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Cognizant Radio Resource Control in Downlink OFDMA Cellular Relay Network

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Abstract:

Relaying and orthogonal frequency division multiple access (OFDMA) are the accepted technologies for emerging wireless communications standards. The activities in many wireless standardization bodies and forums, for example IEEE 802.16 j/m and LTE-Advanced, attest to this fact.

The availability or lack thereof of efficient radio resource management (RRM) could make or mar the opportunities in these networks. Although distributed schemes are more attractive, it is essential to seek outstanding performance benchmarks to which various decentralized schemes can be compared.

Therefore, this paper provides a comprehensive centralized RRM algorithm for downlink OFDMA cellular fixed relay networks in a way to ensure user fairness with minimal impact on network throughput. In contrast, it has been observed that pure opportunistic schemes and fairness-aware schemes relying solely on achievable and allocated capacities may not attain the desired fairness, e.g.,proportional fair scheduling.

The proposed scheme is queueaware and performs three functions jointly; dynamic routing, fair scheduling, and load balancing among cell nodes. We show that the proposed centralized scheme is different from the traditional centralized schemes in terms of the substantial savings in complexity and feedback overhead.

1.INTRODUCTION:

Orthogonal frequency division multiple access (OFDMA) is the envisioned air-interface for 4G and beyond wireless networks mainly due to its robustness to frequency selective multipath fading, and the flexibility it offers in radio resource allocation [1].

However, in order to truly realize ubiquitous coverage, the high data rate opportunity in OFDMA schemes has to reach to user terminals (UTs) in the most difficult channel conditions, for example, cell edge UTs. Therefore, relaying techniques have been earmarked as the best option to address this problem since relay stations (RSs), with less functionality than a base station (BS), can forward high data rates to remote areas of the cell, and thus overcome the high path losses, while maintaining low infrastructure cost [2]. Hence, the future network roll-out is expected to include various forms of relays. We consider networks enhanced with fixed digital relays deployed by service providers in strategic locations.

The combination of relaying and OFDMA techniques has the potential to provide high data rate to UTs everywhere, anytime. In contrast, conventional opportunistic schedulers will rarely serve UTs with bad channel conditions such as cell edge UTs; this defeats the notion of ubiquitous coverage targeted in future networks, and exposes the importance of fair RRM algorithms to facilitate location-independent service, especially when users subscribed to the same service class are charged similarly regardless of their channel conditions.

In this paper, we propose a novel formulation with a novel low-complexity centralized algorithm that achieves a ubiquitous coverage, high degree of user fairness and enables intra-cell load balancing in downlink OFDMA-based multicell fixed relay networks.

The proposed scheme utilizes the opportunities provided in channel dynamism, spatial, and queue and traffic diversities. We show that the scheme provides an efficient tradeoff between network throughput and fairness to all UTs, even to those at the cell edge. We demonstrate the learning ability of the dynamic routing strategy.

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We also show how substantial savings in complexity and feedback overhead can be attained distinguishing the proposed scheme from traditional centralized schemes. To the best of the authors' knowledge, this contribution is unique among the works presented so far in the literature.

2.SYSTEM DESCRIPTION:

In the multi-cellular network, the BS serves UTs either directly or through RSs in a cell. All resources are available in each cell resulting in aggressive resource reuse. The total bandwidth is divided into subchannels, each composed of a set of adjacent OFDM data subcarriers1. The serving BS and each of the RSs in a cell are equipped with user-buffers. User packets arrive at the corresponding BS buffer according to the traffic model. The channel fading is assumed to be time-invariant within a frame duration.

We first consider a generic scenario that is not restricted to a specific geographical deployment of RSs. Thus, potentially, any UT can be connected to any combination of the RSs yet in only two hops as RSs are not allowed to exchange user data. Such unconstrained relay selection or 'open routing' exposes the ability of our routing strategy to dynamically settle for the best route(s) for each UT given an arbitrary relay deployment.

We also present a constrained mode of operation for the routing strategy where geographical relay deployment can be exploited offering substantial savings in feedback overhead. In the proposed scheme, a UT can receive from a group of nodes (BS and/or RSs), and any node can transmit as well to multiple destinations, simultaneously, on different orthogonal subchannels. In addition, any RS is assumed to have the ability to receive and transmit concurrently on orthogonal subchannels.

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A practical concern might arise if orthogonal transmit and receive subchannels happen to be close in frequency band. Since RSs are fixed, they can be deployed with two antennas a directional antenna for the feeder link from the BS and an omni-directional antenna to the UTs, thus, alleviating such concern. Load balancing is usually incorporated with the connection admission control mechanisms in conventional cellular networks and it refers to the hand over (hand-off) of some UTs between adjacent cells to distribute the traffic load among BSs network-wide while maintaining users' quality of service (QoS). Although this load balancing function will be an integral part of any prospective RRM scheme, in the literature of OFDMA-based relay networks, researchers often associate the term "load balancing" with a different function which aims at distributing the load evenly among the cell nodes. The number of OFDM subcarriers handled by a node is often employed in literature as a good estimate of its traffic load [9], [17].

As such, an even distribution of subcarriers balances the load among the nodes cell-wide [9], [18]. Although the scheme in [19] aims at achieving the conventional load balancing among cells using boundary RSs, it employs the number of subchannels as a measure of the traffic load. A balanced traffic load reduces the packet processing delays at the regenerative relays. Moreover, load balancing results in the so called 'relay fairness'; a fair utilization of the energy sources of the RSs if the network employs battery/solar-powered RSs [20]. The following section describes the proposed scheme in details and explains how the load balancing function is integrated.

3.THE BS'S JOINT ROUTING AND FAIR SCHEDULING:

The objective is to maximize the total cell throughput while maintaining throughput fairness among users. The idea is to operate a throughput-optimal scheduling policy, that stabilizes user queues at all nodes, in a system that receives equal inelastic mean arrival rates at only one source node in the cell which is the BS, using two hops at most. Therefore, the fair behavior of such policy is a special case due to our cellular network system model where we consider that all users belong to the same service class and thus have the same mean arrival rates and the same QoS requirements.

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Such policy is perceived fair given a similar scenario in [16]. In [21], a congestion control mechanism is proposed with such policy employed to introduce user fairness, through traffic policing, if the arrival rates are elastic, i.e., the traffic sources can adapt their rates. Otherwise, the authors perceive throughput-optimal scheduling more adequate for inelastic traffic.

Let us define the 'demand' metric for any node-UTlink on subchannelas the product of the achievable rate on that access link and the queue length of the user's buffer at that node, as follows.

$$D_{n,m\to k} = R_{m,k,n} Q_k^m, m = 0,1,2\ldots M, \quad (1)$$

Whereas the demand of any BS-RS m feeder link on sub channel n incorporates the queues at the BS (node 0) and those at RS m and can be expressed as

$$D_{n,0\to m} = R_{0,m,n} \max_k \{(Q_k^0 - Q_k^m), m = 0. \quad (2)$$

The function $(.)^+$ sets negative arguments to zero. Q_k^m Is the queue length of UT k at node m in bits, bytes, or packets of equal length (shown in blue bars in Fig. 1). Whereas $R_{m,k,n}$ and $R_{0,m,n}$ are the achievable rates on the link $node_m - UT_k$ and BS-RS m, respectively, on sub channel n. These rates are calculated, without loss of generality, using the continuous rate formula for adaptive modulation and coding (AMC) given as $R_{i,j,n} = W \log\left(1 + \frac{-1.5.\beta_{i,j,n}}{\ln(5p_e)}\right)$ where $\beta_{i,j,n}$ is the received signal-to-interference-plus-noise ratio (SINR) from source i at destination j on sub channel n considering all the dominant interference observed in the previous transmission. Pe and W are the target bit error rate and the OFDM sub channel bandwidth, respectively. As an alternative, either Shannon capacity formula (possibly with some practical SINR gap or penalty) or a discrete AMC lookup table can be used.

Modulated versions of this metric are used in non-relaying OFDMA [5] and SDMA/TDMA [6] networks. Although our results show outstanding performance employing the earlier metric definition, designing the mathematical structure of the metric is an interesting problem by itself, since differen emphasizes can be imposed on the rate and link weight arguments.

Nevertheless, it can be easily shown that any monotonically increasing function of the metric, in its composite form, will result in the same radio resource allocation (RRA).

A. Mathematical Formulation of the RRA at the BS:

In order to maximize the total cell throughput while stabilizing user queues at all nodes, the RRA scheme needs to assign the subchannels with the highest capacities at any node to the outstanding queues at that node. This can be achieved by optimizing the assignment of subchannels to all links and the assignment of user buffers to feeder links so that the sumdemand is maximized at each allocation instant. The resource allocation at the BS can be formulated as a binary integer linear programming (BILP) problem as

$$\max_{\rho,\gamma} \left\{ \sum_{n=1}^{N} \sum_{m=1}^{M} \sum_{k=1}^{K} \rho_{m,k,n} R_{m,k,n} Q_k^m + \sum_{n=1}^{N} \sum_{m=1}^{M} \gamma_{0,m,n} R_{0,m,n} . \max \left\{ \left(Q_k^0 - Q_k^m\right)^+ \right\} \right\}, \quad (3)$$

Subject to the constraints

$$\rho_{m,k,n} \in \{0,1\}, \forall(m,k,n), \gamma_{0,m,n} \in \{0,1\}, \forall(m,n), \quad (4)$$

$$\sum_{m=0}^{M} \sum_{k=1}^{K} \rho_{m,k,n} + \sum_{m=1}^{M} \gamma_{0,m,n} \le 1, \forall(m,n) \quad (5)$$

$$\sum_{m=0}^{M} \sum_{k=1}^{K} \rho_{m,k,n} + \sum_{n=1}^{N} \sum_{m=1}^{M} \gamma_{0,m,n} \ge \mu,$$

$$\sum_{m=0}^{M} \sum_{k=1}^{K} \rho_{m,k,n} \ge \mu, \forall m \ne 0, \quad (6)$$

$$T \sum_{n=1}^{N} \left(\rho_{0,k,n} R_{m,k,n} + \sum_{m=1}^{M} \gamma_{0,m,n} R_{0,m,n} k_k^m \right) \le Q_k^0, \forall_k$$

$$T \sum_{n=1}^{N} \rho_{0,k,n} R_{m,k,n} \le Q_k^0, \forall(m,n), m \ne 0 \quad (7)$$

In the above, $\rho_{m,k,n}$ is the kth UT binary assignment variable to the mt node, m= 0, 1, 2, . . ., , on the nth sub channel (m= 0 corresponds to BS, and the rest correspond to relays). The variable $\gamma_{0,m,n}$ is the mt relay binary assignment variable to the BS node on the nth subchannel whereas T is the transmission time of the downlink frame and $\mu = [N/(M+1)]$ is the minimum number of sub channels to be assigned to any node (BS or RS), assuming for now uniform user distribution with respect to relay deploy met. The binary indicator k_k^m is 1 if user k has the highest queue difference between the BS and RS_m and 0 otherwise. The constraint in (4) forces the optimization variables to binary values while the constraints in (5) ensure that at most one link is active per subchannel. The constraints in (6) guarantee even distribution of subchannels among all nodes and hence balance the load. Finally, the constraints in (7), unlike the majority of works in the literature, e.g., [9]-[11] and [15], ensure efficient bit-loading and prevent scheduling errors which could occur if the total capacity of the links withdrawing from a particular buffer is greater than the queue length at that buffer. Therefore, solving the optimization problem in such a novel formulation, results in the joint routing and fair scheduling, guarantees efficient use of resources, and balances the load among cell nodes. A discussion on the routing strategy will follow in the next subsection. The unique aspects of the problem formulation leading to the outstanding performance of the proposed scheme are summarized as follows

• No explicit non-linear fairness constraints or functions are imposed and thus a single linear objective function is maximized towards achieving a remarkable combination of both high ubiquitous throughput and user fairness, under the system model considered.

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• The formulation does not imply any kind of preset routes, user partitioning, or resource partitioning, which are known to be suboptimal simplifying techniques.
• Dynamic routing and scheduling are performed jointlyusing the 'differential backlog' represented by the queuelength difference between BS and RSs [22]; this is analogous to the hydrostatic pressure between fluid tanks connected with pipes of different capacities, which are controlled by the on-off assignment variables, while UTs represent the relevant sinks of individual user flows.

• Traffic diversity (statistical multiplexing) is exploited through incorporating the buffer states; this does not require knowledge of the arrival process statistics.

• Load balancing between relay nodes is achieved jointly as well, as in [20], and not by rearranging the optimal allocation, e.g., [9].

The computational complexity, however, of such threedimensional BILP problem is non-polynomial in time and can be approximated to .As such, the complexity might reach prohibitive limits in a system with high density of UTs and RSs given the expected high number of subchannels.

Therefore, in the next subsection, we propose a low-complexity iterative algorithm that virtually updates the buffer states between iterations while satisfying all of the aforementioned constraints.

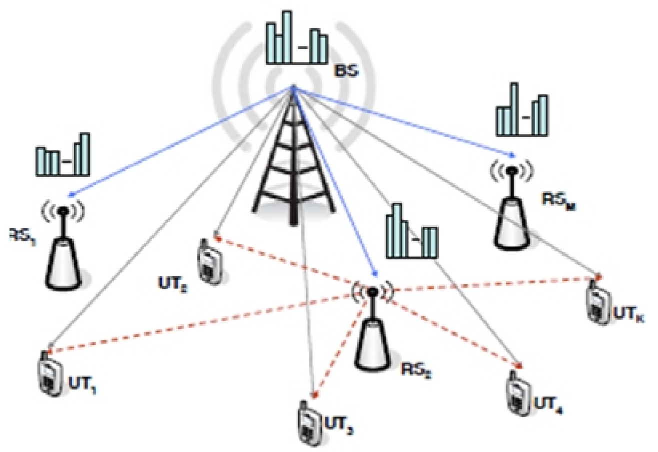

Fig. 1.Example partial network of BS and relays showing a snap shot of user queues and the potential links of the BS and RS2 on subchannel.

4.SIMULATED NETWORK PERFORMANCE:

A. Simulation Models and Parameters:

The simulated network and channel parameters are given in Table I.3 The cellular network consists of 19 non-sectorized hexagonal cells enhanced with 3 or 6 RSs per cell. These relays are placed at a distance of 0.65 of the cell radius from the BS and with a uniform angular spacing. UTs are uniformly distributed within the cell area. Independent Poisson packet arrival processes are assumed at BS queues.

The average arrival rate is 632 packets (188 bytes each) per second per UT. The path-loss model used is = 38.4 + log10() where = 23.5 for BS-RS links and = 35.0 for all other links. RSs transmit to UTs with an omni-directional antenna and receives with a highly directive antenna from the BS. Independent lognormal shadowing is assumed for all links but with different standard deviations. Time-frequency correlated Rician fading is assumed for (LOS) BS-RS links while all other (NLOS) links are assumed to experience time-frequency correlated Rayleigh fading.

B. Simulation Results and Discussion:

Figure 2 shows scatter plots of UT time-average throughput against UT distance from the BS for 6 and 3 RSs with 25 UTs/cell. Each point in the plot represents the time-average throughput (over 100 allocation time frames) for a particular UT within a drop with fixed location and shadowing. The time average is calculated over the downlink frame duration which is 2/3 of the total TDD frame duration. Statistics are collected from 7 cells (the center cell and the surrounding 6 cells) for each of 30 drops. The performance of the proposed algorithm in its open and constrained routing modes and that of the reference PFS scheme are compared.

The distancebased conditional mean of user throughput is approximated by fitting curves of the scatter points as a means of averaging out shadowing. A 7th-degree polynomial well captures the mean coverage behavior of the PFS scheme while only a 3-degree polynomial is adequate for the proposed scheme. For the proposed scheme, the uniform average throughput across the cell area is clearly evident and demonstrated by the almost flat performance from BS to cell edge.

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This implies that a fair service and ubiquitous coverage are provided for all users regardless of their locations, channels, and interference conditions. Some throughput gain is further achieved when the algorithm operates with 6 RSs in its more practical constrained routing mode due to better routing convergence.

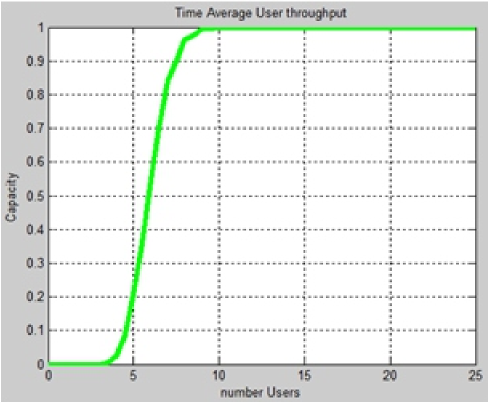
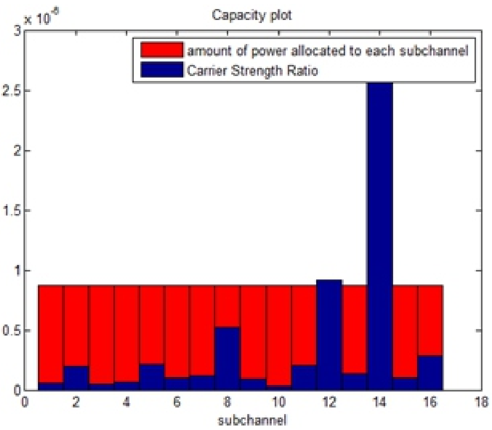


Figure 2 Time-average user throughput as function of user location.



Figure(3) Capacity plot (Red)Amount of power allocated to each sub channels (Blue) Carrier strength ratio.

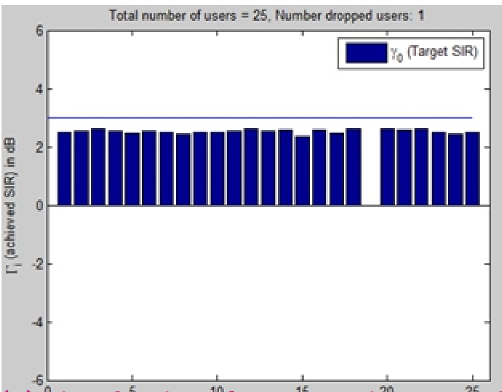


Figure (4) signal-to-interference ratio to number of Users

REFERENCES:

[1] IEEE P802.16j/D1, "Draft IEEE standard for local and metropolitan area networks Part 16: air interface for fixed and mobile broadband wireless access systems: Multihop relay specification," pp. 1002-1007, Aug. 2007.

[2] R. Pabst, B. Walke, D. Schultz, P. Herhold, H. Yanikomeroglu, S. Mukherjee, H. Viswanathan, M. Lott, W. Zirwas, M. Dohler, H. Aghvami, D. Falconer, and G. Fettweis, "Relay-based deployment concepts for wireless and mobile broadband cellular radio," IEEE Commun. Mag., vol. 42, no. 9, pp. 80-89, Sep. 2004.

[3] Z. Han and K. J. Liu, Resource Allocation for Wireless Networks: Basics, Techniques, and Applications. Cambridge University Press, 2008.

[4] D. Niyato and E. Hossain, "Adaptive fair subcarrier/rate allocation in multirate OFDMA networks: radio link level queuing performance analysis," IEEE Trans. Veh. Technol., vol. 55, no. 6, pp. 1897-1907, Nov. 2006.

[5] P. Parag, S. Bhashyam, and R. Aravind, "A subcarrier allocation algorithm for OFDMA using buffer and channel state information," in Proc. IEEE Veh. Technol. Conf., pp. 622-625, Sep. 2005.

[6] M. Kobayashi and G. Caire, "Joint beamforming and scheduling for a multi-antenna downlink with imperfect transmitter channel knowledge," IEEE J. Sel. Areas Commun., vol. 25, no. 7, pp. 1468-1477, Sep. 2007.

[7] P. Viswanath, D. Tse, and R. Laroia, "Opportunistic beamforming using dumb antennas," IEEE Trans. Inf. Theory, vol. 48, no. 6, pp. 1277-1294, June 2002.

[8] H. Kim and Y. Han, "A proportional fair scheduling for multicarrier transmission systems," IEEE Commun. Lett., vol. 9, no. 3, pp. 210-212, Mar. 2005.

[9] C. Bae and D.-H.Cho, "Fairness-aware adaptive resource allocation scheme in multihop OFDMA systems," IEEE Commun.Lett., vol. 11, no. 2, pp. 134-136, Feb. 2007.

[10] R. Kwak and J. M. Cioffi, "Resource-allocation for OFDMA multi-hop relaying downlink systems," in Proc. IEEE Global Commun. Conf., pp. 3225-3229, Nov. 2007.

[11] M. Kaneko and P. Popovski, "Radio resource allocation algorithm for relay-aided cellular OFDMA system," in Proc. IEEE International Conf.Commun., pp. 4831-4836, June 2007.

[12] W. Nam, W. Chang, S.-Y. Chung, and Y. Lee, "Transmit optimization for relay-based cellular OFDMA systems," in Proc. IEEE InternationalConf. Commun., pp. 5714-5719, June 2007.

[13] Ö. Oyman, "Opportunistic scheduling and spectrum reuse in relay-based cellular OFDMA networks," in Proc. IEEE Global Commun. Conf., pp. 3699-3703, Nov. 2007.

[14] V. Sreng, H. Yanikomeroglu, and D. Falconer, "Relayer selection strategies in cellular networks with peer-to-peer relaying," in Proc. IEEEVeh. Technol. Conf., pp. 1949-1953, Oct. 2003.

[15] J. Lee, S. Park, H. Wang, and D. Hong, "QoS-gurarantee transmission scheme selection for OFDMA multi-hop cellular networks," in Proc.IEEE International Conf. Commun., pp. 4587-4591, June 2007.