3GPP TSG RAN WG1 #74bis **R1-134591**
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Title: Remaining Details of Path Loss for High-Rise Scenario

Document for: Discussion and Decision

1 Introduction

At RAN1 #74, an agreement was made on an additional outdoor-to-indoor (O-to-I) scenario for high-rise as described in [1] [2] with the inter-site distance (ISD) changed to 300 m and the detailed 3D channel modeling aspects remaining for further study (FFS) [3].

This contribution discusses the remaining details of path loss for the high-rise macrocell scenario (hereinafter **3D-HMa)** including:

- Line-of-sight (LOS) probability
- Environment height
- Path loss

2 LOS Probability for High-Rise Scenario

For 3D-HMa, the height of indoor user equipment (UE) is expressed as $3(n_{fl} - 1) + 1.5$ m where the floor number $n_{fl} \in \{1, 2,\ldots, x\}$ with the total number of floors $x \in \{4, 5,\ldots, 8\}$ for low buildings and $x \in \{20, 21,\ldots, 30\}$ for high buildings.

In contrast with [1] [2] that proposed 100% LOS probability for indoor UE above the eighth floor, this contribution discusses an alternative based on the 3D-UMa LOS probability equations (assuming applicability to 3D-HMa) as highlighted in Table 1.

Table 1. LOS probability for 3D-HMa.

LOS probability for outdoor users[1)], distance is in meters	Applicability range
$P_{LOS} = \min(18 / d_{2D}, 1)(1 - \exp(-d_{2D} / 63)) + \exp(-d_{2D} / 63)(1 + C(d_{2D}, h_{UT}))$	
$C(d_{2D}, h_{UT}) = 0$	$h_{UT} < 13$
$C(d_{2D}, h_{UT}) = ((h_{UT} - 13) / 10)^{1.5}\, g(d_{2D})$	$13 \le h_{UT} \le 23$
$C(d_{2D}, h_{UT}) = g(d_{2D})$	$h_{UT} > 23$
$g(d_{2D}) = 1.25 \cdot 10^{-6} \cdot d_{2D}^{3} \cdot \exp(-d_{2D} / 150)$	$d_{2D} > 18$
$g(d_{2D}) = 0$	$d_{2D} \le 18$

1) In O-to-I cases, $d_{2D\text{-}out}$ is used to determine P_{LOS}

It is worth noting that the above LOS probability (assuming applicability to 3D-HMa) is independent of the UE height above 23 m or the eighth floor but still depends on the 2D distance between the base station (BS) and UE. For example, $P_{LOS} \approx 83\%$ at the minimum distance of 35 m between the BS and UE, and $P_{LOS} \approx 38\%$ at 300 m between the BS and UE.

3 Environment Height for High-Rise Scenario

For LOS path loss, the break point distance $d'_{BP} = 4\,(h_{BS} - h_E)\,(h_{UT} - h_E)\,f_c / c$ varies with both the UE height h_{UT} and environment height h_E assuming that $h_{BS} = 25$ m for 3D-HMa, $f_c = 2 \times 10^9$ Hz, $c = 3 \times 10^8$ m/s, $h_{UT} = 3(n_{fl} - 1) + 1.5$ m where the floor number $n_{fl} \in \{1, 2, \ldots, x\}$ with the total number of floors $x \in \{4, 5, \ldots, 8\}$ for low buildings and $x \in \{20, 21, \ldots, 30\}$ for high buildings.

Given an LOS event for UE above the eighth floor, the probability for $h_E = 1$ m is $1 / (1 + g(d_{2D}))$ where $g(d_{2D})$ is defined in Table 1. With the probability $g(d_{2D})/(1 + g(d_{2D}))$, h_E may be randomly selected from {12, 15, 18, 21, 24}. Table 2 lists the d'_{BP} values for specific h_{UT} and h_E. The values of $d'_{BP} < 5000$ m are highlighted for the applicability range of LOS path loss.

Table 2. Environment height and LOS break point distance for 3D-HMa.

		d'_{BP} (m)					
n_{fl}	h_{UT} (m)	$h_E = 1$ m	$h_E = 12$ m	$h_E = 15$ m	$h_E = 18$ m	$h_E = 21$ m	$h_E = 24$ m
30	88.5	56000	26520	19600	13160	7200	1720
29	85.5	54080	25480	18800	12600	6880	1640
28	82.5	52160	24440	18000	12040	6560	1560
27	79.5	50240	23400	17200	11480	6240	1480
26	76.5	48320	22360	16400	10920	5920	1400
25	73.5	46400	21320	15600	10360	5600	1320
24	70.5	44480	20280	14800	9800	5280	1240
23	67.5	42560	19240	14000	9240	4960	1160
22	64.5	40640	18200	13200	8680	4640	1080
21	61.5	38720	17160	12400	8120	4320	1000
20	58.5	36800	16120	11600	7560	4000	920
19	55.5	34880	15080	10800	7000	3680	840
18	52.5	32960	14040	10000	6440	3360	760
17	49.5	31040	13000	9200	5880	3040	680
16	46.5	29120	11960	8400	5320	2720	600
15	43.5	27200	10920	7600	4760	2400	520
14	40.5	25280	9880	6800	4200	2080	440
13	37.5	23360	8840	6000	3640	1760	360
12	34.5	21440	7800	5200	3080	1440	280
11	31.5	19520	6760	4400	2520	1120	200
10	28.5	17600	5720	3600	1960	800	120
9	25.5	15680	4680	2800	1400	480	40

4 Path Loss for High-Rise Scenario

Table 3 lists the 3D-HMa path loss models extended from the 3D-UMa path loss models [4]. Changes are highlighted. At the height gain factor $\alpha = 0.6$, the 3D-HMa NLOS path loss is, about 81% of the time, lower-bounded by the LOS path loss. In contrast, for $\alpha = 0.3$, the path loss is, about 19% of the time, lower-bounded by the LOS path loss.

Table 3. 3D-HMa path loss models.

Scenario	Path loss [dB], f_c is in GHz and distance is in meters	Applicability range, antenna height default values
3D-HMa LOS	$PL = 22.0\log_{10}(d_{3D}) + 28.0 + 20\log_{10}(f_c)$ $PL = 40\log_{10}(d_{3D}) + 28.0 + 20\log_{10}(f_c) - 9\log_{10}((d'_{BP})^2 + (h_{BS} - h_{UT})^2)$	$10\text{m} < d_{2D} < d'_{BP}$ $d'_{BP} < d_{2D} < 5000\text{m}$ $h_{BS} = 25\text{m}$ $1.5\text{m} \le h_{UT} \le 88.5\text{m}$
3D-HMa NLOS	$PL = \max(PL_{3D\text{-}HMa\text{-}NLOS}, PL_{3D\text{-}HMa\text{-}LOS})$ $PL_{3D\text{-}HMa\text{-}NLOS} = 161.04 - 7.1\log_{10}(W) + 7.5\log_{10}(h)$ $-(24.37 - 3.7(h/h_{BS})^2)\log_{10}(h_{BS})$ $+(43.42 - 3.1\log_{10}(h_{BS}))(\log_{10}(d_{3D}) - 3) + 20\log_{10}(f_c)$ $-(3.2(\log_{10}(17.625))^2 - 4.97) - 0.6(h_{UT} - 1.5)$	$10\text{ m} < d_{2D} < 5\,000\text{ m}$ h = average building height W = street width $h_{BS} = 25\text{ m}$ $h_{UT} = 1.5\text{ m}$ $W = 20\text{ m}$ $h = 20\text{ m}$ The applicability ranges: $5\text{ m} < h < 50\text{ m}$ $5\text{ m} < W < 50\text{ m}$ $10\text{ m} < h_{BS} < 150\text{ m}$ $1.5\text{ m} \le h_{UT} \le 88.5\text{ m}$
3D-HMa O-to-I	$PL = PL_b + PL_{\text{tw}} + PL_{in}$ **For hexagonal cell layout:** $PL_b = PL_{3D\text{-}HMa}(d_{3D\text{-}out} + d_{3D\text{-}in})$ $PL_{tw} = 20$ $PL_{in} = 0.5d_{2D\text{-}in}$	$10\text{ m} < d_{2D\text{-}out} + d_{2D\text{-}in} < 1000\text{ m}$ $0\text{ m} < d_{2D\text{-}in} < 25\text{ m}$ $h_{BS} = 25\text{m}$ $h_{UT} = 3(n_{fl} - 1) + 1.5$ $n_{fl} \in \{1, 2, \ldots, 30\}$

5 Conclusion

This contribution has presented the following proposal for discussion and decision on the remaining details of LOS probability, environment height, and path loss for the 3D high-rise macrocell scenario referred to as 3D-HMa:

Proposal: Extend the 3D-UMa path loss models to the high-rise scenario without assuming 100% LOS probability for indoor UE above the eighth floor.

6 References

[1] R1-133528, RAN1 #74, CMCC, "On optional high rise scenario."

[2] R1-133916, RAN1 #74, CMCC, *et al.*, "Way forward on high rise scenario."

[3] RP-131088, RAN #61, NSN, "Status report to TSG."

[4] RP-131323, RAN #61, RAN1, "TR 36.873 3D channel model for LTE."