Real-Time Reality

by Arthur R. Andrew III, PLS

A progressive RTK network in California deems the setting up of a base station a thing of the past.

Imagine having the ability to survey using Real-Time Kinematic (RTK) technology anywhere in your local area without having to set up an RTK base station. You just step out of your vehicle, power up the RTK rover and within minutes you have the position needed to within a few centimeters. You then power down the RTK rover, put it back in the vehicle and set off to the next point or job. No more dealing with finding an RTK base station location (or several) or having to hassle with setting up all that RTK base equipment, and leaving someone to watch it or risk leaving it unattended. This technological dream has become a reality and is currently implemented in Orange County, California. The result of an intense pilot project, the Orange County Real Time Network (OCRTN) benefits more than the land surveyor. It also assists the scientific community by improving estimates of earthquake potential and by analyzing—in near real-time—positional elements from an earthquake. Since their GPS partnership project in the 1990s, the scientific and surveying communities in Southern California have shared many resources; the OCRTN is yet another of those valuable resources.

A Concept of Real Proportions

The County of Orange Public Facilities and Resources Department's Geomatics/Land Information Systems Division (Geomatics Division), along with the California Spatial Reference Center (CSRC), initiated a pilot project to develop a real-time Global Positioning System (GPS) network in Orange County for easier and more accurate RTK procedures. The system has enabled surveyors to perform surveys more efficiently, and to obtain better redundancy and assurance in their RTK positions. The scientific community also benefits from the network, as they can now perform real-time crustal deformation monitoring, allowing them to identify areas of concern following a significant earthquake.

The concept began in the late part of 2000. William Young, PLS, then chairman of CSRC and Dr. Yehuda Bock, PhD, director of CSRC and board member of the Southern California

Integrated GPS Network (SCIGN), asked John Canas, PLS, Orange County surveyor, if the Orange County Geomatics Division would be willing to participate in a real-time GPS network pilot project. The proposal suggested that Orange County would serve as a great location for this project as the Division has many years of experience with GPS technology and the current SCIGN Continuous Operating Reference Station (CORS) sites are already in place and could be used for the real-time network. Ken Hudnut, PhD, coordinating board chairman of SCIGN, gave the project team his blessing to upgrade the desired sites to support real-time data streaming. Geomatics Division's roles and responsibilities in this project were to maintain and upgrade the CORS sites to real-time status, collect and archive raw GPS data and provide RTK corrections at no cost to users of the network. CSRC's role was to provide the development, support and expertise required for the project. Through this project, it could be determined if real-time networks would be beneficial and if CSRC could apply the results to future networks in California. Thus, from the pilot project, the OCRTN was developed.

Charting Out the Objectives

The OCRTN CORS site, "WHYT" was installed in June 2001.

There were two main objectives of the OCRTN project. The first objective was to streamline high-rate raw GPS data at a 1-second rate with low latency (less than two seconds) from the CORS sites to a system of computers configured to collect the data located at the Geomatics Division office. From there, the raw GPS data could be accessed by CSRC, SCIGN, and any other requested users. This computer system would archive the 1-second raw GPS data files and generate 15-second RINEX files. The second objective was to generate and make available RTK corrections using the standard Radio Technical Commission for Maritime Services (RTCM) data format (message types 3, 18, 19, 22) to anyone at no cost for RTK surveying and dynamic positioning in Orange County. This would mean that anyone with the proper equipment could use this data for real-time precise positioning.

The SCIGN network consists of approximately 250 CORS sites located throughout Southern California with emphasis on the greater Los Angeles metropolitan region. The majority of the SCIGN CORS sites are monumented with the Wyatt/Agnew Drilled Braced Monument. This monument is a five-legged tripod with stainless steel legs welded together at the top and driven into the ground to the point of refusal, which can be as deep as 30 feet. The OCRTN CORS sites are all equipped with Ashtech Z-12 or Micro-Z dual-frequency receivers (Thales Navigation, Santa Clara, Calif.) with Dorne-Margolin choke ring antennae.

For the scientific community, the SCIGN network plays an important role in providing regional coverage for estimating earthquake potential throughout Southern California. It is used to measure local variations in strain rate that might reveal the mechanical properties of earthquake faults. In the event of an earthquake, this network is an important tool for measuring permanent crustal deformation not detectable by seismographs, as well as the response of major faults to the regional change in strain.

For the land surveyor, the majority of the CORS sites are extremely stable and provide Southern surveyors have had a great working relationship with the scientific community and both groups have benefited immensely from this. In the early 1990s, GPS survey campaigns were performed by the scientific and survey communities together for crustal monitoring. Through sharing of resources, both communities gained extensive knowledge in the field of GPS that typically can only be obtained through years of experience.

A total of 10 SCIGN CORS sites, which have an average station spacing of about 15 kilometers, were selected to make up the current OCRTN network. Of the 10 sites, eight sites already existed and are located in Orange County. One site, “CAT2,” located on Santa Catalina Island also serves as a radio repeater for site “SCMS,” which is located near the ocean in the southern part of Orange County. One additional site, “BLSA,” was installed in November 2002 to fill a void in the northwest portion of Orange County.

Before the real-time network, data at these CORS sites was collected at 30-second intervals and downloaded every 24 hours using telephone lines and 900 MHz radios. Now the data is collected at a 1-second rate and streamed in real-time to the computer system located in the Geomatics Division office via FreeWave spread spectrum 900 MHz radios. These radios have been very reliable and have performed their tasks well.

Further aiding the scientific community, the CORS positions can be analyzed in near real-time to realize horizontal and vertical displacements relative to the network following an earthquake.

Upgrading Sites for Acceptance

The first step to establishing the OCRTN was to upgrade all the sites for streaming real-time data. Glen Offield, senior developing engineer for Scripps Institute of Oceanography at the University of California, San Diego, designed the network of telemetry connections and was able to use two of the sites as repeaters for the sites that did not have a direct line of sight to the Geomatics Division building. Offield and his staff, along with the Geomatics/Geodetic Unit staff, installed the FreeWave radios and Yagi antennae. The computer system is made up of two Dell Precision 340 workstations and was installed in the Geomatics Division office along with an array of antennae located on top of the building used to receive the raw GPS data stream. One workstation is dedicated to archiving raw GPS data and generating RINEX files; the second generates and makes available the RTK corrections. On May 7, 2002, raw GPS data began streaming in real-time from seven sites to the first workstation. The two additional sites were added June 12, 2002.

Art Andrew, PLS, uses the Leica SR530 rover.

IT - Network Issues

In the beginning, we at the Geomatics Division did not realize how essential it would be to build the network infrastructure to support the requirements of our Division and that of the CSRC. However, we found that to serve our surveying clients effectively, we would require a network system that allows them to access the data via the Internet without compromising the security of

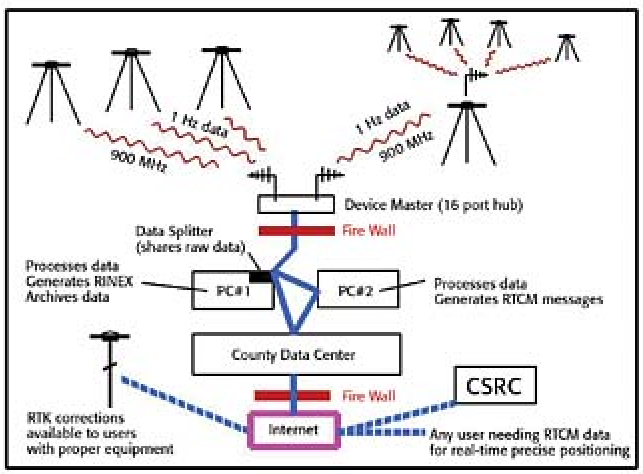
Technology section played a large role and used their expertise in designing and implementing this portion of the network. The result is a secure and robust network that allows access to OCRTN data 24 hours a day, 7 days a week.

Network RTK

Since we had 10 sites streaming data to the Geomatics Division workstation in real-time, our plan was to convert these sites into RTK base stations and generate RTK corrections that would be available via the Internet using Transmission Control Protocol/Internet Protocol (TCP/IP). These corrections would not only be used by Geomatics Division field crews; they could be accessed by anyone at no cost. This required that the RTK rover would need a wireless radio that could access the Internet via TCP/IP. Geomatics Division has a large assortment of GPS equipment from four different manufacturers and we wanted this network to work with our existing equipment. We also wanted to be able to “double determine” from at least two different base stations. This would allow the RTK rover to connect and receive RTK corrections from one base station, compute a position, disconnect and re-connect to a different base station and compute another position. As for the users who aren’t sure where the base stations are located, we needed a method that would automatically stream RTK corrections from the nearest base station to the RTK rover. For communication, we chose AirLink Raven II, CDPD modems. CDPD, which stands for Cellular Digital Packet Data, is an efficient and secure wireless packet data technology ideal for untethered applications. In Orange County, AT&T is the service provider for CDPD.

Current Software Solutions

There are currently two different software solutions running simultaneously, Geodetics RTD (Geodetic Inc., San Diego, Calif.) and Trimble Virtual Reference Station, or VRS (Trimble, Sunnyvale, Calif.). Both products were loaned to the CRSC for testing and evaluation on OCRTN. Both products are similar in that they accept raw GPS data from multiple sites, generate RINEX files, archive files, and generate RTCM messages for RTK corrections. It is transparent to the RTK user which software is generating the RTCM message.



The current OCRTN network infrastructure.

We have two different RTK modes currently in use, nearest base station and single base station. Nearest base station is used when the RTK rover user doesn’t know which base station is closest to his location. Using this mode, the OCRTN workstation receives the RTK rover position (latitude, longitude and height) in the National Marine Electronics Association (NMEA) format and streams the RTK corrections from the closest base station. This mode only allows corrections from one base station. The second mode, single base station, doesn’t require the NMEA position. Each base station has an Internet Protocol (IP) address and designated port number. The RTK rover can then choose from which base station to receive RTK corrections. This mode gives the user the ability to “double determine” a point from more than one base station.

Current RTK Users

To convert the Division's existing RTK rovers to work with OCRTN, the Airlink Raven II CDPD modems and compatible cables were the only purchases necessary. The CDPD modems work well except when affected by cellular network traffic and poor cellular coverage. With help from Bill Haaf, PLS, of the CALTRANS District 12 and James Yaccino from Surveyors Service Company (Apex, N.C.), my staff and I spent considerable time configuring the modems and receivers. At this time, Ashtech/Thales, Leica Geosystems (Atlanta, Ga.), and Trimble receivers are being used for positioning and surveying using RTK corrections from the OCRTN. The users are Geomatics Division field crews, CALTRANS and local private survey firms.

Glen Offield, Robert Deal and Craig Whaley install radio repeater antennas on Modjeska Peak.

The main question during the pilot project of the OCRTN was, "How well does network RTK work?" Based on our field tests so far, which involved positioning points from a single visit, horizontal and vertical accuracies are usually within 2 cm and 4 cm, respectively, 90 percent of the time. Baseline lengths have been from 1 to 37 km and we haven't seen accuracies degrade significantly relative to baseline lengths. We have done comparisons on positions based on both modes (single base station versus double determination) from two or more base stations and positional accuracies are better achieved when positions are "double determined." This method also gives a validity check on the position. The TTF, or Time To Fix (the length of observation time it requires to resolve integer ambiguities in real-time) is usually between 15-120 seconds, and the variation of time depends on the number of satellites being observed and the Positional Dilution of Precision (PDOP) value, which is used to express the strength of the satellite geometry. There are times when an ambiguity fix has been unachievable. Along with the previous causes that affect TTF, site location, satellite obstructions and radio frequency interference (RFI) are other items of consideration when unacceptable results are obtained.

OCRTN already has proven to be an extremely beneficial tool for surveyors and the scientific community in Southern California. It has established a reliable geodetic reference frame for Orange County and provided users with real-time data that can be used for all different aspects of real-time precise positioning. It has truly enabled efficient real-time surveying by a one-person crew by canceling the requirement to set up an RTK base station. It's a land surveyor's dream—now a reality.

Arthur R. Andrew III, PLS, supervises the Geodetic Control unit for the County of Orange in California, where he has been employed for 16 years. He is responsible for all geodetic surveys, including projects involving control, monitoring, deformation and real-time networks. He has been the project manager of the Orange County Real Time Network (OCRTN) and has played a major part in its design and implementation.