Real-Time Video over Heterogeneous Wireless Networks

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Abstract – Recent development, made it possible that end users receive video data simultaneously over multiple interfaces (e.g., cellular and Wi-Fi), consequently, some multipath protocols for this purpose are recently standardized (e.g., MPTCP). However, these protocols cannot provide the requirements of video streaming such as bandwidth and delay constraints. To mitigate these problems, this work, have been implemented three different path-aware scheduler strategies over MMT protocol. Two of them are based on pre-defined thresholds (delay and losses) and one is based on the GDD (Goodput Division Delay) metric. We conduct performance evaluation through NS3 simulation for real-time H.264 video streaming. Among these strategies, GDD achieves appreciable performance in terms of PSNR (Peak Signal-to-Noise Ratio), and packet loss.

Keywords – Multipath delivery, Video streaming, MMT protocol, Path-aware strategy

1. Introduction

Recent technological evolution made it easy for us to record our moments (e.g. by smart phones and digital cameras) and platform developments made it possible to share these videos with our friends (e.g. Facebook, Instagram). Likewise, on-demand video, video conferences, video calls, and online interactive games have become part of our daily routine (e.g. by skype, WhatsApp, cloud online games). Regarding the annual Cisco report [2], mobile video traffic will take 80% of mobile traffic in 2020.

It is a fact that achieving good quality of service for the final user within the video streaming mobile scenario is a quite challenging task, considering the several aspects involved in mobile transmission, such as bandwidth constraints, lossy wireless channels, delay, lack of coverage and congested networks. In this respect, utilizing multipath delivery could mitigate these obstacles because with multiple interfaces receivers can receive data through parallel paths with multiple IP addresses, consequently, providing high quality mobile services. In addition, benefits of using multipath for mobile video streaming include reliability and seamless connectivity, increasing throughput and load balancing [4], [5], thus improved QoE becomes possible.

Fortunately, many servers and smartphones are equipped with multiple interfaces. Multiple interface devices with the ability to connect simultaneously to multiple networks are known as multi-homed devices, and these multi-homed devices can utilize multipath communication by aggregating the available bandwidth from multiple Radio Access Technologies (RATs).

Attempting to deploy multipath solutions for video delivery may encounter significant road-blocks, such as compatibility, networks heterogeneity, out-of-order packets, Head-of-line (HOL) phenomenon, End-to-End delay, overdue packets, and hence cause to outperform the quality of video. One promising approach to overcome above-mentioned challenges is applying path-aware strategies to the video streaming process. Path-aware scheduling approaches employ network environment knowledge to deliver better performing traffic.

In this work, we exploit MPEG Media Transport (MMT) protocol [1] with path-aware strategies. MMT is a multimedia application layer transport protocol that meets our required features, including the ability to transmit video in various heterogeneous network environments and IP networks, supporting Ultra HD (UHD), video on-demand (VoD) and unicast transmission. Moreover, MMT has gotten a lot of attention in virtual reality, augmented reality and digital TV. We believe that there is room to better study and improve it to make MMT aware of path situations. Validating these promising approaches by proposing and evaluating novel multipath solutions for video strategies are the main objectives to address our research problem.

The structure of the paper is organized as follows; Research works related to multipath mobile video routing are discussed in Section 2. In Section 3., the system model and the path-aware strategies are explained. Section 4. provides the
performance evaluation. Finally, in Section 5., we conclude this paper.

2. Literature Review

There are some efforts for multipath delivery, including SCTP [7] and MPTCP [3]. However, they are not sufficient for real-time video streaming. One reason is that they are implemented in the transport layer and the application layer cannot be involved in scheduler strategies. For achieving optimal scheduling performance, the scheduler could take into consideration two functions: content awareness, and path awareness strategy. A good strategy could increase video QoE and QoS. Moreover, the application layer is aware of video features, player buffer or deadlines. Therefore, in this project, we will focus on the application layer because of its influence in scheduling strategy, and we use the application feedback for optimal delivery of the media data.

As described in Section 1., MMT is a recent standard protocol with potential abilities. Therefore, our proposed project aims to improve MMT scheduler strategy to make adaptive and wise path selection. The related work in [6] proposes a synchronization scheme for video streams transported over hybrid delivery: a combination of MMT (for broadcasting) and HTTP (for broadband) streaming. They used SHVC-encoded stream and in their experiment, the base and first enhanced layers are delivered over the broadcast channel, and the second enhanced layer is delivered over broadband networks. The synchronization scheme is implemented at the receiver side and the receiver could request the segments that they can deliver on time. It should be highlighted that the approach does not use any scheduling strategy to manage the paths.

Finally, in this project, we define and improve the MMT scheduler by making the scheduler aware of network situation (we will make MMT aware of video content to prioritize packets in the feature work).

3. Scheduling Strategies

In this section, we have an overview of system model that is used, and then we introduce the defined path-aware scheduling strategies.

The system overview of the proposed MMT framework is presented in Fig. 1. The components are implemented at both sender and receiver sides. We consider the unicast transmission of a single video flow using the MPUDP connection over heterogeneous wireless networks.

At the sender side, there are different components, namely video encoder, MPU unit, scheduler, and the feedback received component. At first, the raw video encodes via video encoder. Then fragmentation will be performed by the MPU unit. The scheduler component is responsible for finding path qualities based on its own strategy and for distributing data over them. Feedback packets are sent periodically by the receiver to the feedback receiver. This information is then evaluated and used by the scheduler for the next packets distribution.

At the receiver side, existing components include packet received, statistic computation, scheduler, reassemble and video decoder. After receiving packets in the packet received unit, statistics should be generated via the statistic computation component. The statistics include goodput, average delay, number of lost packets, moving average jitter and number of packets received. This information should be sent to the sender via feedback. Since feedback is very important and has a high effect on the sender scheduler decision, it is necessary to send it over the most qualified path, thus, there is a scheduler implementation at the receiver side as well. Therefore, feedback packets could be delivered to the sender fast and without loss. If the received packets in the packet received unit are not overdue, then they go to the reassemble component and, consequently, to video decoder unit for error concealment and decoding. Finally, the video is ready to display.

For selecting the path to send packets, the sender follows a strategy defined by its scheduler. This strategy should take into account current conditions for all paths to select the best possible path in each moment. Therefore, the scheduler must employ a path-aware strategy that is able to cope with congestion and link failures appropriately in order to maximize the QoS by reducing delay, improving goodput and increasing PSNR. In this work, we have implemented three different path-aware scheduler strategies. Two of them are based on predefined thresholds and one is based on the GDD (Goodput Division Delay) metric.

The first path-aware scheduler strategy uses the delay thresholds. Before sending each packet, the scheduler compares the current path delay with
the maximum delay defined by the thresholds. If the current path delay is lower than the threshold, packets are split evenly by sending even packets over LTE and odd packets over WiFi. On the other hand, if the current path delay is greater than the threshold, the scheduler sends all packets just over the other (alternate) path. In our work, the scheduler strategy is also available on the receiver side to identify the best path to send feedback information and to estimate packet losses on each path. When the receiver realizes that some packets were missed, it is not possible to figure out over which path those packets were sent through. In other words, it is not possible to know, on the receiver side, what was the path chosen by the sender scheduler for each missed packet. Therefore, in order to compute packet losses in each path, the receiver reproduces the scheduler behavior and estimates the path chosen by the sender.

The second path-aware scheduler strategy follows the same behavior of the first strategy. The difference is that the thresholds are now based on number of packet losses instead of delay. The third and the last path-aware scheduler strategy described in this work is not based on thresholds but on the GDD (Goodput Division Delay) metric. We compute GDD for each path separately and also joint GDD for all paths. The formula below defines the GDD computation as the division of goodput by delay for each path. In the computation of the joint GDD, the joint goodput is divided by the average delay for both paths.

\[ GDD_{current} = \frac{\text{goodput}}{\text{delay}} \]

In order to take into account the network history, we applied the following moving weighted average (MWA) approach:

\[ MWA_{current} = (1 - \alpha) \times GDD_{current} + \alpha \times MWA_{previous} \]

After the \( MWA_{current} \) metric is computed by the scheduler for the current packet, its value is kept by the \( MWA_{previous} \).

Therefore, over time, the \( MWA_{previous} \) parameter has an accumulative effect for the whole simulation. As previously described, the MWA metric is computed for each path separately and also for both paths jointly. The scheduler then identifies the greater value among the three MWA metrics computed. If the winner is the MWA metric for both paths (using the joint GDD), the scheduler splits packets evenly over both paths. On the other hand, if either the MWA computed for the LTE or the MWA computed for the WiFi paths are the winners, the scheduler sends all packets just over the winner path.

4. Performance Evaluation

In this section, we evaluate the MMT-based multipath video streaming scenario. We present and compare results for three different path-aware scheduler strategies that are explained in Section 3. For all the simulations, results are shown in terms of graphs for packet losses in Fig. 2(a) and PSNR Fig. 2(b). The worst results were achieved by the path-aware strategy based on the packets losses threshold. Around 5% of the sent packets were lost and the average PSNR was 34.60 dB with very noticeable errors in the recovered video. Most of the losses are due to the high number of overdue packets. The number of packet losses was halved (from the previous 5%) to around 2.6% for the path-aware strategy based on
the delay threshold. The average PSNR achieved for this scheduler was 36.11 dB. In these two threshold approaches, not proper path selection causes such big losses values, and consequently less PSNR.

Finally, the best results were achieved by the path-aware strategy based on the GDD metric. Only 1.12% of the sent packets were lost and the average PSNR was 37.96 dB. This packet loss ratio is usually considered acceptable for real-time video streaming and the quality of the recovered video significantly improved, specially for the period when LTE is congested.

5. Conclusion

The proposed video streaming approach could enhance the video streaming performance. Multipath path-aware scheduler strategies for video streaming allows simultaneous video delivery on multiple paths based on appropriate bandwidth requirements. Therefore, media data is available faster at the receiver, and consequently contributes to improved QoS and QoE at the receiver. Adaptive path selection helps in adverse network conditions, such as high packet loss and congestion environments. Future work includes improving path-aware strategy, implementing content-aware strategies and applying error resilience for media transferring.

References