A Slicing Algorithm with Initial Quantum for SDN

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***Abstract*—A network slicing approach is able to divide a shared physical network infrastructure into multiple autonomous logical parts designed to meet specific network requirement. This concept is applied in wireless networks by sharing transmission time. Due to the dynamic nature of wireless channels, the initial quantum allocation of the airtime is particularly challenging. In this paper, we propose a network slicing algorithm that considers the initial quantum to be allocated to each slice at the instant of its creation, and dynamically adjusts the quantum according to the demands of the services in the network.**

***Index Terms*—Flexible networks, SDN, Wi-Fi, slicing, airtime, initial quantum.**

I. Introduction

The concept of network slicing was introduced as a new approach to divide a shared physical network infrastructure into multiple autonomous logical parts, called *slices*, whereas each is designed to meet specific network requirements [1].

In the context of network slicing for flexible wireless networks, *airtime* is the crucial resource that needs to be effectively shared. Sharing airtime involves equitably distribute the transmission time by assigning a fraction of airtime, i.e., *quantum*, to each slice. Such approach enables the efficient management of transmissions between the various network entities (users, access points, services, etc.), ensuring a proper resource utilization and minimizing interference among them.

In wireless networks, the initial quantum allocation of resources is particularly challenging due to the dynamic nature of wireless channels and, as far as we know, there is no state-of-the-art in this regard. To address this problem, advanced, programmable monitoring functions capable of providing detailed information about the network behavior are necessary.

By the use of Software Define Network (SDN) techniques, where the control plane is separate from the data plane, and applying In-Band Network Telemetry (INT) techniques [2] to monitor network traffic, it is possible to dynamically instantiate, modify, and terminate network slices. This approach enables a more effective and efficient management of network slices based on real-time network conditions.

That said, our contribution resides in the proposition and first evaluation of a slicing algorithm considering the initial quantum and, by applying INT monitoring techniques, adjusts the quantum of each slice depending on the network conditions. The rest of the paper is outlined as follows. Section II briefly discusses our SDN controller, namely the monitoring solution. Section III presents the slicing algorithm. Section IV presents the emulate scenario where the evaluation was performed. Section V has the initial results. And, finally, in Section VI the main conclusions and future works are enumerated.

II. Network Monitoring

Our SDN controller illustrated in fig. 1 integrates INT techniques. Using Internet Protocol (IP)v4 for the control plane and IPv6 for data plane, we are able to append telemetry information on the IPv6 data packets [2].

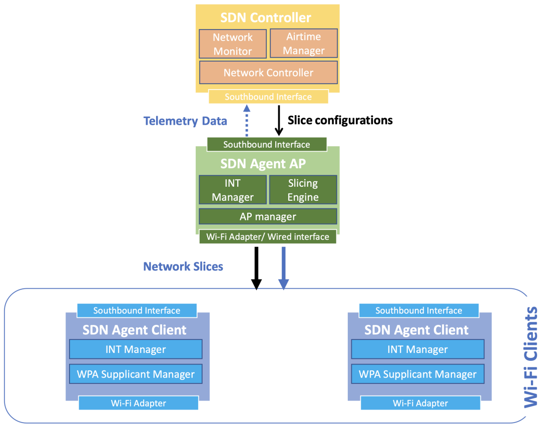

Fig. 1. SDN controller's architecture.

To transmit a package, the source node adds to the data packet the initial INT encapsulation header as well as INT header itself. When packets are sent over-the-air from source to destination nodes, our Quality of Service (QoS) monitor calculates per-flow/per-hop statistics based on timestamps and packet counters. Then a report is generated by the destination node and it is forwarded to the SDN controller, which calculates various Key Performance Indicators (KPIs), such as jitter, delay, and throughput in real-time.

This enables the real-time network monitoring and the application/adjustment of slices' configuration according to the requirements of different services. Thanks to this, depending on the QoS required for each type of service, we can dynamically configure network slices based on airtime, by allocating a quantum to each slice. In this domain, the initial quantum allocation is also important as it determines the resources available to the slice at the beginning of its operation, and may significantly affect the slice's performance and quality of service.

III. Slicing Algorithm

As previously mentioned, the initial allocation of resources in wireless networks is a significant challenge due to the need of constant adaptation (nature of wireless channels) [3]. In addition, the number of active users and their traffic demands can fluctuate rapidly, making it *impossible* to allocate resources in advance. To address these challenges, we developed an algorithm that takes into account the assigns an initial resource allocation and adjusts it dynamically according to the network's requirements. This approach ensures that the resources are allocated efficiently and effectively, meeting the demands of the network and optimizing its performance.

As mentioned in section II, from network monitoring, we obtain crucial information such as throughput, jitter, delay, and packet size. Using this available data, we are able to calculate the required transmission time (1) for each packet, as:

$$\text{TimeTransmission} = \frac{\text{PacketSize}}{\text{Throughput}} + \text{Delay} + \text{Jitter} \tag{1}$$

Considering the total airtime as:

$$\text{Airtime} = \sum_{i=\text{packets}}^{0} \text{TimeTransmission}_i \tag{2}$$

which is the sum of packets transmitted by different services operating in the network. From (2) we can get the amount of each initial quantum for every slice in the wireless network as:

$$\text{InitialQuantum}_s = Q \times \text{Airtime} \tag{3}$$

where $Q \in \{0, \ldots, 1\}$ indicates the amount of airtime to allocate to a specific slice of the network and s indicates the slice. After the slice is created, the initial quantum is converted to a quantum, since it is the amount of airtime required for each slice to satisfy the demanded QoS. So a control loop is running to monitor the network continuously and make decisions on extending or reducing the quantum to adapt dynamically the network.

To ensure isolation between different network slices, which is one of the main challenges of network slicing, we set a minimum quantum time for each slice based on the specific requirements and Service Level Agreements (SLAs) for each network slice. In practice, the minimum quantum value can vary depending on the slice's requirements and the network conditions.

IV. Emulation Scenario

In order to test the previous proposed algorithm, we used a Docker-based scenario that emulates a real one, consisting of two users (clients) and an Access Point (AP), showed in fig. 2, with intermediate elements to also emulate link adaptation problems and noise.

For the creation of network slices and the dynamic quantum adaptation based on the traffic conditions of each slice, we used Differentiated Services Code Point (DSCP). When a packet is transmitted over the network, the DSCP value is examined and the packet is classified and prioritized according to its value. For that, we created two types of slices in downlink: Quality of Service Slice (QoSS) and Best Effort (BE).

QoSS is a type of slice that provides specific QoS guarantees to the applications running on it, so it may provide guarantees for parameters such as bandwidth, latency, jitter, and packet loss as, e.g., Voice over IP (VoIP) application and video conferencing. BE slice is intended to handle traffic that does not require any special treatment. This type of slice is typically used for non-critical applications or for applications that can tolerate variable network performance as, e.g., file transfer.

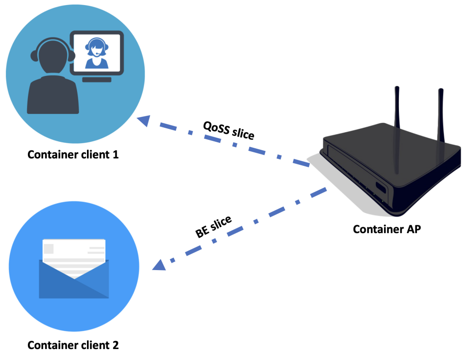

Fig. 2. Docker-based scenario.

V. Results

In fig. 3, we can observe the behavior of the network over time, which is represented by the timestamp value extracted from the header of IPv6 packets. The increasing trend of the QoS type of traffic and the constant linear trend of the BE type of traffic suggest that the QoSS is being allocated with more resources (airtime) than the BE slice, that is also why the QoSS has clearly a higher throughput.

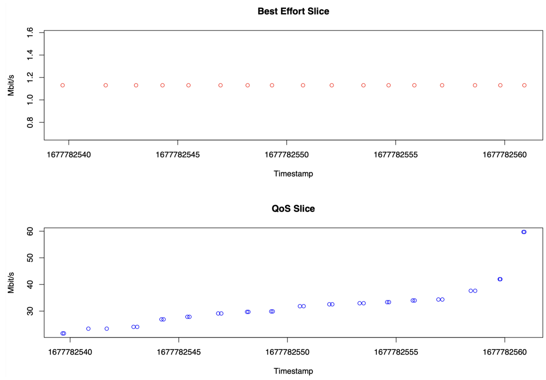

Fig. 3. QoS and BE slices.

VI. Conclusions

In this paper, we presented and evaluated a comprehensive approach towards the network slicing, taking into consideration not only the dynamic behavior of the wireless networks, but also the initial quantum of each slice. As a first tentative, the proposed approach was implemented on top of a Docker-based scenario, and the results clearly suggests that the slicing algorithm is being properly applied.

As future work, we foresee the implementation in a real scenario and have more than two slices.

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