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Combined Uplink Resource Reservation and Power Control for Relay-Based OFDMA Systems

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Abstract— **This work presents a combined Uplink Resource Reservation and Power Control framework for Relay-Based OFDMA systems, i.e. for typical IMT-Advanced candidate systems. The framework serves to provide both fair uplink scheduling and a balanced link budget in a relay deployment. The performance of the proposed framework in a suburban cellular setup is evaluated by means of stochastic, event-driven simulation.**

I. Introduction

Relay-based radio network deployment concepts have been proposed and studied in the context of candidate technologies for IMT-Advanced systems [1]. The motivation is to enable a low cost broadband network deployment by overcoming the range-limitations of broadband air interfaces, especially at high carrier frequencies above 3 GHz. Large research initiatives like the IST-WINNER project [2] consider relays an inherent building block of next-generation wireless systems. Fixed relays for coverage and capacity enhancement are already being standardized by IEEE802.16, Task Group "j" [3] under the term Mobile Multihop Relays (MMR).

Orthogonal Frequency-Division Multiple Access (OFDMA) is the prevailing transmission scheme for next-generation Radio Access Networks. OFDMA-based systems can flexibility sub-divide the available resources in the frequency-domain.

The bidirectional (UL/DL) nature of the communication in mobile and wireless networks requires establishing a balanced link budget (UL/DL cell sizes), because the cell size is determined by whichever link has the smaller range. Unbalanced transmission ranges imply resource under-utilization. Factors that influence the link budget are

- different peak output powers of different station types
- different noise figures / receiver gains / sensitivities
- different service SINR requirements
- power control constraints

An additional requirement is to cope with the effects of frequency synchronization errors and - more severely - Doppler shift, multi-carrier systems with an FDMA component in the UL require an equalized reception of UL transmissions at the BS within a tolerable dynamic range [4].

From this results the need for an uplink power control scheme that takes into account the above constraints. This scheme will consequently have interrelations with the resource allocation (resource scheduling) - because terminals located at the cell edge will have to concentrate their available transmission power on a small number of frequency resources, see below the adaptive modulation and coding - because owing to the equalization constraint, users close to the centre of the cell may not be allowed to use all their available power and maybe also not be able to use the optimal modulation and coding if scheduled in parallel with a "bad" (i.e. cell-edge user). Separating good and bad users in the time-domain could hence contribute to an increase in system capacity, a technique which would be for further study.

It is a trivial observation that for a balanced link budget, the UL power spectral density will have to be in the same order of magnitude as in DL. Eventual differences will mainly be the result of different noise figures, receiver gains/sensitivities and different SINR requirements caused by different UL/DL traffic and service characteristics. As a consequence of what was said above and owing to lower peak power in UTs, less spectral resources can be used. Figure 1 on the following page shows the effect of RAP power advantage (denoted α: "alpha") on the max number of UL resources (denoted nUT, normalized to the number of DL resources nBS which the BS uses in parallel).

The allocation of spectral resources to UL users is not only influenced by their power and channel condition but also by the amount of capacity the users have requested for their UL transmissions. Therefore, this work proposes a framework for a joint resource reservation and UL power control scheme applicable to arbitrary OFDMA based systems. Another novel aspect of the proposed scheme is that it is extended to relay-based deployments, taking into account:

- Different UL power classes of Relay Nodes (RN) and User Terminals (UT)
- Strongly varying capacity requestes between RNs and UTs

II. Scheduling and Resource Reservation

A fair scheduling algorithm is considered that takes into account resources requested by UL users (i.e. both RNs and UTs). The proposed scheme currently encompasses two resource request/reservation strategies.

- single-hop reservation: users inform the serving station about their own buffer fill levels
- multi-hop reservation: users inform the serving station about their own and buffer fill levels plus the reported fill-levels of the subsequent tier's stations

The final paper compares the performance of the two reservation strategies under traffic congestion in the Relay Enhanced Cell (REC).

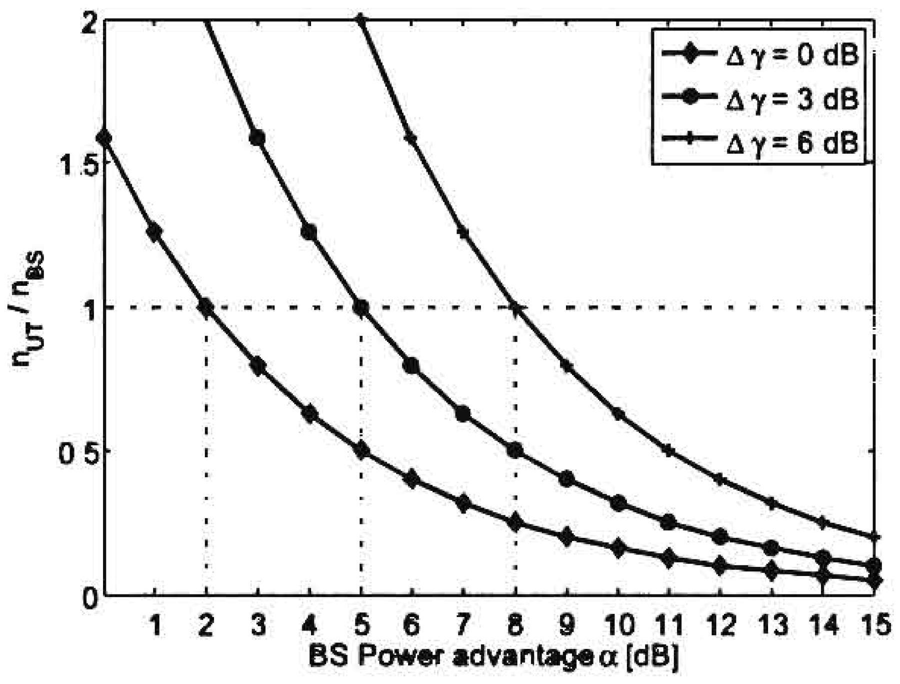

Fig. 1. Ratio of resources usable in UL vs. DL under the assumption of a 2 dB difference between RAP and UT noise figures

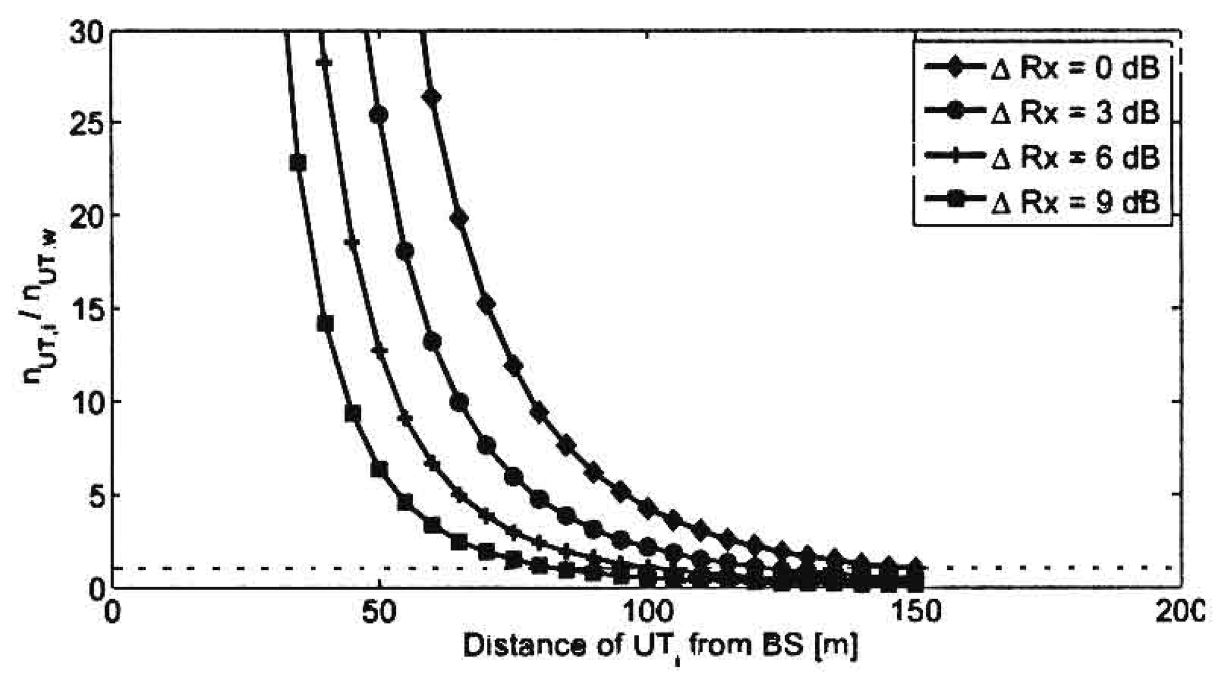

Fig. 2. Max. number of RAUs in parallel for a user at distance d_i, the user with the worst path loss is located at $d_w = 150\,\mathrm{m}$.

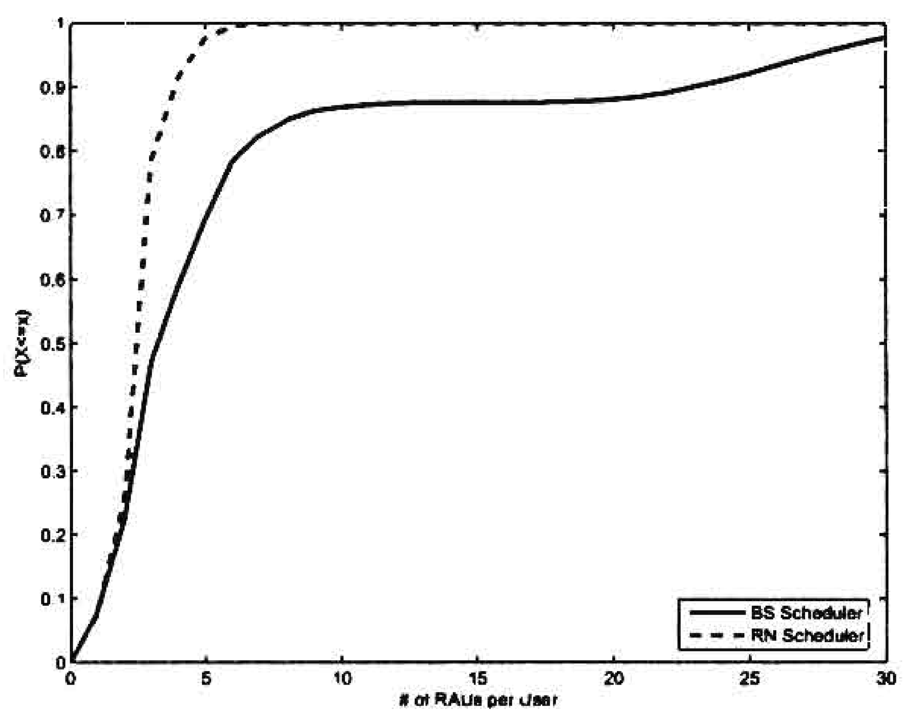

Fig. 3. CDF of scheduling results

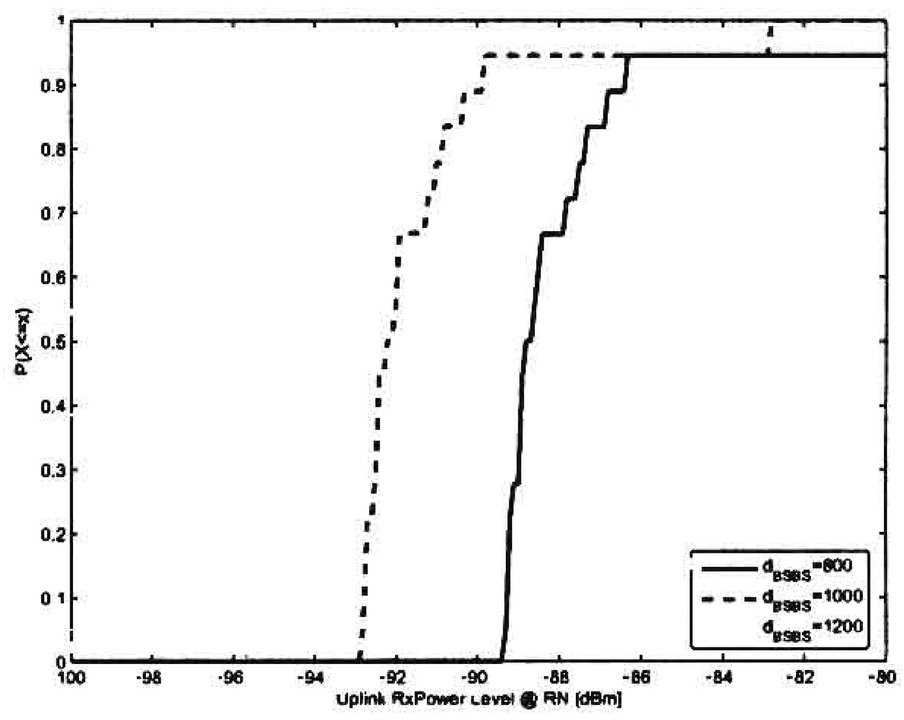

Fig. 4. CDF of the received signal power at the BS

III. Transmit Power Budget

The final paper will show that the maximum fraction of the RAUs available at the BS (n_{BS}) that the UT may use in parallel (n_{UT}) is:

$$\frac{n_{UT}}{n_{BS}} \leq \frac{\Delta\gamma}{\alpha}\frac{F_{BS}}{F_{UT}} \tag{1}$$

Where $\Delta\gamma$ is a measure for the envisaged asymmetry between DL and UL Service SINR Requirements and F denotes the Noise Figure of BS and UT respectively. Figure 1 plots this for the assumption of a 2 dB difference in BS and UT noise figures. The x-Axis varies the BS transmit power advantage α while the parameter is the asymmetry factor $\Delta\gamma$.

The above consideration is only valid for UTs at the cell border.

The power allocation for a user is further influenced by its relative location in the cell as compared to the user with the worst (pathloss) conditions.

The final paper determines the relative number of parallel RAUs that user i can use to be (as compared to the user with the worst UL channel, index w):

$$\frac{n_{UT,i}}{n_{UT,w}} \geq \frac{1}{\Delta Rx}\frac{L(d)_i}{L(d)_w} \tag{2}$$

Where ΔRx is the maximum tolerable dynamic range. Not surprisingly the advantage in the number of RAUs for user i comprises the pathloss advantage this user $L(d)_i/L(d)_w$ has over the 'worst' user w and the allowable dynamic range. Figure 2 illustrates that.

Figure 3 shows the CDF describing the number of RAUs allocated to individual users during the scheduling Maximum at BS is higher because it also serves RNs with high traffic demand.

Figure 4 shows the CDF of the received signal power at the BS measured from different UTs (for varying cell sizes, i.e. inter-site distances of 800m, 1000m and 1200m). It serves as a proof of concept that the power control algorithm manages to gurantee the maximum allowable dynamic range, which was set to 10 dB in the given example.

IV. Conclusion and Outlook

This abstract has proposed a combined Uplink Resource Reservation and Power Control scheme for OFDMA systems in relay-based deployments. The final paper will outline the analytical method to determine suitable UL power allocations in both the RN and the BS subcell. It will also provide extensive results from stochastic, event-driven simulations to assess the performance of the proposed scheme in an urban high-traffic scenario.

References

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