A Study on Dense Cellular Networks Using Graph Coloring

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Abstract - "Anywhere" and "anytime" are the ultimate properties of wireless communications. To achieve these goals, frequency reuse is one of the most important concepts that has to be considered in high user density networks providing various broadband services. This paper proposes an efficient resource allocation algorithm called Group Based Graph Coloring (GBGC) that exploits unused spectrum areas. To achieve this, GBGC groups the users into blocks with each having a leader (Group Head) that connects its cluster members to the base. The Group Head employs a graph coloring algorithm to tether other users to the base station, through the available unlicensed TVWS band. The simulation results indicate that the proposed algorithm achieves a good performance/complexity tradeoff that provides a promising alternative to the case of having only direct communication between the cellular users and the base station.

Keywords- components; Wireless; TVWS; Dense Areas; Clustering; Tethering, D2D

I. INTRODUCTION

One of the most important properties of wireless technology is the ability to operate anywhere at any time. In densly populated areas, such as stadiums and conference halls, a large number of wireless devices contend for the same limited spectrum. The cellular spectrum band is not sufficient to serve all of those mobile users are blocked, while others receive a reduced quality of service. Over the world spectrum is a scarce and its licensed use cannot address the increasing user and emerging the unused-unlicensed spectrum bands, it is possible of new services. Thus, the opportunistic exploitation of unused spectrum bands has received a lot of attention in the recent years. About the unlicensed frequency band, a term commonly used is "frequency white spaces". A portion of this frequency band may be still used by television (TV) operators, but it is considered to also be used by other (secondary) users. Those portions of frequency bands are called television white space (TVWS) bands are called television white space (TVWS) bands and are related to the 50-700 MHz bands [1] Many solution have been proposed to solve the problem of blocked cellular users in dense areas. Some of these solutions concentrate on shortening the distance between the base station transmitter and the receivers by adding more base stations (BSs) [2].

In terms of resource allocation , the objective is to exploit the available channels/resource blocks in such a way that will maximize each user's SINR (which reflects the actual throughput per user) and at the same time will minimize the co-channel interference that is generated due to the allocation of the same resources to different links within the coverage area. This can be done by considering graph coloring algorithms that either minimize the number of required resources (colors) to cover a specific interference graph such that each node receives the minimum required channels [3] In this paper, we introduce a reduced complexity – heuristic algorithm for efficient distribution of the available TVWS channels among the blocked users with reduced complexity. Those blocked users are mainly grouped into small groups; each group has a group has group header connected to the cellular base station. The main contribution of the algorithm is that it distributes the available TVWS resources using graph coloring among the small groups to achieve a higher Quality of service (QoS) with optimum power efficiency.

The rest of this paper is organized as follows: Section II describes the system model. Section III describes the proposed algorithm. Channel allocation in secondary cellular networks are evaluated in Section IV, and Section V concludes the work.

II. NETWORK MODEL

The main challenge for this paper related to distributing the resources of the available TVWS channels among the beyond each cluster. In a similar system setting in [4], the authors consider all the available TVWS channels and use the whole amount of their resource blocks inside each cluster group and they minimize the transmission power of each node to guarantee the low levels of interference among neighboring clusters .The minimization is a concern in high user density networks because it may lead to an unreliable connection between the Group's head and its slaves. This paper proposes an algorithm called Group-Head Coloring (GBGC) for distributing the available TVWS spectrum resources over the groups using the graph coloring theory, to ensure that resources are distributed in an optimum way and that each user's spectrum requirements are satisfied without having user signals interfering with each other.

The work assume an LTE cell with its BS located in the centre, with U users distributed randomly. Some nodes from U are selected to be Group-Head that communicate directly with the BS, and the remaining users are considered to be 'slaves'that communicate with the BS through a Group -Head. The set of Group -Head is denoted by H and the set of slaves is denoted by S, such that $S \cup H = U$ and $S \cap H = \emptyset$.

This approach creates a two-layer transmission scheme, where layer 1 consists of the BS-Group -Head connecting through LTE band and layer 2 consists of Group- Head slaves connecting with the Group-Head slaves connecting with the Group-Head through the TVWS band.The available resources in the LTE layer consist of M channels, and those in the

TVWS consist of N channels.It is assumed that each node can operate on both bands with OFDMA access technology. Each node uses appropriate context information to determine the TVWS bands to be used and the power level at which the user will be allowed to operate in order to avoid harmful interference with incumbent systems and at the same time to minimize spectrum fragmentation and optimize QoS [5]. There is a general parameter K_{ij}^n, which corresponds to the transmitter node for the first subscript j. The superscript n corresponds to the operating channel. In most cases in this paper, j refers to the hotspots and i refer to the slaves. The amount of bandwidth that can be allocated to a user corresponds to a resource block or multiple of resource blocks in a LTE network [6], but for TVWS network each user can be served by 1 resource block. We assume that the available resource blocks can be represented by a pool of colors (B). This pool is initially full, but it gradually decreases at each coloring stage until it becomes empty, in which case it is then reset and the reuse factor simultaneously increases. The system model is represented in Figure 1. Between any two nodes *i* and *j*, the average channel gain to noise power ratio across each resource block n is denoted by g_{ij}^n. Each group can use a set of available resource blocks in the uplink under the condition that it does not cause any interference o another group head.
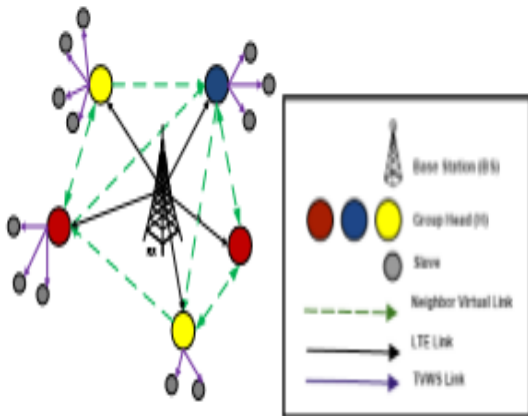

Fig. 1. Group-Head based on Graph Coloring Algorithm

The link variable y_{ij} specifies whether there is a link between the nodes i and j. In the event that $i \neq j$, y_{ij} is equal to 1 if *i* transmits directly to *j* and it is 0 otherwise. The term $y_{ij}=1$ indicates that node *j* is directly connected to the BS (i.e., *j* is a Group-Head) and $y_{ij} = 0$ indicates that *j* is a slave. The U x U matrix Y contains all such variables. The resource block (RB) variable x_{ij}^n indicates if RB n is being used by the (*i,j*) link or not, where each channel contains 13RBs as described later. The parameter x_{ij}^n is equal to 1 if RB n is being used by the (*i,j*) link and it is 0 otherwise. The power variable p_{ij}^n indicates the power allocated to the n'th channel on the (*i,j*) link. The matrices P and X contain the power and channel variables, respectively (with dimensions U x U x max (M ,N)).

For the purpose of this paper, and based on data availability, we consider a similar environment to that of downtown San Francisco, where the BS can operate on Channel 26 (of TVWS frequency bands 542-548 MHz) for mode I devices, while in some regions Channels 22 and 24 (frequency bands 518-524 MHz, and 530-536,resp.) are also available for mode-II

devices. The Federal Communications Commission (FCC) has defined 40 mW as the maximum transmission power for mode-II devices on each of these channels [7].

III. GROUP-HEAD BASED ON GRAPH COLORING ALGORITHM

Grouping refers to the process by which the Group-Head and its slaves are identified. In this paper, we use the K-means clustering technique which is a well-known method in datamining for partitioning data into Q clusters based on similarity metric between the data point and the cluster [8]. Generally the resource allocation for the network can be formulated as a global non-convex problem that grows in complexity as the number of nodes increase. Instead, in this paper a simplified resource allocation algorithm based on graph coloring is proposed that consists of two main steps, The first step in the process involves determining the configuration of the nodes before the available network resources are distributed. This step determines the network Links matrix y. summarized by the flowchart. Steps 2 through 4 identites if such a configuration of nodes is feasible in terms of resource allocation and maintaining user service requirements.If the configuration of nodes is not feasible, the available channels to different users?' In regular cellular networks, repetitive patterns are used in which every channel is periodically (in space) assigned to nodes with specific distances. For example in a fully developed hexagonal structure, In this figure channel assignment is defined by two shift Variation in the parameters that should lead to a better configuration.
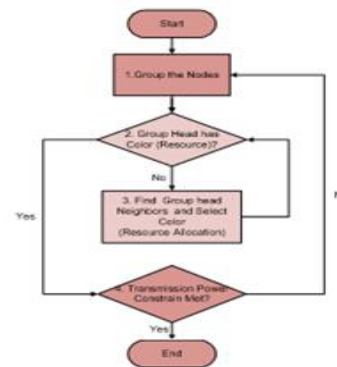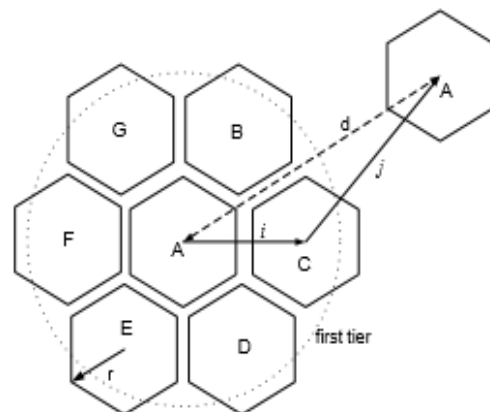

Fig. 2. Proposed Algorithm (GBGC) Steps

Fig.3.Spatial frequency reuse

IV. CHANNEL ALLOCATION IN SECONDARY CELLULAR NETWORKS

An interesting question for a network planner in TV white space spectrum is ,how to assign t parameters $K=i^2 + ij + j^2$ determines the Fig.3.Spatial frequency reuse in a fully developed hexagonal cellular network .cells similar letter share the same channel. No channel sharing exists among the first tier neighbors. Shift parameter ,i ,j defines how channel repeats in space. Frequency-reuserate of each channel across the network [9]. In contrast, the same method can be used in TVWS only for those channel that are available in every cell (which are very few). The availability of channels is significantly a function of location. Furthermore, channel are shared with primary users, here TV broadcasters, which is a different network with a variant requirement that makes network planning non-homogenous. The quality of each channel (in this context defined as signal to noise and interference ratio) depends on primary- to- secondary interference and is significantly channel and location dependent [9].Therefore, any optimal channel allocation mechanism must consider these irregularities in the optimization process. Let define C as the set of all permissible white space channels [10], our focus is toward TV white space channels and therefore C= {2,3,…..,36,38,……51} with each channel representing 6 MHz band with in V/UHF band (based on USA standard [11]. Since more than one channel can be assigned to each cell, the overall network though put depends on how many channels are utilized in each cell without severe mutual interference. Therefore an optimizing algorithm toward maximizing the network throughput (either average or worst-case user throughput) can be set differently according to the level to the level of details involved,

V. RESOURCE ALLOCATION FRAMEWORK

We propose a scheduling policy that allocates two types of resources to cellular and D2D flows- (a) Channel Access, and (b) Receiver Access. D2D traffic is transmitted in an opportunistic fashion by accessing only those system resources unused by conventional cellular traffic. At the same time, the policy seeks to optimize the resources allotted to cellular traffic while satisfying the delay constraints so that a large fraction of the resources can be utilized for D2D transmission.

Channel Access: We propose a hierarchical architecture for channel allocation in which priority is given to the BS, ANs and D2D transmitters in that order. Specifically, the BS is first allowed to schedule its transmissions on any of the *n* available channels. The Ans then schedule their transmissions on channels which do not interfere with BS or other AN transmission. Finally, D2D transmission are restricted to those channels which do not interfere with all BS and AN links using the same channels. We do not specify the exact scheduling policy to be used for channel allocation within ANs or within D2D transmission. Instead we consider the class of all policies that allocate channels such that transmissions do not interfere with each other.

Receiver Access: For scheduling receiver access at the user devices, again, cellular traffic is prioritized over D2D traffic. A users receiver switches to Cell mode whenever the BS or some

AN has some cellular packet scheduled for delivery to the user. The following sections describe the resource allocation algorithm in detail .In every time slot, events occur in the following sequence

- Arrival of packets and association of users with ANs,
- Resource scheduling and signaling at the MAC level,
- Packet transmission,
- Queue update

The difficulty of managing these networks is rooted in the heterogeneous and chaotic nature of the base-stations. Macro,micro, and femto cells have constrained resources, capabilities, and environmental settings which can vary along a number of axes:
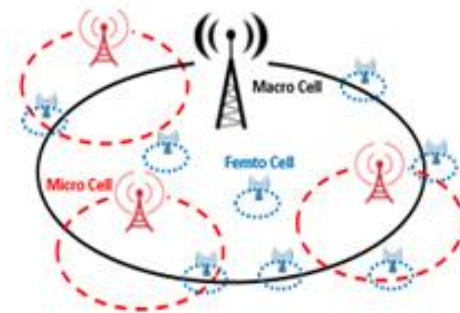

Fig. 1. Heterogeneous Cellular Networks (HCNs) are characterized by the co-existence of different types of cells which vary in their allocatable power, service range, and backhaul capability.

Backhaul Bandwith: There exists a high degree of variability in each cells backhaul capability [2]:most macro cells today have copper T1 links, micro cells haveDirected microwave links back to aggregation stations, and user-deployed femto cells utilize user-owned broadband connections. With LTE supporting up to 100Mps in the downlink, cells backhaul capabilities are becoming constraints on a cells ability to meet traffic demand.

Total Transmit Power/Coverage Range: While macro cells will operate up to FCC spectral limits, femto and micro cells are limited both by cost limitations and health concerns of the general population ,leading to at least an order of magnitude difference in total transmit power capabilities of different cells. As a result of varied transmit power abilities and geographical placement (i.e .on top of a tower, inside a building, etc.),the functional coverage area of every cell can vary from the size of a single home to an entire town. Without careful power control, operators run the risk of causing excessive amounts of interference between cells and choking off the entire networks capacity.

Frequency Range: While many operators posses narrowband spectral slices which range from 900Mhz to 2GHz, smaller cells may be equipped only to utilize certain portions of the total available spectrum order to lower deployment cost. As a result, every cell may only be able to utilize a certain number of frequency sub channels.

Local User Density & Demand: The density of users can vary wildly across time and space (i.e. cities during the day and at night). Additionally, every user can have very different rate demands, ranging from voice (low rate) to streaming video (high rate).

VI. CONCLUSION

This paper addresses the problem of contending for scarce band with resources in high user density cases such as those related to events like the Hajj. To solve this problem, a Group Head based on graph coloring algorithm GBGC is proposed. This solution utilizes the benefit of the TVWS band. The joint problem of channel allocation and receiver time allocation to device-to-device (D2D) flows and conventional cellular flows in a dense network setting. As cellular providers transition from single-tier networks to more heterogeneous deployments, resource allocation will become more challenging.it can be used throughput, backhaul constraints, and co-channel intererence. The benefits of Sorting Hat were illustrated through several numerical examples, which showed a 30-100% improvement in median user throughput resulting from optimizing user-cell association, power control, and channel assignment jointly rather than separately. The lower total power is consumed with a mechanism that is aa good tradeoff between performance and complexity.

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