Opposite-sector uplink interference in broadband FWA networks in high-rise cities

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A deterministic propagation model is used to simulate broadband radio propagation at 3.5 GHz for a fixed wireless access (FWA) network in a high-rise city environment, with linear antenna polarisation. It is shown that some rooftop locations are unsuitable positions for subscriber units (SUs), due to the existence of single- or multiple-bounce reflected rays causing uplink interference. Furthermore, it is shown that it is usually possible to find an SU position just a few metres away on the same rooftop that gives much lower uplink interference.

Introduction: In broadband fixed wireless access (FWA) networks, a number of terminals or subscriber units (SUs) communicate with a single base station or access point (AP). In high-rise cities, the broadband radio channel is characterised by multipath propagation due to reflection, shadowing and diffraction from buildings (which often have a high steel and glass content in their outer walls), causing increased interference [1], especially upstream. The SUs in an FWA network typically have narrow-beam antennas, pointing directly at the AP, but the AP antennas may have wider beamwidths, e.g. 90–120°. Owing to a limited amount of spectrum being available for FWA networks, a four-sector AP may need to reuse the same frequency in opposite sectors. The presence of high-rise buildings may result in an SU in one sector of the AP causing uplink co-channel interference to the opposite receive sector of the same AP.

Ray-tracing model: A random high-rise city building database was generated, with adjustable distribution of building heights, using a Rayleigh distribution [2, 3], and used as input to the ray-tracing algorithm. Deterministic propagation modelling has emerged as a dominant method for site-specific performance analysis [4, 5]. The new ray-tracing propagation model developed for the study presented in this Letter is optimised for FWA scenarios by modelling: AP antenna locations well above the height of ground clutter, reflections off building walls (including signal depolarisation), and multiple diffraction (both off-axis rooftop and terrain). Rooftop diffraction is calculated both before and after the reflection points, since this is the dominant propagation mechanism with rooftop antennas. For a chosen AP position, the image tree is constructed for all building walls, the geometry of each ray is found, the angles of arrival (both azimuth and elevation) at the AP and SU are calculated and the antenna patterns included. The model is based on the uniform theory of diffraction (UTD) and geometrical optics.

Simulation study: A TDMA FWA system in a high-rise city (building height $\gamma = 70$ m [2]) was simulated. The AP has four sectors, each antenna having a 90° half-power beamwidth and gain of 11.1 dBi. The SU antennas point directly towards the facing sector of the AP, and have 20° beamwidth, and gain of 15.6 dBi. Different combinations of vertical and horizontal polarisation at the AP and SU are used. The AP transmit power is set to 1 W (+30 dBm) into the antenna. Uplink power control on each SU is adjusted to achieve a setpoint AP receive power at sensitivity for QPSK, plus a 5 dB fade margin. A two-frequency reuse scheme is used so that opposite sectors transmit on the same frequency in the 3.5 GHz band, with 14 MHz bandwidth. Separate ray-tracing simulations were performed for each city map, taking into account 0, 1 and 2 reflections, respectively, for each ray. Grid resolution used was 5 m, so that a number of positions on each rooftop were simulated. The AP is located on the rooftop of a high-rise building near the city centre, and all rooftops higher than 50 m are considered as potential SU locations. Fig. 1 shows an SU in the north sector, which is producing uplink interference into antenna sidelobes of the south sector of the AP, due to multiple reflections from buildings marked 'r1' and 'r2', and rooftop diffraction over building 'd1'. The following results are for a single city map, but are representative of a number of runs of cities using the same building distribution. For QPSK, the minimum tolerable co-channel interference is 23 dB below the wanted signal, so with setpoint receive power of −72 dBm, the maximum allowable interfering signal level is −95 dBm. Considering only a single high-power interferer, each rooftop SU location is examined for its potential to cause an upstream interference level of more than −95 dBm into the opposite sector of the AP.

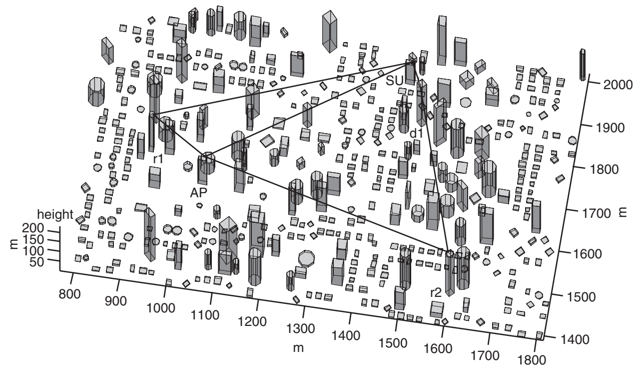

Fig. 1 *3D view of high-rise city and multiple reflections causing upstream interference*

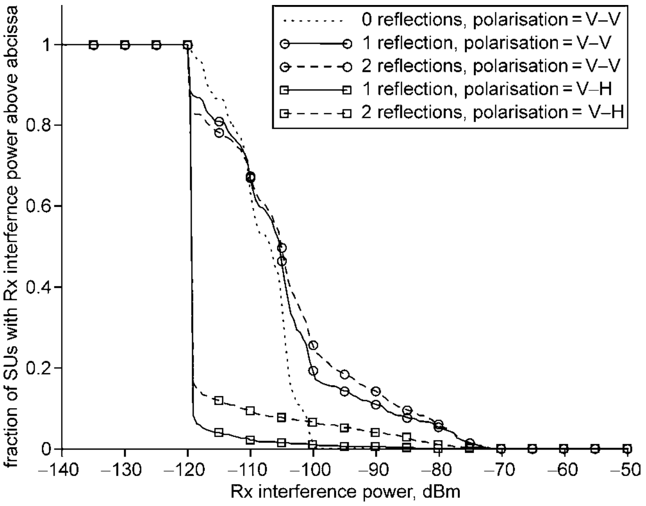

Fig. 2 *cdf plot of upstream interference received at AP from opposite-sector SUs*

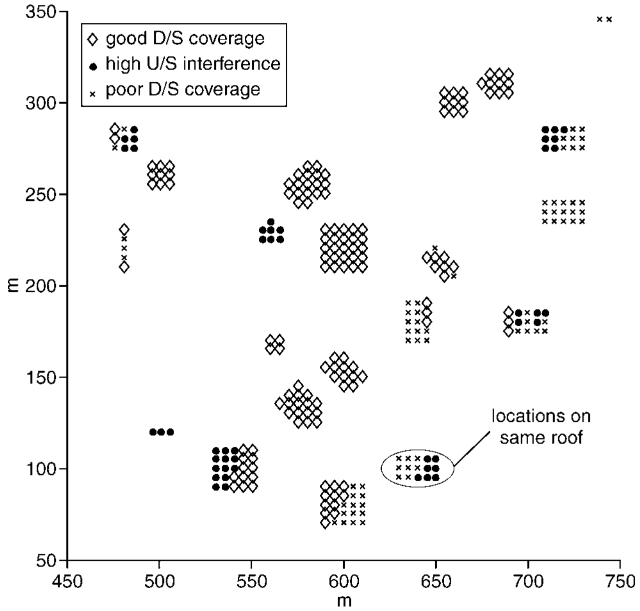

Fig. 3 *Top view of city showing rooftop locations on each building*

Fig. 2 shows the cdf of upstream interference power received at the AP from SUs in the opposite sector, against the number of reflections considered and with a noise floor of −120 dBm. It is seen that for V–H polarisation (i.e. vertical polarisation at the SU, horizontal at the opposite AP sector), the cdf increases only slowly as the interference power reduces, until the interference noise floor is reached. This illustrates the improvement due to the cross-polar isolation of the antennas, but also shows that some upstream reflections still cause interference due to depolarisation at the reflection points. Fig. 3 shows an aerial view of a number of individual locations on each rooftop, classified as either: (*a*) good downstream coverage, (*b*) high upstream interference, or (*c*) poor downstream coverage. It is seen that, on the same rooftop, different physical locations have different received coverage and upstream interference levels. Fig. 4 shows the proportion of buildings that have both good coverage and high upstream interference locations on their rooftop. It is seen that most rooftops with good signal coverage do provide some SU positions, which cause sufficiently-low upstream interference. We conclude that it is usually possible to reduce upstream interference simply by moving the SU to a different location on the same rooftop, whilst still maintaining sufficient signal coverage. Careful antenna positioning during SU installation is recommended to minimise uplink interference.

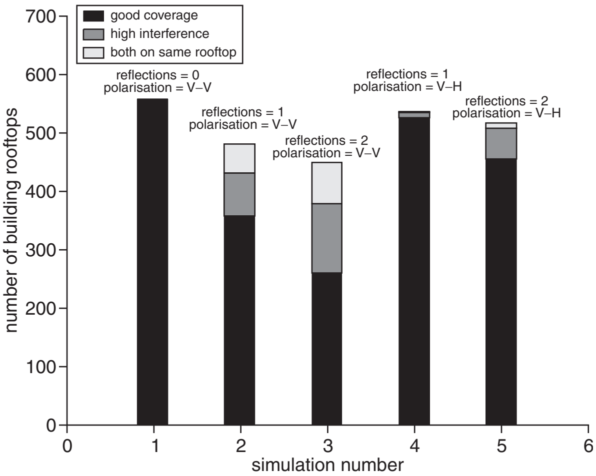

Fig. 4 *Bar chart showing proportions of rooftop locations having good coverage and high interference*

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