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Ericsson Microwave Outlook

Frequency reuse and wide channels – a perfect match

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Frequency reuse and wide channels — a perfect match

How can those service providers with limited access to microwave backhaul spectrum handle the increased data traffic demands?

Data traffic is growing year-on-year in our networks, and RAN is evolving with more spectrum and more spectrally-efficient features — for example, MU-MIMO — alongside densification, to cope with traffic growth. The demand on microwave backhaul capacity is increasing correspondingly. However, many service providers have limited access to microwave backhaul spectrum, especially in traditional bands. It is therefore important to utilize the available spectrum resources in the best possible way.

Microwave backhaul networks are traditionally designed so that links do not interfere with each other by assigning neighboring links different frequency channels. From a frequency allocation perspective, the consequence of such an interference-free design is that each link only has access to a smaller subset of available frequency channels.

Let's consider a simple network design scheme where links in a network are assigned one out of two separated frequency channels that do not interfere with each other (traditional network design). An alternative network design is to give all links access to both channels to increase their overall bandwidth, but in such a design there's an increased risk that the links will interfere with each other, which could increase their respective interference-to-noise ratio (I/N).

The question then arises: can the possible increase in I/N be compensated for by the increased channel bandwidth? The reasoning is that microwave backhaul links typically operate at very high signal-to-interference-and-noise ratio (SINR), and so are bandwidth-limited. Therefore, they would benefit a lot more in terms of capacity from using wider channel bandwidth instead of a very high SINR. In the bandwidth-limited regime, the capacity is approximately linear in bandwidth but only logarithmic in SINR (power). This implies that a wider channel requires less transmit power to support the same capacity as a narrow-band channel with high SINR. In general, lower transmit powers would also generate less interference to neighboring links. Additionally, links experience varying traffic demand over time. It may be so that at certain time instances, some links experience a higher traffic demand while other links experience a lower traffic demand. Consequently, in the case when links adaptively adjust their output powers to meet their respective capacity demands (see Figure 15), the eventual interference between the links will also vary with time and interference is reduced significantly compared to a system that uses fixed output power. In extreme scenarios, it may be that some links are carrying almost no traffic at all. In that case, why not let other links use the available spectrum resource? It would otherwise be a waste of spectrum.

Simulations based on typical network deployment

To quantify the gains of more aggressive channel reuse and traffic-aware output power, we evaluated different network designs by simulating a sub-network of a typical network deployment in India. The deployment and selected sub-network are illustrated in Figure 16. The overall deployment consists of thousands of links while the selected sub-network consists of 122 horizontally polarized 15GHz links with different antenna sizes and hop lengths. This sub-network was chosen because it contains several network hubs where multiple links are co-located. Links on a hub are more prone to interference from neighboring links located at the same hub and are therefore more challenging from a channel reuse perspective.

Two different network designs, namely reuse two and reuse one, are compared. In a reuse two design, each link is allocated one out of a total of two 56MHz channels, where close-by links are allocated separate channels. However, in a reuse one design, all links, including close-by links, are allocated the same 112MHz channel. Thus, for both designs the total spectrum consumed by the network is the same.

Different power allocation methods were also simulated: fixed output power and traffic-aware output power. When conditions allowed, fixed output power was chosen so that 99.995 percent availability for the maximum modulation of 4096QAM was achieved for both channel bandwidths. This means that the 112MHz channel has twice the peak rate of the 56MHz channel, but the same availability of their respective peak rate. However, the maximum output power was 18dBm for practical reasons.

Figure 15: Traffic-aware output power

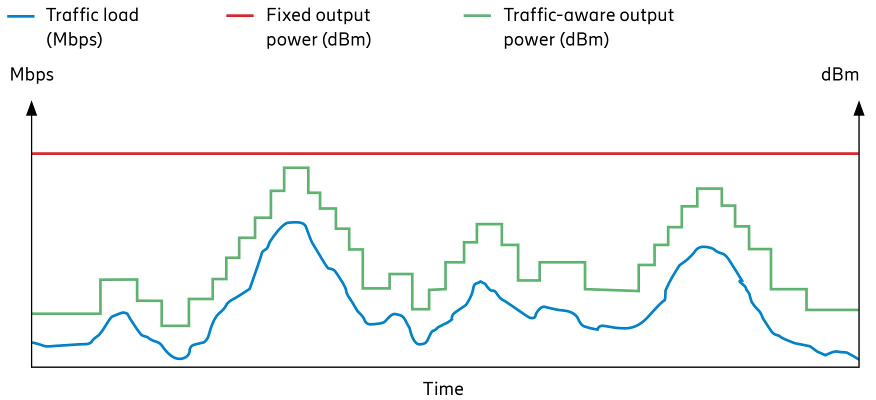
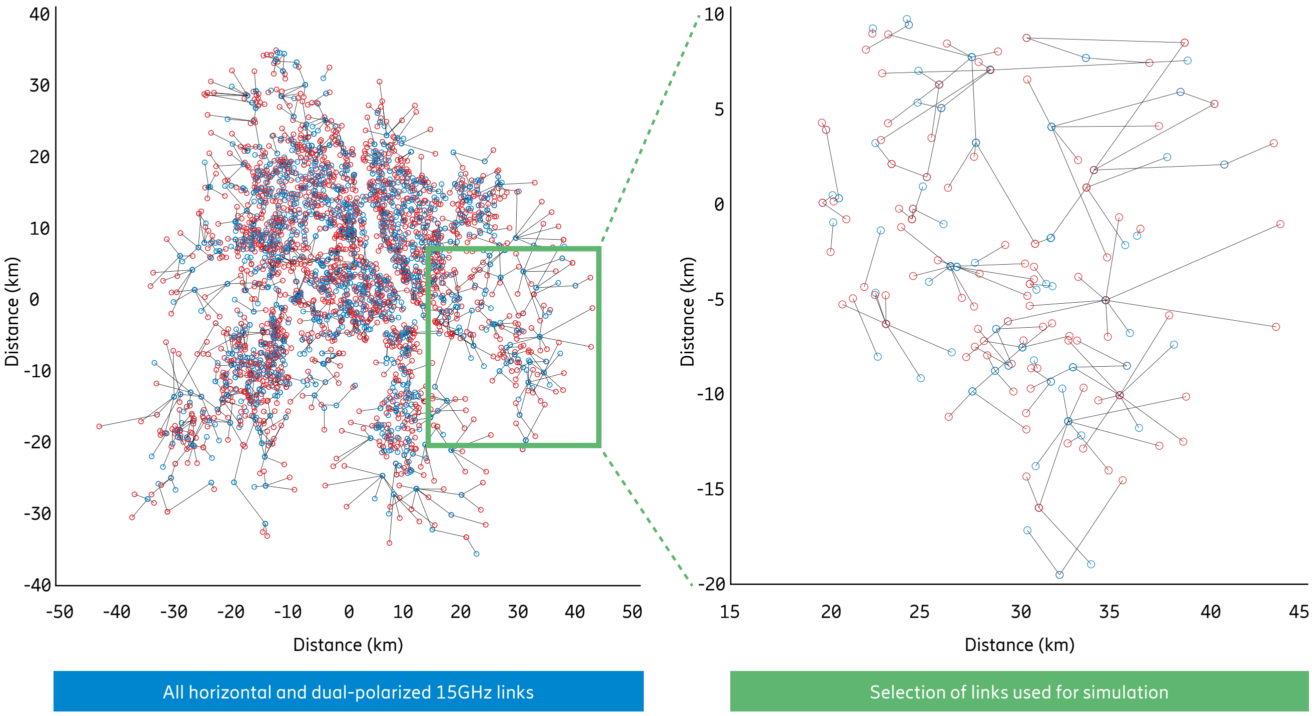


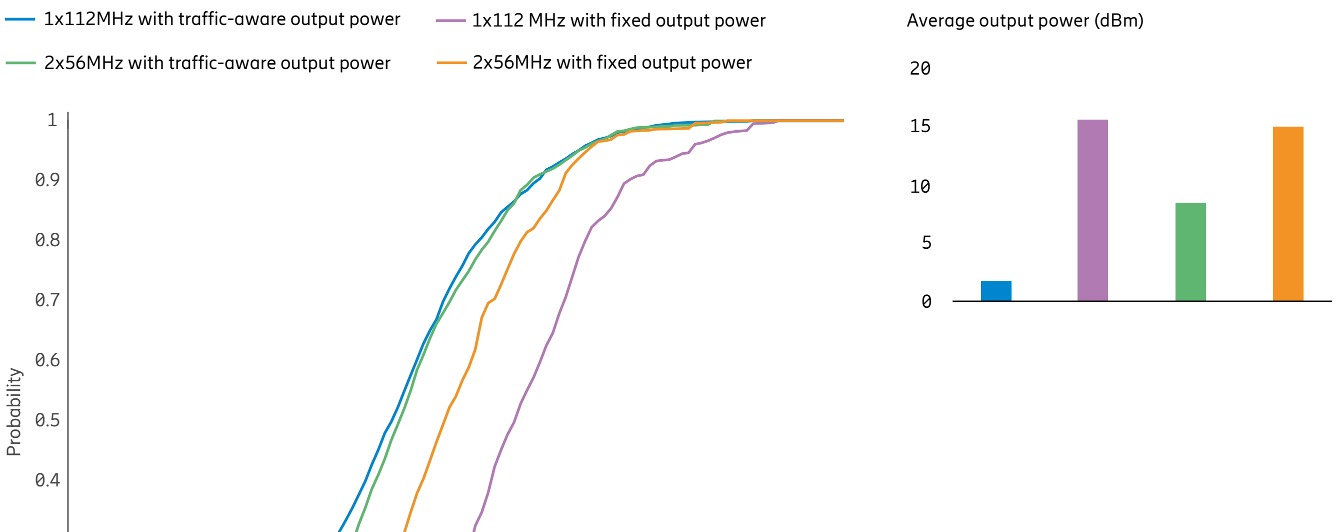
Figure 16: Typical dense network topology in an Indian city, used in simulation



The traffic-aware output power was chosen so that the lowest modulation which fulfills the traffic demand is sought after, that is, it tries to match the output power and modulation to the instantaneous traffic demand as illustrated in Figure 15.

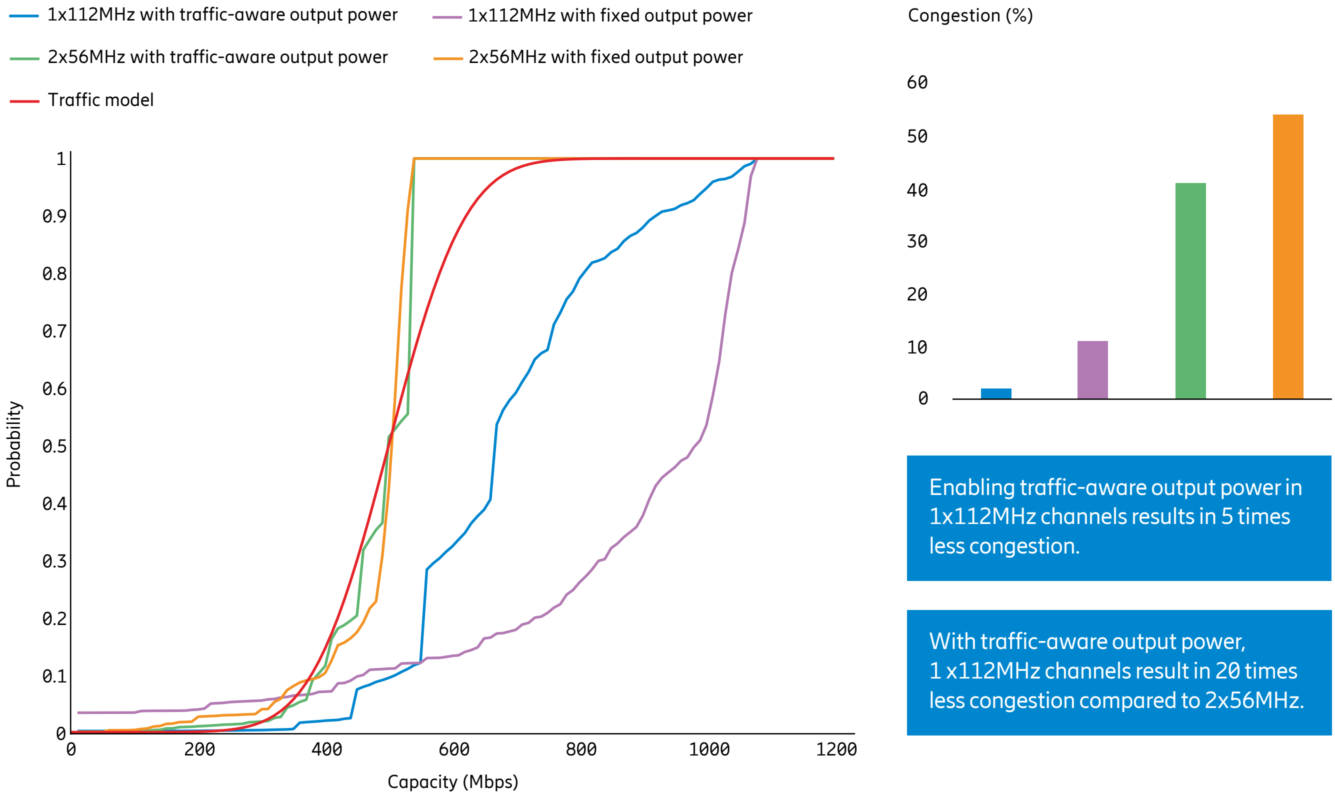
A high traffic demand was assumed and modelled by a normal distributed rate with a mean of 500Mbps and a standard deviation of 95Mbps. Its cumulative distribution function (CDF) is shown in Figure 18. In the simulations, rain cells were placed randomly over the network with a maximum rain intensity of 45mm/hour and the maximum rain attenuation observed in the network was about 35dB. To generate statistics, rain and traffic were generated randomly according to their respective models and in total 50,000 random realizations were generated over the whole network.

Figure 17: Interference with and without traffic-aware output power



When using 1x112MHz channels, traffic aware output power results in 20dB improved interference to noise ratio and 25 times less output power (average).

Figure 18: Comparing 1x112MHz with 2x56MHz channels in a high traffic load simulation



Enabling traffic-aware output power in 1x112MHz channels results in 5 times less congestion.

With traffic-aware output power, 1 x112MHz channels result in 20 times less congestion compared to 2x56MHz.

Simulation results
Figure 17 shows the I/N distribution for the two designs with and without traffic-aware output power. Interestingly, the simulation found that the reuse one (1x112MHz) system with traffic-aware output power has the best I/N performance, even better than the corresponding reuse two (2x56MHz) system. This is because a 112MHz channel needs less output power to support the same capacity as a 56MHz channel and therefore generates less interference. However, using proper planning with two separate 56MHz channels also reduces interference, but the simulations show that a single 112MHz channel is slightly better at reducing interference.

The benefit of using traffic-aware output power compared to fixed output power becomes obvious in Figure 17 where up to 20dB improvement in I/N is observed for 1x112MHz with traffic-aware output power compared to fixed output power. On average, traffic-aware output power results in 14dB of power savings compared to fixed output power for 1x112MHz. A positive effect from traffic-aware output power is also observed in the 2x56MHz case. Therefore, it is recommended to enable traffic-aware output power regardless of channel allocation scheme.

Figure 18 shows the corresponding capacity distribution for the different cases and also the traffic model. Thus, if a capacity curve is to the right of the traffic model, then congestion is less likely to occur. Link congestion is defined as the event when traffic demand exceeds the capacity of the microwave link. We calculated the percentage of congestion out of 50,000 simulations. It is observed that the 2x56MHz system has problems fulfilling the traffic demand and, in fact, it experiences 41 percent and 54 percent congestion with and without traffic-aware output power, respectively. However, the 1x112MHz system performs much better and experiences 2 percent and 11 percent congestion with and without traffic-aware output power, respectively. The simulations also found that the fixed output power case typically generates much higher capacity compared to its traffic-aware counterpart. This is simply a consequence of capacity overprovisioning since the fixed output power is independent of the varying traffic demand. Overprovisioning comes at a price of more output power consumption and interference. The negative effect of more interference is reflected by the higher congestion experienced by the systems with fixed output power. Nonetheless, fixed output power shows the capacity potential of reuse one, and traffic-aware power control will take care of any overprovisioning and provide interference reduction.

On closer analysis of the links that experience congestion, 6 out of the 122 links were found to have clear problems when using the same 112MHz channel, since they are simply too close and therefore suffer from interference. For example, we identified a short link that suffered from strong interference caused by two nearby and much longer links, which typically use much more output power to fulfill their traffic demands. But on the positive side, there were 116 links out of 122 for which reuse one fulfilled the traffic demand with high probability, whereas a reuse two design with a 56MHz channel would have resulted in congestion for those 6 troublesome links.

Conclusions
In conclusion, we need transport solutions that meet the traffic growth in our networks. Such solutions also need to be properly dimensioned, spectrally efficient and sustainable. Furthermore, an efficient way to handle a higher traffic demand with limited spectrum in traditional bands is to enable a more aggressive channel reuse, as was shown in our simulations based on a typical network deployment. In fact, it was shown that using a single 112MHz channel in the whole network, in combination with traffic-aware output power, reduced congestion by 20 times compared to a network with a pair of 56MHz channels. Reuse one can therefore be used to handle higher data traffic demands in our networks with a limitation in spectrum.

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