Dynamic Spectrum Allocation in Femto based LTE Network

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***Abstract*—3GPP has introduced LTE Femto cells to handle the traffic for indoor users and to reduce the load on the Macro cells. However, the current LTE Femto based system is not able to utilize the spectrum efficiently. Hence, we propose a new spectrum allocation method which dynamically allocates the spectrum between Macro and Femto cells and dynamically inside Femto regions based on user traffic demands. This method is applicable only for enterprise cellular deployments in which, all Femtos are deployed in a planned manner.**

I. Motivation

LTE is a 4G cellular standarad proposed by 3GPP to provide high data rates. Due to very high penetration of mobile phones, the demand for bandwidth has been increasing exponentially. As per traffic statistics given by Huawei and Nokia-Siemens [1], [2], 60% of the voice and video traffic in cellular networks comes from indoor environments. Due to poor coverage of cellular networks inside buildings, data rates for indoor users are very low. To increase data rate and provide good coverage for indoor users, Femto (HeNB) is deployed. Since the cost of spectrum license is too high, efficient usage of the same is a must. At present the spectrum is allocated for Macro and Femto cells in a static manner [5], which is not efficiently put to use from the operators point of view.

II. Related Work

Radio Resource Management (RRM) module in LTE system is responsible for spectrum resource, channel allocation, transmission power, modulation scheme. Authors of [3], [4] proposed, how to allocate radio resources between Macro (eNB) and Femto Users. The Femto tries to learn the resource usage pattern of Macro based on their synchronization and adjust the resource block pattern based on the interference. The Femto finds a free slot from Macro and allocates the free resource block to Femto user. This is applicable only when there is less traffic. Authors of [5] proposed the approaches like cognitive radio resource and dynamic fractional reuse scheme to reduce the interference between eNB's via X2 interface and sub-carrier allocation.

Fractional Frequency Reuse (FFR) and Soft Frequency Reuse (SFR) are existing solutions for frequency reuse in LTE Femto based systems [6]. The drawback in FFR is that, it uses the frequency reuse factor three. So the whole spectrum band is not efficiently used. The drawback in SFR is that, it has the frequency reuse factor one and hence it uses the whole spectrum efficiently. But, if the user density is not high in a particular region, the spectrum band used in that region will be wasted. The spectrum allocation is also static. To make an efficient spectrum usage, we propose a dynamic allocation of spectrum which overcomes the drawbacks of FFR and SFR. The brief explanation on the proposed dynamic allocation of spectrum is given below.

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III. Dynamic Spectrum Allocation

The dynamic spectrum allocation is done at two levels:

1) **Dynamic Spectrum Allocation between Macro and Femto:** Here, we are proposing dynamic spectrum allocation between Macro and Femto. For example, if the users in the Femto are low and the users in the Macro are high, then Femto Gateway (F-GW) which controls the HeNBs, will shift the spectrum dynamically from Femto to Macro and vice versa, as shown in Fig 1. The below calculation explains how dynamically the

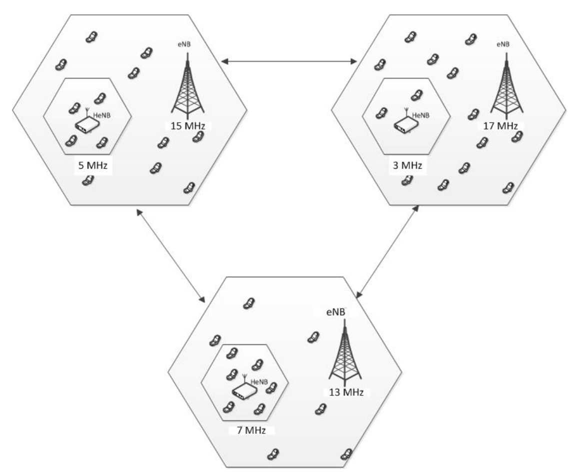

Fig. 1. Dynamic Spectrum Allocation between Macro and Femto

spectrum can be allocated between Macro and Femto. The total bandwidth provided is 20Mhz where as Macro bandwidth is 15Mhz and Femto bandwidth is 5Mhz. One Mhz bandwidth is equvialent to six Resource Blocks (RB). So, Femto has 30 RBs in which minimum one RB must be allocated to the requested user. Assume minimum number of users in Femto is 10. So, minimum of 12 RB are sufficient, where roughly 18 RBs are unused. Now this unused RBs can be used by Macro eNB.

2) **Dynamic Spectrum Allocation inside the Femto region:** Here, we have proposed another dynamic spectrum allocation, in which the spectrum will be allocated dynamically depending upon the user's requests inside the Femto as shown in Fig 2. In this figure, we have taken three Femtos in a Macro cell. The region inside Femto is further divided in to three regions namely inner, middle and outer region as shown in Fig 2. The reason for further dividing regions inside Femto cells is to avoid interference with neighbouring Femto cells.
In Fig 3, the white shaded region (F2) shows the high user density. So different Femtos have different high user density regions. Consider the top Femto (F3) in Fig 3, where inner region (w1) is more crowded when compared to middle region (w2). In this case, we split the w2 spectrum of the middle region into different sub-bands namely w20,w21,w22,. . .,w2N and these sub-bands will be given to inner region (w1) according to its requirement. Even after getting all the sub-bands from middle region (w2), if the combined spectrum (w1 + w2) is not sufficient to serve the users then outer region's spectrum (w0) will be further divided into sub-bands and these sub-bands will be given to inner region (w1+w2).

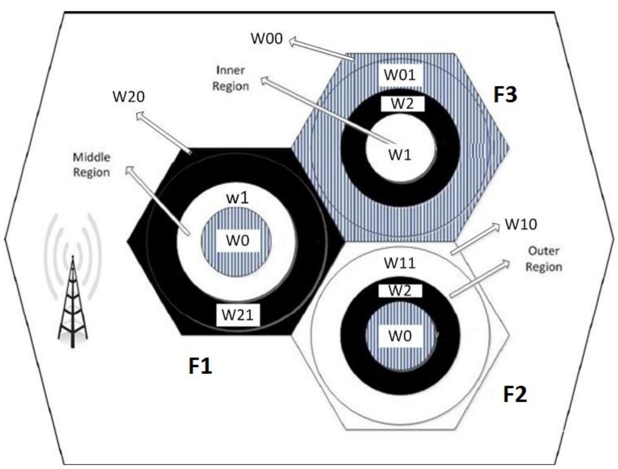

Fig. 2. One Macro and three Femto Scenario

But, we cannot allocate the spectrum in the same manner (Fig 3) if the outer region white (F2) of the Femto is more crowded because in this case, the inner and middle regions of the Femto will provide their sub-bands to outer region. So, it will create interference with the outer regions of neighboring Femtos. To minimize the interference, we further divide the spectrum band (w1) allocated to outer region into two different sub-bands namely w10 and w11 and we also divide the outer region into two regions namely, edge region and non-edge region. Then, we allocate w10 to edge region and w11 to non-edge region. Now all the sub-band aggregation will be done in non-edge region and the edge region will use only w10, irrespective of the user density in this region. By doing this, we can control the interference of spectrum sub-bands of inner and middle region with the spectrum band of the outer region of the neighboring Femto. Then follow the same procedure as explained above for top Femto F3. Hence, the whole spectrum is used more efficiently when compared to SFR.

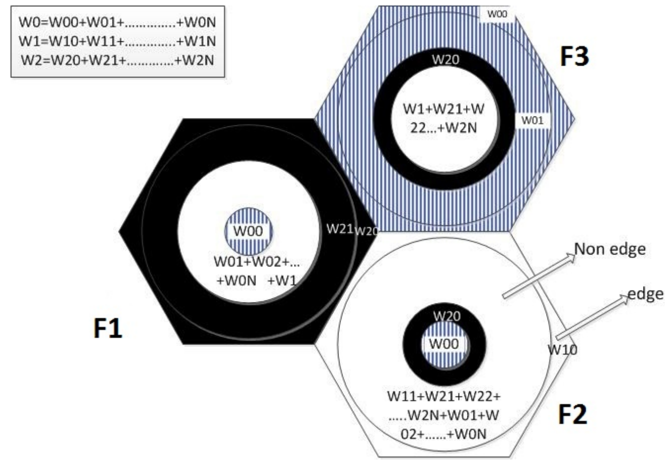

Fig. 3. Dynamic Spectrum allocation inside Femto region

IV. Conclusion

Dynamic allocation of spectrum between Macro and Femto enhances the efficiency of spectrum allocation and provides high data rate to the user. The user will continue to get high data rates even if user density increases. This dynamic allocation of spectrum will avoid the cross-tier interference. Future work comprises of testing the performance of the proposed dynamic allocation schemes through simulation experiments and comparing the results with existing FFR and SFR schemes.

V. ACKNOWLEDGMENT

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