# Dimensioning Cellular WiMAX Part I: Singlehop Networks

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*Abstract*— **Providing diverse broadband services economically to everyone is a major challenge for the telecommunication community. WiMAX or IEEE 802.16 is one of the most promising radio access technology to offer performances similar to wired xDSL systems, which surpass current 3G mobile data rates. Different deployment concepts are foreseen for WiMAX networks. They can cover isolated areas such as rural hot spots, private campus networks, and remote neighborhoods. Even more promising is WiMAX deployed as a cellular network that offers ubiquitous broadband services over large geographic regions to mobile subscribers. This paper discusses an analytical approach to dimension cellular OFDM-based WiMAX networks. Achievable UL and DL Carrier to Interference and Noise Ratios (CINRs) are calculated. A worst case analysis results in valuable indications for dimensioning cellular WiMAX networks within various singlehop scenarios.**

## I. Introduction

Cell planning has been intensively studied in the literature. The majority of research papers are either focussed on a specific wireless system, e.g., UMTS or GSM, or on sophisticated algorithms that automatically plan systems by considering certain optimization criteria, e.g., cost, coverage, or capacity. For instance, [1] lists papers of both types. This paper focus on the OFDM-based IEEE 802.16. It analyzes the system and extract features that affects cell planning. The dimensioning approach evaluates the deployment in typical scenarios.

In [2] the analysis has been applied to multihop scenarios. Based on calculated Signal to Interference Plus Noise Ratio (SINR) values, the mean cell capacity of single- and multihop WiMAX networks has been derived in [3].

For dimensioning WiMAX networks, the worst case CINR within a cellular 802.16 network is relevant. In Downlink (DL), the central Base Station (BS) transmits to the most distant Subscriber Station (SS), which is located at the cell border. In Uplink (UL), the SS at the cell border transmits to the central BS. Interference is generated by co-channel cells that utilize the same frequency channel. In the considered network, DL and UL channels are assumed to be perfectly separated either by a Frequency Division Duplex (FDD) or by a fully synchronized Time Division Duplex (TDD) scheme.

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## II. Clustering and Sectorization

In order to avoid interference in cellular networks, cells are combined into clusters in which frequency channels are uniquely assigned to cells. Figure 1a shows a cellular network with cluster order three. Applying a cluster order $k$, the distance to co-channel cells $D$ is only a function of the cell radius $R$ [4]: $D = R\sqrt{3k}$.

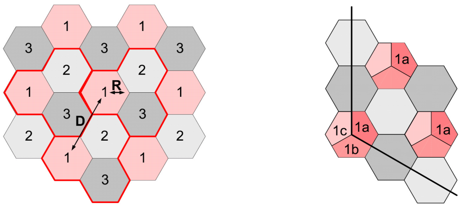
According to [5], the UL Carrier to Interference Ratio (CIR) only depends on the cluster order if noise is neglected and if the neighboring SSs are assumed to be centrally located in their cells. With increasing cluster order, the CIR at a central BS receiving a signal from a SS at the cell border is increasing. With $\gamma$ as the path-loss component, the worst case CIR can be calculated to:

$$\frac{C}{I} = \frac{1}{6}\left(\frac{D}{R}\right)^{\gamma} = \frac{1}{6}\left(3k\right)^{\frac{\gamma}{2}} \quad (1)$$

Dividing cells into sectors is an established technique for further reducing the interference level in cellular wireless networks. Each sector is covered by a sector antenna. The sectorization of cells and the frequency assignment is periodically repeated all over the network. A sophisticated way to allow for sectorization with adaptive antennas is shown in [6]. The BS sector antenna suppresses its transmit energy to regions outside its sector, so the number of interfering co-channel cells can be reduced. Figure 1b shows a cellular network with 3-sectored cells. Only two co-channel cells are visible for the receiving BS sector antenna instead of six in Figure 1a. In DL a receiving SS at the border of a cell receives only interference, which is generated by the two most distant co-channel BSs. Analog to the previous equation, the expected UL CIR in a sectorized and clustered cell is given by the following equation in which $m$ is the number of sectors [5]:

$$\left(\frac{C}{I}\right)_{sector} = \frac{m}{6}\left(\frac{D}{R}\right)^{\gamma} = m\left(\frac{C}{I}\right)_{non-sector} \quad (2)$$

Equations 1 and 2 calculates only the UL CIR. They do not consider noise and they assume that SSs of neighboring cells are located in the center of the neighboring cell. In the following analysis, the effect of noise is considered and the SSs' position is modeled more accurately. Furthermore, the analysis is expanded to calculate the DL CINR as well.



(a) Cell cluster order 3

(b) 3-sectored cells using cluster order 3

Fig. 1: Cellular network

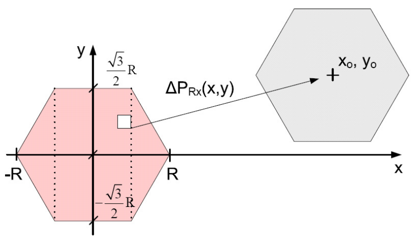



Fig. 2: Interference received from a co-channel cell

## III. Mean Interference of a Distant Cell

During UL transmission, SSs of co-channel cells generate interference. These SSs are randomly distributed within the cell area. Sometimes they are closer to the neighboring cell, and sometimes they are farther. Event-driven simulations can consider the current position of a SS precisely. They average the measures over a certain simulation time. The following analysis is a snap-shot of an actual CINR situation. Averaging the generated interference by just placing all SSs in the center of the cell is not correct, due to the non-linear influence of the pathloss. SSs, which are close to the neighboring cell, increase the co-channel interference more than distant SSs decrease it. In order to model the influence of co-channel interference accurately, the mean interference generated by a co-channel cell is calculated by assuming a planar transmitter with the shape of the hexagonal cell. The transmit power is equally distributed all over the cell surface area. The resulting interference is similar to a simulative approach with reasonable averaging over time. A comparable approach to model interference has been developed by [7]. However, [7] assumed circular cells and it does not consider the effect of noise. Sectorization has not been considered as well.

Figure 2 shows the cell of interest on the right and a co-channel cell that generates interference on the left. The mean interference level that is received by a central BS, which is located at $x_0, y_0$, can be calculated by assuming that each area element of the hexagonal cell transmits with equal fractions of the transmit power. According to its distance to the BS of interest, each fraction of the transmit power is attenuated. Thus, each area element of the distant cell generates one fraction to the overall receive power. By integrating the receive power per area element $\Delta P_{R_x}(x,y)$ over the hexagonal cell area, the mean level of receive power $\overline{P_{R_x}}$ can be calculated (see equation 3). The parameters $G_{T_x}$ and $G_{R_x}$ are the antenna gains at the receiver and the transmitter side.

$$\begin{aligned}\overline{P_{R_x}} &= \int_{area} \Delta P_{R_x}(x,y) \\ &= \int_x \int_y \frac{P_{T_x} * G_{T_x} G_{R_x}}{area}\, pl(x,y)\, dy\, dx \qquad (3)\end{aligned}$$

The cell area and the Pathloss (PL) model (PL coefficient $\gamma$) is given in equation 4. The coordinates $x_0, y_0$ depend on the cell radius and the cluster order.

$$\begin{aligned}area &= \frac{3}{2}\sqrt{3}R^2 \qquad \text{and} \\ pl(x,y) &= \beta \sqrt{(y-y_0)^2 + (x-x_0)^2}^{\,-\gamma} \qquad (4)\end{aligned}$$

Now, the receive power per area element can be integrated over the cell area. To do so, the surface area of the cell is divided in three parts. The dotted lines in figure 2 show the three parts. The limits of the integral in equation 5 are set accordingly.

$$\begin{aligned}\overline{P_{R_x}} &= \int_{-R}^{-\frac{R}{2}} \int_{-\sqrt{3}x-\sqrt{3}R}^{\sqrt{3}x+\sqrt{3}R} \Delta P_{R_x}\, dydx \\ &+ \int_{-\frac{R}{2}}^{\frac{R}{2}} \int_{-\frac{\sqrt{3}}{2}R}^{\frac{\sqrt{3}}{2}R} \Delta P_{R_x}\, dydx \\ &+ \int_{\frac{R}{2}}^{R} \int_{\sqrt{3}x-\sqrt{3}R}^{-\sqrt{3}x+\sqrt{3}R} \Delta P_{R_x}\, dydx \qquad (5)\end{aligned}$$

Unfortunately, the sum of double integrals in equation 5 cannot be resolved into a closed form. Thus, it has been implemented in Matlab.

For the PL, the suburban C1 Metropol PL model from the IST - WINNER project was chosen [8]. Equation 7 list the parameters.

$$\text{NLOS:} \quad \beta = 10^{-\frac{27.7}{10}} \quad \gamma = \frac{40.2}{10} \qquad (6)$$

$$\text{LOS:} \quad \beta = 10^{-\frac{41.9}{10}} \quad \gamma = \frac{23.8}{10} \qquad (7)$$

The mean receive power $\overline{P_{R_x}}$ is normalized to the receive power $P_{R_x}$ of a single SS located at the center of the cell (refer to equation 8). Thus, a factor $(1+intcor)$ results that corrects the wrong assumption of a centered source of interference.

$$\begin{aligned}1 + intcor &= \frac{\overline{P_{R_x}}}{P_{R_x}} = \frac{\overline{P_{R_x}}}{P_{T_x} * G_{T_x} G_{R_x} * pl(0,0)} \\ &= \frac{1}{pl(0,0)} \int_x \int_y \frac{pl(x,y)}{area}\, dy\, dx \qquad (8)\end{aligned}$$

It has to be noted that the correction factor is independent of the cell radius. This is not directly visible from equation 5. Although the cell radius is part of the limits of the integral, its

TABLE I: Interference correction for LOS scenarios in [%]

| cluster order → <br> sectors per cell ↓ | 1 | 3 | 4 | 7 | 12 |
|---|---|---|---|---|---|
| 1 | 24.89 | 7.12 | 5.22 | 2.92 | 1.68 |
| 2 | -21.48 | -15.38 | -13.56 | -8.52 | -8.82 |
| 3 | -41.04 | -27.50 | -24.28 | -20.90 | -15.33 |
| 6 | -48.18 | -33.66 | -30.12 | -24.04 | -19.51 |

TABLE II: Interference correction for NLOS scenarios in [%]

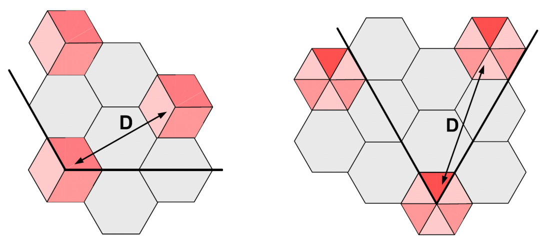
| cluster order → <br> sectors per cell ↓ | 1 | 3 | 4 | 7 | 12 |
|---|---|---|---|---|---|
| 1 | 89.70 | 21.83 | 15.65 | 8.55 | 4.86 |
| 2 | -21.97 | -20.75 | -18.71 | -11.70 | -13.37 |
| 3 | -57.46 | -41.00 | -36.72 | -32.28 | -24.16 |
| 6 | -65.98 | -49.37 | -44.91 | -36.79 | -30.45 |

influence is canceled by the division with the receive power $P_{R_x}$ in equation 8.

The first line of table I (one sector per cell) lists the interference correction ($intcor$) in percent for the Line-of-Sight (LOS) case. The first line of table II shows the Non Line-of-Sight (NLOS) scenario. By comparing the values of both lines it can be seen that for LOS scenarios the correction is lower than for NLOS scenarios. This is due to the higher PL coefficient $\gamma$, which causes the non-linear behavior of the PL attenuation. Beside the PL coefficient, the correction factor depends on the cluster order. With higher cluster orders, the co-channel distance increases. The farther the distant cell, the more it looks like a point source. The influence of the hexagonal surface decreases. Both scenarios, LOS and NLOS show this behavior. In the LOS scenario the values range from 24.89 % to 1.68 %. That means, the mean interference of a distant LOS cell is between 1.68 % and 24.89 % larger than the interference generated by a transmitter located in the center of the cell.

When a cell is covered by sector antennas, the geometry within the network changes. The surface area, which is covered by one frequency channel is no hexagon any more. The shape of a sector and the relative position of interfering sectors depend on the number of sectors per cell and on the cluster order. Figures 1b and 3 show examples of different shapes of sectors and different relative positions between the sectors.

Analog to the calculation above, the mean interference generated by one sector can be derived (refer to tables I and II).




(a) 3-sectored cell using cluster order 4

(b) 6-sectored cell using cluster order 7

Fig. 3: Different shapes and positions of sectors

Since the sector is always farther away than the center of the cell, the correction for two or more sectors per cell is always negative. This means that the mean interference generated by the planar sector is lower than the interference generated by a single source located at the center of the co-channel cell. Apart from cluster order one, the difference between the mean value and the approximation is larger for sectored cells than for non-sectored cell. For instance, the reduction for sectors is larger than 15.38 % for cluster order three and LOS compared to a rising of 7.12 % in non-sectored cells.

Analog to a non-sectored network, the corrections for LOS scenarios are smaller than for NLOS ones. For instance, in table I the reduction for two or more sectors per cell lies between 8.52 % and 48.18 %, whereas table II shows reductions between 11.7 % and 65.98 %. The higher PL coefficient causes this effect. Furthermore, the values depend on the number of sectors and on the cluster order. With an increasing cluster order, the reduction is approaching one. This is due to higher co-channel distances. With an increased number of sectors per cell, the shape of the sector narrows down so that the correction become larger.

## IV. Cellular Scenario

The considered cellular scenario consists of a hexagonal cell with a central BS. The cell is covered by one to six sectors and the network is clustered in groups ranging from three to twelve frequency channels. The first tier of six interfering co-channel cells is considered. The distance to the co-channel cells depends on the cluster order and the cell radius. The BSs of the co-channel cells are also centrally located. In contrast to section II, the unknown and varying locations of the interfering SSs are modeled by means of the mean interference generated by a planar transmitter (refer to section III).

Unlike in section II, noise is considered in the following analysis. Thermal noise (-174 dBm/MHz) is further amplified by a noise figure of 5 dB. Antenna gain is neglected at the receiver as well as at the transmitter. For dimensioning purposes, the cell boundary is of interest where the most robust modulation and coding scheme, i.e., Binary Phase Shift Keying (BPSK) ½ has to be used. The minimum receiver requirement for BPSK ½, i.e., 6.4 dB is taken from the 802.16 standard.

The cellular WiMAX network operates in the upper 5 GHz frequency bands, which had been licensed for indoor and outdoor Wireless Local Area Network (WLAN). The OFDM-based physical layer allocates resources in Time Division Multiple Access (TDMA) on the entire channel bandwidth of 20 MHz. In Europe, the maximum allowed Equivalent Isotropic Radiated Power (EIRP) within the 5 GHz bands is restricted to 1 W or 30 dBm. According to this, BSs and SSs are both transmitting with 1 W. The suburban C1 Metropol PL model from the IST - WINNER project was applied during the analysis. The model has been developed for suburban scenarios in the 5 GHz spectrum [8].

The DL and UL channels of the considered network are perfectly separated. This is accomplished either by synchronized switching points that separate DL and UL transmissions all

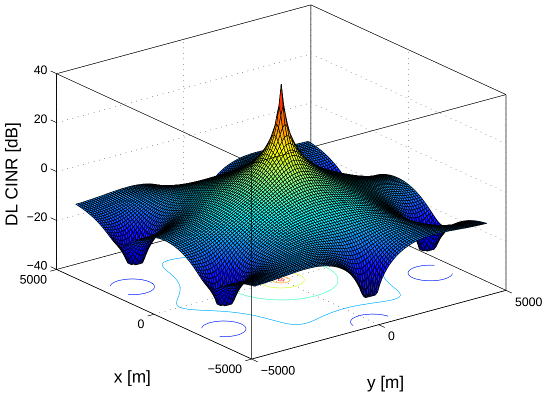



Fig. 4: DL CINR over cell surface area (cell radius 1000 m, cluster order 7, 1 sector)

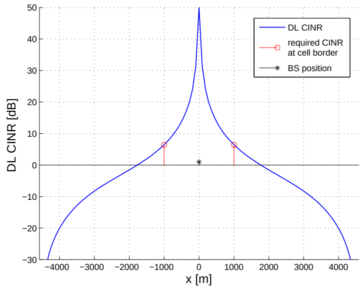



Fig. 5: DL CINR while traversing the scenario (cluster order 7, 1 sector)

over the TDD network or by an FDD scheme where channels are separated in the frequency domain. TDD systems with unsynchronized DL and UL phases observe severe mobile to mobile interference. In the following, only neighboring BSs cause interference in DL, while UL interference is generated by SSs of neighboring cells. It is assumed that during the transmission of interest, every co-channel cell transmits and thus generates interference. This worst case analysis is valid for the broadcast phases in a synchronized network as well as for DL/UL data transmissions in an fully loaded network.

Figure 4 shows the DL CINR plotted over the surface area of an example scenario. The cell radius is 1000 m and the cluster order is seven. The transmitting BS is located in the center while six co-channel cells are located according to the cluster order. It can be seen that the CINR in the middle is quite high but it decreases with the increasing distance to the BS. Near the co-channel cells, the CINR decays drastically. Figure 5 plots the CINR for a SS traversing the cell across the x-axes. One can see the BS position and the cell border. The hight of the two stems at the cell border mark the minimum receiver requirement for BPSK½. It can be seen that the actual CINR level at the border, which is 6.46 dB, is shortly above the minimum requirement. Thus, the shown scenario has a sufficient CINR at the cell radius, but there is hardly no CINR margin left at the border.

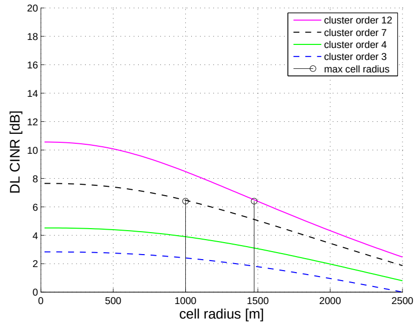



Fig. 6: DL CINR for varying cluster orders (LOS, 1 sector)

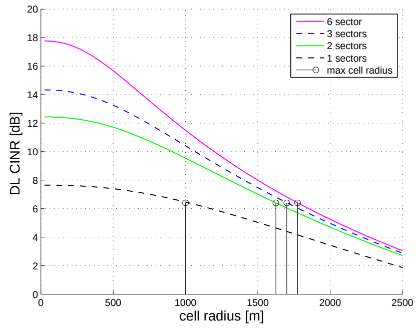



Fig. 7: DL CINR with sectorization (LOS, cluster order 7)

## V. Downlink Transmission

In DL, the central BS transmits to the most distant SS, which is located at the cell border. The CINR at the cell border is plotted versus the cell radius in the following figures.

Figure 6 illustrates the influence of clustering on the DL CINR at the cell border in a LOS scenario. With an increasing cluster order, the co-channel distance increases and the interference level decreases. This leads to an increased CINR at the cell border. The size of the cell radius affects the CINR in the same way: the larger the radius, the higher the CINR at the border. However, it can be seen that not all cluster orders are valid in the LOS scenario. Low cluster orders, such as three and four do not provide a sufficient CINR level at the cell border. Even very small radii are not satisfactory, because co-channel cells are very close and thus the level of interference is too high. For high cluster orders, e.g., seven or twelve, the cell radius can range up to 1000 m respectively 1475 m to provide a proper CINR. Since interference is the limiting factor in this scenario, the system is called *interference-limited*.

In DL, sectorization reduces the number of interferer that are simultaneously receivable by the SS and it reduces the interference power level (refer to section II). Figure 7 shows the CINR at the cell border in a cellular network with cluster order seven and additional sectorization. The graph illustrates that the coverage area can be extended from 1000 m radius without sectorization to 1625 m with only two sectors per cell. A radius of up to 1775 m can be reached when the cell is covered by six sector antennas.

For cluster order three and four, where the area of a cell

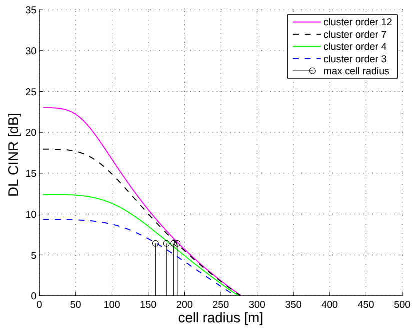



Fig. 8: DL CINR for varying cluster orders (NLOS, 1 sector)

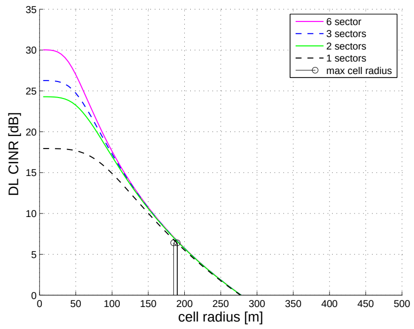



Fig. 9: DL CINR with sectorization (NLOS, cluster order 7)

could not be covered with clustering only, sectorization can increase the CINR at the border to a proper level. This would allow for a valid network deployment with small cluster orders.

In the following the NLOS PL model has been applied to the same scenario. The high PL coefficient attenuates the interference level of distant co-channel cells more than it attenuates the carrier signal of the nearby BS. The CIR is increased. If noise is neglected, equation 1 can be transformed to show the increased (UL) CIR in the NLOS scenario. Inequality 9 is always true because first, the co-channel distance $D$ is always larger than the cell radius $R$, which leads to ${}^{D}/_{R} > 1$ and second, because the PL coefficient of a NLOS scenario is larger than for the LOS case, which leads to $\Delta\gamma > 0$.

$$\begin{aligned} \left(\frac{C}{I}\right)_{NLOS} &= \frac{1}{6}\left(\frac{D}{R}\right)^{(1+\Delta)\gamma} \\ &= \left(\frac{C}{I}\right)_{LOS}\left(\frac{D}{R}\right)^{\Delta\gamma} > \left(\frac{C}{I}\right)_{LOS} \end{aligned} \quad (9)$$

Figure 8 shows the DL CINR at the cell border in the NLOS scenario. The graph shows an increased CINR at small radii, where the carrier signal is much larger than the noise-plus-interference level. All cluster orders are able to cover the entire cell area, at least with cell radii smaller than 160 m. The absolute values of the carrier and the interference signals attenuate faster in NLOS scenarios so that the influence of the constant noise level increases. Although the CIR is higher, the CINR decays much faster in NLOS scenarios. In figure 8 this effect can be seen at large cell radii. The CINR is lower than the figure 6. Since the level of interference in the NLOS example is rather low, it does not affect the CINR a lot, the valid cell radii for different cluster orders vary only between 160 and 190 m. In this scenario the system is *noise-limited*.

Figure 9 plots the DL CINR at the border for a varying number of sectors. For small cell radii, sectorization can increase the CINR at the cell border. For larger radii, the system becomes noise-limited, so that the interference reduction by means of sectorization has nearly no effect on the valid cell radii. Sectorization increases the maximum cell radius of a network with cluster size seven only from 185 to 190 m with any number of sectors.

Beside clustering and sectorization, several other features may increase the CINR level in WiMAX networks and thus extend the DL coverage. They are listed in the following:

- The *BS transmit power* of the BS was aligned to the maximum EIRP allowed in the targeted 5 GHz spectrum. If regulations allow to increase the transmit power, all co-channel BSs may increase their transmit power, too. The signal strength of carrier and interference grow the same way and finally, the CIR stays constant. Thus, an increased transmit power will have nearly no effect on the maximum cell radius in scenarios where the system is interference-limited. Nevertheless, the transmit power affects the CINR in noise-limited scenarios. There, it can increase the DL coverage area.
- The mobility amendment of IEEE 802.16e expands *subchannelization* to the DL data transmission. If BSs transmit on a subset of subcarriers only, the number of interferer per subcarrier can be reduced [9]. However, the spectral density and thus the transmission range stays constant. This feature is beneficial in interference-limited systems.
- During the DL subframe, a BS with adaptive antennas can steer its transmit antenna to the receiving SS so the *BS transmit antenna gain* improves the signal quality [10]. This reduces the inter-cell interference since less power is emitted in undesired directions. If regulations allows to exceed the EIRP by focusing the transmission power and thus increasing the spectral density, the received signal strength at the SSs is increased. This is additionally useful in noise-limited systems.
- In a *non-saturated system* not all co-channel BSs are constantly transmitting. This leads to a reduced level of interference.

The mentioned features to increase the CINR level are only valid during the scheduled DL data transmission. The synchronized broadcast phase of a cellular WiMAX network, in which all cells are transmitting omni-directionally on all available subcarriers cannot be enhanced. A dimensioning approach should focus on this phase as the worst case.

## VI. Uplink Transmission

In UL, SSs transmit to the central BS. For dimensioning, the most distant SS, which is located at the cell border, is most

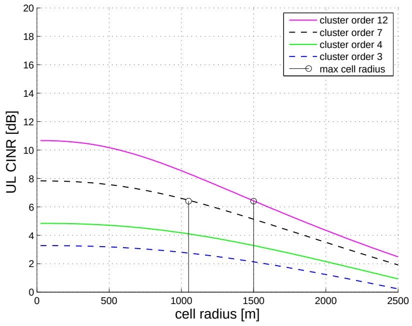



Fig. 10: UL CINR for varying cluster orders (LOS, 1 sector)

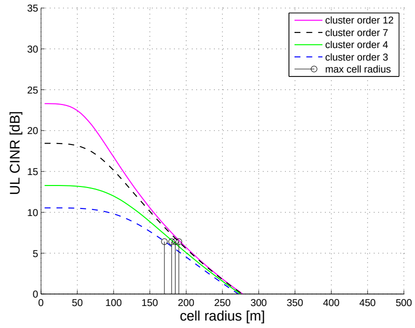



Fig. 12: UL CINR for varying cluster orders (NLOS, 1 sector)

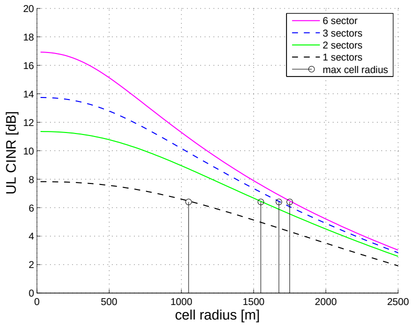



Fig. 11: UL CINR with sectorization (LOS, cluster order 7)

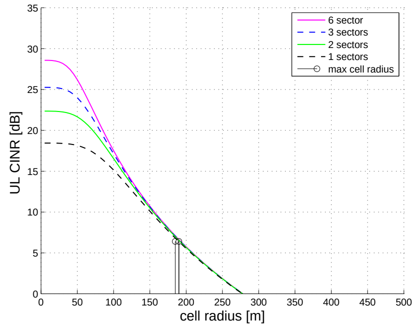



Fig. 13: UL CINR with sectorization (NLOS, cluster order 7)

critical. Interference is generated by SSs of neighboring cells, which utilize the same frequency channel. The mean level of interference as it has been deducted in section III is used. The following figures show the CINR perceived at the central BS while the most distant SS is transmitting.

In general, the UL CINR is quite similar to the DL CINR investigated in the previous section. On the one hand, it is a little bit lower because in UL, the receiver is located at the center of the cell and not at the cell border. Hence, the level of interference is slightly reduced. On the other hand, the CINR is reduced because in UL, SSs generate interference and not the central BSs. As it has been outlined in section III, their mean level of interference is slightly higher.

Figure 10 illustrates the influence of clustering in a LOS scenario. Cluster orders three and four are not leading to a sufficient CINR. Cluster order seven and twelve allow for cell radii of 1050 and 1500 m respectively. Here, the system is interference-limited.

In UL, sectorization reduces the number of SSs that are simultaneously receivable by the BS sector antenna and it reduces the interference power level (refer to sections II and III). Figure 11 shows the UL CINR in a cellular network with cluster order seven and additional sectorization. The radius of the coverage area can be extended from 1050 m without sectorization to 1550 m with two sectors per cell. A radius of up to 1750 m is valid with six sectors per cell.

Figure 12 shows the UL CINR in a NLOS scenario. The CIR is increased with small radii and all cluster orders are able to provide proper signal quality with cell radii smaller than 170 m. With larger cell radii, the CINR decays rapidly due to the high PL coefficient and the resulting influence of noise. Again, the level of interference in the NLOS case is so low that the valid cell radii for different cluster orders vary only between 170 and 190 m. In the NLOS scenario the system is noise-limited.

The UL CINR for cluster order seven and for a varying number of sectors is plotted in figure 13. For small cell radii, sectorization can increase the CINR, but for larger radii, the interference reduction by means of sectorization has nearly no effect on the valid cell radii. Reducing interference does not benefit in a noise-limited system. With two sector antennas per cell it can be increased from 185 to 190 m. With more sectors it remains constant.

Beside clustering and sectorization, several other features may increase the UL CINR level and thus extend the UL transmission range:

- The *SSs' transmit power* was set to the maximum allowed EIRP. Portable and mobile SSs will most probably be battery powered. Their restricted power consumption may force the devices to reduce the transmit power, which will reduce the carrier strength. If all co-channel SSs transmit with reduced power, too, interference is reduced the same way and the CIR stays constant. In interference-limited systems, the possible link distances are nearly not affected. In noise-limited systems, a reduced transmit power leads to a reduced coverage.
- *UL subchannelization* is specified for initial ranging, for Bandwidth (BW) requests and for UL data transmission.

Subchannelization during ranging and BW request procedures allows to focus the transmit power onto a subset of subcarriers. This increases the spectral density by 12 dB and extends the transmission range significantly [11]. Since this feature increases the carrier signal and reduces interference, it is beneficial in both, interference and noise limited systems.
If the transmit power per subcarrier stays constant during UL data transmission, interference-limited systems benefits from subchannelization: if all SSs are using a subset of the available subcarriers, the number of interfering stations per subcarrier is reduced.

- In a *non-saturated system* not all co-channel cells have constantly active transmissions. This reduces the number of interferer.
- During the scheduled part of the UL subframe, the BS can focus its receive antenna to the transmitting SS so that the *BS receive gain* improves the signal quality [10]. Since an adaptive antenna can reduce the received interference and increase the receive carrier strength, it is useful in all scenarios. Note that, the receive antenna characteristic is not restricted by regulations.

Some features to increase the CINR level are applicable during the scheduled UL data transmission, others during the contention based access. Especially subchannelization extends the UL range significantly. If this optional feature is implemented by the manufacturer, the UL transmission is most probably not the limiting factor in a cellular 802.16 network.

## VII. Conclusion

This paper shows an analytical dimensioning approach for planning cellular WiMAX networks within diverse scenarios. In some scenarios severe interference avoids a cellular deployment. In other scenarios noise is the crucial factor that limits the range. In general, the system is interference-limited under LOS conditions and in single frequency networks, whereas it is noise-limited in NLOS scenarios.

Cell planing features (e.g., clustering and sectorization) as well as WiMAX technology options (e.g., subchannelization) allow to handle interference and noise so that WiMAX networks can provide sufficient coverage. Some features are useful in interference limited system because they reduce the inter-cell interference: clustering, sectorization, DL/UL subchannelization for data bursts. Other means are beneficial in noise-limited systems because they increase the received signal strength: increased transmit power, UL subchannelization for contention slots (focussing power). Finally, some options may increase coverage and capacity in both situations: BS antenna gain. However, not all features are applicable in all phases of the transmission. The most critical part of a cellular WiMAX network seems to be the DL broadcast phase. During this phase, neither subchannelization nor antenna gain can be applied. Thus, a dimensioning approach should particularly consider this phase.

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