THE TRANSMISSION OF GNSS DATA IN THE DISTART NETWORK FOR REAL TIME KINEMATIC POSITIONING

Maurizio BARBARELLA, Alessandro BEDIN, Stefano GANDOLFI

DISTART – Topografia – Faculty of Engineering, University of Bologna
viale Risorgimento, 2 - 40136 Bologna, Italy
@mail: (maurizio.barbarella, alessandro.bedin, stefano.gandolfi)@mail.ing.unibo.it

SUMMARY

The GNSS RTK-Networks have been aroused a great interest for the advantages in the surveying of the territory in comparison to the traditional RTK methodology.
The DISTART in the last year has improved a Network for RTK positioning. At present the net is composed by 8 permanent stations. The control centre is nearby the Department of DISTART of Bologna University.
This network is fundamental to investigate all aspects concerning the networks for real time applications. Particularly, not only the topographic feature is investigated, but a very important aspect concerning the data transmission infrastructure is analyzed. In fact the first experimentations demonstrated that the performance of the topographic network depends on the guarantee of a correct data transmission from the GNSS permanent stations to the Control Centre.
To investigate on this field we built a network composed by mixed physical data transmission infrastructure between control centre and the permanent stations on the territory (topographic baselines about 70-80 Km) using university Italian network (GARR) and commercial networks. We studied the time of latency of data transmitted, that is an important aspect of the network, because to solve ambiguities every software for real time network solution needs that the GNSS permanent station observations arrives with a latency not too much greater than a second. Parallely we studied other important aspects of the data transmission in the network like the NAPs (Network Access Protocols), the velocities, the data formats (RTCM 2.X, RTCM 3.0). In this work we want to give the direction to characterize a procedure step by step of a network installation, with the purpose to define a standard, possibly certified, about procedures, materials, softwares to use to install a network of GNSS permanent stations for RTK positioning.

1. THE NETWORKS FOR RTK POSITIONING IN ITALY

At the moment, June 2006, in Italy there are 8 Regions covered by networks: Piemonte, Lombardia, Friuli Venezia Giulia, Emilia Romagna, Umbria and Lazio and in other 9 have

been presented projects from Local Administrations and/or Universities: Trentino Alto Adige, Veneto, Toscana, Abruzzo, Campania, Puglia, Sardegna.

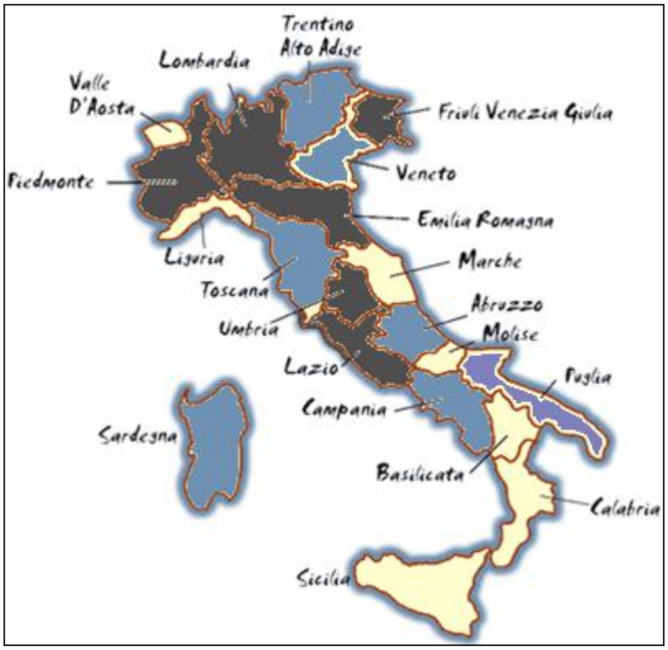

Fig. 1. The Regions of Italy covered (dark grey) and the Regions where there have been presented projects (clear grey) for NRTK

Some Regions are covered by more than one network, like Lombardia and Emilia Romagna.

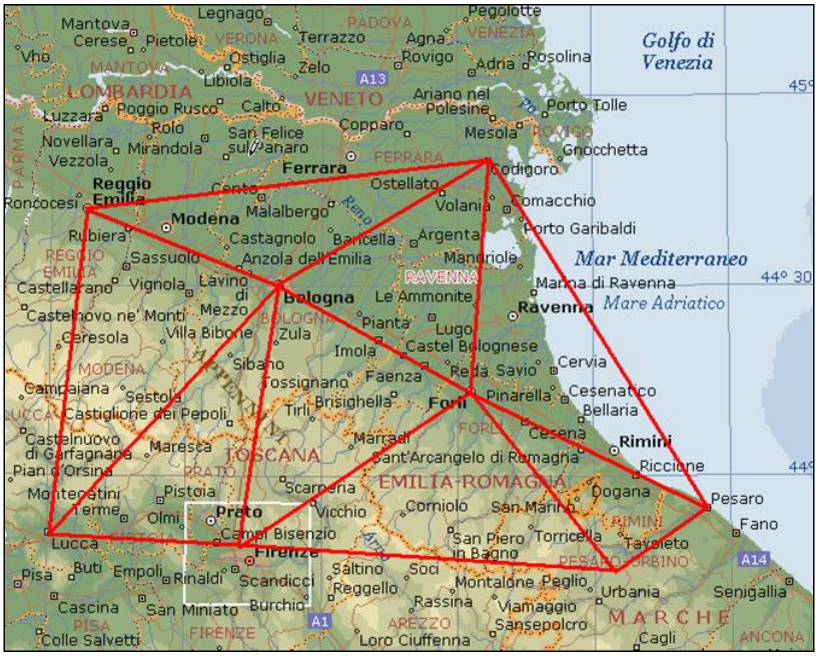

Fig. 2. The DISTART network. The Control Centre is in Bologna

The DISTART network covers, at moment, the east part of Emilia Romagna Region with 8 GNSS permanent stations placed nearby public or private agencies and universities centres. The Control Centre is nearby DISTART Department in Bologna.

The geographic position of DISTART network can be seen how a *trait d'union* between the networks of north and centre/south of Italy.

2. THE DATA TRANSMISSION BETWEEN THE GNSS PERMANENT STATIONS AND THE CONTROL CENTRE

The software installed in the computer of the Control Centre downloads the GNSS permanent stations data, processes them and sends to the users the corrections (FKP or via VRS). So that this system works adequately, it is necessary that the latency time of the data between the GNSS stations and the Control Centre doesn't exceed too much the time of 1 second. This permits to the software to solve in real time the ambiguities for each common satellite. For this reason the aspect of the data transmission assumes an important aspect in the realization of a NRTK. We adopted two kinds of connections: to other university centres we use the GARR (Gruppo Armonizzazione Reti di Ricerca) network, which is the Italian University network, while in the connections to local and private agencies we use a mixed (GARR-commercial) link. In the commercial network we can choose different typologies of connection: ISDN (Integrated Services Digital Network), ADSL (Asymmetric Digital Subscriber Line), SDSL (Symmetric Digital Subscriber Line), VPN (Virtual Private Network), etc. We decided to install in the university external connections the ADSL, for economic reason. There are some steps to face to determine if a type of connection is valid and, if not, to find where the problems are.

To check the latency time, we can use *RTCM decoder software* when the data arriving from the GNSS station are in RTCM 2.X format, and anyway *VisualPulse software* in each format (RTCM 2.X, 3.X, CMR, CMR+). For any epoch we have the latency time to understand if we are in tolerance.

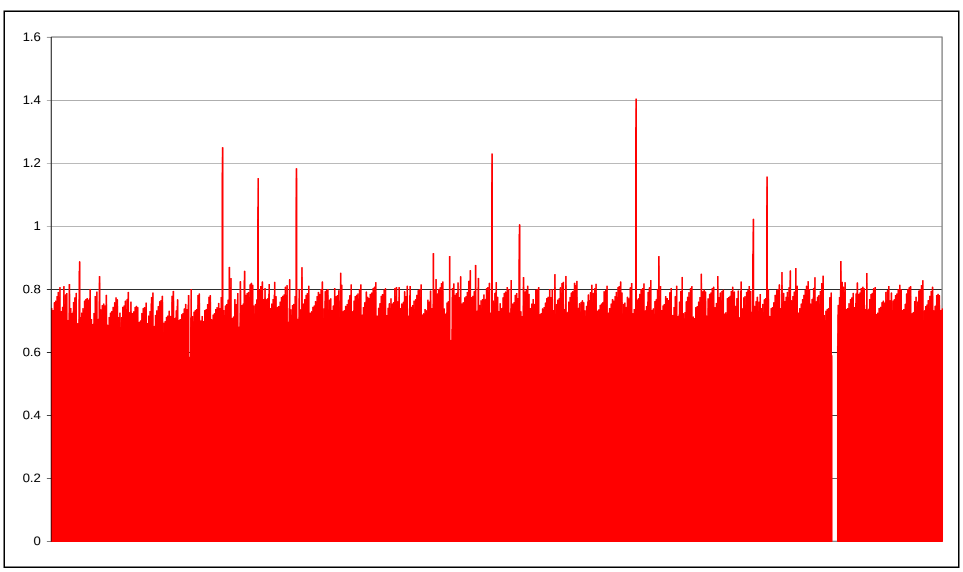

Fig. 3. Latency time in the mixed (ADSL+GARR) connection Reggio Emilia-Bologna in RTCM 2.3 format in a weekday from 14.00 to 17.00

In *Fig. 3* the latency time in a mix route has a mean value of 0.77 sec with some peaks higher than a second, which don't overcome the 10%. There is an interruption of 5 min, which depends by the DISTART network: unfortunately this kind of interruption is frequent in the internal university network and is independent from us. In our connections we don't have particular differences between the GARR connections and the mix connections. We checked the differences in the latency time between RTCM 2.3 and 3.0 too and the advantage is 0.2 sec, with the same conditions and the same number of satellites (between 8 and 12 satellites). This isn't a significant value.

To understand if the increase of the latency time, when there is, depends from the hops (the IP-Internet Protocol, which the data cross), it is recommended a trace route. When the data go by two or more different networks, they cross the NAPs (Neutral Access Points) and these points can increase the latency time. To check this, it is possible to do a trace route of hops with the latency time of each hop. We used Visualroute software of Visualware Inc..

Route Table

Hop	%Loss	IP Address	Node Name	Location	Tzone	ms	Graph	Network
0		137.204.144.4		*			0 1209	Universita' di Bologna
1		137.204.58.252	-	Bologna, Italy	+01:00	120		Universita' di Bologna
2		137.204.2.17	alga11.unibo.it			1		Universita' di Bologna
3	30	193.206.128.125	ru-unibo-rt1-bo1.bo1.garr.n	Bologna, Italy	+01:00	1		GARR-B Backbone and POPs
4	10	193.206.134.237	rt1-bo1-rt-bo1.bo1.garr.net	(Italy)	+01:00	1		GARR-B Backbone and POPs
5	10	193.206.134.49	rt-bo1-rt-rm1.rm1.garr.net	(Italy)	+01:00	5		GARR-B Backbone and POPs
6		193.206.134.118	rt-rm1-rt-rm2-2.rm2.garr.ne	(Italy)	+01:00	5		GARR-B Backbone and POPs
7		193.201.29.10	telecomitalia2-nap.namex.i	(Italy)	+01:00	5		Nautilus Mediterranean Exchang
8		82.184.8.177	host177-8.pool82184.interl	(Italy)	+01:00	7		Telecom Italia SPA
9		151.99.29.152	r-rm199-vl3.opb.interbusin			7		InterBusiness Backbone
10		80.20.8.250	host250-8.pool8020.interb	(Italy)	+01:00	12		Telecom Italia SPA
11		80.17.212.211	-	(Italy)	+01:00	267		Telecom Italia SPA
12	40	**82.104.0.133**	host133-0.pool82104.interl			314		82.104.0.133

Roundtrip time to 82.104.0.133, average = 314ms, min = 312ms, max = 323ms -- 08-Feb-2006 17:03:28 (Collapse Table)

Fig. 4. Trace route of the link Reggio Emilia – Bologna

In *Fig. 4*, we can see that at hop 7 there is the Nautilus NAP, which is in Roma and connects the GARR network with a commercial network. In the graph column the vertical line represents the latency time for each hop and the 7^{th} hop doesn't give problems. The route can change during the data link connection, so the trace route monitors the changing of hops. We made the trace route for each link to our Control Centre computer in continuous modality.

Another check, not strictly necessary, but can be useful, is the baud rate analysis, that gives how many bit per second arrive from each GNSS permanent station. It permits the choice of the right contract connection. We used two softwares: NetLimiter and PRTG, in way that making a check one with the other.

From *Figures 5* and *6*, we can see that the gain with RTCM 3.0 respect to RTCM 2.3 is 3 Kbps, that is, how for the analysis of the latency time, a not significant difference.

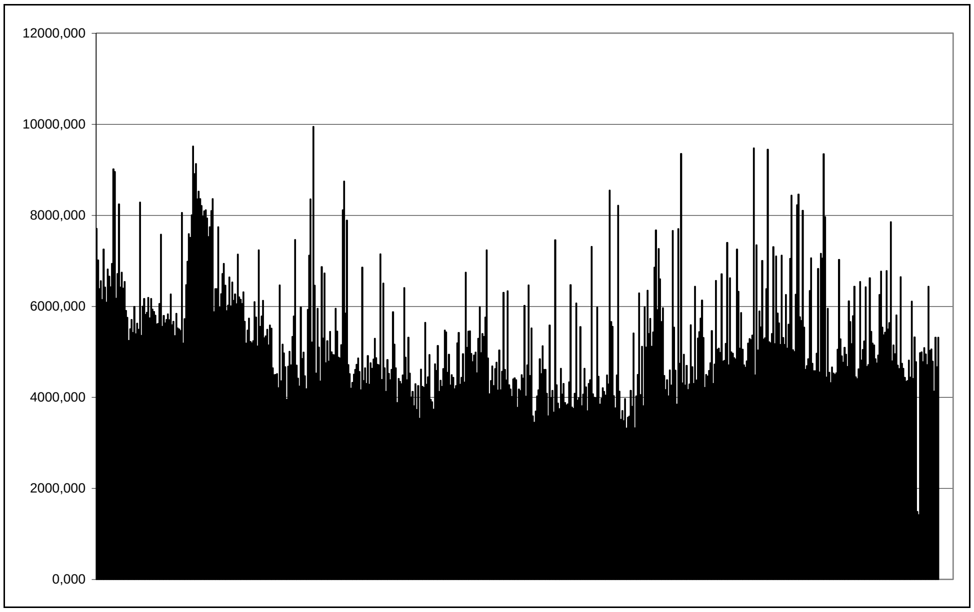

Fig. 5. Velocity in bps of RTCM 2.3 (type 18,19) data of 8-10 satellites from Pesaro route, from 10.00 to 16.30 in weekday

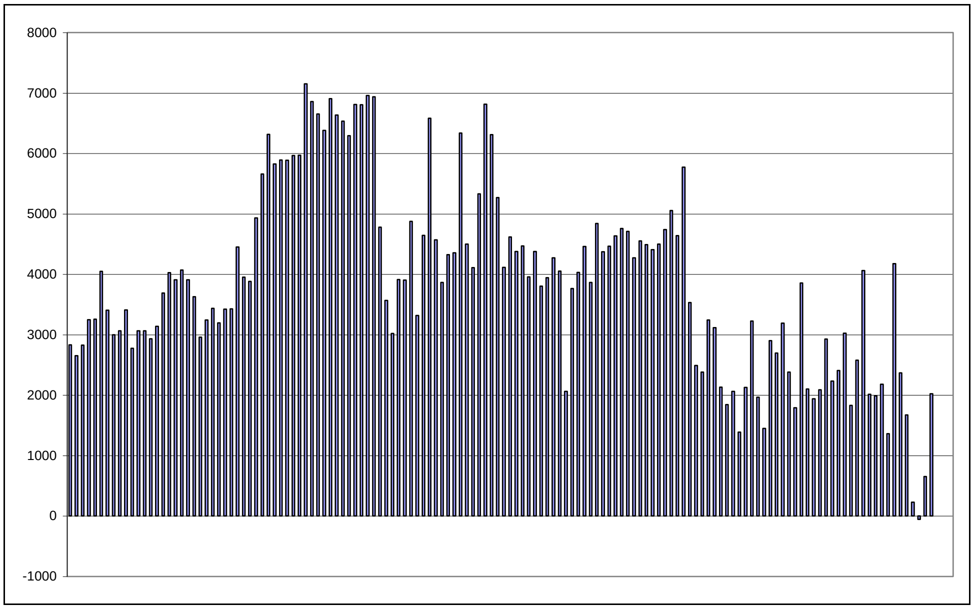

Fig. 6. Velocity in bps of RTCM 3.0 (type 1003) data of 8-10 satellites from Bologna route, from 14.00 to 17.00 in weekday

The softwares for GNSS real time data processing we tested, synchronize their clock with the clock of the machine where are installed. It means that, if the machine clock is no-synchronized, the time, which the software refers, is different from GPS and Glonass time. The difference between GPS and Glonass time can be considered fixed (J. W. Spalding, J. Beser, F. van Diggelen, 1997). This kind of softwares calculates the offsets between UTC and GPS time (the difference between GPS Time and UTC changes in increments of seconds each time a leap second is added to UTC time scale), so we can synchronize our clock machine with a UTC clock. Our clock machine is synchronized with a NTP (Network Time Protocol) server, installed nearby *Istituto Elettrotecnico Nazionale Galileo Ferraris* in Torino. This server is synchronized, through a date code generator, with the caesium clock of the Italian sequence time UTC(IEN). The discard between the server and the UTC(IEN) is continuously monitored, and is always in the tolerance of some msecs.

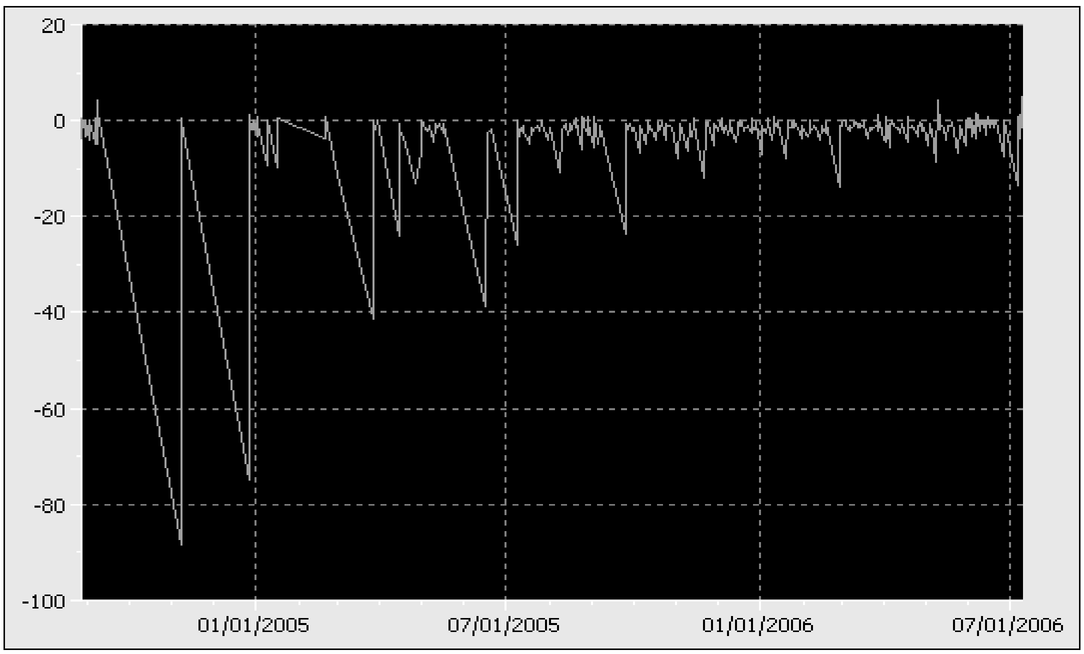

Fig. 7. Discard between a machine clock and a NTP server. The clock machine misses about 1 sec/day, if it isn't re-synchronized. The return to 0 sec value is obtained with a re-synchronization with an atomic clock

In some sites where are installed our GNSS permanent stations, the distance between the antenna and the receiver is longer than 30m. We noted that connecting the antenna to the receiver with an ordinary cable RG-213, longer than 30m, we lost the signals of some satellites. At moment there are other typologies of antenna cables, which give more performances than the RG-213. For example the FSJ1-50A is indicated for long distances connections. In the tables 1 and 2 there are the correspondent attenuation values.

The value of the signal attenuation is

$$\text{attenuation} = 20*\log_{10}(V1/V2)$$

where V1 and V2 are the voltages at the extremities of the cable.

RG-213 attenuation [dB]			
Frequency	***20 [m]***	***30 [m]***	***40 [m]***
L1	**7.04**	**10.56**	**14.08**
L2	**5.92**	**8.88**	**11.84**

Table 1. Attenuation in dBs of RG-213 cable for L1 and L2 carriers

FSJ1-50A attenuation [dB]			
Frequency	***20 [m]***	***30 [m]***	***40 [m]***
L1	**4.9**	**7.35**	**9.8**
L2	**4.5**	**6.6**	**8.9**

Table 2. Attenuation in dBs of FSJ-50A cable for L1 and L2 carriers

3. CONCLUSIONS

The communication between reference stations and computer centre plays a central role in the correct and efficient real time precise positioning using network corrections.

Of course, in addition to the mentioned parameter still necessary to check previously the sites where will be installed the permanent stations with a TEQC (Translate and Edit Quality Checking) and electromagnetic interference analysis as is desirable.

In our study case we determined that the latency time mean values on our connections don't exceed 1 sec for the 90% during a work day connection and found that the latency time of the NAPs in our network is not dangerous for the data transmission. Moreover there aren't significant differences between the RTCM 2.3 and 3.0 from a data transmission aspect.

With this study DISTART intends to contribute to the realisation of a good and stable NRTK installation, where the main steps are:

- **latency times analysis;**
- ***trace route* for the determination of NAPs and evaluation of the delays;**
- **baud rate (bps) analysis on the route *GNSS Permanent Station – Control Centre* (not strictly necessary);**
- **analysis of the components (e.g. antenna cables, antenna's calibration,...) of the GNSS Permanent Stations.**

BIBLIOGRAPHY

1. M. Barbarella, A. Bedin, S. Gandolfi, L. Vittuari*: La trasmissione dei dati nelle reti di stazioni permanenti GNSS per il posizionamento Real Time*. Acts of 8th National Conference of ASITA (2004), Vol. I, pp. 259-264.

2. Radio Technical Commission for Maritime Services: RTCM Recommended Standards for Differential GNSS (Global Navigation Satellite Systems) Service, Version 2.3, RTCM paper 136-2001/SC104-STD, 2001.

3. Radio Technical Commission for Maritime Services: RTCM Recommended Standards for Differential GNSS (Global Navigation Satellite Systems) Service, Version 3.0, RTCM paper 30-2004/SC104-STD, 2004.

4. J. W. Spalding, J. Beser, F. van Diggelen: *Recommendations on Differential GNSS*, ION GPS-97 Meeting, Kansas City, Missouri, 1997.