Design and Planning of WiMAX Networks

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creating and sharing knowledge for telecommunications

Outline – Part I

- What is WiMAX
- Services, applications, and service quality
- Practical Point-to-multipoint, PTM, deployments
- Experimental results for coverage and throughput
- Comparison of the experimental results with outdoor propagation models
- *Cellular Planning:* coverage/capacity, motivation to the usefulness of GIS tools
- Examples of planning Wi-fi and WiMAX networks
- Design and deployment of pre-WiMAX PTP links
- Conclusions

What is WiMAX?

- WiMAX is a IEEE broadband wireless standard for IEEE 802.16 Wireless Metropolitan Area Networks (WMAN) (fully IP)
- There are two standards for IEEE 802.16
  - IEEE 802.16-2004, which defines WMAN technology for fixed access
  - IEEE 802.16e, includes mobility, handover, subchannelisation and enhanced QoS classes
- There will be 802.16m
  - Advanced air interface
  - Convergence with LTE (in ITU)

Channel bandwidth and data rate (IEEE 802.16-2004)

Bandwidth [MHz]	Data rate [Mbps]		
	QPSK	16-QAM	64-QAM
3.5	3.3	6.5	9.8
5.0	4.6	9.3	13.9
7.0	6.5	13.1	19.6
10.0	9.3	18.7	28.0
20.0	18.7	37.5	56.2

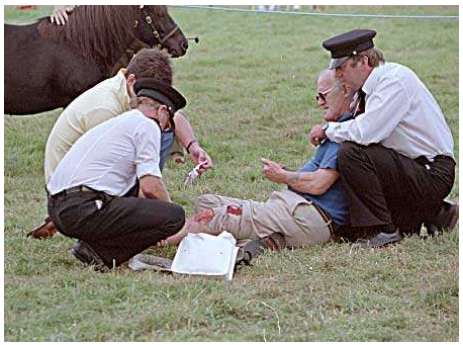
Modulation and codification schemes of 3.5GHz Alvarion equipment (3.5 MHz bandwidth)

Modulation & coding	***Net PHY Bit Rate* [Mbps]**	**Sensitivity [dBm]**
BPSK 1/2	1.41	-100
BPSK 3/4	2.12	-98
QPSK 1/2	2.82	-97
QPSK 3/4	4.23	-94
QAM 16 1/2	5.64	-91
QAM 16 3/4	8.47	-88
QAM 64 2/3	11.29	-83
QAM 64 3/4	12.71	-82

Service quality and flows

- Unsolicited Grant services – Ex: VoIP without silence suppression
- Real Time Polling Service – Ex: Streaming audio and video, MPEG encoded
- Non-real-time Polling service – Ex: FTP
- Best-effort service – Ex: Web browsing, data transfer
- Extended real-time polling service – Ex: VoIP with silence supression

Services and Applications



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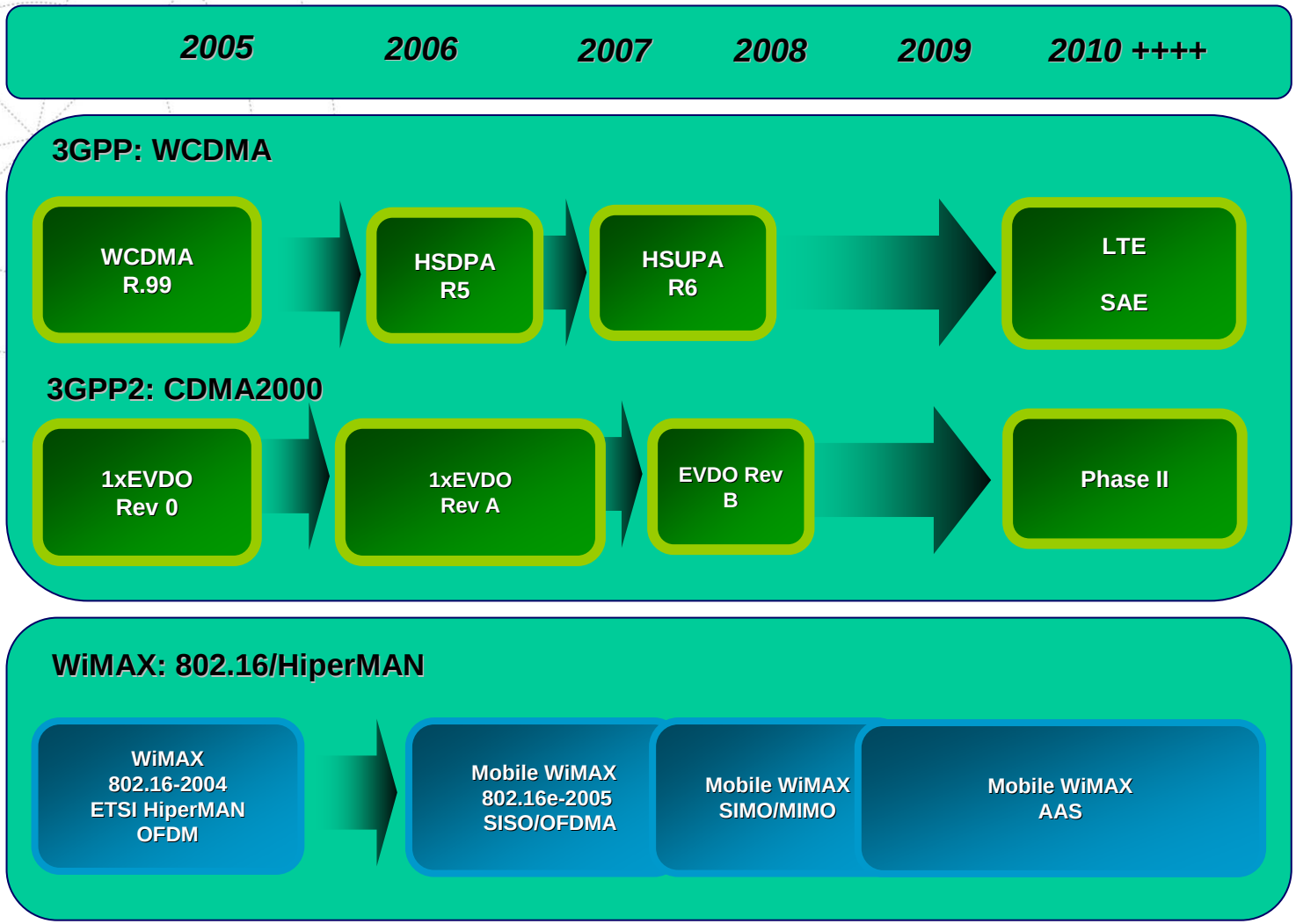
Path to Wireless Broadband Internet [Shakouri, WiMAX World USA 06]



Mobile WiMAX will be available before LTE, Phase II, and 4G

Source: WiMAX Forum

Introduction dates [Shakouri, WiMAX World USA 06]

28 WF Certified Products by:
Alvarion
Airspan
Axxcelera
Aperto
Proxim
Redline
Siemens
Sequence
SR Telecom
Selex
Telsima
Wavesat

Customer premise WiMAX certified Devices for Fixed Services

2006

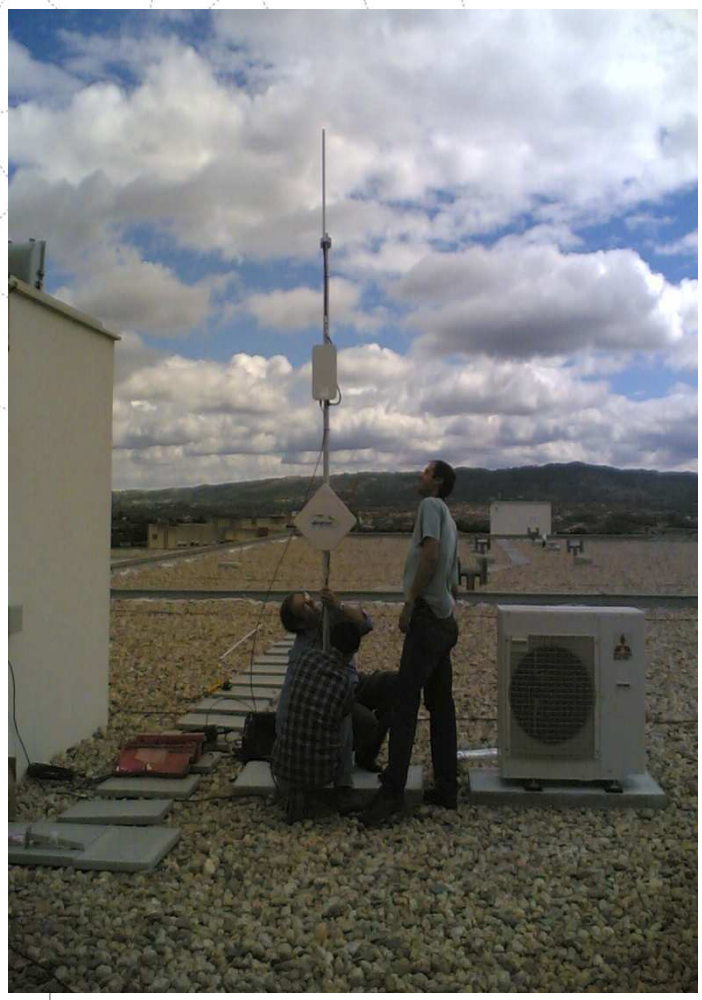
Portable WiMAX Certified Devices for Portable Services

2007

WiMAX handsets and enter-tainment devices

2008/9

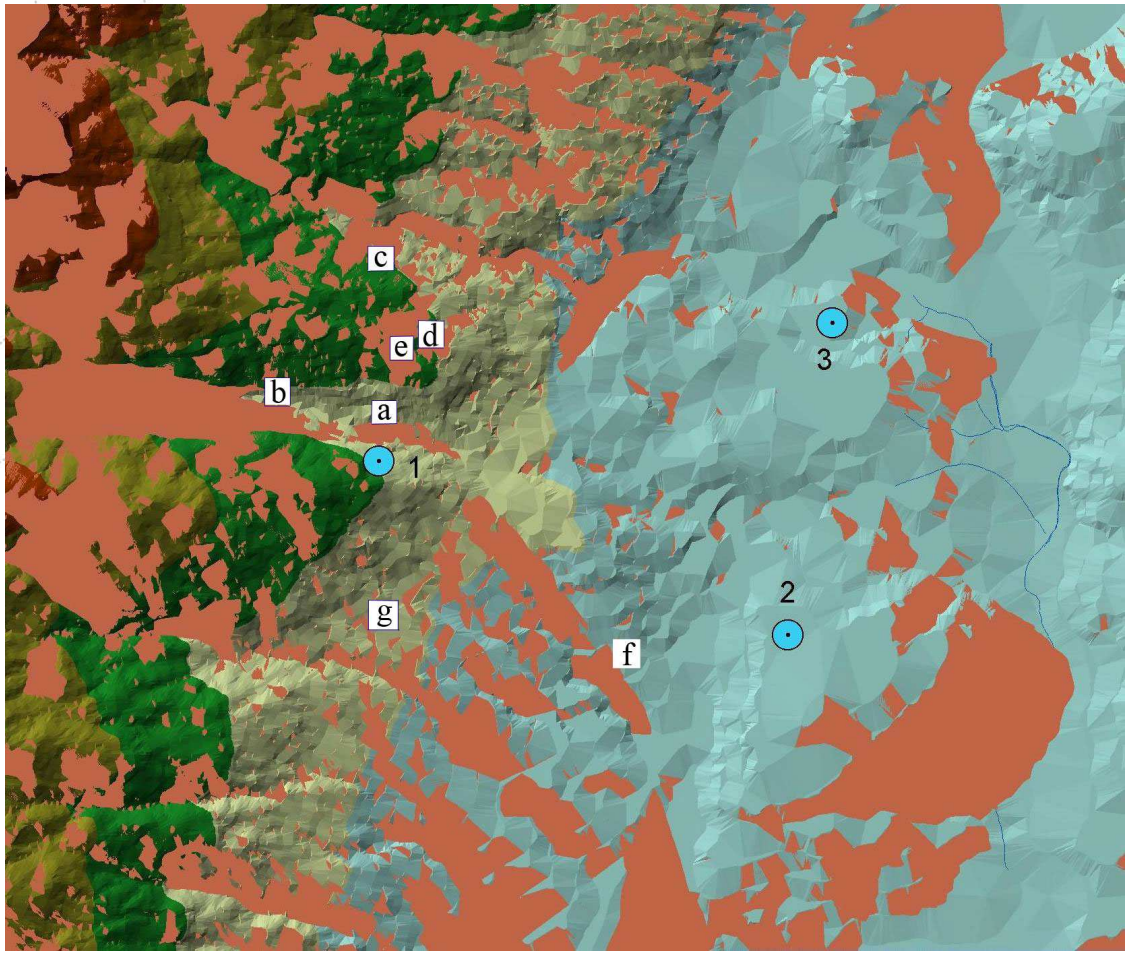
Point-to-multi-point, PTM, cell at 3.5 GHz



The BS was installed at FCS

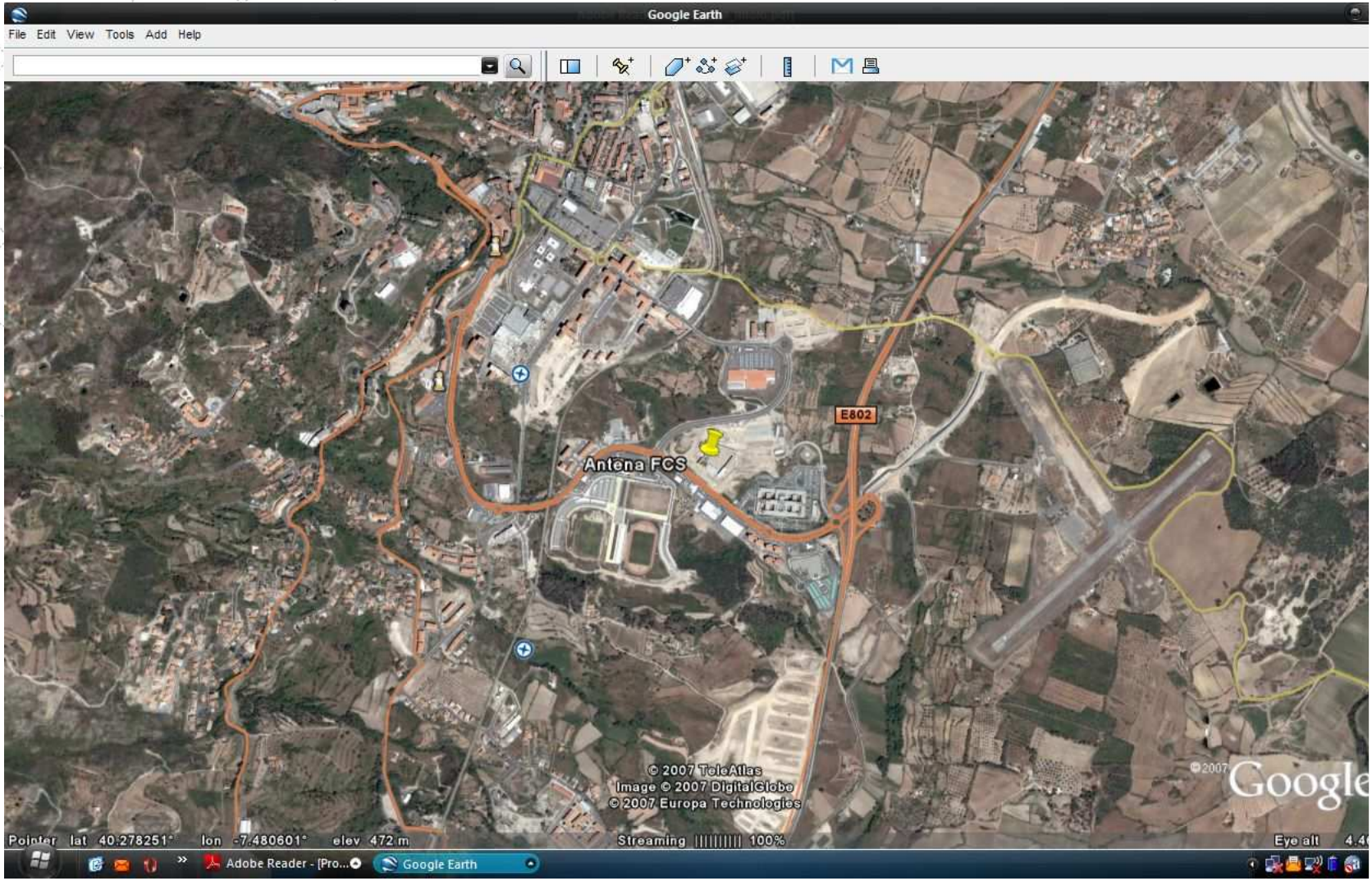
CPEs

Micro-cellular LoS Dimensioning



a – UBI, main building
b – UBI, Faculty of Engineering
c – UBI, Faculty of Social Sciences
d – City Council
e – Police Station
g – Health Centre
f – Hospital

The area under study - Health Science Faculty, FCS

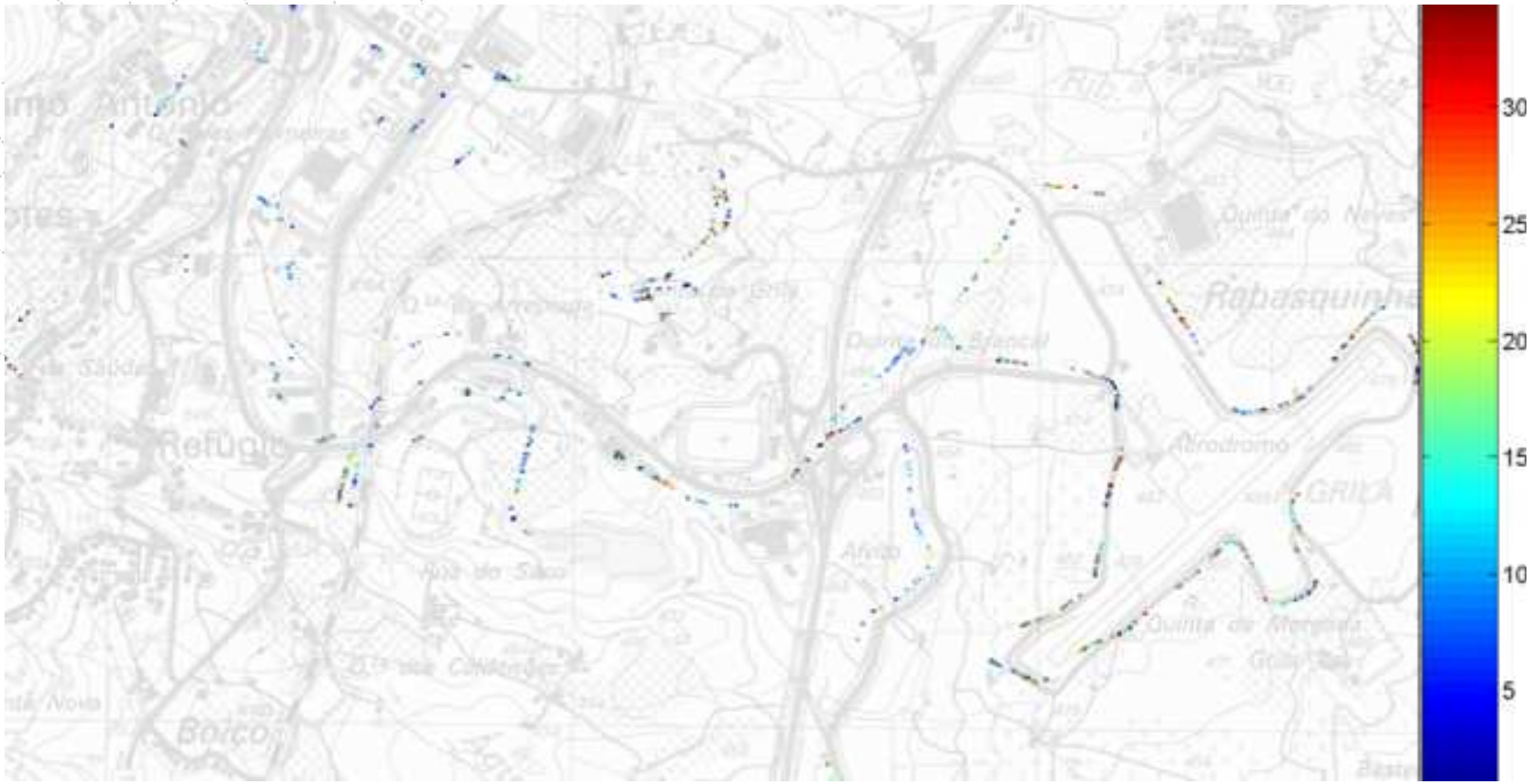


Detailed measurements of SNR in DL

Frequency license bands:

3543-3567.5 MHz

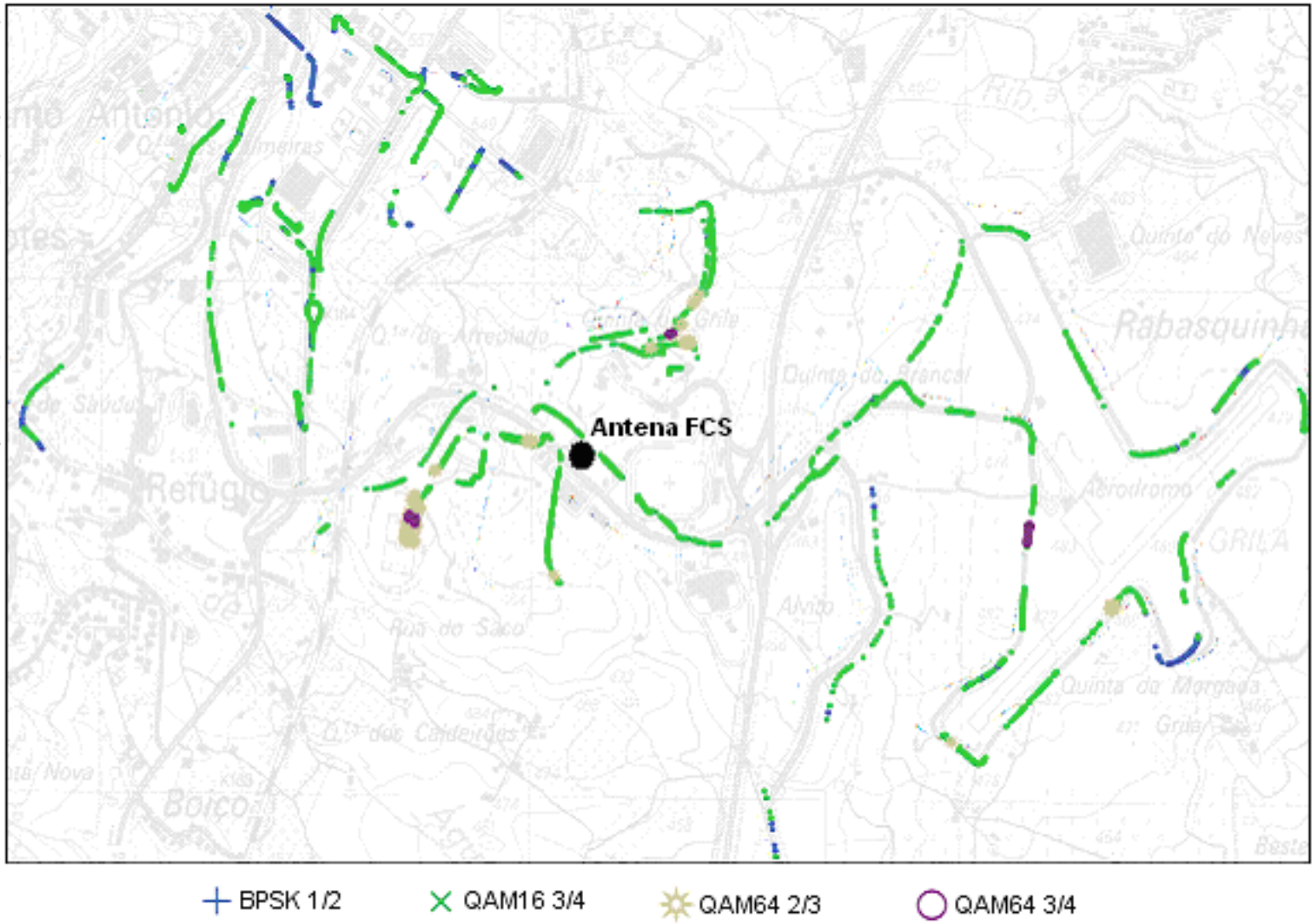
3443-3467.5 MHz



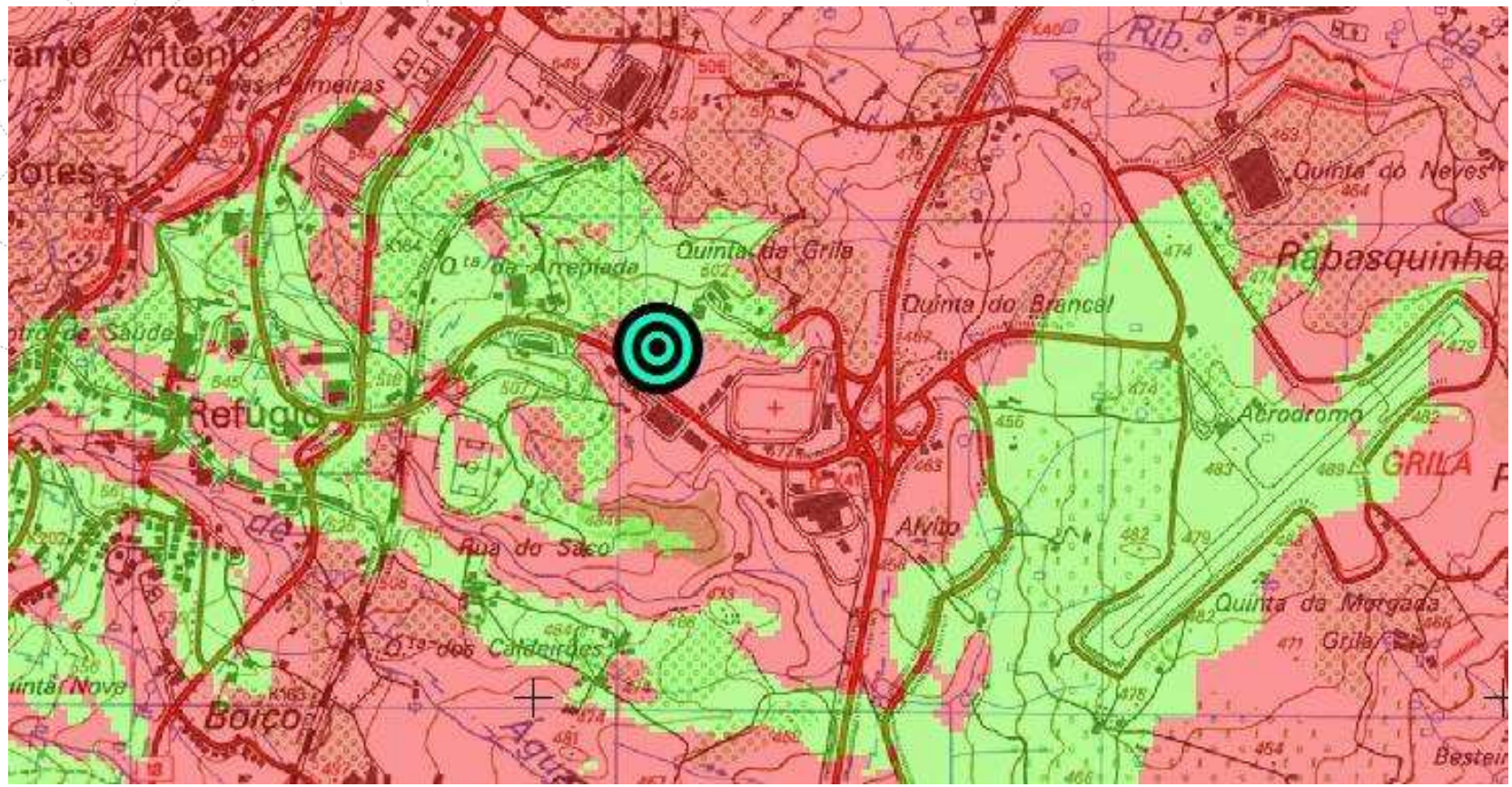
$Throughput_{max}$ = 230 kB/s = 1840 kb/s (per SU)

16-QAM with several coding rates; however it increased to ~ 6 Mb/s after QoS classes were configured

Modulation and coding schemes



LoS Discovery with Geographic Information Systems



outdoor propagation model *

Path-loss Attenuation

lognormal-distributed random variable
typical values (8.2 to 10.6 dB) ($m_S = 0$, σ_S)

$$PL(d) = A + 10 \cdot \gamma \cdot \log_{10}\left(d/d_0\right) + X_f + X_h + S$$

$$A = 20 \cdot \log\left(4\pi d_0/\lambda\right)$$

Correction factors for frequency.

Correction factors for TS (receiver) antenna height above the ground.

$$\gamma = a - b \cdot h_b + c/h_b$$

$$X_f = 6.0 \cdot \log\left(f/2000\right)$$

$$X_h = \begin{cases} -10.8 \cdot \log\left(h_m/2.0\right), & \text{for terrain types A and B} \\ -20.0 \cdot \log\left(h_m/2.0\right), & \text{for terrain type C} \end{cases}$$

Another option is the modified Friis propagation model

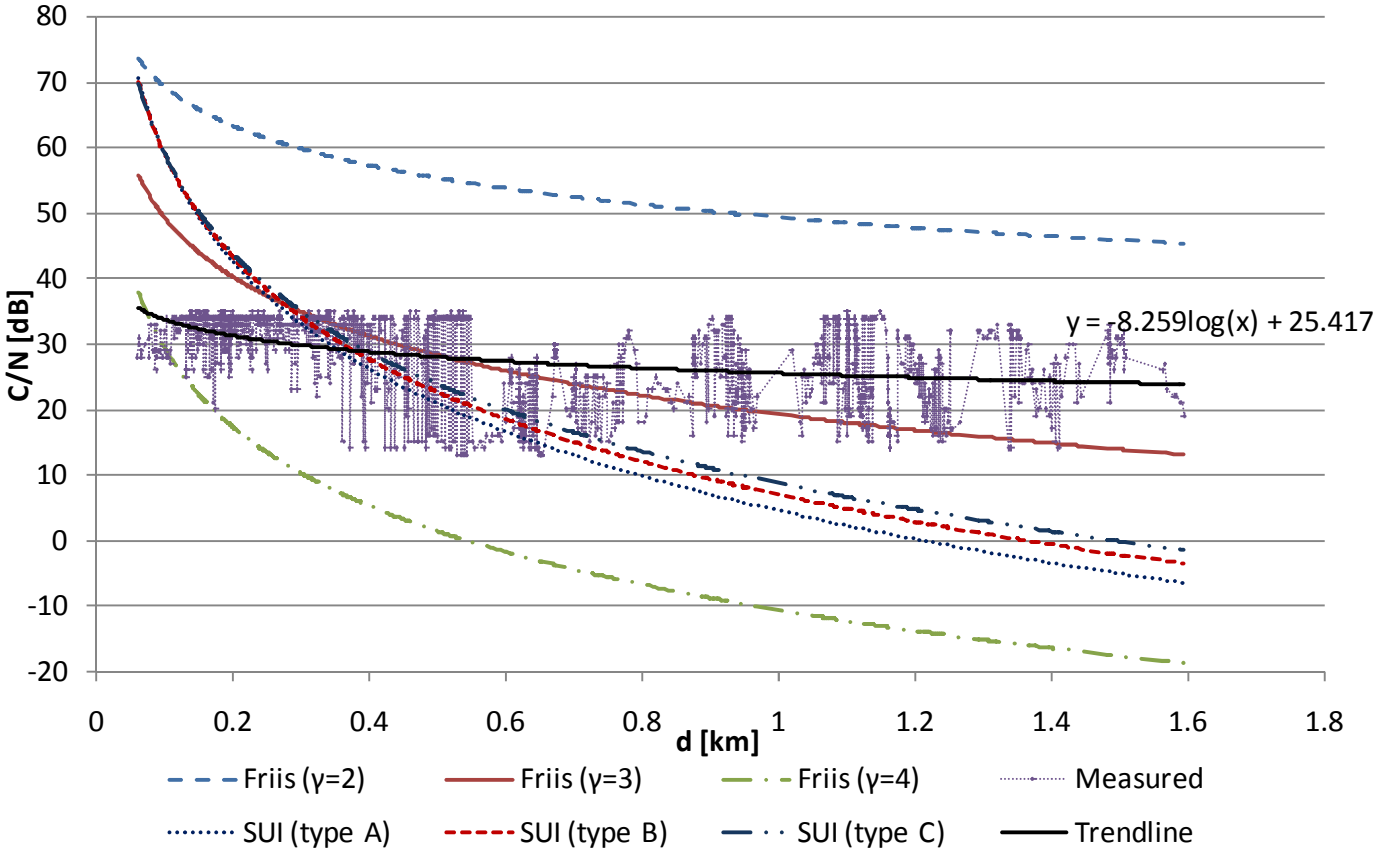
d_0=100 m,
hb is the BS height above ground, in meters (10 < hb < 80 m),
a, b, and c are parameters which are chosen according to three environments.

*[SUI model]

SUI A, B, and C

- The SUI model uses three basic terrain types:
  - Category A - Hilly/moderate-to-heavy tree density;
  - Category B - Hilly/light tree density or flat /moderate -to-heavy tree density;
  - Category C - Flat/light tree density.

SNR trend curve for measured locations around FCS



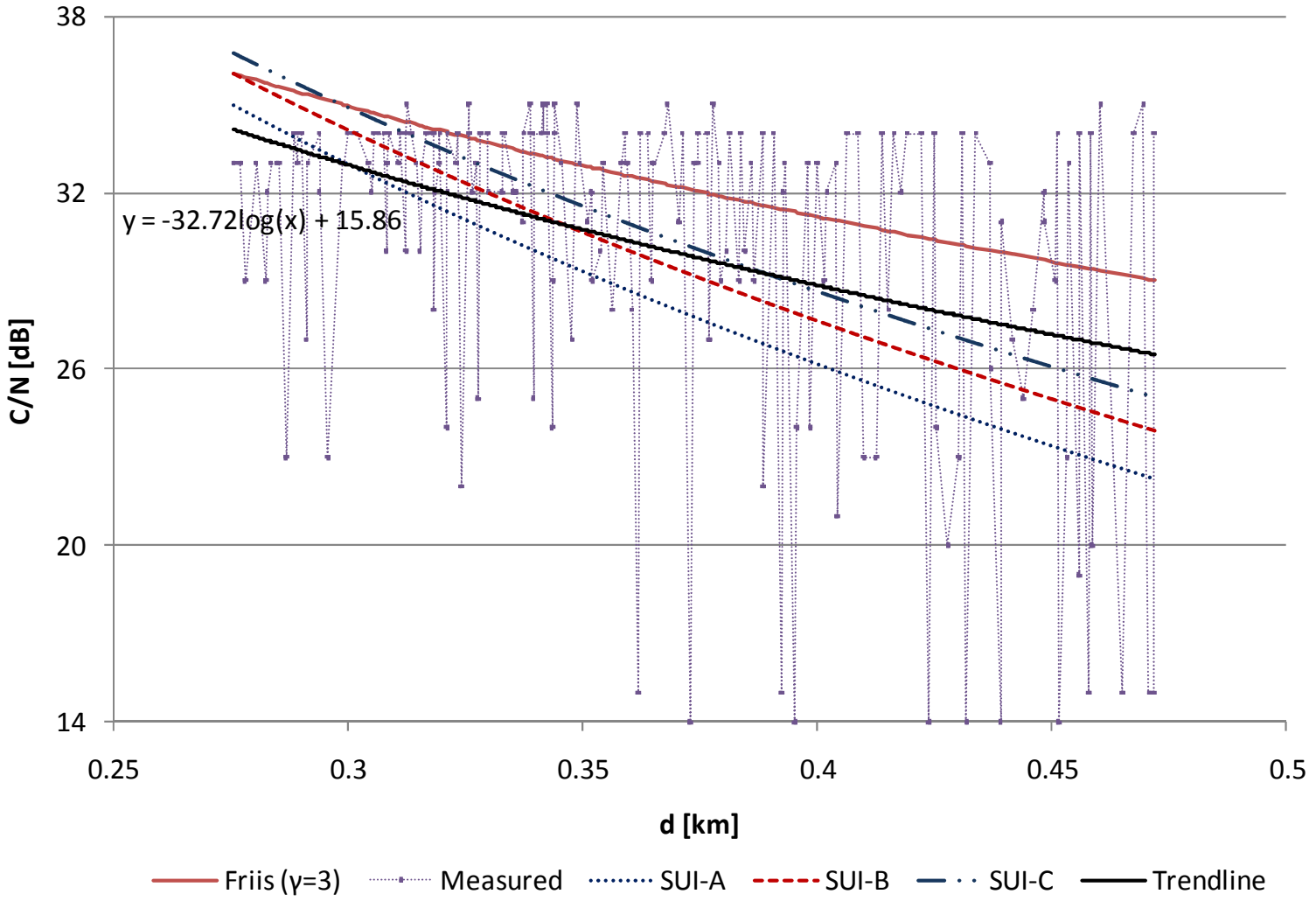
f = 3.5 GHz

b_{rf} = 3.5 MHz

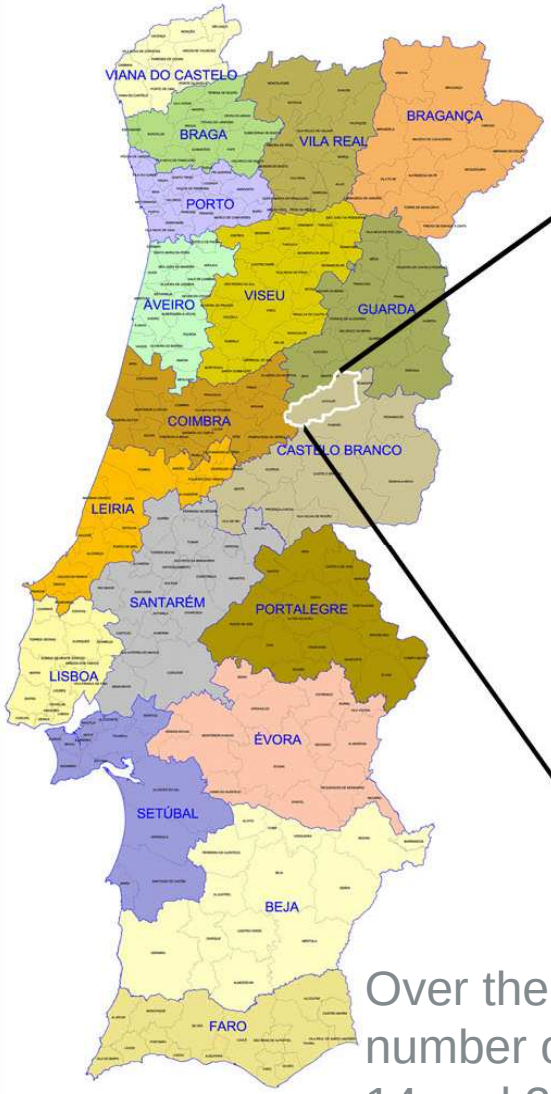
$G_e = G_r$ = 17 dBi

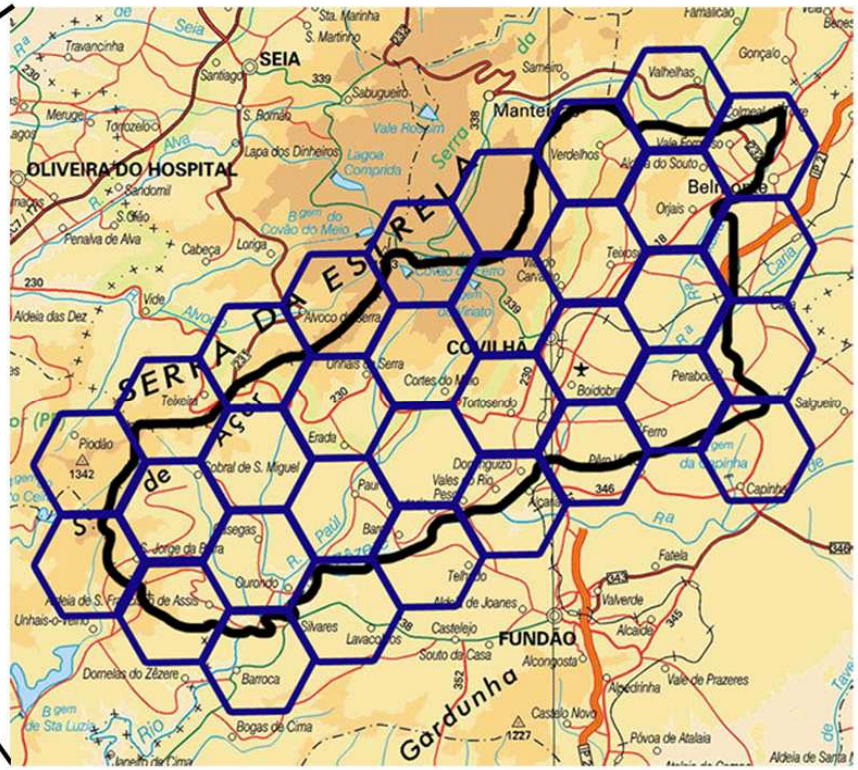
$P_{e\text{-}max}$ = -2 dBW

Measured SNR - distances in the interval [275, 475]m



Cellular Planning





Over the region of Beira Interior, with an area of 550km^2, the number of cells necessary to cover the area under study is 14 and 24cells, approximately, for coverage distances R=4 and R=3km, respectively

Details on planning tools

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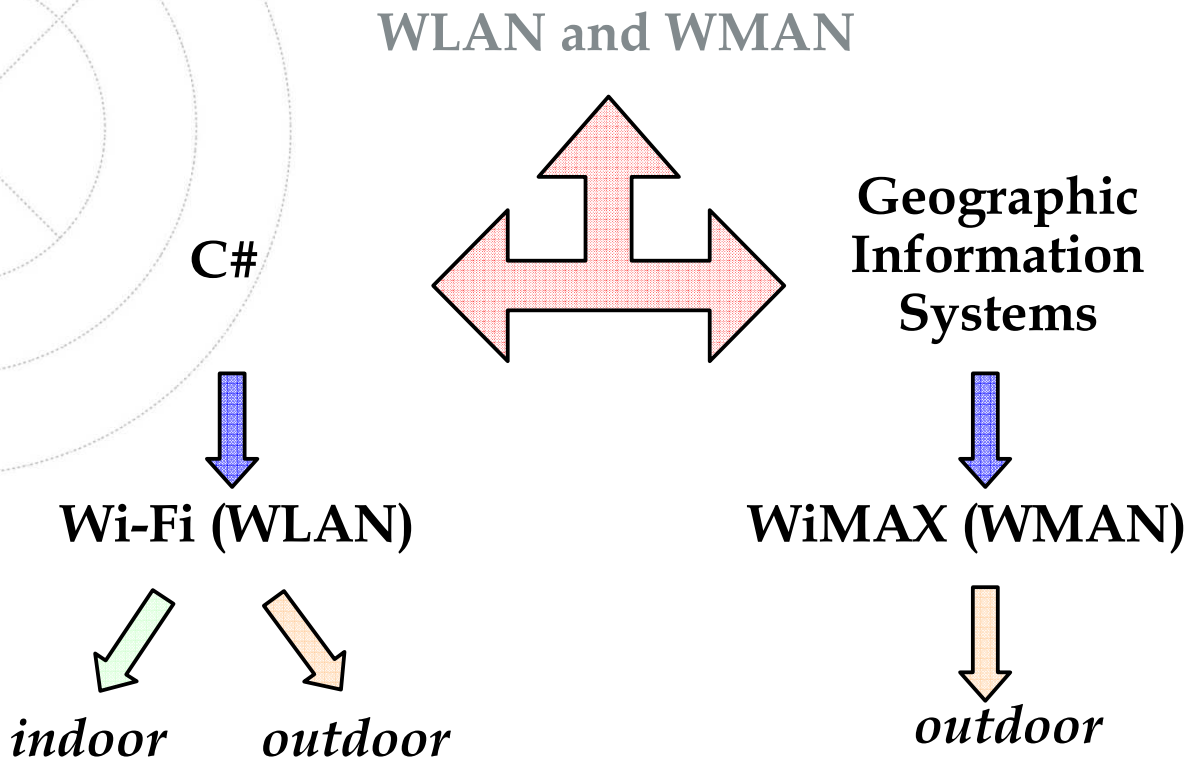
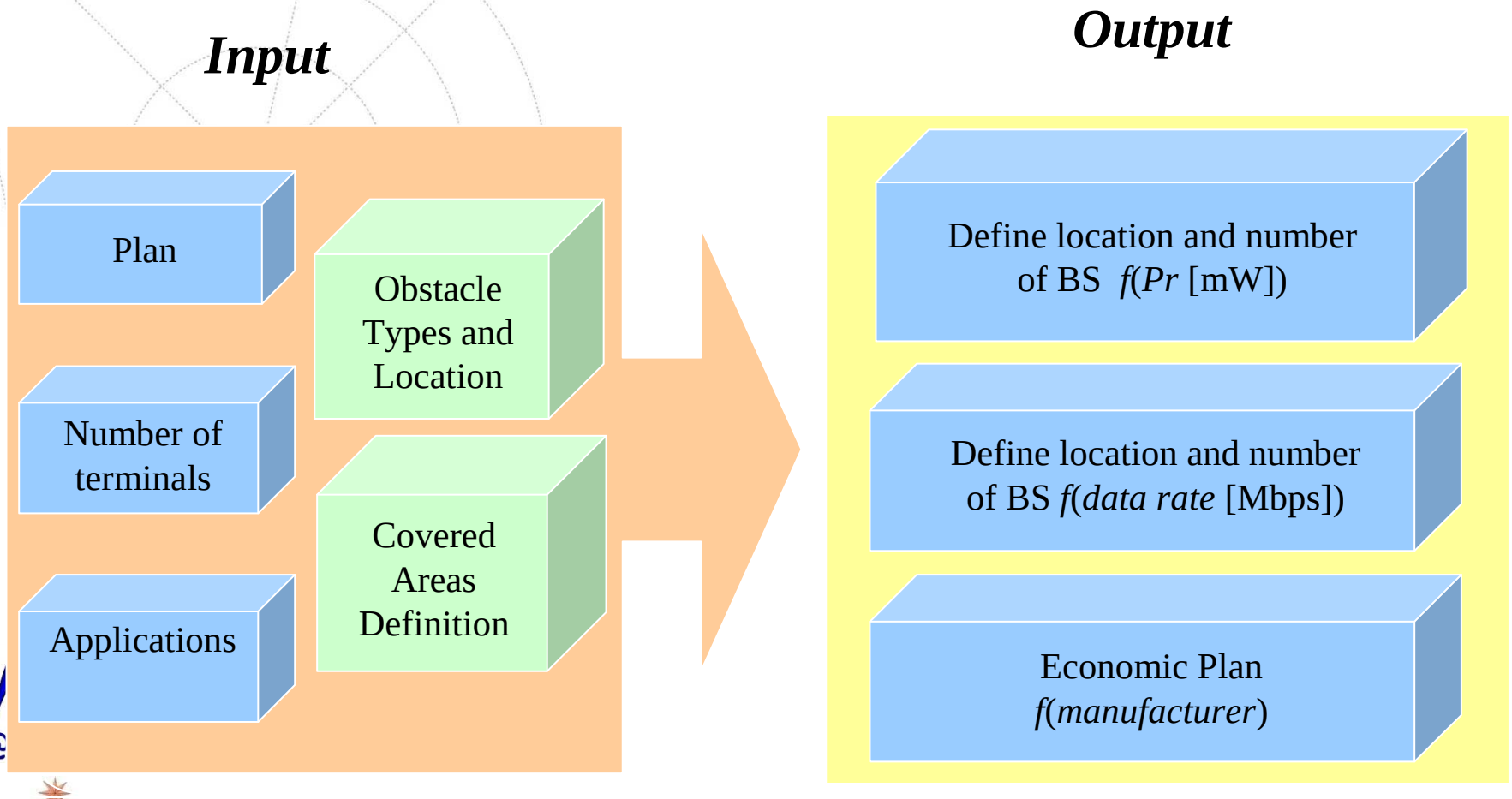
Conception of the Cellular planning tools n



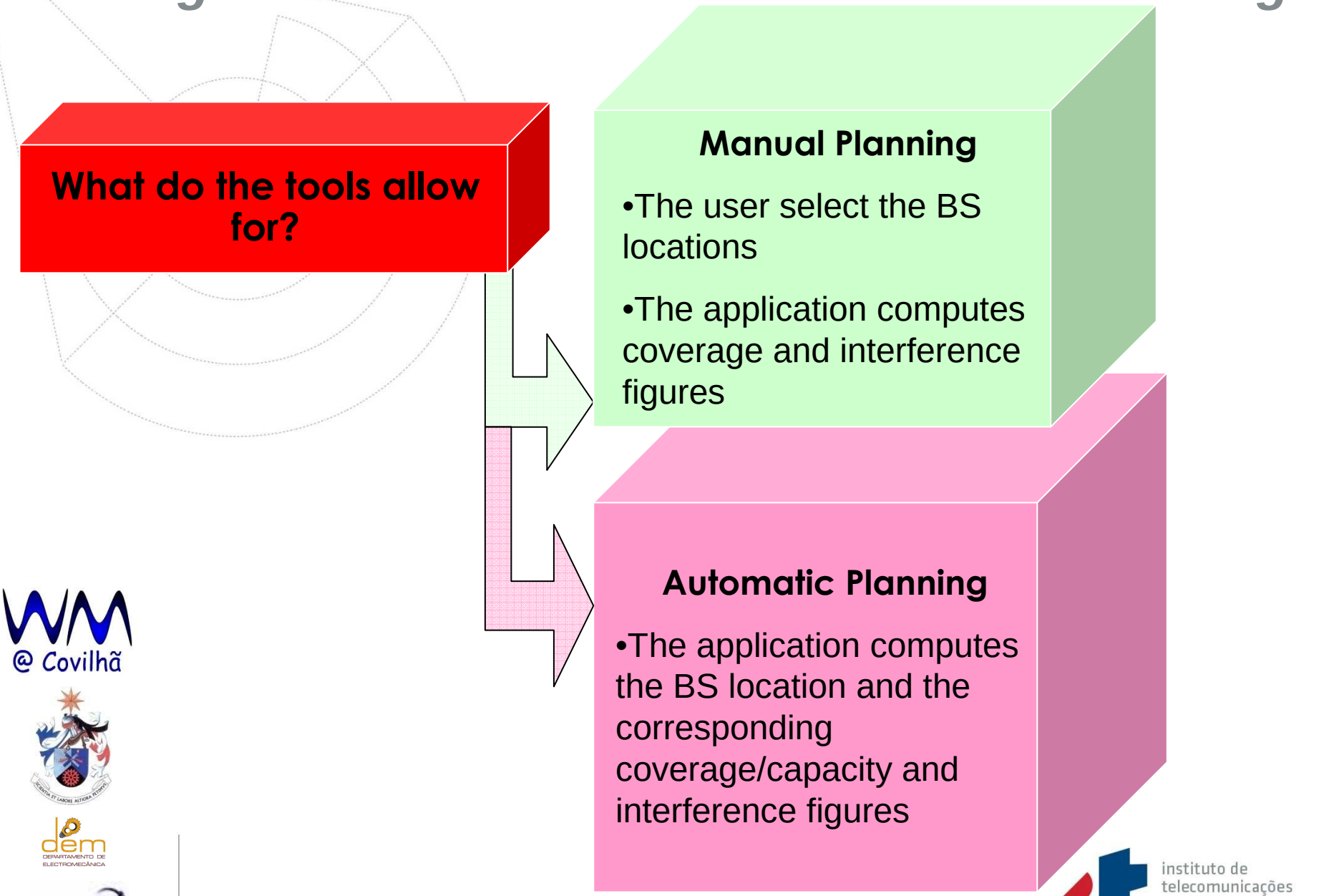
Cellular Planning Tools - Motivation and Scope

- Develop a tool for technical and economical planning of *indoor/outdoor wireless networks.*
- Provide to the wireless network designers an user friendly and efficient planning tool to optimize and simplify a given network
- Addressing:
  - Coverage (considering that all points in a given area should be covered)
  - Capacity (considering the number of users and the corresponding applications)

Planning Tools: Inputs/Outputs



Planning Tools: Manual versus Automatic Planning



Indoor Propagation Model *

Path-loss Attenuation

Sum of partition attenuaction factors for a path (AP – PC)

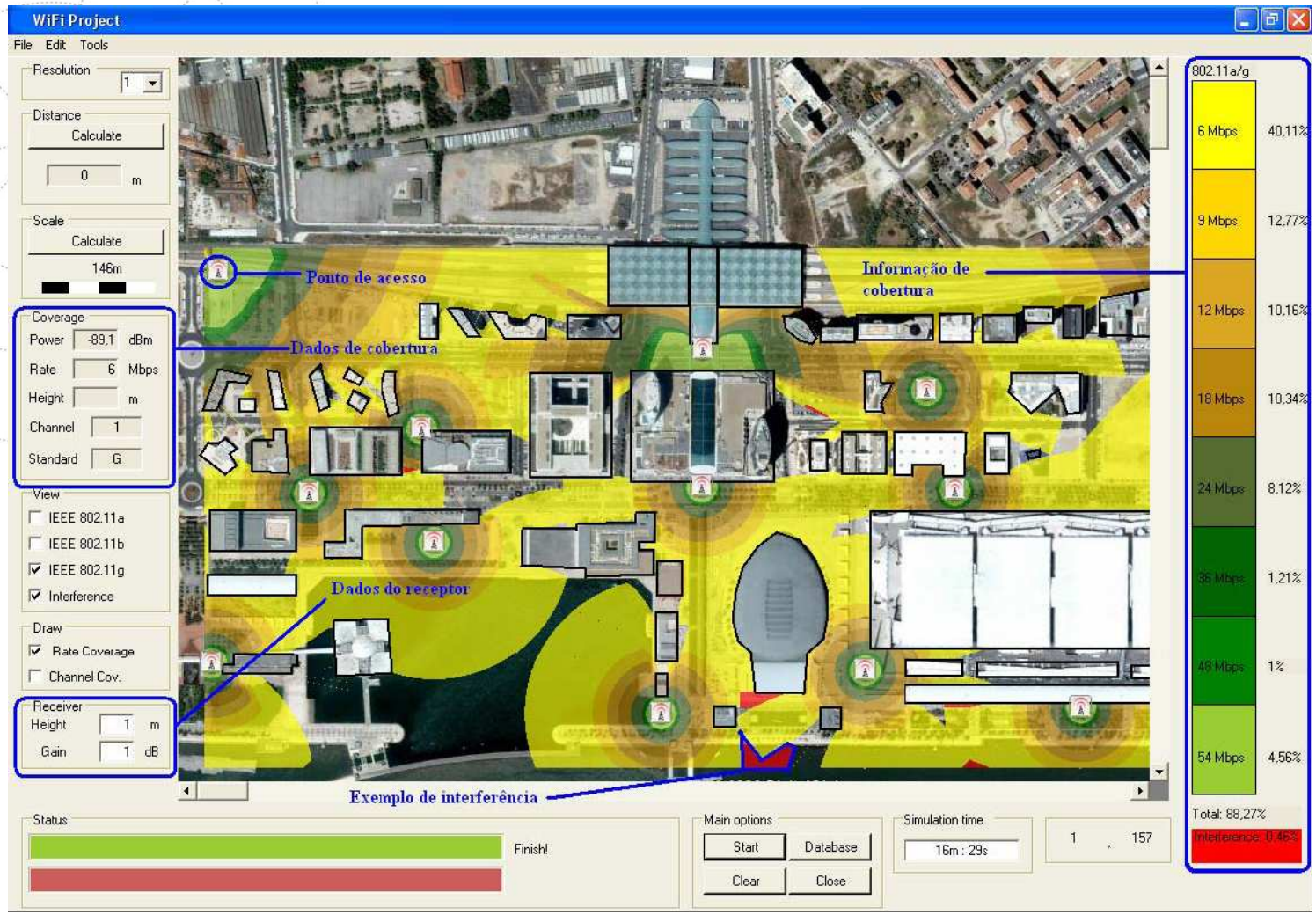
$$\overline{PL}(d)[\text{dB}] = \overline{PL}(d_0)[\text{dB}] + 10\, n_{SF}\, log\left(\frac{d}{d_0}\right) + FAF\ [\text{dB}] + \sum PAF\ [\text{dB}]$$

- $\overline{PL}(d)$: Distance between AP and terminal
- $\overline{PL}(d_0)$: Average Attenuation at reference distance
- n_{SF}: Exponent value for the same floor
- FAF: Floor attenuation factor (12.9 dB) same floor
- $\sum PAF$: Partition attenuation factor for a given obstruction

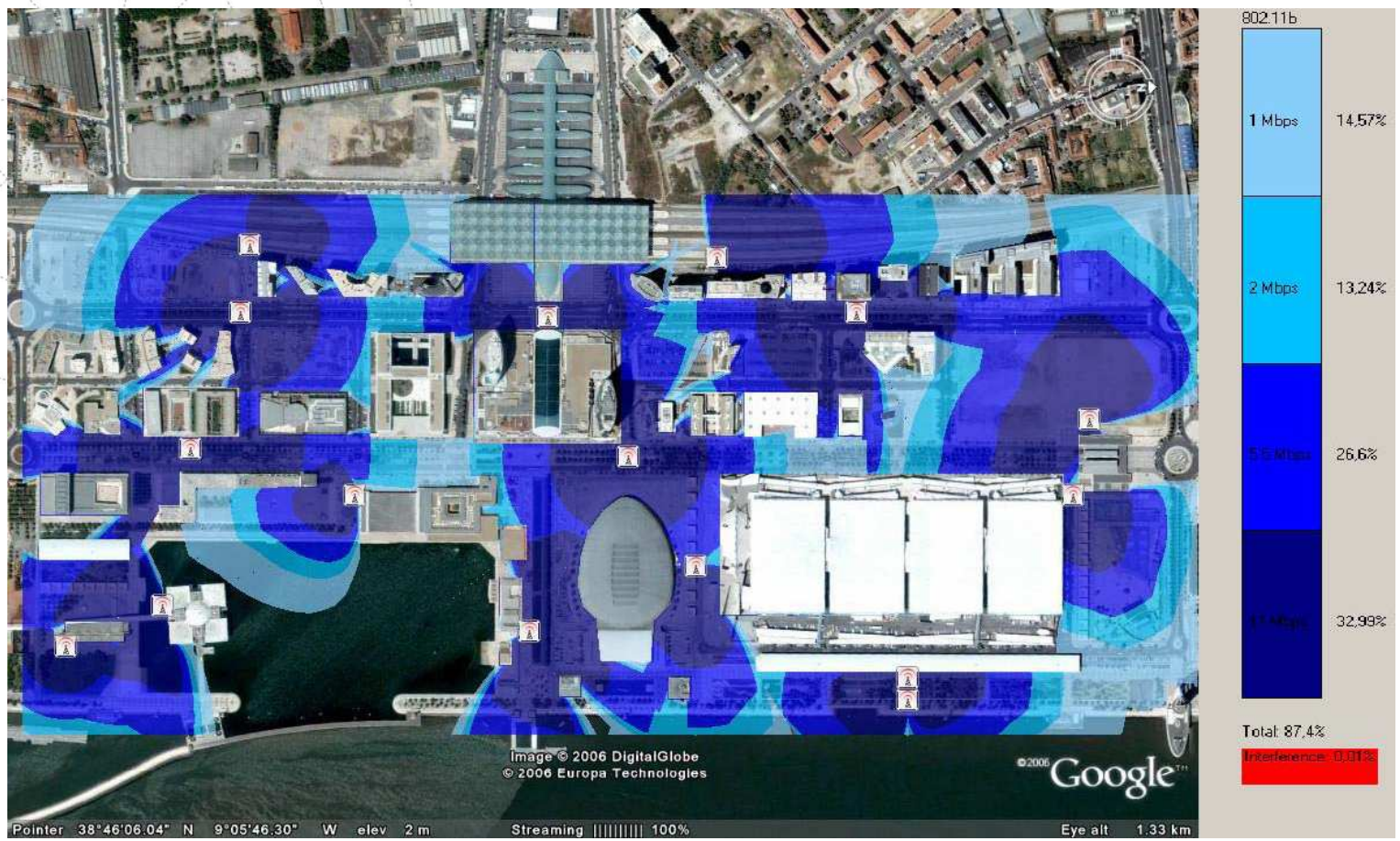
*[Rappaport 2002]

Example 1: Indoor Wi-Fi Planning – IEEE802.11g

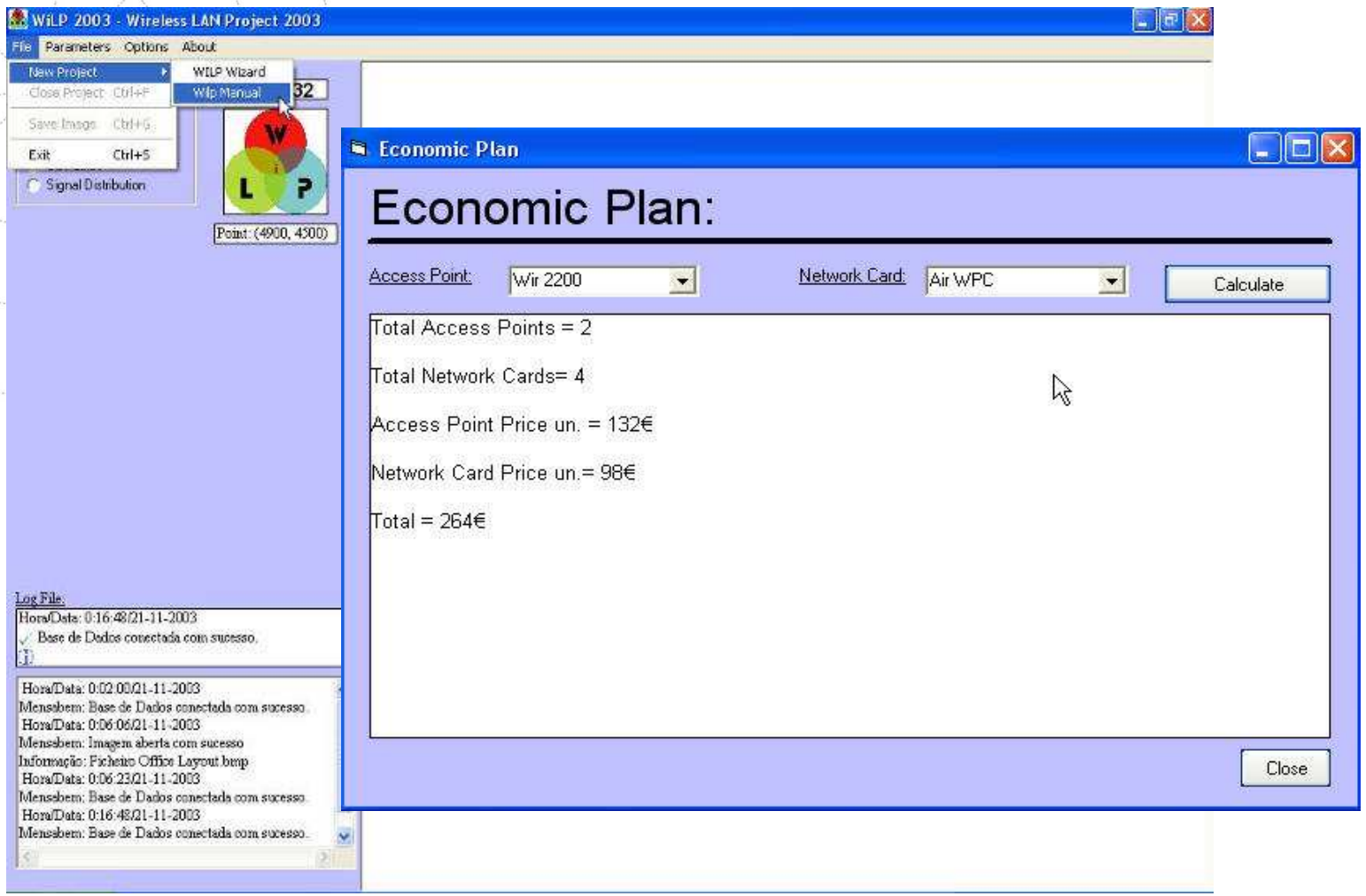
Example 2: Outdoor Wi-Fi Planning – IEEE 802.11a/g (Parque das Nações)



Example 3: Outdoor Wi-Fi Planning – IEEE802.11b (Parque das Nações)



Economic plan

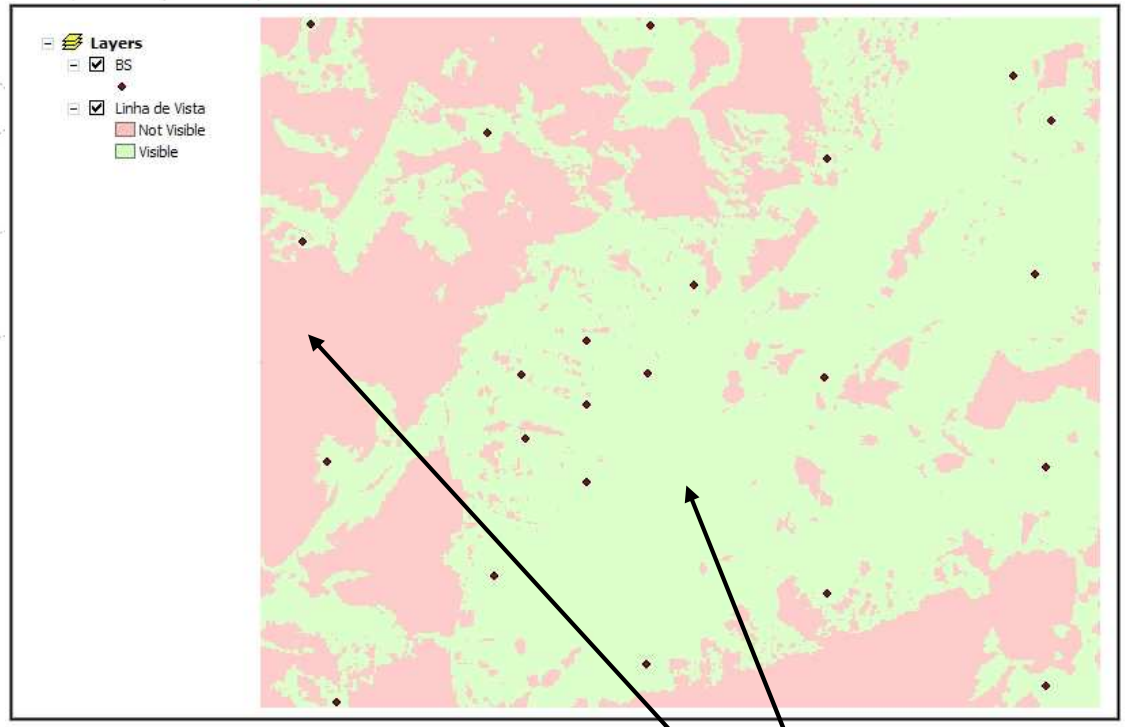


WiMAX Planning: Some Simulation Conditions

Frequency	3.5 GHz
Bandwidth	3.5 MHz
Transmitter power (Rural)	34 dBm
Transmitter power (Urban)	15 dBm
Transmitter gain (BS)	20 dBi
Receiver gain (CPE)	18 dBi
Height of transmitter tower	30 m
Height of CPE's	1 m

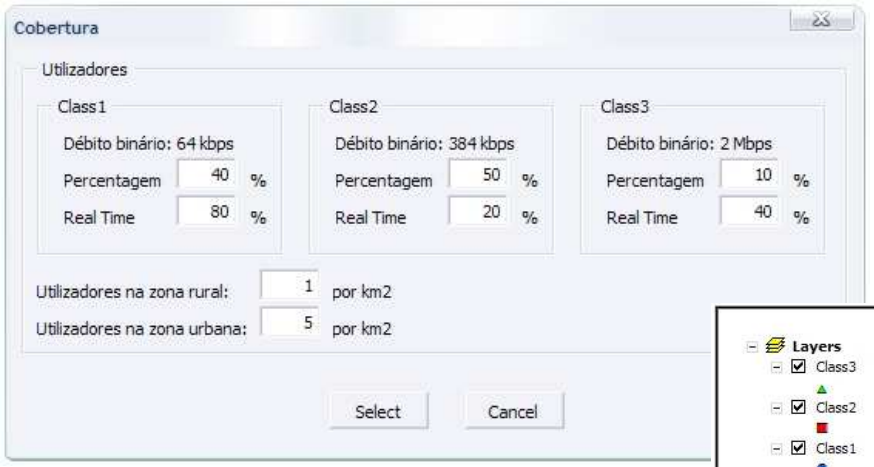
User urban density [users/ km²]	10
User rural density [users/ km²]	0.1
Total number of users	172
Users of class 1 [%]	40
Users of class 2 [%]	50
Users of class 3 [%]	10
Users of class 1 RT [%]	80
Users of class 2 RT [%]	20
Users of class 3 RT [%]	40

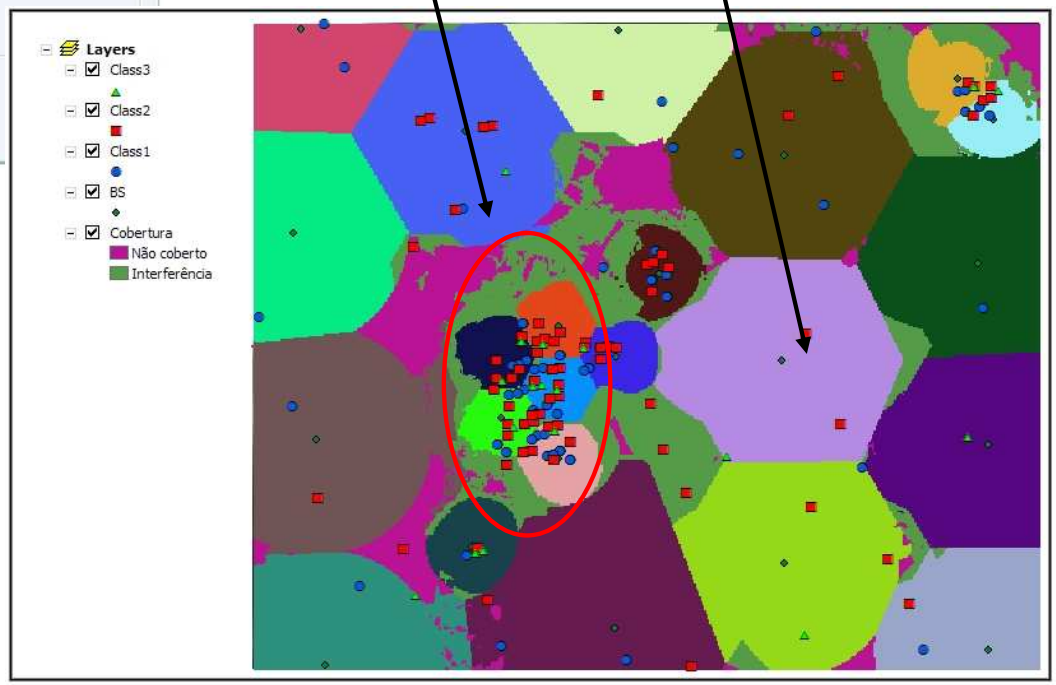
Example 4: LoS and NLoS WiMAX Planning (Base Station Location)



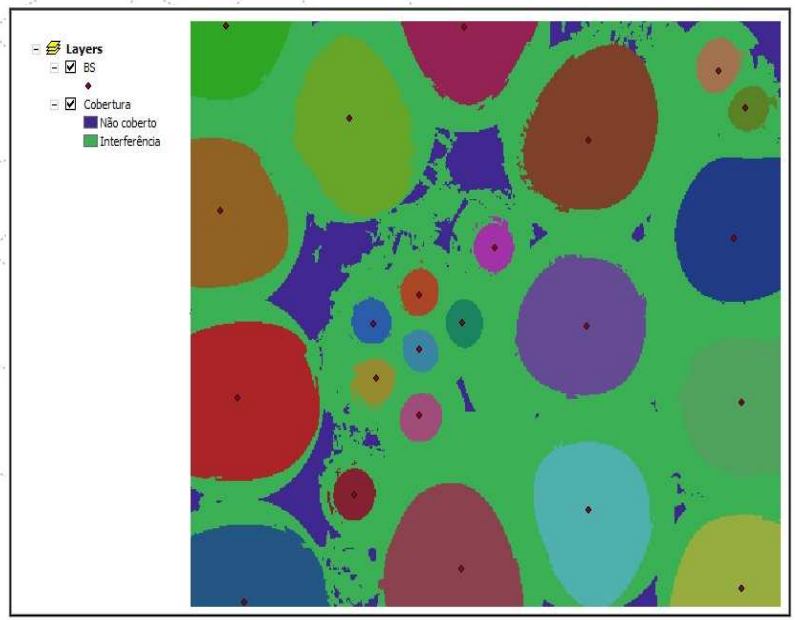
LoS: Line of Sight
NLoS: Non Line of Sight

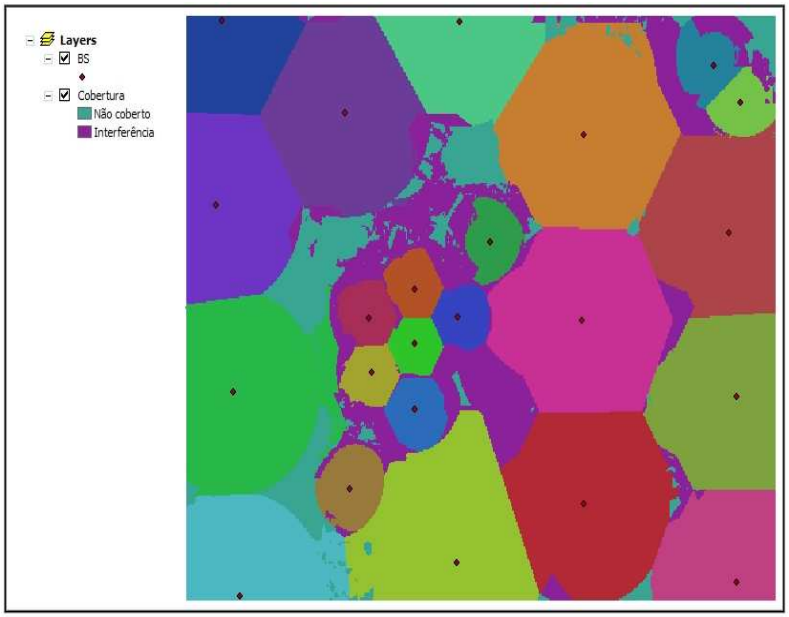
Example 5: WiMAX Planning (Base Station Location Considering Users Distribution)





Example 6: WiMAX Planning (Omnidirectional versus Sectorial Antennas)

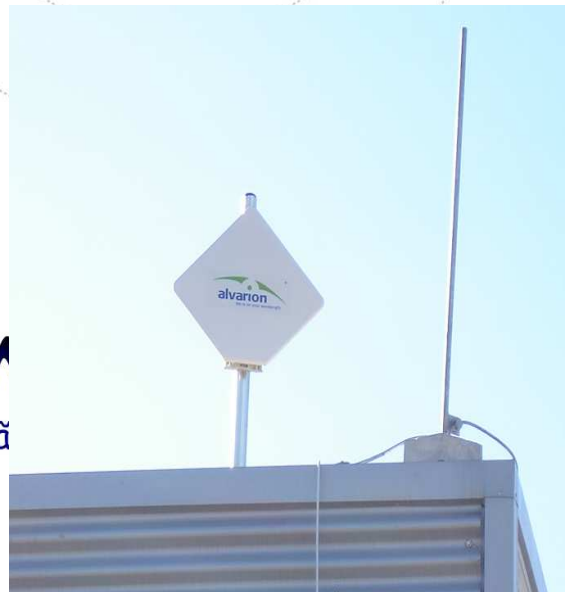




Type of Antenna	Covered area [%]	Area with Interference [%]	Non-covered area [%]
Omni directional	52.3	42.0	5.7
Sectorial	85.0	9.3	5.7

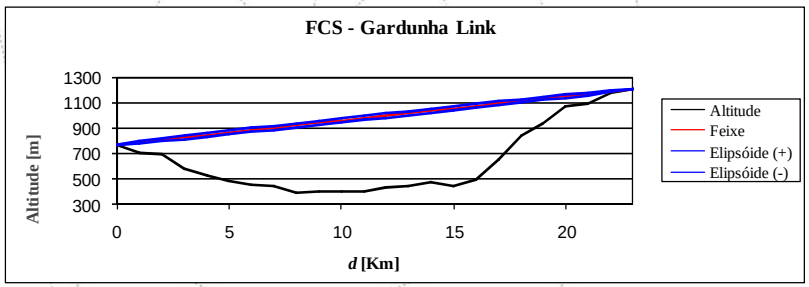
PTP pre-WiMAX Link B100

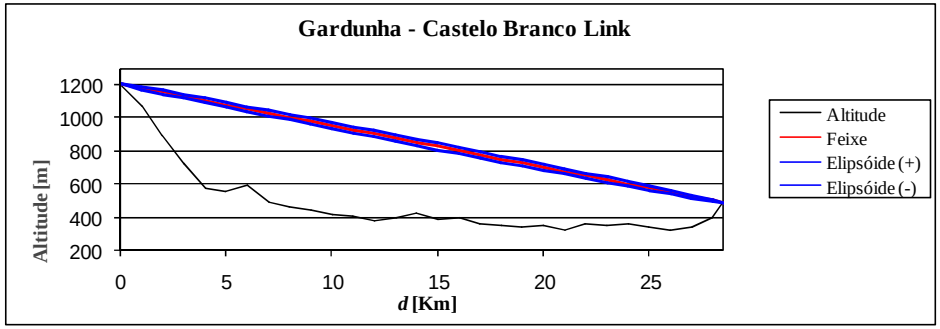
- The point-to-point, PTP, WiMAX link was installed to connect the Health Science Faculty, FCS, to *Reitoria*
- The length of this WiMAX link is 1 138 meters
- f = 5.4 GHz (Pre-WiMAX); $EIRP_{max}$ = 30dBm



Alvarion BreezeNET B

PTP links with relays FCS – Hospital Amato Lusitano





Design of Point-to-point Radio Links

- In IEEE 802.16 standard the bit error ratio due to selective fading is zero if there is LoS
- When fading is considered, the minimum carrier-to-noise ratio, C/N_{min}, is given in dB by

$$\left(C/N\right)_{\min\_with\_fading} = \left(C/N\right)_{\min} + m_u$$

where m_u is the link margin for uniform fading, in dB, and selective fading is negligible

- The probability P that the received power p is less or equal to p_0, in the worst month, may be estimated by using an expression of the form

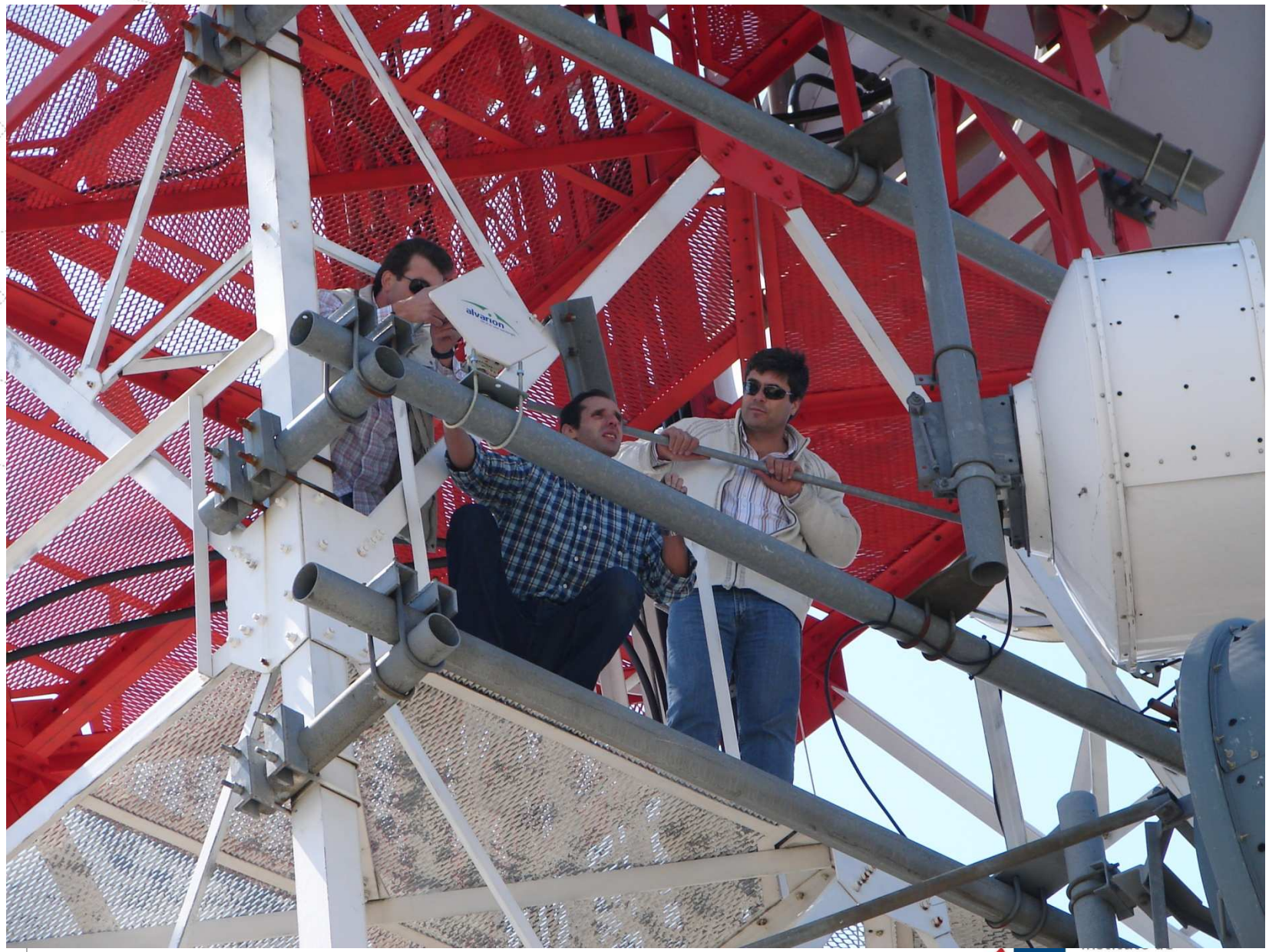
$$P(p \le p_0) = \frac{F}{m} \quad \Leftrightarrow \quad m = \frac{F}{P}$$

where F is the deep fade occurrence factor **(Morita)**

PTP antennas characteristics

5.15 – 5.87 GHz 28 dBi, 4.50, detached, flat, 2'x2'

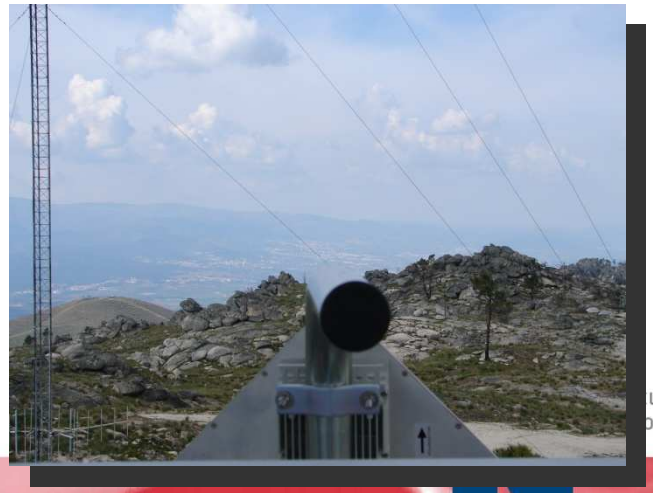
5,15 - 5.87 GHz 21 dBi, 10.5° horizontal x 10.5° vertical, flat.


alvarion

Link Covilhã (FCS) - Gardunha

FCS

Gardunha



Link Gardunha - Castelo Branco

Gardunha

WM @ Covilhã

Castelo Branco

Antenas

Hospital Amato Lusitano

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MobileMAN

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Conclusions

- WiMAX cellular Planning aspects and PTP links design and tools were covered in this presentation
- Coverage, interference, and capacity issues are crucial in planning
- Field trials are being conducted for the PTM cell in Covilhã with *Alvarion* equipment, by using the license given by ANACOM at 3.5 GHz
- Results fit well to the modified Friis equation, γ=3
- LoS dimensioning issues were addressed
- From a planning exercise in the district of Covilhã one concluded that there is a strong need of using sectorial antennas to guarantee an adequate coverage and interference mitigation

Conclusions (cont.)

- The planning tools were built to develop network planning for Wi-Fi (indoor and outdoor) and WiMAX “thinking” about efficiency and user friendliness for students and network designers
- Coverage, capacity, and techno-economical issues were considered as they are crucial in planning
- The planning tool support several types of analysis, including, population density, LoS, power, interference, etc.
- The resulting analysis allows us to see how the several parameters could influence the network planning
- Practical deployments of PTP links were also presented
- Results are promising and will provide experimental feedback to the planning process