SDN-based transparent flow scheduling for heterogeneous wireless LANs

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Abstract—The current local area networks (LANs) are occupied by a large variety of heterogeneous consumer devices, equipped with the ability to connect to the Internet using a variety of different network technologies (e.g., Ethernet, 2.4 and 5GHz Wi-Fi). Nevertheless, devices generally opt to statically connect using a single technology, based on predefined priorities. This static behaviour does not allow the network to unlock its full potential, which becomes increasingly more important as the requirements of services, in terms of latency and throughput, grow. In this paper we present a real-life SDN-based implementation of our previously proposed algorithm that addresses this problem.

I. INTRODUCTION

Today's local area networks (LANs) consist of a plethora of heterogeneous consumer devices, equipped with the ability to connect to the Internet using a variety of different network technologies (e.g., Ethernet, Power-Line, 2.4 GHz and 5 GHz Wi-Fi). Over the next few years, the diversity among devices and technologies is expected to expand further with, for instance, the rise of all kinds of (possibly mission critical) Internet of Things (IoT) devices and multimedia services, as well as the availability of new technologies such as sub-1GHz Wi-Fi (i.e., 802.11ah), 60 GHz Wi-Fi (i.e., 802.11ad) and visible light communications (e.g., Li-Fi). These, mostly wireless, devices and applications have stringent and diverse quality requirements (e.g., low power consumption for sensors or high throughput for 3D video applications) and are very sensitive to network disruptions and degradations (e.g., high latency, congestion or link failures). On the other hand, every network technology has specific characteristics in terms of, among others, maximum throughput, latency, interference and range. An example of such a heterogeneous LAN is shown in Figure 1.

Current LANs are generally managed in a static way, making it impossible to automatically react in a timely fashion to temporary disruptions that cause Quality of Service (QoS) degradations. Furthermore, although being equipped with multiple network interfaces (e.g., tablets and smartphones with 2.4 GHz and 5 GHz Wi-Fi), devices will generally statically select one of the available technologies based on predefined priorities (e.g., 5 GHz Wi-Fi if available, otherwise 2.4 GHz Wi-Fi). In some cases, the user can manually override these priorities, but this is not user friendly, as it is not done in a transparent manner. The abstraction from network connectivity is a key aspect in terms of user friendliness and Quality of Experience (QoE). Furthermore, making network interface
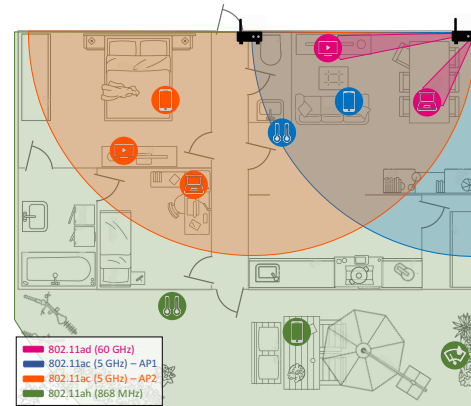

Fig. 1: Example of a future heterogeneous LAN

selection automatic and dynamic would enable optimizations such as multipath routing, load balancing and dynamic path reconfiguration, aiding to unlock the network's full potential. The efficiency of such a dynamic approach will only increase as more and more technologies are introduced to home networks and other LAN environments, such as the previously mentioned sub-1 GHz and visible light communications.

To solve this problem, we previously proposed a transparent load balancing and routing algorithm for LANs [1]. This algorithm aims to discover a global optimal scheduling configuration for all the flows in the network, in order to achieve maximum global throughput based only on real-time monitoring information, allowing it to react to dynamic network changes. In this paper, we present a prototype implementation of the proposed algorithm. The functionality of the algorithm is shown through video stream traffic that needs to achieve its desired rate while background traffic, of varying intensity, coexists in the same network.

II. FLOW SCHEDULING IN HETEROGENEOUS LANS

The LAN flow scheduling problem is modelled as a mixed integer linear program (MILP) formulation [1]. The desired rates of the flows are estimated based on real-time monitoring information which is gathered by a monitoring framework. This is in strong contrast with existing theoretical models (e.g., [2], [3]) that assume detailed instantaneous knowledge of flow throughput requirements and dynamic network conditions. Furthermore, the specific nature of wireless networks
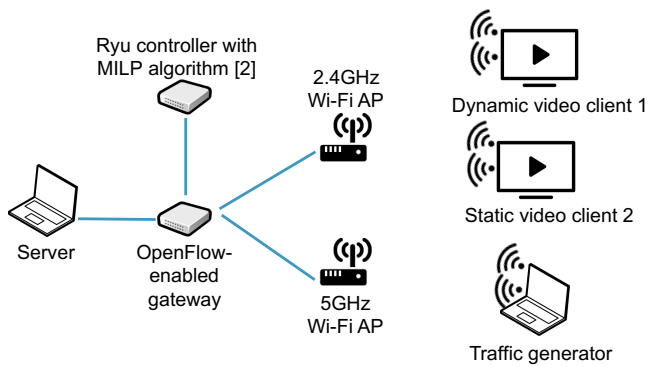
Fig. 2: Architecture of the demo setup

Fig. 3: Impression of the current lab-setup with Ethernet and 2.4 GHz Wi-Fi

is taken into account, where users do not have dedicated network resources but a shared medium instead. Additionally, the algorithm estimates, through additional constraints, the rate that TCP would assign to a flow based on its chosen path as well as that of other flows, and uses that information to find the optimal path for each flow within the fairness rules imposed by TCP.

III. DEMO SETUP

Figure 2 shows the different components of the demo setup and how they are interconnected. At the right-hand side of the figure there are two video clients (e.g., tablets or laptops) that receive a video stream from the server. These clients have both a 2.4 GHz and 5 GHz Wi-Fi interface and will by default be connected to the 5 GHz network. One of the clients will be used as a static baseline for comparison. Besides these two clients, there is also a traffic generator that will be capable of producing background traffic on both frequencies. The server is connected, through an OpenFlow-enabled gateway, with two access points (APs) -one per frequency band- or to one dual band AP. In order to manage and control the network we have opted for a software defined networking (SDN) approach [4].

In particular, our solution relies on the OpenFlow[1] (OF) communication protocol to access and control the gateway in the center of our setup. On this gateway we have installed Open vSwitch[2] (OVS), a virtual multilayer switch that is controllable by the OF protocol. The installment of an OVS allows us to perform transparent handovers between the different available technologies, in this case 2.4 GHz and 5 GHz Wi-Fi, when such a handover is initiated by the OF controller. Note that other technologies can be easily integrated in this setup, when supporting hardware becomes available. For the SDN controller we have opted for the Ryu implementation[3] since it is open source and is actively being developed.

The Ryu controller has two main responsibilities: first of all, gather monitoring information in real-time from the OVS in order to identify the different data flows in the network and their requirements in terms of bandwidth. This is done by the transmission of an OF flow stats request to the OVS that will

reply with a message containing the counter values (i.e. bytes and packets) per (OF) flow. Similarly, information about the different links (through port stat request and reply messages) can be gathered. The Ryu controller will filter out the data flows from the control traffic in the received statistics and pass this information to our algorithm. The algorithm relies on the Gurobi Solver[4] to calculate the optimal solution for the MILP formulation [1]. After the calculations of the optimal setup, the controller will initiate a handover by sending an OF flow modification message to the OVS. A GUI will be provided to show in real-time the measured rates of the video and background streams and to allow to manually add and remove background traffic. An impression of the current lab-setup of the demo (with Ethernet instead of 5 GHz Wi-Fi) can be seen in Figure 3 with at the left side the video being played and at the right side the SDN setup.

The following scenario allows us to demonstrate the dynamic flow scheduling: first, the two video clients are subsequently started and gradually more and more background traffic streams on 5 GHz are introduced. This will be detected by the controller and the algorithm will relocate certain flows to avoid congestion. After the handover process and improvements in video QoE are demonstrated, background traffic is reduced to allow the system to converge to its original state. Afterwards participants can experiment with the system themselves. They can use the user interface to introduce background traffic on either of the two Wi-Fi bands, manually force a handover (with a button), and turn automated band steering on or off for either of the clients.

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