Challenges in Wi-Fi and Femto Offloading and Coexistence Issues

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Abstract. With reference to the increasing data transfer such as video, music, large files on mobile devices e.g. Smartphones, ipads and electronic tablets, there has been corresponding increment in data traffic in the cellular network as the number of users keeps escalating day by day. In the meantime, mobile internet is rapidly evolving towards embedded internet, expanding its reach from people to machines [1]. In fact, the wireless industry now expects 50 billion machine-type devices connected to the global network by 2020. This has brought a huge burden on cellular network operators. The most economical ways are rerouting the data through complementary technologies such as the use of Wi-Fi, Femto, Heterogeneous, opportunistic networks and so on. It is also noted that each of these networks has its pros and cons. These assist network operators to choose one or more systems over the other. This paper considers the challenges of these offloading networks in Wi-Fi and Femto networks and their coexistence issues with each other and other networks.

1. Introduction
The demand for higher data rate, lower latency and low consumption is directing mobile operators worldwide towards methods to handle the huge traffic and congestion that is often experienced by cellular networks. Many have suggested that offloading of huge traffic is the witty or advantageous way due to limited spectrum and cost of infrastructure. Offloading reduces the amount of data being carried on the cellular bands, freeing bandwidth for other users. It is also used in situations where local cell reception may be poor, allowing the user to connect via wired services with better connectivity. According to forecast global mobile data traffic will increase by 10-fold from 2014 to 2019 [2].

With respect to the initiator diversity of data offloading, we categorize data of loading techniques into four types viz data offloading through small cell networks, Wi-Fi networks, opportunistic mobile networks (HetNets) or Heterogeneous, respectively [3]. These are promising methods for now and the future. The evolution Wi-Fi and Femto networks are shown in figure 1. The cellular network functions in the Licensed spectrum and improving it involves the application of new and massive infrastructure which makes it economically unattractive. Most of these offloading technologies operate in the unlicensed spectrum and they require the installation of small user equipment (SUE) in vantage areas to offload the traffic.

2. Works done by other authors
Guillaume de la Roche and et.al talked about access method, comparison between methods, technical challenges and solution, and describe hybrid approaches [4]. While author’s focus on access control strategy as crucial aspect for operator to give preferential access to femtocells for their subscribers [5]. In
this article different mechanisms of access to femtocells were introduced and they did not consider the
general types and coexistence issues. In [6], the authors proposed an integrated architecture exploiting the
opportunistic networking paradigm to migrate data traffic from cellular networks to metropolitan Wi-Fi
access points and narrowed it traffic control and without many other challenges. Again, Alexandros
Kostopoulos and et. Studied the effect of Wi-Fi Offloading on Pricing Wireless Services and they
considered maximizing users’ rewards while meeting constraints on queue stability and energy
consumption. But they did not focus on the detailed challenges and coexistence with other networks [7].
Yuan Wu and el studied the economics and incentive of traffic offloading and they established that it has a
good potential benefits but could reduce the mobile unit data cost due to discontinuous coverage in Wi-Fi
networks. They emphasized that it is vital to consider how much profit in terms of the data cost reduction
[8]. Their reason was that offloading to Wi-Fi requires an arrangement between other operators who own
various Wi-Fi infrastructure and this will be critical in terms of revenue sharing procedures.

3. Wireless Fidelity (Wi-Fi)
There are a number of reasons that attracts mobile network operators(MNO) to be interested in Wi-Fi
offloading. First it helps operators to ease network congestion and improve the quality of service their
customers receive in high-density areas where network congestion is high. Operators can also “expand”
their network coverage, installing hotspots in areas with poor cellular coverage at a much cheaper cost.
Again operators can form partnerships with other businesses/ISPs/MNOs in some areas to let their
subscribers automatically offload onto the business/ISP/MNO Wi-Fi networks there by expanding their
network without making any investment in huge infrastructure. This will help them generate revenue by
giving other operators’ customers roam onto their Wi-Fi network [9]. The performance of an
802.11/802.11b Wi-Fi system is affected by several external wireless-specific circumstances in its
deployment. As with wired LAN systems, throughput and errors in Wi-Fi are product and setup dependent,
which in turn depends on the Wi-Fi design and deployment considerations. These challenges include

Frequency management: First network operator use radio frequency (RF) devices in a given area and
they must cooperate If they operate on the same frequencies at the same time. This makes their
transmissions interfere with each other’s receivers and the need for frequency management [10]. It is
therefore helpful for these operators to identify any existing interference patterns and define the preferred
locations of Wi-Fi APs. There are a number of factors that cause the batteries of devices such as mobile
phones, laptop etc. to depletes or run down quickly. These include low signal strength, brightness the LCD
back light, applications requiring regular updates, live wallpapers etc., the turning on of the Wi-Fi system
of such devices causes a high drain of batteries especially when is turned on for an ample of time [11].
The serious aspect is that if the Wi-Fi is on, it continuously detects any Wi-Fi router of Wi-Fi zone. Also
some mobile phones e.g. iPhone, Samsung Galaxy Note 8 etc. can be used as hotspots for many other Wi-
Fi devices but the challenge is that hotspot causes the phone batteries to run down quickly and causes
excessive heating in the device circuit [12]. Another challenge in this network is lack of mobility There
are no automatic handovers on Wi-Fi devices, so users cannot roam around in the building without
dropping the service from one AP to the other and as such users are compelled to reset their devices in
order to use it in new areas and this is often time consuming and does not encourage users. For instance, if
one is a hotel and using the Wi-Fi network, once he/she leaves the place or sometimes the floor, the
individual has to go through a setup process to be connected to another Wi-Fi network. It becomes
unbearable when one is in the market and wants to use cashless service to pay for the purchases, from one
trader to the other a new set and reset must be done each time. Again one has to get a specific user’s
access code for every Wi-Fi provider in the place. IETF (Internet Engineering Task Force) came up with
the specifications for MIP (Mobile Internet Protocol) and PMIP (Proxy Mobile Internet Protocol) to
address the mobility issues in Wi-Fi [13] but as of now not much has been achieved. Again some Access
Points (APs) have overlapping coverage to share the network, which would greatly increase the number of
devices competing for access and collisions in overlapping areas could lead to deterioration of the whole
network’s throughput. Additionally, Wi-Fi service is Slow; the data rate on the Wi-Fi–air interface is high, in excess of 50 Mbps. However, the actual user data rate is not limited by the air interface but by the ADSL backhaul to the Wi-Fi access point. Typical user data rates on public-access Wi-Fi services in hotels and airport are often lower than 400 kbps, far below the 54 Mbps on the typical Wi-Fi air interface [14] and makes the system slow and could result in delay jitter which is variation in the delay encountered by similar packets following the same route through the network [15]. The Wi-Fi speeds may slow down if the device is too far from the router. The farther one is from the router, the more unreliable the connection and its throughput will become. Another cause for slowdowns is the lack of bandwidth. If everyone is home and using their computers, phones and televisions for data applications, speedy Internet is being spread thin and shared across these multiple devices and often slows down if many people are trying to stream videos, games etc. from, YouTube and Netflix, [16]. Another area where the Wi-Fi data offloading encounters a challenge is in transportation. For vehicular systems, there is a greater advantage of this system as passengers with mobile phones and other devices are able to offload data despite few challenges. However, in areas such as slow and high speed trains, there often exists the experience of loss of packets, extreme slow downloading and uploading and interruptions or breaks of the signal in certain terrains along the journey. The worst of it is that it could take much time to receive data and others services. The cause of such a problem is the lack of sufficient Wi-Fi infrastructure and repeater stations in such areas. Additionally, as passengers are on board in airplanes, they are warned to turn off some devices as mobile phones, laptops which make use of Wi-Fi.

Another problem that the Wi-Fi systems encounters is congestion which is a network condition where traffic bottles up in queues to the point that it noticeably and negatively impacts the operation of the application when operators send huge loads [15]. The variable size of packets makes traffic prediction and guaranteed service provision difficult. So QoS is not always obtained. Congestion is usually caused by low memory, slow processors, bandwidth line and speed mismatch of devices [17]. Provision of QoS suffers as nodes operate on low frequency, Limited Battery Backups and where any node goes down, it may cause the frequent link breaks and end user suffers from poor quality of transmission [18]. As the packets go through the network, Packet loss could occur where they would be being dropped, get lost, or become corrupted while going through the network [15] and in such situations there is no Guarantee of Service. This is because Wi-Fi uses free open spectrum, so there is no guarantee that other Wi-Fi providers will not deploy Wi-Fi service in the same areas, using the same or adjacent frequencies and degrading the current Wi-Fi service. Therefore, there is no quality of service guarantee using Wi-Fi Hot-spot data areas in: Office buildings, Conference and meeting rooms. Furthermore, the solution to Wi-Fi offload is not straightforward [14]. Wi-Fi brings with it a new set of challenges such as how to automatically and seamlessly connect to cellular domains, how to integrate a Wi-Fi network with operator’s policy and charging systems, and so on [19]. There are also security implementations: security features, such as choice of encryption, impacts on AP throughput. The performance drops when using encryption and depends on the vendor and AP model; it may be anywhere from 10% to 25% and may go as high as 50% [9/10] and as such the architecture must also provide mechanisms to defend against the possibility of theft, to prevent denial of service, and to anticipate equipment failure [15].

4. Femtocells
These are cellular network access points that connect standard mobile devices to a mobile operator’s network using residential DSL, cable broadband connections, optical fibres or wireless last-mile technologies [30]. There are many reasons why customers and operators demand femtocells and the services, economies that can be provided by using them. Yet there are many challenges in achieving this potential. These are briefly highlighted here and examined in greater depth. There is the issue of co-layer Interference and this is describing as the unwanted signal received at a femtocell usually sent from other femtocells. This decreases the quality of its communication. Co-layer interference occurs mainly between immediate neighbours due to low isolation between houses and apartments. And the overall interference
can be higher than any of the independent femtocell power level if they are many [20]. Again there is Cross-layer interference especially in CDMA co-channel deployed two-layer networks, due to the fact that both femtocells and macro cells use the same frequency band and due to power control, sudden high transmitting powers can cause the appearance of dead zones, reducing the feasibility of these networks [21]. The power transmission by Femto Access Points (FAPs) consist of the FAPs traffic power and pilot power which shows the data and cell coverage area. The effect of interference on collocated FAPs and MBS is dependent on these power levels. A higher pilot power results in a larger coverage area and has higher chances of causing interference [29].

Again Service availability is one key quality metrics customers use to admire and is a benchmark based on the percentage of time the network is fully capable of offering service. Denial of service often goes on in the network element and causes service disruption to users. This may be caused by attacks usually is in the form of overloading the network element with large amounts of protocol traffic to the point that the network device can no longer function properly. In addition, the authentication Header (AH) provides little for confidentiality, since it doesn’t encrypt the packet in any way [22]. The figure 1 depicts a typical Femto set up.

5. Coexistence between Wi-Fi and small cell networks

Despite the individual challenges of these networks it is also of great concern that as these (the Wi-Fi and Femto exist together other challenges show up. First there is also the problem of interference management between femto and macrocells and mobility management and implementation issues (e.g. synchronization, signal processing and cost [23]). It is also known that if two identical signals are 100 % or 180 degrees out of phase they will completely cancel each another if combined. Since only Wi-Fi working in 2.4 GHz, it has the possibility to interfere with femto and ZigBee networks [24]. Again for users possessing dual-mode handsets endowed with both cellular and Wi-Fi capability (for example, the iPhone), it is hard to convince users to install femtocells since they already have Wi-Fi on these phones. On the contrary, significant numbers of cellular devices are not equipped with dual-mode capabilities and such users could be encouraging to go for femtocells for enhancing their indoor cellular coverage [25]. It is worth noting that technical issues related to the coexistence of Wi-Fi and heterogeneous cellular networks in unlicensed spectrum, such as efficient spectrum sharing and interference mitigation, have not been sufficiently addressed. Additionally, interference will range from macrocell to femtocell, femtocell to femtocell and femtocell to microcell [26]. Quality of service (QoS) based strategy is achieved by splitting the unlicensed spectrum between Wi-Fi and femtocell networks. But the split use of the spectrum between two systems prohibits a high cross-network throughput [26]. Another downside of the femtocell approach is that these are currently all operator specific, there is no simple choice for a building owner who wants to provide their customers with an operator wireless service can easily do that but Wi-Fi can easily provide that
because it is compatible with all phones and devices, regardless of the home network operator [27]. Some Femtocells use standard cellular radio technologies, therefore any mobile device is capable of participating in the data offloading process, though some modification is needed to accommodate the different backhaul connection [28]. On the contrary cellular radio technologies are founded on the ability to do network planning within licensed spectrum. Hence, it may turn out to be difficult, both technically and business wise, to mass deploy femtocell access points. Wi-Fi technology is different radio technology than cellular, but most Internet capable mobile devices now come with Wi-Fi capability.

6. Conclusion
In relation to the above studies it evident that there are numerous challenges that these offloading technologies encounter and these either results in the MNO not being able to maximize the returns with respect to huge capital investment or a lot of customers not being able to get complete satisfaction of their payments. Each technology has been analysed and the outcome is that both have challenges which mobile operator must tackle if their services will be attractive. The anticipated future 5G must be planned for and MNO must be poised to huge data offloading. From the elaborated problems, MNW operators can apply various means to achieve customer satisfaction by cooperating with other NW providers for use of infrastructure and also providing realistic incentives to customer groups.

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