IGS Workshop 2008: Status of Real-time & Pilot Project operations

10 minutes presentations + 30 minutes discussion

(Oral Presentations)

1. **Overview and Status of the pilot project**

Mark Caissy (Natural Resources Canada, Geodetic Survey Division)

2. **Network Management and Data Exchange Interfaces**

Georg Weber (Bundesamt fuer Kartographie und Geodaesie, Germany)

3. **Real Time Pilot Project: Analysis Centre Activities**

Loukis Agrotis (ESOC [Symban Ltd], Robert- Bosch-Str. 5, D-64293 Darmstadt, Germany)

ESOC has taken the role of Analysis Centre Coordinator for the Real Time Pilot Project. The objective is to establish a Pilot Service through the contribution of a number of Analysis Centres and to publish a Real Time combination solution of clock and orbit products. Improvements to this service, through the improvements of the products from the contributing centres, will come through collaboration to enhance the analysis techniques and through improvements to the quality and distribution of the receiver systems. Product comparisons between AC product sets and published IGS Finals will allow assessments of the individual solutions and enable the Real Time community to track the quality of the combination, as well as allowing the ACs themselves to track their performance. The immediate challenge is to reach agreements on standards and formats for data and product dissemination, making them easily available to a wide range of users.

This paper presents the activities undertaken by ESOC and the proposed Analysis Centres towards reaching the Pilot Project Objectives. It covers the initial discussions undertaken so far, the current status of the contributing agencies and the plans for the establishment of the Pilot Service.

4. **Real-time clock estimation for precise orbit determination of LEO-satellites**

André Hauschild (German Aerospace Center DLR, D-82234 Wessling, Germany)

The paper/presentation discusses the real-time estimation of clock offsets for the GPS constellation. A realtime system for clock estimation is currently developed by DLR/GSOC to support up-coming missions which require precise orbit determination in near-real-time. The algorithm is based on a Kalman-filter and estimates the GPS satellite clock based on predicted IGU orbits. The filter processes ionosphere-free combinations

of the code and carrier phase observations from global Ntrip-data streams. The estimated parameters are therefore globally valid and are suitable for orbit determination of LEO-satellites. The accuracy of the orbit/clock-product is assessed with a precise orbit determination of a representative LEO-spacecraft. The results of this analysis are compared to the results obtained using other (real-time) orbit/clock products for the orbit determination.

5. **Progress of the real-time GNSS software development at GFZ**

Junping Chen, Maorong Ge, Markus Vennebusch, Zhiguo Deng(*), Gerd Gendt, Markus Rothacher (Department of Geodesy and Remote Sensing GeoForschungsZentrum Potsdam, Germany) ; (*) Institut of Geodesy University of Stuttgart, Germany

With the increasing number of stations providing real-time data streams, the development of corresponding software packages is playing a much more important role in order to speed up the IGS real-time pilot project. A related software package, as a prototype of the future real-time GNSS software at GFZ, has been developed recently for both real-time deformation monitoring and providing service for applications based on Precise Point Positioning(PPP) under the framework of the G-SEIS (GPS-SurfacE deformation monitoring withIn Seconds).

Besides accuracy, latency and reliability are critical issues in a real-time system. After a brief introduction of the software package, the relevant strategies implemented in the software are discussed in details. We concentrate on the approach for real-time data pre-processing, for improvements in the square root information filter for saving computation time and for efficient on-line quality control within the filter as well. The impacts on the real-time clocks of network geometry, orbit accuracy and tropospheric delay handling and satellite attitude modeling are studied by running the software with simulated data streams. Consequently their effects on real-time positioning are investigated as well.

Using the NTRIP data streaming technology, raw data of globally distributed GNSS stations is retrieved from the BKG Ntrip Client provided by the Federal Agency for Cartography and Geodesy (Germany), and is used for the estimation of both satellite clocks for PPP and station positions in network mode. The results are validated with IGS final products and with known station positions.

6. **Real-time GPS orbit and clock estimation using PANDA software**

Shi C., Lou Y., Zhao Q., Liu J., GNSS Research Center, Wuhan University, P.R. China

In this presentation, the PANDA (Position And Navigation Data Analyst) software, which has being developed at Wuhan University for GNSS data processing for variant applications in both post and real-time mode, is introduced briefly. Then, new strategies for real-time orbit and for clock estimation are discussed in details. They are realized in PANDA software and are tested using simulated real-time data from about 70 IGS stations. The test shows that the accuracy of the derived real-time orbits is about 5cm and that of the 1Hz real-time clock corrections is about 0.2ns, compared with the IGS final

products. The accuracy of the Precise Point Positioning using the estimated real-time products is about 5cm and 10cm for horizontal and vertical component, respectively.

(Poster Presentations)

1. **Efficient dissemination of the orbit predictions in real-time**

Jan Dousa (Geodetic Observatory Pecny, Research Institute of Geodesy, Topography and Cartography)

We developed a unique and efficient dissemination of the IGS ultra-rapid orbits for the real-time applications (either for satellite clock estimation or later usage with precise clocks). The polynomials for each satellite position component in ECEF are estimated, distributed and the orbits can be very simply evaluated by real-time users for any epoch within the hourly validity interval. Different strategies for the polynomials estimation were tested and the requirements and the stability compared. The GOP prototype using NTRIP protocol is provided at ntrip.pecny.cz caster with software developed also for backward routine evaluation of the 'real-time portion' of the orbit prediction with respect to precise IGS rapid product. The distribution aspects are discussed as well as the comparison and reliability of the different strategies.

2. **Real Time GNSS Processing at ESOC: Infrastructure and Initial Results**

John Dow[(1)], Loukis Agrotis[(2)], Carlos-Garcia Martinez[(3)], Alexandre Ballereau[(1)], Pedro Alfaro[(3)] ([(1)]ESOC, Robert- Bosch-Str. 5, D-64293 Darmstadt, Germany, [(2)]Symban Ltd, 22 Marshal's Drive, St Albans, UK, [(3)]ESOC GMV, Robert-Bosch-Str. 5, D-64293 Darmstadt, Germany)

ESOC has been working over the last six years in establishing a Real Time GNSS capability. In the network area, ESOC has a well-established commitment for the installation of GNSS reference stations at the ESA Ground Stations. The receivers benefit from the established station infrastructure, including the presence of on site staff, good horizon masks, geodetic monument stability, powerful communication networks, air-conditioning and connection to atomic or H-maser oscillators. For the last five years the stations have been delivering data in real time to the IGS relays and broadcasters, making a very important contribution to the geographical distribution of the real time IGS network. ESOC is supporting the improvement of the current IGS real time network by trying to encourage contributions from station operators located in areas of sparse coverage.

In parallel to the receiver deployment activities, ESOC has embarked on a program to build a Real Time software infrastructure. RETINA (System for Real Time Navigation) has been modelled after ESOC's experiences in Real Time satellite control systems and includes many of the elements for data processing, archiving and visualisation that are common to such systems. The GNSS data streams from the receivers are treated in much

the same way as a control system handles spacecraft telemetry streams. In this way, RETINA provides a generic infrastructure for access to streaming data, allowing the development of applications that can operate seamlessly with both Real Time and historical data. Generic utilities include configurable applications for graphical and alphanumeric visualisation of data and results, either in Real Time or through retrievals. A Job Scheduling application integrates Batch and Real Time tasks, providing scheduling and monitor and control capabilities. The GNSS processing applications include a batch system for generating near-real time orbit and clock solutions and a Real Time Estimation application which uses the batch orbits to estimate satellite and receiver clocks, Tropospheric Zenith Delays and phase biases. In the paper, the RETINA Real Time and Batch results since the beginning of 2008 will be presented through comparisons with IGS solutions and the issues encountered in the data analysis will be identified and discussed.

3. **Realtime GNSS activities at GeoForschungsZentrum Potsdam**

M. Vennebusch, M. Ramatschi, J. Chen, C. Falck, M. Ge, T. Nischan, M. Rothacher

Currently, GeoForschungsZentrum is working on three different fields towards realtime GNSS: robust on-site GNSS hardware as a foundation of a reliable data source, realtime data transfer/streaming of GNSS raw data and development of a realtime GNSS analysis software.

On the hardware side, GFZ extends its existing GNSS network of 29 stations (21 of them providing highrate / realtime data) for e.g. radio occultation and CHAMP- support. Therefore, new station hardware is being developed with improved reliability features and enhanced remote administration capabilities.

On the data transfer/streaming side, so far, both TCP data streams of proprietary data format and transfer of data files containing 15 minutes of 1-Hz-raw data has been used. Now, in addition, these proprietary data streams are being converted into RTCM3 format and uploaded to a GFZ Ntrip-broadcaster. This approach guarantees both low latency and completeness of GNSS raw data.

On the software side, a realtime-capable, filter-based analysis software is currently under development for applications such as e.g. deformation monitoring or satellite clock estimation in realtime. First results of a prototype software will also be presented in an oral presentation.

4. **West of São Paulo State real time GNSS network**

João Francisco Galera Monico, Daniele Barroca Marra Alves, West São Paulo State University (FCT/UNESP), Brazil

In the past few years, it can be noticed an increasing effort to provide GNSS data in real time with the goal of supporting several applications. In order to follow this tendency a real time GNSS network was set up in west region of São Paulo State, Brazil. One of the main objectives of this network is to increase the number of GNSS active stations in this region in order to provide news opportunities for positioning techniques. Nowadays, six active stations are available. The data are made available in real time through the Internet, by using NTRIP (Networked Transport of RTCM via Internet Protocol) protocol. The station receivers are directly connected to the Internet, and the data are sent to a central computer for being stored and analyzed. This network presents a good configuration to accomplish investigation in the west region of the State, as well as for operational purpose. The establishment of the West São Paulo State Network will contribute with the necessary infrastructure for the development of researches concerning geodesic positioning and investigations and applications related to Meteorology, Ionosphere and others. The interested users in getting real-time data of these stations can use the NTRIP accessing provided by BKG (Federal Agency for Cartography and Geodesy – Germany) home-page. Furthermore, the data can also be accessed directly from FCT/UNESP, where there is a NTRIP Caster installed. Three of these stations provide data for investigating the GPS modernization, specifically the new L2C code. It is an initiative of IGS and the data can be accessed in GSFC (Goddard Space Fight Center) of NASA, in ftp://cddis.gsfc.nasa.gov/gps/data/l2ctest/. Besides, a proposal for participating in IGS Real-Time Pilot Project was submitted and accepted by the IGS Governing Board. The aim is to participate in two categories: Real-time Tracking Stations; and Real-time Data Centers (first type - Real-time Data-file Center). This presentation has the goal of presenting the available infra-structure of the West São Paulo State Network, besides to describe the difficulties for keeping such kind of network always on-line.

5. **The BKG Ntrip Client (BNC)**

Georg Weber, Federal Agency for Cartography and Geodesy (BKG), Frankfurt, Germany
Leos Mervart, Czech Technical University Prague, Department of Geodesy

The BKG Ntrip Client (BNC) is a program for simultaneously retrieving, decoding and converting real-time GNSS data streams from NTRIP broadcasters like http://www.euref-ip.net/home or http://www.igs-ip.net/home. Its purpose is to read GNSS data streams available through NTRIP transport protocol, generate high-rate RINEX Observation and Navigation files to support near real-time GNSS post-processing applications, and/or generate ephemeris and synchronized observations epoch by epoch through an IP port to support real-time GNSS engines, and/or monitor the performance of a network of real-time GNSS reference stations to generate advisory notes. BNC supports the GNSS stream formats RTCM Version 2.x, RTCM Version 3.x, and RTIGS/SOC.

BNC has been developed for the Federal Agency for Cartography and Geodesy (BKG) within the framework of EUREF's Real-time GNSS Project (EUREF-IP) and the Real-Time IGS Pilot Project (RTIGS). It has been written under GNU General Public License (GPL). Pre-compiled binaries are available for Windows, 32-bit Linux, 64-bit Linux, Solaris, and Mac systems from

http://igs.bkg.bund.de/index_ntrip_down.htm.

BNC's Qt Graphic User Interface (GUI) has been written by Leos Mervart, Czech Technical University Prague, Department of Geodesy and includes GNU GPL software components from Oliver Montenbruck, German Space Operations Center, DLR, Oberpfaffenhofen, Dirk Stoecker, Alberding GmbH, Schoenefeld, and Ken MacLeod, Natural Resources, Canada.

6. **Monitoring the Real-time IGS NTRIP Interface**

Georg Weber, Federal Agency for Cartography and Geodesy, Germany (BKG) Carine Bruyninx, Royal Observatory Belgium (ROB)

In 2003 a first NTRIP Broadcaster was set up to disseminate GNSS streams from EUREF and IGS reference stations in Europe over the open Internet. In 2006 this activity was extended by the operation of an NTRIP Broadcaster at www.igs-ip.net, especially dedicated to streams coming from the globally distributed IGS network. Following the latest developments in the Real-time IGS Working Group, since 2008 this Broadcaster takes over the function of an NTRIP Interface for the Real-time IGS Pilot Project.

From the very beginning, it was understood that developing real-time monitoring tools is not only essential but actually indispensable. Hence, shell scripts were written first to once-per-minute detect outages and feed a notification system. Notice Advisories to Broadcaster Users (NABUs) are being sent out to inform station operators in real-time about malfunctioning receivers or problems in the communication link. Meanwhile the assembled Monitor System has been complemented by software (namely the BKG Ntrip Client) which continuously reads and decodes all streams. It is hereby possible to detect corrupted observations and incorrect or incomplete meta-data every second.

The technical part of the RTIGS Ntrip Interface Monitoring System is operated at BKG, and its observations are published on the Web by ROB, see www.igs.oma.be/real_time/. Maps show the distribution of reference stations, corrupted or unavailable streams as well as their latencies and meta-data. Long-term statistics for outages, stream usage, and availability of highrate RINEX files complete the picture. Furthermore, background information is provided to guide users to Real-time IGS resources through related links.