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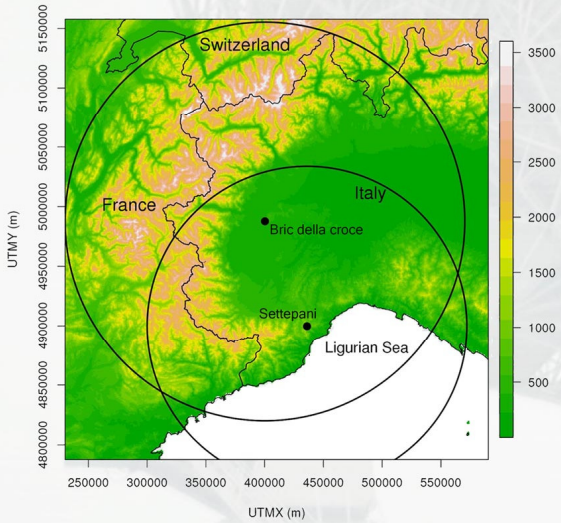
Network connectivity paradigm for the large data produced by weather radar systems

Introduction

Traffic over Internet is constantly increasing due in particular to the enormous exchange of data caused by the so called Internet of things. In these terms, in geosciences there is a growth in number of sensors that are used to obtain data from different sources. This information gathering activity, frequently, must be followed by a complex data analysis, especially when we have large data sets, like the big data. These activities are particularly intensive in resource consumption and they lead to new computational models (like cloud computing) and new methods for storing data, very different from traditional relational databases (like object store, linked open data, NOSQL or NewSQL).

The weather radar systems can be seen as one of the aforementioned sensors: they transmit a large amount of raw data over the network, with 24h/24h continuity and in any weather condition. Weather radars are often located in digital divide areas and, for this reason, radar measurements are sometimes processed partially on site and reduced in size to adapt them to the limited bandwidth currently available in those zones. With the aim to preserve the maximum flow of information, a new network connectivity paradigm for the data produced by weather radar system is presented here. The study is focused on the case of Monte Settepani's operational weather radar system, located over a wild peak summit in north-western Italy.



Expected results and objectives

The availability of the whole information produced by the weather radar and the robustness of the communication system will enable the realization of new computing processes that could improve the estimations of precipitation and the short-term prediction of extreme events. In addition, new storage technologies will be applied to the system to increase its performance and reliability. Further, the interpretation of evolutionary scenarios of extreme events in specific areas of study will allow the indirect assessment of social-economic impacts of these situations, thus allowing to develop preventive strategies of intervention in case of natural disasters. The research will outline innovative technological solutions applicable at national level. So, the final outcome will be a test in real environment of a treatment method of data collected by the weather radar, which may represent a replicable framework, employable in contexts of research and surveillance similar to the case of Monte Settepani.

Methodology

To estimate the necessary bandwidth to tranfer the complete radar information we are using this formula:

$$Bandwidth(bps) = \frac{\frac{360^\circ}{\theta} \cdot h \cdot b \cdot (vB + 2 \cdot vBB) \cdot 8}{t}$$

where θ is the angle of rotation of the antenna, h is the number of elevation, b the number of range bins, vB is the number of acquired variables of 1 byte, vBB is the number of acquired variables of 2 byte and t is the time (in seconds) used by the radar to complete a single scan.

To strengthen the communication system and to create a reusable and general purpose model, we are investigating the current state of the art in communication technologies, trying to find best solutions for site conditions like the ones in Monte Settepani. It's important to take in consideration local existing communication links to avoid additional costs and evaluate the adoption of advanced networking models like overlay networks, SDN and Openflow.

Currently, we are considering mainly satellite communications, WiMax, IEEE 802.11 a/h (Hiperlan), DMR, Tetra, xDSL, optical fiber, 3G and 4G. It's our interest to adopt a fault tolerant method of connection, using multiple communication channels and trying to have a sufficient bandwidth to send the whole piece of information, eventually compressed with a lossless algorithm.

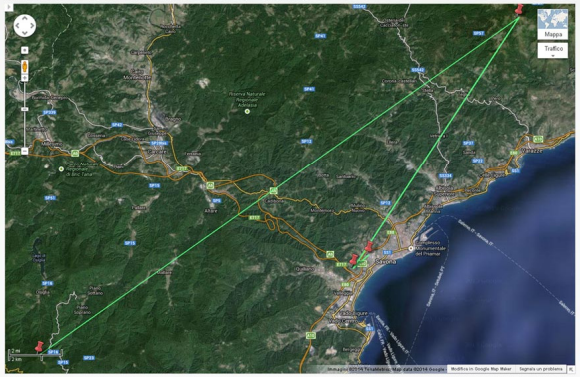
Summarizing, we have to take in consideration a lot of elements like:

- geo-localization of the site;
- characteristics of the area (i.e.: protected areas);
- possibility of infrastructure reuse;
- telecommunication services already offered on site;
- local geo-morphology;
- distance from urban areas or POPs;
- distance from data centre where data will be processed;
- number of necessary "hop";
- mobile operator coverage;
- signal degradation in particular weather conditions (liquid/solid precipitation, fog, lightning…);
- connection capabilities (i.e.: broadcasting, multicasting…);
- asymmetrical bandwidth and configurability (upload vs download);
- available bandwidth and bandwidth caps (like FAP);
- latency and QoS;
- availability of the connection;
- security of the communication;
- licensing;
- costs (capex and opex);
- …

The Piedmont test case

The weather radar system of Monte Settepani (near Savona, at 1 873 m a.s.l.) is supporting the activities of ARPA Piemonte in the control and the monitoring of hydrological and meteorological risks in Piedmont and Liguria.

In Monte Settepani's case, the application of the previous formula lead us to a real bandwidth of 500 Kbps in the uncompressed case and, in case of data compression, to a estimated bandwidth of 165 Kbps (obtained from statistical data: compressed data is about 1/3 of original dimension). Nowadays, weather radar information is partially processed on site and it is reduced in size to be adapted to the limited bandwidth available on the dedicated satellite link (nominal 200 Kbps in Ku band). Unfortunately, sometimes this link can suffer from service interruptions or signal degradations due to the sun alignment (twice per year), due to heavy precipitations or due to antenna icing during severe winter storms. To avoid these problems, in our communication technologies scouting, we are watching especially on the reuse of existing infrastructures (to limit costs) and, in particular, on radio links in frequencies under 10 GHz, to avoid strong signal attenuation due to weather interactions (rain fade).



Monte Settepani's radar could be connected to the existing research network called HPWNet. HPWNet is a modular "hybrid" network (composed by both wireless links and optical fiber) developed by CSP - Innovazione nelle ICT since 2005. The project started with two aims: to develop a wireless backbone in the urban area of Turin, which can be used for the rapid activation of wireless nodes in the city and as a point of departure for extensions towards neighboring municipalities. Wireless link are primarily based on IEEE 802.11 a/h standards (mainly on 5 GHz band but also on 2.4 GHz, 17 GHz and 24 GHz where it is necessary to avoid interference with other existing signals), utilizing devices from several different vendors.

Band	Frequency	Connections
HF	3 - 30 MHz	Radio link
VHF	30 - 300 MHz	Radio link
UHF	300 - 1000 MHz	Tetra/DMR, satellite (P band)
L	1 – 2 GHz	2G (GPRS), 3G (EDGE, HSDPA, UMTS), 4G (LTE), satellite
S	2 – 4 GHz	Radio link
C	4 – 8 GHz	Radio link, satellite, weather radar
X	8 – 12 GHz	Radio link, weather radar
K_u	12 – 18 GHz	Radio link, satellite
K	18 – 26 GHz	Radio link, weather radar
K_a	26 – 40 GHz	Radio link, satellite
V	40 – 75 GHz	Radio link
W	75 – 111 GHz	Radio link, military radar

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