Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**An Analysis of co-channel interference between mesh and PMP systems operating in the frequency range 2-11 GHz**
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Re:	Amendment to Coexistence Recommended Practice – derivation of coordination guidelines for mesh and PMP systems
Abstract	This paper provides an analysis of the interference between co – channel mesh and PMP systems operating in the frequency range 2-11GHz. A coordination guideline is derived to complement the guidelines for mesh to mesh and PMP to PMP scenarios included in the draft amendment to the coexistence recommended practice.
Purpose	To provide a coordination guideline for recommendation 3-4.
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An Analysis of co-channel interference between mesh and PMP systems operating in the frequency range 2-11 GHz

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Summary

This document provides an analysis of the co-channel interference between a mesh system and a PMP system operating in the frequency range 2-11 GHz. A coordination distance guideline is derived. This guideline is proposed for use in Recommendation 3-4 of the draft amendment to the coexistence recommended practice, to complement the guidelines already derived for mesh to mesh and PMP to PMP interference scenarios. The majority of the results were produced by using a purpose-designed mesh simulation tool. This tool uses a Monte Carlo method to produce probability distributions for interference levels between systems, each iteration laying out a different random model of a system, based on a specified range of parameters.

Description of the analysis

Mesh systems in this frequency range use antennas that vary in beam-width from approximately 20 degrees to omni-directional. The PMP system is assumed to use a 90 degree sector antenna at the base station and a narrow beam antenna at the subscriber station.

The analysis requires the use of a Monte Carlo simulation technique, to evaluate the interference from a mesh system to a PMP system. In the other direction, a simpler analysis is possible, since there is normally only a single interferer.

The simulator has been used to derive results provided in several previous contributions and is described in Appendix 1. Further information can be found in several other contributions to the results of the coexistence recommended practice. The system parameters have been adjusted to be suitable for the 2-11 GHz band and, as far as possible, follow the values included in the draft coexistence practice IEEE 802.16.2a/D4-2003. These are expected to be the same as the values adopted in the final published version of the standard.

Mesh systems are deployed on or near rooftops, in order to make use of building and terrain losses and thus improve frequency reuse. This feature also improves coexistence with other systems and typically reduces the coordination distance. When one system is a mesh and the other system is PMP, the PMP base station interference dominates, due to the wide beam antenna and height of the base station above surrounding terrain. Table 1 below shows simulation results for base station interference (the worst case), for a range of urban and suburban environments. The Rayleigh factor R characterises the distribution of building heights. A factor of zero indicates free space paths (no buildings). A factor of 5 is characteristics of a semi-rural environment with mostly low buildings, whilst a factor of 20 typifies a city environment.

Most of the simulation runs were carried out using a frequency of 3.5 GHz. A small sample trial was also made for 10.5 GHz and the results found to be more favourable. At present, known and planned mesh systems in the required frequency range all operate below 5 GHz, so the analysis has concentrated on this part of the range.

Results from the simulations

Table 1 shows a selection of results from the simulation runs. Each run comprised 10,000 trials, in which the mesh layout was varied at each iteration. Additional simulation runs, not listed here, were carried out in order to determine the worst- case configurations. These all showed better results than the cases listed in table 1, which is therefore considered to be a fair basis for the derivation of a coordination guideline.

Table 1; Simulator Results

Frequency	Mesh antenna beamwidth	R (Rayleigh Factor)	D (Mesh to PMP distance)	Interference level
3.5 GHz	45 degrees	20	25 km	<-114.5 dBm/ MHz (1)
3.5 GHz	45 degrees	5	50	<-114.5 dBm/ MHz
3.5 GHz	45 degrees	0	100 km	Exceeds required threshold
3.5 GHz	120 degrees	5	50 km	<-114.5 dBm/ MHz
3.5 GHz	90 degrees	5	50km	<-1114.5 dBm/ MHz
10.5 GHz	120 degrees	5	50 km	<<-1114.5 dBm/ MHz (2)

Note (1): the value of –114.5 dBm/ MHz corresponds to the interference limit for multiple interferers used in the recommended practice.

Note (2); the results at 10.5 GHz were several dB better than at 3.5 GHz. However, mesh equipment parameters for this frequency range are not known, so that values have been estimated. It is therefore reasonable at the present time to use the 3.5 GHz guideline for coordination purposes.

Conclusions

The results show that with a Rayleigh factor of 5, a 50 km coordination distance is adequate. This corresponds to an environment with mostly low buildings. Factors below 5 would be very exceptional, since mesh systems of the type described are only deployed on rooftops. A reduced coordination distance is possible when a higher Rayleigh factor can be relied on but, to cater for the suburban environment, it is considered prudent to use the lower figure. A simple calculation shows that the reciprocal case of base station to mesh interference produces similar levels of interference (in fact, about 2 dB worse) but the margins provided by the 50 km coordination distance are adequate to cover this.

Thus, it is concluded that a coordination distance between co-channel mesh and PMP systems of 50km is satisfactory. As with other coordination guidelines, this will not be perfect for every combination of equipment and terrain characteristics but is expected to cover >99% of possible situations. It is therefore proposed to include this guideline in Recommendation 3-4 of the recommended practice.

Appendix 1

The simulator models a mesh system as a series of links, laid down in a random pattern in a rectangular coverage area. The dimensions of the system and the link density can be varied as required, as can the parameters of the radio equipment and antennas. Each link is assigned a length between a defined minimum and maximum length, with all link lengths having equal probability.

The PMP BS sector is placed in the most severe position and pointed directly at the mesh. In a mesh network, there are potentially multiple interferers on each channel, so that the signal from all possible contributing stations must be added together ate the victim station. The geometry is shown in the following diagram.

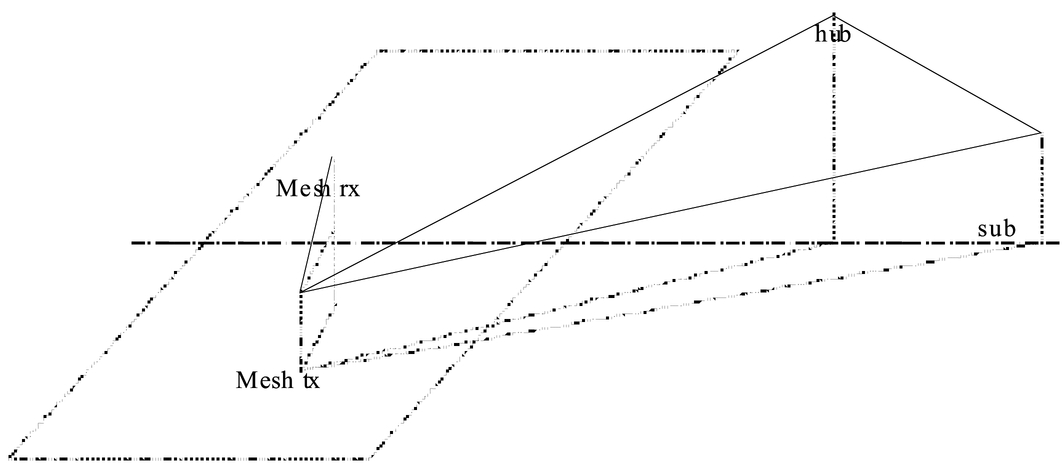

Fig. 1; Interference geometry

Simulation method

The main attributes of the model are:
-Monte-Carlo simulation with realistic MP-MP system parameters.
-Line-of-sight propagation probabilities calculated from Rayleigh roof height distribution function as per RAL-CRABS WG3 report D3P1B. The distribution is characterised by the Rayleigh factor, R.
-Interfering power summed at PMP base or subscriber using full 3D geometry to compute distances and angles between lines of sight and antenna bore-sights.
-Effect of Automatic Power Control granularity (ATPC) included.
-Mesh antenna is wide beam with 20-120 degree beam-width. (an omni – mesh would slightly increased interference probability but the results have a margin to cover this)
-Atmospheric attenuation to ITU-R P.676-3 (negligible at these frequencies)

-Rain attenuation to ITU-R P.840-2 (negligible at these frequencies)

The interference target maximum level in the model is –114.5dbm/MHz measured at the victim receiver input. A large number of trial runs of the simulator tool (typically 10,000) are used to generate a histogram of interfering signal against probability of occurrence. The deduced minimum spacing is based on the worst- case value of interference. In practice this has a very low probability so that the results below are conservative.

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