IGS Real-time Network Prototype

M. Caissy

In order to better serve the multi-disciplinary user community, the IGS continues to enhance its standards, infrastructure and availability of data and products in accordance with its strategic plan. In preparation for the future delivery of real-time products, the IGS, through the efforts of the Real-time Working Group, has implemented a real-time network prototype for global real-time data/product collection and distribution. The prototype design is modeled on the recommendations of the IGS "Towards Real-time" workshop, held in April 2001. This presentation will illustrate the current status of the network prototype and highlight the major elements. Management aspects and performance characteristics will also be featured.

Real Time Aspects, the JPL Perspective

R. Muellerschoen

The JPL architecture for a real-time Wide Area Differential GPS (WADGPS) system was first put forward by Tom Yunck in 1995. A commercial North American WADGPS system based on the JPL architecture and software was implemented in 1997 through partnership with Satloc, Inc and in 1996 the US Federal Aviation Administration (FAA) selected the JPL architecture and software as a prototype for their Wide Area Augmentation System (WAAS). In a paper presented at the Institute of Navigation National Technical Meeting in January, 2000 entitled “An Internet-Based Global Differential GPS System, Initial Results,“ Muellerschoen described the world’s first real-time global differential GPS (GDGPS) system. Using Internet-based technology for real-time streaming and novel algorithms for on-site data editing of GPS data from NASA’s Global GPS network (GGN), combined with the real-time orbit determination software, RTG (Real-Time GIPSY), Muellerschoen reported achieving ~20 cm real-time positioning accuracy for a ground-based GPS receiver.

In the four years since, JPL continues to refine techniques and algorithms, improve upon the robustness of the network infrastructure, and upgrade its operations. The system has evolved into a fully operational and highly reliable service. Combined NASA and commercial resources have allowed it to remain economically viable. Users have access to two independent operation centers. These centers have redundant computer infrastructures and redundant communication channels (Internet and Frame Relay) for access to the global raw observables. The ground network has evolved into a diverse network-of-networks, providing multiple paths for the raw observables. And software technology has also been continuously refined to improve both the reliability and accuracy through automatic fault detection and tuned orbit estimation techniques.

The GDGPS service provides a real-time 1-Hertz correction stream to authorized users via several communication channels. The first is the open Internet, where a user can connect to a TCP or UDP server running at one of the operation centers. A second dissemination system was developed together with a commercial partner, Navcom Technology Inc., a Division of John Deere. The system uses three Inmarsat geosynchronous communications satellites to relay the correction messages on their L-band global beams, and provide global coverage from latitude –75° to +75°. A third distribution method now in development will provide support for space borne operations through NASA's Tracking and Data Relay Satellite System (TDRSS). Low Earth orbiters will have access to seamless coverage at all latitudes. This new TDRSS Augmentation Service for Satellites (TASS) should enable autonomous onboard orbit determination to better than 10 centimeters in real-time.

Our third generation of corrections reduces latency by two seconds without sacrificing robustness. Adaptive weighing methods have been developed to self compensate long-term GPS clock biases. We continue to investigate filtering and modeling techniques to reduce short-term biases. Automatic switch over of failed or missing stations allows consistent correction latencies. And robustness is further provided by automatic and graceful transition of differential correctors in case of failure of any one process.

To support the development of standards for real-time data dissemination, JPL provides the IGS with 5 globally distributed real-time 1-Hertz data streams. High quality data standards are maintained through stringent on-site data editing at the remote sites to ensure that phase breaks are appropriately flagged and large (> 20 meter) range outliers are discarded.

Acknowledgement

The work described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

Global Products for GPS Point Positioning Approaching Real-Time

Y. Gao, P. Heroux, M. Caissy

The real-time availability of precise GPS satellite orbit and clock products has enabled the development of a novel positioning methodology known as precise point positioning (PPP). Based on the processing of un-differenced pseudorange and carrier phase observations from a single GPS receiver, positioning with centimeter to decimeter accuracy can be attained globally. Such accuracy can currently be achieved only through differential processing of observations acquired simultaneously from at least two receiver stations. The potential impact of PPP on the positioning community is expected to be significant. It brings not only great flexibility to filed operations but also reduces labor and equipment cost and simplifies operational logistics by eliminating the need for base stations. Global consistency is another significant gain over the differential approach. Although IGS post-mission precise orbit/clock products are now available for public access, the demand for real-time orbit/clock products is expected to increase as end-users apply this methodology to support single-point real-time kinematic (SP-RTK) positioning applications.

This paper will address issues related to the development and implementation of precise point positioning models that are likely to affect future real-time kinematic applications. They include new algorithm development, error/bias identification and characterization, and estimation strategy for un-differenced carrier phase processing. Accelerated convergence and improved ambiguity resolution algorithms are among several challenges that require increased research efforts. Furthermore, the availability of real-time orbit/clock products is of importance to the successful development and implementation of the new technology and widespread adoption by the user community. Numerical results will also be presented to show the positioning accuracy attained with datasets acquired from different environments using real-time precise orbit/clock products currently available. Features of a software package that has been developed at the University of Calgary to facilitate user access to the PPP methodology presented in this paper will also be described.

The EUREF-IP Ntrip Broadcaster: Real-time GNSS data for Europe

D. Dettmering, G. Weber

The Internet is an excellent medium for the real-time collection and exchange of GNSS data. It is best qualified for broadcasting differential corrections as well as other observed or derived GNSS products. The EUREF community, as being responsible for the regional densification of IGS in Europe, decided to set up and maintain a real-time GNSS infrastructure on the Internet using stations of its European GPS/GLONASS Permanent Network EPN. A pilot project has been established called EUREF-IP (IP for Internet Protocol). The purpose of this project is the dissemination of Differential GPS corrections (DGPS) for precise positioning and navigation and the dissemination of raw GNSS data in support of various other real-time activities.

The EUREF-IP real-time GNSS data service uses a new dissemination technique called "Networked Transport of RTCM via Internet Protocol" (Ntrip). Ntrip stands for an HTTP application-level protocol streaming GNSS data over the Internet. The main component of the service is an Internet Broadcaster which currently provides access to about 140 real-time data streams.

This paper introduces the EUREF-IP Ntrip Broadcaster with its available real-time data streams from different networks. It focuses on data availability and latency, positioning accuracy, and service monitoring aspects.

ESA/ESOC Real Time Infrastructure

C. Garcia, J. Dow, J. Perez, I. Romero

During the second half of 2002 and the first half of 2003 ESA/ESOC has updated its GPS Network for the provision of high rate real time data at all the sites (Kiruna, Kourou, Malindi, Maspalomas, New Norcia, Perth, Redu and Villafranca). It has been possible thanks to the availability of very stable IP connectivity. An application has been developed that is flexible enough to be used in different configurations to take into account the firewalls that are present in the various subnetworks (Intranet, corporate LANs and operational LANs). A compression scheme for the standard NMEA format has been developed to reduce the bandwidth. All the stations have been equipped with redundant Linux computers. The provision of the real time data of the first stations of the ESA/ESOC Network to the IGS Real Time project is expected by early 2004.

A HTTP Based Technique for Streaming GNSS Data Over the Internet

H. Gebhard

The massive worldwide growing of Internet capacity enables the introduction of new services such as Internet Radio or Internet Video-on-Demand, which transfer continuous data-streams by IP-packages. These services include the data transport via mobile IP-Networks like GSM, GPRS, EDGE, and UMTS where costs are nowadays rapidly decreasing.

As a consequence, the global Internet can be used for the real-time collection, exchange, and broadcast of GNSS data within the framework of IGS. Compared to Multimedia applications, the bandwidth required for streaming GNSS data is relatively small. The introduction of a real time streaming of GNSS data via Internet as a professional service is demanding with respect to network transparency, network security, program stability, access control, remote administration, scalability and client simplicity.

This paper will discuss several possible technical/protocol solutions for streaming IGS data over the Internet: Unicast vs. IP-Multicast, TCP vs. UDP, Client/Server vs. Client/Server/Splitter architecture. Based on this discussion, a novel HTTP-based technique for streaming GNSS data to stationary or mobile clients over the Internet is introduced. It allows simultaneous access of a large number of Desktops, PDAs, Laptops, or GNSS receivers to a broadcasting host over wired or mobile IP-Networks.

Starting with System design questions, this paper will describe the “Networked Transport of RTCM via Internet Protocol (Ntrip)” system. The Protocol design and the basic communication of all Ntrip components (NtripServer, NtripClient, NtripCaster) will be discussed.

GFZ's Development of GPS Real-Time Network

R. Galas, W. Köhler

The presentation describes the real time infrastructure developed at GFZ. Currently GFZ's GPS real time network is composed of ten globally distributed stations. These autonomous stations make 1Hz GPS observations available. The tracking station architecture, hardware as well as software are described. The data is streamed over the internet using UDP protocol. Additional S/W modules allow to dispense old data files on user request. Various aspects of the real time network operation and data handling are discussed in detail. Finally, selected network monitoring utilities and the data performance are presented.

Impact of Imperfect Orbits on Ground-based GPS Atmospheric Sounding Applications

P. Fang, Y. Bock, S. Gutman

This study assesses the practical impact of less perfect orbits upon real-time troposphere sounding applications using ground-based GPS. In the process of estimating tropospheric delay, especially when relatively short session of data are used, a few factors in terms of precise orbit quantity and quality can negatively impact the outcome of the delay estimates. The contributing factors may include: 1. reduced number of satellites included in the precise orbits due to quality control rejection, 2. precise orbits produced using global network with poor geographic configuration (network holes), 3. precise orbits generated with data gaps, especially in the end of a session due to data supply interruption, 4. less behaving satellites included in the precise orbits. Factor 1 will result in lack of observations to be used for estimating the delay. The spatial distribution of the observations will also be poor, implying the delays may not be sensed in certain direction. Factor 2 will cause orbit accuracy loss over certain region, thus introducing bias in the delay estimates. Factor 3 implies orbital arcs are estimated with less data to fit which may affect the quality of predicted orbits. This situation is different from full span of data are used while the orbit product latency is increased which may still produce reasonably good predicted orbits.

Real-Time IGS Protocol, Formats and Software Tools

K. MacLeod, M. Caissy, R. Fong, B. Twilley, J. P. Bartolome, C. Garcia-Martinez, R. Galas, R. Muellerschoen

Members of the Real-Time IGS (RT-IGS) working group have spent the last two years designing, developing and implementing a prototype real-time network. During this period, message formats and an exchange protocol where established. With the basic infrastructure established, real-time operational centers developed software tools to enable the transmission and reception of real-time data. This poster describes the existing RT-IGS architecture, formats, protocols and enabling software.

Real-Time Wide-Area Differential GPS Corrections from Natural Resources Canada

P. Collins, F. Lahaye, K. MacLeod, Y. Mireault, P. Heroux

Natural Resources Canada (NRCan) has been providing real-time wide-area differential corrections for Canadian GPS users for the last 8 years. These corrections are now the foundation for the Canadian Differential GPS Service (CDGPS) which has been in operation since September 2003. The current

pseudorange-based corrections are the first step towards high-precision phase-based corrections. The modified-RTCA message format used by NRCan has the ability to encapsulate sub-centimetre-level corrections to enable a seamless transition to higher quality performance. The current positioning quality within Canada is on the order of 70cm 2drms. The positioning quality achieved with the phase-based corrections is currently limited to 40cm 2drms due to the regional nature of the observing network. NRCan is currently testing its correction software with a prototype global solution using approximately 20 stations from both the IGS LEO network and the nascent IGS real-time network. Positioning results with these corrections is on the order of 20cm 2drms. It is envisioned that further algorithm and orbit refinement will improve these results toward the level of 10cm 2drms. With this level of corrections, not only does high precision navigation become a reality for Canadian GPS users, but also real-time precise time transfer and tropospheric monitoring.

Swedish Activities During 10 Years as a Data Provider and Customer of the IGS: Realtime Applications

C. Rieck, P. Jarlemark, R. Emardson, J. Johansson, B. Stoew, A. Frisk

The Swedish permanent network (SWEPOS) consists of 57 stations that produce GPS, and GLONASS, data available via TCP/IP connections in real time. We have developed GNSS processing software for real time different real time applications. It is based on a Kalman filter that simultaneously estimate clock offsets, atmospheric parameters, and, if necessary, improvements to the satellite clocks and coordinates. In this presentation we focus application related to real time transfer of time and frequency using GPS carrier phase data and estimation of Zenith Total Delay (ZTD) caused by the neutral atmosphere and the estimation of the Total Electron Content (TEC).

For time and frequency applications the filter and data communication software proved to be capable to perform relative time and frequency comparisons in real-time. Differences of about 50 ps rms between real-time processing and GIPSY standard post-processing for short baselines are achievable. An important advantage is that no day boundary problems exist. The ZTD quality is typically 15 mm in terms of rms difference to post-processed ZTD time series. This level of uncertainty is useful in many navigation applications and if an additional reduction in the uncertainty can be obtained the usefulness for short-term weather forecasting could be significant.