LTE Traffic Offloading Onto Wi-Fi Direct

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Abstract: Mobile network operators (MNOs) the world over are facing a common structural problem in their businesses. Traffic growth is outstripping the capacity of their mobile network deployments in urban "hot zones", making it difficult to hold a phone conversation during rush hour. As a result, 3GPP is currently investigating possible scenarios for device-to-device (D2D) offloading in LTE networks. One solution is Wi-Fi offload which uses the 802.11 network protocol rather than using mobile wireless connections from the carrier such as 3G or LTE. Wi-Fi offload transparently connects devices to fixed hot-spots or Wi-Fi access points (AP) when they are available. By using a Wi-Fi connection to the Internet, the carrier's mobile network is bypassed, thereby significantly reducing the demand on available spectrum. While the products and specifications for Wi-Fi offloading are still maturing, industry activity is increasing. In this paper, we study the performance of WiFi Direct as a prominent technology for D2D communications in urban environments [1]. We also discuss some of the potential performance gains for WiFi Direct communications in the presence of 3GPP LTE network-level management.

***Keywords**: Device-to-devic , data offloading, cellular networks, Wi-Fi direct, Wi-Fi*

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I. INTRODUCTION

Cellular network provide a wide range of advanced services constantly providing to serve the increasing subscriber populations. However, their ability to meet user expectations is at risk given the constant influx of new customers and the increasing numbers of multimedia service requests [1]. Another problem for network clients is the limited battery budget of their mobile devices; this becomes a serious limitation for many throughput-hungry applications. Both of these problems require significant changes in the way we approach wireless content delivery.[2]

Traditional solutions firstly focus on increasing deployment cell density. Owing to shorter radio links,

smaller cells provide higher bit rates and require less energy for uplink transmission, especially in dense urban environments. However, deploying larger numbers of smaller cells can become prohibitively expensive, and the complexity of interference management may increase much over what is desired. Increasing need for offloading solutions is caused by the explosion of Internet data traffic, especially the growing portion of traffic going through mobile networks. This has been enabled by smartphone devices possessing Wi-Fi capabilities together with large screens and different Internet applications, from browsers to video and audio streaming applications.

Therefore we highlight the Wi-Fi direct technology [3], since it is already available on most client devices and does not reuse the more expensive cellular bands. With this study, we demonstrate how cellular traffic can be effectively offloaded onto Wi-Fi Direct device to-device (D2D) links and provide the estimated gains in energy efficiency and capacity from such offloading. We show how the shorter range and simpler protocol of network assisted D2D communications allow users to benefit from higher data rates over short distances without compromising their battery life.

II. OVERVIEW OF EXISTING TECHNOLOGY

1.1. 3GPP LTE

LTE (Long Term Evolution) or the E-UTRAN (Evolved Universal Terrestrial Access Network), introduced in 3GPP R8, is the access part of the Evolved Packet System (EPS). The main requirements for the new access network are high spectral efficiency, high peak data rates, short round trip time as well as flexibility in frequency and bandwidth.
The first step towards an IP based packet switched (green in figure 1) solution was taken with the evolution of GSM to GPRS, using the same air interface and access method, TDMA (Time Division Multiple Access).

The Evolved Packet System (EPS) is purely IP based. Both real time services and datacom services will be carried by the IP protocol. The IP address is allocated when the mobile is switched on and released when switched off.

The new access solution, LTE, is based on OFDMA (Orthogonal Frequency Division Multiple Access) and in combination with higher order modulation (up to 64QAM), large bandwidths (up to 20 MHz) and spatial multiplexing in the downlink (up to 4x4) high data rates can be achieved.

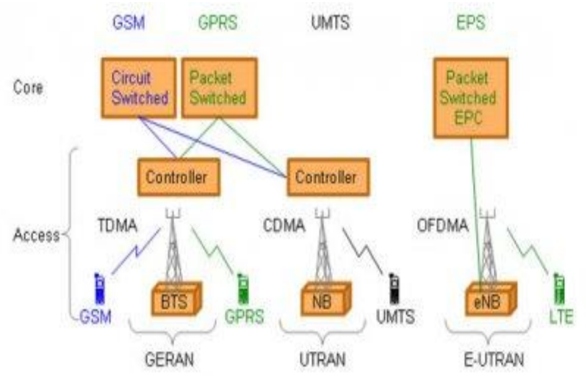

Figure1. Network Solutions from GSM to LTE

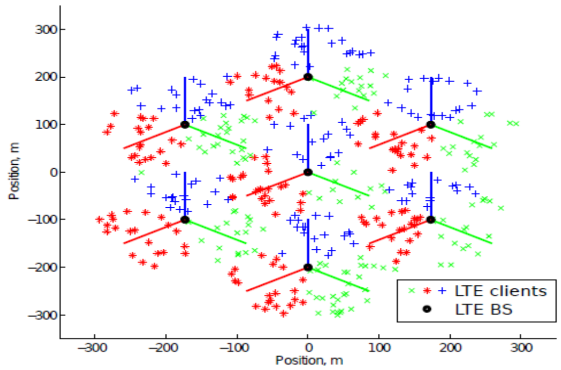

Figure 2: Example 3GPP LTE deployment and user positioning [2]

In this paper, we consider one of the standard 3GPP scenarios (named urban microcell in [4,5]), with a relatively high user density of 20 client devices per sector. We choose this dense deployment as a reference in order to recreate conditions where D2D would be most needed, i.e., when cellular networks face difficulty supporting the offered load. An example of the considered layout, is presented in Figure 2.

The important practical benefit of LTE is that it provides cost-efficient wide-area coverage; the network can be made very large at a reasonable price. Moreover, LTE uses very complex signal processing in the transceiver, which tends to be rather power hungry. Combined with lower data rates, this results in poor energy efficiency.

1.2. WI-FI Technology

Wi-Fi is the name of a popular wireless networking technology that uses radio waves to provide wireless high-speed Internet and network connections. A common misconception is that the term Wi-Fi is short for "wireless fidelity," however this is not the case. Wi-Fi (wireless fidelity) is a generic term that refers to IEEE 802.11 standard for Wireless Local Area Networks(WLANs). Wi-Fi works with no physical wired connection between sender and receiver by using radio frequency (RF) technology -- a frequency within the electromagnetic spectrum associated with radio wave propagation. When an RF current is supplied to an antenna, an electromagnetic field is created that then is able to propagate through space. The cornerstone of any wireless network is an access point (AP). The primary job of an access point is to broadcast a wireless signal that computers can detect and "tune" into. In order to connect to an access point and join a wireless network, computers and devices must be equipped with wireless network adapters.

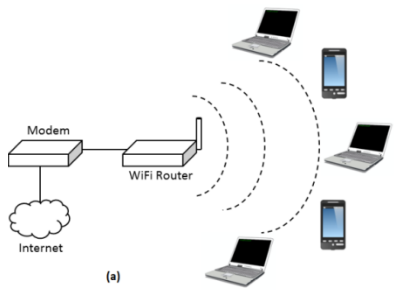

Figure 3: Wi-Fi Network Architecture

1.3. Wi-Fi Direct

The need to wirelessly send data to nearby devices without the use of other hardware is not a new thing. One of the first and most widespread solutions was Bluetooth, which has been around since 1998. Bluetooth is awesome for connecting peripherals to a computer (like mice or keyboards) or using a wireless headset, as these don't require fast data transfers. Bluetooth is not a fast technology, and setting it up is not hassle-free either.

But WiFi is different: it has high speeds, and it's much easier to configure. This is why Wi-Fi Direct was invented: it is a technology for fast, wireless transfers of files between devices and, thanks to the much easier configuration, it can also be used for connecting basically anything wirelessly.

Wi-Fi Direct is built upon the IEEE 802.11 protocol stack [6] and enables efficient D2D connections in unlicensed bands. In contrast to LTE, it is a far simpler protocol, thus it consumes less energy. Additionally, since it operates over shorter links, it achieves better levels of spatial reuse than LTE. Currently, most mobile devices have multi-radio capabilities, i.e. they can flexibly use both LTE and Wi-Fi interfaces. We consider a population of clients using Wi-Fi Direct to communicate with their respective partners. We randomly activate a number of client devices, and then pair each one of them with one of its neighbors. We assume that the devices utilize all the available bandwidth when exchanging data, and we are interested in the achievable data rate. This approach allows us to explore the system capacity without narrowing down to a particular model for content distribution or service discovery, and thus compare the achievable performance levels against the pure LTE.

Figure 5 presents the performance comparison with LTE-only users deployed across the same area.

Figure 4: Wi-Fi Direct

1.4. D2D LINKS

Device-to-device (D2D) communication that enables direct communication between nearby mobiles is an exciting and innovative feature of next-generation cellular networks. It will facilitate the interoperability between critical public safety networks and ubiquitous commercial networks based on e.g. LTE. As Figure 5 suggests, D2D links achieve highly diverse performance across a given deployment. They range from being orders of magnitude better than LTE to being practically useless. We hence try to identify certain categories of D2D links that perform well.

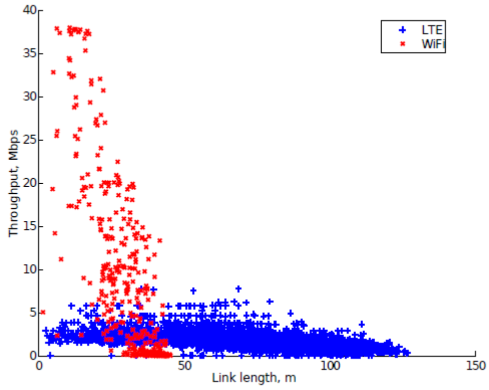

Figure 5. Wi-Fi vs LTE uplink throughput scatter plot [6]

In addition, we study their interaction with existing Wi-Fi networks by positioning a number of access points (APs) throughout the deployment; each AP has five legacy clients that are streaming data to it.

The APs and their clients make up a set of rogue nodes that are not managed in any way by the LTE network and only consume resources, which could have otherwise been available for WiFi Direct communications [6].

III. ENABLING LTE OFFLOADING ONTO WI-FI

If we assume (extending the proposals in [7]) that the cellular network can help its users in determining when/if a partner of interest (i.e., one with which they want to communicate) is in proximity, users can quickly and efficiently move their traffic sessions onto D2D links, thus increasing their data rates and offloading the cellular network traffic . As a result, the clients using D2D links would enjoy the improved transfer rates delivered by the shorter links.

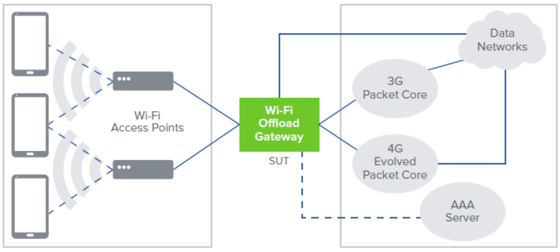

Figure 6: Wi-Fi Offloading with 3GPP

Figure 6 presents the Wi-Fi Offloading with 3GPP with Large Wi-Fi networks are being introduced to serve locations where people do not move frequently. For instance, broadband Internet service with the ability to handle offloaded mobile traffic is available at a growing number of residential, private business, and public locations. For example, Wi-Fi is increasingly available in offices to authorized users—often including guest accounts that only provide Internet access and are walled off from other local users and devices. Similarly, residential broadband providers routinely offer and install Wi-Fi routers, also known as access points (AP), for little to no additional cost.
In practice, of course, protocols will have to be developed to allow the cellular network and the client device to negotiate the offloading process and ensure service continuity. We assume these

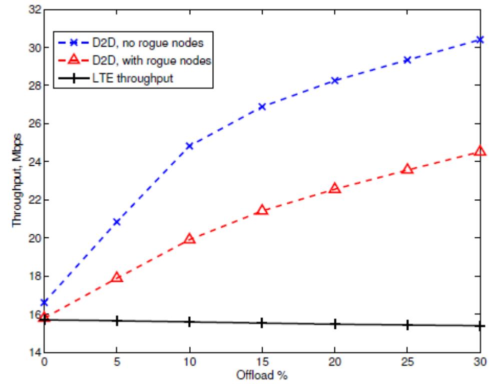

Figure 7. D2D offload throughput

protocols exist, and that some percentage of active LTE users have decided to move their traffic sessions to D2D links [8]. As Figure 7 demonstrates, there is a clear increase in cellular network throughput when offloading is enabled, and the more we offload, the higher is the gain. Naturally, there is also a limit on how many sessions can be offloaded (which is about 30%). As the figure shows, D2D links perform best when the offloading percentage is low, and their performance degrades as the number of offloaded traffic sessions grows.

IV. CONCLUSIONS

From above information we can say Wi-Fi Direct will very much affect the achievable performance gains from offloading onto D2D. But this is only one form of network assistance; there are many other ways in which the network can assist D2D links to improve service quality and continuity.

For example, should the network be given the ability to control which D2D links are established, it could avoid offloading onto D2D links that degrade network and/or user performance. Similarly, if the network can control when certain D2D links transmit, it could potentially establish scheduling zones when groups of non-competing D2D links are allowed to communicate, thus potentially significantly reducing contention and improving throughput and energy efficiency of D2D links (here the reader is referred to works [9,10,6]).

Of course, advanced power control options also become available when network assists D2D communications [11]. If we summarize these result network-assisted D2D offloading is a very promising technique, which enables significant performance improvement in beyond-4G networks.

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