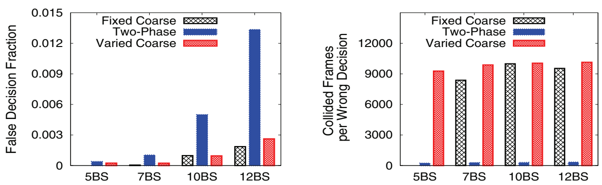
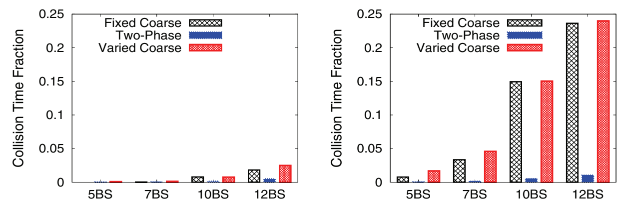
	5 BS Max Q: 600 - 1600 - 2600 - 3600	7 BS Max Q: 600 - 1600 - 2600 - 3600	10 BS Max Q: 600 - 1600 - 2600 - 3600	12 BS Max Q: 600 - 1600 - 2600 - 3600
Collision Time Fraction	Greedy: 0.049 - 0.029 - 0.021 - 0.016 Gibbs: 0.131 - 0.094 - 0.073 - 0.062	Greedy: 0.21 - 0.113 - 0.076 - 0.057 Gibbs: 0.309 - 0.248 - 0.204 - 0.17	Greedy: 0.648 - 0.46 - 0.326 - 0.234 Gibbs: 0.619 - 0.524 - 0.46 - 0.403	Greedy: 0.847 - 0.72 - 0.585 - 0.459 Gibbs: 0.759 - 0.685 - 0.615 - 0.567
False Decision Fraction	Greedy: 0.015 - 0.009 - 0.006 - 0.004 Gibbs: 0.04 - 0.03 - 0.023 - 0.019	Greedy: 0.05 - 0.026 - 0.017 - 0.012 Gibbs: 0.075 - 0.058 - 0.048 - 0.039	Greedy: 0.15 - 0.094 - 0.062 - 0.042 Gibbs: 0.129 - 0.102 - 0.085 - 0.073	Greedy: 0.215 - 0.154 - 0.112 - 0.082 Gibbs: 0.157 - 0.128 - 0.108 - 0.095
Collision per False Decision	Greedy: 439 - 657 - 960 - 1217 Gibbs: 429 - 639 - 885 - 1124	Greedy: 408 - 629 - 890 - 1139 Gibbs: 402 - 629 - 857 - 1095	Greedy: 310 - 521 - 751 - 1000 Gibbs: 342 - 547 - 772 - 997	Greedy: 241 - 425 - 632 - 856 Gibbs: 296 - 485 - 691 - 908

Figure 12: Results for the fine adaptation process. Fine adaptation is simulated for different period ranges.



(a) False decision fraction (b) Collided frames / false decision

Figure 13: Microscopic results for greedy selection.



(a) Greedy selection (b) Gibbs selection

Figure 14: Performance of two-phase adaptation.

range of q is also varied among 600, 1600, 2600 and 3600 frames, to study its impact.

Results: The performance of RADION with an increased number of femtocells is presented in Figs.12, 13 and 14. These results clearly corroborate our findings from the prototype evaluation, thereby demonstrating RADION's scalability in dense deployments. While fewer false decisions are incurred with coarse adaptations (Fig.13(a)), the collision duration per false decision is also longer (Fig.13(b)). The contrary is true with fine adaptation (smaller collision duration per false decision but a higher number of false decisions) as seen in Fig.12. RADION combines the best of coarse and fine adaptation and provides a significant reduction in the time spent in collisions (Fig.14). As with prototype results, the greedy approach outperforms Gibbs sampling; increased probing collisions and hence, false decisions are seen with Gibbs sampling. The table in Fig.12 shows the impact of q's range on fine adaptation. Increasing the range of q provides more time for estimating BDR on the current frequency chunk. Hence, false decisions due to inaccurate BDR estimates and thus, collision durations are reduced. However, adapting q's range is a double-edged sword. For small ranges, its performance is dominated by false decisions, while at large ranges it is dominated by collision duration per false decision. Hence, adapting q's range alone is not sufficient; the two-phase process as in RADION is needed.

6. CONCLUSIONS

We design and implement RADION, arguably the first self organizing resource management framework for OFDMA femtocell networks. RADION consists of three key building blocks i.e., *client categorization, resource decoupling* and *two-phase adaptation and allocation*. RADION allows appropriately chosen clients to opportunistically reuse the spectrum while isolating resources for the other clients in a distributed way. We implement RADION using a WiMAX testbed to show its quick convergence to an efficient resource allocation in real settings. We also demonstrate the scalability and efficacy of RADION in larger scale settings with simulations. We only consider downlink performance, however, a similar approach can be applied to the uplink. As part of future work, we plan to investigate the impact of power control at the BSs.

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