International Journal of Advanced Technology in Engineering and Science www.ijates.com
Volume No 03, Special Issue No. 01, March 2015 ISSN (online): 2348 – 7550

ENHANCING VIDEO DISSEMINATION USING JOINT ROUTING IN CELLULAR AND ADHOC NETWORK

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ABSTRACT

In my research work to improve disseminating videos to mobile users by using a hybrid cellular and ad hoc network. In particular, we formulate the problem of optimally choosing the mobile devices that will serve as gateways from the cellular to the ad hoc network, the ad hoc routes from the gateways to individual devices, and the layers to deliver on these ad hoc routes. We develop a Mixed Integer Linear Program (MILP)-based algorithm, called POPT, to solve this optimization problem. We then develop a Linear Program (LP)-based algorithm, called MTS, for lower time complexity. We, therefore, propose a greedy algorithm, called THS, which runs in real time even for large hybrid networks. We conduct extensive packet-level simulations to compare the performance of the three proposed algorithms. We found that the THS algorithm always terminates in real time, yet achieves a similar video quality to MTS. Therefore, we recommend the THS algorithm for video dissemination in hybrid cellular and ad hoc networks. The videos are secured using the Misbehavior Routing Authentication and digital signature method. Load and distribution method is used to transmit the secured videos.

***Keywords*: Wireless Networks, Video Streaming, Quality Optimization, Resource Allocation**

I INTRODUCTION

MOBILE devices, such as smart phones and tablets, are getting increasingly popular, and continue to generate record-high amount of mobile data traffic. For example, a Cisco report indicates that mobile data traffic will increase 39 times by 2015. Sixty six percent of the increase is due to video traffic [1]. Unfortunately, existing cellular networks were designed for unicast voice services, and do not natively support multicast and broadcast. Therefore, cellular networks are not suitable for large-scale video dissemination. This was validated by a measurement study, which shows that each HSDPA cell can only support up to six mobile video users at 256 kbps [2]. Thus, disseminating videos to many mobile users over cellular networks could lead to network congestion and degraded user experience. This network capacity issue may be partially addressed by deploying more cellular base stations, installing dedicated broadcast networks [3] or upgrading the cellular base stations to support Multimedia Broadcast Multicast Service (MBMS) [4]. However, these approaches all result in additional costs for new network infrastructure, and might not be fully compatible with existing mobile devices. Hence, a better way to disseminate videos to many mobile users is critical to the profitability of cellular service providers.

In this paper, we study video dissemination in a hybrid cellular and ad hoc network. Fig. 1 depicts the underlying network, consisting of one or several base stations and multiple mobile devices equipped with heterogeneous network interfaces. Mobile devices not only connect to the base station over the cellular network, but also form an ad hoc network using short-range wireless protocols such as WiFi and Bluetooth. Mobile devices relay video traffic among each other using ad hoc links, leveraging such a free spectrum to alleviate bandwidth bottlenecks and cut down the expense of cellular service providers. Throughout the paper, we denote mobile devices that directly receive video data over the cellular network and relay the receiving data to other mobile devices over the ad hoc network as gateways. Notice that although we do not explicitly consider centralized access points in the short-range network, our formulation and solutions are general enough, and can be readily applied to WiFi and Bluetooth access points.

Figure 1 shows the block diagram of hybrid cellular and ad hoc network. Disseminating videos over a hybrid cellular and ad hoc network is not an easy task because transmission of video data must adhere to timing constraints inherent in the delivery and playback of video content.

Traditionally, video servers use computationally complex transcoders [5] to reduce the video coding rates to guarantee on time delivery of video data. However, in a hybrid network, real-time transcoding is not feasible on resource-constrained mobile devices. Thus, we employ scalable videos [6] for in-network video adaptation [7]. More precisely, at the base station, scalable coders encode each video into a scalable stream consisting of multiple layers, and each mobile device can selectively forward some layers to other mobile devices in a timely fashion.

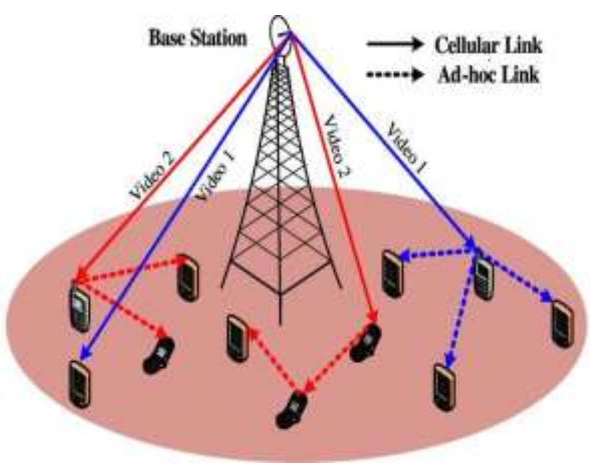

Fig 1. A Hybrid Cellular And Ad Hoc Network

To deliver the highest possible video quality, we study an optimization problem that determines: 1) the mobile devices that will serve as gateways and relay video data from the cellular network to the ad hoc network, 2) the multihop ad hoc routes for disseminating video data, and 3) the subsets of video data each mobile device relays to the next hops under capacity constraints. We formulate the optimization problem into a Mixed Integer Linear

Program (MILP), and propose an MILP-based algorithm, called POPT, to optimally solve it. We found that both MTS and THS achieve a similar video quality, which is close-to-optimum video quality with at most a 2 dB gap observed. More importantly, the THS algorithm has a much lower time complexity than POPT and MTS. It always terminates in real time, and supports large hybrid networks with 70+ mobile devices. Hence, we recommend the THS algorithm for video streaming over hybrid cellular and ad hoc networks. Last, we also build a real video dissemination system among multiple Android smart-phones over a live cellular network. Via actual experi-ments, we demonstrate the practicality and efficiency of the proposed THS algorithm.

The rest of this paper is organized as follows: We give our system's overview, build up notations, define, and formulate our optimization problem in Section 2. This is followed by the proposed algorithms presented in Section 3. We evaluate the algorithms using extensive simulations and experiments in Sections 4. The paper is concluded in Section 5.

II VIDEO DISSEMINATION IN HYBRID NETWORKS

In this section, we first describe our system's overview and notations used frequently in the paper. We then state our problem that schedules to stream videos optimally, and formulate this problem as an MILP problem.

2.1 System Overview and Notations

We consider a hybrid network (see Fig. 1), which consists of a cellular base station and several mobile devices. Table 1 summarizes the notations used in the paper. The base station concurrently transmits K videos to U mobile devices, where each mobile device receives and renders a video chosen by its user. Throughout this paper, we use node to refer to both the base station and mobile devices. All mobile devices are equipped with two network interfaces for cellular and ad hoc networks, respectively. Examples of cellular networks include EDGE, 3G, and 4G cellular networks, and examples of ad hoc networks are WiFi ad hoc and Bluetooth networks. Mobile devices can always receive video data from the base station via cellular links. They also form an ad hoc network and exchange video data over it. Unlike cellular networks, ad hoc connectivity is not guaranteed because ad hoc networks, such as WiFi ad hoc and Bluetooth networks, have a rather short range, less than a few hundreds of meters, and are prone to disconnections due to user mobility.

Distributing videos in a hybrid network is challenging because: 1) wireless networks are dynamic in terms of connectivity, latency, and capacity, and 2) video data require high throughput and low latency. To cope with these challenges, we employ layered video coding [6], such as H.264/SVC [8], to encode each video into L layers. Layer 1 is referred to as the base layer, which provides a basic video quality. Layers 2; 3; . . . ; L are enhancement layers, which provide incremental quality improvements. An enhancement layer is decodable if all layers below it are received. With layered videos, we can dynamically adjust the number of layers sent to each mobile device. While the adjustments may be done very frequently, a subject user study [9] reveals that frequent quality changes lead to degraded viewer experience. Therefore, we divide each video into multiple D sec video segments, where D is a small number (e.g., 1 or 2 seconds). Quality changes are only allowed at boundaries of segments. We study an optimization problem of selecting transmission units from W consecutive segments to transmit to mobile devices over the hybrid network. The W consecutive segments considered for selection form a scheduling window.

Given that the base station maintains a global view of the hybrid cellular and ad hoc network, the scheduler on the base station computes the schedule for all cellular and ad hoc links. The base station sends a new schedule to mobile devices every DW^0 secs. The mobile devices then distribute transmission units following the schedule. To maintain the tractability, our schedule does not explicitly specify the transmission time of each transmission unit. Rather, the order of transmission units is determined by the importance of transmission units. We denote the list of transmission units sorted by their importance as a precedence list. Mobile devices skip transmission units that have not been received, and check their availability again whenever a transmission unit is completely sent.

2.2 Optimization Problem Formulation

We first build up the video and network models. Then, we formulate the considered scheduling problem.

2.2.1 Rate-Distortion (R-D) Model

Our objective is to maximize the video quality under network bandwidth constraints. A popular method to achieve such quality-optimized system is to use a rate-distortion model, which describes the mapping between video rates and degrees of quality degradation in reconstructed videos. R-D models capture the diverse video characteristics and enable media-aware resource allocation. Due to flexible and complicated prediction structures of layered video streams, existing scalable R-D models [10] are fairly complex and may not be suitable for real-time applications. Hence, we adopt a low-complexity discrete R-D model below. The distortion caused by not sending a transmission unit $t_{k;s;l}$ to a mobile device can be divided into two parts [11], [12] : 1) truncation distortion and 2) drifting distortion. Truncation distortion refers to the quality degradation of pictures in segment s itself, and drifting distortion refers to the quality degradation of pictures in other segments due to imperfect reconstruction of reference pictures. We assume each segment s contains multiple groups-of-picture (GoPs) and, thus, can be independently decoded. This practical assumption eliminates the needs to model drifting distortion. More specifically, we empirically measure the mapping between the node location and link capacity several times, and use the resulting values for capacity estimation.

Cellular networks control the interference via various multiple access methods (such as FDMA, TDMA, and CDMA) and via proper network planning (to avoid intercell interference). At a high level, the base station runs a centralized algorithm to allocate air-time to mobile parameter. Interference in ad hoc networks is harder to control as the air-time allocation is done by distributed media access control (MAC) protocols. We model the air-time allocation using the conflict graphs. A conflict graph is used to learn links that cannot be simultaneously activated due to interference. This happens in ad hoc networks because mobile devices use the same frequency for transmission. Two links interfere each other if at least one end of a link is in the transmission range of one or two ends of the other link. An independent set refers to a subset of vertices where no two of them are adjacent.

2.2.2 Controlling Dissemination Latency

Our optimization problem only determines which transmission units to send in the current scheduling window, but does not model the fine-grained delivery time of each transmission unit. We should mention that the unit delivery time could be modeled using time-indexed Integer Linear Program (ILP) [13] . In time-indexed ILP formulations, all time intervals are expressed as (rounded to) multiples of a sufficiently small time slot. In these formulations, short time slots are essential for good performance, but short time slots also lead to a large number of decision variables and render the formulation computationally intractable.

We do not employ time-indexed ILP in our formulation, but use two other approaches to control latency. First, we limit each unit to be sent over at most H hops in each scheduling window, where H is a small integer and a system parameter. Second, we employ the paths on the breadth-first trees for unit delivery, which is detailed in the following: Let $A_{k;s;l}$ be the set of nodes that already have unit $t_{k;s;l}$. Nodes in $A_{k;s;l}$ are potential sources for distributing $t_{k;s;l}$ and all other mobile devices are receivers of that transmission unit. To avoid inefficient paths, we only consider the paths that follow the breadth-first tree from the source a to all mobile devices not in $A_{k;s;l}$. Figure 2 presents an example of a breadth-first tree, which is formed to deliver unit $t_{k;s;l}$ from device 1 in $A_{k;s;l}$ to four receivers. Device 1 is the root of the tree, and nodes 2 and 3 are in level 1.

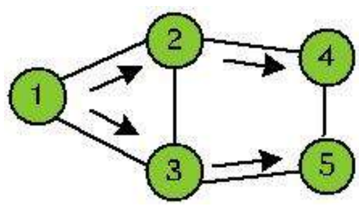

Fig 2. An Illustrative Breadth-First Tree for Unit Delivery

Distributing transmission units over breadth-first trees not only limits the distribution latency and avoids loops, but also reduces the complexity of the considered problem without sacrificing the solutions' quality. This is because paths that do not follow breadth-first trees are inefficient and should be avoided.

III SCHEDULING ALGORITHMS

In this section, we present three algorithms to solve the scheduling problem in a hybrid cellular and ad hoc network.

3.1 An MILP-Based Algorithm: POPT

The formulation consists of linear objective functions and constraints with integer decision variables ($x^{a;v;u}_{k;s;l}$) and real-value variables (_$_u$ and _$_q$). Hence, it is an MILP problem and may be solved by MILP solvers. However, observe that constraints in (2d) and (2e) include all the maximal independent sets I_q (1 _ q _ Q) in the conflict graph, and finding all I_q itself is an NP-Complete problem [14]. Therefore, it is computationally impractical to consider all Q maximal independent sets. Jain et al. [16] propose a random search algorithm for deriving a subset of maximal independent sets that is sufficient for optimal schedulers. Li et al. [15] show that this random search algorithm is inefficient, and propose a priority-based algorithm to find the maximal independent sets that will be used in the optimal schedule with high probability. The priority-based algorithm works as follows: First, the shortest path between the source-destination pair of each flow is calculated. Then, the number of shortest paths traversing through each link is used as its priority. Next, the algorithm uses an anchor link to iterate through the links from high to low priority. For each anchor link, the algorithm scans through all links that are not its neighbors in the conflict graph, and creates a set of new maximal independent sets, where every maximal independent set contains the anchor link. A link covered by any maximal independent set will not be considered as an anchor link. The algorithm stops once all links are covered by at least a maximal independent set. Readers are referred to Li et al. for more details on this algorithm.

3.2 A Throughput-Based Heuristic Algorithm: MTS

Since MILP problems are NP-Complete, the POPT algorithm does not scale well with the number of mobile devices. Hence, we develop a heuristic algorithm, called Maximum Throughput Scheduling (MTS) algorithm that was first presented in Do et al.[17].This algorithm consists of two steps. In step 1, we derive the demand capacity $c^\wedge_{u;v}$ for each link from mobile device u to v. We iterate through the transmission units following the precedence list, which generally starts from lower to higher layers and from earlier to later segments. For each transmission unit, we first schedule it to be delivered to all mobile devices that have not received that unit yet, over the ad hoc links. Mobile devices that cannot receive the transmission unit from peer mobile devices are scheduled to receive the unit from the base station over the cellular network if their cellular data rate is enough to do so. More specifically, among mobile devices that do not have the unit, the base station selects a device with the highest number of children in an ad hoc tree rooted at that device, and sends it the unit.

3.3 A Tree-Based Heuristic Algorithm: THS

Both POPT and MTS algorithms employ optimization problem solvers. Although commercial and open-source solvers are available, these solvers might lead to long running time in the worst-case scenarios. Hence, we next propose a greedy scheduling algorithm that does not rely on any solvers. We call it Tree-Based Heuristic Scheduling (THS) algorithm, and it works as follows: We first sort all the transmission units in the W-segment scheduling window in descending order of importance, by layer, segment, and video. We then go through these WL units, and sequentially schedule the transmissions to all mobile devices. For each transmission unit, we first consider dissemination over the ad hoc network. If the ad hoc network cannot deliver this unit to all mobile devices in time, we fall back to the cellular network. The scheduler sends the unit to a device with highest cellular data rate among those which have not received the unit. The parameters such as end-to-end delay, throughput are calculated with the existing system system and they are increased compared with the existing system.

IV SIMULATION RESULTS

We conduct extensive packet-level simulations to evaluate our proposed algorithms in this section.

4.1 Settings

We employ a well-known network simulator, NS2. We emphasize that NS2 captures many more details in a hybrid cellular and ad hoc network, and provides simulator results closer to real life, compared to the flow-based simulations used in earlier work. We implement all the proposed scheduling algorithms in the simulator. The video file which is in .DAT format is employed in the program to check parameters for the existing and proposed method and also the error rate for the video is calculated as video before sending and after sending is calculated. In DAT format the video classified as Inter frame, Predictive frame and Bipredictive frame. Based on the priority, time and length of the frame the videos are transmitted. The negative acknowledgement is also calculated. The error rate is minimized after the transmission so that the video received is viewed clearly.

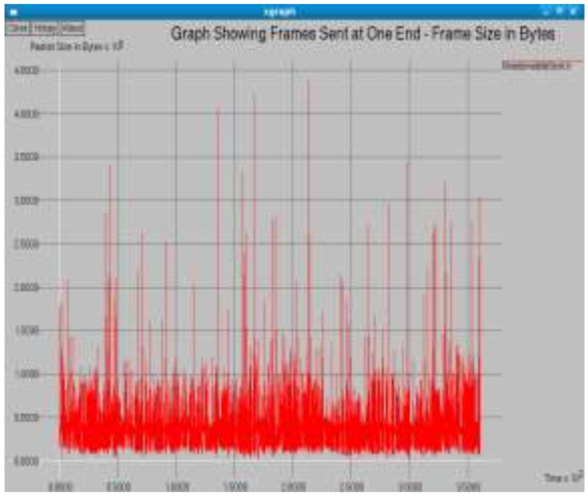

Fig 3. Video Before Sending

Figure 3 shows the graph between time and the packet size in bytes of the video before sending. Figure 4 the graph between time and the packet size in bytes of the video after sending.

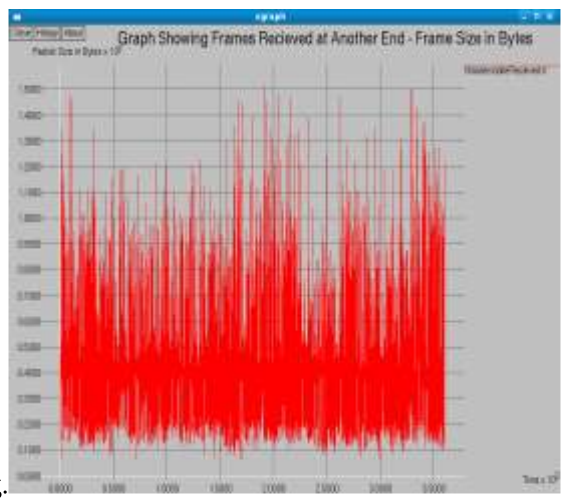

Fig 4. Video After Sending

V CONCLUSION

We studied the problem of optimally leveraging an auxiliary ad hoc network to boost the overall video quality of mobile users in a cellular network. We formulated this problem as an MILP problem to jointly solve the gateway selection, ad hoc routing, and video adaptation problems for a global optimum schedule. We proposed three algorithms: 1) an MILP-based algorithm, POPT, 2) an LP-based algorithm, MTS, and 3) a greedy algorithm, THS.

Via packet-level simulations, we found that neither POPT nor MTS scale to large hybrid networks. This is because they both employ numerical methods to solve optimization problems. Therefore, we recommend the THS algorithm, which terminates in real time even when there are 70+ mobile devices in the hybrid network. In the THS algorithm the security is added to the video and it can be various applications where Security is an important thing. It can be used in military command-and-control and in some emergency cases.

VI ACKNOWLEDGMENT

First and foremost, we wish to express our deep gratitude and indebtness to our institution and our department for providing us a chance to fulfill our long cherished of becoming Electronics and Communication engineers.

We wish to acknowledge with thanks the excellent encouragement given by the management of our college .We wish to express our hearty thanks to the Principal of our college and HOD. We are committed to place our heartfelt thanks to all teaching and supporting staff members, lab technicians and friends, and all the noble hearts that gave us immense encouragement towards the completion of our project. Finally we thank almighty for bestowing the gifts of life on us and also for providing us the necessary help through his lovely creations in this endeavor of us.

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