. Perkins, C. and Bhagwat, P.(1994), "Highly dynamic destination-sequenced distance-vector

routing (dsdv) for mobile computers," Proc. of the SIGCOMM 1994 Conference on Communications Architectures, Protocols and Applications, pp. 234-244.

16. Tran, Duc A. and Raghavendra, H.(2006), "Congestion Adaptive Routing in Mobile Ad Hoc Networks," *IEEE Transactions on Parallel and Distributed Systems*, Vol. 17, No. 11, pp. 1294-1305.