International Symposium on Wireless and Pervasive Computing (ISWPC 2011)

Conference Programme

- Wednesday 23\textsuperscript{rd} of Feb 2011
  - Context-aware Computing
  - Sensor Networks
  - MIMO Systems
  - Ad-hoc Networks & Routing

- Thursday 24th of Feb 2011
  - Wireless Computing
  - Air Interfaces
  - Sensor Networks (II)
  - Wireless Multimedia

- Friday 25th of Feb 2011
  - Ad-hoc Networks & Routing (II)
  - Emerging Networks
  - Air Interfaces (II)
Multirate-aware Concurrent Multipath Transmission Mechanism

Ming-Fong Tsai, Chi-Huang Shih, Ce-Kuen Shieh, Wen-Shyang Hwang

Forward Error Correction with Interleaving Mechanism Combining Cognitive Technology for Video Streaming over Wireless Networks

Ming-Fong Tsai, Chih-Heng Ke, Hao-Ming Liang, Hsiung-Yu Huang

Optimal Frame Rate Allocation for Unicast and Multicast Wireless Video Communication

Nitin Khanna; Aditya Jagannatham
Multirate-aware Concurrent Multipath Transmission Mechanism

Ming-Fong Tsai¹, Chi-Huang Shih², Ce-Kuen Shieh¹, and Wen-Shyang Hwang³

¹Institute of Computer and Communication Engineering, Department of Electrical Engineering, National Cheng Kung University, fone@hpds.ee.ncku.edu.tw
²Department of Computer Science and Information Engineering, Hung Kuang University, clshih@sunrise.hk.edu.tw
³Department of Electrical Engineering, National Kaohsiung University of Applied Sciences, wshwang@mail.ee.kuas.edu.tw

ABSTRACT

Concurrent Multipath Transmission (CMT) mechanisms have been proposed to improve the transmission performance by means of concurrently transmitting data packets via two or more network interfaces. Based on the wireless cognitive radio, that can dynamically adjust the transmission parameters of the specified device, the required CMT mechanism in the wireless environment differs from that in the wired one since the multirate capacity which the data transmission can take place at a number of different rates according to channel conditions, is characterized in wireless networks to cater for the error-prone problem. Accordingly, this paper extends previous CMT mechanisms to propose Multirate-aware Concurrent Multipath (MCM) transmission mechanism to maximize the data good-put in wireless networks. Compared with the previous CMT mechanisms, the MCM mechanism has a higher data throughput and obtains the better transmission performances in terms of end-to-end delay, packet loss rate, decodable frame rate, and peak signal to noise ratio.

Keywords: Multirate Capability, Cognitive Radio, Concurrent Multipath Transmission

I. INTRODUCTION

Owing to the powerful processing capacity and various access techniques in wireless Internet, the contemporary machines are capable of transmitting data simultaneously through two or more network interfaces. Accordingly, the Concurrent Multipath Transmission (CMT) mechanism is proposed as a transmission technique to send the source data packets concurrently through two or more transmission paths in packet-based network. The CMT mechanism has long been known that it can improve the fault tolerance and link recovery for packet delivery, as well as provide the larger aggregate transmission bandwidth, load balancing, and faster bulk data downloads. In addition, the CMT mechanism has been recently proposed to reduce the packet losses rate and transmission end-to-end delay time. Related work in [1] combined the CMT mechanism with the Forward Error Correction (FEC) technique and adopted the path interleaving for video transmission in wireless networks. The proposed CMT mechanisms adaptively adjusted the FEC parameters and interleaved data packets over multiple transmission paths to reduce the packet losses, resulting in a good video quality.

In wireless networks, IEEE 802.11 operates in the multirate mode that the data transmission can take place at a number of different transmission rates according to channel conditions. When the bit error rate is sufficiently low, the 802.11 host transmits data with high transmission rate. Otherwise, the data rate is decreased to reduce the degree of data corruption although the nodes with lower data rate consume the more channel resources than the nodes with higher data rate. Accordingly, the wireless transmission performance can be highly related to the multirate channel characteristic. The work in [2] combined the multirate capability, packet forwarding, and routing mechanism in the context of multi-hop ad hoc networks. This paper proposed a joint routing and rate control algorithm in the cross-layer manner to enhance the transport throughput and occupy less overall network resources by appropriately selecting the system parameters. In [3], a multirate aware sub-layer which was independent of Internet Protocol (IP) layer was presented to fully utilize the multirate channel characteristics. The main function of the multirate aware sub-layer is to select the node with the higher data rate as the next hop to forward source data. In [4], authors proposed a rate-adaptive and multirate-aware multicast routing protocol for mobile ad hoc networks. During the process of path discovery, the quality of wireless links was estimated to suggest the optimal transmission rates, and then the estimation results were used to calculate the total transmission time incurred by the mobile nodes on the path. Among several considered paths from a source to a destination, their proposed routing mechanism selected the paths to obtain the lowest total transmission time. The previous researches in [2-4] obtain the maximum transmission throughput based on the multirate characteristic. However, few works in the multipath transmission context are aware of the multirate capacity in the wireless environment.

Since the multirate characteristic is essential for the design of a wireless transmission system, it is desired for the existent CMT mechanisms to exploit the multirate capacity in wireless networks. This paper accordingly extend previous CMT mechanisms to study a Multirate-aware Concurrent Multipath (MCM) transmission mechanism combined with the FEC technique to maximize the data good-put in transporting packets over wireless channels. In
MCM transmission system, each wireless node could be equipped with two or more network interfaces and these interfaces have to operate concurrently with the same or different data rate to transmit data on their respective transmission paths. To support the MCM transmissions, the wireless cognitive radio is a technique for wireless communications in which a wireless node can adjust its transmission parameters, such as the data rate and frequency, to avoid communication interference with licensed or unlicensed users [5]. Based on the technique support of FEC and the wireless cognitive radio, the MCM mechanism establishes the data transmission paths according to the strategy that the nodes with higher data rate on the path are selected to maximize the transmission throughput. In transmitting data packets over multiple paths, the MCM mechanism deliberately distributes the data proportion assigned to the paths and FEC protection, and continues using the data distribution protocol of the CMT mechanism to achieve the maximum data good-put at the data receiver.

The remainder of this paper is organized as follows. The MCM transmission mechanism is described in Section II. Section III discusses the analysis of the experimental results as compared with the conventional CMT mechanisms. Finally, Section IV presents the conclusion and future work.

II. MULTIRATE-AWARE CONCURRENT MULTIPATH TRANSMISSION

![Figure 1: Two-path MCM transmission](image)

In the scenario of the multirate-aware concurrent multipath transmission, each node is equipped with two or more network interfaces to connect two or more wireless nodes concurrently. Each wireless network interface can communicate with its connected node by appropriately adjusting the transmission rate and transmission frequency based on the wireless cognitive technology. In order to obtain the better transmission performance, the MCM transmission mechanism selects the data forwarding paths to achieve the maximum transmission throughput. Figure 1 illustrates an example of the MCM transmission mechanism as two concurrent data forwarding paths between the sender and the receiver are considered. When the packet loss rate for each link is assumed to be similar, the MCM mechanism chooses the links with 11 Mbps to construct the path 1 and path 2, even though selecting the links of 2 Mbps is a shortest-path solution. Furthermore, the MCM mechanism distributes the transmitted data among paths according to their packet loss statuses and the forward error correction technique is employed to combat with the possible transmission losses and errors. The detailed description of the MCM mechanism is described in the following sections.

A. Multirate-aware multipath establishment

Within a data transmission path, the maximum throughput of the node $i$, $Node_i$, is calculated by finding the maximum data rate among wireless interfaces attached to $Node_i$:

$$T_{Max_i} = \max(\{Node_{i,1}, Node_{i,2}, ..., Node_{i,N}\}),$$  \hspace{1cm} (1)

where $j$ is the number of wireless network interfaces. Hence, the maximum transmission throughput in one end-to-end path $p$ is the minimum transmission rate among nodes:

$$T_{Max_p} = \min(T_{Max_i}).$$  \hspace{1cm} (2)

The maximum transmission throughput in multiple end-to-end paths is a summation of the maximum transmission rates of multiple paths:

$$T_{Max_mp} = \sum_{p=1}^{NP} T_{Max_p},$$  \hspace{1cm} (3)

where $NP$ is the number of available data transmission paths between the sender and receiver. Based on Eq. 3, the MCM transmission mechanism can construct the data transmission paths to achieve the maximum end-to-end throughput.

B. Data distribution control

Since the maximum transmission throughput is not necessarily to ensure the maximum data good-put in the presence of packet losses, the MCM mechanism distributes data packets to all available paths based on two following factors: the congestion packet loss and the FEC recovery capacity. In addition to preventing congestion losses, the FEC mechanism increases the data good-put by adopting redundancies to recover data losses/errors on the transmission paths. Therefore, except for the link transmission rate, the amount of transmitted data and FEC redundancies determines the path good-put. When the transmission paths can be known, the proposed MCM mechanism obtains the maximum data good-put by finding a maximum summation of path good-put for all transmission paths. The protocol of the data distribution control can be found in our previous conventional CMT.
C. System implementation

We implemented the MCM transmission system based on the functionality of the IP firewall as well as the divert socket. IP firewall filters packets traveling up or down the IP stack and can redirect filtered packets to a divert socket. On the other hand, divert socket is one element of general BSD socket and can be bound to a specific port of the host for IP packet interception and injection. As showed in Figure 2, when data packets travel down from the application layer, the IP firewall redirects them to a specific system port. Then MCM transmission system employs the divert socket to bind this specific port and receives IP packets from it. A complete IP packet is consisted of the IP header, transport protocol header and data payload. To support the multipath transmission capacity, we modify the destination IP address in the IP header to create an alternative routing path, and then recalculate the checksum value for IP validation purpose. After the appropriate packet content processing, the redirected IP packets are then injected back into the general network protocol stack using the same port, and finally arrive at the assigned destination under the assumption that no loss occurs during the transmission.

![Figure 2: Multipath transmission using packet redirection](image)

According to the packet redirection technique, the data packets can be transmitted into different paths by relaying packets among the nodes in the planned routing path. It is noted that the desired routing table is maintained in each intermediate nodes on the path. In the traditional IP in IP tunneling, an additional bandwidth overhead is increased to risk packet loss during transmission because of adding control headers to the original packet. Conversely, our packet redirection method will not increase the bandwidth cost with little mathematical calculation.

III. PERFORMANCE RESULTS

In this paper, we established the multipath transmission environment based on the wireless overlay network infrastructure [6]. The experimental topology was showed in Figure 1. The Bit Error Rate (BER) in each wireless link was $10^{-6}$ in default. The sender side transmitted data packets from two different sources to the receiver side. One data source was the video data and another was the background data to generate various traffic loads. For the video source, a MPEG-4 video sequence "Foreman" obtained from the TKN video library was adapted during the simulation. The "Foreman" trace file had a common intermediate format with a GOP size of 9 and comprises 300 frames. The video stream was transmitted in 1 kilobyte packets at a rate of 30 frames per second (fps). The request bandwidth of "Foreman" sequence was 800 kilobit per second. We made the performance comparisons between conventional CMT mechanism and MCM transmission mechanism in terms of the average transmission end-to-end delay, packet loss rate, Decodable Frame Rate (DFR), and Peak Signal to Noise Ratio (PSNR). The DFR is the percentage ratio of the number of decodable video frames to the amount of all video frames in the "Foreman" sequence. A video frame is decodable if it can be decoded successfully and all frames it depends on are also decodable. The transmission end-to-end delay and packet loss rate are related to the network-level quality measurement, while the DFR and PSNR value measure the application-level quality. Table 1 presents the network settings of three scenarios conducted in this paper.

<table>
<thead>
<tr>
<th>Link Parameters</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data rate</td>
<td>fixed</td>
<td>1 Mbps–11 Mbps</td>
<td>fixed</td>
</tr>
<tr>
<td>BER</td>
<td>$10^{-6}$</td>
<td>$10^{-6}$</td>
<td>$10^{-4}$, $10^{-5}$</td>
</tr>
</tbody>
</table>

In the first scenario, the transmission data rate assigned to each wireless link is fixed during the experiment, as showed in the Figure 1. Among two compared mechanisms, the conventional CMT mechanism always selects the shortest transmission path to transmit source data packets, while the MCM mechanism constructs the transmission path with the maximum data transmission throughput in order to obtain the better packet delivery quality. Figure 3 and Figure 4 present the performance results in terms of the transmission end-to-end delay and the packet loss rate. It can be observed in Figure 3 that both the transmission end-to-end delays of the conventional CMT mechanism and the MCM mechanism increase as the background traffic is increased. However, the transmission end-to-end delay of the conventional CMT mechanism increases sharply when the traffic load is larger than 3 Mbps. It is noted that the amount of the traffic data is evenly distributed to the two paths and for the conventional CMT mechanism, the available data throughput is bound to the minimal link data rate among the selected paths (i.e., 2Mbps...
for respective paths according to Figure 1). Accordingly, when the amount of source data and traffic data exceed 4 Mbps, the congestion-related delay and loss can be easily observed for the conventional CMT mechanism. This also explains the burst rise of the packet loss rate curve represented by the conventional CMT mechanism in Figure 4. On the other hand, the MCM mechanism has a slowly increased end-to-end transmission delay and maintains a very low packet loss rate as the background traffic load is ranged from 1 to 5 Mbps. From Figures 3 and 4, the MCM mechanism utilizes the multirate capacity to prevent the negative effect induced by link congestion.

To evaluate the video delivery quality, the performance results of the decodable frame rate and PSNR are shown in Figure 5 and Figure 6, respectively. It is noted that the lower decodable frame rate indicates poor motion smoothness in the video presentation. From Figures 5 and 6, we observe that as the traffic load varies from 1 Mbps to 5 Mbps the MCM mechanism can keep the constant DFR and PSNR curve. On the other hand, the CMT mechanism has a decreased DFR as well as PSNR curve when the traffic load exceeds 3 Mbps. At the traffic load of 5 Mbps, the MCM mechanism improves the traditional CMT mechanism by 7.4 dB in average PSNR and 17% in average PFR.

In the second scenario, the transmission rate of each hop is dynamically selected at a range of 1Mbps ~ 11Mbps. The remaining set-up keeps unchanged. Figure 7 shows the results of the transmission end-to-end delay in the dynamic data rate condition. Compared to the results presented in Figure 3, the traditional CMT mechanism has the lower transmission delay curve in Figure 7 as the traffic load exceeds 3 Mbps since the available data throughput obtained by the CMT mechanism can be higher in average
than that provided by the static data rate scenario. In addition, for the MCM mechanism, the transmission delay shown in Figure 7 is slightly higher than that shown in Figure 3. However, the MCM mechanism has better performance than the CMT mechanism in terms of the end-to-end delay. Figure 8 shows the packet loss rate in the dynamic data rate condition. From Figure 8, we can have the similar observations as in Figure 7. For the application-level quality measurement, Figures 9 and 10 shows the DFR and PSNR results in the dynamic data rate condition, respectively. Form Figure 9 and 10, the MCM mechanism outperforms the CMT mechanism, and obtains the PSNR gain of 4 dB and the DFR gain of 11% as the traffic load is 5Mbps.

IV. CONCLUSIONS

The conventional CMT mechanisms are unaware of the multirate capability in wireless networks. Accordingly, the MCM transmission mechanism relies on the wireless cognitive technique to construct the transmission paths with the maximum transmission data rate and also applies the FEC mechanism to ensure a high data good-put at the data receiving end. The experimental results show that the MCM transmission mechanism has the higher multipath throughput to support the transmission of video data and FEC redundancies, and gives better video delivery performances in terms of packet loss rate, end-to-end delay, DFR, and PSNR than conventional CMT mechanism.

REFERENCES