Cost/Revenue Trade-off in the Optimization of Fixed WiMAX Deployment with Relays

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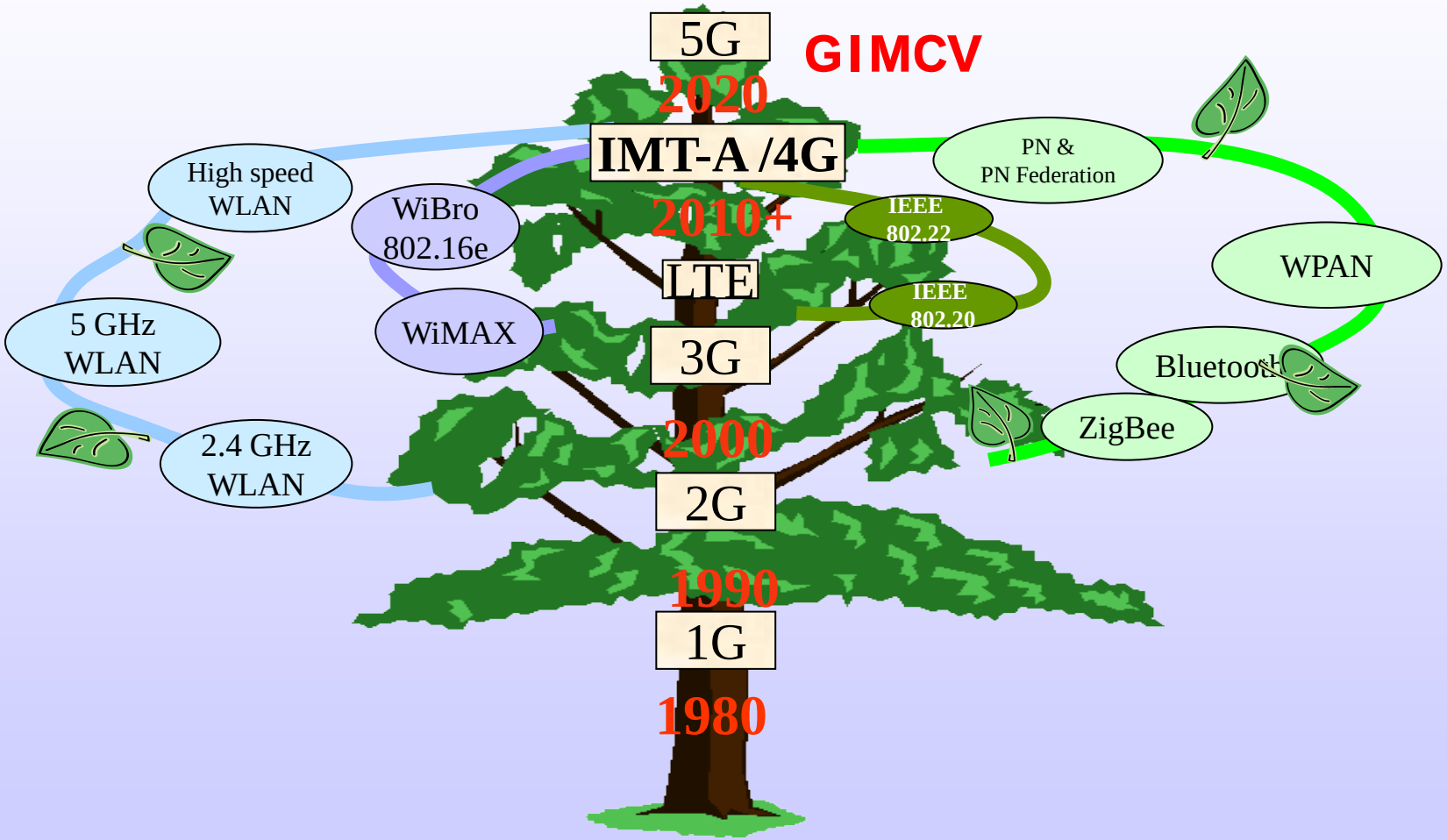
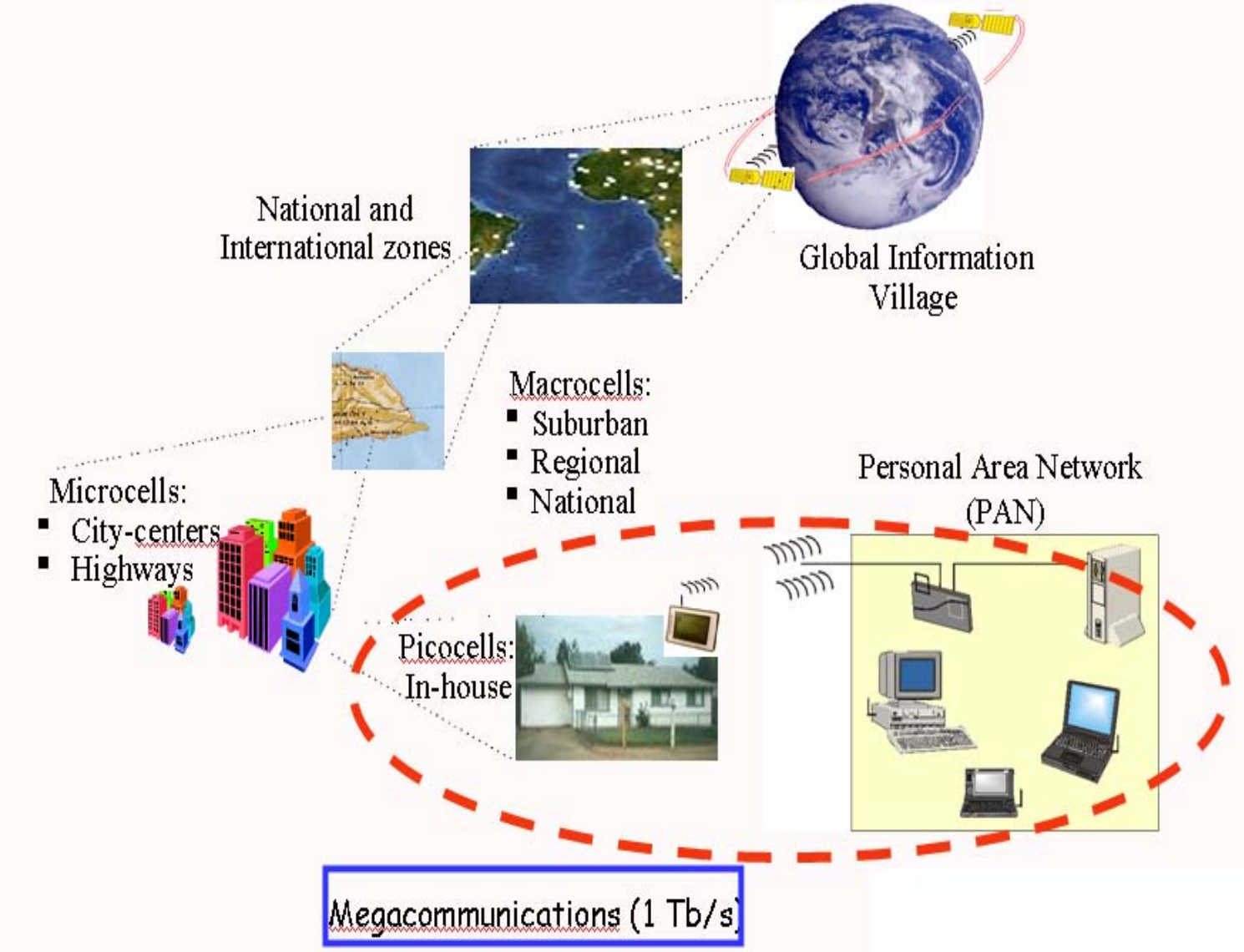
Presentation Structure

1. Global Information Multimedia Communication Village (GIMCV) and its environments
2. Evolution towards Wireless Broadband Systems
3. Fixed/mobile WiMAX spectrum
4. Fixed/mobile WiMAX demonstrators in Portugal
5. Formulation for the supported cell/sector throughput
6. A glimpse on cost/revenue optimization and cellular planning tools

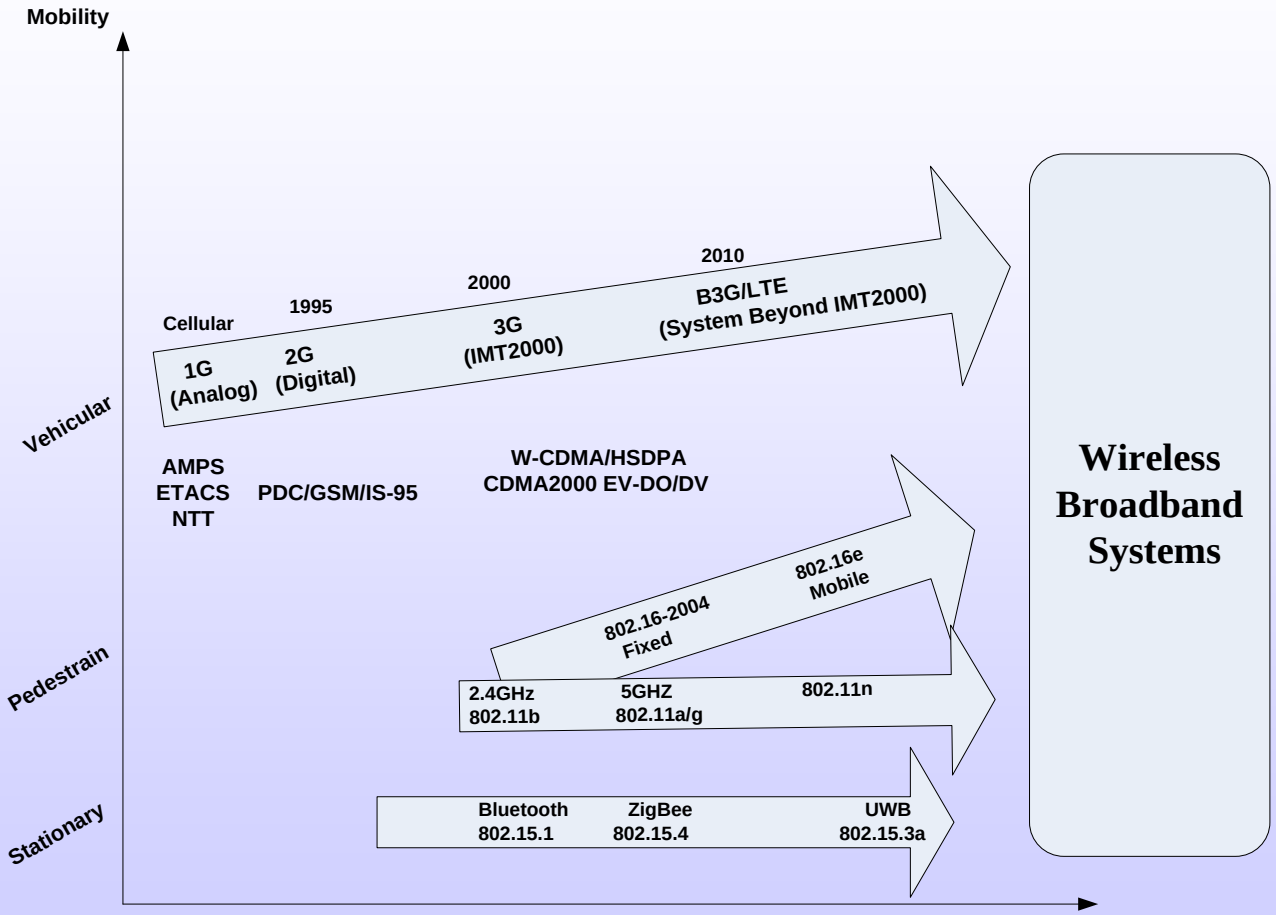
Global Information Multimedia Communication Village



GIMCV Environments



Evolution of Wireless towards Wireless Broadband Systems

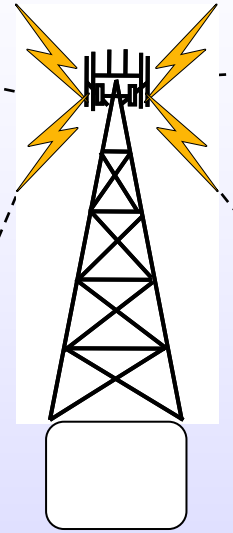


Data Rate	~40k	2M	14M	54M	100M	1G	b/s
Spectral Efficiency	0.4	0.4	2.8	2.7	5	10	b/s/Hz
Radio access Tecnologies	TDMA QPSK	TDMA QPSK	Adaptive QAM	OFDM/QAM Adaptive coding		MIMO Adaptive array	

Fixed (IEEE 802.16-2004) and Mobile (IEEE 802.16-e) Operation

Broadband Access for Enterprise

802.16-2004



Nomadic Broadband complementary to 3G, EDGE & WiFi

802.16-e

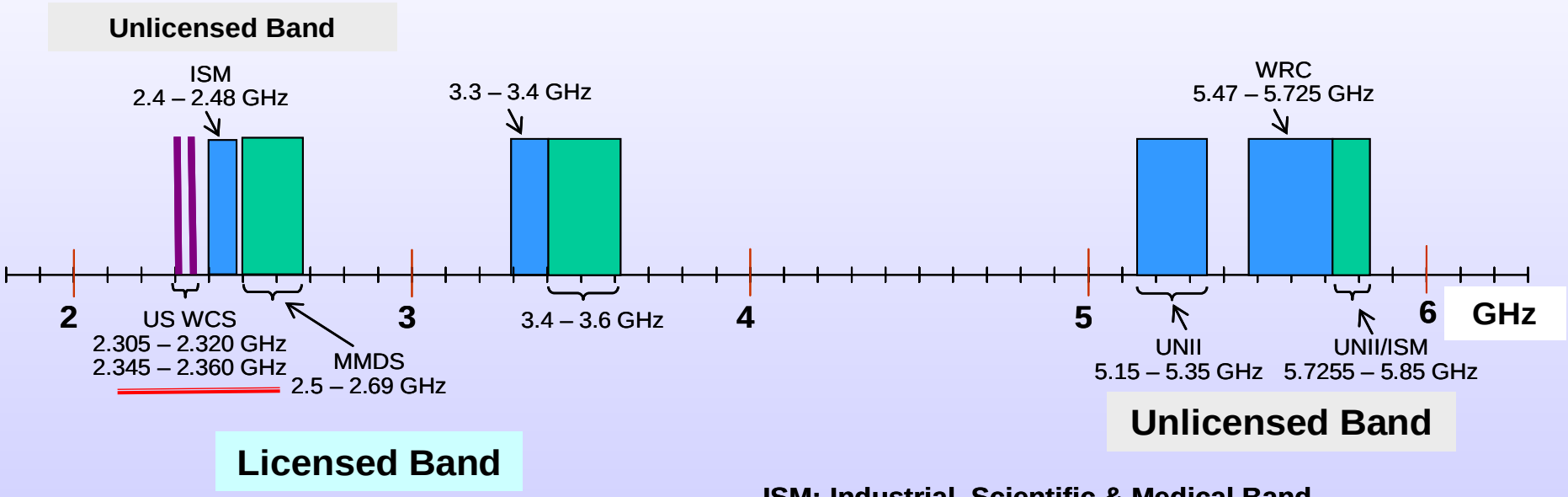
Broadband Access for Public hotspots and *Mesh* Networks

802.16-2004

Broadband Access @ Home complementary to DSL & Cable

802.16-2004

2-6 GHz band available for WiMAX

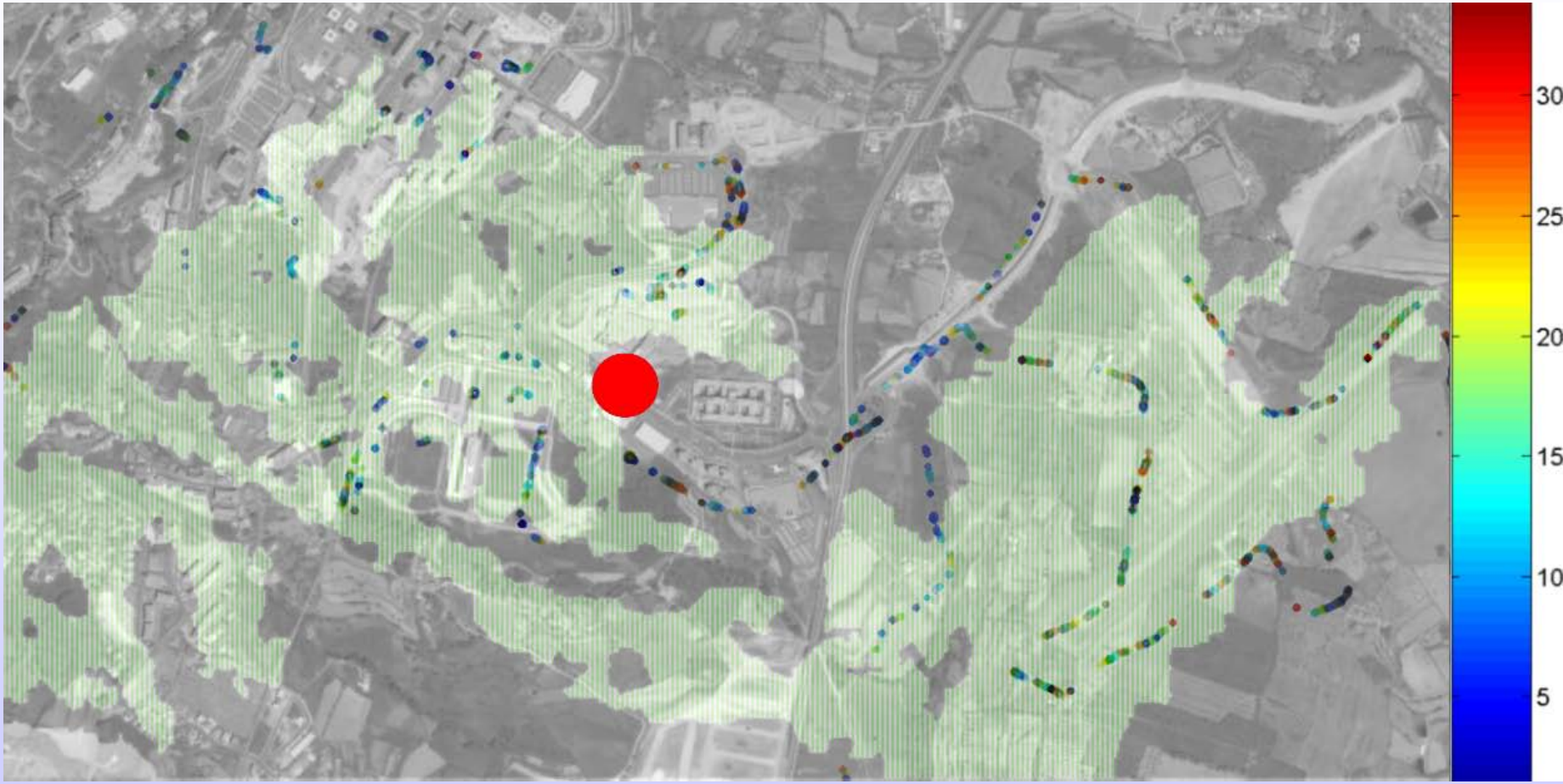


ISM: Industrial, Scientific & Medical Band
UNII: Unlicensed National Information Infrastructure band

Point-to-multipoint demonstrator at 3.5 GHz, Health Science Faculty

Signal-to-noise ratio, *SNR*, measurements

Detailed measurements of *SNR* in DL

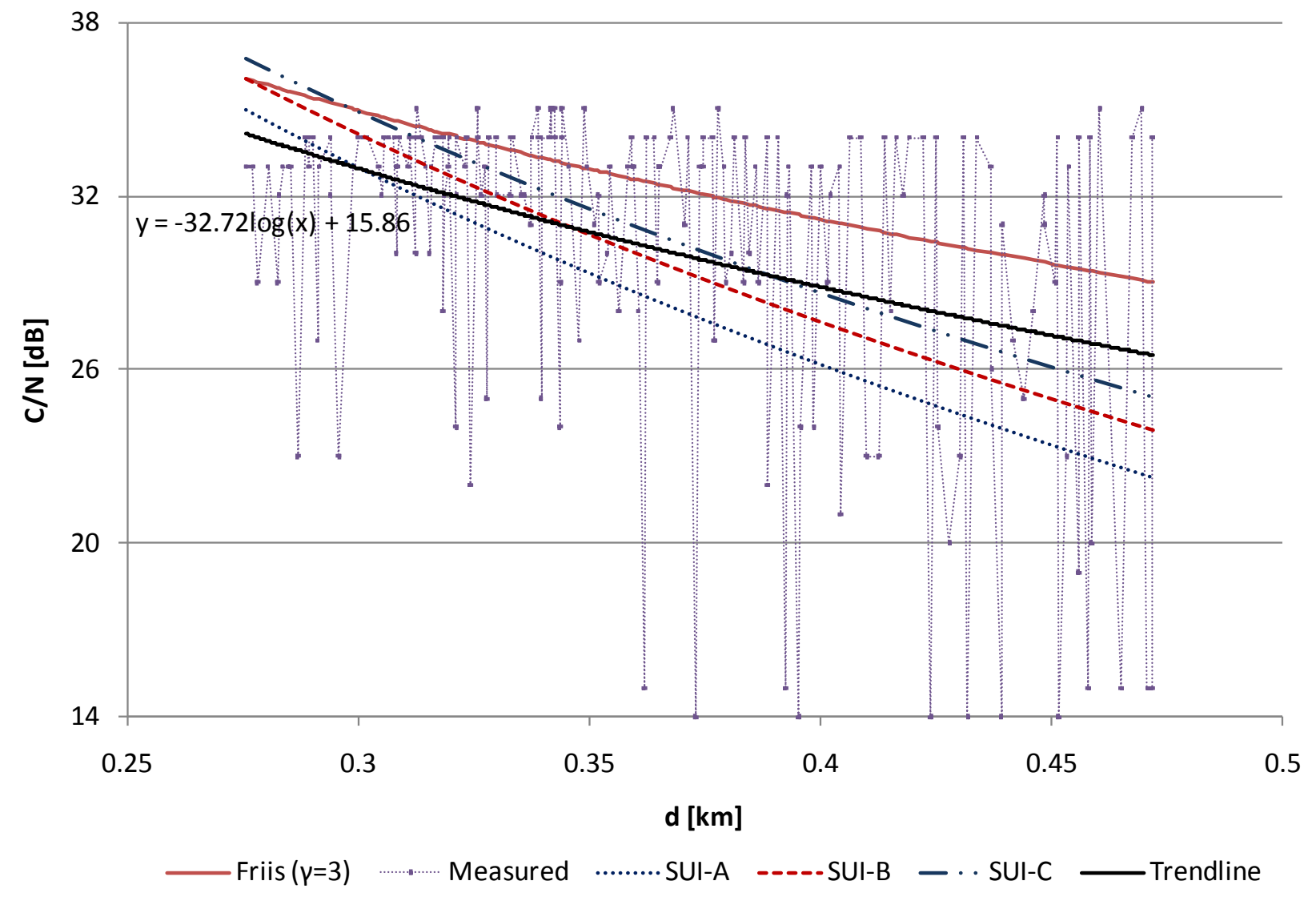


Frequency license bands:
3543-3567.5 MHz
3443-3467.5 MHz

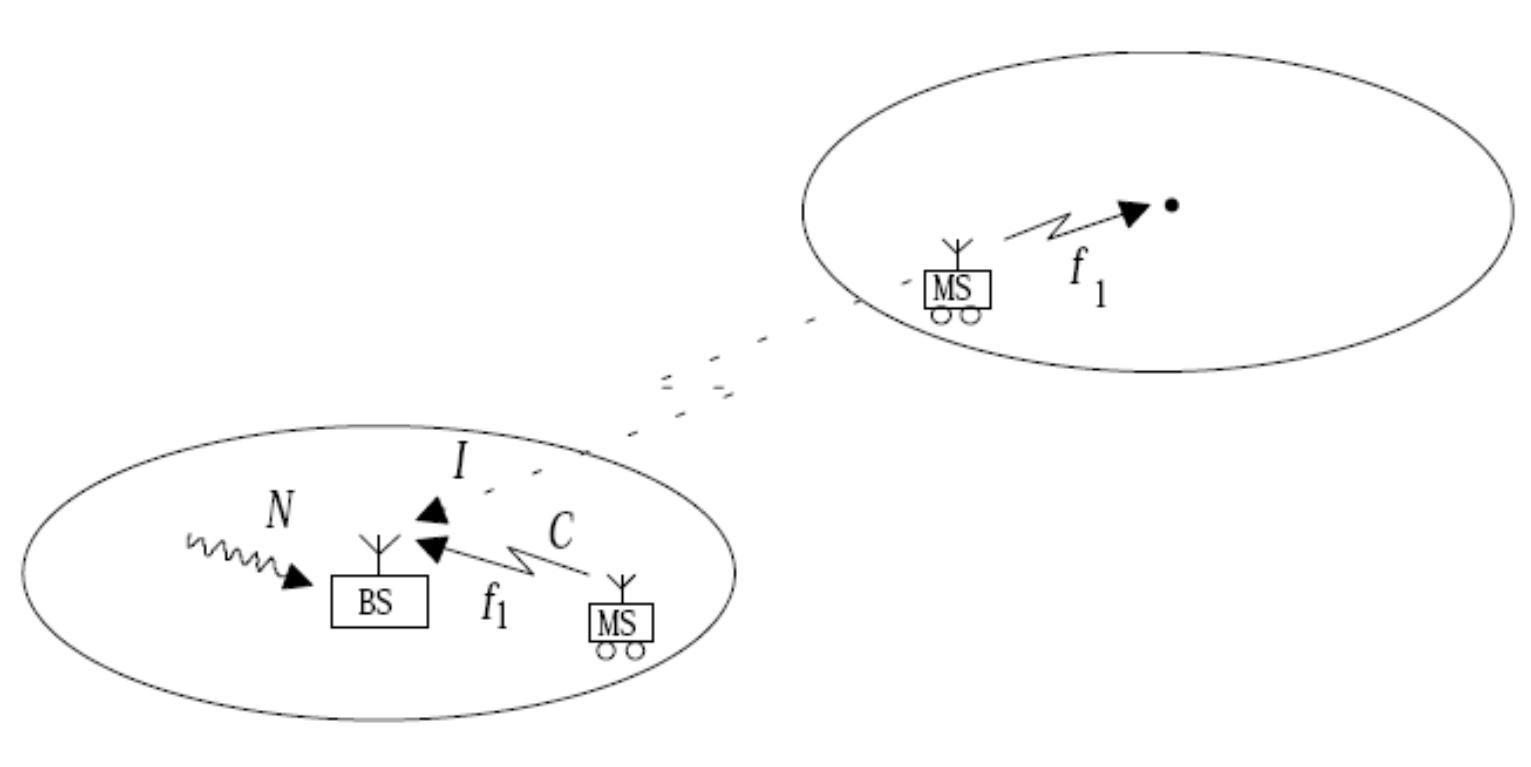
$Throughput_{max}$ = 230 kB/s = 1840 kb/s (per SU)

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

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

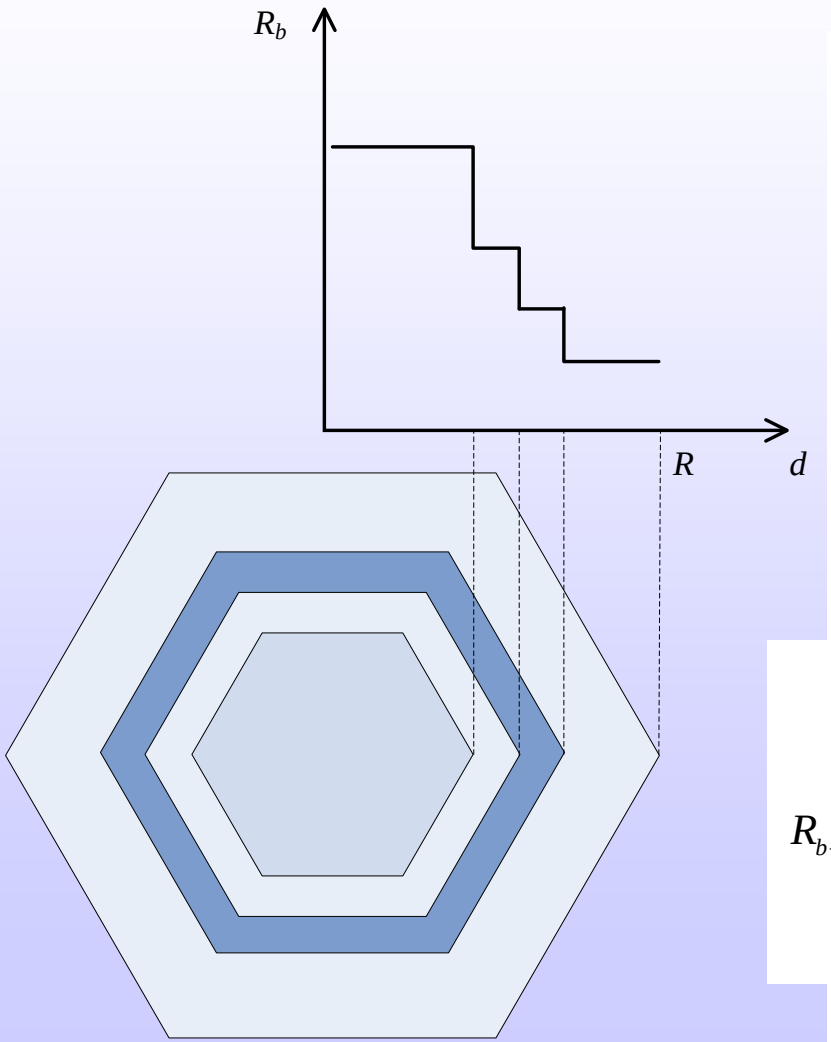


The frequency reuse problem …



- *I* - interference power
- *N* - noise power
- *C* - power of the received carrier

Step distances for CNIR *vs* supported Physical throughput

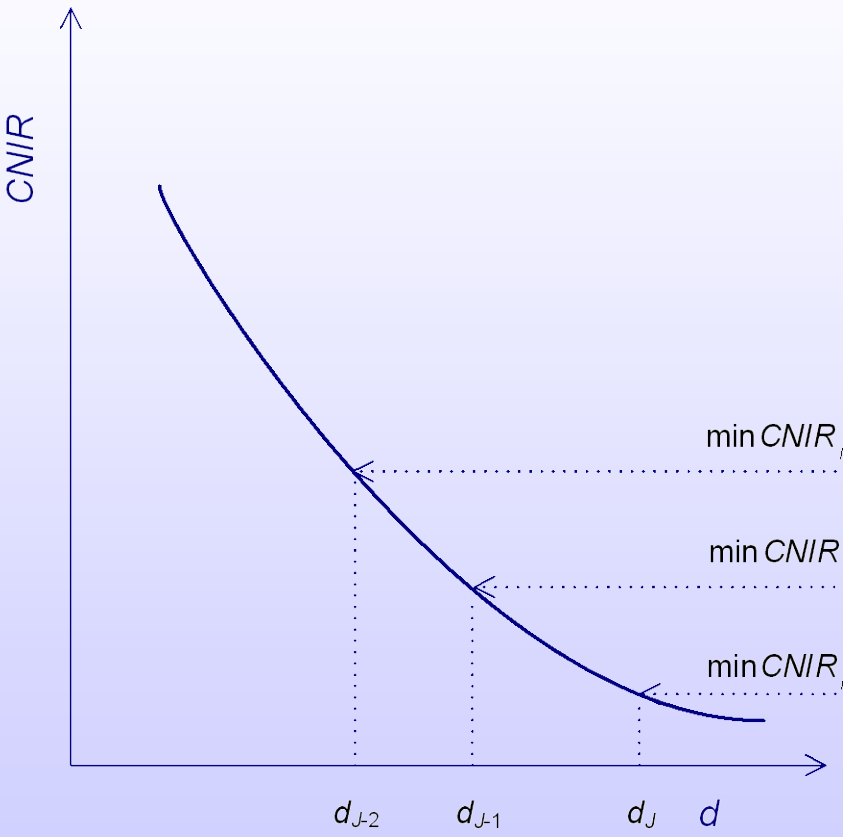


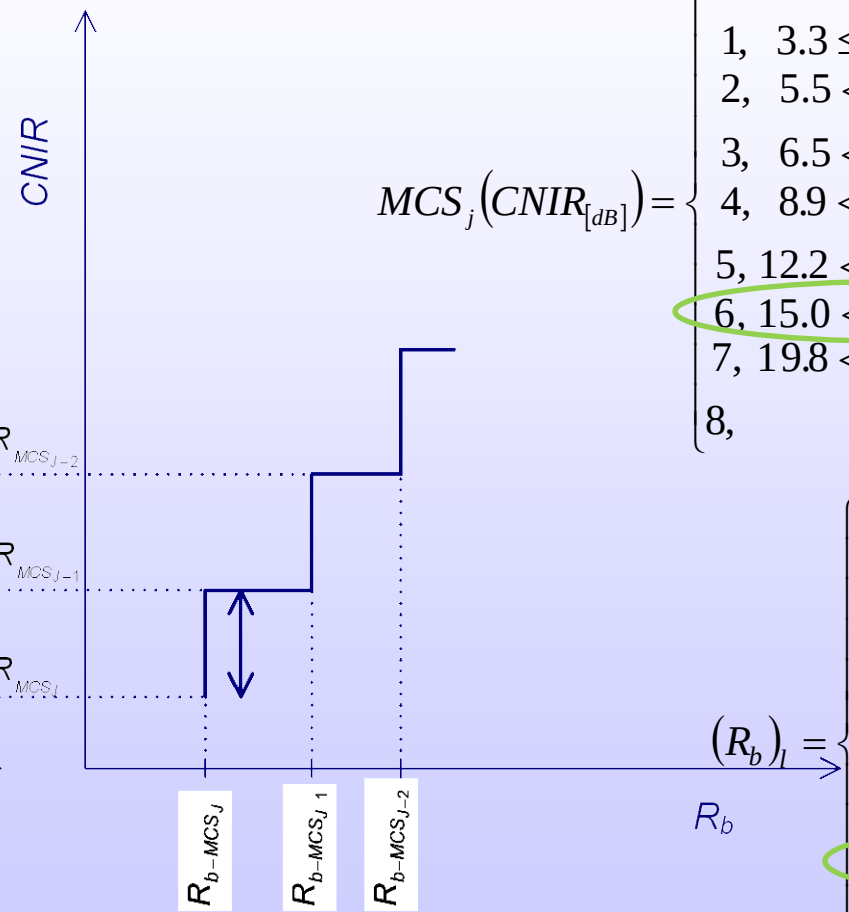
- There are J different coverage rings in a cell, each supporting a different MCS (for instance, J = 4 in Figure)
- The distances that correspond to the steps between consecutive MCS are represented by d_j, j = 1, 2, …, J. Here we denote the order of the MCS as MCS_j
- The supported throughput is obtained as

$$R_{b-\sup} = \frac{\iint_{O} R_b(d,R,K)\,dxdy}{\frac{3\sqrt{3}}{2}\cdot R^2} = \frac{\sum_{j=1}^{J}\left(\frac{3\sqrt{3}}{2}\cdot\left(d_j^2 - d_{j-1}^2\right)\cdot\left(R_b\right)_{MCS_{1st}+1-j}\right)}{\frac{3\sqrt{3}}{2}\cdot R^2}$$

where $(R_b)_{MCS1^{st}+1-j}$ is the throughput for the jth coverage ring

Rings *vs* supported PHY throughput





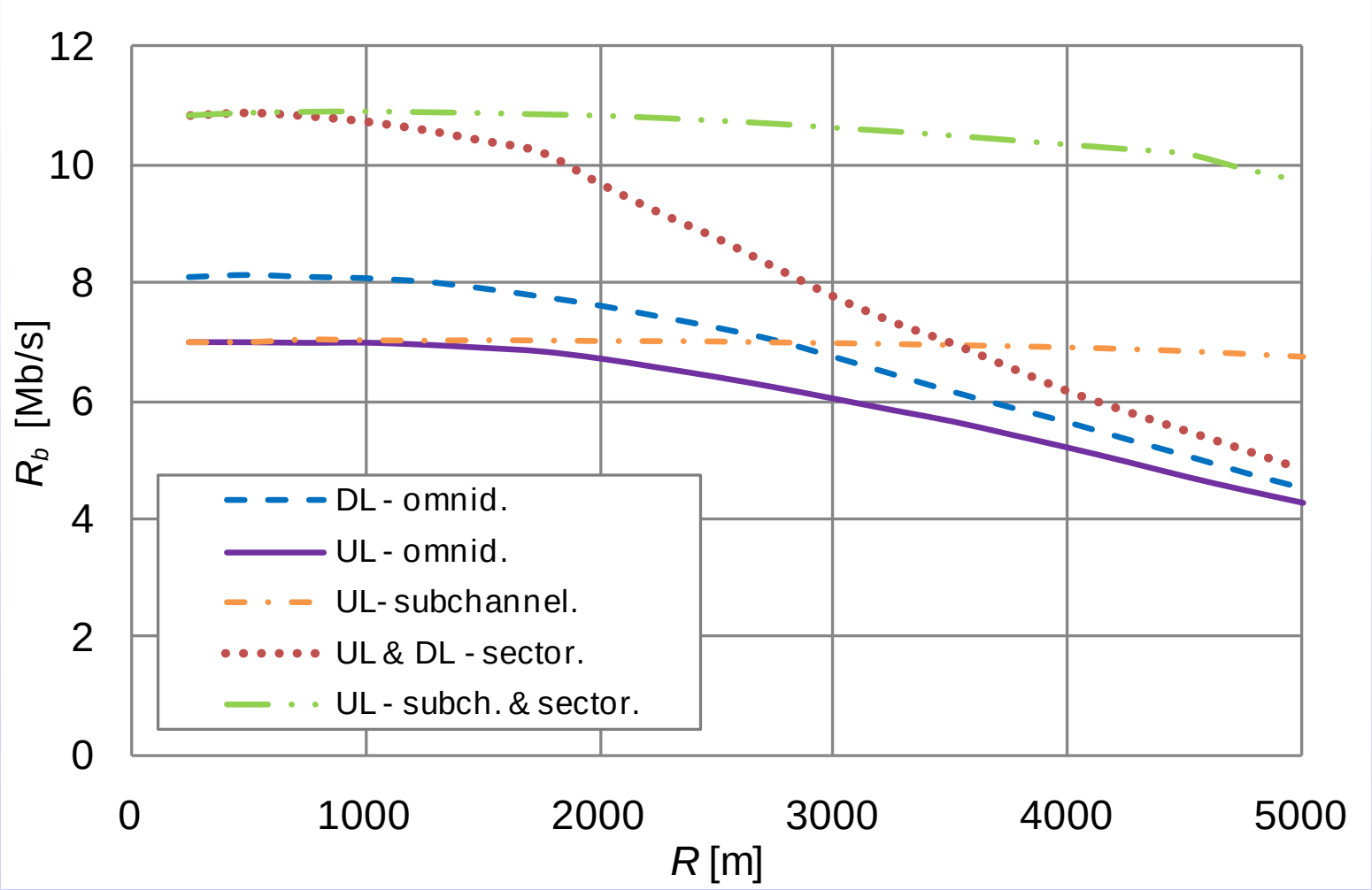
$$MCS_j\left(CNIR_{[dB]}\right)=\begin{cases}0, & CNIR<3.3\\ 1, & 3.3\le CNIR<5.5\\ 2, & 5.5<CNIR<6.5\\ 3, & 6.5<CNIR<8.9\\ 4, & 8.9<CNIR<12.2\\ 5, & 12.2<CNIR<15.0\\ 6, & 15.0<CNIR<19.8\\ 7, & 19.8<CNIR<21.0\\ 8, & CNIR>21.0\end{cases}$$

$$\left(R_b\right)_l=\begin{cases}0, & l=0\\ 1.41, & l=1\\ 2.12, & l=2\\ 2.82, & l=3\\ 4.23, & l=4\\ 5.64, & l=5\\ 8.47, & l=6\\ 11.23, & l=7\\ 12.27, & l=8\end{cases}$$

$$d_j=cnir^{-1}\left(\min\left(CNIR\left(\left(R_b\right)_{MCS_{1st}+1-j}\right)\right)\right),\ j=1,\ \ldots,\ J.$$

Supported Cell/Sector Throughput

for K = 7



Fixed WiMAX Assumptions for Cost/Revenue Optimization

Costs without relays

(Hypothesis "B" is the for the future, when prices will go down)

Costs		Omnidirectional without relays
C_{fi}[€/km^2]	K=1	15.71
	K=3	47.14
C_{BS}[€]		18 000 (**A**) -> 9000 (**B**)
C_{Inst}[€]		10 000 (**A**) -> 1 000 (**B**)
C_{bh}[€]		5000 (**A**) -> 2500 (**B**)
$C_{M\&O}$[€/year]		4000 (**A**) -> 1000 (**B**)

Costs with relays ***for omnidirectional and tri-sectored BS antennas***

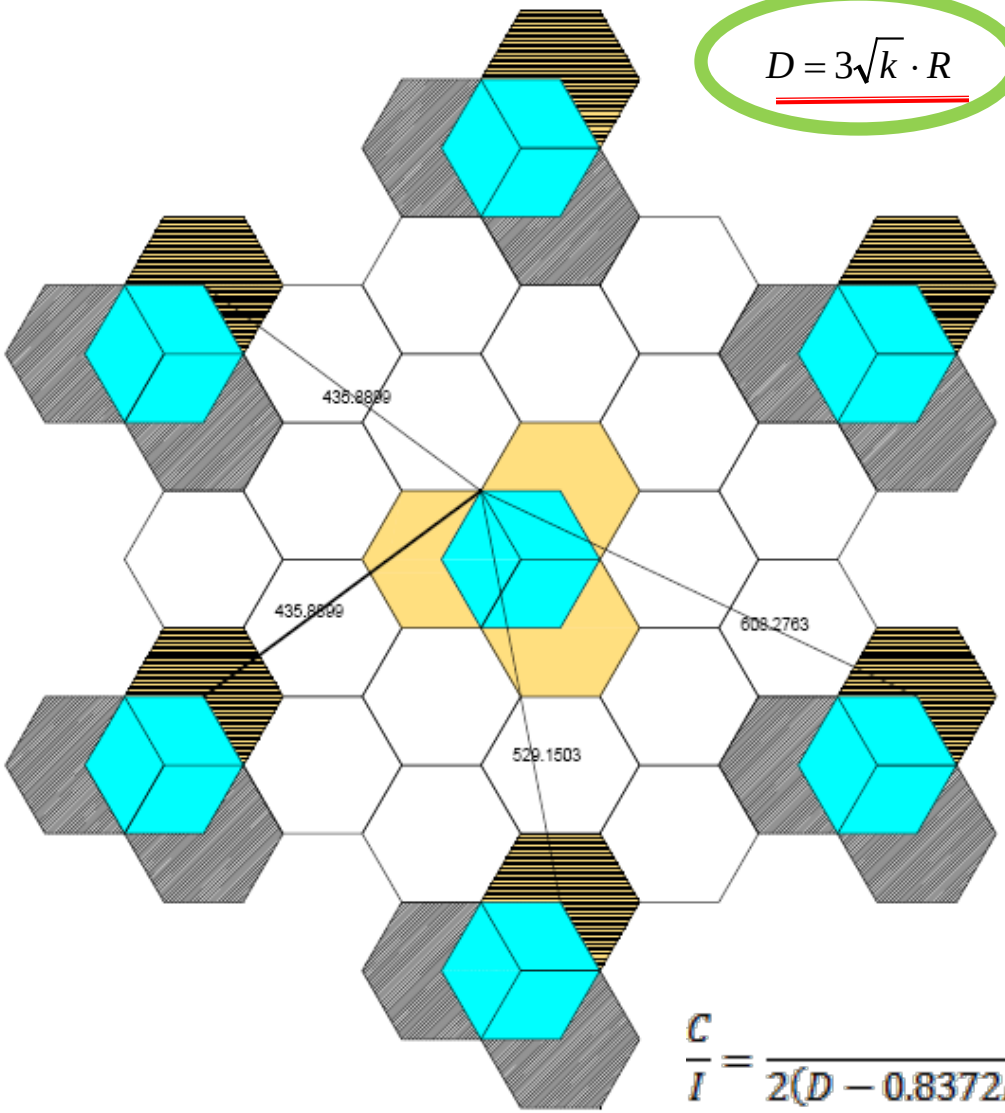
Costs	Omnidirectional	Tri-sectored
C_{fi}[€/km^2]	47.14	47.14
C_{BS}[€]	4800	6800
C_{Inst}[€]	1333.33	2000
C_{bh}[€]	833.33	833.33
$C_{M\&O}$[€/year]	833.33	833.33

Revenues

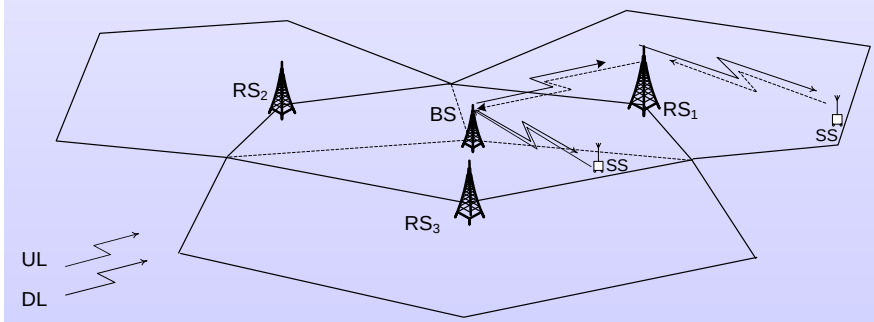
A given price for 1 MB of information is assumed, e.g. 0.0025 €/MB or 0.005 €/MB

Challenge: Coverage Scenario with Relays

$$D = 3\sqrt{k} \cdot R$$



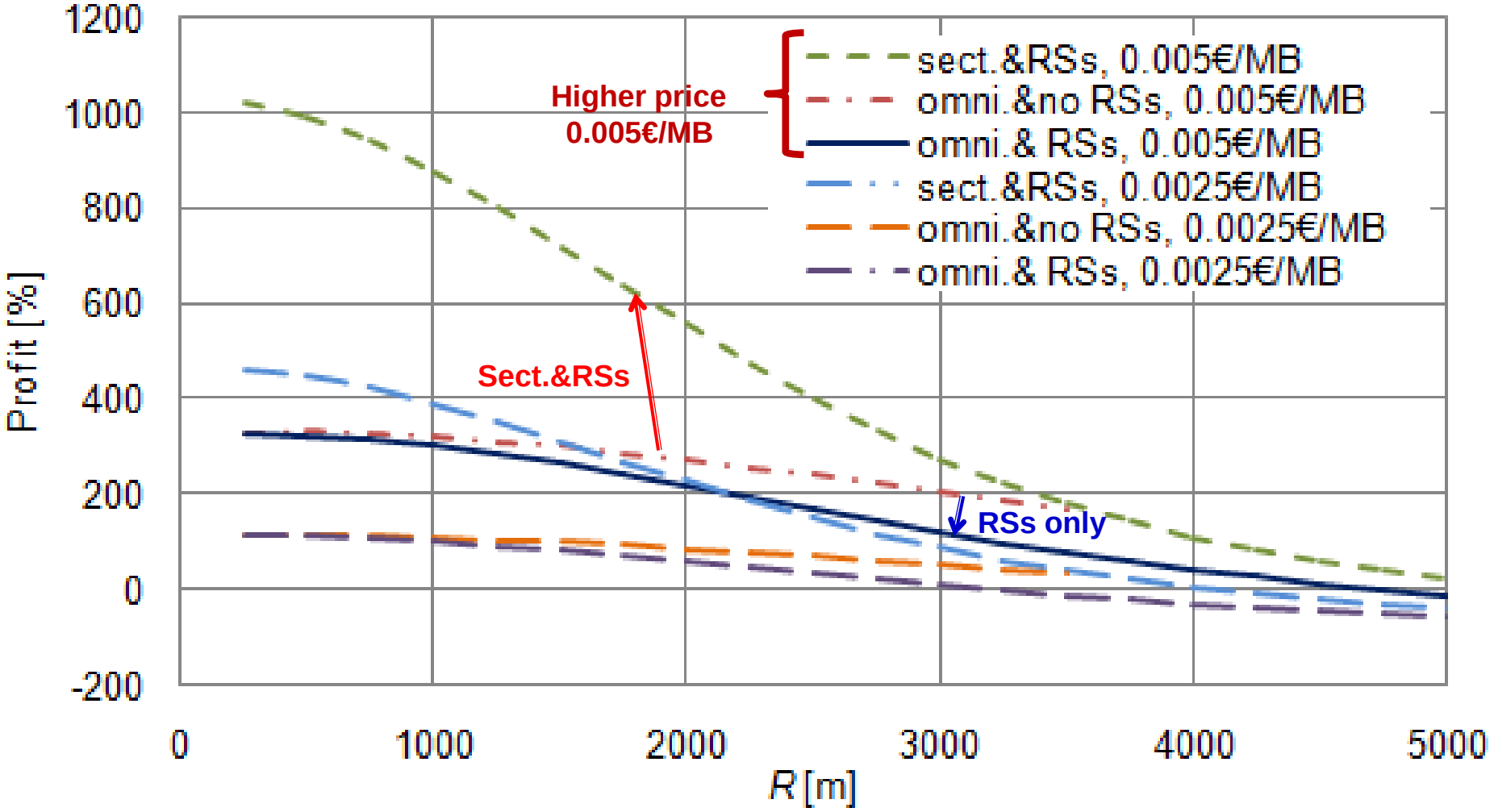
- DL Scenario and 240º sector coverage in Relay Station (RS) coverage area
- The central coverage area BS may have omnidirectional or tri-sectorial antenna



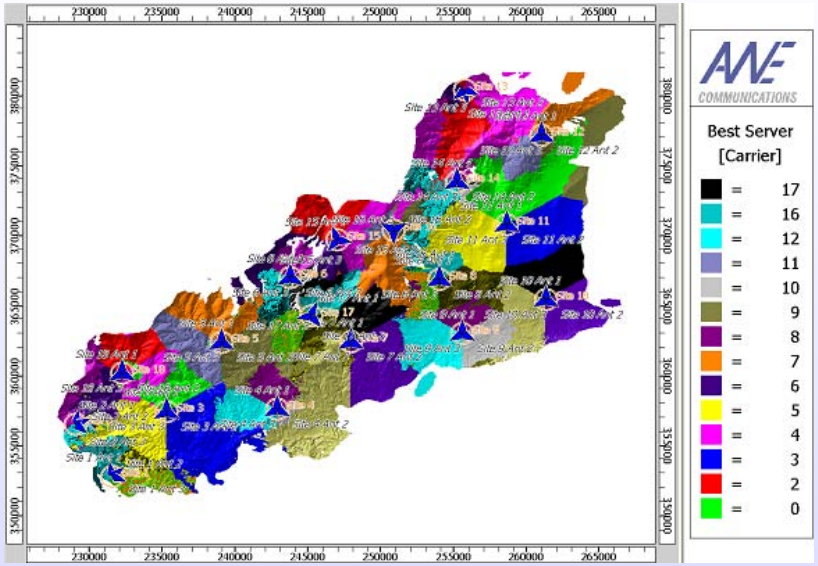
D: reuse distance
R: coverage distance or cell radius

$$\frac{C}{I} = \frac{R^{-\gamma}}{2(D-0.8372R)^{-\gamma} + (D+0.09535R)^{-\gamma} + (D+0.8866R)^{-\gamma}}$$

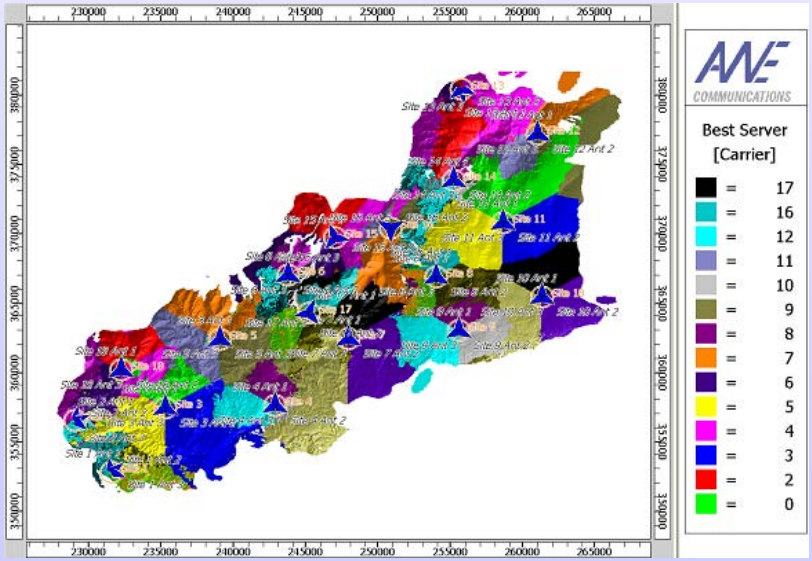
Profit: comparison



Cellular Planning: Maps with "best server" cells

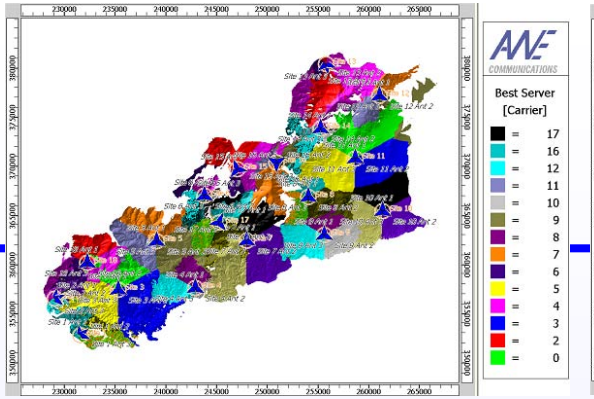


BPSK ½

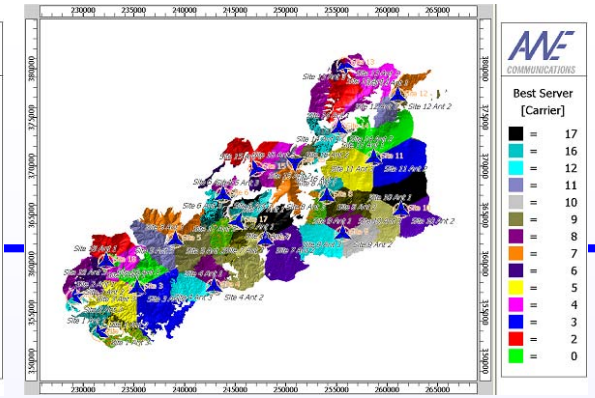


BPSK ¾

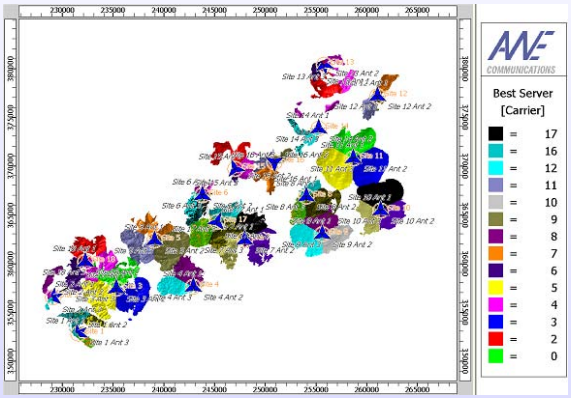
Over the region of Beira Interior, with an area of 550km^2, the number of cells necessary to cover the area under study is 14 and 24cells, approximately, for coverage distances *R*=4 and *R*=3km, respectively



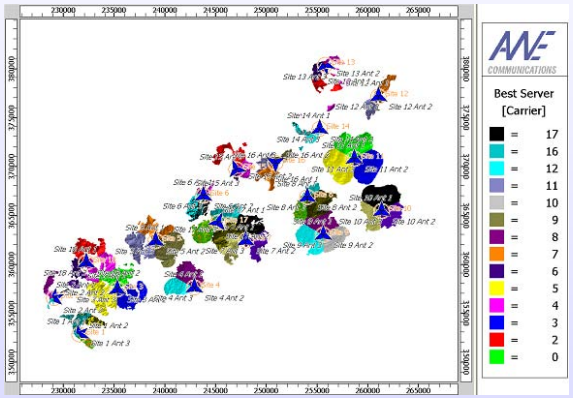
(a) QPSK ½



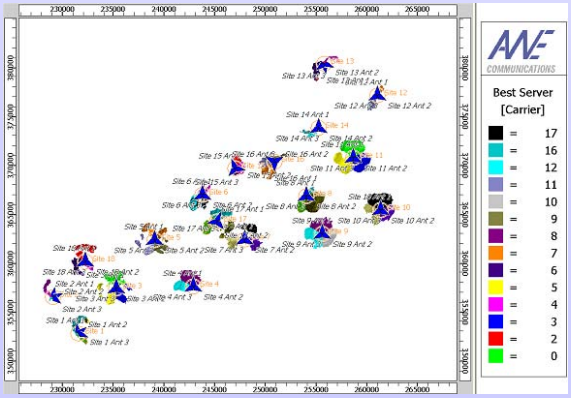
(b) QPSK ¾



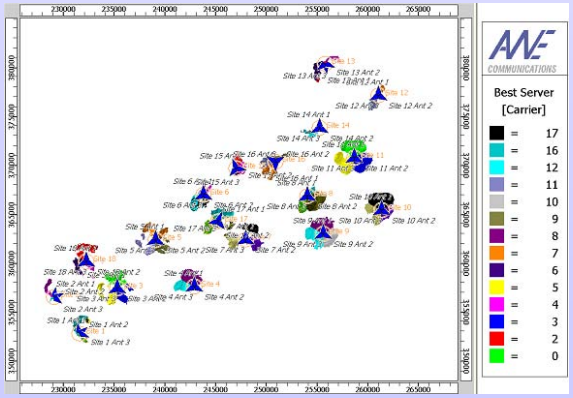
(c) 16-QAM ½



(d) 16-QAM ¾



(e) 64-QAM 2/3



(f) 64-QAM ¾

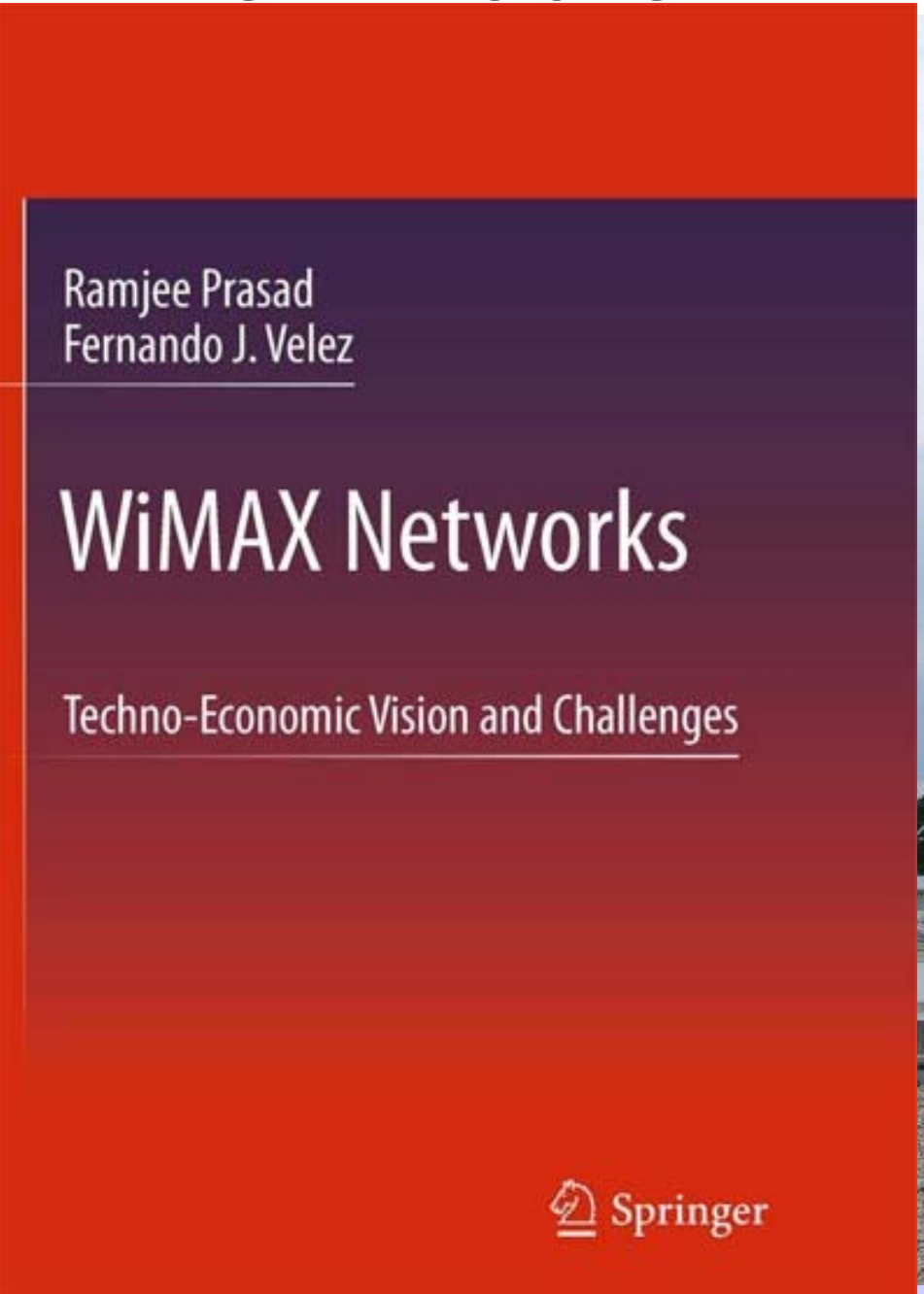
Conclusions

- By weighting the physical throughput in each concentric cell coverage ring by the size of the ring, the contribution from each transmission mode (or MCS) is included in a formulation to obtain the average supported throughput
- The use of sectorization is clearly advantageous
- Improvements are achieved for the longest coverage distances with the use of sub-channelisation in UL
- Relays are cheaper than full-functionality BSs
- With Relays, the need of resources for BS-to-RS communications causes a decrease in throughput (only partially compensated by sectorization)

Conclusions (cont.)

- **Results show that the use of relays with sectorization (an example is presented for *K* = 3) enables to achieve higher profit**
- **The optimum (maximum) values occur for coverage distances up to 1000-1500 m**
- **Future broadband wireless access technologies will certainly be based on multi-hop networks with relays**

New Mobile WiMAX BS at 5.4 GHz



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