Emerging Network Technologies and Network Neutrality Conformance

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Abstract:

The Network Neutrality principle states that, in order to preserve the openness of the Internet, Internet Service Providers (ISP) should be prohibited from blocking or differentiating between content from different application providers, and the end users should have equal access to all legal content on the Internet. The Network Neutrality issue is critical as it can have a considerable impact on the future Internet design principles and associated laws and policies. In this paper, we discuss some of the challenges in monitoring Network Neutrality conformance, focusing on the content provider discrimination. In addition we discuss the emerging network technologies such as Giga-LTE, LTE in Unlicensed spectrum (LTE-U) or Licensed Assisted Access (LAA), LTE Broadcast, LTE Wi-Fi Aggregation (LWA), MulteFire, etc., and discuss how they may affect Network Neutrality.

Index Terms: **Network Neutrality, Carrier Aggregation, Disruptive Technologies, Giga-LTE, LTE-U, LWA, LWIP.**

I. INTRODUCTION

THE principles of Network Neutrality are aimed at providing equal access to all content and applications available on the Internet, thereby prohibiting the ISPs from blocking or differentiating between different types of traffic based on its source or ownership [1]. In the absence of Network Neutrality, the ISPs can block or throttle the content from some providers over others. In addition, they can slow down certain types of traffic, such as peer-to-peer traffic, or over-the-top content to monetize their own services or as a traffic management tool. In addition, the big players such as Google, Facebook, etc. can pay more money to the ISPs for a more reliable and faster access to their content, as compared to other content providers.

The opponents of Network Neutrality, consisting mainly of the ISPs, argue that differential pricing and Quality of Service (QoS) is essential for network management and obtaining the revenue for investing in network infrastructure. In addition, they assert that the principle or no blocking and no throttling can lead to increased security threats in the network. On the other hand, the proponents, consisting mainly of content providers and users, allege that Network Neutrality is essential for preserving the essence of the Internet i.e. openness, non-discrimination, user-democracy, promote innovation, and provide low cost access to the content available on the Internet [2].

Hence, to overcome the threats imposed by the non-neutral traffic management strategies adopted by various ISPs [3], the government authorities in different parts of the world are now in the process of regulating Network Neutrality by law. For example, the open-internet rules by the Federal Communications Commission (FCC) of Unites States state that there should be no blocking of legal applications, content or services, and, no blocking, throttling, or preferential treatment of one set of traffic over other [4]. However those rules are presently being reversed by the present US administration.

At present, a lot of work has been done, focusing on framing the laws and regulations of Network Neutrality [5], [6]. From the network point of view, the research on Network Neutrality has primarily been focused on how different network management practices can lead to violation of network neutrality. In addition, the impact of disruptive technologies as zero-rating, multi-bit rate streaming, Over the Top (OTT) applications, etc. on Network Neutrality have also been discussed widely [7]. Global mobile data traffic is growing at an alarming rate, and is expected to increase seven-fold from 7.2 Exabytes per month in 2016 to 49.0 Exabytes per month in 2021 [8]. A number of solutions such as acquiring new spectrum, offloading data to Wi-Fi, Femtocells, etc.,have been proposed to manage the ever-increasing data traffic. However, as the traffic is growing at a very high compound average growth rate, these solutions are no longer sufficient. As a result, a number of emerging network technologies, such as Giga-LTE, LTE-U, LTE-Broadcast, etc, and other carrier-aggregation schemes are being deployed by network operators to manage the rapid increase in mobile data traffic. Most of these techniques are based on the use of unlicensed spectrum to offload traffic from the licensed spectrum of the service providers. Although these solutions are expected to provide high network performance, while managing the increase in data traffic, they can lead to unfair use of the shared unlicensed spectrum. Hence it is important to analyze the impact of such technologies on Network Neutrality and fairness.

In the present work, we mainly focused on the emerging network management strategies (Giga-LTE, LTE-U, etc.) that are being heavily debated, and discussed in detail about their impact on Network Neutrality. In addition, we also discussed various challenges faced by the Network Neutrality regulators for monitoring Network Neutrality conformance. The rest of the paper is organized as follows: Section II includes a brief discussion on the challenges in monitoring Network Neutrality conformance;

Section III includes a discussion on various disruptive network technologies and their impact on network neutrality, followed by discussion and conclusions in Section IV and V, respectively.

II. CHALLENGES IN MONITORING NETWORK NEUTRALITY CONFORMANCE

The Internet was developed with the sole aim of transferring user data packets from source to destination, in a reliable or in a best effort manner. However, mobile data networks, both wired and wireless, have evolved extensively from analog communication systems in the first-generation to advanced high performance fifth generation digital networks with advanced capabilities. This tremendous transformation of the Internet is the main reason why the Network Neutrality principle is important for the future Internet. In this section, we will discuss some of the challenges that have to be addressed by the policy makers and law enforcers to ensure that all ISPs strictly conform to the various Network Neutrality rules and regulations.

A. *Network Neutrality Violation Detection*

There are a number of ways in which ISPs can throttle or discriminate between the mobile data traffic originating from different content providers. A number of techniques such as Deep Packet Inspection (DPI), priority based scheduling, port blocking, application based flow control, Multi-Protocol Label Switching (MPLS), etc, can be employed by the ISPs for controlling the traffic flow through their network in order to maximize their revenue. In most of these cases, the end user might not be able to figure out the cause of difference in performance and can misinterpret it as network congestion. Although different tools have been proposed for network neutrality violation detection [9],[10],[11],[12], it is very difficult to point out whether the degradation in the network performance is due to network conditions or due to ISP policies. In addition, different mechanisms for discrimination can be used by the ISP in different situations (for instance based on time of day), and hence it is very challenging to monitor network neutrality conformance using a single tool or mechanism.

B. *Traffic and Network Management*

Due to an enormous increase in mobile data traffic and the development of advanced applications and devices requiring Quality of Service for their operation, ISPs have a legitimate right to use various network management techniques and policies. However, the Network Neutrality regulators must make sure that they do not use such practices to discriminate the traffic from different sources, in order to increase their revenue or kill the competition. For instance, the permission to block spam, malware and viruses for security reasons can be misused by the ISPs to apply their own selfish policies and violate Network Neutrality. In particular, ISPs might offer additional services such as IPTV, VoIP, etc. in addition to broadband access. In such cases it is very likely that they can reserve the bandwidth for guaranteeing their performance, while giving best effort treatment to the other OTT applications. There can be many other reasons such as congestion management, optimal allocation of resources, QoS, etc. for which the ISPs can control the traffic or give preferential treatment to certain types of traffic. However, proper regulatory intervention is required to ensure that Network Neutrality is not violated. In addition, the traffic management policies implemented by the ISPs should be made transparent so that the Content Providers, end users, and the policy regulators should have sufficient information about how the data traffic is handled by the ISPs. In addition, the regulating bodies must decide carefully about what management policies should the ISPs be permitted to use. For instance, in the case of congestion in wireless networks, should all the customers be throttled equally or should those with poor radio conditions be throttled more.

C. *Pricing*

Due to the ever increasing mobile data traffic, network operator resources are being fully utilized, with relatively small economic payoff. This has resulted in the adoption of various kinds of pricing strategies by the ISPs in order to achieve more control over their network. An acceptable differential or tiered pricing plan should charge differently only on the basis of overall data allowance, or the base performance for each service class, and not on the basis of the application or content being accessed by the user. However, it should be made sure that the ISPs do not violate Net Neutrality. For instance, the ISPs can throttle the content from a competitive service provider, in order to lower its competition, and claim that a customer was throttled because of their subscribed service class. In such cases, it is challenging to ensure that the reason for the lower performance is due to the service class and not due to the discrimination by the ISP. In addition, the ISPs can charge the content providers for accessing the subscribers, and this can result in barring the entry for new players and hence can hinder innovation and growth. In addition, ISPs assert that if they are not allowed to charge differentially for provisioning of the QoS to the end users, they will have less incentive and thus they will lose motivation to invest in their network. However, it cannot be guaranteed that the profit achieved by network operators will be invested in the infrastructure in the right proportion.

III. EMERGING NETWORK TECHNOLOGIES

In this section, we will introduce some emerging network technologies and discuss their impact on Network neutrality.

A. *Giga-LTE*

Giga-LTE is an emerging high-speed wireless network technology, capable of providing up to 1.17 Gbps data rates, based on the combination of two heterogeneous wireless technologies: LTE and Wi-Fi [13],[14]. This service, developed collectively by the Korean telecommunication corporation KT and Samsung, is based on the Multi-Path Transmission Control Protocol (MP TCP), and supported over KT's existing Wi-Fi network. MPTCP combines the 3-Band Carrier Aggregation (CA) LTE and Giga Wi-Fi streams into one big fat pipe, providing 4 times and 15 times faster service than the tri-band Carrier Aggregation LTE-Advanced standards, and existing LTE standard respectively.

Mobile data traffic is rapidly increasing, and is expected to grow at a compound annual rate of 57 percent until the end of

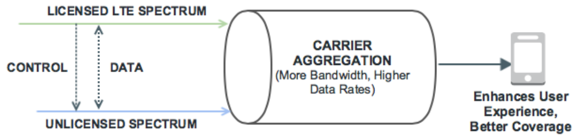

Fig. 1. LTE in Unlicensed Spectrum

2019. Therefore, newer technologies such as 5G will be deployed extensively in the future. Giga-LTE is one such technology that is expected to help the mobile carriers compete in the future. The high data rates that have been achieved through carrier aggregation can help in accelerating innovation and technical advancement in mobile communication. LTE was designed to operate over the licensed spectrum exclusively assigned to the mobile operators, for which they had to pay significant amounts. Due to the growing demand for cellular capacity, utilizing the unlicensed spectrum to increase speed and capacity is being considered as a possible solution by a number of big players in the communication sector. However, such technologies can be a threat to Network Neutrality. Although the proponents of such carrier aggregation schemes assert that such technologies would use only a small fraction of the unlicensed Wi-Fi spectrum, unrestricted use of this spectrum can lead to serious Network Neutrality issues. Service Providers can build LTE networks based totally on the free 5GHz unlicensed spectrum, instead of hybrid mechanisms. In such cases, the Wi-Fi users can experience a loss in the quality of experience, and there can be unfair distribution and use of the unlicensed spectrum among the contending parties leading to the violation of Network Neutrality principles if content is routed based on technology. In addition, Giga-LTE is currently available for use only with a handful of the Samsung devices (S6 and S6 edge) and the users with other devices cannot experience the advantages provided by this cutting edge technology. Similarly, other operators can pair up with their partners and in this way the end user would lose the freedom of choosing the operator and device of his choice while enjoying the benefits of high data rate and benefits provided by such technologies. This is against the principles of Net Neutrality and proper regulatory measures should be taken to avoid such situations that are anticipated to occur in the future.

B. LTE-U/ U-LTE/Licensed Assisted Access (LAA)

LTE in Unlicensed spectrum (LTE-U) is a technique that was originally proposed by Qualcomm and Ericsson for using LTE in Unlicensed spectrum as a proposal for solving the 1000x challenge (Mobile data traffic is expected to increase 1000 times in the next decade). It is based on the concept of carrier aggregation, where the unlicensed spectrum, generally used for Wi-Fi networks and the licensed LTE spectrum are aggregated, either for downlink (SDL Mode-Supplemental Downlink) or for both downlink and uplink (TDD-Mode) [15], [16]. LTE-U is designed to enhance the coverage provided by LTE in the licensed spectrum utilizing small-localized cells operating at 5GHz, as shown in Figure 1.

LTE-U allows the seamless integration of LTE and LTE-Advanced with the unlicensed spectrum through carrier aggregation, allowing mobile operators to provide better data rates and more capacity by offloading the mobile data traffic onto unlicensed frequency bands more effectively and efficiently. This can further enhance the user experience by offering them faster speed and better coverage, leading to a robust and seamless mobile broadband environment. In addition to providing an enhanced Quality of Experience (QoE) for the end users, it provides a cost-effective solution for mobile operators to deal with the ever increasing data surge, as the same core technology can be used in the unlicensed spectrum.

Although LTE can carry more data using the same amount of spectrum as Wi-Fi and also provide better coverage, there is a need for that boost as Wi-Fi is already capable of providing hundreds of Mbps of data rate. In addition, if mobile operators are freely allowed to use the unlicensed spectrum without any kind of restrictions, then this can lead to degradation in the quality of connection in home and office Wi-Fi networks. This can lead to the violation of Network Neutrality as all the users will not get a fare share of the available spectrum, depending on which technology they are using LTE-U or simple Wi-Fi. As the mobile operators can move their customers between LTE-U and only LTE at their own will, they can control the quality and hence attract more customers to use their service as compared to other carrier Wi-Fi options or home networks. As LTE is designed for use in the paid licensed spectrum, hence all the traffic is managed by a single operator and such management may not operate fairly with other users in unlicensed bands, as compared to co-operative networks such as Wi-Fi. This is clearly a threat to Network Neutrality. Even if some kind of fairness mechanism is deployed by the network operator, it cannot ensure proper use as different heterogeneous technologies can use the unlicensed spectrum according to their requirement and so there is a need of some kind of coordination between the different operators and some regulations to safeguard the quality for Wi-Fi users and to preserve Network Neutrality. In addition, similar to the Giga-LTE as discussed above, such technologies would require new features in terms of both the mobile devices and network equipment, so users cannot access the new network technology unless they purchase the device that supports it. In this way the end user loses the freedom of choosing the operator and device of his choice and yet being able to enjoy the benefits of high data rate and benefits provided by such technologies.

C. LTE Broadcast

As discussed in the previous section, mobile video traffic is increasing rapidly and is expected to dominate all other forms of traffic. According to [8], more than 50 percent of the mobile data will be video by 2019. Due to advancements in network technology, and increase in the number of smart devices, mobile users expect uninterrupted access to video content on the Internet. The usage of LTE Broadcast can help mobile operators manage the network capacity by broadcasting the popular content such as mobile TV, video streaming, etc. LTE Broadcast is based on the evolved Multimedia Broadcast Multicast Service (eMBMS) [17]. With the evolution of LTE, many features including the dynamic switching between broadcast and unicast, etc., have been evolved, making LTE Broadcast more robust and scalable. Thus it can be used to deliver video streaming content to a large number of users in a cell, using roughly the same bandwidth as required by a single user. It will also allow network operators to support a wide variety of bandwidth intensive use cases such as video streaming, internet of things, software updates, mass live streaming, such as in the case of sports events. It provides an efficient distribution of live media, by allowing multiple users to receive the same content simultaneously, and is hence more profitable for the operators. It allows efficient use of spectrum and other network investments, allowing the development of new business models and applications over the core capabilities of the LTE.

However such a mechanism can lead to the violation of Network Neutrality as the LTE Broadcast data will be given higher priority and hence higher QoS as compared to other applications over the top. The eMBMS standard allows network operators to reserve up to 60 percent of a channel for LTE Broadcast content [18]. Although the operators claim that only 10 to 20 percent of the channel will be used for broadcast, there can be an unfair use of the channel if there is no regulation regarding the broadcast data usage limits. Although LTE Broadcast has been proposed as an effective technology to be used in congested scenarios, there are no specific rules to define a congestion situation, and in that case the operators can degrade the quality for other users, provisioning them with low quality video content that has been compressed and optimized for compensation of the lack of quality. Although it has been pointed out that LTE Broadcast may be allowed legally as a technology driven network management strategy, its unregulated use can lead to unfair throttling of the content for other users, and might be used by the network operators to kill its competition and attract more users. Hence, even though broadcasting can allow the operator to deliver the media content to a number of users simultaneously, while consuming the bandwidth equal to a single user, with the same level of QoS, its unrestricted use can lead to the violation of network neutrality. In addition, it has been anticipated that the LTE Broadcast technology can potentially be the next-generation TV for Internet, using the unlicensed spectrum.

Small cells operating in unlicensed spectrum can help increase the coverage, thereby enhancing the end user experience. In this way a large amount of data can be offloaded from licensed spectrum to the 5GHz unlicensed band, thereby localizing the broadcast capacity while maintaining the quality of experience for the end user. In such cases, it can have Network neutrality repercussions similar to other techniques such as Giga-LTE and LTE-U operating in the unlicensed spectrum, as discussed above.

D. *LTE Wi-Fi Aggregation (LWA) and LTE Wi-Fi aggregation using IPSec tunnel (LWIP)*

LWA combines the licensed LTE spectrum and unlicensed Wi-Fi bands to provide an enhanced user experience [19]. It allows inter-networking between WLAN and LTE using the LTE dual-connectivity framework. The data payload of LTE is split and the base station or the eNodeB (enhanced Node B) splits the payload, which is transferred over Wi-Fi and LTE networks for the downlink data transmission. This technique requires no change to the Wi-Fi air interface as it involves the tunneling of LTE radio access network transmissions in a 802.11 frame. Unlike other aggregation schemes that require new hardware, this technique only requires software updates in the eNodeBs, to be deployed successfully. The traffic flowing over the Wi-Fi network is anchored by the eNodeB. Figure 2 depicts the basic functioning of the LWA technique in a collocated deployment scenario. This involves integration of LTE eNodeB or base station and the Wi-Fi access point and the scheduling decisions are made at the packet level, based on the system utilization and radio channel conditions.

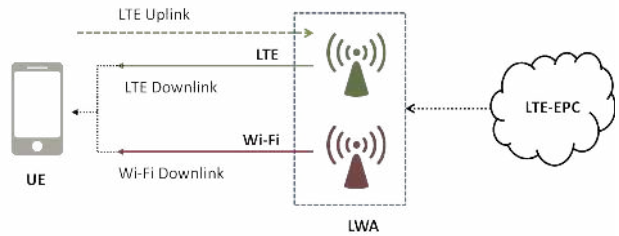

Fig. 2. LTE Wi-Fi Aggregation

The LWIP aggregation technique involves the use of IPsec tunnels to provide LTE-WiFi aggregation, without making any major changes to the wireless local area network (WLAN) infrastructure. In this case, some of the traffic is routed directly between the eNodeB and the mobile device while the remaining traffic is transmitted to the mobile node through the WLAN infrastructure using the IPsec tunnel.

Although the LWA technology is based on the physical and MAC layers of the Wi-Fi network, which allows the sharing of unlicensed spectrum with other traffic, it can lead to the violation of the Network Neutrality if no fairness mechanisms are employed. The decision for routing the downlink traffic through LTE and Wi-Fi or only LTE is made by the base-station controlled by the operator. Hence, in case of high congestion in the cellular network, more and more data can be routed through the WLAN, resulting in un-fair use of the un-licensed spectrum. This is anti-competitive as the routing decision will be made by the operator with the main aim of optimization of its own network resources. Hence, although such techniques might result in better performance, and are easy to deploy without any special hardware requirements, their unrestricted use can lead to Network Neutrality violation.

E. *MulteFire*

MulteFire technology aims at combining the benefits of LTE-like high performance and Wi-Fi-like ease of deployment. It is an innovative wireless network technology, aimed at implementing the LTE features entirely in the unlicensed spectrum. The design of MulteFire technology is tightly coupled with the 3GPP standards and hence supports many of the features of LTE including enhanced capacity and high data rates, seamless mobility, security, differential QoS, support for LTE applications such as Voice over LTE (VoLTE), Internet of Things (IoT), etc. On the other hand, it is a self-contained architecture, that can be implemented in unlicensed spectrum by neutral hosts, thereby

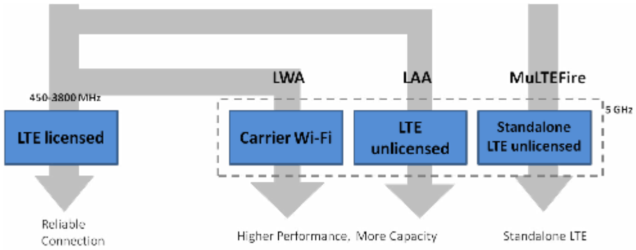

Fig. 3. Comparison between different aggregation techniques

providing Wi-Fi-like simplicity of deployment. It can be easily deployed by small to medium sized enterprises, ISPs, mobile operators, building owners, etc. In most of the above discussed technologies, the operator is required to have an anchor in the licensed spectrum, which limits their capabilities and potential use. However, as the MulteFire technology is operated entirely in the unlicensed spectrum, it can easily co-exist with the licensed LTE as well as other unlicensed technologies. According to the specifications of the MulteFire Release 1.0 [20], no special modifications are required in the 3GPP Public Land Mobile Networks (PLMN) for inter-networking with the MulteFire networks. However, to incorporate some enhanced features, it is required that the PLMN must have some MulteFire specific features. In addition, efficient co-existence with other technologies in unlicensed spectrum, is also taken care of in MulteFire technology. In this case, Listen-Before-Talk (LBT) procedure is used, whereby the transmitter of the radio signal will first sense the channel and transmit only if the channel is idle.

Unlike the above techniques that partially utilize the unlicensed spectrum to provide higher data rates and to expand the capacity, the MulteFire technology is entirely based on the unlicensed spectrum. In addition, as the LBT procedure is used for effective co-existence with the other technologies, it overcomes many drawbacks of the other techniques that requires an anchor to the licensed spectrum. However, it can be seamlessly interconnected with the 3GPP cellular standards and hence it can lead to Network Neutrality and fairness issues if it is not ensured that the unlicensed spectrum is shared in a proper way, and the interference is minimized.

IV. DISCUSSION

In this paper, we mainly focused on fairness and Network Neutrality issues that arise from the co-existence of LTE and other technologies such as Wi-Fi in the unlicensed spectrum. Most of the technologies discussed in the previous section are license-anchored, and operate simultaneously in unlicensed and licensed spectrum bands, as shown in Figure 3. Such techniques allow the traffic to be moved dynamically across the unlicensed and the licensed spectrum, and are hence, less sensitive to the congestion and interference caused in the unlicensed spectrum. This is so because most of the techniques do not employ any mechanisms to ensure efficient co-existence with the technologies in the unlicensed spectrum. For instance, the techniques such as LTE-U, Giga-LTE, LAA, LWA, etc. may involve shifting the traffic from unlicensed to licensed spectrum in case of congestion, resulting in reduced sensitivity to other technologies operating completely in the unlicensed spectrum. In case of unlicensed only technologies, overuse of spectrum by one technology can result in a strong reaction from the other technologies. Hence such techniques are designed for fair co-existence with the competing technologies. However, in the case of licensed-anchored technologies, as they have a backup in the licensed spectrum, they might not suffer much in case of congestion in the unlicensed spectrum, resulting in violation of fairness and Network Neutrality principles. Although some of the above techniques take the fair co-existence into consideration, by employing procedures such as LBT, etc., they might use a lot of unlicensed spectrum band and, if the access is not restricted, provide poor QoS when in congestion. In addition, the channel selection procedures in case of aggregation techniques in unlicensed bands can interfere with the automatic channel selection techniques used in most of the unlicensed technologies such as Wi-Fi. Hence, there is a need for proper regulation and guidelines for enforcing the Network Neutrality principles, and ensuring that the existing unlicensed spectrum users do not suffer a degradation in the performance due to introduction of new hybrid aggregation technologies, as discussed above.

V. CONCLUSION

Due to the popularity of emerging network technologies for enhanced performance and capacity management, it is important to ensure that the carrier aggregation techniques that are anchored in licensed spectrum should not be able to use the unlicensed band in an unfair manner. In the present work, we provide an insight into some emerging network technologies such as LTE-U, LAA, LWA, LWIP, etc., and discuss how they can lead to the violation of Network Neutrality.

VI. ACKNOWLEDGEMENT

This work has been supported by the research project: Development of Automated SaaS Compatibility Techniques over Hybrid/Multi-site Clouds (N-17-NM-CA02-S01) of Korea Institute of Science and Technology Information (KISTI), Daejeon, Korea.

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