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Mobile Data Offloading the Growing Need with Its Solutions and Challenges

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Abstract— From the last few years, the popularity of video, social media and Internet gaming across a range of new devices like smartphones and tablets has created a surge of data traffic over cellular networks. Device to device connectivity will give rise to a new universe of applications that will further create stress on network capacity [3]. In the next three years alone, it is accepted that data traffic will grow towards tenfold creating a tremendous capacity crunch for operators. While data revenues are expected to only double during this period, which will create a huge gap. As a result, different innovative solutions have emerged to manage data traffic. Some of the key technologies include Wi-Fi, LTE Small Cell and Relay, femtocells, DTN-based Network, and IP flow mobility. Therefore, telecom operators need to constantly review their implement traffic offloading mechanisms that will help them manage their network load and capacity more efficiently. This paper describes various data offload strategies and considers the challenges and benefits associated with each of them. This paper aims to provide a survey of mobile data offloading technologies including insights from the business perspective as well.

Keywords- *Mobile data offloading, Wi-Fi, LTE Small Cell, femtocells, disruption tolerant network*

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I. INTRODUCTION

Due to the rapid growth of smartphones and tablets, data traffic on the networks is on the rise from last few years. Upto 2015 it is expected that, mobile connections are to reach the 7.4 billion by surpassing the global population. As the popularity of data guzzling applications, social networking, video and online gaming are growing rapidly, will further drive data consumption and create tremendous strain on the networks. The cost of delivering data continues to rise more rapidly than revenues, which is expected to grow seven fold from $53 billion in 2010 to reach $370 billion3 (USD) by 2016. The Global mobile data traffic is expected to grow to 10.8 exabytes (1 exa = 1018) per month by 2016, this figure is an 18-fold increase over 2011 [1]. This unprecedented increase in data traffic is very much challenging for existing cellular networks. Mobile data offloading, refers to the use of complementary network technologies and innovative techniques for delivery of data which is different from originally targeted mobile/cellular networks. This alleviate congestion and make better use of available network resources. The objective behind this is to maintain quality of service (QoS) for customers, which also reduce the cost and impact of carrying capacity-hungry services on the mobile network. From the current scenario we should expect that mobile data offloading will become a key industry segment in coming future as the data traffic on mobile networks continues to increase rapidly.

The primary driver of mobile data offloading is clearly the rise of data traffic on cellular networks, which is causing congestion and ultimately degrading customer experience about quality of service. This rise can be attributed to a number of factors: 1) With the incoming of high-end devices such as laptops, tablets, and smartphones, which can multiply traffic. 2) The growth in average traffic per device, particularly due to increasing mobile network connection speeds and improvement in the features of mobile devices. Both these factors give rise to an individual's contact time with the network creating traffic problem. 3) The increase in mobile video content, which has much higher bit rates than other mobile content types, which enhance the users' viewing experience, large screen sizes and optimization of video for mobile devices contribute to the growth of video traffic. 4) The availability of mobile broadband services at prices and speeds which is comparable to those of fixed broadband, taking together with the increasing trend toward ubiquitous mobility are other contributing factors in growth of data traffic on mobile networks.

Now a days cost reduction, improving customer experience, and new business opportunities gives rise to mobile data offloading. So, because of this reasons, most mobile operators have introduced and started to implement a mobile data offloading strategy. So far, Wi-Fi and femtocells have emerged as the preferred offloading technologies. In addition, there are number of optimization approaches to relieve congestion on their networks. The main objective of this article is to provide artistic solution to mobile data offloading, covering both technological and business aspects.

Mostly, the data traffic patterns depend upon the type of device, its form factor, time of the day, type of application and a particular location of users. For example, the largest data consumption spread is for 3G routers, falling in the range of 1-16 GB per month, after that PCs, followed by tablets, while M2M average volume traffic is below 10 MB per subscription.

Many of the above factors combined with the increasing device diversity makes network capacity planning and load management even more complex. For optimizing the usage of the network elements and the traffic flow, mobile data offload is the solutions that can enable the optimum utilization of network. For radio spectrum Data traffic offload can help lowering the operating load on base stations. It also provides an opportunity for reducing usage costs by offloading data to alternate networks.

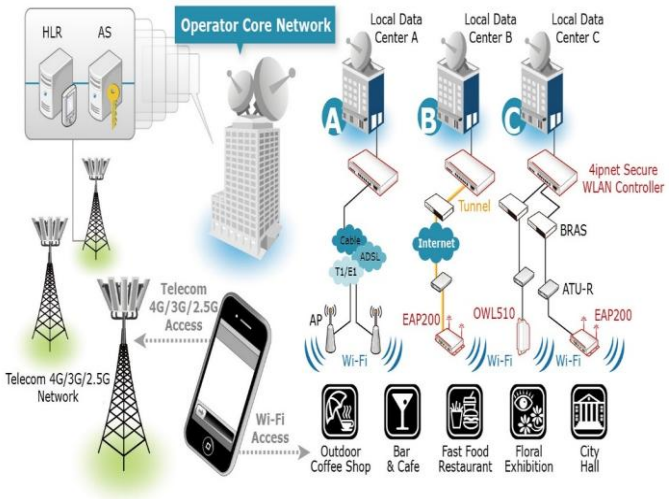

Figure 1. Traffic increases and need of Mobile Data Offloading

According to Research, in 2010, about 16% of mobile data was diverted from mobile networks; this is expected to grow to 48% by 2015. As data offloading can help operators avoid signal choking and revenue loss, it is emerging as one of the best options to manage network capacity and load in coming future. A robust data offload solution can provide telecom operators with the flexibility to control data flow across the network based on traffic patterns.

We cover the existing mobile data offloading solutions. Since Wi-Fi and femtocells have evolved as mature technologies, they are covered in relatively more detail compared to other emerging technologies. Business perspectives on mobile data offloading are presented, including vendor and operator strategies. The question of how to evaluate the effect of offloading is addressed, followed by a discussion of challenges associated with offloading. Finally, we conclude the Article.

II. SOLUTIONS FOR MOBILE DATA OFFLOADING

A. Mobile Data Offloading Via Wi-Fi

Wi-Fi stands for "wireless fidelity". It is a wireless connectivity solution based on IEEE 802.11 standards. Primarily it is used for broadband access in an indoor environments. Wi-Fi provides higher data rates but with limited coverage and mobility compared to conventional mobile communication technologies like Universal Mobile Telecommunications System (UMTS), high-speed packet access (HSPA), and Long Term Evolution (LTE). As Wi-Fi is undergoing a paradigm shift toward ubiquity and outdoor/city-wide Wi-Fi networks are very popular.

Now for our mobile data offloading, Wi-Fi comes as a natural solution. It is possible due to the built-in Wi-Fi capabilities of smartphones. Due to degradation of cellular services in overloaded areas and an increasing number of users are already using Wi-Fi to access Internet. From the service provider's point of view, Wi-Fi is attractive because it allows data traffic to be shifted from expensive licensed bands to free unlicensed bands upto 2.4 GHz and 5 GHz. The main approaches for operators to offload data traffic onto Wi-Fi networks, which are depending on the level of integration between Wi-Fi and cellular networks [4].

1) The *network bypass* or *unmanaged data offloading*:

In this case the users' data is transparently moved onto the Wi-Fi network, whenever they are in Wi-Fi coverage, which completely bypasses the core network for data services. On the other hand Voice services, continue to be delivered via the core network. While this approach seems attractive as it does not require any network equipment. But it has some drawbacks also, First, the operator loses visibility and control of its subscribers
whenever they are on the Wi-Fi network. Second, the operator is unable to deliver any subscribed contents such as corporate VPN, ringtones, etc. which losses revenue. Despite its disadvantages, this approach is adopted as an immediate offloading solution and control over data connectivity. A *managed data offloading* approach can be adopted by operators who do not want to lose control of their subscribers. This is achieved by placing an intelligent session-aware gateway.

2) An *integrated data offloading:*

This approach provides the operator with full control over subscribers as well as the ability to deliver any subscribed content while the users are on the Wi-Fi network. For this the integration of cellular and Wi-Fi networks is required so that a bridge can be formed between the two networks through which data flow can be established. For coupling cellular and Wi-Fi networks there are two architectures: loose coupling and tight coupling. In loose coupling, the networks are independent, no major cooperation is require between them. On the other hand, in a tight coupling system, the networks share a common core and majority of network functions such as vertical handover, resource management, and billing are controlled and managed centrally. The 3GPP I-WLAN standard [3] It provides a solution to transfer data between the mobile device and the core network through a Wi-Fi access network. The underlying concept is to establish a controlled tunnel between the mobile device and a dedicated I-WLAN server in the cellular network layered architecture of cloud computing. This architecture is commonly used to demonstrate the effectiveness of the cloud computing model in terms of meeting the user's requirements [10].

B. Mobile Data Offloading Via Lte Small Cell And Relay

The concept of small cells is similar to Wi-Fi, the only difference is that these connect to the radio network and it provides a higher coverage. This works both on licensed as well as unlicensed spectrum by offloading data traffic from the

cellular network and saving radio spectrum. The important thing about these low powered radio nodes is that, they are very useful to offload data in high density and high traffic areas. As this solution is deployed and managed by the operator, it is suitable with long-term strategy of mobile operators.

But it has its own challenges associated with installation complexities which can adversely impact capital and operating expenditures. An advantage of LTE small cells is that they can be easily deployed with low skilled workers. But they are in the early stages and not yet ready for mass deployment. Wi-Fi hotspots and LTE small cells will co-exist to address selective offload of data from various devices.

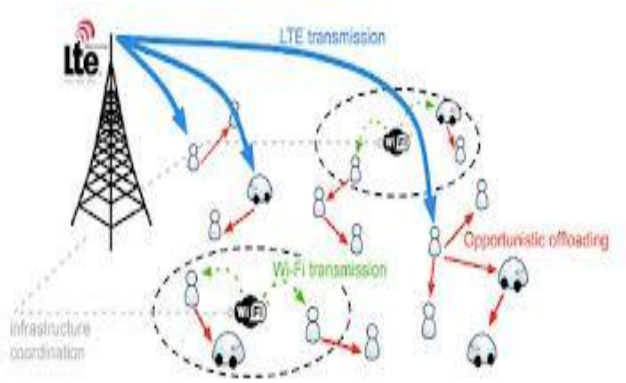

Figure 2. mobile data offloading via lte small cell

C. *Mobile Data Offloading Via Femtocells*

A femtocell is a small cellular base station which is mainly designed for indoor use i.e. for in a home or office. The service provider's network is connects via broadband (DSL) digital subscriber line. It allows the service provider to extend service coverage especially in areas where access would otherwise be limited or unavailable. Femtocells provide operators an improvement in both coverage and capacity, especially indoors. The concept of femtocells is applicable to which all are standard GSM, wideband code-division multiple access (WCDMA), World-Wide Interoperability for Microwave Access (WiMAX), and LTE. Femtocells provide a highly effective method of easing the traffic which is carried out by a microcellular network.

Data offloading through femtocells is effective because of number of reasons, some of which are as follows [4].

1) The usage occurs primarily 55 percent in the home and 26 percent occurs in the office [5]. Thus, the operators get the opportunity to offload heavy users through femtocells.
2) Femtocells represent an operator deployed and managed service, and hence provide a seamless experience to users.
3) Femtocells are able to deployed quickly, unlike traditional macro cellular deployments, which take much longer due to site acquisition, purchase of radio infrastructure and backhaul, etc.

In femtocell environments is connected to the user's broadband connection, then over the Internet and to the operator's cellular network or other Internet destinations. Whenever a subscriber comes into the coverage of femtocell, the user equipment (UE) automatically associates itself with it. Now traffic flows through the femtocell and the subscriber's broadband connection. The femtocell offloads both the Node and the radio network controller (RNC), which further reduces the load on the macro cellular network. Standard IP traffic offload (SIPTO) [6], is a new standard, currently under development. This technique will enables the operator to offload certain types of traffic at a network node close to the UE's location. The current standardization process mainly considers two types of policies for offloading which is based on: access point name (APN) and deep packet inspection (DPI).

The advantage of Wi-Fi is that it operates in unlicensed bands, operators have access to much larger free spectrum to cater for any size of Wi-Fi deployment, on the other hand, Femtocells require careful planning as they operate in licensed and limited spectrum bands. The advantage of Femtocells is that it can capture 100 percent of traffic, whether it is voice or data, and it is not bother about whether it originates from a feature phone, smart phone, or a laptop, but this is usually not possible in the case of Wi-Fi. Another one is that, femtocells can provide guaranteed QoS using licensed bands, whereas Wi-Fi cannot guarantee about QoS.

D. *Mobile Data Offloading Via IP Flow Mobility*

IP flow mobility [8] is a recently standardized technology in the Internet Engineering Task Force (IETF). By using this technology an operator can shift a single IP flow to a different radio access without disrupting any ongoing communication. For example, Consider a user connected to a cellular base station having multiple simultaneous flows a voice call and a file download moving into the coverage of a Wi-Fi hotspot. The terminal or network, upon detection of the Wi-Fi access, decides to shift the file download on the Wi-Fi network. If the user leaves the Wi-Fi coverage just for a single time, the file download is seamlessly shifted back to the cellular network. This IP flow mobility provides operators with a better data traffic management solution by selectively offloading heavy users and thus alleviate congestion on their networks. By this user also get its benefit because he is able to enjoy high bandwidth connections and a better experience.

E. *Mobile Data Offloading Via DTN-Based Network*

To cope up with explosive traffic demands on current cellular networks with limited capacity, Disruption Tolerant Networking (DTN) is used to offload traffic from cellular networks with high capacity and free device-to-device i.e. D2D networks.Current DTN-based mobile data offloading models are based on simple and unrealistic network assumptions which is heterogeneous. This model do not take into account the heterogeneity of mobile data and mobile users. A mathematical framework is required to study the problem of multiple-type mobile data offloading under

realistic assumptions. This mathematical framework should have certain characteristics like;

1) Mobile data are heterogeneous in terms of size and lifetime,
2) Mobile users have different data subscribing interests, and
3) The storages of offloading helpers are limited.

We formulate the objective which is required for achieving maximum mobile data offloading as a submodular function maximization problem with multiple linear constraints of limited storage, and propose three algorithms, suitable for both the generic and more specific offloading scenarios, respectively. This is needed for solving this challenging optimization problem. The designed algorithms effectively offload data to the DTN by using both the theoretical analysis and simulation investigations. The maun algorithm used for this DTN-based mobile data offloading are i) Greedy Algorithm (GA), ii) Approximation Algorithm (AA), and iii) Homogeneous Algorithm (HA).

In our DTN-based mobile data offloading system, some chosen users, which are called as helpers. They will have to participate in the offloading. Incentives for these users can be provided by using some micro-payment scheme, or the operator have ability to offer the participants a reduced cost for the service or they can offer better quality of service [9],[10]. The multiple-type mobile data offloading scheme should have to considered. There are two types of nodes in the system, known as offloading *helper* and mobile data *subscriber*, respectively. The service provider first chooses some users that are willing to participate in data offloading by itself. When it has a set of mobile data items which is required to be deliver or to be downloaded, the storage allocation decision is made, and it then transmits the mobile data to these chosen helpers through the cellular network according to the storage allocation policy they have. These offloading helpers then further propagate the data to other subscribers that are interested in the data by short range device-to-device communication. However, the subscribers after obtaining the data will not propagate the data further to others at all the time that are interested in them. If a subscriber could not receive the data from any helper after a specified duration which is called as "tolerable", which is related to the data lifetime, it can directly ask to receive the data from the cellular network. Then, subscribers, according to their interests, can obtain the corresponding data from these helpers by the DTN communication paradigm.

III. CHALLENGES IN MOBILE DATA OFFLOADING

There are some key challenges that arise while implementing a data offloading solution, especially offloading through Wi-Fi. It is necessary to addressed such challenges properly. The first challenge associated with data offloading is user experience. Service providers must required consistent user experience and service continuity. It is independent of the underlying offloading solution. This includes providing a transparent login across different networks which avoids disruptions in service continuity. A subscriber's authentication data is required to be present in the home location registry (HLR) in case of 3GPP networks, which cannot be accessed easily through non-3GPP networks such as Wi-Fi.

An integrated offloading approach with the SIM-based authentication procedure, by including an authentication, authorization, and accounting (AAA) server in the core network, will ensure transparent sign-on and seamless in-session handover between 3GPP and Wi-Fi networks. Further, as the Wi-Fi network does not have QoS guarantees, a QoS-drivenvertical handover from Wi-Fi to 3GPP networks, which is essential in order to ensure the QoS for users, especially when the Wi-Fi network is experiencing congestion. The network cannot force a device to switch on the Wi-Fi interface. This creates challenges for those operators who want to implement a Wi-Fi offloading solution. But currently no outdoor Wi-Fi planning tools are available in the market, creating challenges in optimal deployment of outdoor Wi-Fi access points. Also, If we want Wi-Fi offloading solutions on a large scale then it is necessary to address roaming agreements between different Wi- Fi networks.

In case of femtocells, a major challenge is interference management. By deploying femtocell a two-tier network is created, which result in creating interference either of co-tier or cross-tier. In co-tier interference, a femtocell causes interference to a neighboring femtocell, which may be severe in the case of dense deployments. And in cross-tier interference, when a femtocell causes interference to the downlink of a nearby macrocell user. Similarly, a macrocell user can cause interference on the uplink of a nearby femtocell. Resulting in the interference for both Uplink and Downlink.

One of the most important challenge in mobile data offloading, in deriving offloading solution is to distinguish between different user segments and network conditions [11]. Application, device, and subscriber awareness are required. All the decisions regarding selective offloading should be on-time basis and thus effectively managing the overall process is a crucial factor in mobile data offloading techniques.

IV. CONCLUSION

This article surveys about the current state of mobile data offloading. It is expected that mobile data offloading will become a key industry segment, essential for business point of view in the near future due to the unprecedented pace at which data traffic is rising on mobile networks. Data offloading provides both smart traffic management solutions to service providers for alleviating congestion from their networks and also provides them with new business opportunities.

It is quite but true evident that service providers are struggling to manage the data traffic explosion. But with this it is necessary to know that there are already many commercially available offloading options such as Wi-Fi offload, LTE small cells / relay nodes, femtocells, ip flow mobility, DTN-based Network, etc. However, data traffic is expected to continue to grow and to manage this growth efficiently. So, it is extremely important that operators start evaluating their capacity and networking requirements now. Operators should also start planning for network upgrades, and develop a roadmap for deployment and roll-out of LTE small cells / relay nodes and integrated Femto Wi-Fi solutions to address their medium to long-term needs.

Service providers must also note that different types of offload solutions will continue to co-exist, therefore they

need to carefully evaluate each of these options, or a combination of these based on their requirements, customer demographics and business objectives. A successful offload strategy will help to the operators to minimize capital and operating expenditures and also heighten quality of service while improving customer experience.

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