Tech-Topic Analysis 6

S. Khan, et al., "Application-Driven Cross-Layer Optimization for Video Stream Over Wireless Networks," IEEE Communications, vol. 44, no. 1, January 2006.

Overview

Multimedia applications are becoming increasingly more popular. Wireless networks are going to have trouble supporting applications like video conferencing and media streaming. The layered approach to network design will be unable to handle these highly demanded applications on mobile systems. The authors offer an alternative approach to network design called Cross-layer design (CLD). Unlike the previous approach, CLD does not consider each layer in isolation. It instead considers the dependencies and interactions between layers and does cross-layer optimizations. There has been a lot of previous research on CLD. Researchers have approached CLD from the top-down and from the bottom-up. The authors continue by mentioning a plethora of related research in the field of CLD. In their approach to CLD, information is passed between layers in a top-down and bottom-up directions. They use cross-layer optimization and in their implementation the optimization considers the application layer, the data link layer and the physical layer. This way of implementing CLD is unique because it jointly optimizes parameters and it evaluates the performance gain by experimenting in a testbed. The authors also analyze the trade-off between performance gain and the additional computation and communication cost of the optimization.

Next, the paper describes the cross-layer architecture. The architecture has N layers as well as a cross-layer optimizer (CLO). This CLO takes in abstracted parameters from each layer and returns optimized parameters based on information from other layers. The optimization consists of three steps: 1) Layer abstraction, 2) Optimization, 3) Layer reconfiguration. Abstraction is used to avoid a lot of data processing and communication overhead. It does this by reducing the number of parameters. There are four classifications of parameters: 1) Directly tunable, 2: Indirectly tunable, 3) Descriptive, 4) Abstracted.

The paper then follows by giving a background on video streaming. Video streams are usually encoded into a sequence of consecutive frames called a group of pictures (GOP). Within a GOP there are three types of frames. These frames are I-frames, P-frames, and B-frames. When decoding, if an I-frame is lost than it causes more distortion than losing a P-frame. The authors use a graph to show distortion depending on which frame is lost. All layers must be adaptive to overcome the challenges of streaming video. This adaptation can be achieved by using cross-layer optimization. In order to measure the quality of the video the authors use a method called the peak signal-to-noise ration (PSNR).

The authors then give a brief scenario where cross-layer optimization is used. They present a figure which has 3 users who are streaming video from a base station. Periodically, the system is optimized at the beginning of each GOP. At that time the CLO takes abstracted parameters and optimizes them based on certain

layer-specific parameters. The goal of the optimization is to maximize the PSNR. The CLO selects the parameters which achieve the highest average PSNR of all users.

The cross-layer optimization uses different methods of abstraction for each layer. The radio link layer consists of the physical layer and the data link layer. At the radio link layer, four key parameters are abstracted. These parameters are the transmission date rate, the transmission packet error rate, the data packet size, and the channel coherence time. These parameters are used to compute transition probabilities that decide when to consider the retransmission of important frames. The application layer uses the rate distortion profile for abstraction.

After the parameters are abstracted, the cross-layer optimizer takes them as input. The optimizer considers the source distortion and the expected loss distortion. They use these things to figure out the expected user quality for every parameter set. Next the optimizer simply chooses the parameters with the highest expected user quality.

Following their explanation of the process of cross-layer optimization, the authors then cover their details of their simulation. They had three users streaming 3 different videos. The videos all had the same resolution (276x144) and the same frame rate (20 frames/s). Each GOP had 15 frames, which consisted of a leading I-frame and 14 P-frames.

The paper analyzes the performance gain of cross-layer optimization in two scenarios. One is where the optimizer uses PSNR, which includes rate distortion. The other is where the optimizer uses expected number of decodable frames (ENDEF), which does not include rate distortion. In all scenarios, cross-layer optimization with rate distortion had an increase in average PSNR over those without CLO.

Lastly, an analysis of the cost of CLD is performed. The CLA has three types of cost, which are that it performs substantial computation, it has communication overhead, and it is more difficult to manage. A main challenge of CLA is keeping the number of parameter sets small, so that there are less objective functions to calculate and compare. CLA may be less efficient with a larger number of users so the joining of users objective functions may be necessary. This may cause a suboptimal solution for some users.

Analysis

This paper could use some work on its structure. At the end of the introduction, the paper fails to give an outline of what is to come. Without an outline a reader does not know what to expect. Another structural critique I have is that figure 2 mentions Carphone, Foreman, and Mother-Daughter. However, the authors do not explain that those labels represent different videos until 2 pages after the figure is first referenced.

There are also some content related issues I have with this paper. They authors mention a way to measure the quality of a video called peak signal-to-noise ration (PSNR). Using this measurement, they create an objective function. They say that the objective function can be either the average video quality of the all users or

it could be the video quality of an individual user. For there experiments, they decided to use the average. However, they give no reasoning for why the use the average of the PSNR. Also, later in the paper the use the mean square error as the quality measure for cross-layer optimization. They do not mention why the used MSE over PSNR. They should have said why they chose one method over the other. Very thorough research in related work.

The paper does give a good contribution. The authors do a good job of convincing the reader that their research is useful. Mobile multimedia applications are definitely becoming more popular and networks are going to have to deal with providing this content to a lot of users. From their introduction, it is obvious that the authors have done a lot of research about related work. They know exactly what has been accomplished when it comes to CLD, and how their implementation is different. In their simulation, the implementation with cross-layer optimization outperformed the one without. Besides discussing the performance gains, the paper also gives an analysis of the cost of CLD. It does not seem like other papers take into account the negative effects of CLD. This paper provides an analysis of the costs as well as ways to improve CLD and make it less computationally expensive. One last thing I liked about the paper is how they refer to other papers for more information on a topic. Readers with little background knowledge may be confused by some of the topics. Providing references to papers for more information allows readers to easily get familiar with a complex concept.