IEEE P802.11
Wireless LANs

Aggregate throughput and channelization

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Abstract

The proposals for the high data rate 2.4 GHz PHY by Micrilor at one side and by others like Harris, Raytheon and Lucent have been compared with respect to aggregate throughput.
The major difference between the Micrilor proposal and the others is that the Micrilor one is based on two and not three independent channels, while the reuse of one of the two channel allows a 6 dB isolation by using another set of code words.
The aggregate throughput in access point based networks is analysed for two and three channel cases.

1. Medium reuse efficiency

The throughput density - in Mbit/s / cell (/ floor / channel) - depends on the co-channel rejection (medium reuse) properties of the modulation scheme. For a multi-channel access point based infrastructure the system planning and installation of access points relates to carrier sense thresholds, target cell size, and both co-channel and adjacent channel rejection.

(This contribution will not consider effective net throughput effects as a result of frame overhead (MAC and PHY), networking environment, higher layer overhead or throughput measured as result of benchmark test application.)

Planning scenario's for wireless LANs and cellular telephone systems are different in various ways. Wireless LANs use in a cell around an access point a single channel for both up- and down-link (half-duplex operation). The LAN traffic has another nature (bursty, packets) in contrast to the circuit-switched type of traffic. There might be more traffic from the access point, while the stations in different spots within the cell are active in random way. When we look for the wireless LAN scenario to tolerable co-channel interference from an adjacent cell, we have to be aware that an ACK is sent without individual carrier sensing.
Furthermore, we have to be aware of the path loss model. In practice the path loss for indoor environments grows above a certain distance faster than the exponential model models. By the presence of walls and other limiting effects, there will extra drops and a multi-breakpoint reflects the limiting effects of the exponential model. In outdoor environments the height of the antennas is relevant for breakpoints in the path loss model.

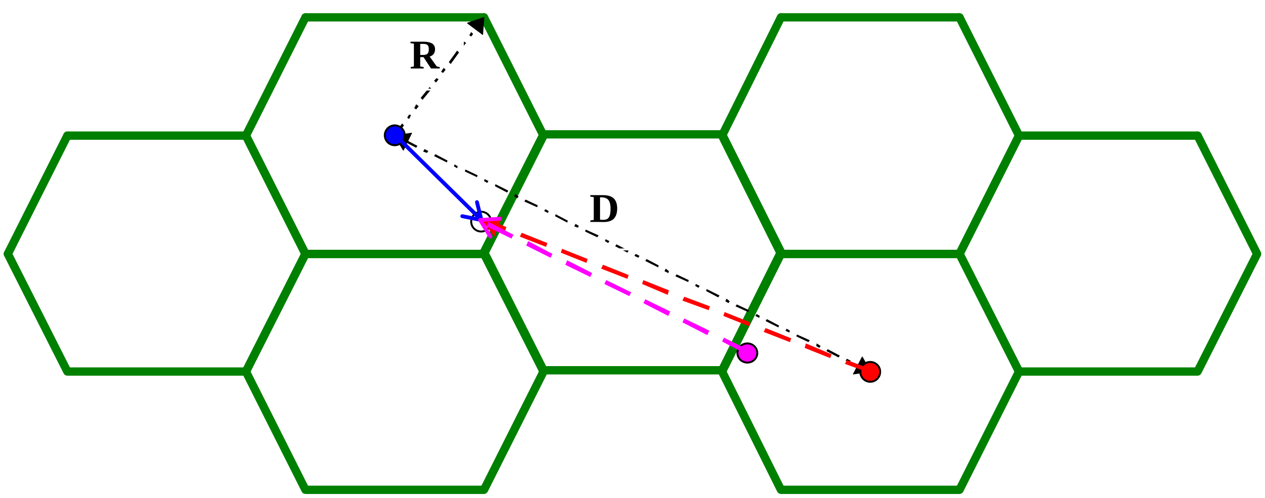

Fig. 1. Illustration of medium reuse distance
(difference between cellular (up/down link) and LAN (CSMA/CA))

The medium reuse efficiency, MRE, stands for the ratio between the area of cells where a single channel can be used, and the total area. In an ideal homogeneous (two-dimensional) environment characterised by an exponential path loss with coefficient γ the medium reuse efficiency is given for

wireless LANs by $MRE = [\, 2 + CSIR^{1/\gamma} \,]^{-2}$

and

cellular telephone by $MRE = [\, CSIR^{1/\gamma} \,]^{-2}$

with CSIR as required co-channel interference rejection.

It will be clear that in the first expression there is less dependency on CSIR.

Table 1. MRE values for wireless LANs and cellular telephone systems.

CSIR	MRE wireless LAN			MRE cellular telephone		
	$\gamma=3$	$\gamma=3.5$	$\gamma=4$	$\gamma=3$	$\gamma=3.5$	$\gamma=4$
6 dB	0.078	0.082	0.086	0.40	0.45	0.50
8 dB	0.068	0.073	0.078	0.29	0.35	0.40
10 dB	0.058	0.065	0.070	0.22	0.27	0.32
12 dB	0.049	0.057	0.063	0.16	0.21	0.25

2. Installation of access points

For the installation of access points which use the same channel and operate independently, the distance has to be large enough with respect to the carrier sense (CRS) or defer threshold. With a transmit power of 50 mW we could use –70 dBm threshold stands for a defer range 60 meter as illustrated in Fig. 2. This –70 dBm creates in fact a limit for independently operating access points as will be illustrated in Fig. 4 with hexagons.

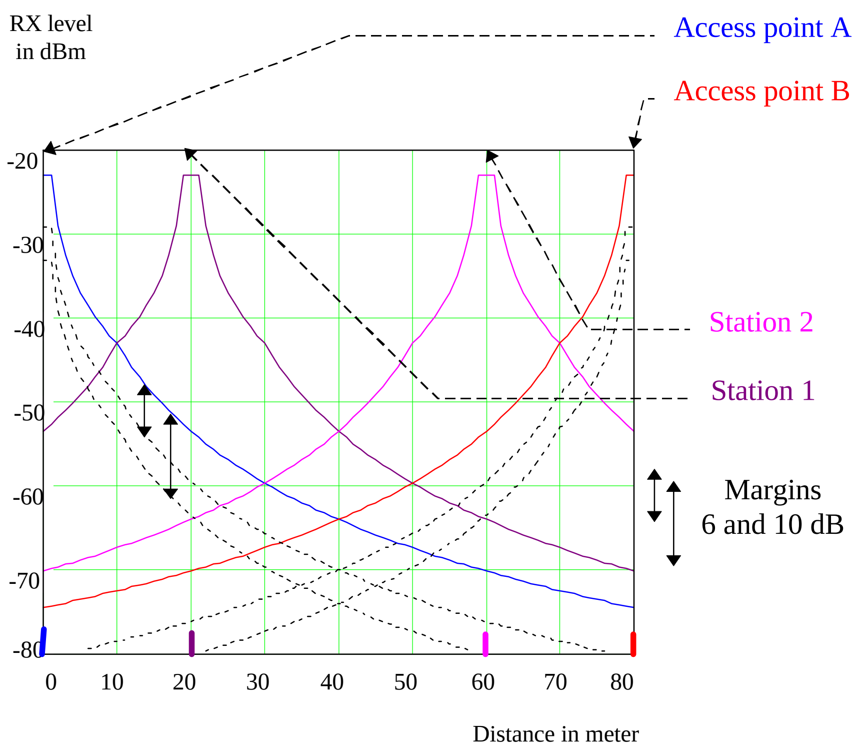

Fig. 2. Receive levels around access points and stations
with CRS threshold based on target cell size
(CRS threshold -70 dBm or lower @ TX power ≤ 50 mW).

Maybe it is simpler just to look to the figure above. To isolate well between stations 1 and 2 the distance between them has to be two times larger than their distance to the access points. (2 R vs. R gives say 10 dB protection for the interfering ACK). If the tolerable co-channel interference would be 6 dB, the distance between the two stations could be 34 % less (1.32 R vs. R gives say 6 dB protection for the interfering ACK). With the 6 dB better co-channel rejection the distance between access points could go down from 4 R to 3.32 R. In a two-dimensional homogeneous environment with a path loss of 10 dB per distance doubling ($\gamma = 3.3$) this means an improvement in MRE from 1:16 to 1:11 . At a higher exponential path loss coefficient ($\gamma > 3.3$) that difference in MRE will be less. In practice we find for larger distances a higher path loss increase above a certain distance like in office environments (multi-breakpoint model). Likely there will be extra isolation between the cells (walls between the access points with same channel). This helps for reuse at a larger distance, but not for nearby reuse. It looks like the occurrence of a larger path loss coefficient, which helps systems with a CSIR relatively more.

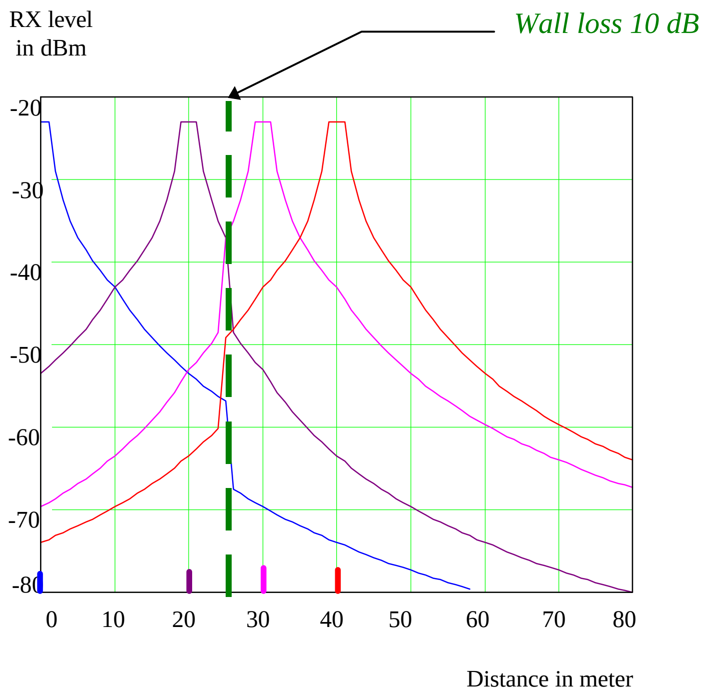

Fig. 3. Receive levels around access points and stations with 10 dB wall.

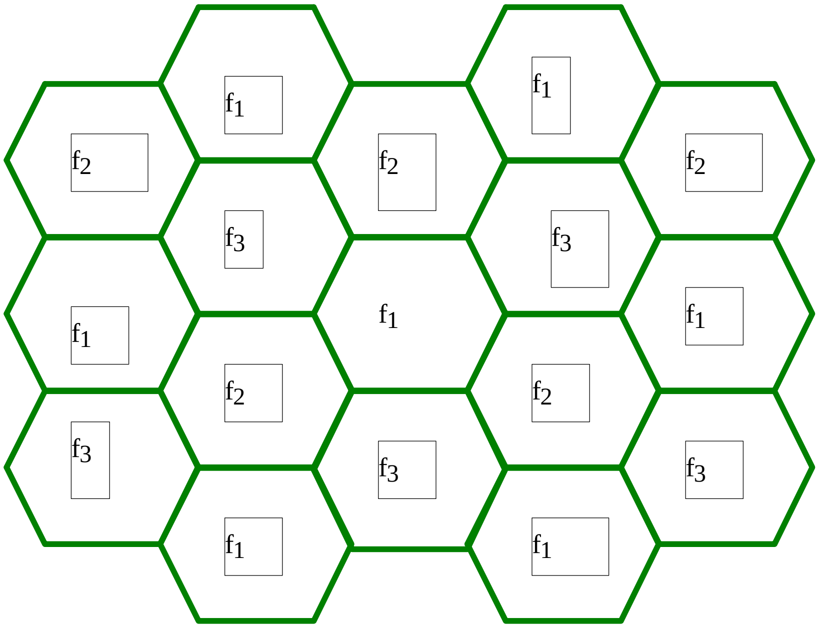

Fig. 4. Frequency reuse for hexagons with cell radius of at least 24 meter
(with CRS threshold -70 dBm or lower @ TX power ≤ 50 mW).

The way access points are installed, has to be in line with the restrictions of a building. Similar effects occur for the reference building scenario of Fig. 5. However, pairs of neighbour rooms share the medium.

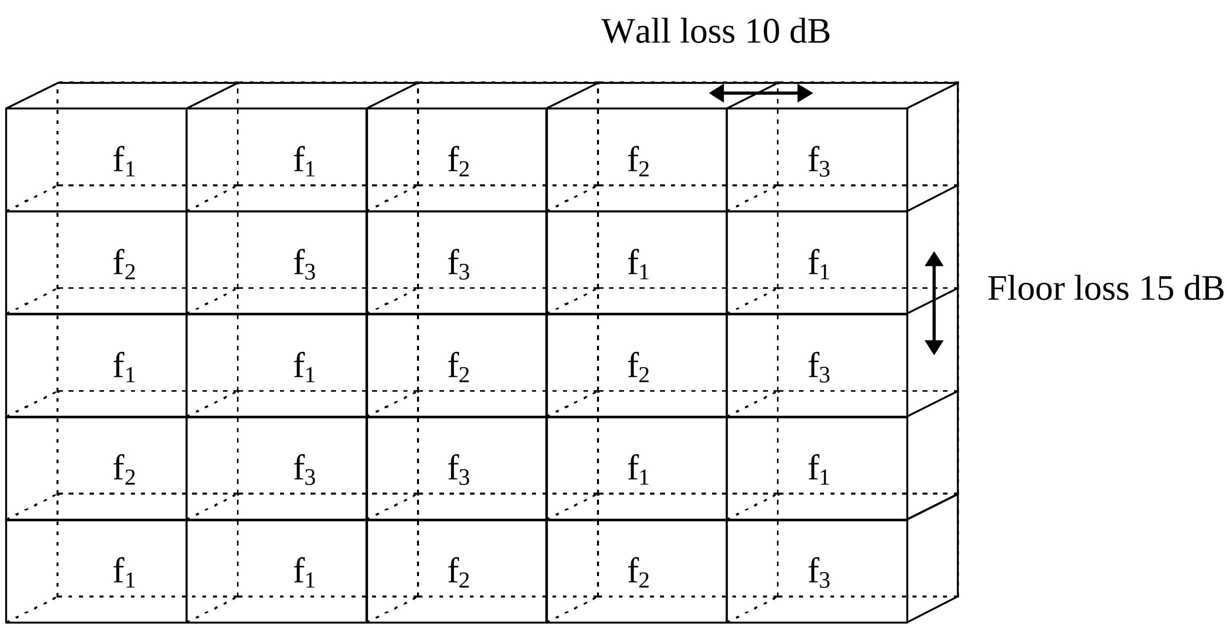

Fig. 5. Frequency reuse for some reference building
(with CRS threshold -70 dBm or lower @ TX power ≤ 50 mW).

3. Collocated systems and adjacent channel rejection

The 35 dB adjacent channel rejection as adopted for DSSS 2 Mbit/s allows three collocated systems with access points using one of the three channels. As long as the interference does not come from a transmitter within 2-3 meter, the reception over 60 meter will be reliable. The 2-3 meter does not only relate to the adjacent channel properties with respect to 60 meter TX-RX distance, but also to the RF/IF blocking or CRS effects by the adjacent channel. To avoid such effects the recommended distance between access points (antennas) is at least 2-3 meter.
By similar requirements for the receiver (SAW filter and system degradation) and the transmitter (spectrum regrowth) as with DSSS 2 Mbit/s the same 35 dB could be met for the high data rate PHY 2.4 GHz.

4. Conclusion

Medium reuse properties for a wireless LAN infrastructure with access points are different from those for cellular telephone. This is the result of using a single (half-duplex) channel for both up- and down-link. Therefore, the medium reuse is much less dependent on the required co-channel interference ratio. In practice the impact of a 6 dB co-channel rejection improvement with respect to the medium reuse factor is rather limited for indoor environments. In office-like environments the extra isolation between cells enhances this effect. A three channel solution is needed for a complete system solution which supports collocated systems in terms of aggregate throughput.
Therefore, the advantage of a better medium reuse per channel as presented by Micrilor will not compensate for missing the third channel.