# The Insights of Mobile Data Offloading: A Comparative Study

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***Abstract*—** For past few years, the cellular companies have experienced exponential growth in subscribers. The unprecedented rise in mobile data traffic puts huge burden on existing cellular networks. To tackle aforementioned issue, various solutions have been proposed in recent years. One of such working solution is mobile data offloading, which refers to the process of offloading cellular network data either to a co-existing cellular network or a third party network. A third party network can be a community network managed by its users, a Wi-Fi mesh network or a licensed band femtocell. Recently, many studies have emerged related to mobile data offloading. Hence, there is a need to have a comparative study of these techniques to understand which technique might be useful for a particular scenario at hand. This paper discusses various data offloading schemes and comprises a detailed study that we conducted on data offloading using Wi-Fi Access Points, Device-to-Device, Wireless Mesh Network, and femtocells techniques. In addition, the paper also discusses other advanced mobile data offloading techniques such as IP Flow Mobility, Core Network, and Delay Tolerant Network.

***Keywords*—*Mobile Data Offloading, Access Points, femtocells, Device-to-Device, Wireless Mesh Network***

## I. Introduction

The significant evolution in cellular networks and the introduction of 4G/5G technologies have now made possible the ubiquitous Internet access to almost all the mobile users. As a result, most of the traditional Internet traffic is gradually migrating to cellular networks resulting in overburdening of resources and congestion. Mobile data offloading refers to a process of using complementary network technologies, such as Wi-Fi Access Points (APs) and Femtocell, to deliver the data which was originally required to be delivered by cellular networks [1]. Complementary network is a high capacity and low cost network such as Wi-Fi, femtocells, Wireless Mesh, and Device-to-Device (D2D) technologies [2]. Data offloading promises to decrease significantly the amount of cellular data, thereby releasing the bandwidth for other cellular users. Moreover, it also decreases the impact of capacity-consuming services on a cellular network [1]. Researchers from Cisco announced that mobile data traffic will grow at a Compound Annual Growth Rate (CAGR) of 53% from 2015 to 2020, reaching 30.6 Exabyte per month by 2020 [3]. It is also predicted that 75% of network traffic would be produced by multimedia contents [4]. Cellular network now covers most of the populated-part of the world. The rapid growth of the Internet users and their demands are the biggest challenges for the network service providers. To address such challenges, the most suitable solution is to either increase network capacity or to control the connection speed and limit data usage [5]. However, these solutions are expensive and/or almost impractical to be implemented. An alternate solution is to perform the data offloading, where a portion of data can be offloaded from primary links and transferred using alternate means of communication between mobile users, without any need for an infrastructure backbone [6].

Mobile data offloading comprises two types: (a) delayed offloading and (b) on-the-spot offloading [7]. In delayed offloading, delivery of heavy traffic is delay until a device comes into a Wi-Fi hotspot proximity. At that point, data packets are re-routed through the Wi-Fi AP [8]. For data that has in-time delivery constraints and no Wi-Fi is found, the data is delivered via the cellular network. On the other hand, in on-the-spot offloading, when the Wi-Fi network is available, data transmission is done through the Wi-Fi AP. Otherwise, the traditional cellular communication is performed in usual fashion. On-the-spot offloading technique is easy to implement as smartphones nowadays come with built-in capability of using one interface at a time.

As the data traffic on the cellular network tends to increase, it is expected that in near future, the cellular data offloading will become a key industry. In the past few years, there have been many solutions that are proposed to solve the problem of mobile data offloading, but there is no comprehensive study that does a comparative analysis of these techniques in terms of different options that we have for mobile data offloading. Hence, there is a need to have a comparative study of these techniques to understand which technique might be useful for a particular scenario at hand. We conduct the study of mobile data offloading techniques in this paper, and discuss in detail the mobile data offloading technology and its existing solutions.

The rest of the paper is organized as follows. In Section 2, we provide an overview and motivation of mobile data offloading. Section 3 discusses various architectures of mobile data offloading solutions with a discussion on state of the art, and Section 4 concludes the paper.

## II. Motivation

With the advent of smart phones, the multimedia and social sharing applications are becoming more popular. However, increasing demands of content and growing number of mobile users are also putting huge burden on cellular networks. According to a Cisco report [9], the volumes of requested data from cellular networks has increased significantly, and global mobile traffic is estimated to increase about 50 Exabyte per month by 2021, which is 5-times growth over 2017. About 78% of this mobile traffic will be video-based by 2021. This constant

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increase in traffic is a big problem for cellular networks, and they are likely to become more congested in future; the mobile users may experience degraded quality of service (QoS), e.g., low download speed [6], [10-11], [12].

One solution to cope with the increasing traffic load on backhaul links is that the cellular network provider must invest in the infrastructure improvement to increase its capacity, by deploying more base stations and/or access points, and high bandwidth links. However, this solution is not feasible in the long run as the continuous increase in demand of data and traffic will soon surpass the capacity of the upgraded infrastructure. In recent years, the mobile data offloading has emerged as a promising solution to offload the time insensitive, delay tolerant traffic from the backhaul links with the support of opportunistic forwarding of data among mobile nodes during contacts [12–13]. In the modern cellular technologies, such as 4G LTE, the backhaul links are usually of high capacity. However, it is important to mention here that only 88 countries/territories provide 4G LTE services as measured by OpenSignal.com from October to December 2017 [14]. Moreover, some developing countries still have no, or a partial 3G coverage [15]. Therefore, mobile data offloading has been emerged as an active area of research in order to reduce the traffic burden on the backhaul links. Some of the existing cellular data offloading solutions are discussed in the subsequent text.

Cellular to Mesh (C2M) offloading is one of the working solutions in which data is offloaded from LTE-A cellular network to Wi-Fi mesh networks [16]. Such mesh networks are created and managed by residential users collaboratively. Mobile Network Operators (MNOs) can lease mesh networks to offload data and to reduce their servicing cost [17]. BeWiFi service offered by Telefonica [1] is one kind of Community Network (CN), which offloads the cellular data to its mesh networks [18]. Mobile data offloading via third-party Wi-Fi Access Points (APs) or femtocells are other solutions to implement the data offloading. Use of third party Wi-Fi APs and femtocells can decrease the cellular network congestion significantly and enhance a user's QoS experience [18-19]. As the mobile data offloading may involve third party Wifi-APs or other networks, pricing of using such networks is very important [41]. Besides, keeping in view the important of data offloading, researchers are now investigating the feasibility of mobile cloud offloading [42]. However, in this paper, we do not focus on cloud offloading techniques.

D2D communication is also an effective data offloading solution. D2D, sometimes called as opportunistic communication [4], is a technology in which adjacent mobile devices set up a dedicated link. Direct exchange of data is performed via the D2D links [20]. D2D decreases the load on radio access network and the core network as well. In past few years, the research has been undertaken in utilizing Delay Tolerant Networks (DTNs) to implement mobile data offloading. DTNs enable delayed sharing of data among network neighbors using appropriate short-range wireless technologies such as Bluetooth, Wi-Fi, and Near Field Communication (NFC) [21]. Femtocells have also been utilized to provide mobile data offloading. A femtocell can connect the user to his/her service provider network via Digital Subscriber Line (DSL) or any other Internet Service Provider (ISP) [22]. Another technique in the similar context is to transfer traffic through fixed Wi-Fi APs, which is a formal solution to reduce burden on the cellular networks. In such technique, APs act as the backhaul links [19]. End-users located inside a Wi-Fi AP area utilize the capabilities of AP to exchange the cellular data. Wi-Fi APs generally provide the users a better connection speed and higher throughput than the cellular network [7]. However, the coverage area and mobility within the Wi-Fi AP cell is limited. Because deploying a Wi-Fi AP is cost effective compared to deploying a base station, many cellular providers such as AT&T, Verizon, T-Mobile, Vodafone, and Orange have started integrating an increasing number of wireless APs in their cellular networks to encourage data offloading [5].

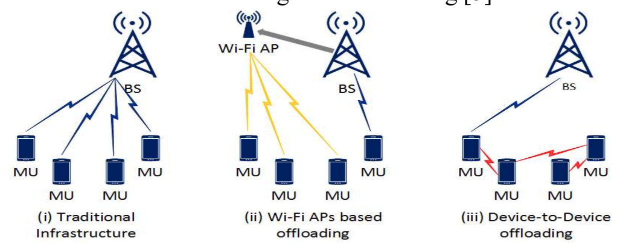



*Figure 1 Comparison between traditional infrastructure and different data offloading approaches*

In this paper, we discuss some of the data offloading techniques that provide various mechanisms to deliver cellular data off the grid. There are many options available to offload the burden from the cellular network to mobile devices [8] [19] [23]. Some of the offloading schemes based on Wi-Fi APs, Femtocell, and D2D are discussed in the subsequent sections.

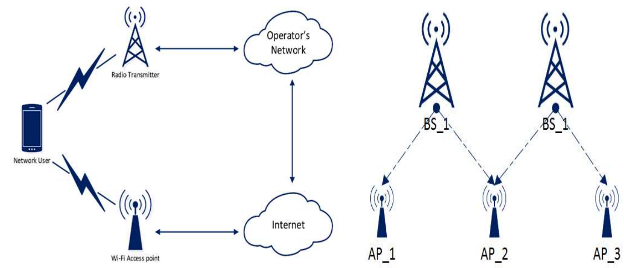
## III. Data Offloading Techniques

As discussed earlier, data offloading refers to the process of using underutilized network resources to deliver the data off the network, which was originally targeted for cellular network. Figure 1 depicts the basic differences between traditional cellular network infrastructure and the infrastructures with modifications to achieve the goal of data offloading. Figure 1(i) shows that in a traditional infrastructure, both the voice and data services are provided to users via macro cell Base Station (BS). No matter how many times a user requests a specific chunk of data, the user's request will be traversed through cellular core network. Figure 1(ii) depicts the Wi-Fi based offloading mechanism, in which cellular data is offloaded to those Wi-Fi APs, which are located near to the requester. Each time a user sends request for a previously requested data, requester is connected to the AP rather than macro cell BS. In Fig 1(iii), another technique named as D2D offloading is shown, which uses the dedicated user to user links to offload the cellular traffic. In D2D technique, the earlier requested data content is cached in a target user's memory and is delivered to other nearby users if they request for the same content [4]. All of these techniques are detailed in following subsections.

### A. Data Offloading via Wi-Fi Access Point

The key benefit of using data offloading via Wi-Fi APs is unlicensed band for radio transmission, thus making it impossible to interfere with cellular network traffic. Moreover, user devices already are equipped with Wi-Fi transceivers makes it simpler. Mobile operators are deploying such Wi-Fi APs in their points of interest like malls, markets, airports etc.

The benefits of data offloading to Wi-Fi networks have recently been studied and quantified [8], [22]. Approximately 80% of the traffic generated by the mobile users is indoor where Wi-Fi access is available frequently [24]. Therefore, the data traffic can be offloaded to Wi-Fi APs easily and effectively. For better Internet services experience, a large number of users are preferring Wi-Fi technology over cellular data services [1], as it permits the data traffic to be handed over from expensive licensed bands to free unlicensed bands (2.4 G Hz and 5 GHz) [1]. According to a study [8], deploying Wi-Fi network is comparatively less expensive than by expanding the currently




*(a)* *(b)*

*Figure 2 Mobile Data Offloading via Wi-Fi Access Points*

deployed base station network. Figure 2(a) shows a general architecture of how a cellular network operator connects a user to a Wi-Fi Access Point. User's data is offloaded to a Wi-Fi AP from where the user retrieves the data.

There are three approaches for MNOs to offload data traffic onto Wi-Fi networks, depending on the level of integration between Wi-Fi and cellular networks [1]. In one approach, whenever the user enters into a Wi-Fi hotspot area, the user's data services are transparently transferred onto Wi-Fi network bypassing the core network infrastructure. Hence, this approach is called *the network bypass* or *unmanaged data offloading* [1]. However, voice services are continued to transfer through the deployed cellular network infrastructure. This approach is simple and easy to implement as it requires no extra network deployment, but it has some limitations. The main drawback is that the operator loses the control of its users when device is in Wi-Fi hotspot area, which makes the service operator unable to provide the other subscribed services such as corporate Virtual Private Network (VPN), ringtones, etc. to the user. From the user's point of view, this approach is attractive because user has better experience of data services. The operator can implement this model of data offloading by simply providing an application in the users' smartphones, which is capable of automatically switching from cellular network data services to Wi-Fi interface whenever user enters into a Wi-Fi hotspot area.

Pahlajani *et al.* presented, *managed data offloading* in which the service provider places an intelligent session-aware gateway to avoid losing control on its subscribers [25]. The gateway is used to transfer the data traffic and hence helps in offloading the data from the network. In this approach, the integration of mobile network and deployed Wi-Fi network is not required. The *integrated data offloading* approach is implemented by the authors in [26] by coupling the Cellular network with the Wi-Fi network. This approach provides full control to the service providers over their subscribers. Moreover, it also enables the service provider to deliver any subscribed services to the user while the user is on the Wi-Fi network.

`In data offloading performed via APs, a Wi-Fi APs network is established in the cellular BS range, so that all APs could get sufficient signal strength from the cellular BS to serve the offloaded users efficiently. Multiple APs could work under a single BS as shown in Figure 2(b). If multiple BS discovers a single AP, the AP decides based on signal strength, to which BS it needs to be connected. Moreover, a single Wi-Fi AP can be served by multiple APs at the same time to increase the efficiency of the offloading and to achieve parallelism.

Two architectures for coupling of cellular and Wi-Fi networks are: (a) tight coupling and (b) loose coupling [1]**.** In (a), all the major functions of network, such as resource management, handover, and billing are centrally managed and controlled, and both the cellular network and Wi-Fi network function on a single backbone network. Alternatively, in (b), both networks are independent.

Some studies focus on delay-tolerant offloading schemes [26], [27]. Applicability of such schemes depends on assumption to have data that may not be time critical and can be transferred later. In such situations, uploading device can afford to delay the upload, up to a time threshold. The device waits to find a Wi-Fi hotspot, and if it does not find one, uploads the content using the cellular network. Even though this kind of offloading scheme can take off some traffic burden from cellular network, but cannot be deployed where user wants real-time response [18].

## *B. Data Offloading via Femtocell*

A femtocell is a small, low-power cellular base station, typically designed for use in a home or small offices. A broader term that is more widespread in the industry is micro-cell, with femtocell as a subset – also called femto Access Point (AP).

Data offloading via femtocells can be effective for a number of reasons. First, the primary usage occurs indoor such as in homes or offices. According to [1], 55% of cellular data usage occurs within homes vicinities, whereas 26% usage occurs in offices [28]. Thus, the MNOs avail the opportunity to offload their substantial data through femtocells. Second, femtocells allow a service to be deployed and managed by the network operator. Therefore, femtocells provide a seamless experience to users as the customer satisfaction still lies on the network operator rather than a third party. Third, femtocells can be deployed very quickly as compared to deploying a new macro cell base station. Traditional macro cellular utilizations take much longer due to site attainment, buying of radio infrastructure, and backhaul equipment etc. In a typical environment, traffic flows wirelessly to the femtocell from a user environment. Thus, the traffic goes through the Internet either to the MNOs core network or to any content provider. Whenever a user comes into the range of a wireless transceiver, deployed in a femtocell, the User Equipment (UE) automatically connects itself to the femtocell. Now the traffic, previously travelled between macro cell BS and UE, flows between femtocell and UE. This traffic includes the macro cell BS traffic as well the RNC (Radio Network Controller) traffic, which significantly reduces overall burden on macro cellular network.

Suppose a user requests for a content from a specific content provider, such as YouTube (Figure 3). The request traverses to the cellular core network via the broadband AP (e.g. DSL Wi-Fi AP) and femtocell gateway. The request reaches the core network, and requested content is provided to the user traversing back on the same route through which the request arrived. The content definition is cached at femtocell gateway (unlike the regular cellular network scenario) and next request for the same data content will be fulfilled without contacting the RNC and macro cell BS, resulting a quicker response time. A standard, named as SIPTO [29], enables the MNO to offload their core network traffic to the macro cell BS located closer to the network

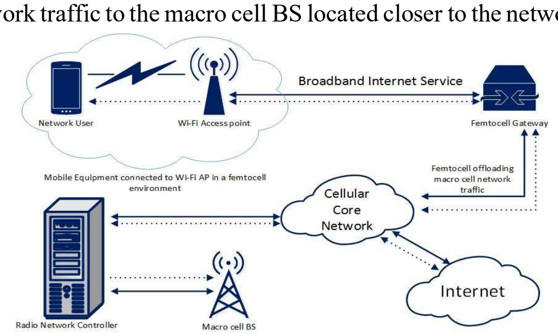



*Figure 3 Mobile Data Offloading via femtocell*

users. This allows the femtocell gateway to connect directly the Internet without connecting to cellular core network. Table 1 provides a comparison between Wi-Fi and femtocell offloading techniques.

*Table 1 Comparison of Wi-Fi and femtocell offloading techniques*

| Wi-Fi Offloading | Femtocell Offloading |
|---|---|
| Operates on unlicensed frequency band | Requires expensive license band with limited spectrum to operate |
| MNOs utilize larger free spectrum to tailor any Wi-Fi deployment | Deployment needs careful consideration due to expensive band |
| Cannot handle large amount of traffic due to quick battery drainage | Apprehend all traffic including voice and data packets |
| Can operate at higher data rates (as high as 600 Mbps) [30] | Operate at limited data rates |
| Cannot provide guaranteed QoS [18] | Provides users guaranteed QoS |

## C. Cellular-to-Mesh Network offloading

Most studies carried out on mobile data offloading schemes, emphasized that the network initiated offloading schemes require significant architectural enhancements [31]. One exception is Cellular-to-Mesh (C2M) offloading, which does not require extra ordinary changes. In C2M, the base station of a macro cellular network (i.e. LTE-A network) serves mobile stations. Each mobile station has an LTE-A and a Wi-Fi

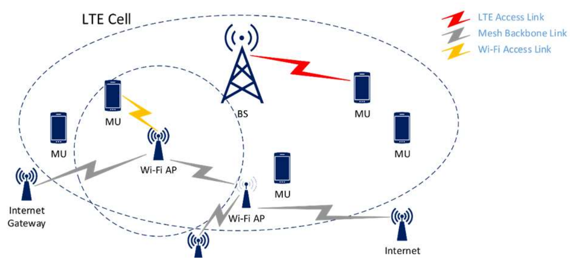



*Figure 4 "C2M" Mobile Data Offloading to Mesh Networks*

interface. The LTE-A macro cell covers multiple Wi-Fi mesh networks partially, which are managed collaboratively by the mobile users themselves. This decreases the burden of MNOs, and provides the operational flexibility to users. In practical offloading consideration, as shown in Figure 4**,** a user explores if the device is in range of a Wi-Fi mesh network. If yes, connection establishment is initiated which is handled by the macro cellular BS. 3GPP introduced a mechanism, ANDSF, to help the mobile users explore for the non-3GPP networks [32]. The Mobility Management Entity (MME) traverses the control signals between LTE-A BS and the core network. The sole purpose of MME is to handle the information about energy consumption by the BS and traffic requests [16]. Moreover, the information about capacities offered by the mesh networks is also maintained by MME. The offloading process, after MME processing, is forwarded to go through the process of dynamic network based traffic optimization, in which the gateway component named as PDN Gateway (P-GW) works as the mobility broker between 3GPP and non-3GPP networks. Now, the user is offloaded from the cellular network and provided the external packet data connectivity from a mesh network.

In C2M architecture, the number of Wi-Fi mesh networks depends on the MNO's requirement, if the mesh networks are deployed and managed by MNO. As depicted in Figure 5, a single MNO can own multiple BS and each BS can serve multiple Wi-Fi APs in range. Different MNOs own different APs as well as different APs mesh networks. Moreover, a single mesh network or a single AP from a mesh network can serve multiple MNOs. Therefore, if there is a community network (CN) that is created and managed by the residential users collaboratively, the CN mesh network can simply be leased by a MNO. A CN mesh network can also be accessed by multiple

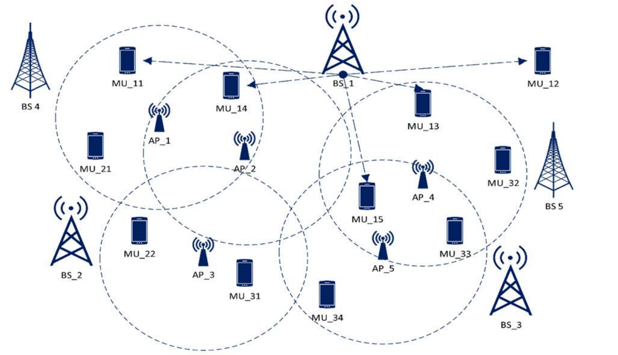



*Figure 5 Mobile data offloading via D2D links*

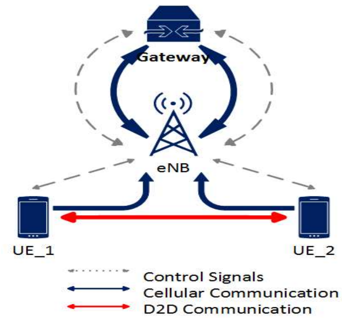



*Figure 6 Different MNOs own different APs*

MNOs, thus reducing the operational burden on the MNO. MNOs can simply utilize the mesh network without bothering maintenance and operational requirements.

Apostolos, *et al.* proposed an architecture, which aimed at reducing the costs on MNOs side [16]. The scheduling policy discussed in [33], is formulated at every macro cellular BS, which takes the offloading decisions independently. In the evolving 4G/5G cellular networks, some details must be considered to discuss the C2M offloading techniques. For example, there should be a framework, which maximizes the cellular offloading benefits, and reduce the cost for mesh networks. This type of framework must work on both the small residential mesh networks and the larger community networks. The C2M infrastructure must make it sure that all the mesh nodes participate in the offloading task.

## D. Data offloading via Device-to-Device (D2D) technique

D2D communication involves a direct interaction between two User Equipment (UEs) without accessing BS or backbone network [23], [34]. Usually, the communication takes place using unlicensed band (outband) or cellular band (inband). Generally, in cellular network, all communication must go via the BS even if both the mobile users are in the range of each other (Figure 6). The advantage of D2D communication is not only restricted to increase the efficiency but also D2D improves delay, fairness, and energy efficiency. D2D is suitable for low data rate services, like text messages [35]. The cellular communication and D2D use cellular band as cited in most literatures [36]. The interference mitigation between D2D and cellular communication is discussed with the cellular band [37-38]. Researchers have proposed an overlay band for D2D to avoid the problem of interference [20], [39]. Besides, some researchers have emphasized on the use of outband rather than inband to avoid the use of valuable cellular spectrum [40]. The communication in outband D2D is performed through controlled or autonomous techniques. Controlled techniques are adopted by BS whereas the autonomous techniques are adopted by users [23]. D2D is mostly performed via Wi-Fi Direct and Bluetooth,

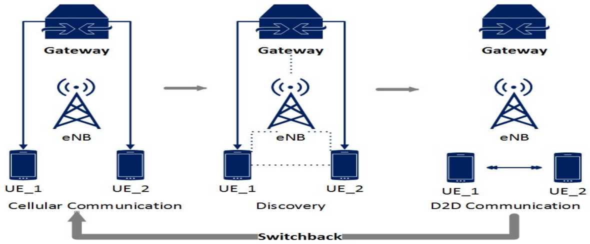



*Figure 7 Data offloading model using D2D communication*

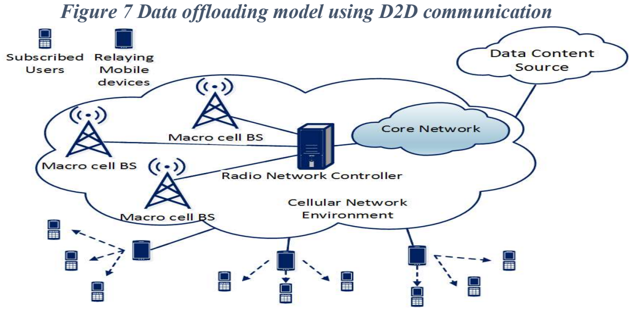



*Figure 8 Mobile Data Offloading via D2D*

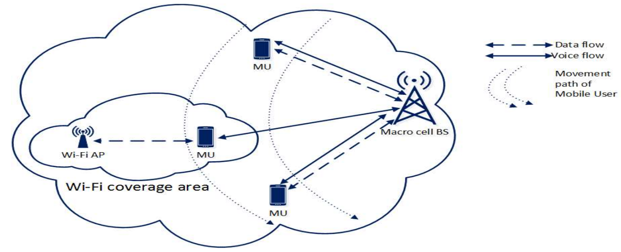



*Figure 9 Mobile Data Offloading via IP Flow Mobility*

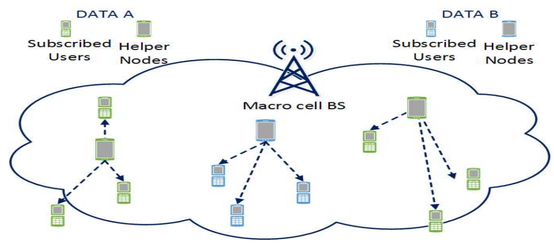



*Figure 10 Mobile Data Offloading via Delayed Tolerant Network*

and faces some issues in coordination of the two different bands. Figure 7 shows the D2D architecture based on cellular data offloading. It depicts that UE1 and UE2 are connected to cellular network, and are routing the cellular data through the Evolved Node B (eNB) and core network infrastructure. The gateway manages the routing table, issues the IP packets to the proper destination, and can assist in locating the other UE.

A gateway is able to detect the potential D2D traffic when it processes the IP header of the packet. As it detects the D2D candidates, it informs the UEs to start the discovery process. Discovery request is initiated by the device and is sent to other one using a signal sequence. When other device receives the signal, the discovery is made. As they find each other, a D2D session is created. As the session expires or devices go away from the feasible range of communication, the D2D communication is terminated and cellular data is reactivated.

Besides, as most of the information on mobile network is delivered via content service providers such as YouTube, Newspaper, games etc., the following procedure is followed whenever a user requests for some content: First, BS accepts the request from the mobile device and forwards that request to RNC. RNC processes and sends the request to core network, and the request is delivered eventually to Content Delivery Service (CDS), which then responds with the requested content. Same process is followed to deliver the content to mobile user but in opposite direction. In this whole process, the request passes through the BS, RNC, CN and then to content delivery network.

The service provider can take advantage of delay-tolerant network and provide content only to relaying devices or users (Figure 8). Relaying devices received the content from the BS station. The users can further disseminate the content to other subscribers. Subscribers are in the proximity of relays and are able to communicate using Wi-Fi or Bluetooth with relays. The major challenges in this technique include heterogeneity of data, nodes, different user's demands, priority of data, and the storage and battery constrains of user.

### *E. Data offloading via IP Flow Mobility*

IP flow mobility allows the mobile devices to switch between different radio access networks without interrupting the ongoing communication. The technology is in the phase of standardization by Internet Engineering Task Force (IETF). As shown in Figure 9, suppose a user in cellular BS coverage area has voice flow (straight line) and data flow (dotted line) simultaneously, while moving towards a Wi-Fi hotspot. On the discovery of Wi-Fi signals, the smartphone shifts the data flow from cellular BS to Wi-Fi AP. Upon leaving the Wi-Fi coverage area, the data flow is shifted back to cellular data service without any interruption.

### *F. Data offloading via Delayed Tolerant Network*

Disruption or Delay Tolerant Network (DTN) is a mobile data-offloading scheme in which some devices are chosen as helper devices [27], which are actually intermediate brokers between cellular network and subscribed users. Two types of nodes are considered in DTN data offloading: helpers and subscribers. First step is to choose the helper nodes, which are willing to participate in offloading process. Whenever a MNO wants to offload the data to an external network, the MNO chooses the helper(s) and the data to be rerouted. Then, the helper nodes disseminate the data to the subscribers within the proximity. Finally, the data is relayed to the external network to be sent to the subscribed user. D2D could be used to further propagate the data towards the intended receiver mobile station.

For instance, let us consider a two-hop network model (Figure 10). Here, two-hop network model means that there are only two-hop distance between the intended receiver and the cellular BS. First hop is from cellular BS to the helper node and second hop is from helper node to the receiver node. MNO decides to offload the data by following DTN mechanism and data is relayed to helper nodes. However, the intended receiver is not able to receive the data within a time threshold, and receiver directly starts the communication with the cellular network. There are two different types of data, A and B. The MNO's DTN algorithm will select the helpers H1, H4 and H5 for transmission of data A and H2, H3 for transmission of data B. Subscribers will receive their requested data via the appropriate helper nodes decided by the MNO.

### *G. Core Network offloading*

Figure 11 shows core network as the backbone of a cellular network. It consists of Gateway GPRS Support Node (GGSN) and Serving GPRS Support Node (SGSN). GGSN is a bridge between the GPRS network and external packet switch network. SGSN handles all the packet switching data in the network. Data offloading is done in core network by placing an offloading gateway between the core network and RNC. All the data traffic is transferred directly to/from Internet services through gateway bypassing the core network. If the generated request is for some content residing on some Internet service, gateway detects that request by using different attributes such as Access Point Names APN [1]. The gateway changes the traffic route and transfers the traffic to the closest Internet exchange point.

## IV. Conclusion

This paper gives a detailed overview of mobile data offloading schemes. In near future, mobile network operators will face a huge challenge in users' demands as the number of subscribers are growing. Experimental deployments of 5G networks made it even more challenging for the cellular companies to meet the ever-growing user requirements. To address these issues, we tried to provide an omnidirectional view to mobile data offloading techniques being used in the field. In our opinion, it depends on the operational requirements and business strategies of cellular companies, in deciding which scheme they want to follow. It also depends on the physical conditions and terrain of locality in which the services need to be provided as each scheme have its own pros and cons.

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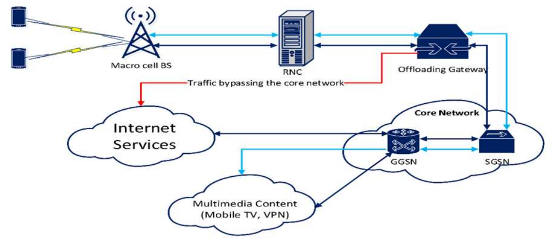


*Figure 11 Core Network Offloading*


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