Supporting High Bandwidth Applications with 60GHz Outdoor Picocells

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1. INTRODUCTION

Industry research predicts that aggregate bandwidth requirements will increase by 1000-fold by 2020 [1]. This staggering growth is taxing mobile cellular networks past their limits and creating a capacity crisis [2]. Existing methods to increase capacity have reached their limits: spectral efficiency is slowly approaching the Shannon limit [4], and acquiring more physical spectrum provides limited capacity gains, while facing both regulatory hurdles and high monetary costs [2].

A 60GHz Picocell Architecture. But there is hope. Higher carrier frequencies, particularly millimeter-wave (mmWave) bands (30-300GHz), offer an attractive alternative using highly directional beams. Take 60GHz for example. First, the 60GHz band provides 7GHz of unlicensed spectrum, and supports the IEEE 802.11ad standard. Second, since mmWave bands have much shorter carrier wavelengths, *e.g.* 5mm for 60GHz, it is possible to pack large antenna arrays into relatively small form factors that are suitable for mobile devices. Third, the high density of elements allows very high aggregate bandwidth, while the narrow directional beams limit interference and provide potentially "unlimited" levels of spatial reuse. Finally, low-cost 60GHz radio chips are already available on the mass market, *e.g.* Dell Latitude 6430u laptops can be ordered with multi-Gbps WiloCity 60GHz chips for an additional $37.5. Clearly, 60GHz links offer an attractive and practical solution that satisfies many of our requirements.

In this paper, we propose a picocell architecture using 60GHz links (Figure 1). Our vision has square picocellular base stations densely deployed on lampposts or building ledges, with each station mounting multiple antenna arrays on each of its "faces." Properly tuned, each array can transmit independently to a different mobile user. Assuming 6x6 square-inches on a side, this accommodates 36 60GHz 100-element arrays. With each array transmitting at 2Gbps, a single base station can transmit up to 288Gbps!

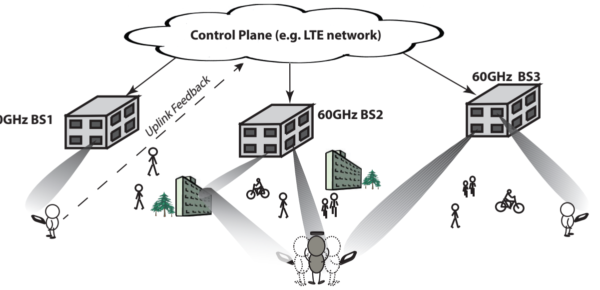

Figure 1: A potential 60GHz picocell architecture for outdoor mobile broadband. Each base station contains many antenna arrays, each with a large number of elements. Each base station can track users, form highly directional beams simultaneously to multiple users, and create high-bandwidth transmissions.

2. INITIAL MEASUREMENT STUDY

We take a measurement approach to exploring the feasibility and challenges of 60GHz picocell systems. Unlike prior efforts that focus on propagation models [3, 5, 6], we experiment with off-the-shelf 60GHz radios, and study key feasibility questions of 60GHz picocells. These include questions about transmission range, robustness to blockage, mobility support and interference footprint. Our experiments lead to the following findings:

- *Range.* Within FCC's power regulations, 60GHz offers coverage area that exceeds 150m for 693Mbps and 84m for 2+Gbps, more than enough for large outdoor picocells and dispelling concerns about oxygen signal absorption.
- *Robustness.* Testbed measurements show 60GHz links can penetrate common foliage, and a sparse set of basestations is sufficient to establish links while avoiding blockage from the user body and other pedestrians. 60GHz signals can also reflect off of many outdoor surfaces, and introduce no more than 5dB signal loss. Thus reflection paths provide good alternatives to line-of-sight links.
- *Mobility.* Detailed signal strength measurements show that directional antennae can easily keep up with pedestrian mobility rates, and only need to realign once every few seconds to maintain high rate connections.
- *Interference Footprint.* 60GHz's small interference footprint translates into a significant boost in spatial reuse. Thus 60GHz picocells can be densely deployed with significant overlap but minimal interference.

Based on these results, we believe 60GHz outdoor picocells are indeed feasible in the near future, and can potentially offer the orders of magnitude increase in network capacity we need. However, realizing this immense potential requires a concerted effort to overcome a number of technical challenges such as user tracking, control plane design and cross-layer optimization. We plan to address these challenges in follow-up research.

3. REFERENCES

[1] http://www.techjournal.org/2011/09/mobile-broadband-useage-is-set-to-explode-infographic.
[2] http://money.cnn.com/2012/02/24/technology/spectrum_crunch_solutions/index.htm.
[3] CORREIA, L., AND REIS, J. Wideband characterisation of the propagation channel for outdoors at 60 ghz. In *Proc. of PIMRC* (1996).
[4] COSTELLO, D., AND FORNEY, G.D., J. Channel coding: The road to channel capacity. *Proc. of the IEEE 95*, 6 (2007), 1150–1177.
[5] MATIC, D., HARADA, H., AND PRASAD, R. Indoor and outdoor frequency measurements for mm-waves in the range of 60 ghz. In *Proc. of VTC* (1998).
[6] RAPPAPORT, T. S., BEN-DOR, E., MURDOCK, J. N., AND QIAO, Y. 38GHz and 60 GHz angle-dependent propagation for cellular amp; peer-to-peer wireless communications. In *Proc. of ICC* (2012).