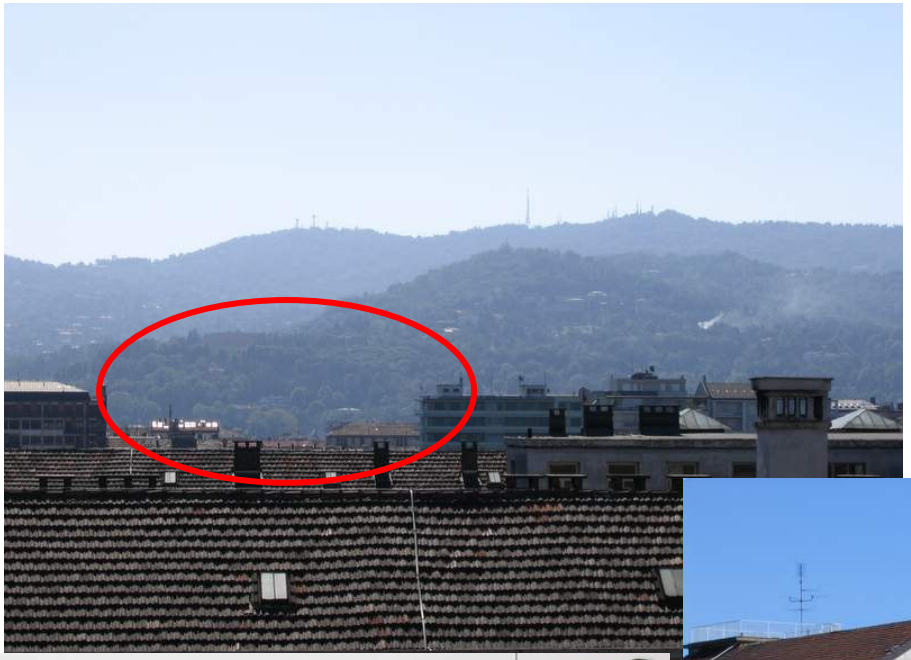
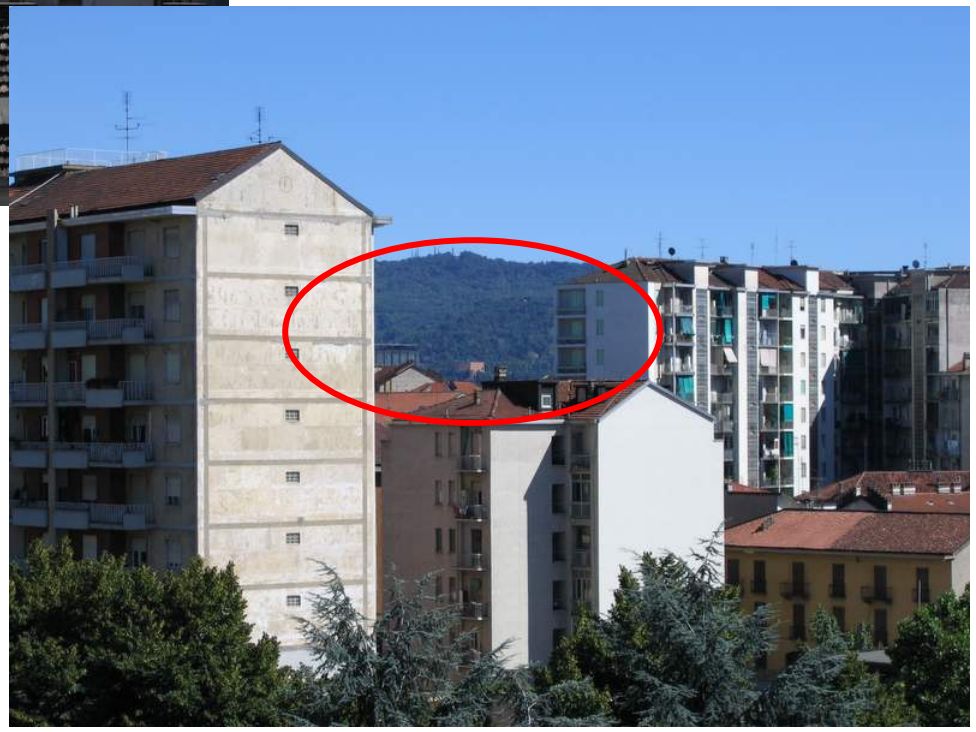
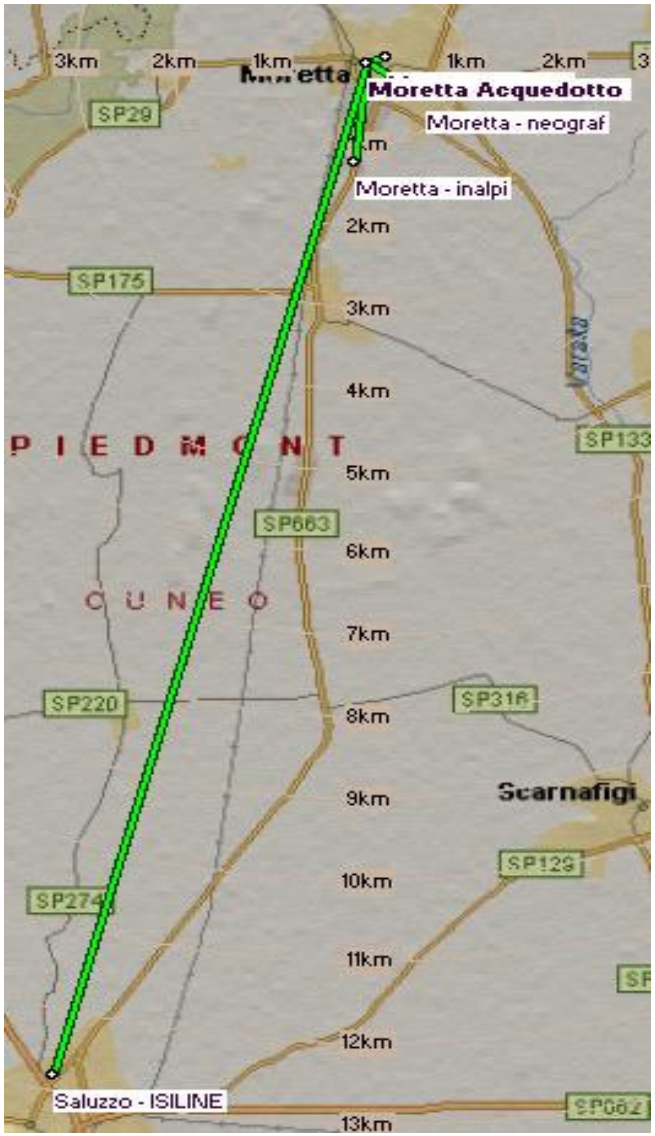
Sperimentazione WiMAX: SS installate a Torino





WiMAX: Saluzzo



Sperimentazione WiMAX: specifiche Radio

Table 1-5: Radio Specifications

Item	Description				
Output Power (at antenna port)	AU-ODU	28dBm +/-1dB maximum. Power control range: 15dB 18-28dBm @ +/-1dB, 13-18dBm @ +/-2dB			
	SU-ODU	20dBm +/-1dB maximum, ATPC Dynamic range: 40 dB			
Modulation	OFDM modulation, 256 FFT points; BPSK, QPSK, QAM16, QAM64				
FEC	Convolutional Coding: 1/2, 2/3, 3/4				
Bit Rate and Typical Sensitivity (PER=1%)	Channel Spacing	3.5MHz bandwidth		1.75MHz bandwidth	
	Modulation & Coding	Net Phy Bit rate (Mbps)	Sensitivity (dBm)	Net Phy Bit rate (Mbps)	Sensitivity (dBm)
	BPSK 1/2	1.41	-100	0.71	-103
	BPSK 3/4	2.12	-98	1.06	-101
	QPSK 1/2	2.82	-97	1.41	-100
	QPSK 3/4	4.23	-94	2.12	-97
	QAM16 1/2	5.64	-91	2.82	-94
	QAM16 3/4	8.47	-88	4.24	-91
	QAM64 2/3	11.29	-83.0	5.65	-86
	QAM64 3/4	12.71	-82.0	6.35	-85

Table 1-5: Radio Specifications

Item	Description		
Frequency	Unit/Band	Uplink (MHz)	Downlink (MHz)
	AU-ODU-3.5a	3399.5-3453.5	3499.5-3553.5
	AU-ODU-3.5b	3450-3500	3550-3600
	SU-ODU-3.5	3399.5-3500	3499.5-3600
Operation Mode	AU, Micro Base Station	FDD, Full duplex	
	SU	FDD, Half Duplex	
Channel Bandwidth	■ 3.5 MHz ■ 1.75 MHz		
Central Frequency Resolution	0.125 MHz		
CPE-ODU-AV Integral Vertical Antenna	18dBi, 15° AZ x 18° EL, vertical polarization, compliant with EN 302 085, V1.1.1 Range 1		
CPE-ODU-AH Integral Horizontal Antenna	18dBi, 18° AZ x 15° EL, horizontal polarization, compliant with EN 302 085 V1.1.2 Range 1		
Antenna Port (CPE-ODU-E, AU-ODU)	N-Type, 50 ohm		
Max. Input Power (at antenna port)	AU-ODU	-60dBm before saturation, -17dBm before damage	
	SU-ODU	-20dBm before saturation 0dBm before damage	

Propagation Measurement - 3.5 GHz

E' cruciale acquisire informazioni sul comportamento del canale radio nella banda a 3.5 GHz in condizioni urbani, suburbani e rurali.

Tre tipologie di acquisizioni:

- Monitoraggio dei link su lungo periedo (RSSI, SNR, modulazione)
- Acquisizione dei livelli di campo EM lungo differenti route
- Acquisizione dei livelli di campo EM ad altezza variabile

	UpLink [MHz]	DownLink [MHz]	Channel Bandwith [MHz]
BS 1	3477.25	3577.25	3.5
BS 2	3466.75	3566.75	3.5

Modulation	Code rate	Sensitivity dBm	Raw Bit Rate DL fixed (Mbps) 3.5 MHz BW	Net throughput DL fixed (Mbps) 3.5 MHz BW
BFSK	1/2	-100	1.41	1.128
	3/4	-98	2.12	1.696
QPSK	1/2	-97	2.82	2.256
	3/4	-94	4.23	3.384
16QAM	1/2	-91	5.64	4.512
	3/4	-88	8.87	7.096
64QAM	2/3	-83	11.29	9.032
	3/4	-82	12.71	10.168

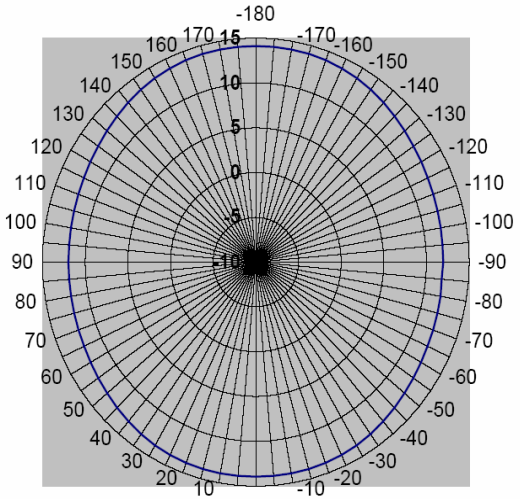
Propagation Measurements/drive tests

Il van e' equipaggiato con:

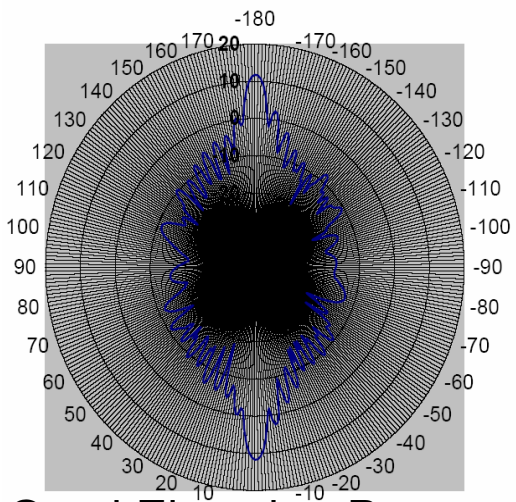
- un palo telescopico: misure ad altezza variabile (2-10 m).
- Antenna Omnidirezionale
- GPS (geographic positioning)
- Spectrum Analyzer

Omni Directional Antenna 3.5GHz – 3360 Fibreglass Omni

Gain 13 dBi
Pol. Verticale



Omni Azimuth Pattern



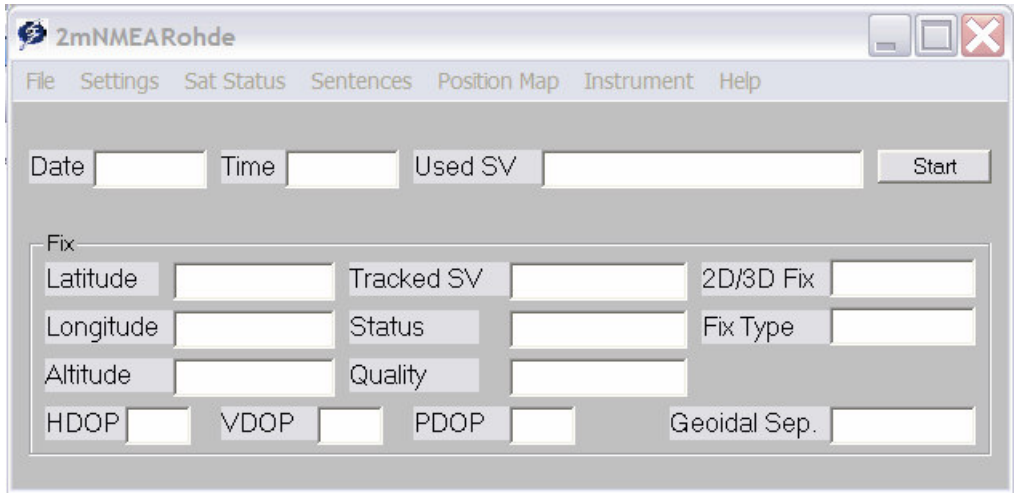
Omni Elevation Pattern

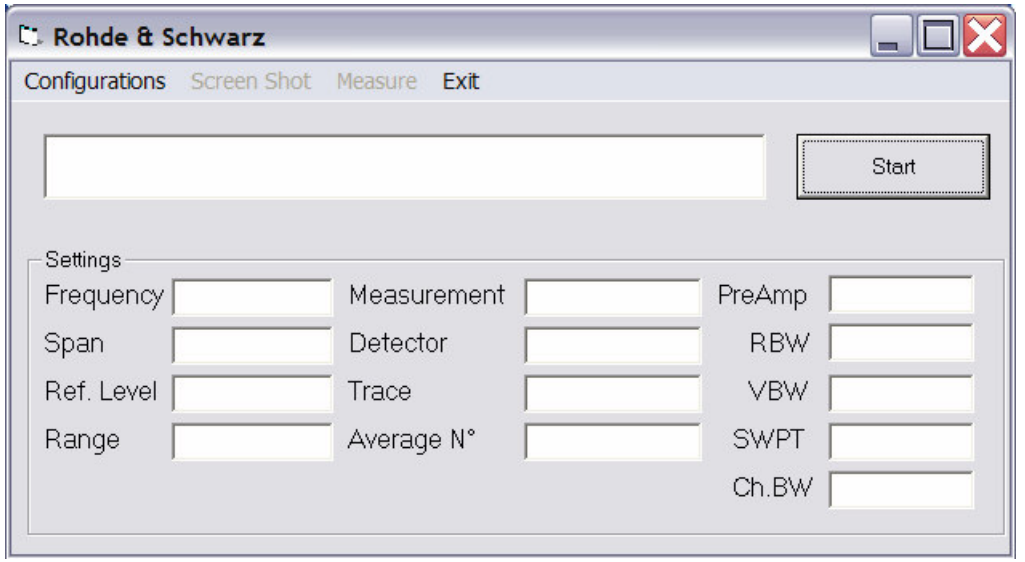
Van - Strumentazione

- Position location equipment (GPS)
- Software di acquisizione (gestione del GPS/analizzatore di spetto/storing)
- Spectrum analyzer
- Low noise amplifier
- Band pass filter (*3-4-3.5 GHz*)

GPS: NovAtel's FlexPak™

Software di acquisizione





Allocated Spectrum - CANAVESE

Canale 1 [MHz]	3465 - 3466,75	3565 - 3566,75
Canale 2 [MHz]	3466,75 - 3468,5	3566,75 - 3568,5
Canale 7 [MHz]	3475,5 - 3477,25	3575,5 - 3577,25
Canale 8 [MHz]	3477,25 - 3479	3577,25 - 3579

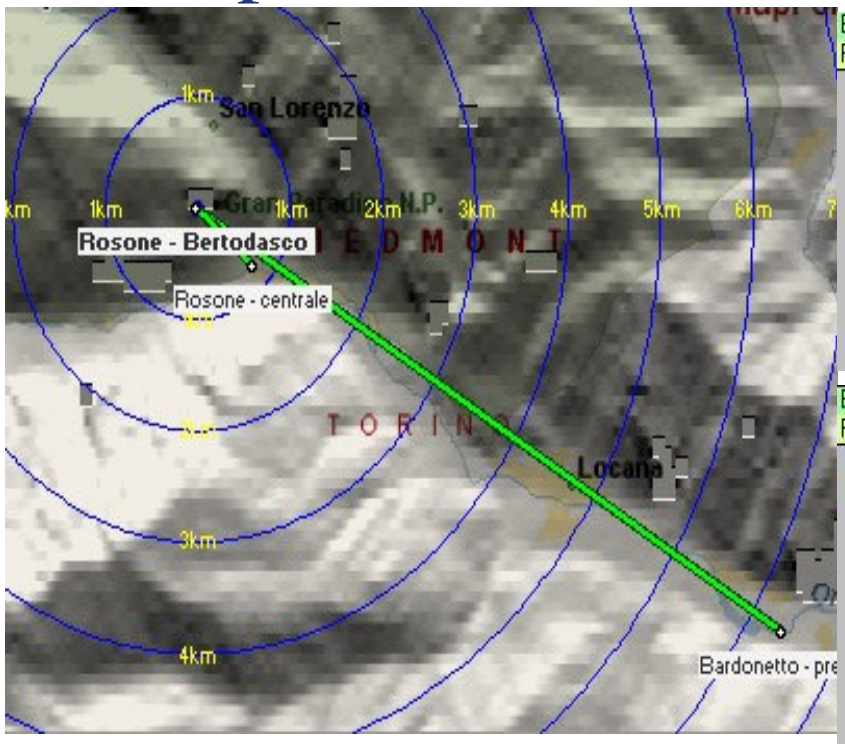
	UpLink [MHz]	DownLink [MHz]	Channel Bandwith [MHz]
BS 1	**3477.25**	**3577.25**	**3.5**
BS 2	**3466.75**	**3566.75**	**3.5**

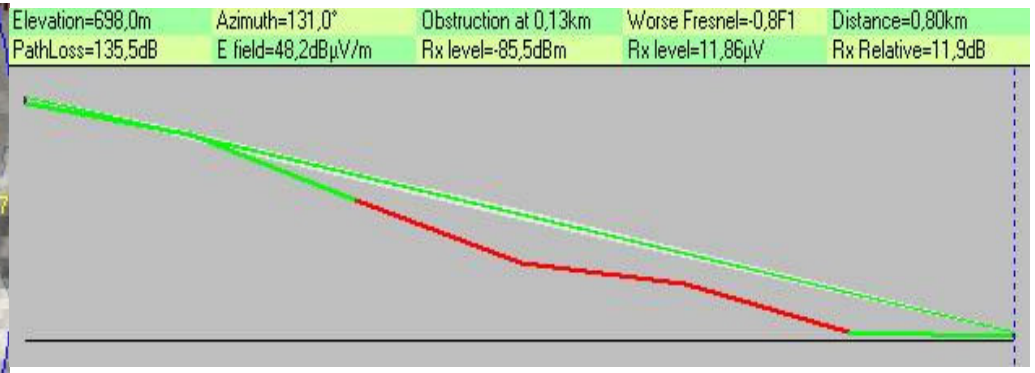
Metodologia di acquisizione

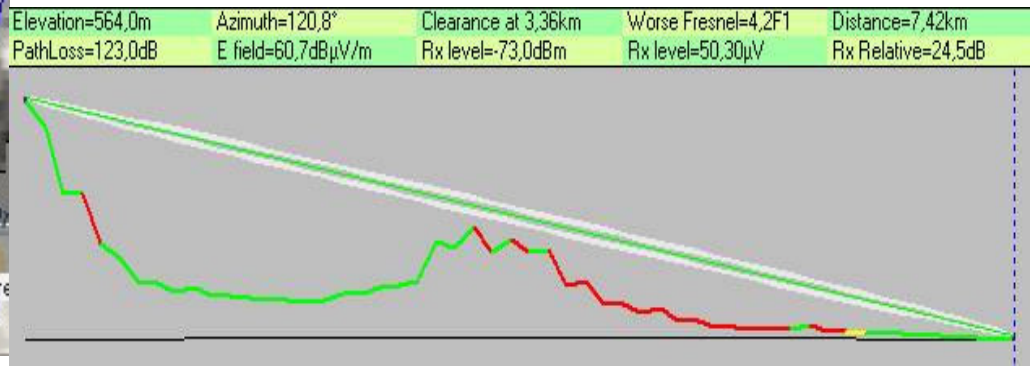
- 3566.75 MHz (DL) (channel bandwidth 3.5 MHz)
- Calibrazione del sistema
- Misura della potenza di segnale ricevuto (dBm)
- Misure georeferenziate: Latitudine/longitudine/quota
- Storing su hard disk per successivo processing

Time[hhmmss]	Latitude[deg]	Longitude[deg]	Altitude[m]	HDOP	VDOP	PDOP	Instr. Measure [dBm]
……..							
133009	45,3588616666667	7,73127333333333	314	0,8	1,2	1,5	-66.81
133013	45,3587966666667	7,73134166666667	314	0,8	1,2	1,5	-63.32
133017	45,3587316666667	7,73141166666667	313,9	0,9	1,2	1,5	-65.64
133021	45,3586666666667	7,73148166666667	313,8	0,8	1,2	1,5	-67.7
133025	45,3586016666667	7,73155166666667	313,8	1	1,5	1,8	-63.2
……							

Sperimentazione WiMAX: Primi risultati





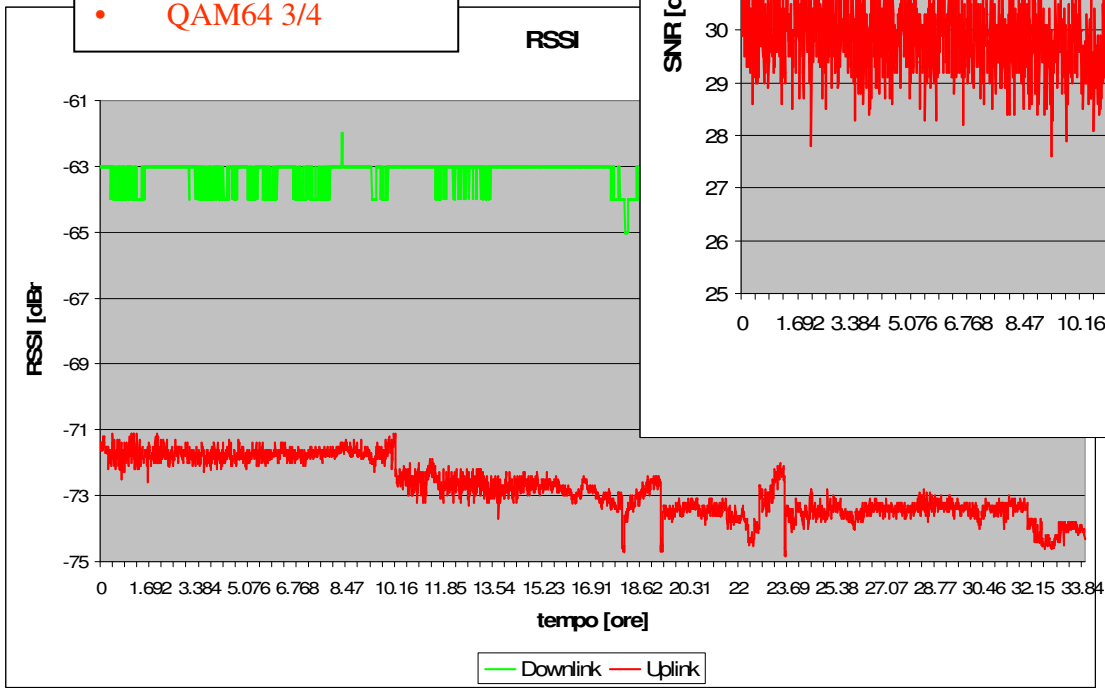


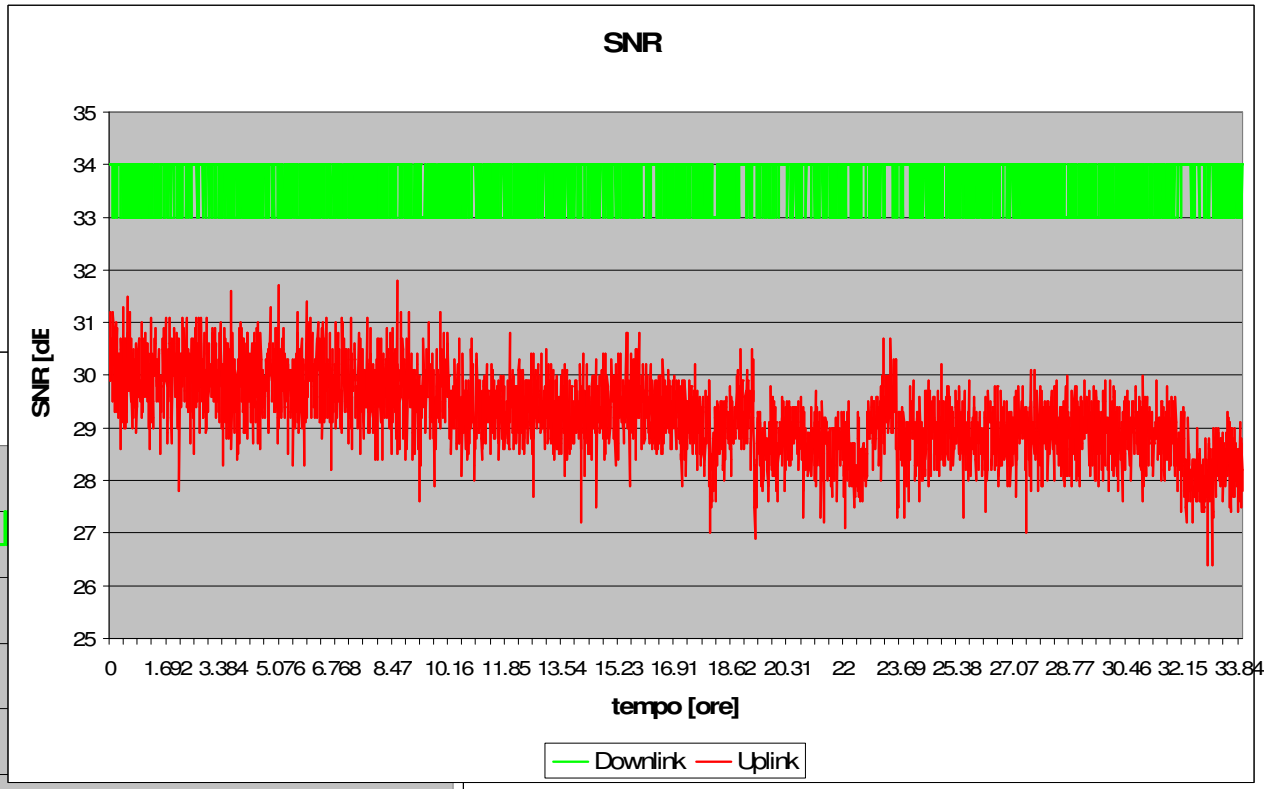
- I profili di tratta si riferiscono al Bardonetto e al Rosone Bardonetto

Caratterizzazione della variabilità temporale del canale

MODULAZIONI

- BPSK 1/2
- BPSK 3/4
- QPSK 1/2
- QPSK 3/4
- QAM16 1/2
- QAM16 3/4
- QAM64 2/3
- QAM64 3/4



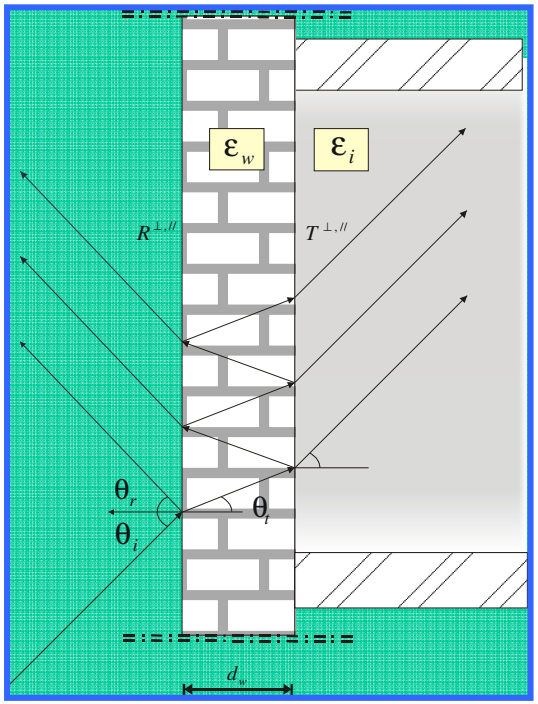


"time varying shadowing"
il cui rate è correlabile allo shift Doppler associato al movimento degli scatteratori.

BS Potenza in TX: 28dBm

….in corso

- Fitting dei dati
- Andamento Path loss
- Confronto con diversi modelli di propagazione
- Misure outdoor/indoor



WiMAX: Test di livello MAC

Throughput massimo

Throughput, delay, packet loss, jitter

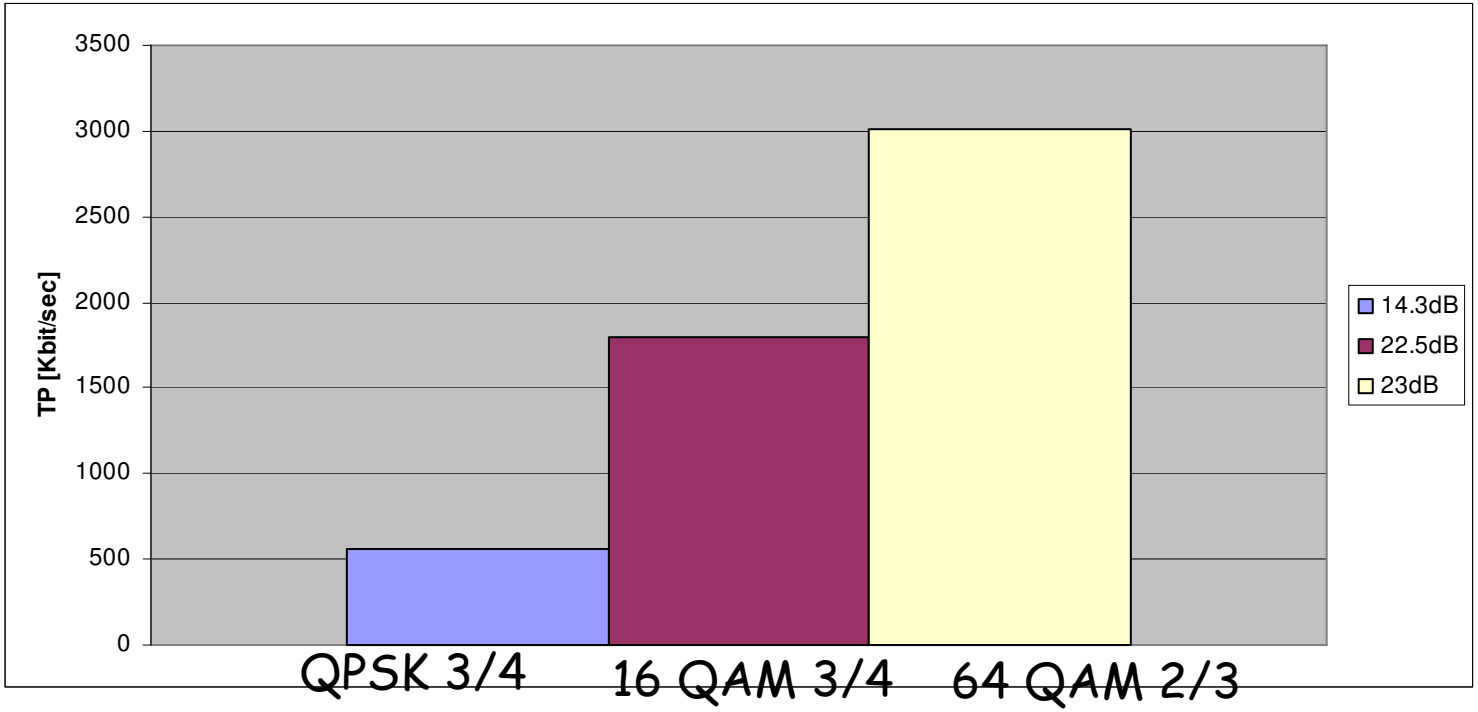
Variazione Payload

Fairness su UDP e TCP

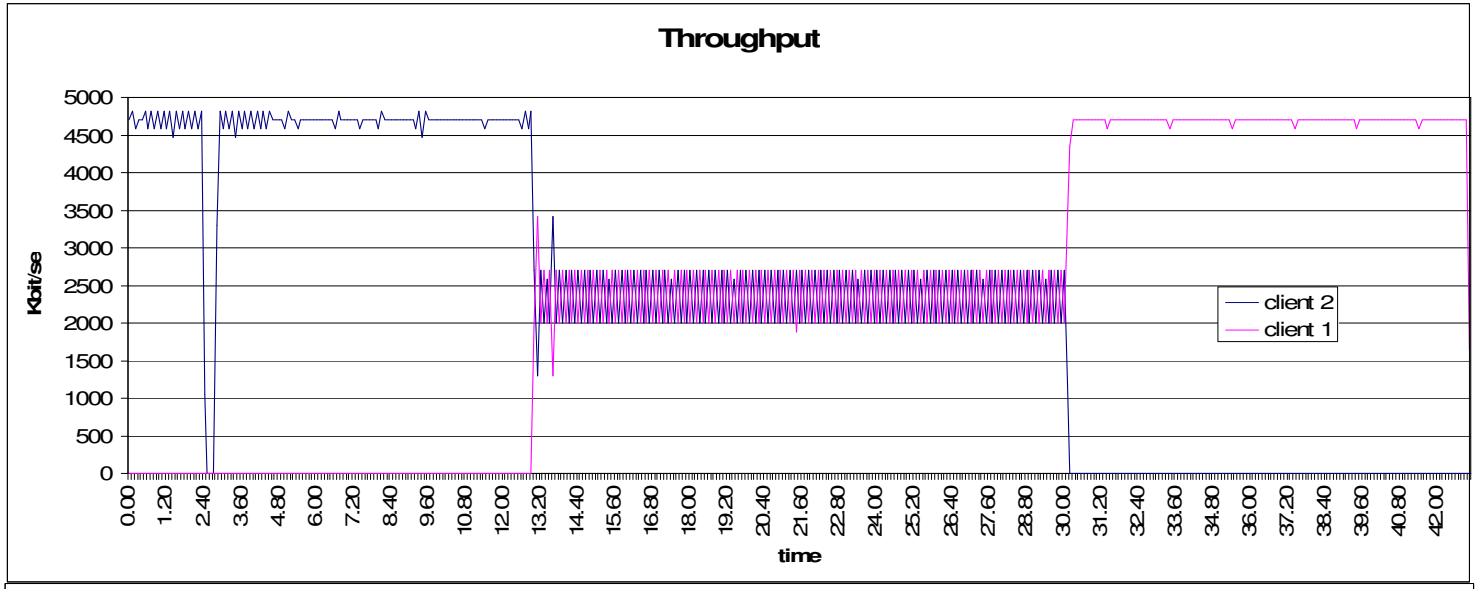
QoS (TCP, UDP, VoIP)

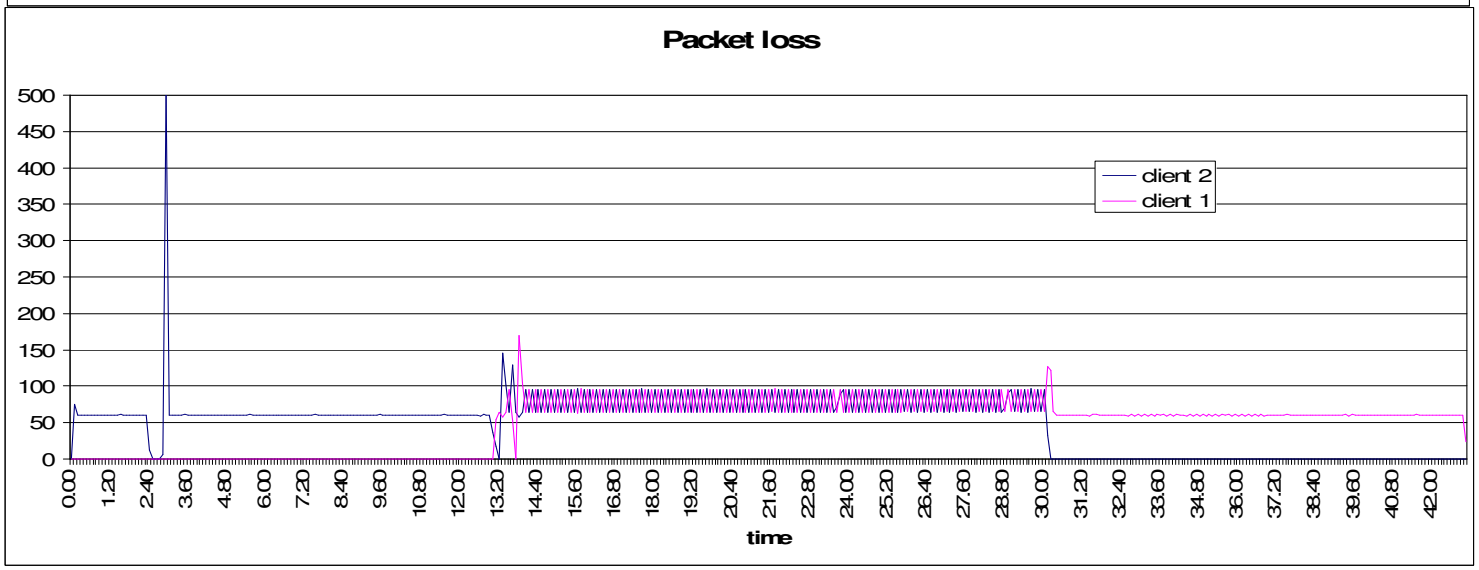
WiMAX: arcuni risultati sede Politecnico

- Parametri
  - Guadagno BS: 15 dB
  - Guadagno SS: 18 dB
  - Tx BS: 21 dBm
- Linkbudget
  - Pathloss per CSP = 114,9 dB
  - RX presso CSP = 21 + 15 + 18 - 114,9 = -60,9dBm

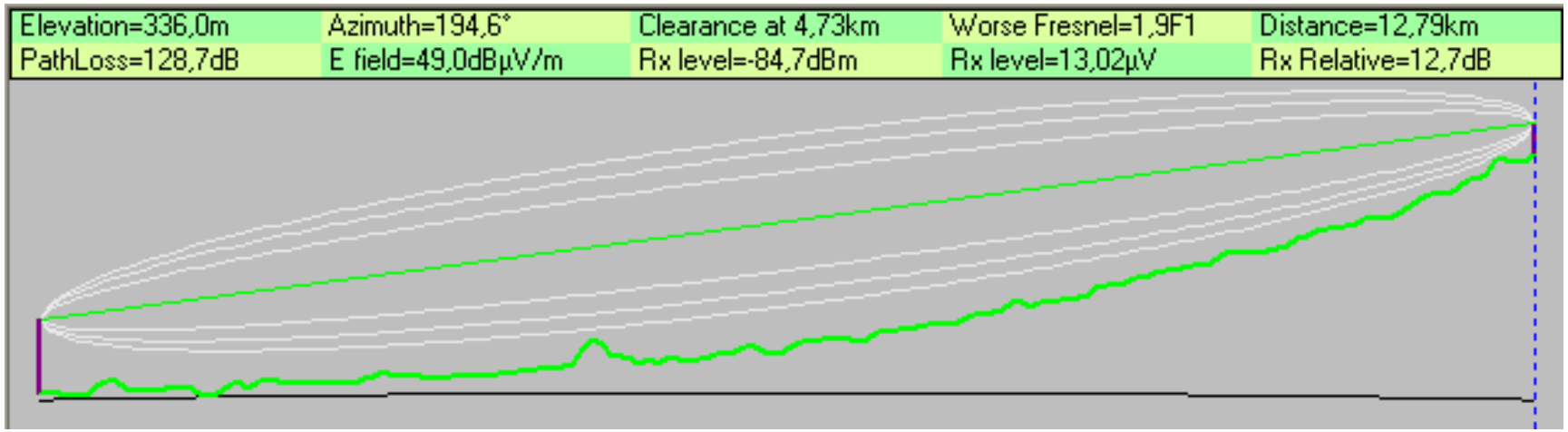


WiMAX: alcune misure sede Politecnico





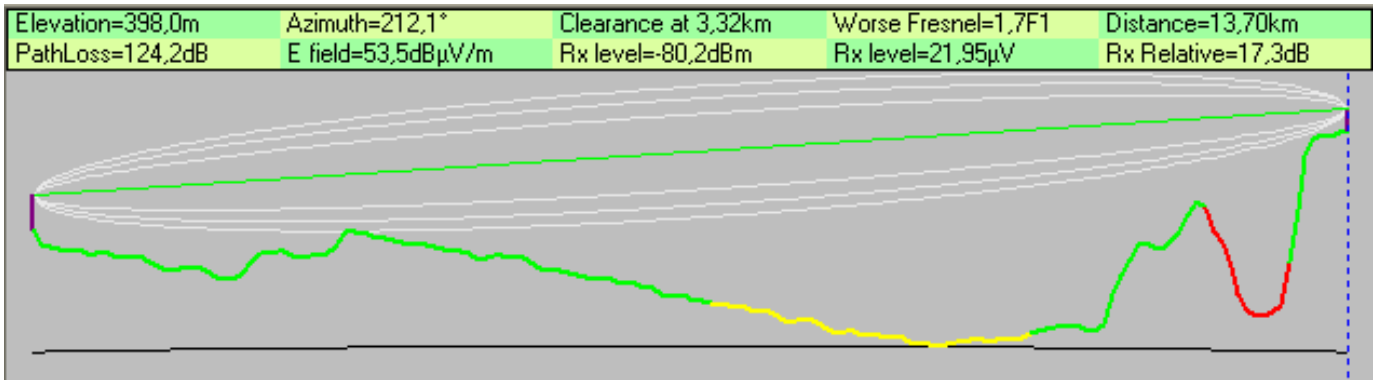
WiMAX: Saluzzo



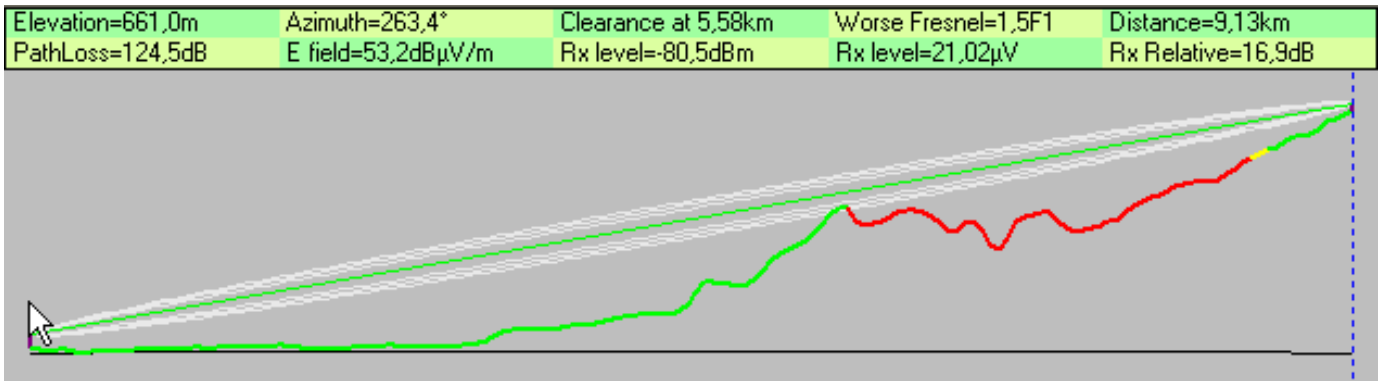
- Guadagno
  - BS: 17dB
  - SS: 18 dB
- Potenza TX
  - BS: 19 dB
  - SS: 16 dB

- Link Budget:
  - BS: 18 +16 + 17 -124:
    - Calcolato: -74 dBm
    - Misurato: -91 dBm
    - SNR 9,7 dB
  - SS: 17 + 19 +18 -124,7:
    - Calcolato: -70 dBm
    - Misurato: -89 dBm
    - SNR: 12 dB

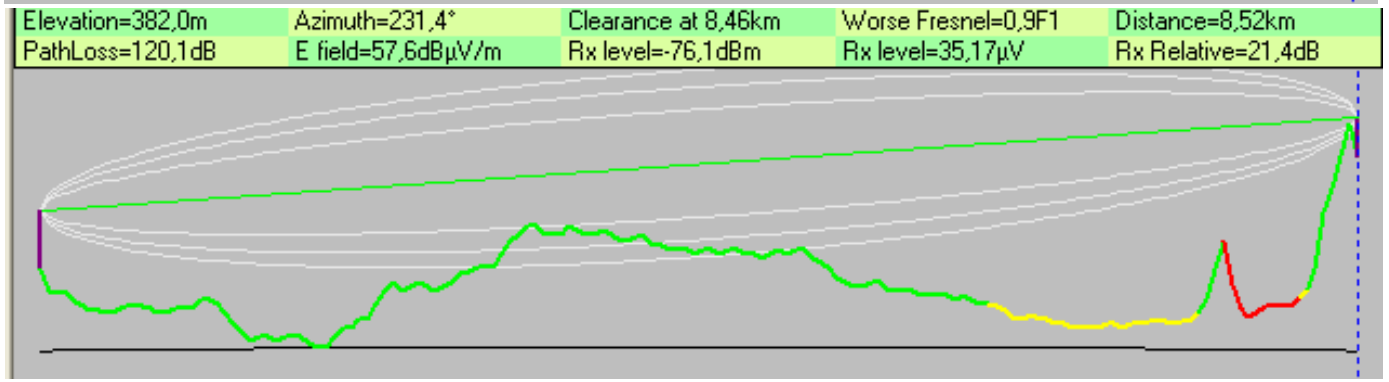
WiMAX: Profili di tratta



Vauda

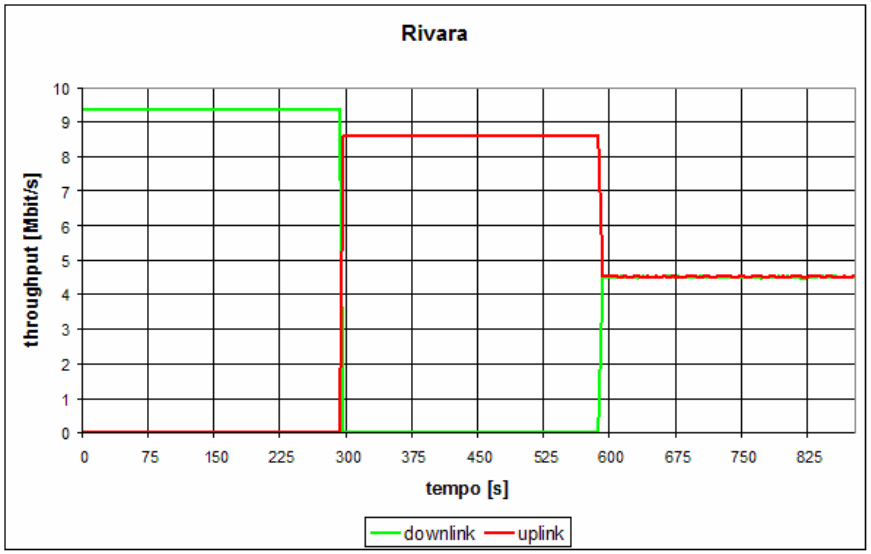


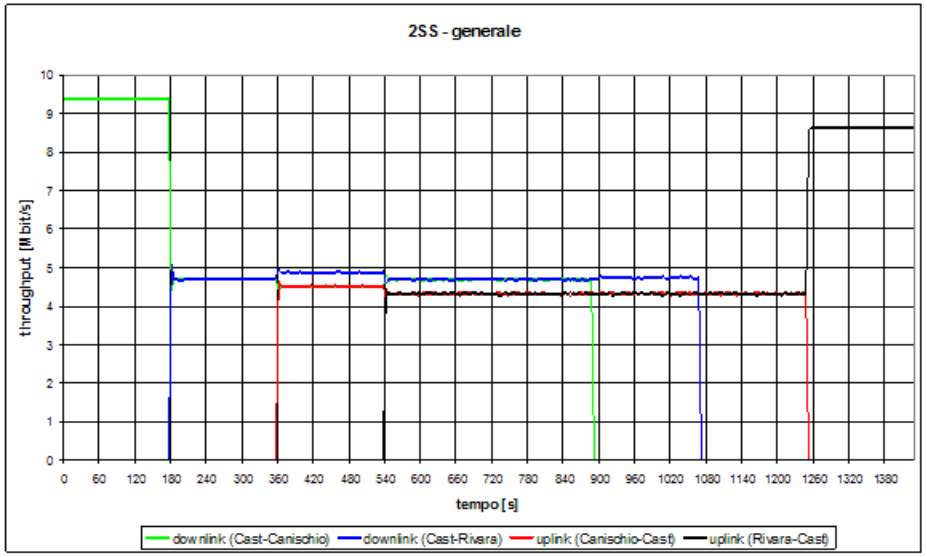
Canischio

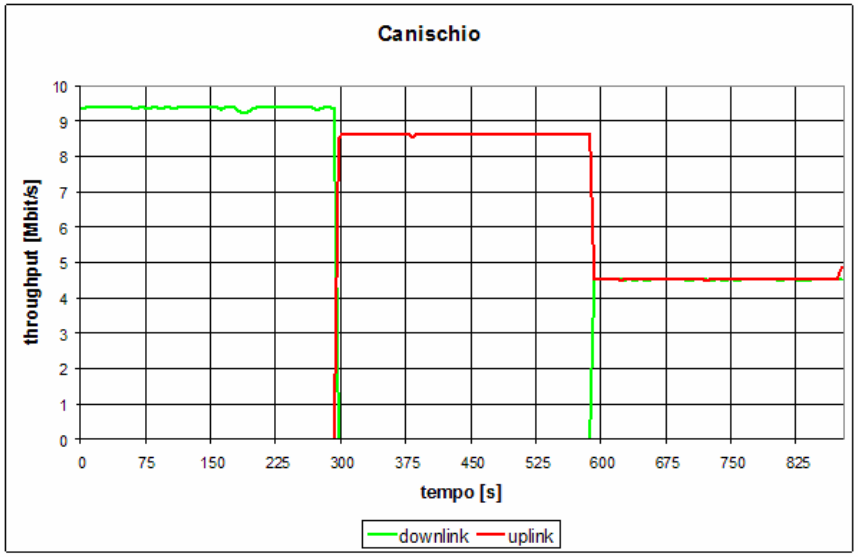


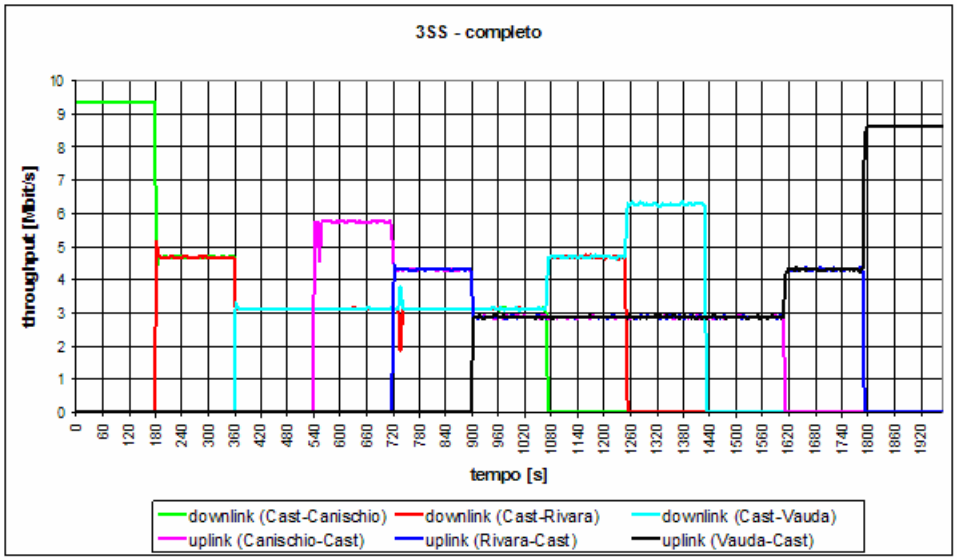
Rivara

WiMAX: Prestazioni

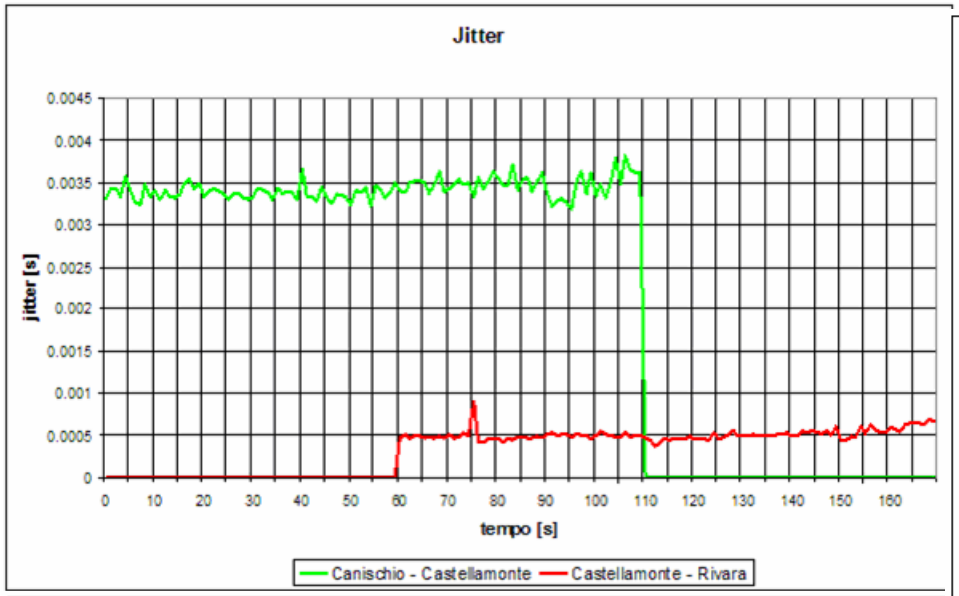


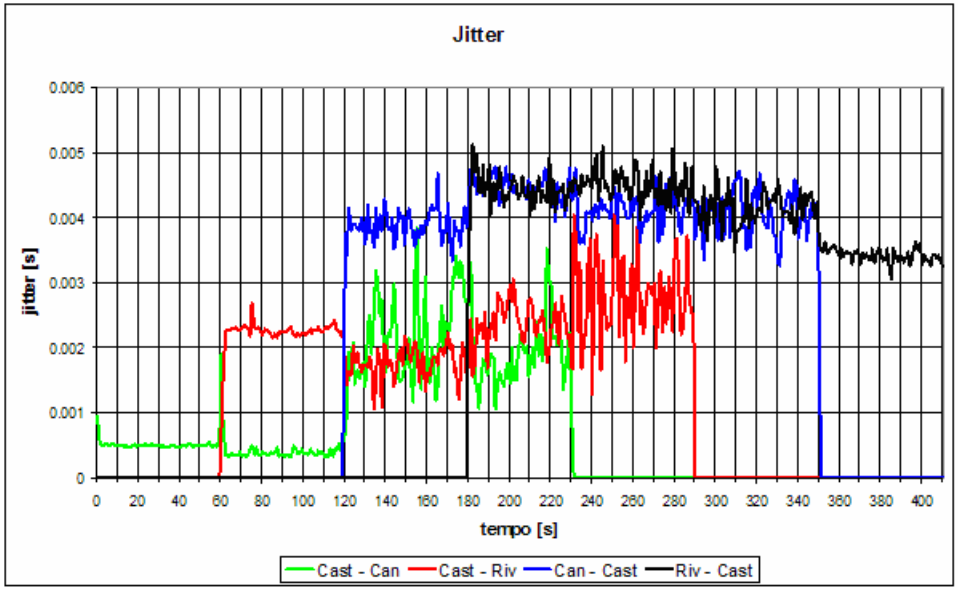


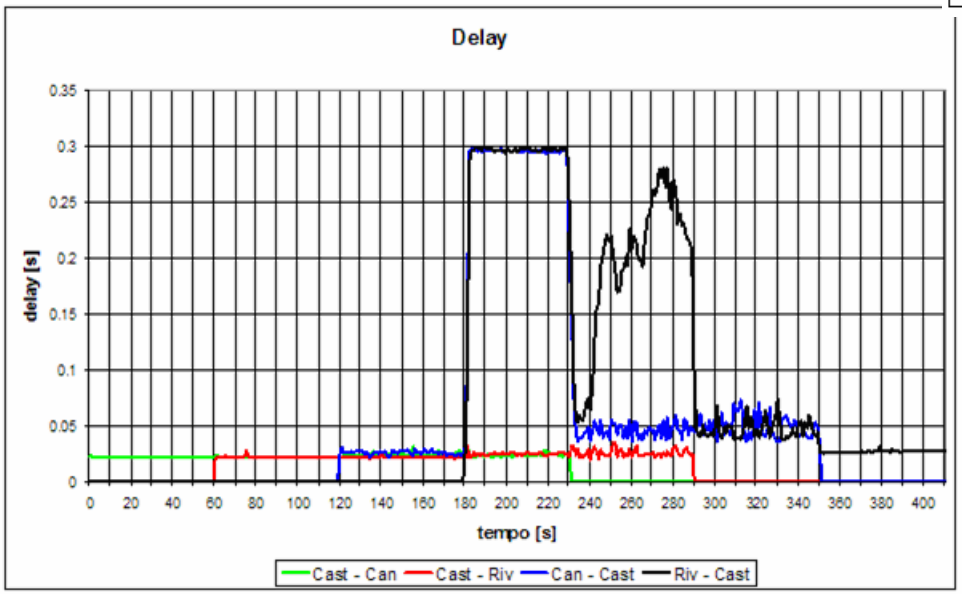


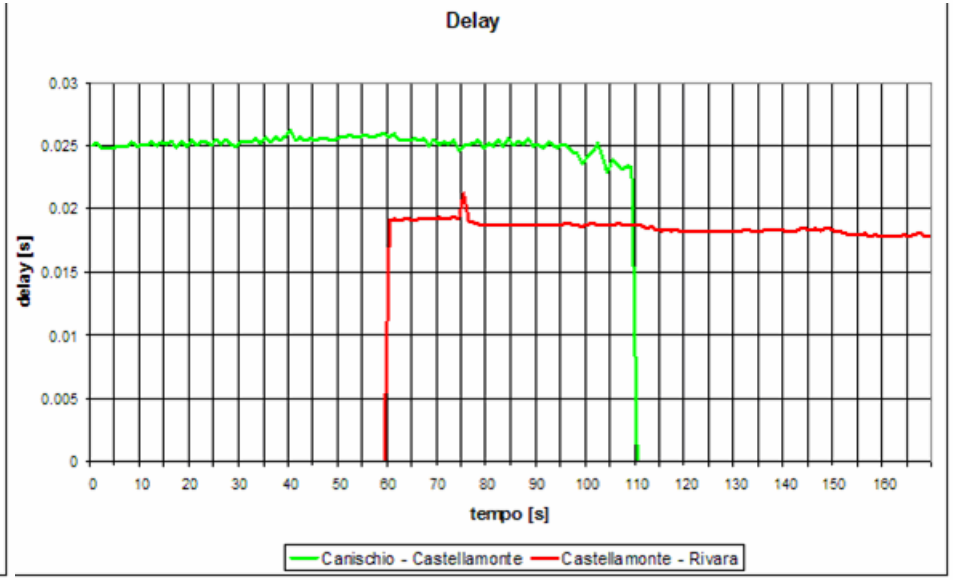


WiMAX: Prestazioni









WiMAX: conclusioni

Funziona!

L'installazione Rapida

Facilità di puntamento in città

Buone prestazione vs "visibilità"

WiMAX: Conclusioni

L'ambito rurale!

Elevato raggio di copertura (> 10 km)

Elevate prestazione

- 5 Mbit/s per link
- Aggregato pari a 11 Mbit/s

Installazione completa di una SS su tetto:

circa mezza giornata (ma con infrastruttura!)

Ottima soluzione per combattere il Digitale Divide

WiMAX: Punti aperti

- Ampio dibattito su quale ruolo possa giocare WiMAX come tecnologia di accesso broadband
- Pro: WiMax come reale alternativa al doppino di rame per connettere case ed imprese ad Internet Mobile nelle reti 4G
- Contro: WiMax come tecnologia di nicchia non in grado di vincere la competizione dei fornitore 3G e ADSL

WiMAX: Punti aperti

- La banda 3.5 GHz poco adatta per applicazioni indoor
- Limite potenza: 3 W, limitata banda
- Lunghezza delle sperimentazioni: annunciata proroga fine 2006
- Che tipo di licenze concedere: regionali o nazionali
- Competizioni con altre tecnologie, in particoalre HSDPA

WiMAX: Opportunità Reali

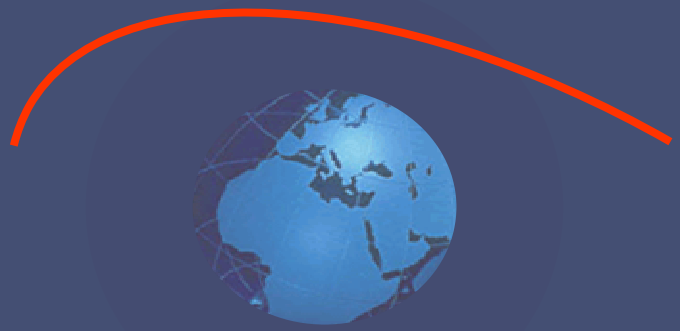
- Distribuzione per aree in cui non sia conveniente arrivare con un backbone wired
- WiMAX come soluzione per l'ultimo Miglio interfacciato a backbone in fibra (Fiber To Base Station)
- Accesso
  - Di sicuro WiMAX è l'alternativa all'ADLS in zone rurali dove l'ADLS non è conveniente
  - Integrazione con AP WiFi
  - Utenza business che richiede più banda

WiMAX: il 4G ?!

Difficile dare una risposta, dipende molto dal regolatore, ma sicuramente la tecnologia (le tecnologie) vincente sara' OFDM e, in prospettiva, MIMO

CREATE-NET

Building the global networked society of the future



www.create-net.it

- **802.16-2004 WiMAX.**

  This is based on the 802.16-2004 version of the IEEE 802.16 standard and on ETSI HiperMAN. It uses Orthogonal Frequency Division Multiplexing (OFDM) and supports fixed and nomadic access in Line of Sight (LOS) and Non Line of Sight (NLOS) environments. Vendors are developing indoor and outdoor Customer Premises Equipment (CPE) and laptop PCMCIA cards. The initial WiMAX Forum profiles are in the 3.5 GHz and 5.8 GHz frequency bands.

- **802.16e WiMAX.**

  Optimized for dynamic mobile radio channels, this version is based on the 802.16e amendment and provides support for handoffs and roaming. It uses Scalable Orthogonal Frequency Division Multiplexing Access (SOFDMA), a multi-carrier modulation technique that uses sub-channelization. Service providers that deploy 802.16e can also use the network to provide fixed service. The WiMAX Forum has not yet announced the frequency bands for the 802.16e profiles, but 2.3 GHz and 2.5 GHz are the most likely initial candidates. Certification is expected to start in the middle of 2006 when the certification labs open, with the first certified products available in the first quarter of 2007.

  IEEE 802.16e offers improved support for Multiple Input Multiple Output (MIMO) and Adaptive Antenna Systems (AAS), as well as hard and soft handoffs.

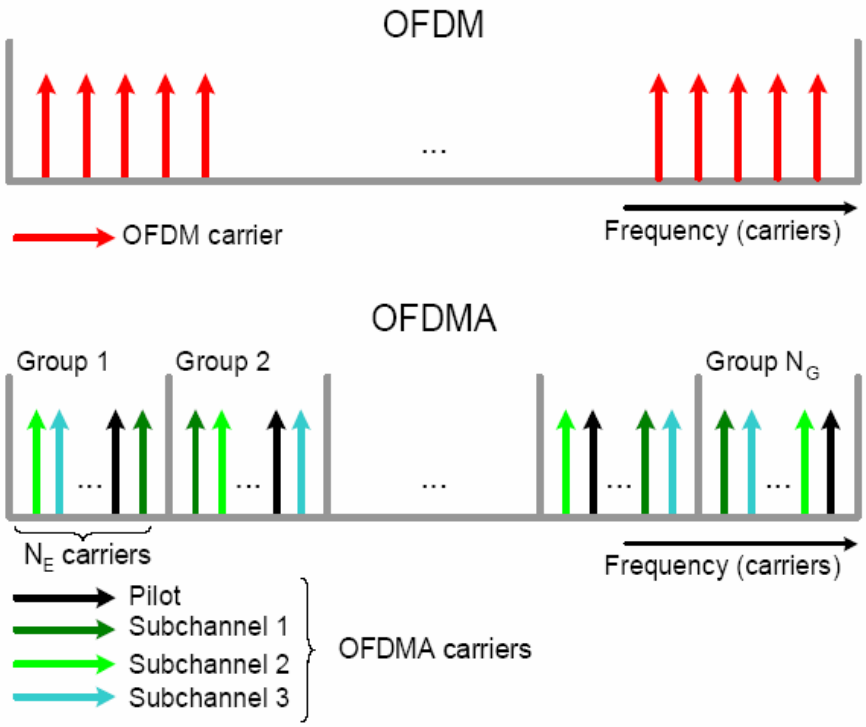
Different 802.16 profiles

Spectrum	Duplexing mode	Channel bandwidth (MHz)	FFT size	IEEE Standard
3400-3600	TDD	3.5	256	806.16-2004
3400-3600	FDD	3.5	256	806.16-2004
3400-3600	TDD	7	256	806.16-2004
3400-3600	FDD	7	256	806.16-2004
5725-5850	TDD	10	256	806.16-2004
2495-2690	TDD	1.25, 5, 10, 20	128, 512, 1024, 2048	802.16e
2495-2690	TDD	4.375	512	802.16e
2495-2690	TDD	8.75, 15	1024	802.16e
2300-2400	TDD	1.25, 5, 10, 20	128, 512, 1024, 2048	802.16e
3300-3600	TDD	3.5	512	802.16e
3300-3600	FDD	3.5	512	802.16e
3300-3600	HFDD	3.5	512	802.16e
3300-3800	TDD	4.375	512	802.16e
3300-3900	TDD	1.25, 5, 10, 20	128, 512, 1024, 2048	802.16e
3300-3900	TDD	7, 10	512, 1024	802.16e
3300-3900	FDD	7, 10	512, 1024	802.16e
3300-3900	HFDD	7, 10	512, 1024	802.16e

OFDM and OFDMA

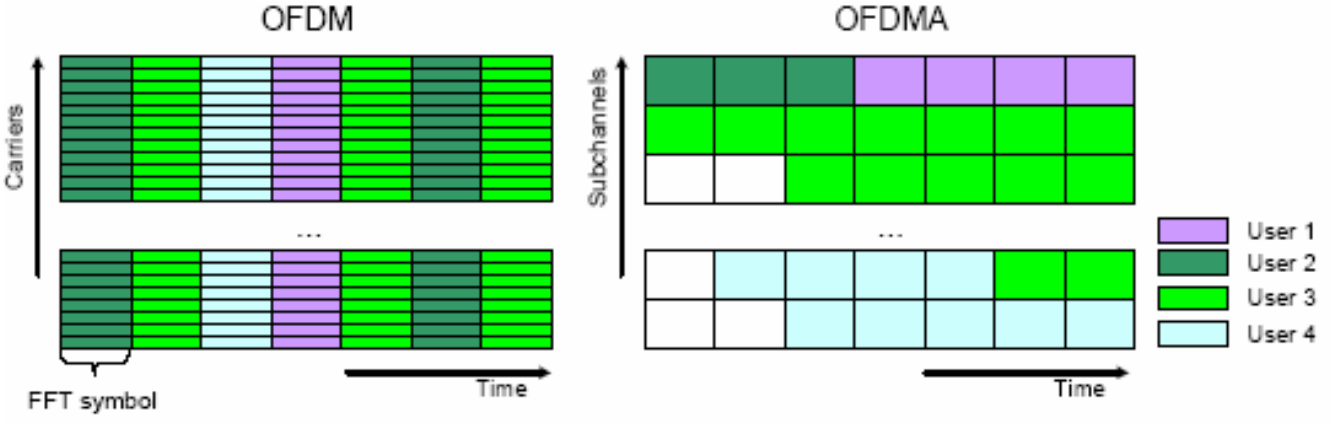
- **802.16-2004** suited to fixed applications that use directional antenna because **OFDM** is inherently less complex. As a result, networks may be deployed faster and at a lower cost.

- **OFDMA** gives **802.16e** profiles more flexibility when managing different user devices with a variety of antenna types and form factors. It brings a reduction in interference for user devices with omnidirectional antennas and improved NLOS capabilities that are essential when supporting mobile subscribers. *Subchannelization* defines subchannels that can be allocated to different subscribers depending on the channel conditions and their data requirements. The number of subcarriers can adjust dynamically for different conditions.



*OFDMA divides the carrier space into **NG** groups, each of which has **NE** carriers, and into NE sub-channels, each with one carrier per group. In OFDMA with 2048 carriers, for instance, this translates in NE=32 and NG= 48 in the downlink, and NE=32 and NG= 53 in the uplink, with the remaining carriers used for guard bands and pilots. Coding, modulation and amplitude are set separately for each sub-channel based on channel conditions to optimize the use of network resources.*

OFDM and SOFDMA



- SOFDMA (Scalable OFDM Access) can assign a subset of subcarriers to individual users. By using different subcarriers multiple people can connect at the same time on the same frequency without interference. The number of subcarriers can adjust dynamically for different conditions.

Modulation and coding schemes 802.16d.

Rate ID	Modulation rate	Coding	Information bits/symbol	Information bits/ OFDM symbol	Peak data rate in 5 MHz (Mb/s)
0	BPSK	1/2	0.5	88	1.89
1	QPSK	1/2	1	184	3.95
2	QPSK	3/4	1.5	280	6.00
3	16QAM	1/2	2	376	8.06
4	16QAM	3/4	3	568	12.18
5	64QAM	2/3	4	760	16.30
6	64QAM	3/4	4.5	856	18.36

PHYSICAL LAYER SUMMARY

Designation	Applicability	MAC	Duplexing
WirelessMAN-SC	10-66Ghz Licensed	Basic	TDD, FDD, HFDD
	2-11Ghz Licensed	Basic, ARQ, STC, AAS	TDD, FDD
WirelessMAN-OFDM	2-11Ghz Licensed	Basic, ARQ, STC, AAS	TDD, FDD
	2-11Ghz License-exempt	Basic, ARQ, STC, DFS, MSH, AAS	TDD
WirelessMAN-OFDMA	2-11Ghz Licensed	Basic, ARQ, STC, AAS	TDD, FDD
	2-11Ghz License-exempt	Basic, ARQ, STC, DFS, MSH, AAS	TDD

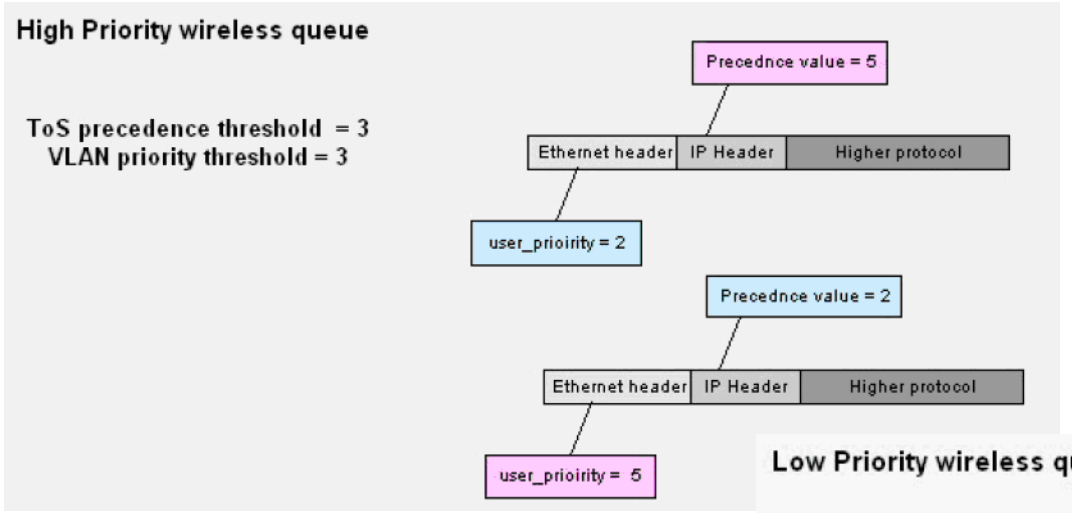
AAS - Adaptive Antenna System
MSH - Mesh Network.
DFS - Dynamic Frequency Selection.

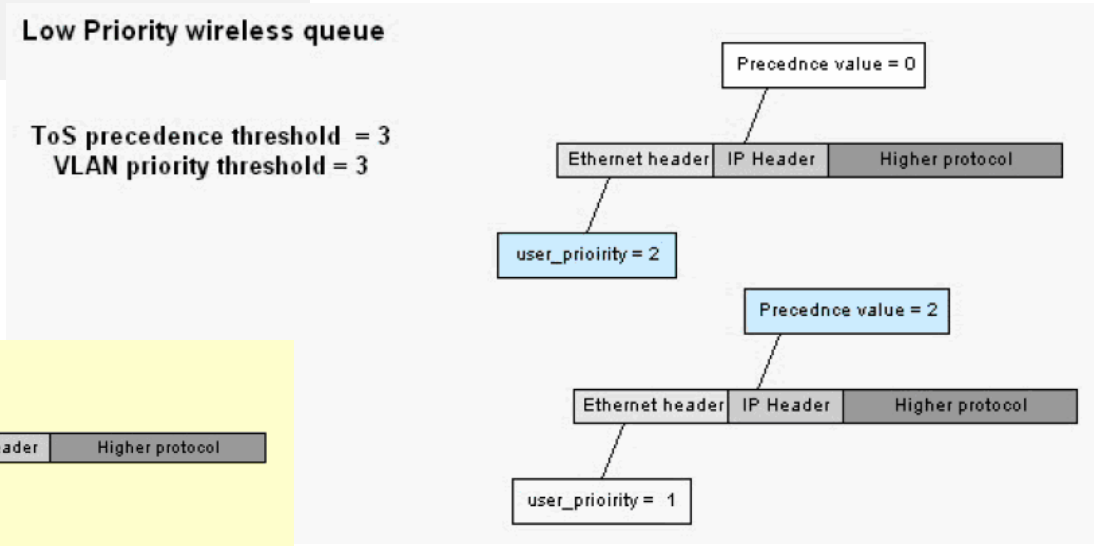
Standard 802.16 - WiMAX

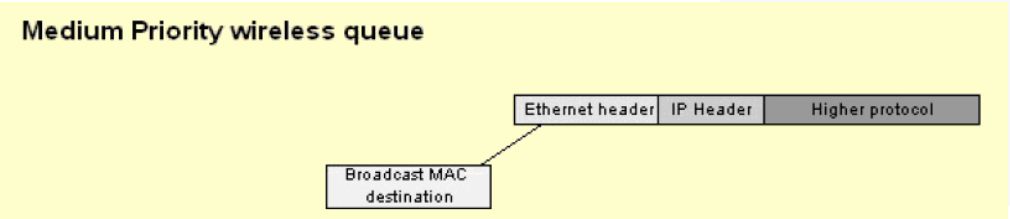
Definition	Devices	Locations/ Speed	Handoffs	802.16-2004	802.16e
Fixed access	Outdoor and indoor CPEs	Single/ Stationary	No	Yes	Yes
Nomadic access	Indoor CPEs, PCMCIA cards	Multiple/ Stationary	No	Yes	Yes
Portability	Laptop PCMCIA or mini cards	Multiple/ Walking speed	Hard handoffs	No	Yes
Simple mobility	Laptop PCMCIA or mini cards, PDAs or smartphones	Multiple/ Low vehicular speed	Hard handoffs	No	Yes
Full mobility	Laptop PCMCIA or mini cards, PDAs or smartphones	Multiple/ High vehicular speed	Soft handoffs	No	Yes

- 802.16-2004 is fixed access
- 802.16e optimized for mobile access (vehicular speeds)

Precedenza nel sistema Alvarion (II)







- Adding subchannelization, and the two key smart antenna methods favored by the WiMAX Forum - MIMO and AAS or beam forming - could increase coverage from two to nine kilometres radius for an urban base station with mobile support, a 20-fold increase in subscriber capacity. The WiMAX Forum has not announced the key spectrum profiles for 802.16e yet but the first are likely to be 2.5GHz and 2.3GHz because these are where the largest planned networks - those of Sprint Nextel in the US and Korea Telecom and SKT in Korea, will be.

		Standard	Full-Featured
Cell Radius	LOS	10-16 km	30-50 km
	NLOS	1-2 km	4-9 km
	Indoor Self-Install CPE	0.3-0.5 km	1-2 km
Max Throughput per 60 °Sector	Downlink	11.3-8 Mbps	11.3-8 Mbps
	Uplink	11.3-8 Mbps	11.3-8 Mbps
Max Throughput per CPE at Cell Edge	Downlink	11.3-2.8 Mbps	11.3-2.8 Mbps
	Uplink	11.3-2.8 Mbps	0.7-0.175* Mbps
Maximum # Subscribers		Less	More

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WirelessMAN-OFDMA	2-11Ghz Licensed	Basic, ARQ, STC, AAS	TDD, FDD
	2-11Ghz License-exempt	Basic, ARQ, STC, DFS, MSH, AAS	TDD

AAS - Adaptive Antenna System
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SCHEDULING TYPES AND QOS

Scheduling Type	QoS
Unsolicited Grant Service (UGS)	Max Sustained Traffic Rate, Maximum Latency, Tolerated Jitter
Real-Time Polling Service (rtPS)	Max Sustained Traffic Rate, Min Reserved Traffic Rate, Committed Burst Size, Maximum Latency, etc
Non-real-time Polling Service (nrtPS)	Committed Information Rate, Maximum Information Rate
Best Effort (BE)	Maximum Information Rate