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Dragana Skorup
University of Banja Luka, Faculty of Architecture, Civil Engineering, and Geodesy, Bosnia and Herzegovina, dragana.skorup@aggf.unibl.org

Slavko Vasiljević
University of Banja Luka, Faculty of Architecture, Civil Engineering, and Geodesy, Bosnia and Herzegovina, slavko.vasiljevic@aggf.unibl.org

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* corresponding author

Dragana Skorup *

University of Banja Luka, Faculty of Architecture, Civil Engineering, and Geodesy, Bosnia and Herzegovina, dragana.skorup@aggf.unibl.org

Slavko Vasiljević

University of Banja Luka, Faculty of Architecture, Civil Engineering, and Geodesy, Bosnia and Herzegovina, slavko.vasiljevic@aggf.unibl.org

CORS NETWORKS, ASPECTS OF BUSINESS MODELS IN EUROPE AND THE REGION

ABSTRACT

The paper describes the functioning of CORS permanent networks in the world. Special attention has been paid to the EPN network and the regional CORS networks in Bosnia and Herzegovina, Serbia, Montenegro, and Croatia. BiHPOS: SRPOS and FBiHPOS, AGROS, CROPOS, and MONTEPOS were analyzed from the aspect of mutual data exchange with the aim of achieving better location accuracy and removing deficiencies in the network geometries. Due to their individual development, as well as mutually concluded agreements on data exchange, measurements obtained using GNSS today have a wide range of applications, such as maritime communication, aviation, engineering work, earth monitoring, and many more. Also, the points of the region included in the EPN network with the aim of exchanging data at the European level are shown.

Keywords: *GNSS, CORS networks, EPN*

1. INTRODUCTION

GNSS (Global Navigation Satellite Systems) are satellite-based systems that enable the calculation of the 3D position of any point on the earth's surface. The essence of the measurement is determining the distance based on the product of the time required for the GNSS signal to propagate from a satellite to the receiver and the speed of light. [1]. The most famous global navigation systems are the American GPS (Global Positioning System), the Russian GLONASS (GLObalnaya NAvigazionnaya Sputnikovaya Sistema), the European satellite navigation system Galileo, and the Chinese satellite navigation system BDS (BeiDou System).

GNSS technology has become indispensable in positioning, navigation, and timing, known in the literature as PNT (Positioning, Navigation, and Timing) in a wide range of military and civilian applications. Accordingly, GNSS is being supported by CORS (Continuously Operating Reference System), which is a common type of GNSS ground-based augmentation infrastructure used by governments to distribute centimeter-accurate PNT information worldwide [1].

The paper will focus on the basic concepts of CORS networks, the standards used for data exchange, as well as the models represented in Europe and the world. First, the operation of CORS networks on the European continent was examined, followed by an examination of networks in Europe and the region. Finally, the possibility of improving communication and data exchange was presented to provide more efficient, reliable, and cost-effective information.

2. CORS NETWORKS

A continuously operating reference system is the primary technique for establishing regional three-dimensional geodetic data. CORS networks, including global large-scale and regional small-scale networks, are used globally, owing primarily to the rapid development of satellite positioning technology, information technology, and network technology. The three-dimensional coordinate system is defined and extended by CORS and GPS networks [2].

Each CORS network consists of a series of GNSS stations interconnected by reliable communications to achieve real-time computations and controls. Each station requires, as a minimum, a receiver, an antenna, a communication device, and a power supply. In certain cases, additional equipment is installed for data transmission and control. Also, additional customer service is required for network configuration and maintenance, which can be carried out remotely using radio communication, mobile network, or internet connection. CORS networks are established for numerous reasons, but the accuracy of the final information depends on how the network is constructed. There is a difference between DGPS (Differential GPS), which uses code observations, and PDGPS (Precise DGPS), which uses carrier phase observations [3].

2.1. BASIC COMPONENTS OF CORS

CORS, as the three-dimensional control network datum, is the result of advanced new technologies such as satellite positioning technology, network computer technology, and so on. It consists of [2]:

- datum station network (network of reference stations);
- data processing center;
- data transmission system;
- data broadcasting system;
- user application system.

The reference stations are connected to the monitoring and analysis center through the data monitoring system, which again forms a special-purpose network.

The network of reference stations consists of a large number of evenly distributed reference stations that collect data from satellites, send them to the data processing center and provide a service for monitoring the integrity of the entire system.

As the system control center*, the data processing center* receives data from all reference stations, stores them, converts them, and calculates coordinates and corrections. Then the data files, saved in certain formats, are distributed to users. The control center is the core part of CORS and the key to realizing high-precision real-time dynamics positioning. The whole system is based on the principle of continuous observation of all reference stations in real time. The control center itself automatically generates a virtual reference station (including coordinates of reference stations and GPS observations) that corresponds to the mobile station and provides information to users (who require measurements and navigation with information on differential phase-carrier phase correction in a universal format) to be able to calculate the exact position of mobile stations in real time.

The data transmission system serves to transmit data from the reference stations to the analysis and monitoring center using fiber lines. The system consists of the following:

- hardware part - data transmission system and
- software control module.

The data broadcast system sends positioning and navigation data to users using mobile networks, UHF radio, the Internet, and so on.

The user application system consists of a system for receiving user information, a network-based RTK (Real-Time Kinematic) positioning system, a precision post-processing system, an autonomous navigation system, a positioning monitoring system, etc.

2.2. HISTORY OF THE ESTABLISHMENT OF THE CORS NETWORK

The history of CORS is related to NOAA's (National Oceanic and Atmospheric Administration) and NGS's (National Geodetic Survey) to define, maintain, and provide access to the NSRS (U.S. National Spatial Reference System). The concept of covering the US (United States) with a CORS network to improve NSRS was first introduced by Strange in 1994, and a year later, a preliminary description of the CORS system was published by Strange and Weston [4]. Along with them, many other organizations realized that they would receive great benefits in the future from the development of such a system. Some of them are US Coast Guard, US Army Corps, Federal Aviation Administration, US Geological Survey, and so on. Some countries have developed their navigation systems [1]:

- The United States of America – GPS;
- Russia - GLONASS;
- China – BDS;
- European Union - Galileo.

3. STANDARDS OF CORS NETWORK

Most GNSS receiver manufacturers are developing their data formats. They are mostly coded, binary formats that require the use of software/hardware supplied by the manufacturer and imply maximum system reliability in real time. Since CORS systems use different brands and types of receivers, the problem occurs with data interoperability. International formats are introduced to overcome this problem [5].

3.1. POST-PROCESSED DATA FORMATS

When archiving GNSS data, original formats are used to adapt the data to the internal application in terms of compatibility with applications and technologies for further processing. However, the internal formats do not allow software from other companies to process that data, so the general recommendation is to use the open standard RINEX (Receiver INdependent EXchange) [6].

The main advantage of the RINEX format is reflected in the possibility of its use for GNSS data independently of the equipment manufacturer. Also, the RINEX format can be used in a wide variety of post-processing software and analysis tools. There are currently several versions of the RINEX format used for GNSS data exchange, and the latest accepted version is RINEX v. 3.05. In the current version, easier and clearer reading is enabled, the addition of BDS signals and codes to fully support the second and third generation of BDS, as well as the addition of values in GLONASS navigation systems [7]. RINEX file specifications can be obtained from the IGS (International GNSS Service) website. IGS is an international GNSS service providing open access to high-quality GNSS data, products, and services to support the terrestrial reference frame, Earth observation, research data, PNT, and many applications that have played a major role in the development of science and society since 1994. It comprises over 200 self-financing agencies, universities, and research institutions in more than 100 countries [8].

3.2. REAL-TIME DATA FORMATS

The RTCM-SC104 (Radio Technical Commission for Maritime Service – Special Committee 104) data format is recommended for real-time GNSS services. RTCM has published global standards that enable the exchange of GNSS data [6]:

- RTCM 10402.3 RTCM Recommended Standards for Differential GNSS Service Version 2.3. A standard used to distribute real-time differential GNSS data from a single reference station directly to the user;
- RTCM 10403.1 Differential GNSS Services - Version 3 - Amendments 1, 2, and 3. Standards used for the distribution of real-time differential GNSS data that includes GNSS network corrections;
- RTCM 10410.1 Standard for NTRIP (Networked Transport of RTCM via Internet Protocol) is an application-level protocol that supports GNSS data sharing over the Internet. It is a generic protocol based on HTTP/1.1. (Hypertext Transfer Protocol). NTRIP is designed to have the ability to disseminate differential correction data and other information to GNSS stationary and mobile users over the Internet. Also, it enables wireless access to the Internet via Mobile IP networks such as GSM, GPRS, EDGE, or UMTS.

NTRIP is conceived as an open, non-proprietary protocol characterized by the following [9]:

- Based on the popular HTTP standard for streaming;
- Ability to share any type of GNSS data;
- Sharing a large amount of information simultaneously for thousands of users using modified Internet Radio broadcasting software;
- Independence of service providers and users;
- The possibility of sharing over any IP mobile network due to the use of TCP/IP.

4. DIFFERENT MODELS OF THE CORS NETWORK

CORS networks have been developed at local, national, and global levels for scientific and commercial purposes in various sectors. The operating model of CORS networks can be different between countries, starting with government organizations playing their role, and ending with the private sector or a network of private companies [10].

CORS systems have been developed by the government, the private sector, and academia. Local government agencies provide GNSS positioning information for a limited geographic area, such as a city. Regional transport departments aim to support research and mapping at the national or regional level. Federal geodetic organizations support the relative positioning and generation of data related to the entire country. Global interagency services enable the expansion of GNSS activities around the world. The private sector provides differential correction information to users who pay for these services [10].

The ICSM (Intergovernmental Committee on Survey and Mapping) has developed its CORS hierarchy based on Rizos's idea (2008) [6]:

- *Level 1 (Tier 1):* IGS, more precisely, international GNSS services that contribute to the development of the international terrestrial geodetic reference frame ITRF (International Terrestrial Reference Frame);
- *Level 2 (Tier 2):* national geodetic network or backbone of the national geospatial reference system and framework or datum;
- *Level 3 (Tier 3):* state or private GNSS networks which provide access to data realization through positioning services.

Rizos proposed a model for establishing CORS networks and services derived from them [11]:

- Institutional CORS infrastructure - without commercial services;
- State CORS infrastructure - manages commercial services;
- State CORS infrastructure - licenses data to the private sector;
- Corporate CORS infrastructure in private ownership - performs commercial services;
- CORS infrastructure in private ownership - performs commercial services.

Which of these models or combinations will prevail varies from country to country.

4.1. THE UNITED STATES OF AMERICA

No private or government service in the USA has built high-level, nationwide precise positioning services. The CORS network for the Federal Government and other infrastructure was set up by NGS within NOAA [1]. It was formed up of 137 GPS reference stations, including those from the NGS tracking network, the USCG (the United States Coast Guard) differential network, the WAAS (Wide Area Augmentation System) of the US FAA (US Federal Aviation Administration), and the tracking networks developed by the USACE (USA Corps of Engineers) [2].

The role of NGS is to provide a geodetic framework for all positioning of national importance. The agency coordinates with over 1800 multi-purpose CORS stations across the country (including Alaska) established by the government, researchers, or for private use and constitutes a new generation of the American national kinematic reference system. Each organization shares its data with the NGS, which analyses and monitors the data that is then published to users for processing. This system's stations are all fully equipped with dual-frequency GPS receivers and ground ring antenna. Every day they unload data and record them in RINEX format in intervals of 1s, 5s, 15s, and 30s. This system provides reference station coordinates and data from GPS satellite tracking stations to users worldwide via the Internet. Other services include coordinate system transformation and geoid determination. When observations at the endpoints last at least 4 hours, using the CORS relative positioning accuracy of the baseline endpoints of 26-300km, an accuracy of 1cm in the horizontal direction and 3.7cm in the vertical direction is achieved with a 95% confidence level [2].

Meanwhile, industry services have begun to connect positioning services such as SmartNet North America, which uses a licensing model to connect 600 CORS across the region, where data is licensed by the government and private CORS. Different suppliers can use the same CORS infrastructure to increase the consistency of providing PNT information thanks to the data licensing model [1].

4.2. EUROPE

The EPN (EUREF Permanent Network) is a network of continuously operating stations built by European countries and individual organizations (academic groups and universities). The EPN was established by the Sub-Commission of Europe for the Regional Reference Frame EUREF (Regional Reference Frame Sub - Commission for Europe) and the IAG (International Association of Geodesy) as a cooperative regional network with constant work [12]. EPN's current task is to maintain the European spatial regional reference framework. In addition to being a frame of reference, CORS in European countries such as Germany, Great Britain, and Switzerland still provides post-processing and precise positioning based on real-time differential and kinematic techniques.

The primary purpose of the EPN is to provide access to ETRS89 (European Terrestrial Reference System 89), which represents the standard GNSS coordinate system of the EU (European Union) [13].

The central EPN system managed by ROB (Royal Observatory of Belgium) performs the daily connection and acts as a link between the reference stations, the data, the analysis center, and users, and also maintains the EPN information system.

RINEX data from EPN stations are available via FTP (File Transfer Protocol) from two regional centers positioned in Germany and Austria and one historical center managed by ROB. Real-time EPN data is obtained from three regional NTRIP transmitters located at the Italian space agency, the German BKG (Bundesamt für Kartographie und Geodäsie), and the ROB.

INSPIRE (INfrastructure for Spatial InfoRmation in Europe) is a directive that sets the rules for the establishment of a spatial data infrastructure in the EU. The implementation rules explain how the various components of the infrastructure work. Metadata, data interoperability, service network, and data sharing are covered in the Implementing Rules. The INSPIRE directive requires that member states exchange data between themselves and the EU institutions, as stated in the implementation rules "Data sharing" [14].

4.2.1. The United Kingdom

The CORS network in the United Kingdom is controlled by a single organization. The National Mapping Authority, represented by the Ordnance Survey, is in charge of managing the national geospatial reference system as well as producing, maintaining, and distributing geospatial data [15]. It has partnered with a few commercial information providers, including Leica Geosystems, SmartNet (UK and Ireland), Trimble’s VRS Now, Topcon Positioning System’s TopNetPlus, AXIO-FarmRTK, NET’s, and Soil Essential’s Essentials Net, to offer positioning services in addition to managing over 100 CORS stations for their OSnet service. OS Net, a raw data distributor, is licensed by Ordnance Survey [1].

4.2.2. Sweden

Sweden was among the first European countries to use GPS for navigation, research, and mapping. Lantmateriet, the Swedish authority in charge of mapping, cadastre, and land registry, manages the national CORS network known as SWEPOS and is responsible for geodata coordination throughout the country. The Swedish reference networks, as well as national development, research, and support, are managed by the department of geodesy at Lantmateriet. The control center has access to GNSS data in real time from around 300 stations spread across the nation [1].

4.2.3. Germany

The satellite positioning service SAPOS (der SAtellitenPOSitionierungsdienst) of the German Surveying and Mapping Authority is responsible for the realization of a network of about 270 CORS stations. CORS is owned by the state. SAPOS is a joint project of the Working Committee of the German Geodetic Administration and the authorities of the Federal Republic of Germany, AdV (Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland). It has a fee-based commercial business model and offers consumers three positioning services. With the proper licenses, industry services nationwide can access SAPOS data [1].

5. CASE STUDY IN EUROPE AND THE REGION

In Europe, there are thousands of CORS stations whose data are used for high precision in various applications ranging from reference frame maintenance, monitoring of tectonic deformations and sea-level variations, long-term climate monitoring, weather prediction, space weather, and so on [16].

The EPN was created in 1995 and was a European attempt to coordinate the exchange of GNSS CORS data and metadata. Today, it consists of more than 300 participating stations that follow the EUREF guidelines and whose data and metadata are coordinated by the EUREF station. EUREF also took the initiative to coordinate and analyze data of the EPN Dens. (EPN densification), with 1800 GNSS stations for which metadata is collected and analyzed. In addition to EUREF, there is also E-GVAP (EUMETNET EIG GNSS water VApour Program), which collects and distributes GNSS tropospheric delays and water vapor data from more than 3500 GNSS stations worldwide, but most of which (3000) are located in Europe [16].

Also, Europe is currently building the EPOS (European Plate Observing System), which aims to support Earth science based on 800 GNSS stations. The layout of the European analytical centers, showing the systems for which data is collected, is shown in Figure 1.

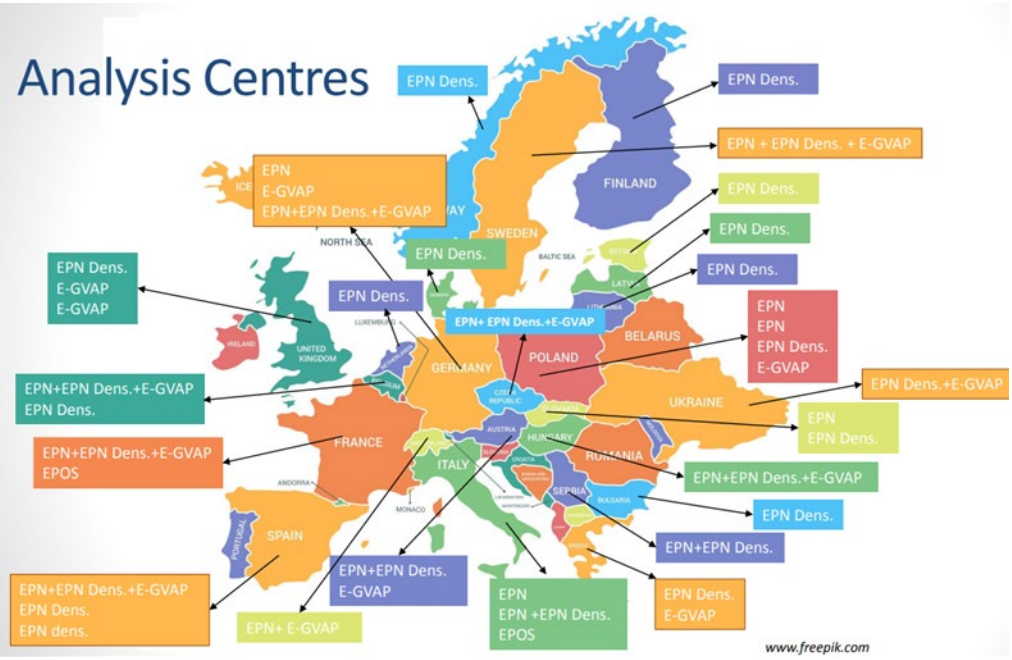

Figure 1. Analysis centers in Europe [16].

The EPN monitoring network has grown significantly from the initial 35 continuously operating stations in 1996 to the 330 multi-GNSS reference stations today. Figure 2 shows the stations of the EPN network. All stations deliver daily data, while 55% deliver data in real time.

83 European agencies work on the EPN monitoring network, based on data from 2019. Of these, 33% are universities, 28% are research-space agencies, 36% are mapping agencies, and several private companies [12].

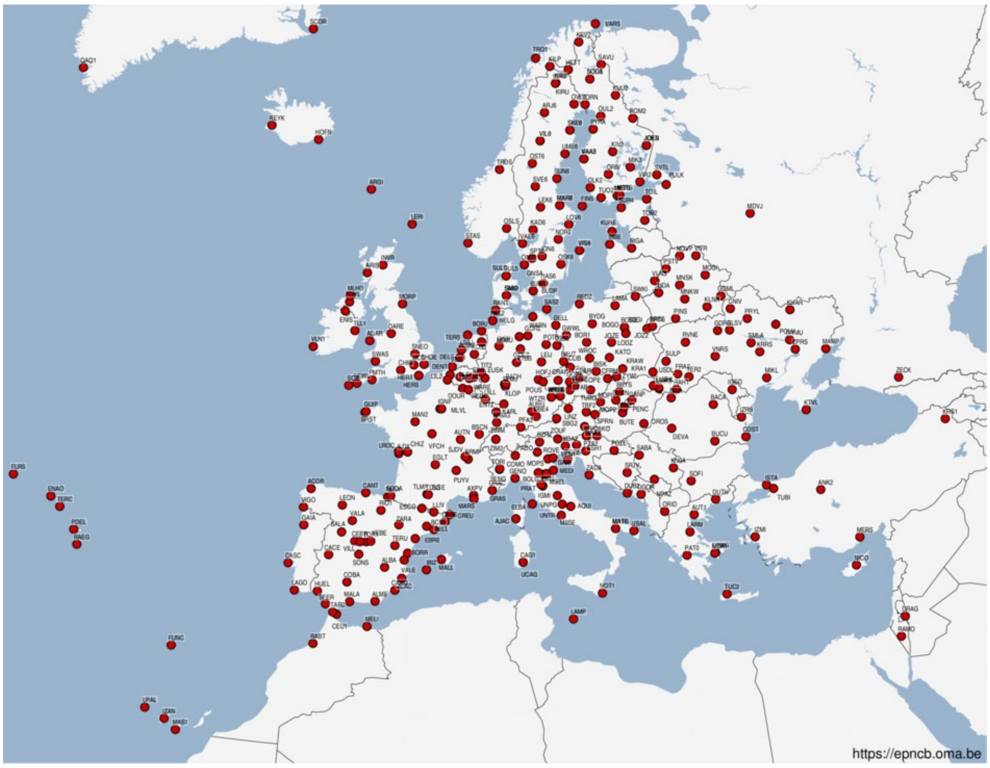

Figure 2. The stations of the EPN network [7].

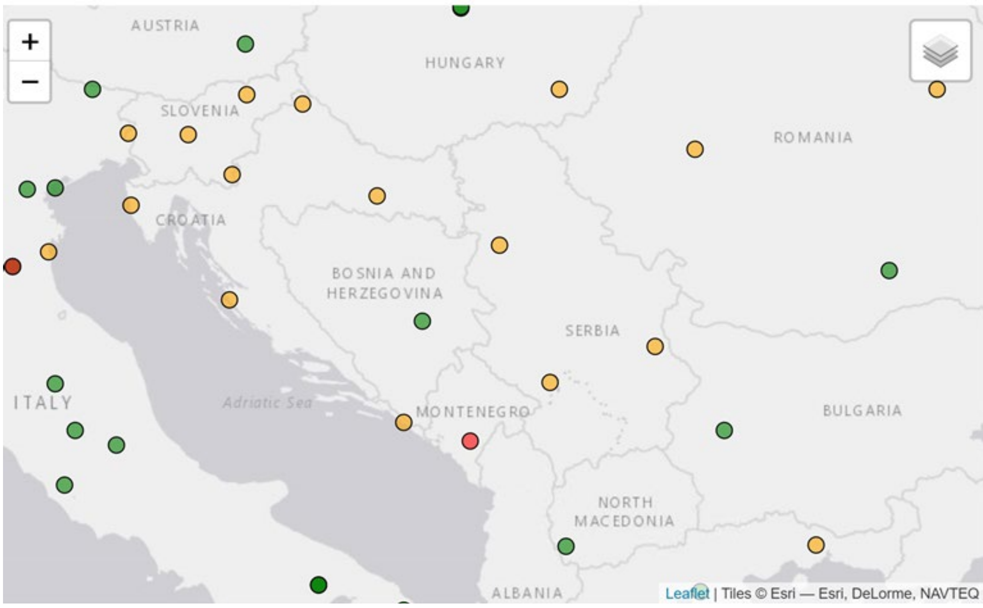

Figure 3. The position of CORS stations in the region which are included in the EUREF network [7].

The position of CORS permanent stations included in the EUREF network is shown in Figure 3. Green-marked stations provide daily, hourly and real-time data, the orange ones only provide daily and hourly data, while red-marked stations provide only daily data.

Table 1. *List of stations in the region that are included in EPN with their specifications [7].*

COUNTRY		Bosnia and Herzegovina	SERBIA	CROATIA	MONTENEGRO
NUMBER OF STATIONS		1	3	5	1
NAME OF STATION		SRJV00BIH	KNJA00SRB (Knjaževac, SRB) NPAZ00SRB (Novi Pazar, SRB) SABA00SRB (Šabac, SRB)	POZE00HRV (Požega, HRV) CAKO00HRV (Čakovec, HRV) PORE00HRV (Poreč, HRV) ZADA00HRV (Zadar, HRV) DUB200HRV (Dubrovnik, HRV)	DGOR00MNE (Podgorica, MNE)
SPECIFICATIONS	RECEIVER TYPE	LEICA GR30	All stations: TRIMBLE NETR9	All stations: TRIMBLE ALLOY	COMNAV M300 MINI
	SATELLITE SYSTEM	GPS+GLONASS+GALILEO+BDS	GPS+GLONASS+ GALILEO+BDS GPS+GLONASS+ GALILEO+BDS GPS+GLONASS	GPS+GLONASS+ GALILEO+BDS+ QZSS[1]	GPS+ GLONASS+ GALILEO+ BDS
	ANTENNA	LEIAR25.R4 LEIT	TRM41249.00 TZGD TRM115000.00 TZGD TRM55971.00 TZGD	TRM115000.00	CNTAT350
	DATA PROVIDED	Daily, hourly and real-time data	Only daily data	Only daily and hourly data	Only daily data
	DATE ROUTINELY ANALYSED BY	ASI[2], BEK[3], BEV[4], RGA[5], UPA[6].	ASI, BEV, RGA, UPA. BEV, RGA, SGO[7], SUT[8], WUT[9]. BEV, RGA, SGO, SUT, UPA	ASI, BEV, MUT[10], SGO, WUT. ASI, BEV, MUT, SGO, UPA. ASI, BEV, MUT, SGO, WUT. ASI, BKG, MUT, SGO, SUT. ASI, BKG, SGO, SUT, UPA.	ASI, BEV, RGA, UPA.
	INCLUDED IN EPN	28. 11. 1999.	27. 9. 2015 21. 6. 2015. 21. 6. 2015.	16. 6. 2013.	15. 12. 2019.

CORS in Bosnia and Herzegovina and countries in the region will be described below.

The first EUREF campaign in the Balkans, called "Balkan98", was realised in 1998 to include the Balkan countries in EUREF. The participating countries were the Federal Republic of Yugoslavia, Bosnia and Herzegovina, and Albania. The BIHREF 98 GPS campaign was organized and implemented on the territory of Bosnia and Herzegovina as part of the EUREF 98 GPS campaign. With this campaign, Bosnia and Herzegovina joined EUREF with Albania and Yugoslavia [17]. As part of the project, 29 new permanent stations are planned.

1 QZSS (Quasi-Zenith Satellite System).
2 Centro di Geodesia Spaziale G. Colombo, Matera.
3 Kommission für Erdmessung und Glaziologie (Bayerische Akademie der Wissenschaften), Munich.
4 Federal Office of Metrology and Surveying Austria.
5 Republic Geodetic Authority, Serbia.
6 University of Padova, Padova.
7 FOMI Satellite Geodetic Observatory, Budapest.
8 Slovak University of Technology, Bratislava.
9 Warsaw University of Technology, Warsaw.
10 Military University of Technology, Poland.

The second EUREF campaign started in 2010 and had the following objectives [18]:

- Densification of points in the Republic of Serbia and Macedonia;
- Control over the existing reference system;
- Integration of the Republic of Serbia into European geodetic activities.

5.1. BIHPOS: SRPOS AND FBIHPOS

The network of permanent GNSS stations in the Republic of Srpska SRPOS was implemented in the "BiHPOS" Project. The initial position of BiHPOS network points is shown in Figure 4. The project was a joint venture of institutions in Bosnia and Herzegovina and was supported by the European Commission. The main goal of the Project is the integration of two systems of SRPOS permanent stations for the territory of the RS (Republic of Srpska), which is under the jurisdiction of the Republic Administration for Geodetic and Property Affairs, RUGIPP (Republička Uprava za Geodetske i Imovinsko-Pravne Poslove) and FBiHPOS for the territory of the FBiH (Federation of Bosnia and Herzegovina), which is under the jurisdiction of the Federal Administration for Geodetic and Property Affairs, FGU (Federalna Geodetska Uprava). With their synchronization, the entire territory of Bosnia and Herzegovina is covered with satellite positioning [19].

The initial constellations of the SRPOS system are:

- 17 permanent GNSS stations;
- control center in Banja Luka;
- jurisdiction (Administrator and owner) – RUGIPP.

The FBiHPOS network was initially characterised by the following:

- 17 permanent GNSS stations;
- a control center in Sarajevo;
- jurisdiction Administrator - FGU.

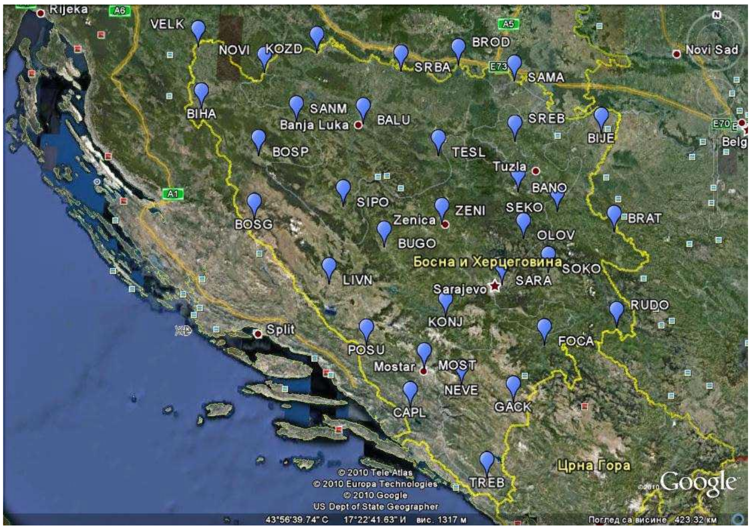

Figure 4. The position of the BiHPOS network [20].

Today, the **SRPOS** network consists of 22 permanently operational reference GNSS stations (Figure 5) at an average distance of 50 km to 70 km. SRPOS is under the jurisdiction of

RUGIPP. The network was expanded with five additional stations compared to the initial state. Mutual data exchange is carried out to provide adequate geometry for both networks, so SRPOS uses the data of additional eight FBiHPOS stations. Data is exchanged with the networks of permanent stations in Croatia, Serbia, and Montenegro - CROPOS, AGROS, and MontePOS – in order to connect the BiHPOS network with the EPN and to improve service coverage in border areas [21].

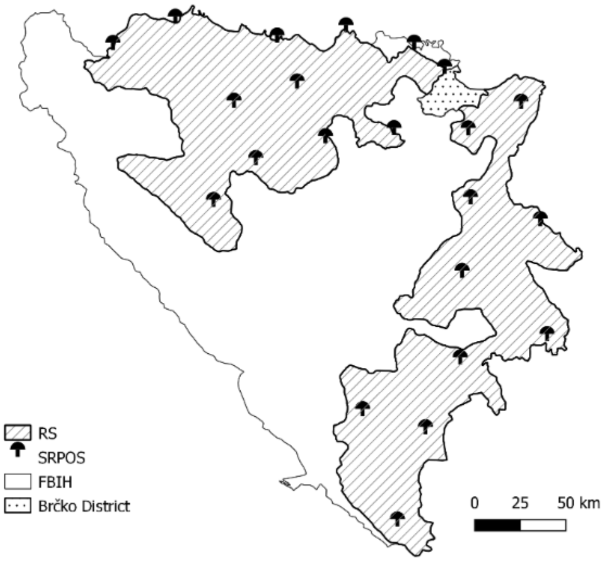

Figure 5. The position of the SRPOS points [21].

The **FBiHPOS** network was expanded with two additional permanent stations and is characterized by the following [22]:

- 19 permanent GNSS stations;
- Permanent GNSS stations are located in an urban environment to facilitate access, management, and security;
- The stations are located near the state border to achieve the level of autonomous functioning, assuming that the full operability of the network enables functioning up to 20 km outside the network polygon;
- 12 stations from the Republic of Srpska and three from the neighboring Republic of Croatia are included in the permanent network to optimize the geometric shape.

In Sarajevo, there is only one CORS permanent station (Figure 6) included in the EPN.

Figure 6. CORS station in Sarajevo [7].

5.2. CROPOS

The Croatian positioning system, CROPOS, was launched on 9 December 2008 by the State Geodetic Administration. During the following period, maintenance, development, and upgrading of the CROPOS system were carried out to ensure work reliability and also to improve existing services. Based on signed agreements, with the aim of better coverage of the border area, as well as preventing loss of reliability in case of interruption of operation of individual reference stations, the Republic of Croatia exchanges data with the Republic of Slovenia, Hungary, the Republic of Montenegro and Bosnia and Herzegovina. Fifty-one reference stations are included in this networked solution and the calculation of correction parameters [23].

The system developed at high speed, so from the day it was put into use until 2018, the availability of the system increased by 99.9%. The number of registered users is also continuously growing, so by 2018, as many as 869 companies with a total of 1293 user names were registered using the VPPS (High Precision Positioning Service), more precisely, the application of the GNSS RTK measurement method in real-time.

During the system establishment, 30 reference GNSS stations were installed, evenly distributed throughout the country at a distance of 70 km from each other. Subsequently, three more reference stations (Nova Gradiška, Hvar, and Dubrovnik) were established to congest the network. The layout of CROPOS network points is shown in Figure 7.

In 2011, the State Geodetic Administration proposed five CROPOS stations for inclusion in the EPN. After a period of control and data analysis, all five stations were successfully included in EPN in June 2013. The stations included are: CAKO (Čakovec), DUB2 (Dubrovnik), PORE (Poreč), POZE (Požega) and ZADA (Zadar).

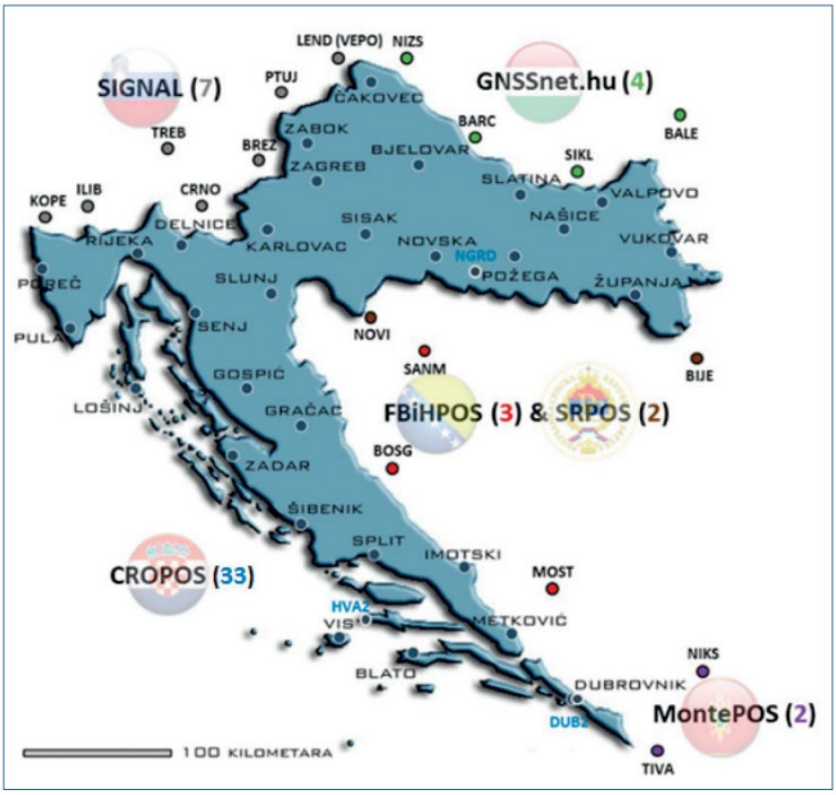

Figure 7. The position of the CROPOS points [23].

5.3. AGROS

In 2001 the network of permanent stations was proposed by the Republic Geodetic Authority in Serbia. The network was established in December 2005 as part of the EUPOS (EUropean Position Determination System) program. The EUPOS was organised by the Berlin Senate Department for Urban Development, which is supported by the European Academy of the Urban Environment. AGROS consists of 30 stations, one control center in Novi Sad, and fully established RTK and DGNSS services, both based on the VRS (Virtual Reference Station) concept. Permanent stations are installed at the buildings of local Real Estate Cadastre offices. AGROS currently consists of 29 permanent GNSS stations (Figure 8) equipped with Trimble receivers. Three AGROS stations (Šabac, Novi Pazar, and Knjaževac) have been included in the EPN since 2015 [18].

Figure 8. The position of the AGROS points [18].

5.4. MONTEPOS

MontePos is composed of nine continuously operating stations and is part of the state infrastructure implemented by the Real Estate Administration in 2005 as the patronizing institution for the field of geodesy in Montenegro.

Network-RTK is a centimeter-accurate, phase-based, real-time positioning technique that can operate at distances of several tens of kilometers while using the nearest station method to provide corrections to ground receivers, but without the ability to receive Galileo and BDS. Nine continuously operating MontePOS permanent stations are relatively regularly distributed throughout the entire territory of Montenegro, at an average distance of about 70 km (Figure 9).

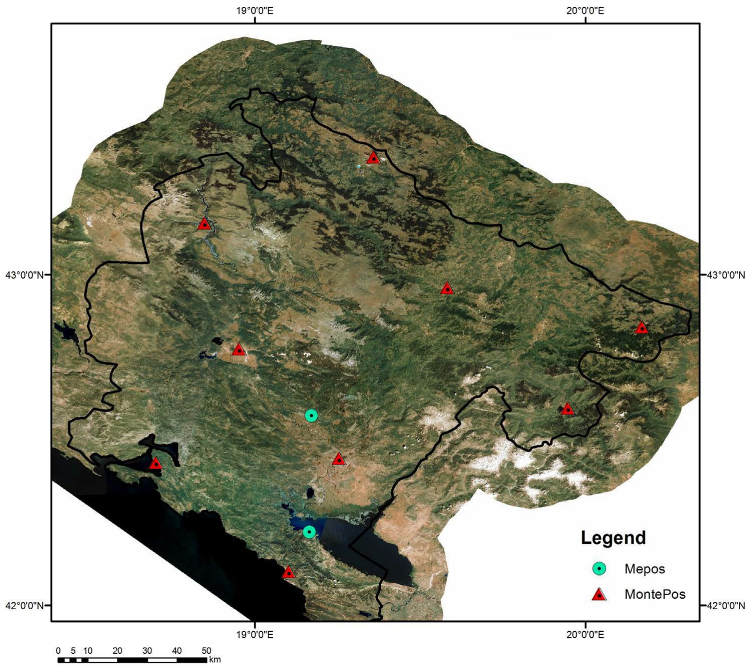

Figure 9. The position of the MontePOS points [24].

At the beginning of 2019, the implementation of the MontePN project was started by the Ministry of Science of Montenegro. It aimed to establish a permanent station network infrastructure, with the possibility of receiving GPS, GLONASS, Galileo, and BDS signals. According to the recommendations for the densification of the EUREF network and the given guidelines for connecting GNSS permanent station networks in the EPN, the establishment of the MontePN network (Figure 10) was realized by the tendency to join the EPN [24].

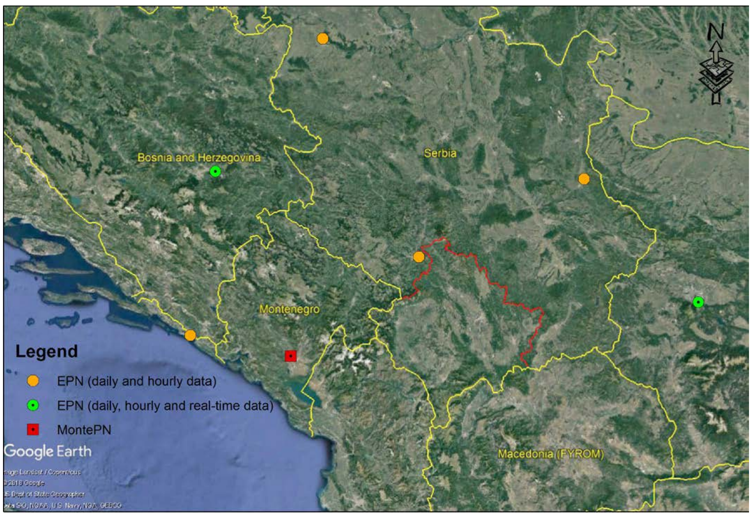

Figure 10. The position of the permanent station of the MontePN network [24].

Montenegro has not yet been included with any MontePOS station within the EPN network. The accession of the MontePN point will significantly contribute to the effort of Montenegro through the improvement of the existing legal regulations related to the field of geodesy, to work towards the adoption of ETRS as the official coordinate system in Montenegro, and the recommendations of EUREF [24].

6. LEGAL REGULATIONS IN THE REGION

Quality legislation can influence the implementation and establishment of a network of permanent GNSS stations. The following regulations regulate this area into a region:

- Regulation on the application of satellite measurements in geodesy - Federation of Bosnia and Herzegovina;
- Regulation on establishing a network of GNSS permanent stations - Republic of Serbia;
- Regulation on the application of global navigation satellite system technology in the fields of survey and cadastre - Republic of Serbia;
- Regulation on the method of performing basic geodetic works - Republic of Croatia;
- Regulation on cadastral survey of Republika Srpska - Republika Srpska.

In the RS, there are no law regulations in this area. However, basic guidelines of the GNSS surveying method for the cadastre needs are given as part of the Regulation on the cadastral survey of the Republic of Srpska [25]. Also, there is an Instruction for the application of the Global Positioning System method for determining detail points [26], as well as a brochure for using the SRPOS network of permanent stations [19].

In the FBiH, the Regulation on the application of satellite measurements in geodesy is in force [27]. This regulation determines the geodetic works during real estate surveys that can be realized using GNSS methods, as well as the methodology, accuracy, and calculation procedures used on that occasion. Also, the Rulebook describes the BiHPOS state network of reference GNSS stations of Bosnia and Herzegovina, as well as the transformation of WGS84/ETRS89 coordinates into the state coordinate system.

In the Republic of Croatia, this area is defined by the Regulation of the method of performing basic geodetic works [28]. The CROPOS network is described in Section 1 of this Regulation, and the method of using the CROPOS network and GNSS measurement methods are explained in more detail in the Annex to the regulation on geodetic studies.

In the Republic of Serbia, there is a Regulation on the establishment of a network of GNSS permanent stations [29] and a Regulation on the application of global navigation satellite system technology in the fields of state survey and cadastre [30]. The Regulation on the establishment of a network of GNSS permanent stations regulates the manner and conditions under which networks of permanent stations using GNSS technology are established on the part of the entire territory of the Republic of Serbia.

7. CONCLUSIONS

Today, CORS networks are used worldwide for scientific and commercial needs in various application sectors. Data should be made available with minimal restrictions to optimize the benefits of these networks. Also, it is important for users to contribute to the system by sharing data to improve the application system. By sharing information and using international standards, redundancies are reduced, and the scope of use is expanded.

The paper describes the CORS network in Europe and the region, as well as how the current infrastructure was perceived, in order to identify potential areas for progress and collaboration in data exchange. It was concluded that in order to achieve complete transparency, it would be necessary to resolve the so-called "gray" zone between public and private GNSS users. With an open exchange model, the advantage of GNSS can be optimized, resulting in continued government support for the GNSS program and development.

By analysing the experience and structure of CORS networks in Europe, the subject of further research could be the examination of the optimality of local CORS networks from the point of densification of existing ones, the quality of PNT services at each spatial point, and the need for modernization of existing stations from the aspect of signal reception from new global satellite systems, application of modern algorithms and equipment for eliminating sources of errors.

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AUTHOR’S BIOGRAPHIES

Dragana Skorup

Dragana Skorup was born on 20 September 1992 in Nevesinje. She completed undergraduate studies in 2015 at the Faculty of Architecture, Civil Engineering and Geodesy, University of Banja Luka. In the same year, she enrolled in master's studies at the Faculty of Technical Sciences, University of Novi Sad, study programme of Geodesy and Geomatics, which she completed in 2016. She is a PhD candidate at the Faculty of Technical Sciences, University of Novi Sad.

Slavko Vasiljević

Born in 1989 in Zagreb. He graduated in 2012 from the Department of Geodesy, Faculty of Architecture, Civil Engineering and Geodesy with a GPA of 10.00. He was awarded the Golden plaque from the University of Banja Luka as the best student of the FACEG. He earned his master's degree in 2015 from the Department of Geodesy and Geoinformatics, Faculty of Civil Engineering, University of Belgrade, with a 10.00 GPA. He is currently working on his doctoral thesis at the Faculty of Civil Engineering, University of Belgrade. His research focuses on engineering geodesy and deformation analysis of engineering structures.

CORS МРЕЖЕ, АСПЕКТИ ПОСЛОВАЊА У ЕВРОПИ И РЕГИОНУ

Сажетак: У раду је приказан начин функционисања CORS перманентних мрежа у свијету. Посебна пажња дата је EPN мрежи, као и регионалним CORS мрежама у Босни и Херцеговини, Србији, Црној Гори и Хрватској. BiHPOS: SRPOS и FBiHPOS, AGROS, CROPOS и MONTEPOS анализиране су са аспекта међусобне размјене података с циљем постизања боље прецизности локација и уклањања недостатака у геометријама мрежа. Њиховим појединачним развојем, као и међусобно склопљеним споразумима о размјени података, мјерења добијена помоћу GNSS данас имају широку примјену, почевши од морског саобраћаја, авијације, па до инжењерских послова, праћења земље и слично. Такође, приказане су тачке региона које су укључене у EPN мрежу с циљем размјене података на европском нивоу.

Кључне ријечи: GNSS, CORS перманентне мреже, EPN