Wi-Fi Offloading – A Promising Solution to Solve Network Congestion

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Abstract – **Wi-Fi provides an invaluable complement to cellular in the delivery of high-quality broadband services to smartphone users, particularly indoors. Cellular networks offer high performance, wide area blanket coverage but do not always cover indoor locations well. Wi-Fi fills these gaps.**

Wi-Fi traffic from both mobile devices and Wi-Fi-only devices together will account for more than half of total IP traffic by 2022. Mobile data offloading or simply data offloading refers to the use of complementary network technologies and innovative techniques for delivery of data originally targeted for mobile/cellular networks to alleviate congestion and making better use of available network resources. By offloading users from the 3G/4G network to Wi-Fi networks, mobile operators can add more capacity in an affordable and flexible way.

Wi-Fi offloading demands that carriers thoroughly test it to ensure a transparent, high-quality experience for customers. This includes providing a transparent high quality experience for users that is sustained even as user and application demands grow.

Keywords: Wi-Fi offloading, On-the-spot offloading, Delayed offloading, Managed Data Offloading, Integrated Data Offloading

I. INTRODUCTION

THE wireless capacity is nearing Shannon's limit, researchers in academia and industry are looking for the next best solution. Of course, no single modification will cure the entire problem; rather, the evolving system will need to exploit every opportunity that comes along. This paper focuses on two opportunities to reduce cellular load (*a*) Exploiting the proliferation of Wi-Fi access points through offloading; (*b*) Exploring collaboration among wireless devices. The first opportunity is applicable to an urban area where Wi-Fi is enabled whereas the second opportunity suits almost everywhere.

This is not an attempt to estimate spectrum needs for either cellular or Wi-Fi (see for example ITU document) [1]. Rather, the aim is to examine the long-term dynamic between Wi-Fi and cellular usage, the suitability of Wi-Fi as a capacity solution, the user and business motivation of Wi-Fi implementations and the resultant traffic loading on the cellular network. It is traffic loading per site which ultimately drives cellular spectrum needs.

Wi-Fi provides an invaluable complement to cellular in the delivery of high-quality broadband services to smartphone users, particularly indoors. Cellular networks offer high performance, wide area blanket coverage but do not always cover indoor locations well. Wi-Fi fills these gaps at venues where local owners and users need improved coverage and access speed. However, we see little evidence that today's Wi-Fi networks significantly reduce traffic levels on the cellular network. On the contrary, there are signs that when high quality Wi-Fi and cellular are both available to users, the traffic on both increases. Qualitative and quantitative analysis of some of the most advanced markets reveals that the majority of today's Wi-Fi traffic is incremental or complementary to cellular traffic. Venue based Wi-Fi will play an increasing role in providing indoor broadband connectivity. It will be used by cellular operators to deliver an "always best connected" value proposition but will not reduce demand for capacity on cellular networks.

The prospects for Wi-Fi delivering significant capacity relief in areas of the cellular network facing congestion are limited. On the contrary, Wi-Fi and cellular traffic are expected to grow in parallel and rapidly, offering complementary capabilities. Both technologies will require additional spectrum to deliver ubiquitous broadband connectivity.

II. WHY WI-FI OFFLOAD?

Internet traffic is increasing exponentially every year and will increase more by the year 2022, Mobile and offload from mobile devices together will account for 48 percent of total IP traffic by 2022, a testament to the significant growth and impact of mobile devices and lifestyles on overall traffic. Wi-Fi traffic from both mobile devices and Wi-Fi-only devices together will account for more than half (51 percent) of total IP traffic by 2022, up from 43 percent in 2017. In 2017, wired devices accounted for the majority of IP traffic. And a significant portion of this traffic will be due to wireless. As a result, cellular networks are becoming heavily congested. Nearly three-fifths of traffic (59 percent) will be offloaded from cellular networks (on to Wi-Fi) by 2022 [2].

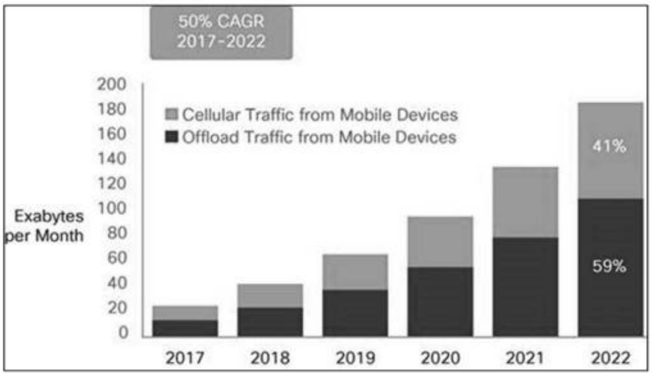

Figure 1. Global Mobile Data Traffic Offload to Wi-Fi [2].

This unprecedented growth of data traffic can be attributed to several factors, like: the introduction of high-end devices such as smart-phones, tablets, laptops, handheld gaming consoles, etc. that can multiply traffic, also the growth in mobile network connection speeds and the rise of mobile video content that increase the average traffic per device. Mobile video traffic has already surpassed 50% of total mobile data traffic and continues to increase. The availability of mobile broadband services at prices and speeds comparable to those of fixed broadband is also an important factor for the unprecedented growth of data traffic.

Mobile data offloading or simply data offloading refers to the use of complementary network technologies and innovative techniques for delivery of data originally targeted for mobile/cellular networks to alleviate congestion and making better use of available network resources. The objective is to maintain Quality-of-Service (QoS) for customers, while also reducing the cost and impact of carrying capacity hungry services on the mobile network [3]. Most mobile operators worldwide have already started to implement an offloading solution.

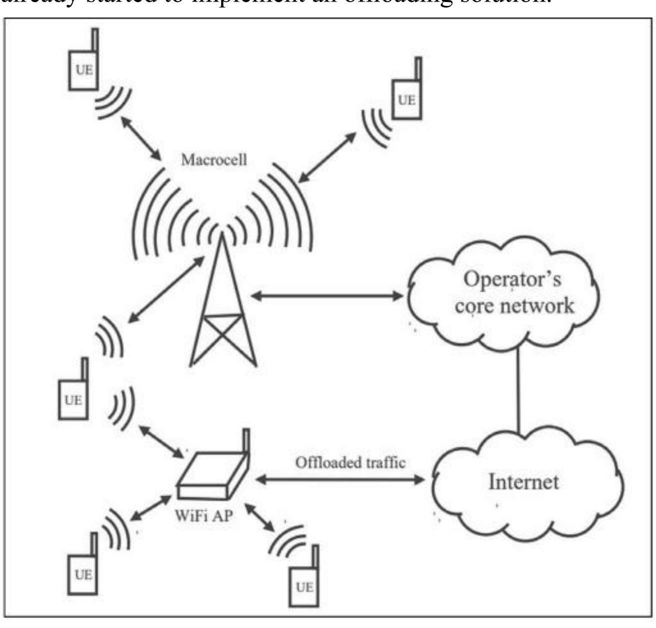

Figure 2 Mobile Data Offloading via Wi-Fi APs.

Now-a-days communication devices such as smart-phones, laptops and tablets etc. come with mobile data broadband capabilities built-in, as they are designed to download content anywhere, any time. While some mobile operators urgently need a cost-effective way of satisfying customers' ever-increasing hunger for more bandwidth, this is not the only driver for Wi-Fi offload. As devices with built-in Wi-Fi perform better in Wi-Fi networks (with speeds up to 1.5 Gbps) than in 3G/4G – especially indoors – mobile operators need to be able to deliver a good Wi-Fi-based end-user experience. Furthermore, with more and more new types of devices being designed specifically as "Wi-Fi only," the operator can decrease churn and can retain subscriber by offering Wi-Fi.

By offloading users from the 3G/4G network to Wi-Fi networks, mobile operators can add more capacity in an affordable and flexible way [4]. It has been seen that operators from the developed world have built Wi-Fi offload networks proactively in areas with heavy mobile broadband usage such as universities – and reaped the rewards of reduced cost and lower churn due to better user experience.

Alternative offload solutions that only focus on bypassing the packet core gateways in the mobile core will only decrease the load on these nodes and not offload the entire network including the Radio Access Network (RAN). Using femto-cells for offloading is a way of building the 3G radio network cost-effectively, but femto-cells do not provide an option of increasing the footprint quickly through partners the way that Wi-Fi does.

Additionally, most Wi-Fi-enabled devices try to establish a Wi-Fi connection as the first choice whenever available. Some applications can only be used on Wi-Fi. It is no surprise that carrier Wi-Fi has rapidly gained interest and Wi-Fi offload has become a priority among mobile operators globally.

III. WHY WI-FI?

Following factors augment the choice of Wi-Fi as an alternate technology for offloading cellular data traffic:

- Research shows that most of the internet data consumption happens when the user is stationary (*i.e.* not mobile) *e.g.* within a building, house, office compound, malls etc. Thus, mobility is not even required here.
- Nowadays, almost all of the smart devices come with Wi-Fi support. So, no additional cost is required from a subscriber perspective.
- Wi-Fi networks operate on the unlicensed frequency bands and cause no interference with cellular networks. Wi-Fi is usually ubiquitously available in urban areas, either deployed by operators as commercial hotspots or deployed by users for residential usage [5].

Thus, Wi-Fi becomes an obvious choice for network operators. It can help improve cellular coverage and increase capacity through spectrum reuse in areas where most of the data traffic is being generated *e.g.* in a building. Thus, the cellular network shall be used for high QoS intensive traffic as well as mobility requirements [6] *e.g.* VOIP, whereas Wi-Fi shall be used for low QoS data traffic *e.g.* downloads, web surfing etc.

IV. TYPES OF OFFLOADING

Wi-Fi offloading seems the most viable solution at the moment. Building more Wi-Fi hotspots are significantly cheaper than network upgrades and build-out. Many users are also installing their own Wi-Fi APs at homes and work. If a majority of data traffic is redirected through Wi-Fi networks, carriers can accommodate traffic growth only at a far lower cost. Given that there is already a wide-spread deployment of Wi-Fi networks, Wi-Fi offloading addresses the "time-to-capacity" issue for the currently pressing need of additional network capacity.

There are two types of offloading:

- On-the-spot Offloading, and
- Delayed Offloading.

On-the-spot offloading is to use spontaneous connectivity to Wi-Fi and transfer data on the spot; when users move out of the Wi-Fi coverage, they discontinue the offloading and all the unfinished transfers are transmitted through cellular networks. Most of the smart-phones which give priority to Wi-Fi over the cellular interface in data transmissions can be expected to currently achieve on-the-spot offloading.

In delayed offloading, each data transfer is associated with a deadline and as users come in and out of Wi-Fi coverage areas, it repeatedly resumes data transfer until the transfer is complete. If the data transfer does not finish within its deadline, cellular networks finally complete the transfer. Most smart-phones with Wi-Fi are already performing on-the-spot offloading by default. But delayed offloading is relatively new.

There is no doubt that both on-the-spot and delayed offloading reduce the load on mobile networks. But an important, yet the under-addressed question is how much benefits offloading can bring to network providers and users. Network carriers are interested in knowing how much traffic load Wi-Fi offloading takes away from cellular networks under a given or future Wi-Fi network deployment. On-the-spot offloading is currently being offered through smart-phones. Since carriers do not have control over Wi-Fi networks that users connect to, they have no idea how much on-the-spot offloading helps them even now letting along the future. How much does the new notion of delayed offloading help reduce their traffic given the projected amount of data growth in the future? The answers to these questions can provide clues on their price and cost restructuring strategies.

V. OFFLOADING TECHNOLOGY OVERVIEW

The Third Generation Partnership Project (3GPP) has specified three different technologies that enable offloading from 3GPP standardized mobile data networks (Global System for Mobile Communications (GSM)/ General packet radioservice (GPRS), Wideband Code Division Multiple Access (WCDMA), High Speed Packet Access (HSPA) etc.) to Wi-Fi for multimode terminals (with both 3GPP and Wi-Fi interfaces). These technologies are described briefly below [7].

i. Generic Access Network (GAN) which is also referred to as Unlicensed Mobile Access (UMA), whereby a GAN Controller (GANC) is deployed in a mobile core network (emulating a Radio Network Controller) to enable 3GPP-WLAN vertical handovers for UMA enabled terminals [8].
ii. Inter-working Wireless LAN (I-WLAN) which specifies interfaces for common control mechanisms (*e.g.* authentication) for 3GPP and WLAN interworking, and the Packet Data Gateway (PDG) toprovide gateway functionality for WLAN access towards the 3GPP core network[9].
iii. Access Network Discovery and Selection Function (ANDSF), an entity within the 3GPP Evolved Packet Core (EPC) which provides means for the mobile operator to define policies which dictate how ANDSF enabled terminals could connect to non-3GPP access (WLAN, Worldwide Interoperability for MicrowaveAccess (WiMAX), etc.) [10].

VI. WI-FI OFFLOADING APPROACHES [11]

There are three main levels of integration between the Wi-Fi network and cellular networks, which are:

- Network Bypass or Un-managed Data Offloading,
- Managed Data Offloading, and
- Integrated Offloading.

The first approach is un-managed data offloading, or bypass offloading, considered the easiest type of offloading, where data is directed to Wi-Fi whenever the coverage is found with no need for equipment instalment. The voice services in this type of offloading will remain on the mobile core network. This immediate offloading solution suffers from different issues such as: 1) the operators will lose visibility, control on their own subscribers. 2) the operators will not be able to send subscribed content, which leads to lost revenue[12].

The second approach, managed data offloading, is used by the operators who don't want to lose control of their subscribers, however, they are not allowed to send subscribed content. The third offloading approach is integrated data offloading, which empowers the operators with full control over their subscribers along with the ability to send subscribed content [13]. The drawback of the latter offloading, in order to establish the data flow forming a bridge between a cellular network and a Wi-Fi

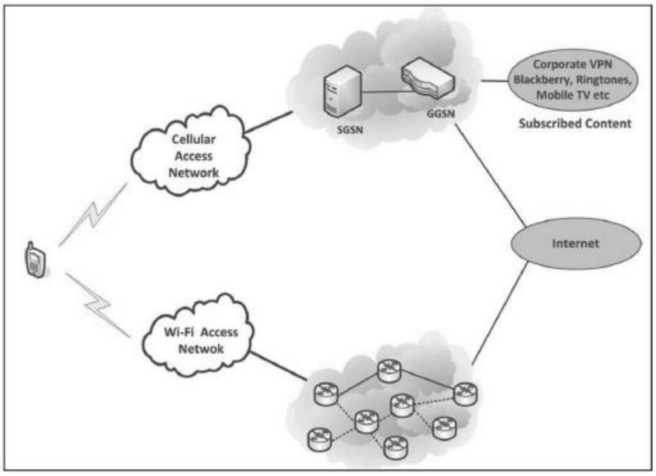

Figure 3. Un-managed Data Offloading.

network, is needed. Integrated offloading raises the coupling architecture concept for Wi-Fi with cellular systems, which can be divided into two coupling architectures: loose coupling and tight coupling [13].

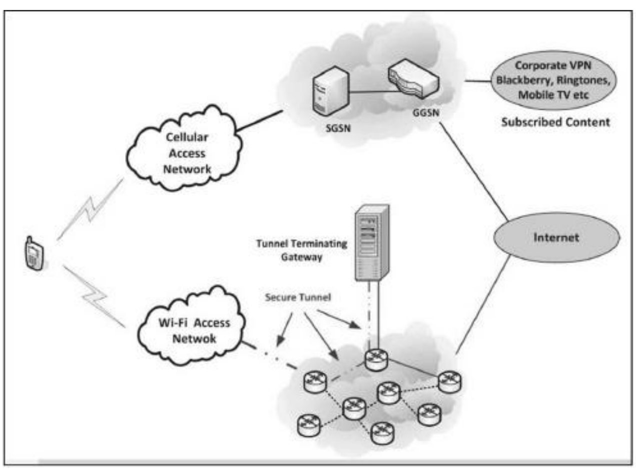

Figure 4. Managed data offloading.

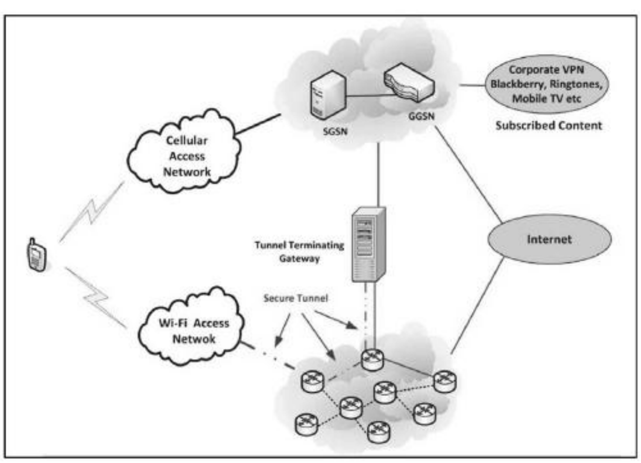

Figure 5. Integrated Data Offloading.

TABLE 1 – COMPARISON OF VARIOUS TYPES OF OFFLOADING TYPES

Offloading Type	Advantage	Disadvantage
Unmanaged Data Offloading	1) there is Wi-Fi coverage move data to it. 2) bypasses the core network. 3) QoS for voice services delivered by the core network.	• operators lose control of subscribers. • operator loses revenue.
Managed Data Offloading	operators have control on subscribers.	operator loses revenue.
Integrated Data Offloading	operators have control on subscribers. operators don't lose revenue.	need to form a Coupling bridge between Wi-Fi and cellular system.

VII. CONCLUSION

Cellular/Wi-Fi integration and one of its outcomes *i.e.* Wi-Fi offload is a promising technology enhancement both from the operator and the end-user perspective. Its offerings are tremendous, and its true potential should be tapped. Wi-Fi offload in the true sense is aimed to be an end-user agnostic provider of seamless mobility and service. Though it is still a long way to go to achieve these offload features, the standardization process bears witness that it is going to happen soon.

There are some crucial points which need to be considered for effective deployment of Wi-Fi Offload. One, the dawn of this technology can truly be seen only when the Wi-Fi footprint in India increases to the level that the offload scenarios are feasible and economically lucrative. Another important point which can be envisaged is to form policies to facilitate fair revenue sharing between the Wi-Fi Operator, the Mobile Network Operator and other entities involved if any, so that there is a minimal dispute. It should also be considered and assessed whether the Wi-Fi service providers, having integration and revenue sharing with licensed networks, will need to have some type of license obligations. Also, to be given serious thought is the spectrum crunch that 2.4 GHz band will face, once Wi-Fi offloads solutions are widely deployed. To address this, some other bands must be explored considering their efficiencies for Wi-Fi and can be considered as an excellent candidate for Wi-Fi deployments in the near future. Security considerations like the impact of Wi-Fi offload solutions on Location Based Services need to be thoroughly examined and addressed [14].

Wi-Fi offloading provides a number of benefits for users, carriers, and their Wi-Fi network partners. At the same time, Wi-Fi offloading is complex and demands that carriers thoroughly test it to ensure a transparent, high-quality experience for customers. This includes providing a transparent, high-quality experience for users that is sustained even as user and application demands grow. These solutions must also be easy for service providers to deploy, including integrating with existing customer billing systems and with administration systems for ongoing management and monitoring.

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