Chapter 80
An Adaptive Packet Loss Recovery Method for Peer-to-Peer Video Streaming Over Wireless Mesh Network

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Abstract P2P video streaming over WMN includes different multimedia applications such as IPTV, video surveillance and video conferencing. It also introduces some challenges such as required level of QoS. Packet loss recovery methods can improve the experienced amount of QoS which leads to better video quality on peers. Although ARQ and FEC methods have been used in many video streaming applications, they are unable to provide enough level of QoS in P2P video streaming over WMN. Hybrid methods improve the performances of packet loss recovery schemes. But they do not carefully consider the characteristics of the source and the destination nodes, thus are not suitable for P2P video streaming over WMN. Therefore, in this study, an adaptive packet loss recovery method is proposed to select the loss recovery policy according to the source and the destination characteristics and loss probability of communication.

Keywords Packet loss recovery · Video streaming · QoS · P2P · WMN

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Acronyms

ARQ	Automatic Repeat reQuest
BMS	Buffer Map Status
FEC	Forward Error Correction
MANET	Mobile Ad-hoc NETwork
P2P	Peer-to-Peer
QoS	Quality-of-Service
QoE	Quality-of-Experience
WMN	Wireless Mesh Network

80.1 Introduction

WMN is an emerging communication network for seamlessly Internet access over the Internet. In WMN, each sent packet can be delivered at the destination node in a multi-hop manner according to the employed path selection routing protocol [8]. Self-healing, self-configuration and scalability are three important benefits of using WMN. On the other hand, low transmission coverage in most of the wireless mesh nodes such as laptops, tablets and mobile phones [5] and node mobility are two well-known drawbacks of them. Each node can either use nearby node or wireless mesh router for communicating to other nodes using multi-hop technique. This technique lets the network be more scalable and robustness, especially in peer churning. A WMN is a special type of MANET; however, some important differences between MANET and WMN is that wireless mesh networks consist of stable backbone, large coverage area and high power nodes i.e. wireless mesh routers [8]. In order to route data among existing nodes in WMN, there are three types of path selection algorithms including reactive, proactive and hybrid routing protocols [3, 10].

Recently, P2P systems have been used in many video streaming applications. A P2P system is a distributed system so that clients directly communicate with each other and there is no specific infrastructure [4]. Each peer has both the rules of a client and a server simultaneously. P2P networks can be setup over LAN, WAN or the Internet. Each peer needs a specific or compatible software for participating in P2P overlay [19]. One of the most interesting applications of P2P networking is multimedia communication. Nowadays, P2P video and audio conferencing can be adopted by P2P platforms using special applications such as Skype in order to provide better performances in conferencing [11, 16]. There are many P2P structures for P2P content sharing application [5]. P2P systems can be divided into three categories including structured, unstructured and hybrid systems [4]. Moreover, based on the employed topology, P2P systems can be implemented as mesh or tree structures [11].

Mesh and root are the two most important architectures for P2P video streaming [19]. The root architecture is suitable for live video streaming. However, the mesh-based architecture performs better in disruptive networks like wireless mesh networks [11]. In mesh-based P2P architecture, a central server named Tracker keeps the statuses of all peers and their neighbours. If one peer wants to join the mesh, it first asks the tracker for neighbours' list and, then, sends joining messages to some of them randomly. Figure 80.1 describes a sample mesh topology in P2P video streaming over WMN which contain 2 central server including video source and tracker that have wired communication to mesh access point. Also there are 4 mesh access points which connect to each other with a physical wireless channel. Each wireless mesh node may have many overlay neighbours which represented by a dotted line.

In this paper different packet loss recovery methods for P2P video streaming over large scale disruptive networks such as wireless mesh networks are evaluated. In addition, an adaptive packet loss recovery method for P2P video streaming over wireless mesh networks will be proposed. Results show that the loss recovery ratio of this method is really considerable in comparison with other approaches. In other words, this method reduces end-to-end delay in video streaming. Therefore, live video streaming can be adopted in large scale networks.

80.2 Proposed Method

In disruptive networks like mobile networks, the loss probability is high [6]. In P2P video streaming, the effects of loss can be propagated in the whole overlay which leads to low video quality on receivers [1]. In order to cope with this problem, packet loss recovery is a conventional method in video streaming [13].

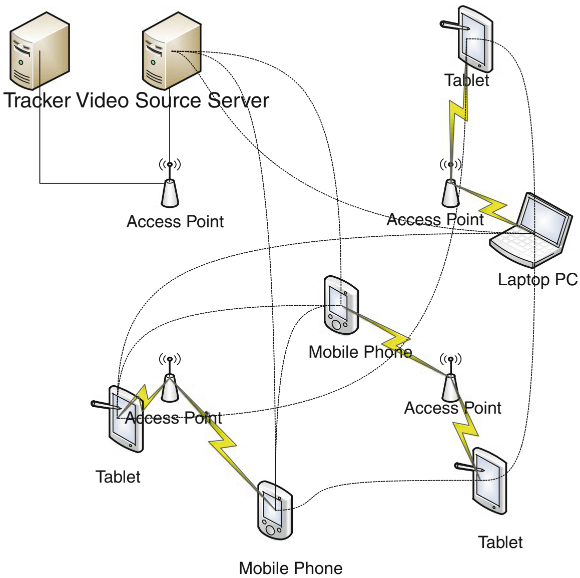


Fig. 80.1 Mesh topology in P2P video streaming over WMN

There are three types of packet loss recovery methods in video streaming including ARQ [15], FEC [17] and hybrid ARQ [2]. In adaptive packet loss recovery method, the redundancy of FEC codes can be computed and generated according to the packet loss ratio between source and destination nodes before packet transmission. As depicted in Eq. 80.1, the redundancy of FEC parity codes for maintaining a residual loss probability not more than p_{max} is [9]:

$$R_{FEC} = \min\{R|\varepsilon \le p_{\max}\}$$
$$\varepsilon = \sum_{k=R+1}^{D+R} \binom{D+R}{k} p^k (1-p)^{R+D-k} \frac{k}{D+R} \tag{80.1}$$

where D is number of data packets, R is number of additional redundant packet, ε is the upper bound of residual loss probability and p is the probability of loss. Then, a suitable loss recovery policy will be adopted for packet protection against loss based on the performance of that policy in loss recovery between source and destination nodes. Figure 80.2 show the loss recovery algorithm in each frame sending process.

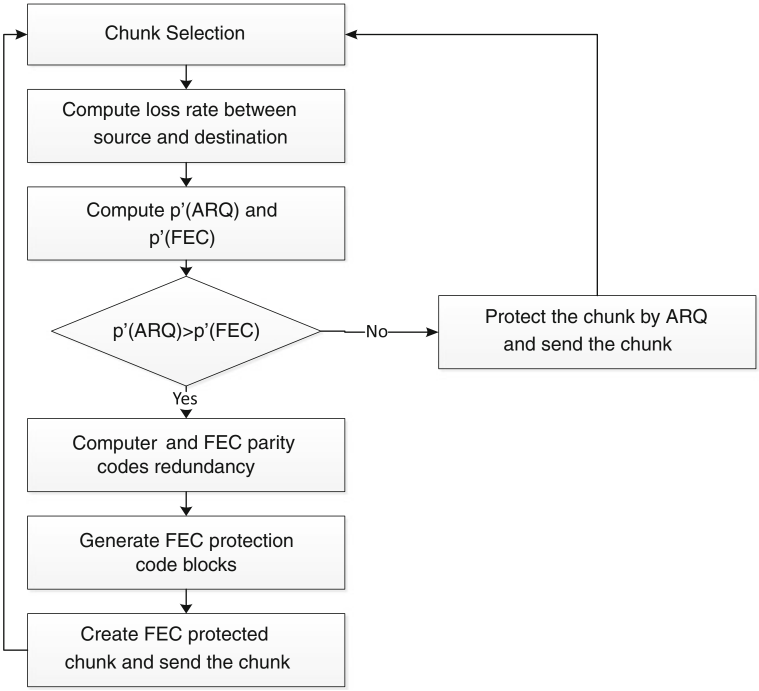


Fig. 80.2 Packet loss recovery selection algorithm

80.3 Problem Statements

In computer network, simulation is the common part of network research and design. In this technique, network behavior will be modeled by simulator software and the performance of the network will be evaluated. OMNeT++ [14], a popular tool, is a discrete event-based simulator for communication networks which includes several simulation frameworks. In this research, the OverSim and the INETMANET frameworks have been used for P2P video streaming over WMN simulation. The INETMANET framework is an extension of the INET package which is specifically designed for wireless networking. OverSim package is an overlay and P2P simulator and contains several solutions for structured and unstructured overlay networks. Moreover, different network performance metrics have been evaluated including end-to-end delay, video distortion, dependency loss and start playing time.

End-to-End delay is the required time for transferring a video packet from the source to the destination node in a multi-hop manner. In this manner, a video packet may forward through wireless overlay nodes or wireless mesh routers. End-to-end delay is one of the most important parameters in live video streaming [12]. Each communication protocol in P2P video streaming should mitigate an upper bound of this metric in order to provide high video quality on peers.

Distortion is the amount of video packet loss that a node experience due to network errors or interdependency among video frames. Dependency loss refers to the lost video frames due to existing dependency among video frames in a GoP [7, 18]. In other words, dependency loss is the percentage of lost video frames due to the loss of the base frames i.e. I or P frames. The amount of dependency loss is between 0 and 1. In video frame protections, this parameter shows the efficiency of the GoP based frame protection protocol against the loss due to inability of decoding the received video frames. As soon as a peer finishes its initial buffer stage, it can start the playback of video frames immediately. This time can be called start playback time. The start playback time is the average of time that takes for receiving and buffering enough video frames as well as decoding them for

Table 80.1 Conditions of P2P video streaming over wireless mesh network simulation

Variable	Value
Simulation time	600 s
Video Trace File, Fps, Codec	Silence of the Lambs, 25, MPEG4
Distribution model	Random
Entrance time interval	Uniform(1, 3)
Packet size, MTU	100 Kb, 7891 bytes
Propagation model, P_{MAX}	Path Loss Reception Model, 0.001
Peer Video Buffer, GoP (N_P, N_{PB})	100 s, (3, 2)
Peer neighbors in overlay	Random (3, 6)
MANET routing, Overlay topology	Reactive, Mesh topology-Pull
Node mobility type, speed	Pedestrian, 1.5 mps

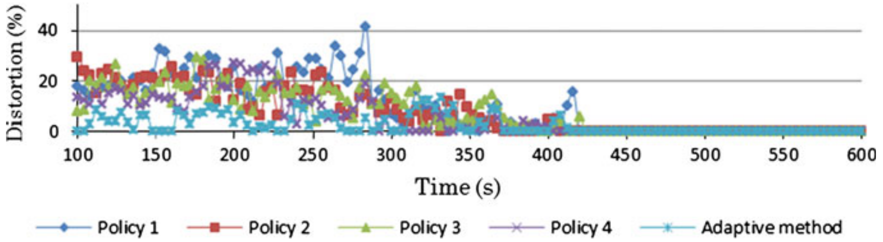


Fig. 80.3 Packet loss in different packet loss recovery methods against simulation time

Fig. 80.4 Packet loss in different packet loss recovery methods against network size

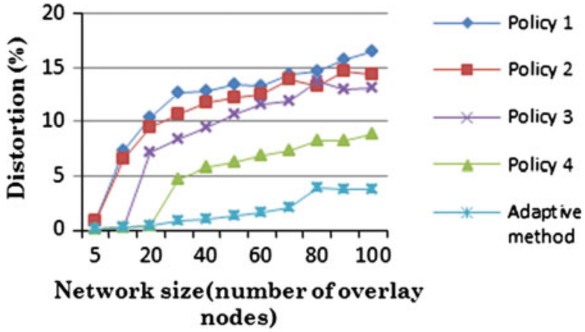
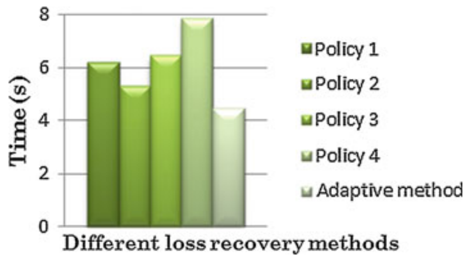


Fig. 80.5 End-to-end delay in different packet loss recovery methods



starting the video playback. This parameter indicates the efficiency of a packet loss recovery method in P2P video streaming. The simulation conditions for performance evaluation of adaptive packet loss recovery method in P2P video streaming over wireless mesh networks are depicted in Table 80.1.

80.4 Performance Evaluation

Here, five different packet loss recovery policies have been adopted in order to evaluate and compare different loss recovery methods in P2P video streaming over WMN. These methods are as follows:

1. ARQ: protecting the video chunks using simple ARQ method.

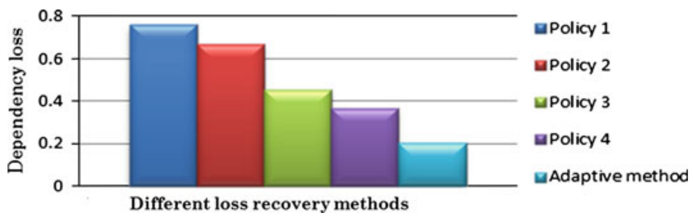


Fig. 80.6 Dependency loss in different packet loss recovery methods

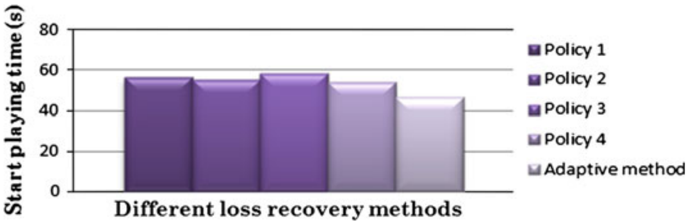


Fig. 80.7 Start playing time in different packet loss recovery methods

2. Unequal Importance Hybrid ARQ II: protecting the video chunks that contain I frames using Hybrid ARQ and other video chunks using the simple ARQ method.
3. Unequal Importance Hybrid ARQ II: protecting the video chunks that contain I and P frames using Hybrid ARQ and other video chunks using the simple ARQ method.
4. Hybrid ARQ II: protecting the video chunks using Hybrid ARQ method.
5. Proposed method: protecting the video chunks using Adaptive loss recovery method.

In proposed adaptive loss recovery method, each node selects different loss recovery approaches for each video chunk based on the probability estimation of loss (p') between source and destination. If FEC protection is selected, FEC parity codes will be generated according to P_{max} and size of the chunk. Figure 80.3 shows the amounts of distortions of different loss recovery methods in P2P video streaming over wireless mesh network across the simulation time.

Moreover, the proposed method is scalable by the size of network which works fine in high density loss situations. Figure 80.4 shows the amounts of distortions in different loss recovery methods across the overlay size.

As seen in Figs. 80.4 and 80.5, the proposed method performs very well in both mitigating the distortion and the end-to-end delay which are the two most important parameters in live video streaming. Moreover Fig. 80.6 compares the efficiency of protection methods in protection of important frames against loss. As seen in this picture the proposed method works very well in frame protection.

As can be seen in Fig. 80.7, the proposed method also works fine in P2P live video streaming over wireless mesh networks.

80.5 Conclusion

Based on the obtained results, the performance of the proposed adaptive packet loss recovery method is considerable. The main advantage of the method is its ability of decreasing end-to-end delay while increasing the QoE in peer to peer live video streaming over error prone networks like wireless mesh networks. This study showed that adaptive packet loss recovery methods can be adopted in error prone networks and overlays with high churning. Moreover, estimation of packet loss between source and destination nodes can improve the overall loss recovery performance and mitigate end-to-end delay and distortion.

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