Experimental Analysis of the Sensitivity to Interferences in Geographical Unlicensed Wireless Networks

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Abstract

Local, and Metropolitan Wireless Networks are often used to provide basic connectivity services, especially in areas where wired solutions are not yet implemented or not applicable. Unlicensed wireless networks have attracted a large interest, thanks to their low realization cost, with several limitations caused by regulatory, power restrictions and the presence of interferences. The paper analyses the possibility to increase the insensitivity to interferences by introducing new constraints on the antenna pattern and adopting transmission diversity techniques. To this purpose, a network has been designed and realized, providing coverage to a wide rural area in the hills of Piedmont, a region located in North-Western Italy. Once constructed, the network performance has been monitored and characterized, in terms of coverage capabilities, signal quality, data delivery throughput, and noise immunity.

1. Introduction

Wireless networks have been largely used to overcome digital gaps all over the World [1]. Satellite connections, Third Generation (3G) mobile networks, (Wi-Max) licensed systems and Wi-Fi unlicensed networks have been implemented to provide adequate connectivity in remote and isolated places.

Among all solutions, satellites have been considered to provide wideband connectivity: in principle, by satellite communication, any remote place in the world can be reached, and intermediate repeaters are not needed. However, satellite bandwidth is very expensive, real time services are often affected by latency, and X-band propagation suffers environmental diseases and negative weather conditions. For all these reasons, satellites represent an excellent mean to provide low bandwidth connectivity to the most isolated places in the world [2].

3G is considered a valid alternative to satellite for providing connectivity in rural places as mobile networks are spread all over the world, also in Developing Countries. Unfortunately, 3G access is much more expensive than other forms of bandwidth provisioning; moreover, in rural regions cellular base stations (BSs) are spread over large areas, cells have huge dimensions and the quality of the connection suffers of lack of signals and interference [3].

Licensed Wireless Metropolitan Access Networks (WMANs) represent nowadays the best and more reliable way to provide wideband connectivity to rural areas, with lower costs for end-users and better insensitivity to the interference. At the moment, the most implemented solution is represented by Wi-Max, especially in rural regions of Developed Countries, since it is still too expensive in the Developing ones. The coverage capabilities are limited by interference also in this case, even if less than in the case of 3G networks.

Unlicensed WMANs, derived by the Wireless Local Access Network (WLAN) standards IEEE 802.11x, represent an adequate alternative, particularly for Developing Regions. This solution is also implemented in rural regions of Developed Countries; however, the interference can dramatically limit coverage capabilities and bandwidth provisioning [4].

A new incoming standard for the construction of Wireless Regional Access Networks (WRAN) is being approved: it will use both licensed and unlicensed frequencies in the part of UHF bandwidth no more used after the switch-off from analogue to digital TV broadcasting. The utilization of lower frequencies will allow the coverage of huger areas respect to WMANs, but it will require to the system a stronger insensitivity to interferences [5].

2 Antenna directivity and diversity

All listed system (but the satellite one) are affected by interferences, so different implementations of the physical layer can be designed to reduce such negative impact in order to improve the network performance. In particular, network systems working in unlicensed frequency bands are even more sensible to interferences, because of

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the possible coexistence of several systems in the same scenario and the radiated power limitation that intrinsically characterizes the system.

To improve the insensibility to interferences, the paper takes into account two possible actions that could be transformed in improvements to spectrum regulatory. The first one is relate to the use of antenna with improved directivity and extended power limitations as a function of the angular direction. The second one takes into account the possibility to adopt diversity transmission schemes to dynamically improve the receiver insensitivity to the noise.

Last generation transmitting systems, including Multiple Input Multiple Output (MIMO) ones, implement the concept of diversity for the realization of the physical channel between the transmitter and the receiver, thanks to the use of more than one antenna at both sides of the link [6]. The last mobile and networking standards take into account the use of diversity, at least at one side of the channel. Time diversity may increase significantly the performance of the link, but normally it requires a huge bandwidth. For this reason, its application is limited to Wireless Personal Area Networks (WPAN), mainly for Ultrawideband connections [7]. Spatial diversity needs antennas separation and thus, space is required also on the client-side, and this is not easy to accomplish within Client Premise Equipments (CPEs). Polarization diversity, instead, can be implemented without increasing the space: antennas with double polarizations can be realized within the same radome, not modifying the overall dimensions of the system.

3. The experiment

The wireless network has been realized in the Monferrato region, an area in North-Western Italy, not far from the city of Torino. This area is mainly agricultural, with vineyards, apple and nut trees fields mixed to small forests. Only small villages are present, population density is low, and houses are almost uniformly scattered over the territory. As a real case, the Municipality of Verrua Savoia has been selected.

Verrua Savoia is located in a hilly area, on the plain border; it covers a territory of about 16 square kilometers, where about 1400 inhabitants live, with half of the population aging more than sixty-five years old. Only one factory, three small shops, two restaurants and one bar are present; the economy is mainly agricultural, for ninety percent devoted to family needs. As a business case, for telecom companies, the Municipality is a losing affair: for long times, no wideband connectivity has been provided to the inhabitants.

Topographically, the Municipality area is very appropriate to develop a wireless network. Fig.1 shows the orographic profile of the area, together with the urbanization density and the scattering of the houses.

An accurate study has been done before realizing the network to analyze the presence of interferences on the unlicensed Hiperlan frequencies: as expected, in all the territory of Verrua Savoia, but especially in the region border on the plain, the exposure to interferences was very strong. Therefore, our group decided to implement the network using diversity; 5GHz 802.11n standard has been chosen, with both base stations (BSs) and client premise equipments (CPE)s working with double polarization antennas.

Fig.1 shows also the network topology: red lines represent the P2P radio-links (backhaul) with high directivity, that connect the BSs. The coverage of the 95% of the municipality territory is guaranteed by 4 Hiperlan BSs, placed in strategic positions. In particular, one BS was placed in the top of a hill, where the equipment feeding is provided by solar panels. Each BS uses sector antennas to improve the coverage of the territory and to have a less interference exposition with respect to omnidirectional antennas; each BS is composed by 2 Point-to-Multipoint (P2MP) radio-link, but BS1 realized with 3 P2MP radio-links, as shown by yellow lines in Fig.2.

The network connectivity has been offered for free, in order to be able to involve a huge number of inhabitants. In fact, the analysis and study of the performance of the connection is more consistent and effective in presence of high level of network traffic. The bandwidth is taken from a distribution point placed in a city 35Km far from Verrua Savoia and transferred to the municipality by means of a radio-link.

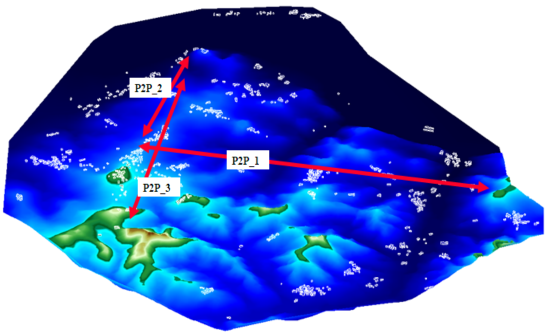

Figure 1: Orographic profile of Verrua Savoia Municipality and network topology.

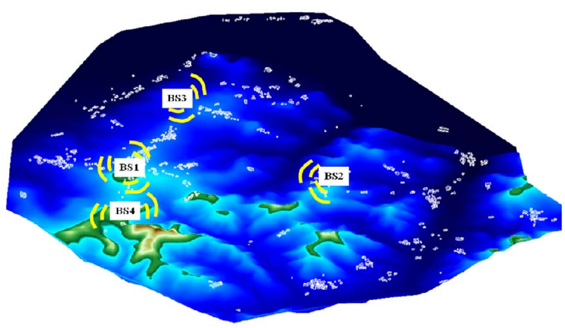

Figure 2: Network P2MP links for each BS, realized by sector antennas.

The network is realized in order to be more insensible to the interferences: for this purpose the radio-links antennas work on polarization diversity. In addition, it has been decided to use sector (and not omnidirectional) antennas, with high directivity only on vertical plane, for the P2MP links, reducing of 10dB the irradiated power on the horizontal plane. It has been imposed to work at 7dBm/MHz instead of the maximum value (17dBm/MHz). Realizing a network not irradiating (receiving) on the horizontal plane permits P2MPs to not disturb each other and to be more insensible to interferers that usually are far, hence from horizon. P2P links, instead, are high directive (at least 20dB on both horizontal and vertical plane), therefore more robust to interferences, and they work only on polarization diversity.

4. Performance monitoring and results

The evaluation of the network performance has been carried out by means of the analysis, for each BS, of the number of active BSs (possible cause of interferences and, consequently, of the data rate limitation), the minimum registration level of the users CPEs and by the measure of throughput and ping time on each radio link to the BSs and on any link between the BSs and the CPEs.

Table I shows the number of active BSs, measured in the 4 BSs of our network and the average value of the interferers, both for omnidirectional and sector antennas. For each P2MP of the network we have scanned the spectrum for 3 values of channel width: 5MHz, 10MHz and 20MHz. In the second and third case, are present interferers. In Fig. 3 are reported screenshots of the scan operation.

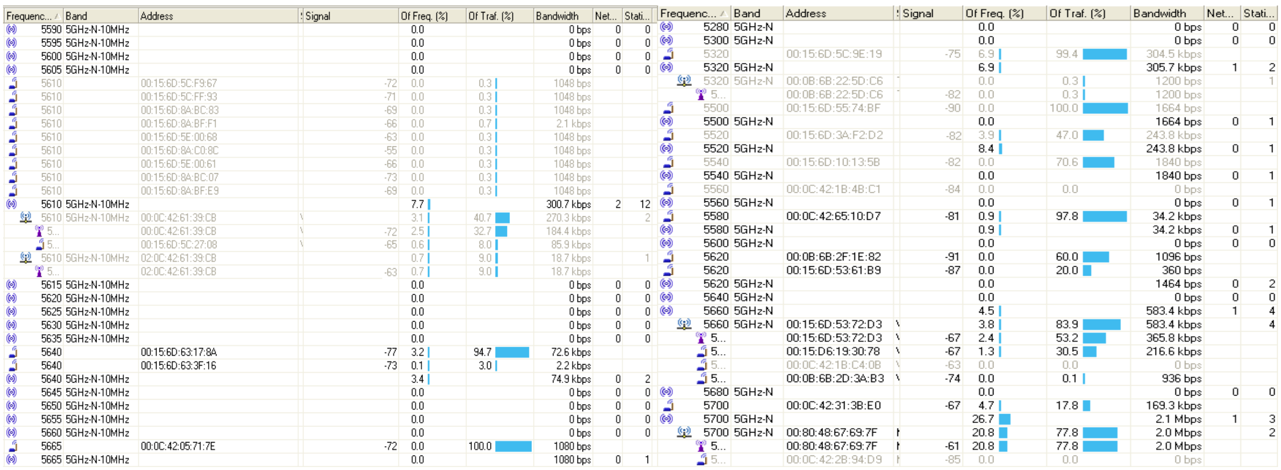

Figure 3: Screenshot of the scan operation. A high number of interferes is present.

BASE STATION	NUMBER OF INTERFERERS BSs							
	5MHz	SECTOR [dBm]	10 MHz	OMNI [dBm]	SECTOR [dBm]	20MHz	OMNI [dBm]	SECTOR [dBm]
BS1_P2MP1	0	-	14	-57	-76	12	-58	-72
BS1_P2MP2	0	-	14	-61	-78	16	-56	-72
BS1_P2MP3	0	-	33	-62	-79	15	-59	-71
BS2_P2MP1	0	-	4	-71	-80	14	-61	-73
BS2_P2MP2	0	-	3	-68	-79	16	-59	-71
BS3_P2MP1	0	-	7	-70	-81	67	-62	-76
BS3_P2MP2	0	-	9	-72	-83	55	-59	-72
BS4_P2MP1	0	-	2	-68	-80	13	-60	-73
BS4_P2MP2	0	-	2	-66	-78	11	-61	-75

Table I: number and registration value of interferers for each BS of the network, comparing omnidirectional and sector antennas

Table II refers to the CPEs registration value for each BSs. It has been calculated as the average of the registration value of all the CPEs connected on each BS. The signal strength is very high even if are present other active BSs than can cause interference problems.

	Average CPE Registration value [dBm]	Tilt [deg]
BS1_P2MP1	-51.76	6
BS1_P2MP2	-56.47	2
BS1_P2MP3	-	4
BS2_P2MP1	-58.44	4
BS2_P2MP2	-56.81	5
BS3_P2MP1	-62.5	5
BS3_P2MP2	-60.57	4
BS4_P2MP1	-63.21	3
BS4_P2MP2	-58.92	2

Table II: average CPEs registration value and antenna tilt for each BS antenna

	Throughput DL/UL [Mbit/s]	Ping time [ms]
P2P_1	42/85	1.5
P2P_2	22/7	1
P2P_3	34/8	1
CPEs (average)	22/8	1

Table III: throughput and ping time on radio links

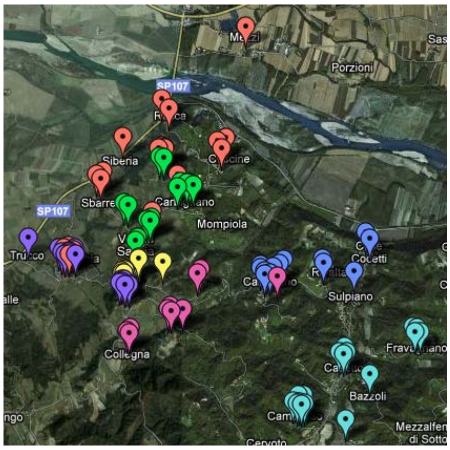

Figure 4: Distribution of the connected users

In table III, the throughput of each radio link to the BSs and the throughput of the links connecting CPEs to BSs are reported. Also in this case, even in presence of interference, the network performance are very high, and also the links connecting the users CPEs have an high bandwidth availability (calculated as the average throughput for all the CPEs in the network).

At the moment, the number of connected users is equal to 131. The users are almost uniformly spread in all the four network BSs (Fig. 4). For each user CPEs at least 21Mbit/s are available, full duplex; usually, during the evening and the weekend, the total network traffic grows from some Mbit/s up to 20Mbit/s without any problem of disconnection or latency.

5. Conclusion

This paper has presented the analysis of the performance of an unlicensed wireless network whose performance is increased by enhancing antenna directivity and imposing the use of transmission polarization diversity. The data show that, even in presence on a high number of interferers, the connection quality and stability are significantly improved. For this reason, two actions are suggested. One is represented by the adoption of regulatory rules that enforce enhanced radiated power limitation towards the horizon for P2MP antennas. The second is represented by the use of polarization diversity techniques. Both this actions would greatly benefit the realization of geographical unlicensed wireless networks on the territory.

6. References

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