Interactive Video Transmission over Wireless Ad Hoc Networks using Multiple Sources and Multiple Description Coding

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Abstract
This paper tackles the problem of interactive video transmission over wireless ad hoc networks. We propose a mechanism using multiple sources to transmit interactive video coded with Multiple Description Coding (MDC) scheme over wireless ad hoc networks. MDC is a coding scheme that provides greater flexibility for video coding. Simulation study has been carried out using discrete event simulator to compare the performance of the proposed mechanism with other conventional method. Simulation results show that the proposed mechanism successfully reduces the number of bad periods and shortens the average length of bad periods. On the other hand, the increment in network workload, due to the additional overhead created by MDC coding, does not significantly affect the network throughput because better load balancing is achieved using multiple sources. This observation clearly demonstrates the possibility of improving video quality using the proposed mechanism.

1. Introduction

Ad hoc wireless networks are defined as a group of wireless devices that utilizes mutli-hop radio relaying and are capable of operating without any support of fixed infrastructure [1]. Video transmission over wireless ad hoc networks is currently an active research topic motivated by the increase in bandwidth of wireless channels and also the computing power of mobile devices. Video applications are expected to be offered in future wireless networks.

Video transmission is a very challenging task because of its rigid bandwidth requirements and delay guarantees. It becomes more complicated over wireless networks due to the fact that wireless channels are more prone to error and interference. Furthermore, the topology of ad hoc networks changes frequently due to node movement, causing the links are broken and established at high frequency. This creates higher loss and much difficulty for video streaming. Much research has been done to tackle this problem in order to provide reliable video transmission over wireless ad hoc networks. One possible solution is using flexible video coding schemes with high fault-tolerant to error. Multiple Description Coding (MDC) scheme fulfills this requirement. It is a video coding scheme that generates multiple equally important video streams at the same rate so that each description alone provides low but acceptable quality and more descriptions together leads to higher quality [2, 3]. This feature is very attractive because the probability of losing all descriptions during transmission is much smaller as compared to losing the only description in other conventional coding scheme. Theoretically, this feature guarantees minimum video quality as long as at least one description reaches the receiver.

One drawback of using MDC is the increase in network overload. For the same amount of video traffic, MDC scheme generates more packets than the conventional video coding schemes do. This additional overhead could affect the network performance, especially wireless ad hoc networks which are very sensitive to additional workload. With this in mind, we propose the use of multiple sources to transmit multiple descriptions video to reduce the influence of the additional workload. Each source sends only one or a few descriptions of the same video. The reasons of using multiple sources are twofold. Firstly, it helps to obtain better load balancing within the network because the additional overhead is divided equally among all the video sources. Besides, it increases the meeting probability between the receiver and the sources because in wireless ad hoc networks, the sources and receiver are allowed to move freely. Considering the tradeoff between performance and overhead, a common and reasonable model is using two descriptions. For that reason, we primarily deal with two sources and two descriptions in this paper.

The rest of the paper is organized as follows. In section 2, the implementation of the proposed mechanism is explained. Section 3 shows the simulation study and followed by results and discussion in section 4. Finally, we conclude this paper in section 5. Possible future work is also briefly explained in this section.

2. Overview of the Proposed Mechanism

This section gives details of the proposed mechanism. Firstly, we introduce the basic concept of MDC coding scheme, which is a promising approach emerges as a more reliable mean of transmission for video applications. An MDC coder generates multiple equally important video streams (also knows as descriptions) in such a way that each description alone can be reproduced to obtain video at low but acceptable quality, any additional descriptions received increase the video quality on top of the minimum level. Generally, MDC coding generates larger number of packets for the same amount of video data as compared to other conventional coding schemes. This additional workload may create significant harm to the network performance, especially in wireless ad hoc networks. Consequently, the implementation of MDC alone may not achieve the desire objective in improving video quality. With this in mind, some researchers have proposed multistream coding with multipath transport [4, 5]. In this approach, the source sends multiple descriptions video using disjoint paths, as shown in Figure 1. This approach is said to achieve better load balancing and avoid interruption due to single-path failure.

We adopt the idea of using different paths to achieve better load balancing in our proposed mechanism, but instead of using multiple disjoint paths, we use multiple sources to distribute the same video streams. This aims to distribute the additional overhead more evenly within the network. Besides, this can also provide fault-tolerant to the video application because a single source failure will not lead to complete service breakdown. The concept of multiple sources is motivated by multipoint-to-point transmission over peer-to-peer networks to provide reliable video streaming [6]. In peer-to-peer networks, several sources send the same video to the receiver and the receiver will discard duplicated frames. Applying this concept directly to wireless ad hoc networks is impractical because additional redundancy affects the overall network performance badly. Hence, the concepts of MDC coding and multipoint-to-point transmission are combined to obtain the mechanism proposed in this paper.

In our proposed mechanism, the coder located at each source encodes the same video using exactly the same MDC scheme and produces identical set of video descriptions. The sources will not send out these descriptions until further instruction from the receiver is received. The receiver is responsible to determine from which source to receive which description (or descriptions) and inform the sources on the decision. The receiver can make the selection based on many criteria; this paper deals with the simplest way in which the receiver requests only one description from each source. Another alternative is requesting more descriptions from reliable sources and fewer descriptions from unreliable sources. This method involves more complicated implement to determine the reliability of the sources, and beyond the scope of this paper.

In this paper, we primarily deal with two-source two-description model, as shown in Figure 2. For simplicity, we assume source 1 sending description 1 and source 2 sending description 2. The implementation is rather simple but it can give an overview of its performance and present a fair comparison study.

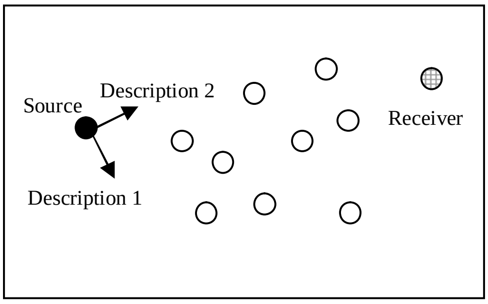


Figure 1. Multiple Descriptions with Multipath Transport.

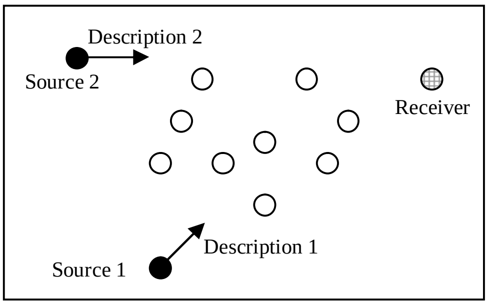


Figure 2. Two-source Two-Description model.

3. Simulation Study

The simulation has been carried out using an event driven simulator called NS2 [7] with CMU wireless extension [8]. The simulation topology contains 20 nodes with the size of 1000 meters by 600 meters. A rectangular shape area has longer average length of routes to create more connection breaks during the simulation [4]. The node mobility is modeled using the Random Waypoint Model used in [8]. The level of mobility depends on the maximum speed of the nodes. Six different maximum speeds are used: 5m/s, 10m/s, 12.5m/s, 15m/s, 17.5m/s and 20m/s, respectively. Also, we consider only continuous mobility case with zero pause time. It means that every node travels continuously from a randomly assigned starting location to a random destination at a random speed between 0 and maximum speed within the predefined area. For each maximum speed, ten different scenarios are generated to observe the average effects. Five random cross traffics of 8.2kbps each are also introduced in the network.

We evaluate the performance of the proposed mechanism using interactive video application at 128kbps. The frame size is set to 1024 bytes. Three cases are observed for the comparison study, as shown in Table 1. Case I is a common video transmission model from one source to one receiver without using MDC (single description). Meanwhile in case II, only one source is used to send both descriptions of video. Case III is the proposed mechanism as explained in the previous section, two nodes are assigned as video source and each node sends only one description.

The frame size is set to 1024 bytes. Therefore, for single description model (case I), the packet size is the same as the frame size. Two descriptions are used in case II and III, each frame is therefore coded into 2 packets, each packet representing one description and having half of the frame size (512 bytes). A total of 10,000 frames are sent and the simulation time is 900 seconds, which is more than enough for the transmission to complete.

During the simulation, we trace the receiving of each description according to its sequence number. The quality of a frame depends on the number of descriptions received. If both descriptions are received, the frame is called a good one. If only one of the two packets is received, the frame is called acceptable. Otherwise, the frame is declared as a bad frame [4]. If one or more consecutive bad frames are received, we called it a bad period. Each bad period represents an interruption on the video streaming. Besides, the number of consecutive bad frames received indicates the length of a bad period. The performance evaluation is based on the number of bad periods and the average length of bad periods. The smaller the parameters are, the better the video quality is.

Case	Number of Sources	Number of Descriptions	Packet Size (bytes)	Packets per frame	Transmission Interval (sec)
I	1	1	1024	1	0.064
II	1	2	512	2	0.064
III	2	2	512	2	0.032

Table 1. Simulation Details

4. Results and Discussion

As mentioned in the previous section, the performance evaluation metrics are the number of bad periods and the average length of bad periods. The performance of each case, in term of the number of bad periods, the average length of bad periods and the network throughput, is observed in this section. In addition, the quality of the frames received is also presented.

Figure 3 shows the number of bad periods. It is obvious that case II has the greatest number of bad periods and case III has the smallest number of bad periods. Numerically, case III successfully reduces the number of bad periods by 30% to 45% as compared to case I, and 45% to 55% as compared to case II. Clearly, the proposed mechanism gives the best performance in term of the number of bad periods. In addition, another important observation from this graph is the poor performance of case II. It directly implies that the implementation of MDC does not necessary enhance the quality of video streaming, but creates unnecessary workload that worsens the network performance. Therefore, careful consideration has to be taken into account.

The average length of the bad periods is shown in Figure 4. The graph shows that case III has the shortest average length of bad periods, and this is followed by case II. Case I, which does not implement MDC, has the longer average length of bad periods. Case III gives the shortest average length of bad periods, which is about 10% to 35% shorter than case I. Therefore, it is fair saying that the implementation of MDC (case II and III) successfully shortens the average length of bad periods.

The main drawback of MDC is the higher overhead due to larger number of packets sent. In our simulation, the number of packets sent in case II and III are doubled as compared to case I. Figure 5 shows the network throughput. Case II has the lowest throughput and this directly demonstrates that the overhead does actually affect the network performance as predicted. Fortunately, this influence is made less significant in our proposed mechanism with better load balancing using multiple sources. In the same graph, case I and III have almost the same throughput, where the difference is only 0.2% to 0.6%; case III is 1% to 2% better than case II.

Next, we compare the quality of the frames received in each case. Figure 6 shows the comparison. For case I, the frame is either good or bad because there is only one description per frame. For case II and III, the frames are categorized as good, acceptable or bad depends on the number of descriptions received, as explained in the previous section. In Figure 6, we can observe that the proposed algorithm has the smallest number of bad frames, which is about 5% lesser than case I. We can also observe that using MDC alone as in case II does not reduce the quantity of bad frames, as shown in Figure 6(b). In term of the quantity of good frames, it can be observed that the proposed mechanism has the lowest percentage of good frames. This situation is explainable because the number of acceptable frames is increased. This compensation is

In Summary, it is observed that using MDC scheme alone for video transmission does not necessary help in improving the video quality. The extra overhead created could degrade the overall network performance as shown in case II. However, this problem has been overcome using the proposed mechanism because the additional overhead is distributed evenly among multiple sources as shown in case III. This leads to better load balancing and severe local congestion can be avoided. Consequently, the video quality is improved.

5. Conclusions and Future Work

In this paper, we have proposed a mechanism to improve the quality of video streaming over wireless ad hoc networks. We have adopted the Multiple Description Coding (MDC) coding scheme which have been proven feasible in improving the video quality for transmission over ad hoc networks. In order to obtain better load balancing and to increase the probability of receiver meeting with video source, multiple sources are used to send different description of the same video coded with MDC scheme. Primarily simulation results have shown that the proposed mechanism successfully improves the video quality, in term of reducing the number of bad periods and shortening the average length of bad periods. Further simulation using real video trace is a possible direction of future work. Besides, it is desired to integrate the proposed mechanism with suitable routing algorithm in order to reduce overhead, to increase efficiency and to support video multicasting.

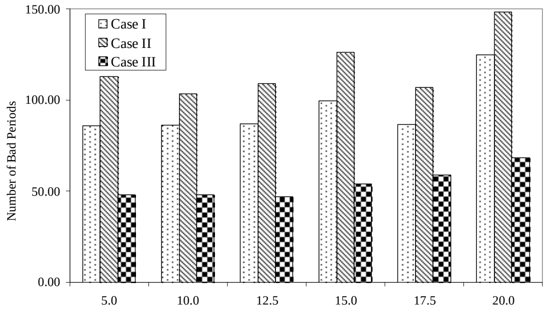


Figure 3. Number of Bad Periods

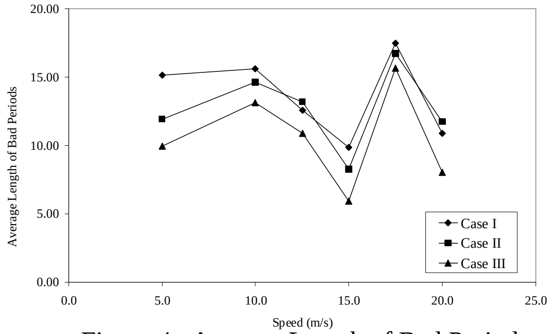


Figure 4. Average Length of Bad Periods

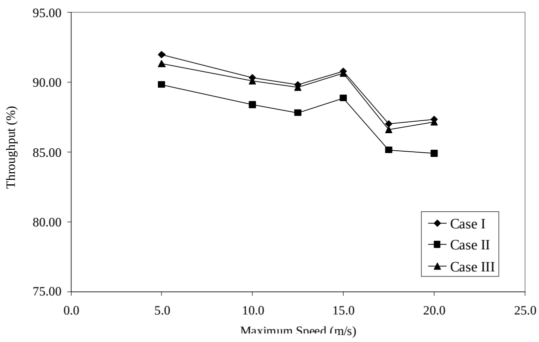
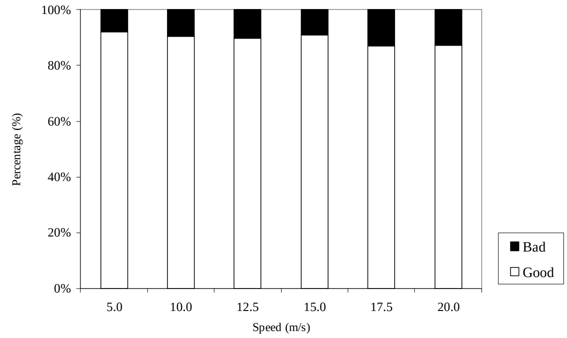
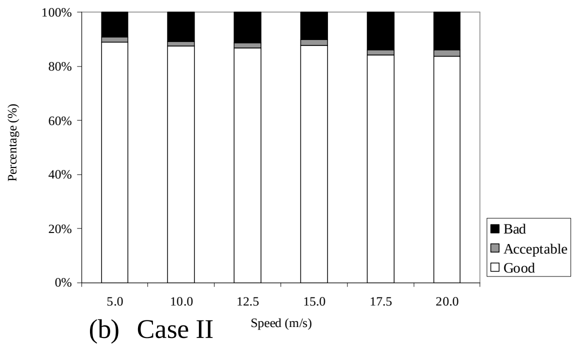


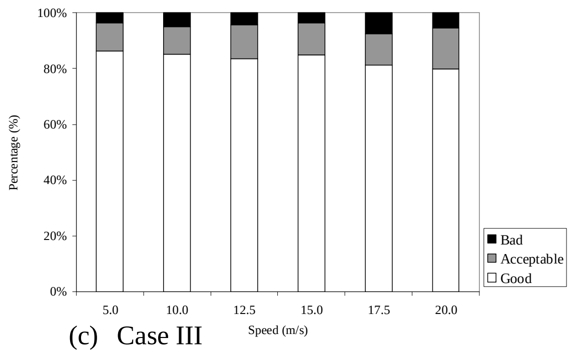
Figure 5. Throughput



(a) Case I



(b) Case II



(c) Case III

Figure 6. Quality of Video Frames:
(a) Case I; (b) Case II; (c) Case III.

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