Multicasting MDC Videos To Receivers with Different Screen Resolution

[Extended Abstract]

Rohan Gandhi
Purdue University
gandhir@purdue.edu

Dimitrios Koutsonikolas
University at Buffalo, SUNY
dimitrio@buffalo.edu

Y. Charlie Hu
Purdue University
ychu@purdue.edu

ABSTRACT

A primary challenge in multicasting video in a wireless LAN has been to deal with the client diversity in terms of channel diversity: clients may have different channel characteristics and hence receive different numbers of packet transmissions from the AP. Various schemes exploiting layered video coding schemes such as MRC and MDC have been proposed to address this problem. With the advent of smartphones, a new form of client heterogeneity, that different portable devices have different screen resolution and hence desire different numbers of layers, has become increasingly prominent. In this paper, we propose a practical transmission strategy selection method that takes into consideration this new form of client diversity and show it can increase the number of layers received by clients by up to 62%, compared to a scheme that is oblivious of the client screen resolution diversity.

Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous; C.2.1 [**Computer Communication Networks**]: Network Architecture and Design—*Wireless Communication*

General Terms

Design, Performance

Keywords

streaming media, MDC, WiFi, client diversity

1. INTRODUCTION

A primary challenge in multicasting video in a wireless LAN is to deal with the client diversity – clients may have different channel characteristics and hence may receive different numbers of transmissions from the AP. A promising approach to dealing with receivers experiencing different packet delivery ratios (PDRs) is to exploit source-coding techniques such as Multi-Resolution Coding (MRC) [1] and Multiple Description Coding (MDC) [3]. In contrast to a conventional media coder that generates a single bitstream, MRC and MDC encode a video into multiple substreams and reception of more substreams generally improves the video quality.

In the wired Internet, individual clients can independently decide how many substreams (layers or descriptions) to receive from the server according to their individual available bandwidth from the server. In a wireless network, however, all substreams transmitted share the medium; sending higher layers or more descriptions reduces the bandwidth available for sending lower layers/fewer descriptions.[1] The problem of selecting the optimal strategy (*i.e.,* the optimal amount of redundancy for each MDC description/MRC layer) has been extensively studied in the past (e.g., [5]) and more recently ([4, 2]).

All these works considered client diversity in the form of varying channel conditions (typically expressed as different PDRs). As smartphone devices become increasingly popular, a new form of client diversity becomes increasingly prominent. Different portable devices (laptops, PDAs, smartphones) have different screen resolution. For example, a laptop is more likely to have a higher screen resolution than a mobile phone. When a video is divided into multiple layers, the resolution of the video per layer is reduced. Supporting clients with lower resolution can then be achieved just by simply sending fewer layers. In other words, sending a higher resolution video to a client with lower screen resolution will not provide the expected performance benefits, while at the same time it may waste bandwidth.

Consider the following (simplified) scenario: A video stream encoded in 4 layers is multicast to two wireless clients with PDRs $P_1 = 0.9$, $P_2 = 0.3$. Assume that the AP selects the strategy that maximizes the sum of the layers decoded by the two clients (other objective functions are easily incorporated). Table 1 shows the Strategy Performance Table (SPT). The SPT lists the expected number of decoded layers with each strategy for every PDR. A strategy (X_1, X_2, X_3, X_4) sends X_i packets from layer i, $i = 1, 2, 3, 4$. When a resolution R is used, the SPT includes only strategies $X_i = k \cdot R, k \in \mathbb{N}$, under 4 different cases.

The SPT is calculated based on the total number of transmissions possible on a wireless channel for a single GOP[2] and number of video packets in a GOP. More details of calculating the SPT are in the next section. In the following scenarios, we consider that there are 8 packets per layer for a given GOP and there are 48 transmissions possible.

Scenario 1: Two laptops. Both clients are able to display all 4 layers. In this case, the best strategy distributes the transmissions equally among the 4 layers (12, 12, 12, 12) delivering 3.98 layers to client 1 and 0.03 layers to client 2 for a total of 4.01 useful layers.

Scenario 2: One laptop, one smartphone. Assume

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[1] For simplicity, we will use the term “layer” for both MRC layers and MDC descriptions in the remaining of the paper.

[2] In MDC, video content is partitioned into a sequence of pictures referred to as group of pictures. A GOP is divided into a sequence of packets for delivery over the network.

Table 1: Strategy Performance Table with resolution $R = 4$ for two clients with PDRs 0.9 and 0.3 in 4 different cases. The video stream is encoded into 4 layers. Each layer consists of 8 packets for a given GOP. The total number of transmissions allowed at the AP before the deadline of the GOP is 48.

	Dec. Layers		
Strategy	$P_1 = 0.9$	$P_2 = 0.3$	*Sum*
Max Layer = (4,4)			
(48,0,0,0)	1	0.99	1.99
...	...		
(12,12,12,12)	3.98	0.03	4.01
...	...		
(36,12,0,0)	1.99	0.89	2.88
...	...		
(0,0,0,48)	1	0.99	1.99
Max Layer = (4,2)			
(48,0,0,0)	1	0.99	1.99
...	...		
(12,12,12,12)	3.98	0.03	4.01
...	...		
(36,12,0,0)	1.99	0.89	2.88
...	...		
(0,0,0,48)	1	0.99	1.99
Max Layer = (2,4)			
(48,0,0,0)	1	0.99	1.99
...	...		
(12,12,12,12)	2.00	0.03	2.03
...	...		
(36,12,0,0)	1.98	0.89	2.87
...	...		
(0,0,0,48)	1	0.99	1.99
Max Layer = (2,2)			
(48,0,0,0)	1	0.99	1.99
...	...		
(12,12,12,12)	2.00	0.03	2.03
...	...		
(36,12,0,0)	1.98	0.89	2.87
...	...		
(0,0,0,48)	1	0.99	1.99

the smartphone can only display at most 2 layers. If the smartphone client is the one with the low PDR ($P_2 = 0.3$), then the optimal strategy happens to be the same as in Scenario 1 (12,12,12,12). However, if the smartphone client is the one with the high PDR ($P_1 = 0.9$), then using the optimal strategy for Scenario 1 results in a total of 2.03 useful decoded layers instead of 4.01. In contrast, with a strategy (36,12,0,0) which transmits only two layers, the two clients can decode 1.98 and 0.89 layers, respectively, for a total of 2.87 useful layers.

Scenario 3: Two smartphones. In this case, both devices can only display at most two layers. The optimal strategy is again (36,12,0,0) which only transmits only two layers.

The above scenario shows that heterogeneity among client devices should also be considered while making a strategy selection. In this work, we study the performance benefits of considering the heterogeneous screen resolution nature of the client devices in multicasting video streams over WiFi using a multi-layer video encoding technique. While our preliminary study here focuses on MDC videos, our findings apply to other techniques such as MRC or the combination of network coding with MDC/MRC.

2. MDC WITH DEVICE HETEROGENEITY

The primary challenge in sending layered video for WiFi delivery is how to select the optimal transmission strategy, which maximizes the number of *useful* layers decoded at the clients, given the total number of transmissions the AP can send before the deadline of a set of frames X, and the packet deliver ratio (PDR) at the receiver(s). As stated earlier, a strategy determines the number of packets to send for each layer. Table 1 shows the difference in the number of layers decoded for the same strategy at different PDRs. For example, in case of Max Layers = (4,4), strategy (12,12,12,12) decoded 3.98 layers at PDR = 0.9 and the same strategy decoded 0.03 layers at the PDR = 0.3. Therefore it is essential to select the optimal strategy based on the channel conditions.

[4] provides an online method for selecting the optimal coding strategy. The basic idea is search all possible strategies. However, a brute force search can be computationally prohibitive as both the number of strategies, *i.e.,* how each of the X transmitted packets can be coded, and the number of reception outcomes under each transmission strategy, *i.e.,* all the possible ways the X transmissions can be received under a PDR, are exponential. [4] incorporates a number of optimizations to drastically reduce the search complexity so it can be performed online. The optimizations include considering triangular coding schemes, reducing inter-layer coding strategies by assigning groups of transmissions to coding different layers, reducing the number of outcomes by grouping equivalent outcomes, and avoiding performing Gaussian Elimination in decoding.

We modified the screen resolution oblivious strategy selection method in [4, 2] to take into account of the screen resolution diversity as follows. In [4, 2], the expected number of decoded layers (assuming the video is split into L layers) is given by $E = \sum_{i=1}^{L} i * P_i$, where P_i is the probability of receiving exactly i layers. The expected number of layers for each strategy differs based on the channel conditions because P_i varies for different channel conditions. This approach assumes all the clients can display the same maximum number of layers L. Assume now that client 1 can only display at most $L_{max} < L$ layers. In this case, we modify the formula for the expected number of decoded layers to take into account the device display capability: $E' = \sum_{i=1}^{L_{max}-1} i * P_i + \sum_{i=L_{max}}^{L} L_{max} * P_i$ where L_{max} is the maximum number of layers the device can display. For a single client AP selects a strategy that maximizes E (or E').

In the online protocol, clients periodically send feedback to the AP specifying the number of packets received during each GOP. Based on the feedback, the AP estimates the PDRs to the clients and selects the new transmission strategy. As the PDR can be different for different clients, the number of decoded layers at each client will also be different. Thus strategy selection is effectively a multi-objective optimization problem as suggested in [4]. In this paper, we fix the objective function in strategy selection to be the sum of the numbers of useful decoded layers across all clients. For two clients, the objective function becomes maximizing (*E1’ + E2’*). The server scans through all the strategies to select a strategy that maximizes the objective function, and carries out transmissions of coded packets using 802.11 broadcast.

3. PRELIMINARY EVALUATION

We used the Glomosim simulator [6] and the methodology from [4, 2]. We placed an AP in the center of the simulation area and the clients uniformly on a circle around the AP. To evaluate the performance of the protocols under different loss scenarios, the clients were placed close to the AP and we generated link loss rates in a controlled manner, by artificially dropping packets at each client following a Bernoulli model.

We used the 802.11 MAC layer with a fixed bitrate of 5.5Mbps and RTS/CTS disabled, as in most operational networks. Data packets were broadcast at the MAC layer. The feedback messages sent by clients were unicast at the MAC layer for increased reliability. Clients send the feedback every 200 msec.

The video stream was a constant bit rate (CBR) traffic over UDP at 2.56 Mbps for a duration of 100 sec. The GOP duration was set to 1 sec. The stream consisted of $L = 4$ layers. Client 1 can display 2 layers whereas client 2 can display all 4 layers. We divide the GOP into segments for simplicity. In this case, the number of segments per GOP is set to 10. There are 8 video packets per layer per segment. The server calculates the SPT for all the PDRs ranging from 20% to 100% with increments of 5%.

As the 802.11 has a bitrate of 5.5Mbps and the video rate is 2.56Mbps, there is a scope of adding redundancy to improve performance. We used intra-layer network coding to add the redundant packets as in [4].

We compare the performance of our method (referred as *New_Method*) which considers the maximum layers that can be displayed by different clients against the method (referred as *Prev_Method*) from [4, 2]. The simulation cases are generated by varying the PDRs for the two clients independently between 20% and 100%.

Figure 1 shows the gain (in terms of the sum of the number of decoded layers for the two clients) of the *New_Method* over the *Prev_Method* for a variety of scenarios. We observe that taking the screen resolution into account improves performance up to 62%.

Figure 2 provides more details on the scenarios when the *New_Method* outperforms the *Prev_Method*. The X-axis shows the PDR for the client ($Client_1$) that can decode 2 layers (PDR_1), whereas the Y-axis shows the PDR for the client ($Client_2$) that can decode 4 layers (PDR_2). It can be seen that the *New_Method* improves the number of layers decoded only when PDR_1 is more than 0.5 and PDR_1 is more than PDR_2. This is because, when the PDR_1 is higher than PDR_2, the *Prev_Method* selects a strategy that benefits $Client_1$ and can decode more than 2 layers for $Client_1$. However, as $Client_1$ can display only 2 layers, the benefits are lost. Scenario 2 in Table 1 falls in this region.

When the PDR_1 is lower than 0.5, there is no performance improvement. This is because at lower PDR_1, both methods select strategies that decode less than 2 layers for $Client_1$. We also observe the gain of using *New_Method* diminishes when PDR_2 approaches 1. This is because the number of layers decoded by $Client_2$ already grows closer to 4.

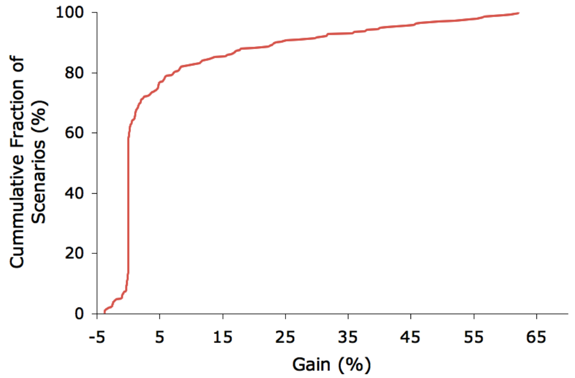

Figure 1: CDF of the gain of optimal strategies by the new method over the previos method.

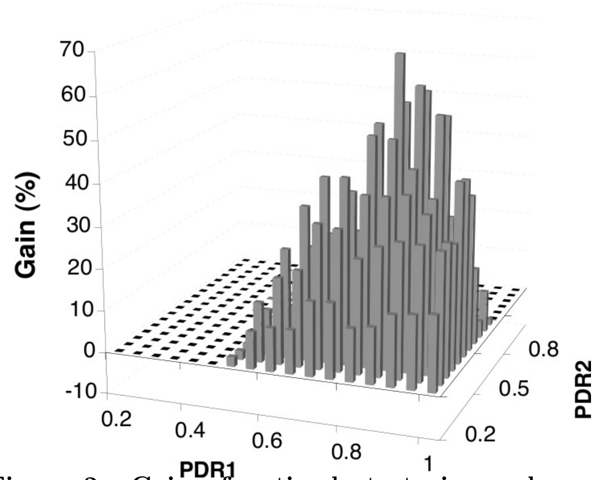

Figure 2: Gain of optimal strategies under new method for 2 clients when their PDRs are varied from 0.2 to 1 with a step of 0.05.

4. CONCLUSIONS

Motivated by the observation that performance benefits by multicasting the layered videos such as MDC and MRC is affected by the clients that have different screen resolution, we propose a practical transmission strategy selection method that takes into consideration this new form of client diversity in selecting the optimal transmission strategy to maximize the total number of useful, decodable layers at the clients. Our method improves the performance of MDC videos by up to 62% for 2 clients with different screen resolution. Though our method presented here focuses on MDC, the technique can be applied to other layered video coding techniques such as MRC or MRC / MDC with network coding.

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5. REFERENCES

[1] M. Effros. Universal multiresolution source codes. *IEEE Trans. on Information Theory*, 47(6), 2001.

[2] R. Gandhi et al. The impact of inter-layer network coding on the relative performance of MRC/MDC WiFi media delivery. In *Proc. of NOSSDAV*, 2011.

[3] V. Goyal. Multiple description coding: compression meets the network. *IEEE Signal Processing Magazine*, 18:74–93, Sept 2001.

[4] D. Koutsonikolas et al. Online WiFi delivery of layered-coding media using inter-layer network coding. In *Proc. of IEEE ICDCS*, 2011.

[5] A. Majumdar et al. Multicast and unicast real-time video streaming over wireless LANs. *IEEE TCSVT*, 12(6), 2002.

[6] X. Zeng, R. Bagrodia, and M. Gerla. Glomosim: A library for parallel simulation of large-scale wireless networks. In *Proc. of PADS Workshop*, May 1998.