Application-Aware Self-Optimization of Wireless Mesh Networks with AquareYoum and DES-SERT

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I. Introduction

During the last years, wireless mesh networks (WMNs) have become popular for offering simple and convenient Internet access possibilities beyond the reach of the wired backbone. WMNs achieve this larger geographical coverage by building a wireless multi-hop network connected to the wired backbone network. The client devices are thereby enabled to easily exchange data and access the Internet from anywhere in either the WMN or the wired backbone network. But the improved support for mobility and accessibility comes at the price of more complex topologies and thus considerable management and configuration effort for the developer.

Self-optimization describes the cooperation of autonomous resource management (RM) tasks or intelligent configuration algorithms network planning and optimization tasks. This is seen as a promising option for reducing the management effort in wireless networks in general [1], and is hence in particular interesting for WMNs. Commonly, self-optimization consists of three actions which are continuously repeated. The first action is the measurement of the network quality. This allows to monitor the network for unintended failures and incidental defects. Secondly, these measurement results allow to execute an adequate optimization action if necessary. Finally, external parameters are considered for making the network more effective. Normally, these parameters trigger a reconfiguration of a number of radio parameters or RM algorithms which however also depend on external network planning decisions or policies of the network provider.

One major challenge for any self-optimizing network is routing. This holds in particular for WMNs where the wireless medium introduces new issues that have to be addressed and demand for novel routing approaches. The *DES-SERT* framework [2] (DES - **S**imple and **E**xtensible **R**outing-Framework for **T**estbeds) was created to take on these issues and experiment with them in the *DES-Testbed* [3].

In this demonstration we show how the combination of the *DES-Testbed* using *DES-SERT* and the idea of using application-layer information for network management which is implemented by the *AquareYoum* [5] (**A**pplication and **Qu**ality of Experience **A**ware **Re**source Management for **You**Tube in Wireless **M**esh Networks) suite, can benefit from each other's functionality to further improve the overall self-optimization performance. In detail, the network status information provided by *DES-SERT* can be used by *AquareYoum* to better evaluate which parameters should be changed and which actions should be taken.

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II. The routing framework DES-SERT and AquareYoum

The *DES-SERT* framework permits the operating system independent implementation of proactive, reactive and hybrid routing protocols. In conjunction with the *DES-Testbed* it enables a fair comparison and evaluation of routing protocols for WMNs. For analysis, debugging and configuration purposes the *DES-SERT* daemon can be accessed via a command line interface (CLI) and SNMP. In this way, it can provide information like packet retransmissions, duplicate packets or routing tables to the experimenter. The selected link and routing metrics of the used routing protocol provide additional information which can be accessed via the CLI.

Aquarema [4] (**A**pplication and **Qu**ality of Experience **A**ware **Re**source **Ma**nagement) is an application-aware resource management framework. Its key idea is to utilize the *application comfort* (AC) which characterizes the application-layer performance of a program for a optimization actions. Monitoring the AC allows to react prior to a Quality of Experience (QoE) degradation and hence ensures the customer satisfaction. For this purpose, four components are interacting. The network-application interaction is assured by the *application monitor*, a light-weight tool installed at the client. It signals the presence of an application to the *mesh advisor* and constantly monitors the AC. In case of an imminent QoE degradation, the AC falls below a threshold. This is immediately reported to the mesh advisor. The mesh advisor evaluates this warning together with the information about the network status that it periodically receives from the *mesh monitor* tool and then decides about a network optimization action which is executed by an adequate *radio resource management tool*.

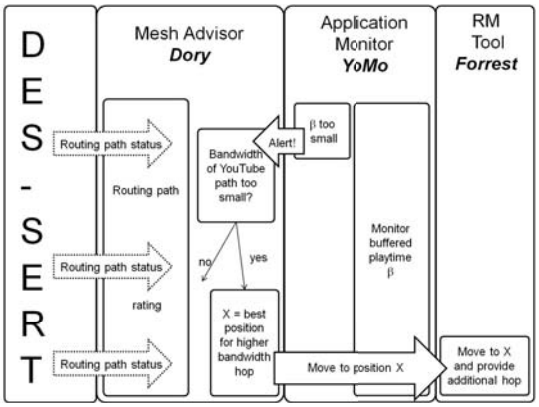

Fig. 1. Interaction of the components during the demo

AquareYoum [5] is an implementation of this idea for the case where WMNs are used as access networks for clients displaying YouTube videos. Together with an RM tool which is able to seamlessly move the YouTube flow from a congested gateway to a less loaded one, it has proved to greatly increase the customer satisfaction.

Thanks to the project G-Lab, *AquareYoum* and *DES-SERT*, originally designed independently, have been successfully combined. Firstly, we were able to prove the scalability of the *AquareYoum* concept by implementing it in the *DES-Testbed*. Secondly, the subsequently described demo will show that *AquareYoum* is an interesting option for triggering the manifold RM possibilities enabled by *DES-SERT*.

III. Demo Setup

Our demo intends to underline two facts. On the one hand, it will show that WMNs are a suitable means for flexibly complementing or replacing parts of a broken, destroyed or sabotaged wired Internet backbone. On the other hand, it will demonstrate that *AquareYoum* is useful beyond the access network domain for networks where self-optimizing algorithms are already running.

For this purpose, we use one client laptop, located in Würzburg and displaying a YouTube video. It is connected to the G-Lab experimental facility which allows to communicate with the *DES-Testbed*. The *DES-Testbed* in turn assures the link to the wired Internet and acts as an interconnection between the two fixed infrastructure components.

The course of interaction of the components is shown in Figure 1. The mesh advisor *Dory* queries the *DES-SERT* routing daemon for information about the state of the network. The application monitor tool *YoMo* monitors the YouTube AC which is defined as the amount of playtime β the YouTube player has prebuffered. The RM tool *Dory* is able to trigger is the robot *Forrest* which carries a mesh node on its back. If advised so, it will move to a nonfunctional part of the network and is consequently able to compensate for node failures.

The demonstration of a successful interaction of *AquareYoum* and *DES-SERT* consists of 7 steps:

1) A node failure happens. This might have manifold causes, e.g. an electrical failure or blackout or a mechanical manipulation (intentional or unintentional).
2) The routing protocol implemented in *DES-SERT* recognizes the broken route and replaces it with another one provided by some other mesh nodes.
3) While the new route does guarantee a successful packet delivery, it does not offer enough bandwidth for the YouTube video. As a result, β falls below the critical threshold and *YoMo* sends an alarm message to *Dory*.
4) By evaluating the information from *DES-SERT*, *Dory* knows that the bandwidth of the path that the YouTube video currently takes is not sufficient and that no better path exists. As a consequence, it triggers *Forrest* to move to the location of the nonfunctional mesh node.
5) *Forrest* moves to the location defined by *Dory*.
6) The routing protocol recognizes the new and better route and moves the YouTube flow to this path.
7) As a result the AC of the YouTube video increases again and the video playback continues without stalling.

IV. Conclusion and Outlook

The demo shows how two tools, originally designed for different tasks in the scope of WMNs, can be combined to maintain the QoE despite of changing topologies within the WMN. This cooperation of remote partners was facilitated by the G-Lab experimental facility. Beyond this, the successful cooperation of *AquareYoum* and *DES-SERT* shows that the *Aquarema* concept and its core idea, the cross-layer resource management enabled by application comfort monitoring, are useful concepts beyond the scope of access networks.

The *DES-SERT* framework in turn allows the evaluation of routing protocols in WMNs for varying requirements. It enables the easy implementation of several WMN routing protocols, thereby allowing an autonomous and resilient network operation. If, however, the information provided by *DES-MON* is used as an input for *AquareYoum*, a more holistic view on the network allows to trigger an increase of the network resources if the application demands are not satisfied. Future works will be dedicated to supporting more applications, introducing more application layer metrics, and triggering more resource management actions.

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