COLLISION-DETECTION BASED RATE-ADAPTATION FOR VIDEO MULTICASTING OVER IEEE 802.11 WIRELESS NETWORKS

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ABSTRACT

Wireless video multicasting/broadcasting is an efficient method for simultaneous transmission of data to a group of users. But the multicasting rates are fixed in current IEEE 802.11 PHYs standard. In this paper, we propose a novel collision-detection based rate-adaptation scheme (CDRA), which fully exploits the potential of rate adaptation capability of wireless physical layer, to improve service qualities of video multicasting. The received signal strength indication (RSSI) and packet error ratio (PER) are comprehensively used to detect collision. The PER-guided rate adjustment algorithm is performed when no collision happens. Otherwise the collision-avoid mechanism works. By detecting the collision, our scheme could adaptively select the maximum data rates for video multicasting. We construct a practical multicasting test-bed in IEEE 802.11b network and carry out extensive experiments. The results show that CDRA achieves throughput gain up to 166% and PSNR gain to 139% compared with existing methods.

Index Terms— Multicast, Collision Detection, Rate Adaptation

1. INTRODUCTION

In recent years, the demand on video applications over wireless network has risen with the increases in both the bandwidth of wireless channels and the computational power of mobile devices. Multicasting/Broadcasting is an effective solution for simultaneous transmission of data to a group of users. By employing different modulation and channel coding schemes, the 802.11 PHYs provide multiple transmission rates. However, only the lowest rates in the basic rate set are permitted to be used to multicast/broadcast some control information by current IEEE 802.11 standard[1]. At the same time, it also does not specify any algorithm or protocol to efficiently utilize multiple transmission rates.

A large variety of rate adaptation schemes have been presented in the literatures [2-6]. However, most of them are designed for unicast, such as ARF (Automatic Rate Fallback) [2] and SampleRate [6], which implement a simple open-loop rate adaptation scheme (i.e., without feedback from the receivers) due to their simplicity. A key problem of such open-loop schemes is that they do not consider the impacts of collision. There are some other works take account of collision, such as CARA [4] and RRAA [5]. In CARA, the transmitter adaptively uses Request-to-Send/Clear-to-Send (RTS/CTS) messages and Clear Channel Assessment (CCA) function to detect the frame collisions. The rate adjustment is prevented when collision occurs. But they cannot be directly applied to multicast, since the feedback messages would be explosive by multicasting receivers. The packet error ratio (PER) based rate-adaptation method (PBRA) [3] could reduce the number of feedback messages. But it ignores that the collision also results to packet error. Specifically, if the rate in collision is decreased, a higher PER will be in return.

In this paper, we propose a novel collision-detection based rate-adaptation (CDRA) scheme. It first performs a collision detection to exclude interference impacts, and then adjusts the date rate according to channel quality. The received signal strength indication (RSSI) and PER information are jointly used to distinguish the causes of packet error, either by collision or weak signal. Depending on the specific reasons, different actions are taken at the link layer: if a collision is detected, the transmitting station would perform an exponential back-off processing. Otherwise, if the weak signal error occurs, the rate adjustment algorithm works. CDRA uses the PER information to measure the channel quality and adjust the data rates. We carry out extensive experiments in a practical IEEE 802.11b video multicasting test-bed. The results show that CDRA gets better performance on throughput and video quality compared with existing methods.

The rest of the paper is organized as follows. The procedure of collision detection and rate adaptation is given in section 2. The implementation of CDRA is described in section 3. The experimental evaluations and results are shown in section 4 and finally we conclude this paper in section 5.

2. COLLISION-DETECTION AND RATE-ADAPTATION

2.1. An Overview of CDRA

CDRA system consists of two parts: a client module which resides on a handheld or a wireless laptop, and an AP module which resides on an access point. CDRA runs most of the optimization logics in the AP module, and the client module only provides some feedback information.

Client module: the client module resides on a handheld or a wireless laptop. In the client module, we use a VLC media player

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to receive the broadcast data. The client module is also responsible for providing some feedback information for the AP module.

AP module: In the AP module, we use a VLC media server to broadcast video data which is packaged into RTP packets. The AP-side CDRA module includes two sub-modules: Collision-Detection module and Rate-Adaptation module. The collision-detection sub-module is to distinguish the packet error reasons, and the rate-adaptation sub-module is used to adjust the physical rate dynamically depending on the current channel quality.

We construct a practical IEEE802.11 multicasting/ broadcasting system in our building. Fig. 2 shows the floor-plan of the building where we carry out our experiments. In the figure, S denotes a sender (AP), I1 and I2 denote two hidden node, and P1~P5 represent 5 receivers with different locations. The system is implemented in Linux+Madwifi platform with IEEE 802.11b networks which includes four kinds of physical rates. To remove any random effects and short-term fluctuations, we ran each experiment 10 times and the average results are presented.

In this test-bed, we first perform some experiments to discover the difference between collision and weak signal error. And then, we investigate the relationship between PER and physical data rates.

2.2. Collision and Signal Error Detection

We use RSSI and PER information to detect collisions. RSSI is reported by most device drivers including the MadWifi driver that we use in our system, and PER reflects the quality of the channel. The intuition behind using RSSI and PER to detect collision comes from some knowledge of the electromagnetic wave theory. According to the electromagnetic wave theory, for the same data rate, packets suffering a collision result in a higher RSSI than that suffering signal attenuation.

Fig. 3(a) plots the measured value of RSSI at different locations. We perform the measurement under different physical data rates with and without interference. In the figure, the legend *C* indicates the scenarios with interference, while *S* to no interference. It is obviously observed that the average RSSI with collision are much higher than that with no collision; the range of RSSI is from 25dBm to 70dBm with collision, while 8dBm to 40dBm with no collision. We conclude that if RSSI is larger than the *HIGH_RSSI* threshold, assigned to 40dBm in our system, the packet collision occurs; if RSSI is less than the *LOW_RSSI* threshold, assigned to 25dBm, the packet errors are completely caused by signal error.

The RSSI curves are overlapped between 25dBm and 40dBm for the collision error and the signal error. We cannot distinguish them only by using RSSI information. But we assume that the PER value should be very low in the condition of no collision, because the signal strength is still strong in this area. Fig. 3(b) validates our assumption. When the value of RSSI is between 25dBm and 40dBm, the PER by signal error are less than 15%, while that by collision are more than 20%. So when RSSI is between 25dBm and 40dBm, we conclude that if the value of PER is larger than a certain value, which is defined as *MID_PER* and assigned to 16% in our system, the packet errors are caused by the collision, otherwise it is caused by the signal error.

According to the above experimental results and analysis, we use RSSI and PER information to do the collision and signal error detection. Suppose $\overline{rssi}$ is the minimum average RSSI of all nodes and I is the sign of collision, where

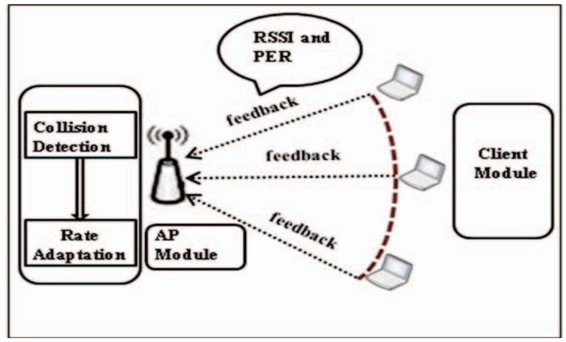


Figure 1: Fundamental structure of our CDRA system, which consists of AP module and Client module.

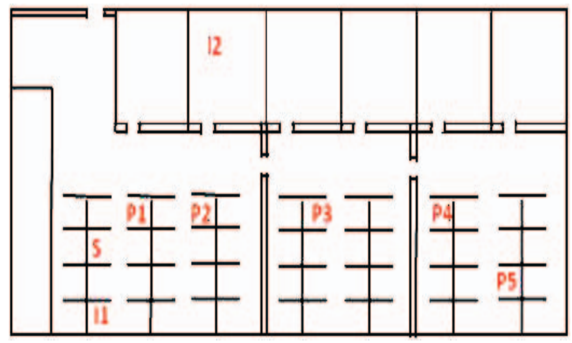
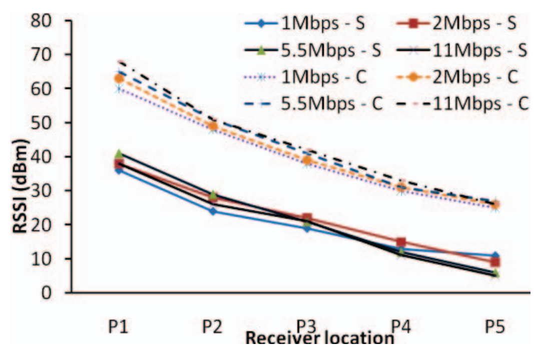
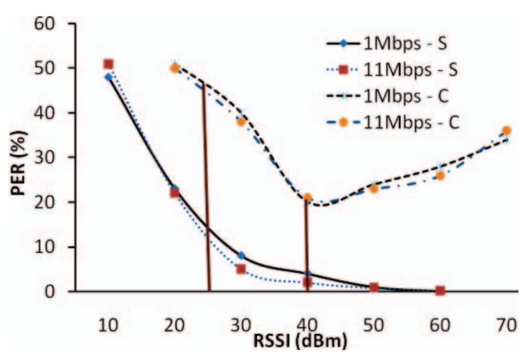


Figure 2: Experiment setting, where S is the sender, I1and I2 are two hidden nodes, and P1~P5 are receiver locations.



(a)



(b)

Figure 3: a) Interference effect on RSSI; b) Interference effect on PER with different RSSI.

$$I = \begin{cases} 0, & \text{if } \overline{rssi} \le Low\_RSSI; \\ 0, & \text{if } Low\_RSSI < \overline{rssi} < High\_RSSI \\ & \& \ \overline{per} \le MID\_PER; \\ 1, & \text{if } Low\_RSSI < \overline{rssi} < High\_RSSI \\ & \& \ \overline{per} > MID\_PER; \\ 1, & \text{if } \overline{rssi} \ge High\_RSSI. \end{cases} \quad (1)$$

I=1 means a packet loss is caused by collision, while $I = 0$ means a packet loss is caused by signal error.

2.3. PER-Guided Rate Adjustment

In this section, we first investigate the relationship between the PER and the physical data rates at different locations. Then, based on the PER measurements, we design our PER-Guided rate adjustment algorithm. In our measurement setup, one of the stations runs an Iperf[7] client to generate UDP traffic streams, while others run an Iperf server to receive the traffic and collect the statistic data.

Fig.4(a) plots the PER curves of a practical IEEE 802.11b system at different locations with varying locations and physical rates. We also plot the throughput curves in Fig. 4(b). Note that using a higher physical rate can get a higher throughput, although the corresponding PER is also higher. But as the distance increases, its throughput decreases more abruptly than others. We should select appropriate physical rate dynamically to maximize the useful throughput.

According to above observation and under the condition without collision, we conclude that when the value of PER is lower than *LOW_PER* which is assigned to 13%, different physical data rates have approximately the same PER and the higher rate can get a higher throughput. On the contrary, if a PER is higher than *HIGH_PER* which is assigned to 31%, the throughputs of different physical rate are almost same. But the PER with higher rate would increase more rapidly than others. Let $\overline{per}$ denotes the maximal average packet error ratio of all nodes. R denotes the selected rate, R++ and R-- means selecting a higher or a lower rate in the usable rate set, where

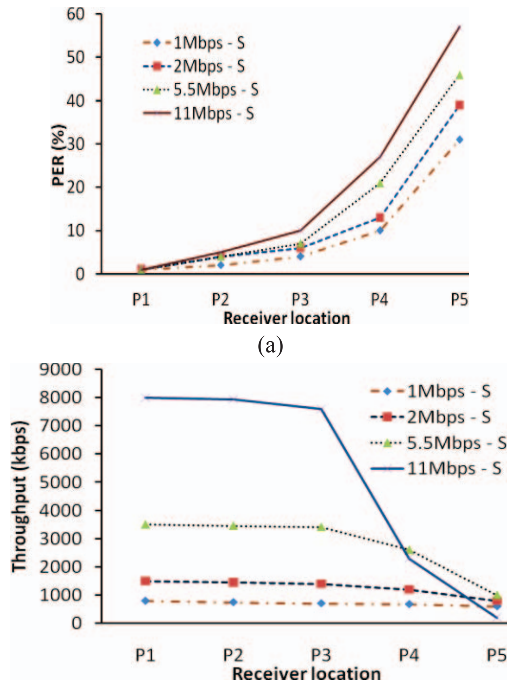
$$R = \begin{cases} R_{cur}++, & if \quad I = 0 \,\&\, R_{cur} < R_{\max} \\ & \& \,\overline{per} < LOW\_PER; \\ R_{cur}--, & if \quad I = 0 \,\&\, R_{cur} > R_{\min} \\ & \& \,\overline{per} > HIGH\_PER; \\ R_{cur}, & else. \end{cases} \quad (2)$$

If the collisions are detected, the rate would not be adjusted. On the contrary, if a packet loss is caused by the signal error, we adjust the rate according to PER.

3. IMPLEMENTATION OF CDRA

We implement the CDRA rate-adaptation algorithm in an AP device with Linux+Madwifi platform. The system framework is illustrated in Fig.1. Once receiving packets, the client module is responsible for sending back the RSSI and PER information to the AP periodically.

The AP runs the CDRA algorithm periodically, and adjusts the physical rate dynamically according to the feedback information from clients. In order to guarantee that all clients could



(a)

(b)

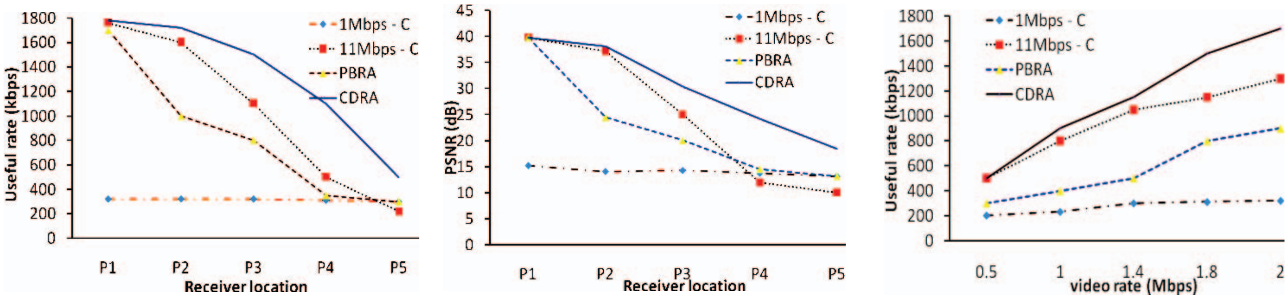
Figure 4: a) PER comparison of different physical rates, b) Throughput comparison of different physical rates.

be covered, we start with the 1Mbps base rate in IEEE 802.11b standard.

The pseudo-code is presented as follows:

```
/***********************************************/
Collision_Detection(){
    if ( avg_rssi >= HIGH_RSSI)
        return 1;
    else if ( avg_rssi <= LOW_RSSI)
        return 0;
    else {
        if ( avg_per <= MID_PER)
            return 0;
        else
            return 1;
        }
}
Rate_Adaptation() {
    if(( avg_per >= HIGH_PER)&&
            (cur_rateindex > min_rateindex))
        cur_rateindex --;
    else if (( avg_per <= LOW_PER)&&
            (cur_rateindex < max_rateindex))
        cur_rateindex ++;
    return  cur_rateindex;
}
Run(){
    while(1){
        if(Cpllision_Detection() == 0)
            Rate_Adjustment(Rate_Adaptation());
        Sleep(TIME_INTERVAL);
    }
}
/***********************************************/
```

Figure 5: The pseudo-code of CDRA algorithm



(a) (b) (c)

Figure 6: The performance comparison of our system with other schemes. a) Useful rate comparison with video rate fixed at 1.8Mbps; b) PSNR comparison with video rate fixed at 1.8Mbps; c) Useful rate comparison with video rate changeable.

4. EXPERIMENTAL EVALUATION AND RESULTS

All experiments are conducted in a real IEEE 802.11b test-bed showed in Fig. 2. The experiment platform consists of Linux and Atheros DWL-G650 Chipset. For performance comparison, PBRA scheme, which don't consider interference impacts, and fixed-rate schemes are also implemented.

First, we compare the performances of different schemes with interferences. The AP broadcasts a video stream with rate at 1.8Mbps. And other two fixed interferential nodes, I1 and I2, send interfering signal at a constant rate of 1Mbps. We plot the available rate of different mechanisms in Fig. 6(a) and corresponding Peak Signal to Noise Ratio (PSNR) in Fig. 6(b). The figures show that CDRA outperforms the fixed-rate mechanisms in all locations. It is because CDRA adjusts the data-rate dynamically according to the channel quality. Compared with PBRA, CDRA gets the usable rate gains up to 166% and PSNR gains up to 139%. The performance loss of PBRA is mainly because PBRA cannot distinguish the collision error from the weak signal error. When a high PER is caused by collisions, in PBRA, a lower rate will also be selected. This will lead to a higher PER in return. Since it will take more time to transmit a packet by using the lower rate, this will increase the probability of collision.

We also compare the performance with different video rates. In this test, the receiver's location is fixed at P3. The AP broadcasts video streams with different video rates. Also the two fixed interferential nodes send interfering signals at a constant rate of 1Mbps. At each location, the test is repeated five times and the average useful rate is presented in Fig. 6(c). From the figure we find that CDRA always performs the best. We also see that when the video rate increases, CDRA gets more useful rate gains compared with both the fixed-rate schemes and PBRA. The low physical rate, such as 1Mbps in the fixed-rate scheme, is unsuitable to transmit high-bit-rate videos as its throughput is too low. We also know that PBRA cannot distinguish the collision error from the signal error. PBRA would select a lower rate even when a high PER caused by collision. Therefore, with the video rate increases, CDRA gets more useful rate gains. For high-bit-rate video applications, such as HD video streaming, CDRA is more suitable than the existing schemes.

5. CONCLUSION

In this paper, a collision-detection based rate adaptation algorithm (CDRA) is proposed. In CDRA, we first use the RSSI and PER information to discern the exact causes of packet error, and then the PER-guided rate adjustment algorithm is implemented to adjust the physical rate dynamically. Compared with PBRA, CDRA has achieved the useful rate gains up to 166% and PSNR gain up to 139% under interference environments. Also with increased video rates, the performance of CDRA is becoming better compared with other schemes.

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