Performance Optimization in Access Networks Using a Combined Control Strategy

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I. Introduction

The different applications used in the Internet become more and more complex, including very different capabilities for communicating such as content streaming or progressive download. However, from the users perspective the main interest has not changed. The user is interested in the content transported over the network, and simply wants a usable and smooth application. In this context, the terms Quality of Experience (QoE) gained a lot of attention in the last years.

In our previous work [1], we introduced *Aquarema* (Application and Quality of Experience Aware Resource Management) and showed that compared to approaches that are based on network information only, the use of application information which characterize the application-layer performance of a program significantly increases the possibilities to improve the QoE of the users. Therefore, we implemented an example use case of our concept in a wireless mesh testbed [2].

In this work, several additional control mechanisms have been implemented to widen the range of Resource Management (RM) actions. This demo gives an overview on these mechanisms by illustrating several example cases. Furthermore, we extend our implementation from YouTube videos to a variety of applications and services. Finally, the demo illustrates how different control mechanisms can be combined and used in parallel to further enhance the resource management.

In the following, we briefly introduce the concept of *Aquarema*. Afterwards, the testbed setup is explained including the implemented control actions and the extensions made to our previous work. In Section IV we provide an overview on the scenarios that are shown in the demo.

II. The Aquarema Concept

Aquarema [1] (**A**pplication and **Qu**ality of Experience **A**ware **Re**source **Ma**nagement) is a resource management framework, which uses application information to recognize a user's QoE degradation. The main components of *Aquarema* are depicted in Figure 1 and will be explained in the following. Further details bout *Aquarema* can be found in the original publication [1].

The framework consists of three different logical units, monitoring, control and the coordination between both. The monitoring part is covered by the *application monitor* and the *mesh monitor* which monitor the application or the network respectively. In case of the risk of a QoE degradation, a control or resource management action is initiated to adequately react on the current situation. The coordination which reaction should be done in which situation is done by the *mesh advisor*. It collects the monitoring information and if necessary, sends orders to the control units.

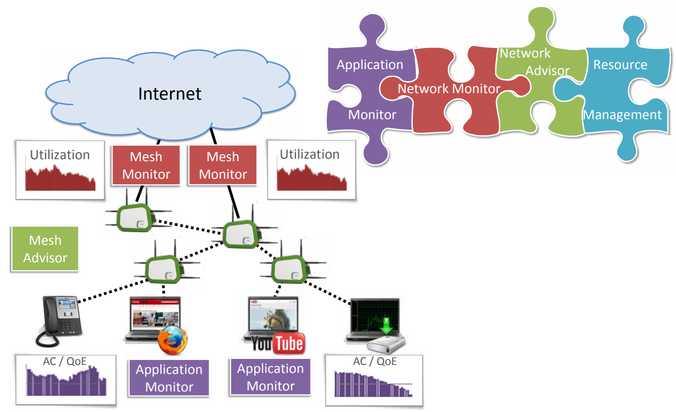


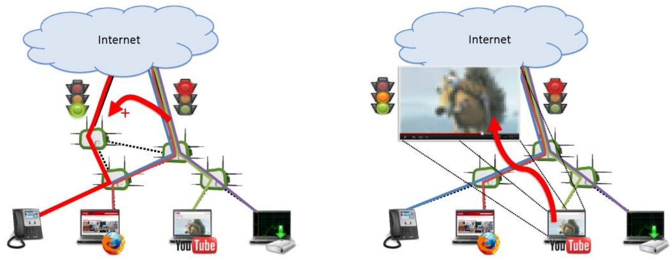
Fig. 1. The Aquarema concept.

III. Implementation of the Concept and Mechanisms

To prove and evaluate the concept of *Aquarema*, a Wireless Mesh Network (WMN) testbed has been setup and a basic implementation of *Aquarema* has been created: *AquareYoum* [2]. So far, the application considered in this implementation were YouTube videos where the current buffer state of the video was used as an indicator for the current QoE. For this demo, we extended our implementation to include web browsing and file downloading which users' QoE is estimated from the page load times and the download throughputs respectively. Furthermore, we added the support for Scalable Video Codec (SVC) videos, where the video frame rate and application layer packet loss can be used as an indicator for the QoE of the video. We implemented four different approaches to react on either application or network level, which are described in the following.

A. Gateway Selection (Network level)

For this approach, we assume that multiple gateways to the Internet exist in WMNs. The idea of Gateway Selection, illustrated in Figure 2(a), is to dynamically assign the clients to different gateways depending on the current load situation in the network. That way, it is possible to reach an application-aware load balancing that allows for a better overall QoE. This



(a) Gateway selection. (b) Video resolution change.

Fig. 2. Resource management tools.

RM mechanism can be applied to all kind of applications, i.e. video, web browsing and file downloading.

B. YouTube Video Resolution Change (Application Level)

In case of YouTube video streaming, another possibility to react on a possible QoE degradation is to change the resolution of the video. Depending on the video, YouTube currently offers 240p (i.e. 240 pixels vertical resolution), 360p, 480p, and even High-Definition (HD) videos with 720p, 1080p or ”Original” which means a resolution of up to 4096x3072 pixels (4K). Each playback video quality requires different download bandwidths and consequently, a change in the video quality results in a lower or respectively, higher download throughput of the YouTube video. This effect is exploited by the RM tool. If enough bandwidth is available, the video quality is changed to high quality. However, if the network is congested and a low buffer level of the YouTube video is monitored, a lower quality is suggested for the video to ensure a smooth video playback without stalling (i.e. interruptions), illustrated in Figure 2(b).

C. YouTube Buffer-Based Prioritization (Network Level)

If no control actions are taken, the flows currently running in the network compete against each others according to the normal TCP principles or just try to take all necessary bandwidth in case of UDP applications. This might result in some flows having sufficient capacities while others suffer from not having enough. However, this problem cannot be solved by normal load balancing as enough bandwidth is not necessarily an indicator for an acceptable QoE of a service. For instance, if considering two YouTube videos running in parallel, one 360p, one 480p, both videos might have equal bandwidth but only the smaller video is able to increase its buffer while the larger one can only keep the buffer at a steady level that might be very low. The same situation can appear, when a YouTube video and a file download share the same link. The idea of buffer-based prioritization is to take into account the current buffered playtime of each video and to always prioritize the videos whose buffer are below a certain threshold. That way, the risk of stalling due to small buffered playtimes can be significantly reduced.

D. SVC Video Quality Change (Application Level)

A video transmitted with SVC consists of several quality layers. Apart of a base layer, that ensures a minimal possibility to display the video, several enhancement layers exist. Each enhancement layer offers additional image information increasing the video quality, the frame rate or the resolution and thus the users' QoE. However, each of these layers is optional and can be left out. Based on this knowledge, the idea of this mechanism is analogous to the YouTube video resolution change. If there is enough bandwidth available, the number of transmitted enhancement layers is increased to provide a better quality. If there is not enough bandwidth anymore, the number of layers is reduced.

IV. SCENARIOS

In the demo, we show two scenarios to illustrate the different RM mechanisms as well as the combination of them. The scenarios are shown in our local Wireless Mesh Testbed in Würzburg. We examplify two different policies how the resources in an access network can be managed. The first policy is a QoE-oriented policy, the second one is called energy-efficient policy. In the following, we briefly explain both policies.

A. QoE-Oriented Policy

The aim of the QoE-oriented policy is to maximize the overall QoE in the network by using all available resources if necessary. Whenever, a new application is added, the RM mechanisms react on the new network situation. To maximize the overall QoE in the network, first all resources are utilized. Afterwards, if necessary the application quality is reduced. Thus, first, Gateway Selection and Buffer-Based Prioritization are used to distribute the services on all available gateways according to the application state. Only when all available resources are used and still not enough bandwidth is available to provide an acceptable QoE to all services, the quality of YouTube or SVC videos is decreased.

B. Energy-Efficient Policy

The idea of the energy-efficient policy is primarily to reduce the number of used resources, and to adapt the services in the network to these resources. This time, instead of activating additional resources in terms of gateways for the new applications, prioritization and the quality and resolution change mechanisms adapt the services to work on the already activated resources with acceptable quality. The policy tries to ensure the maximal possible quality to all services with a minimal number of used resources. Activating an additional gateway and switching services there is only the final option if all other RM mechanisms could not handle the situation anymore.

REFERENCES

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