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Quality of Service Management in Wireless Local Area Network: Survey and Discussions

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Abstract- *Few years have witnessed a significant increase in the use of portable computing devices such as smart phones, tablets and laptops. The popularity of these devices and the emergence of a range of innovative mobile applications and online services are driving the demand for more reliable wireless communication connectivity. Despite the maturity of mobile radio technologies such as 3G and 4G, Wi-Fi still represents a cheaper, faster, and more reliable communication alternative for many wireless users. Fast advance in the design of 5G cellular networks has motivated many research works in the recent years. The main research challenges are given by the explosive growth of traffic burden, the rise of energy consumption constraints, the unprecedentedly high demand for broadband mobile connectivity and Quality of Service (QoS). Therefore the appearance of new technologies and system designs is vital to bear such high demand in networks infrastructures, In this work present the review for IEEE 802.11 wireless local area networks and their importance in wireless communication.*

Keywords:- Wireless communication, IEEE 802.11, Fifth generation, Mobile communication.

Introduction

Today's devices, such as phones, wireless access points (APs), sensors, and other machines, are often equipped with multiple networking technologies to enable them always to stay connected. This connectivity allows users to use a plethora of Internet and other services through technologies like Digital Subscriber Line (DSL), Long-Term Evolution (LTE), or IEEE 802.11 with even more technologies in the future such as IEEE 802.11ax/ay or 5G solutions [4]. We expect this trend to continue, with a further increase in available technologies. From this follow two scenarios: (i) technologies cover similar scenarios but do not share spectrum, such as LTE and IEEE 802.11 bring Internet access to users, (ii) technologies cover different scenarios but share the spectrum, such as IEEE 802.11 and Bluetooth. Currently, technologies are isolated, and applications or the operating system takes care of technology selection. This isolation leads to inefficient use of each technology; for example, one technology is congested while another has plenty of free resources. To truly achieve the high bandwidth and low latency requirements of today's services, orchestration across technologies needs to be in place. Only a holistic approach allows optimizing the performance of services in these heterogeneous networks.

The exponential growth of wireless data services towards the fifth generation (5G) has triggered the huge number of low power nodes such as WiFi and small cells, widely deployed in enterprise and other public places to provide ubiquitous access for mobile users with simultaneous active connections to more than one base station or access point [2], which is explored to support high throughput and seamless mobility in 5G networks. Contrasting to the increasing new requirements from users for WiFi networks, e.g., mobility, high bandwidth and customized service support, the management and operation of today's local wireless access networks is often very inflexible, and ignores the specific demands from numerous applications.

Moreover, WiFi and other wireless access networks are often deployed in their own infrastructures and organized uncoordinated, neighboring access points cannot be leveraged to reduce transmission delays and improve user mobility, not to mention exploiting the power of multiple access points to improve network throughput. Over the years, we have witnessed a tremendous increase in the utilization and availability of wireless networks and devices. The number of connected devices has reached 18 billion in 2017 and will further grow to 28.5 billion in 2022. Similarly, the heterogeneity and complexity of (wireless) networks are increasing as new technologies (e.g. IEEE 802.11ay and 802.11ax) are being released. As a consequence, the management burden increases as each of these wireless communication technology has its own unique characteristics (e.g., capacity and range). Furthermore, these networks are typically being managed statically as, for instance, no centralized intelligence is present and connections are being established based on default priorities (e.g., connecting to the closest infrastructure device by default). This makes them unable to automatically react in a timely fashion to temporary disruptions that cause Quality of Service (QoS) degradations [5]. More importantly, the traffic within these networks is characterized by heterogeneous Quality of Service (QoS) demands and different transmission rates, as each wireless user might be running a different application. Moreover, these demands are increasing over time as more bandwidth-hungry services are introduced. However, since the Wi-Fi spectrum is a finite resource, a significant increase in the wireless traffic will ultimately result in congestion within the network, affecting the overall quality of coverage, and reducing the overall performance.

Software-defined network (SDN) is an interesting innovative paradigm for programmable network by decoupling the control plane and data plane of networks. This dramatically simplifies network control and enables innovation and evolution by abstracting the control functions of the network into a logically centralized control plane. Moreover, the concept of network function virtualization (NFV), effectively separates the abstraction of functionalities from the network hardware and substrate. By extending SDN to mobile and wireless networks, it leads to a new trend, i.e, software-defined wireless network (SDWN). With the functionality abstraction from hardware and the logically centralized control, SDWN can address the challenges of wireless network, and improve the efficiency on multiple wireless access networks. Recently, the SDWN concept is realized in wireless access networks and cellular networks through different approaches.

As both modern connected devices and wireless networks are equipped with multiple communication technologies, efforts have been made to allow devices to simultaneously use different communication technologies or to switch in real-time between them. This dynamic network and traffic management allows for network optimizations such as multipath routing, load balancing, and dynamic path reconfiguration. This stands in stark contrast to traditional approaches that typically delegate this to the application layer, or even worse, to the user. The most important dynamic multi-technology frameworks and standards that have been proposed are IEEE 1905.1, Multipath Transmission Control Protocol (MPTCP), LTE Wireless Local Area Network Aggregation (LWA), and ORCHESTRA.

In order to increase the QoS within these networks, support future technologies and account for rising traffic demands or user expectations, intelligent management approaches are needed. In the previous section, we have listed different solutions that enable network features such as inter-technology handovers or load balancing, needed to perform the necessary optimizations in the wireless networks. The coordination among all the devices in the network and the use of real-time monitoring information are essential to account for the ever-changing wireless context. Recently, the Software-Defined Networking (SDN) paradigm has found its way to these wireless networks to facilitate, among others, station mobility.

II. Related Work

Current interference management solutions for dense IEEE 802.11Wireless Local Area Networks (WLANs) rely on locally measuring the cumulative interference at the Access Point (AP) in charge of adjusting the spectrum resources to its clients. These solutions often result in coarse-grained spectrum allocation that often leaves many wireless users unsatisfied and increases the spectrum congestion problem instead of easing it. In this paper [1] we present a centralized interference management algorithm that treats the network-wide interference impact of each channel individually and allows the controller to adjust the radio resource of each AP while it is utilized. This coordinated allocation takes into account the Quality of Service (QoS) requirements of downlink flows while minimizing its effect on neighbouring APs. Therefore, this paper proposes a novel approach for quantifying the interference impact of each employed channel and jointly addressing the user-side quality requirements and the network-side interference management. The algorithm is tailored for operator-agnostic Software-Defined Networking (SDN)-based Radio Resource Management (RRM) in dense Wireless Fidelity (Wi-Fi) networks and adopts a fine-grained per-flow approach.

The inflexible management and operation of today's wireless access networks cannot meet the increasingly growing specific requirements, such as high mobility and throughput, service differentiation, and high-level programmability. In this paper [2], they put forward a novel multipath-transmission supported software-defined wireless network architecture (MP-SDWN), with the aim of achieving seamless handover, throughput enhancement, and flow-level wireless transmission control as well as programmable interfaces. In particular, this research addresses the following issues: 1) for high mobility and throughput, multi-connection virtual access point is proposed to enable multiple transmission paths simultaneously over a set of access points for users and 2) wireless flow transmission rules and programmable interfaces are implemented into mac80211 subsystem to enable service differentiation and flow-level wireless transmission control.

To ensure high performance for vehicular access networks, Software Defined Networking (SDN) technology is an efficient solution offering programmability, flexibility and a centralized view of the network. Nevertheless, to guarantee an efficient mobility management, some improvements are needed. In particular, a limitation on the number of exchanges between SDN controller and network devices and a better flow tables' management are required. To achieve that, the ideas of flow rules' pre-deployment and mobility-aware management of flow rules' lifetime have been proposed. However, existing approaches have two major limitations: accuracy and adaptability. Indeed, network load (accuracy) and network devices' feedbacks (adaptability) are not considered, two factors impacting flow rules management. That is why, in this paper, [3] they define a state-based approach using connection/disconnection information reported by network devices to improve adaptability. Moreover, they propose a mobility-aware and load-aware flow rules management to improve accuracy. Finally, they specify a new flow rules' pre-deployment policy based on flow tables occupancy rate, vehicles mobility and SDN control channel load.

Wireless devices have a plethora of technologies at their disposal to connect to the Internet and other services. Management and control of each technology are traditionally isolated, and coordination between technologies is nearly nonexistent. This isolation leads to poor resource usage, which in turn reduces performance and service guarantees. To satisfy growing user demands, we need to leverage the different service guarantees offered by each technology. Additionally, we need to improve orchestration between technologies to increase performance and flexibility while offering a more extensive range of service guarantees and maximizing resource utilization across networks and users. In this work, [4] they present the general challenges one encounters when managing heterogeneous wireless networks. They argue that the primary challenge is the heterogeneity itself, the number of different devices and technologies, the different service requirements, and the increasing complexity as a consequence. However, technology abstraction can overcome these challenges. They provide an overview of state of the art commercial and scientific solutions and show their strengths and weaknesses. Based on this, we discuss the current status and what future challenges still await to provide full seamless heterogeneous wireless network management.

The number of connected devices has reached 18 billion in 2017 and this will nearly double by 2022, while also new wireless communication technologies become available. Since these modern devices support the use of multiple communication technologies, efforts have been made to enable simultaneous usage and handovers between the different technologies for these devices. However, existing solutions are missing the intelligence to decide on fine-grained (e.g. flow or packet level) optimizations that can drastically enhance the network's performance (e.g., throughput) and user experience. To this extent, they [5] present a multi-technology flow-management load balancing approach for heterogeneous wireless networks that dynamically re-routes traffic through heterogeneous networks, in order to maximize the global throughput. This dynamic approach can be deployed on top of existing solutions and takes into account the specific characteristics of the different technologies, as well as station mobility.

Device-to-Device (D2D) communication allows for users placed in a cell to establish direct connections with each other using several connection modes. In this paper, they [6] propose Multi-Path D2D (MPD2D), a mathematical optimization framework that accounts for the availability of D2D modes under the requirements dictated by a process of flow requests. MPD2D selects the combination of cellular and D2D links that boosts network performance as much as possible. They consider Underlay and Overlay as in-band D2D modes reusing cellular frequencies with scheduled resources and the out-band D2D mode exploiting WLAN frequencies and the 802.11 random access scheme to complement cellular resources. They model throughput, energy consumption, interference, and per-flow network requirements, so to define a network utility function that accounts for throughput and power efficiency. Moreover, they formulate a user satisfaction metric that accounts for the history of users within the cell. Integrating such a metric in a throughput optimization problem is lightweight yet very effective to drive towards almost complete fairness.

Dense Small Cell networks are considered the most effective way to cope with the exponential increase in mobile traffic demand expected for the upcoming years and are one of the foundations of the future 5G. However, novel architectures are required to enable cost-efficient deployments of very dense outdoor Small Cell networks, complementing the coverage layer provided by macro-cells. In this regard, two important challenges need to be solved to make this vision a reality: i) increased traffic dynamics, which are translated into more frequent handovers, and ii) cost-efficient deployment of large number of Small Cells. In this paper, they [7] propose and evaluate SENSEFUL, an novel architecture addressing the two problems highlighted above: Software-Defined Networking (SDN) as the key technology to promote adaptability to a varying environment and provide efficient mobility solutions in the dense access layer, and novel wireless backhauling technologies where traditional wired connectivity does not meet cost/efficiency restrictions. The use of directional antennas in millimeter-wave communication promises high spatial reuse at multi-gigabit-per-second data rates in dense wireless networks. Existing work studies such networks using commercial hardware but is limited to individual links. Moreover, such hardware typically allows for little or no control of the lower layers of the protocol stack. In this paper, they [9] study the performance of dense millimeter wave deployments featuring up to eight stations. To this end, they use a practical IEEE 802.11ad millimeter-wave test bed that allows access to the lower layer parameters of each station. This enables us to analyze the impact of these parameters on upper layer performance. they study, for first time to our best knowledge, issues such as the impact of channel contention on the buffer size at the transport layer, the effect of frame aggregation, and the efficiency of spatial sharing. Their results show that using large buffer sizes with TCP is harmful due to channel contention despite the multi-gigabit-per-second data rates.

III. IEEE 802.11

In general, the IEEE 802.11 architecture consists of basic service set (BSS) which is a collection of stations that communicate among themselves. The architecture can be classified into three operating modes as illustrated in Below figure (a). The first operating mode is the independent basic service set (IBSS), shown in Figure-1(a). In the IBSS mode, stations are communicating with each other without any connection to an external network (i.e. access point) and creates an ad hoc network. It has a short lifespan and only serves a specific purpose such as exchanging or sharing files. Hence, in a real-world WLAN deployment, the second operating mode which is an infrastructure BSS (referred to as BSS throughout this thesis) is more preferable to an ad hoc type of network. BSS allows a station to communicate with any other stations irrespective of their location and distance. Below figure (b) illustrates the architecture of a BSS that includes the presence of a single access point(AP) , which provides connectivity to a wired network and eventually to the internet. Practically, the AP relays the received frames from the source stations to the intended destination within its serving BSS. Therefore, all stations must communicate through the AP though the destination station is in the same BSS. Prior to initiating a transmission, a station must be associated with the AP by exchanging important information such as radio synchronization and supported data rates. Finally, the third operating mode defined in the IEEE 802.11 standard is an extended service set (ESS). Below figure (c) demonstrates the architecture of ESS which comprises a set of two or more BSSs that form a single sub network. ESS architecture extends the network coverage by allowing internetworking among APs in the joint BSSs via a wired local area network to forward traffic and facilitate movement of stations. It is commonly deployed in large public or corporate places such as university campuses, corporations, airports or shopping malls [8].

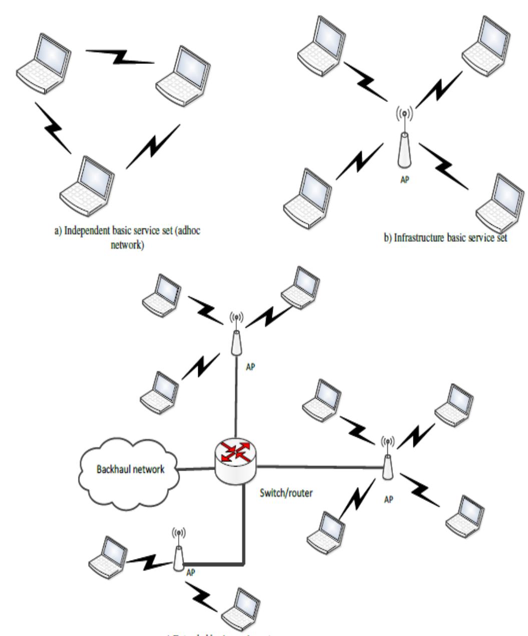

Fig 1: IEEE 802.11 LAN architecture [8].

IV. Conclusion

The popularity of Wi-Fi technology has also made its way into the work place and public spaces such as airports, train stations, and university campuses. Large scale Wi-Fi networks are built by deploying Radio Frequency (RF) overlapping Wi-Fi Access Points (APs), in order to guarantee good signal coverage and redundant connectivity to the user. These modern enterprise Wi-Fi networks are managed by IT officers who are constantly facing the challenge of satisfying the increasing demand of their network users for more capacity and better connectivity. Unlike wired networks, where the size of the network is fixed and the amount of traffic can be predicted, enterprise Wi-Fi networks are very dynamic as wireless users can join and leave at any moment. More importantly, the traffic within these networks is characterized by heterogeneous Quality of Service (QoS) demands and different transmission rates, as each wireless user might be running a different application.

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