Tech Brief

Taking 802.11n Outdoors

IEEE 802.11n, the high-throughput version of Wi-Fi, is a complex standard combining multiple techniques to increase throughput in wireless networks. In this tech brief, we will look at each of those techniques and explore the ones that are particularly relevant to outdoor Wi-Fi networks.

Outdoor networks, such as those built to provide public Wi-Fi access or support public safety, meter reading, or intelligent traffic systems, must overcome their own unique challenges. Links traverse distances an order of magnitude longer than those in indoor networks, resulting in lower signal strengths and a greater variety of paths a signal can take from origin to destination. Interference is a much bigger factor, and can come from sources not usually seen indoors, including powerful rooftop or tower transmitters. Finally, outdoor networks must scale differently than indoor networks. They often consist of thousands of access points, with each one within range of tens of neighbors, requiring better coordination and sharing of airtime resources.

Devices following the 802.11n draft standard can achieve extraordinary throughputs under the right conditions by employing combinations of the following techniques:

Major, throughput-doubling techniques:

- Simultaneous multi-antenna reception (MRC – Maximal Ratio Combining)
- Multiple simultaneous data streams (MIMO – Multiple In, Multiple Out)
- Double-width channels – (40 MHz rather than 20 MHz)

Minor changes:

- More OFDM subcarriers (52 rather than 48)
- Reduced forward error correction redundancy (5/6 instead of 3/4)
- Shorter guard intervals between packets (400 ns rather than 800 ns)
- Shorter “greenfield” preambles
- Reduced interframe spacing
- Frame aggregation
- Block acknowledgements

Of the first three major techniques, the most useful to outdoor networks is MRC. Typically, throughput at a given distance can be doubled by combining signals from three antennas. While most earlier 802.11g access points have two antennas, they only have one radio receiver. A diversity switch allows the single receiver to briefly sample the signal quality on the two antennas, after which it picks one to receive each packet. The signal from one antenna is used while the other antenna’s signal is simply discarded. In contrast, MRC systems have a full, dedicated receiver for each antenna. They operate simultaneously to capture three signals and add them together. By adjusting the weight and phase of each signal as they are added, noise received on multiple antennas can actually be cancelled out, resulting in the best possible signal-to noise ratio for the combined signal; hence the name “Maximal Ratio Combining”.

MRC helps address multiple challenges particularly important in outdoor networks. Often, coverage is limited by the uplink – the link from the client device to the access point. While the downlink signal can be improved by increasing the transmit power of the access points, this is rarely practical for client devices. In public access networks, users may join using whatever devices they already own, from laptops to handhelds and smartphones. Battery life, size, and cost often limit the power of transmitters in client devices. In addition to better transmitters, outdoor access points often have higher gain antennas and are mounted high up on poletops or buildings. Because of this, they statistically experience somewhat higher noise levels than client devices on the ground, which are more likely to be shielded from interference by buildings and trees. Both of these effects favor the downlink over the uplink, so any technology that helps equalize the uplink’s performance is particularly welcome. MRC addresses both components of the asymmetry, by enhancing the signal received from the client through the addition of multiple copies, and by canceling noise.

The enhanced throughput and link reliability from MRC can be enjoyed by any client device – it is fully backward compatible with 802.11g clients since no changes are required on the client transmitters.

The other major techniques for improving throughput in 802.11n are most effective in indoor networks. MIMO is an innovative way to send two or more data streams in parallel over the same channel. The multiple receivers can pick out each data stream individually, adding its signals and canceling the other streams. By repeating the postprocessing for each stream, throughput can be doubled, or with more antennas, tripled or quadrupled. Multiple streams require more signal strength, however, and in long range links the best throughput can be obtained by dedicating all receivers to decode a single stream. The highest MIMO bit rates can only be sustained over very short links with high signal strengths. Importantly, MIMO requires compatible devices on both ends of the link. For these reasons, it is useful for a subset of links in an outdoor mesh network with high signal strengths, but less so for client links, where signals are weaker and a wider variety of legacy devices may need to be supported.

Channel bonding, where a pair of adjacent 20 MHz channels are used to create a double-wide 40 MHz channel, is also most useful indoors, where the entire radio band may only need to support a handful of links. In large-scale outdoor networks, it is critical to distribute channels intelligently among the links so that airtime can be shared and interference can be avoided. Situations where it makes sense to devote more than one channel to a single link in order to improve its throughput are rare.

The minor tweaks listed above do not increase performance significantly when taken individually, but together their contribution can be great. Within a mesh network, many of the tweaks can be used to boost throughput. Once again, only 802.11n client devices may take advantage of them, since compatibility must be negotiated. Timing changes such as the short guard intervals and reduced interframe spacing, and the greenfield preamble may only be used when no legacy devices are present, making them most suitable for isolated indoor environments.

802.11n, and particularly its MRC component, can dramatically improve throughput and reliability in outdoor Wi-Fi networks.

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