Extending the availability area of positioning services ROMPOS

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Abstract
In Romania there are installed 74 GNSS permanent stations, since 1999 and in 2012 the network was completed, touching the density recommended by European organizations. This fact allows providing high quality ROMPOS (Romanian Position Determination System) services inside the network. Providing reliable ROMPOS services in the frontier zone is possible due to cross – border GNSS raw data exchange from close border GNSS reference stations. Nowadays Romania, through National Agency for Cadaster and Land Registry has signed a few cross - border GNSS data agreements with homologous authorities from Hungary, Moldova and Ukraine and has good cooperation perspectives by similar authorities from Serbia and Bulgaria, with whom these kind of data exchanges were already tested. ROMPOS real time services are accessed through internet data services. Considering the fact that there are a few areas in Romania where these kind of data services have no coverage, to use the real time positioning services it is required to use alternative methods to retransmit the products afferent to these services.

Key words
Permanent station, position determination service, RTK/DGNSS, user

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1. Introduction

Transition from GNSS post processing methods to real time determination requires the achievement of regional, national and local GNSS augmentation systems.
These systems provides to users auxiliary information, called differential corrections for compassing centimeter level in precision of real time positioning. Such kind of system, including these services is also Romanian Position Determination System – ROMPOS, realized by National Agency for Cadaster and Land Registry (NACLR), according to standards elaborated by European organization EUPOS (European Position Determination System) for realizing in Central and Eastern Europe an integrated system for such kind of services. EUPOS services are designed for provide an homogenous positioning in terms of performances, using DGNSS and RTK methods, this being guaranteed inside of EUPOS coverage area. For touching this goal, a good cooperation between neighbors and members is required. This paper presents and argues the necessity of GNSS data exchange by all Romania`s neighbor countries.
ROMPOS real time services are provided only via internet and are accessible only in areas covered by mobile data services. For areas where internet is unavailable are usable alternative methods to retransmit differential corrections and these methods will be also presented in this paper.

2. Regional and local GNSS permanent networks

a. EUPOS network

EUPOS is a regional homogenous GNSS network, realized by 18 specialized institutions in Central and Eastern Europe, adopting some common standards, normative, methodologies and procedures.

Tabel 1: Numărul staţiilor ROMPOS incluse în EUPOS

EUPOS National system	Area (km^2)	Planned reference stations	Realized EUPOS reference stations
ROMPOS	237.500	73	74

Fig. 1: EUPOS reference stations – 459 stations [1]

b. ROMPOS network

Nowadays, National GNSS Permanent Network includes 74 reference stations (Fig. 3), coherently and uniformly distributed across the country. After September 2008, this network became the framework of ROMPOS, providing for the first time in Romania real time precise positioning services.

In terms of equipment, the network is inhomogeneous. There are two manufacturers: Leica and Topcon (Fig. 2).

Fig. 2: Types of ROMPOS stations

Starting with NACLR participation in the frame of EUPOS project, was taken into account the compliance of specific products and services standards (*EUPOS Technical Standards, Guidelines For Single Site Design, Guideline for Cross-Border Data Exchange, Guideline for EUPOS Reference Frame Fixing*).

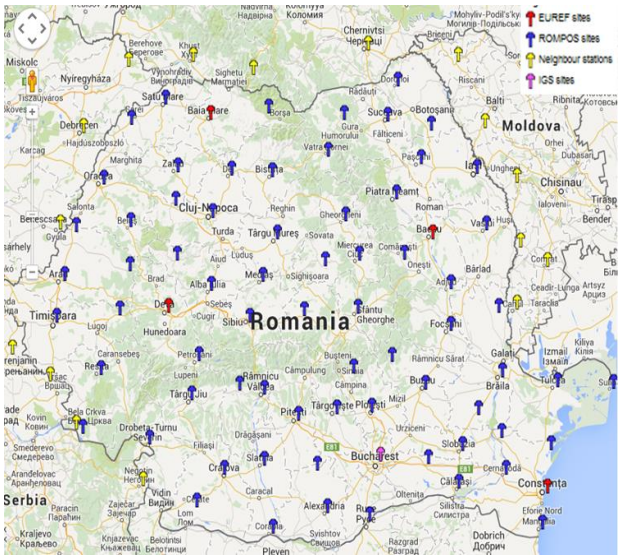

Fig. 3: National GNSS Permanent Network [2]

Quality of EUPOS/ROMPOS services depends more by choice of installation place and design.

EUPOS member countries must follow the installation standards to guarantee the national networks high quality. Standards compliance lead to homogenous services supply in the entire EUPOS coverage area, unconcerned the user position.

National Center for ROMPOS Services (NCRS) is a part of NACLR and it works based on EUPOS standards, implementing all requirements included.

3. General features of ROMPOS

ROMPOS is based on a framework of GNSS reference stations installed and managed by NACLR. There is a single exception the IGS station from Bucharest, called BUCU, which is installed and managed by Technical University of Civil Engineering of Bucharest through Faculty of Geodesy.

GNSS reference stations works permanently, providing real time data and post processing data in sessions of 1h and 24h. GNSS reference stations are interconnected, including the neighbor stations (near the border area).

The average distance between stations is about 70 km. The equipment were installed to provide the long term stability of the GNSS antennas. These antennas are placed to ensure a "free obstruction" skyline and to avoid the sources of bias and multipath. Using right calibrated antennas, the multipath effect can be reduced. Most of the antennas of ROMPOS stations were individual absolute calibrated, using the best techniques available in the world. Also, the receivers are double frequency and geodetic class.

The stations receive signals from NAVSTAR GPS system and 69 are GPS – GLONASS. When GALILEO

will be in Full Operational Capability (FOC), will be proposed an upgrade for equipment.
Coordinates of the GNSS antennas are computed with a high precision (better than 1cm) in ETRS89 (*European Terrestrial Reference System* 1989), densifying the EUREF stations (Bucureşti, Bacău, Baia Mare, Constanţa, Deva).
There are also a quality management system to support users to obtain best results in terms of precision, integrity and system availability. It is important to ensure a high level of availability (minimum 99%) and integrity of the entire system. The malfunctions, interruptions and quality decrease of data are identified real time by the administrators.
The national reference stations are compatible with the most of other GNSS systems, ROMPOS being interoperable with EUPOS.
ROMPOS services are provided by NACLR, through National Center of ROMPOS Services, which is intended to monitor and control the GNSS stations activity for the automatic transfer of data to central data server, which are used for post processing position determination (the ROMPOS – GEO service) and to provide positioning services and products for real time applications.

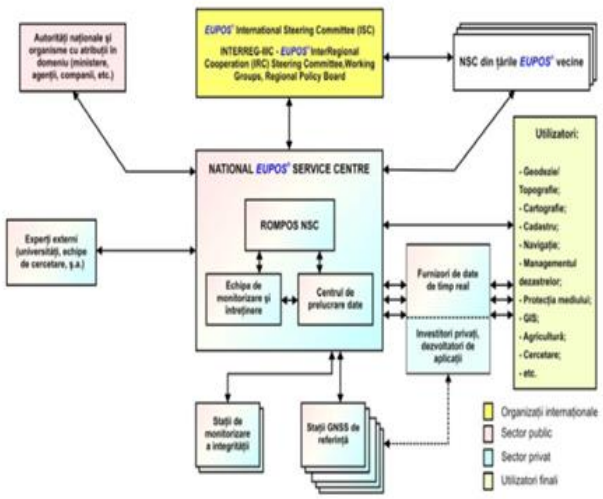

Fig. 4: National Center for ROMPOS Services (NCRS)

NCRS structure (Fig. 4) recommended by EUPOS include:
- national GNSS reference network;
- the center for data processing;
- the system administrators. Each GNSS station has also its own administrator. CNSR is also supported by IT specialists from the IT department of the institution;
- for a continuous improvement of the ROMPOS services, NCRS cooperates with other national and international organisations;
- NCRS directly cooperates with similar EUPOS centers, especially from neighbor countries;
- NCRS specialists regularly participate to EUPOS Council meetings and has suffrage in this structure;
- now the ROMPOS real time services are provided free of charge to a wide range of users.

4. Services offered by ROMPOS

ROMPOS includes 3 main types of services:
- *ROMPOS DGNSS* – for real time kinematic applications, with an accuracy range from 3m to 0,5m;
- *ROMPOS RTK* – for real time kinematic applications, with an accuracy range from 0,5m to 2cm;
- *ROMPOS GEO* (*Geodetic)* for post processing applications, with an accuracy better than 2cm.
The transfer of differential corrections from reference stations to user may be realized as follows: radio waves, mobile communication systems GSM/GPRS or internet.
There are also, two main types of real time positioning products: single base (from one site) and network, such as VRS, FKP şi MAC (MAX şi i-MAX).
Transmission of OMPOS RTK and DGNSS differential corrections is centralized, from NCRS via internet. The RTK receiver must be equipped with GSM modems to access internet and receive differential corrections. In this case, with one single GNSS receiver, real time users can be determine very quickly (seconds or minutes) their own position and also can check the precision of positioning. Coordinates are determined relatively to A class national geodetic network and due to this fact this values are obtained directly in European Terrestrial Reference System 1989 (ETRS89) which offers an homogeneity of all determinations.
To transform coordinate values from ETRS89 to National Reference System S42 (ellipsoid Krasowsky 1940, Projection Stereographic 1970), NACLR offers for free the TransDatRO software, which can be download from official website: www.ancpi.ro.
For users who want the implementation of TransDatRO software in GNSS RTK field receivers, NACLR provide the grids for transformation and the computing algorithm. As a result, coordinates determined by GNSS RTK field receivers which have implemented the transformation grids of TransDatRO application can be obtained directly in the field (on the whole country) in S42 system.
NACLR also realized the web site www.rompos.ro which deliver information about the system.
ROMPOS is managed through a specialized software package for post processing and real time services, Leica GNSS Spider. This software packages realizes: monitoring and control of GNSS reference stations, managing and archiving the post processing data, qualitative and quantitative data analyses, network configuration, creation, management and delivery of specific products and services, monitoring of the system users etc. Also, system is highly secure, computation and network management being separated from data delivery,

thus being realized the infrastructure and user data protection.
Due to the large dimensions of the network which implies a lot of calculations, the network is divided in 4 clusters which run on two servers. This architecture realize the processing on two servers and, in case of malfunction not being affected the whole network. The clusters have common stations between them, which permits their superposition (see Fig. no 5).

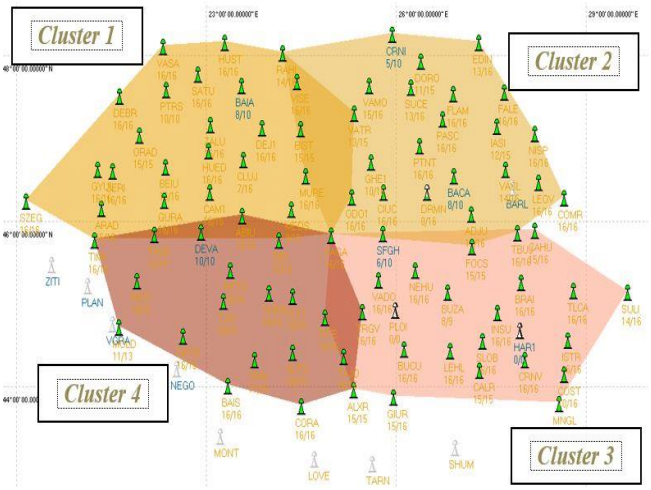

Fig. 5: The clusters of ROMPOS network

5. Means to extend the ROMPOS real time services availability

Considering only GNSS reference stations of each country, accuracy and reliability of positioning services will be degrade in border zones due to mission of some geometric information outside the network.
The exchange of raw GNSS data delivered by near border GNSS permanent stations may be helpful for every EUPOS National Services Center for guaranteeing homogenous accuracy and performances of the system.
On this line, EUPOS Technical Working Group realized a document „Guideline for Cross-Border Data Exchange" which regulates the general frame for EUPOS stations for choosen the data exchange, data format and transport protocol.
GNSS reference networks are used to generate differential corrections, due to fact that is possible to model and correct the distance errors, which reduce the RTK and DGNSS precision of positioning commensurate to distance between rover and GNSS reference station. The most important errors which affect the GNSS positioning are caused by ionosphere, troposphere and satellite orbits. The goal of GNSS network is to model and estimate these errors and to deliver differential corrections to the real time users for obtaining better precisions in position determinations.
EUPOS reference stations have different receiver types. Also, different reference stations and software applications are used to offer standard EUPOS services. For this reason it is important to ensure GNSS real time data exchange, in standard formats. EUPOS members uses RTCM (Radio Technical Commission for Maritime Services) standards for cross border data exchange. As a result of RTCM standards evolution, the content and format of the GNSS data stream are improved significantly, message types being improved. It is recommended to exchange data in RTCM 3.x format for EUPOS data centers, according to [3].

Table 2: GNSS data exchange agreements between Romania and neighbor countries

Agreement	GNSS data stations which are the subject of agreement		Signed
	Romania	Neighbor countries	
ROMPOS – **GNSS Net.hu (Hungary)**	Arad Oradea Satu Mare Timişoara	Vásárosnamény Debrecen Gyula Szeged	Yes 2010
ROMPOS – MOLDPOS (Moldova)	Dorohoi Flămânzi Iaşi Vaslui Târgu Bujor Brăila	Cahul Edineţ Faleşti Nisporeni Leova Comrat	Yes 2010
ROMPOS – ZAKPOS (Ukraine)	Satu Mare Baia Mare Vişeu de Sus Dorohoi Tulcea	Khust Rakhiv Chernovtsi Izmail	Yes 2012
ROMPOS – BULiPOS (Bulgaria)	5 stations	5 stations	No
ROMPOS – AGROS (Serbia)	4 stations	4 stations	No

GNSS data streams received from neighbor stations are used only for ROMPOS network products, for extending the coverage area of network services, according to cross border GNSS data exchange agreements. RINEX files should not be generated from public data streams.
For out of network areas for which the GNSS data exchange is realized, there is modeled the errors due to ionosphere, troposphere and satellite orbits, and corrections delivered to users are reliable. These real time services offered by extended systems are quality, being able to obtain precise positioning (see Fig. 6).

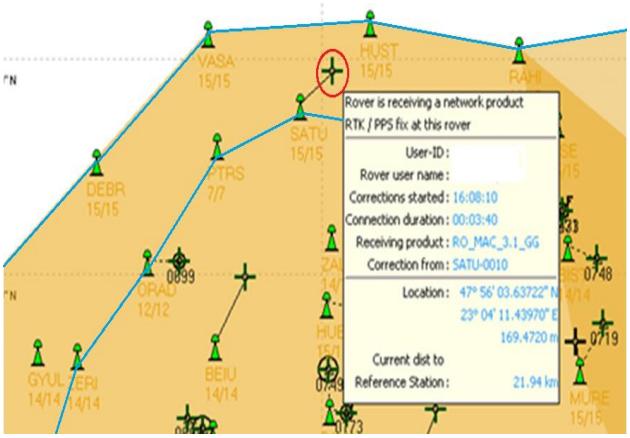

Fig. 6: Outside network measurements, near Hungary and Ukraine borders – user of Ro – MAC product which has "fixed" type solution

On the other side, in areas where the cross border data exchange is not realized (Serbia and Bulgaria), precise position determination of the users is more difficult (see Fig. 7).

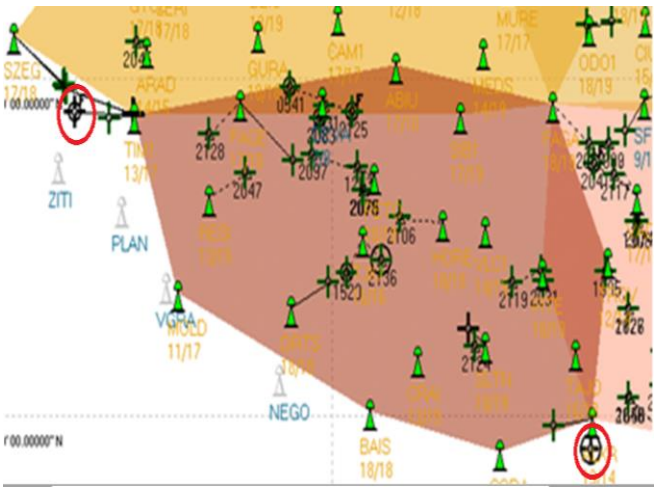

Fig. 7: Measurements outside network, where the data exchange is not realized (Serbian and Bulgarian borders) – network products users (real time RTK) which have "float" type solutions

Delivery of real time services from positioning services center to the users is realized via internet, using GSM/GPRS connections. Thereby access to rhis services implies data services coverage.

In areas where internet access is unavailable (due to lack of GSM/GPRS data coverage) and there are necessary real time services, products of these services can be transmitted through a radio transmitter. In these conditions are used auxiliary equipment which takes differential corrections transmitted by positioning systems and retransmit them, via radio waves, where the data signal coverage is unavailable.

This system should have a good operating autonomy, regardless of field conditions, thus being possible by using auxiliary power supplies, protection against damage, transport etc. Through this kind of equipment the coverage area of real time services will be extend.

There are many cases of using these devices:

1. Radio transmitters have an important usefulness where the data signal coverage doesn't exists and through these, the availability area of differential corrections can be extended. In this case the radio transmitter is installed in a covered area with data signal, which allows the connection to GNSS network server. Thereby, differential corrections are taken via internet and retransmitted in the uncovered interest area where users equipped with RTK receivers works. Thus, the correction message can be accessed by an unlimited number of receivers equipped with an adequate radio modem. For realizing good quality determinations using differential corrections, the approximate position which will be transmitted to server will be from work area and not the position of the radio transmitter, due to fact that distance between them may be long.

2. Radio transmitters may be used also in areas where the mobile data coverage exists, but it whishes that field receivers to receive a specific message, which the network server don't provide. In this situation, the system which contains the radio transmitter in the work area will transmit to the NTRIP server an approximate position, for which will receive differential corrections. These corrections are received through NTRIP server via internet and will be retransmitted to the field rovers through a radio modem in a specific data format, which can be accessed by receivers.

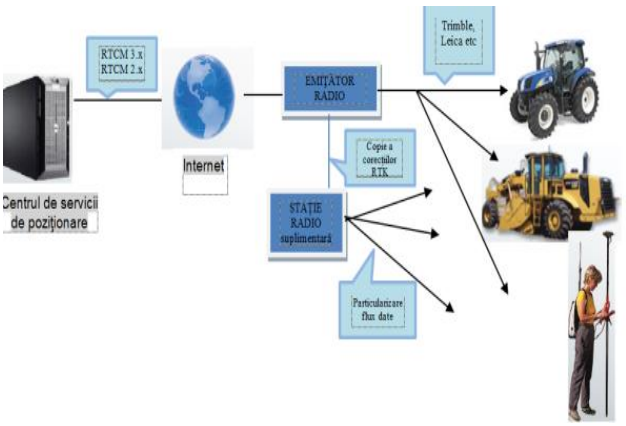

Fig. 8: The extension of differential correction transmission using a radio transmitter and supplementary radio stations

3. For transmitting the data stream using much frequency or much differential corrections message types, should be connect another radio transmitter – a supplementary radio base (see Fig. 8). Thereby the use of differential corrections to different rover models is improved.

The RTK data are delivered via mobile internet in RTCM

SC 104 vs. 2.x și 3.x standard data formats. In case of using a proprietary data format, the GNSS receiver must be able to decode the data streams in such way that software installed on field equipment to be able to process it.
The National Center for Cartography have two similar systems for retransmission of differential corrections, which are equipped with all tools necessary for the field work whereby it is possible to work in uncovered data signal areas.

6. Conclusions

Position determination services are designed to ensure a consistent positioning in terms of performance, using DGNSS and RTK methods, this being guaranteed throughout the coverage area of the network underlying the system. In order to achieve this objective it is necessary the cooperation between neighboring networks. Positioning accuracy and reliability of services will degrade near border areas due to the omission of information from some geometric information. By signing agreements on the exchange data from similar permanent networks from Bulgaria and Serbia, will pave the provision of real-time quality data also in the border areas.
Accessing services created on the basis of permanent station networks should be as easy user to cover as many of these requirements. This can be achieved through the use of services and equipment to complete them.

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[5] Cooperation agreement regarding GNSS data echange between the National Agency for Cadastre and Land Registration of Romania and the Agency for Land Relations and Cadastre of Moldova Republic
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