# Performance of Low Cost Radios in the Implementation of Long Distance Wireless Links

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## Abstract

Low cost digital radios are emerging as an efficient resource for the realization of long distance (multikilometric) point-to-point telecommunication infrastructures in underdeveloped and Third World Countries. To analyze the performance of these architectures, we realized several LOS wireless links ranging from 50 to 300 kilometers. The links were based on the use of commercial IEEE802.11a/h radios. For the purpose of the research, an open source control software implementing significant modifications to the MAC layer of the standard was implemented. Experimental results show excellent performance and stability, even when the link ranges more than 100 km

## 1. Introduction

Nowadays the realization of telecommunication infrastructures in underdeveloped and Third World countries is considered a major need, together with water, food and other primary goods supply [1]. Typically, regions with low housing density and bad transport connectivity cannot provide adequate health assistance and schooling to their inhabitants, being exposed, as a consequence, to emigration and decline. IP based intra-connectivity represents an efficient way to establish basic vital services like telemedicine and distance learning, together with the possibility to deliver low cost IP extranet services (VOIP, internet provisioning, access to centralized Administrative databases).

In several countries there is not a commercial interest for the realization of IP communication infrastructures. For this reason, it is fundamental to identify adequate inexpensive solutions. To date, the most convenient one is represented by the exploitation of radio links based on low cost wireless architectures [2]; this solution does not require huge investments like the one needed to construct underground wired networks. For this purpose, the key point is the identification of a suitable solution for the realization of high capacity and low cost point to point links. Some authors are experimenting links based on the WiFi standard IEEE 802.11, introducing major Layer 2 modifications that allow the optimization of these radios for point to point links [3], [4], [5].

Recently, our research group has been working on the manufacture and realization of transmitters obtained by assembling IEEE 802.11a and IEEE 802.11h radios into obsolete PC architectures [5]. The transmitters were specifically designed for the realization of MultiKiloMetric (MKM) radio links, a MKM link being defined as a point to point bidirectional radio connection ranging from 50 km to 300 km. Preliminary results showed stability, reliability and good performances. For this reason, we realized a MKM experimental network with hops in Northern Italy, Switzerland and Austria, to measure capabilities and limitations of the system configuration over longer periods.

## 2. Transmitter design

The first step of the design is the choice of the radio. At the moment IEEE 802.16 protocol based radios are too expensive to be implemented in low cost MKM links. For this reason we took into account only IEEE 802.11 protocol based radios. Different commercial solutions, together with personalized hardware implementation assembled in our Labs, were tested. Concerning the modulation chipset, an optimum performance can be obtained by use of Atheros components. Software drivers are available within open source distribution packages like MadWiFi and OpenHal. Some commercial radios based on Atheros chipsets show an excellent performance, even if they can be bought with very low cost budgets, especially in terms of radio sensitivity. As an example, the radio we have manufactured exhibits -71 dBm sensitivity for a 54 Mb/s Layer 1 Data Rate, -89 dBm sensitivity for a 6 Mb/s Layer 1 Data Rate. Some commercial components guarantee data transfer even when the signal is as lower as -94 dBm.

All radios were mounted on mini-PCI cards inserted on PC or nanoPC platforms. As operative system we used a dedicated linux distribution; the radio was controlled through a specifically designed software, able to control and manipulate Layer 1 and Layer 2 parameters of the communication. Fig. 1.a shows and example of transmitter setup, while Fig. 1.b shows a printout of the graphical interface of the radio-controlling software.

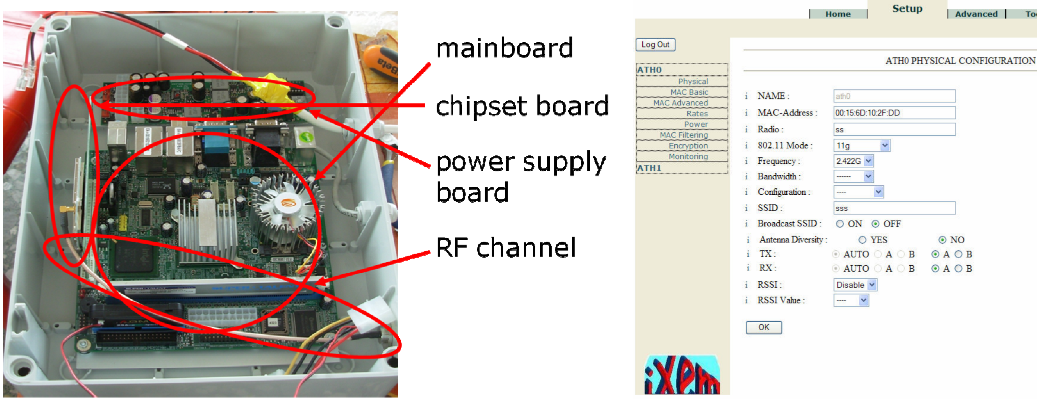


Fig.1. (a): example of realization; (b): printout from the software console

The modifications introduced on the Layer 2 are mainly related with timing management of the protocol. As a result, the transmission setup is not coherent with the default IEEE 802.11 standard, even if this situation does not represent a limitation for the realization of dedicated point to point links.

To increase the Data Rate of the system, the transmitter platform was designed to host up to four radios. The radios are connected to a single antenna by means of waveguide frequency multiplexers. Data transmission is managed by exploiting the bonding capabilities of the operative system and splitting the incoming/outgoing data stream over the bonded channels. All multiplexers were designed and manufactured within our Labs.

## 3. MKM Network

To test the performance of the transmitters, a MKM network was designed and implemented. The network is formed by 9 links between hops deployed in 9 different locations. Hop location was chosen to be representative of different environment conditions: urban, rural, hill or high mountain sites. Tab.1 shows hops position and characteristic, Tab.2 illustrates link characteristics. As one can observe, hops position were chosen to be representative of a sufficient variety of locations; link clearance (calculated for the band 5.5-5.7 GHz) varies from poor to excellent conditions and link length belongs to a range between 50 and 300 km.

| Hop | Location | Country | Environment | Height a.s.l. [m] |
|---|---|---|---|---|
| 1 | Politecnico di Torino, Torino | Italy | urban – flat | 255.0 |
| 2 | Verrua Savoia, Italy | Italy | rural - hill | 290.0 |
| 3 | Capanna Margherita, Monte Rosa | Italy | high mountain | 4556.0 |
| 4 | Passo dei Salati, Alagna Valsesia | Italy | mountain | 2936.0 |
| 5 | Pian Cavallaro, Cimone | Italy | Mountain | 1860.0 |
| 6 | Arcello, Pianello Val Tidone | Italy | rural - hill | 328.0 |
| 7 | Valluga Berg Station, Sankt Anton am Arlberg | Austria | mountain | 2810.0 |
| 8 | Corvatsch Berg Station, St. Moritz | Switzerland | mountain | 3270.0 |
| 9 | Weissflugipf Berg Station, Davos | Switzerland | mountain | 2810.0 |

Tab.1. MKM hopes location and characteristics

| Link | Start | End | Clearance | Length [km] |
|---|---|---|---|---|
| 1 | Verrua Savoia | Capanna Margherita | Excellent | 88.95 |
| 2 | Politecnico di Torino | Capanna Margherita | Excellent | 97.70 |
| 3 | Verrua Savoia | Passo dei Salati | Sufficient | 80.13 |
| 4 | Passo dei Salati | Corvatsch Berg Station | Excellent | 162.35 |
| 5 | Capanna Margherita | Pian Cavallaro | Excellent | 295.16 |
| 6 | Capanna Margherita | Valluga Berg Station | Sufficient | 227.51 |
| 7 | Passo dei Salati | Arcello | Excellent | 161.39 |
| 8 | Corvatsch Berg Station | Weissflugipf Berg Station | Good | 47.50 |
| 9 | Weissflugipf Berg Station | Valluga Berg Station | Good | 47.88 |

Tab.2. MKM links under test

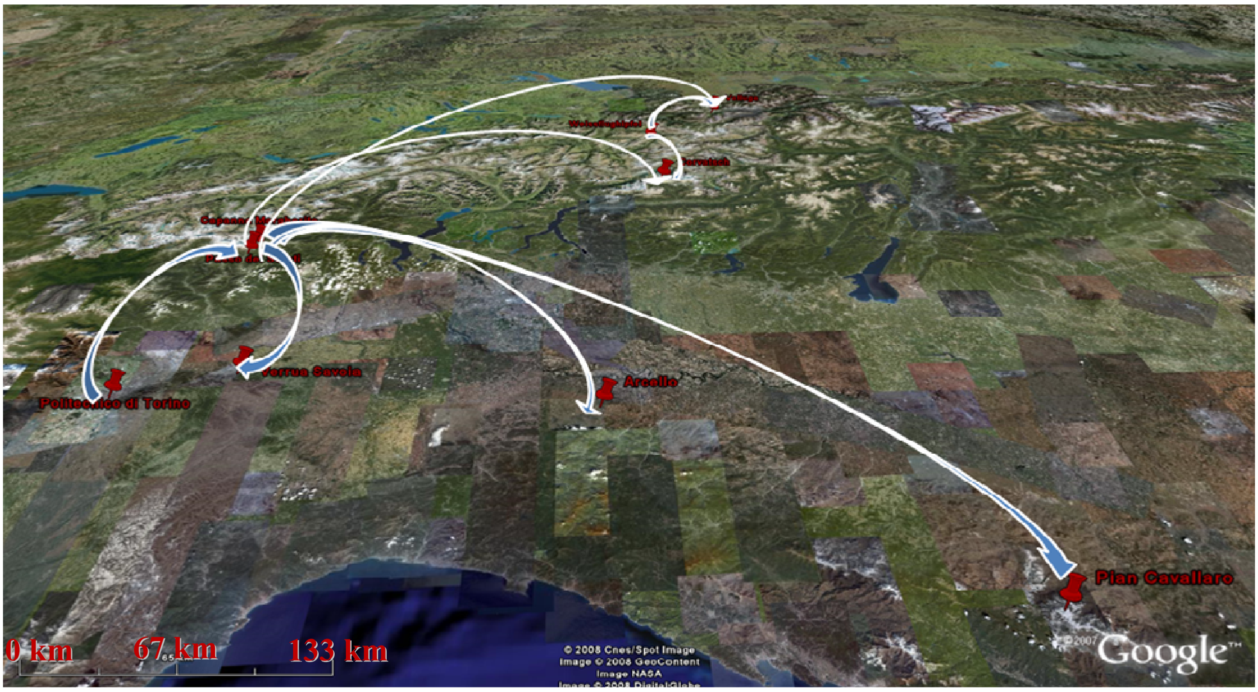

Fig.2. MKM network

All the links were designed to work in the Hiperlan Type 2 European bandwidth (from 5.49 to 5.71 GHz). This frequency range is available for scientific experimentations if effective isotropic radiated power (EIRP) is limited within 30 dBm. Regulatory limits were strictly applied to all links. Every point to point link was realized by means of a transmitter mounting one or more radios, connected to commercial antennas manufactured by Andrew (model No. P4F-52-NXA); to interconnect the transmitter (or the multiplexer) and the antenna low losses RF cables were used (Andrew model No. HELIAX LDF4-50A).

Fig. 2 shows a tridimensional representation of the MKM network, obtained with Google Earth. Hops are represented by red labels, links by white/blue arrows. It is possible to appreciate the complexity of the network and generality of the system. Fig.3 shows some radio path printouts.

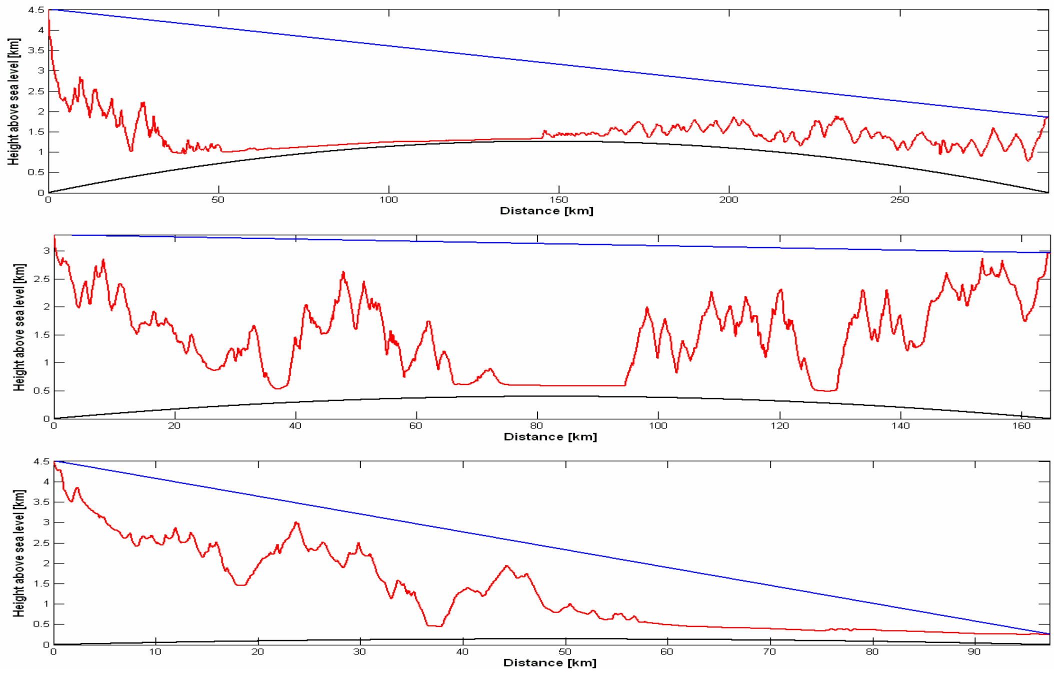

Fig.2. MKM links: (a): link No. 5, (b): link No.2, (c): link No. 4

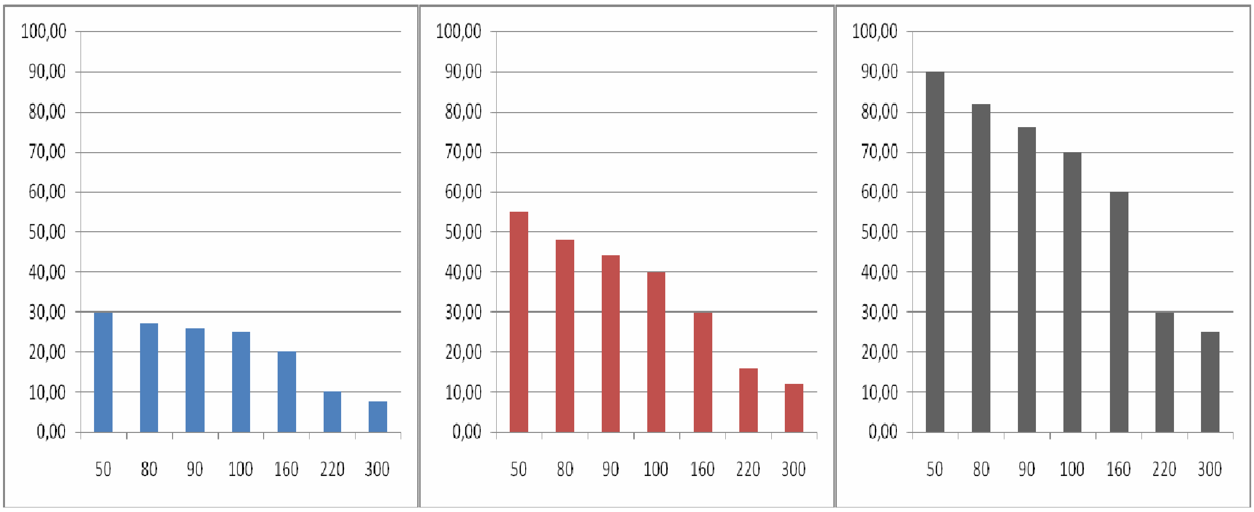


Fig.4. Real throughput [Mb/s] measured on different hops distance
(a): single radio, (b): two bonded radios , (c): four bonded radios

## 4. Test results

Once the MKM network was setup and configured, the links were activated and kept under constant monitoring. Fig.4 shows the average throughput we measured on the links over an aboservation period of one week per link. It is possible to appreciate the optimum performance of the system, that confirms the possibility to implement it for real applications. The real throughput performance ranges up to the 65% of the maximum Data Rate at Layer 1.

All the links were satisfactorily stable and sufficiently indipendent from weather and environment conditions. Only the links hosted at Capanna Margherita, at 4556 metres above sea level, on the top of Monte Rosa, the second tollest mountain of Europe, suffered occasional disconnections. To analyse possible correlations with weather variations, since this location is exposed to hostile variable and localised weather conditions, a meteo unit was mounted in the surroundings of the transmitter. A detailed analysis will be presented in next publications.

## 5. Acknowledgments

The work was supported by Andrew srl and receive the patronage of the President of the Piedmont Region Administration Council .

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