Virtual Reference Stations (VRS) (RTN)
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Overview

- Why VRS/RTN?
- The Concept of Virtual Reference Stations
- A typical network setup
- Required Hardware
- Data communication
- VRS Performance
Classical RTK Surveying

- Local reference station required
- Error growth with baseline length
- Rover/Reference distance is limited due to error growth
- Reliability and Performance decrease with distance from reference
Limitations of Classical RTK Surveying

- Limited range from single reference station
- Potential gross error in establishing reference station
- No integrity monitoring
- Dependency on single reference station
- Productivity loss
- Coordinate System
- Security
- Communications FCC
- Power supply
Classic RTK Example
VRS - How does it work?

- Uses observations from multiple reference stations
- Continuously monitors integrity of reference station data
- Models systematic errors including:
  - ionosphere
  - troposphere
  - satellite orbit errors
  - multipath
- Creates a unique virtual reference station for each user’s location
- Delivers the data in RTCM or CMR+ format to the rover
GPS Positioning

Four distance measurements are needed to determine position and time
GPS Signals

- Troposphere and Ionosphere affect signals
GPS Signals

- Troposphere
  - Region of atmosphere where weather occurs (up to 50-80 km altitude)
  - Wet and Dry component
  - Varies largely based on water vapor content in the atmosphere
  - Frequency independent
  - Affects GPS heights
GPS Signals

- Ionosphere
  - Region of atmosphere 50-1000 km filled with charged particles
  - Creates non-linear dispersion of electromagnetic signals (frequency dependent)
  - Varies substantially based on sunspot activity, solar flares, latitude and time of day and elevation of the satellite signal
GPS Signals

- Variable signal paths and piercing points
Satellite-Receiver Double Differences

\[ \nabla \Delta p = \nabla \Delta \rho + \nabla \Delta d_{\text{ion}} + \nabla \Delta d_{\text{trop}} \]

\[ \nabla \Delta \Phi = \nabla \Delta \rho + \lambda \cdot \nabla \Delta N - \nabla \Delta d_{\text{ion}} + \nabla \Delta d_{\text{trop}} \]
What do we do about the differential Iono and Tropo errors?

- Keep distances between base and rover short.
  - Assume that the remaining errors are the same at both base and rover
  - Greater the distance is, the less likely this assumption is to be valid
What do we do about the differential Iono and Tropo errors?

- Model the iono and tropo
  - Using observations from known stations, create a model of the biases
  - Concept used for creating the broadcast models for the tracking segment of GPS
  - Concept used for FAA WAAS Augmentation system on a national level
  - VRS Concept
Why use VRS/RTN™?

- Extended operating range with improved initialisation and accuracy
- Increased productivity
- Eliminates need to establish reference station
  - Set-up, power, physical security become non-issues
- Provides integrity monitoring
- All users in common, established coordinate frame
- Eliminates dependency on single reference station
- Uses established communications
Data Flow in Network using digital cell phone

Reference Station ➔ Raw Data ➔ Reference Station

GPS Network ➔ Router

Reference Station ➔ Reference Station
Data Flow in the Network

Reference Station

Reference Station

Raw Data

GPS Network

Router

Rover

Reference Station

Reference Station
Data Flow in the Network

Reference Station

Reference Station

Raw Data

GPS Network

Router

NMEA Position

Reference Station

Reference Station
Data Flow in the Network

Reference Station

Raw Data

GPS Network

Router

NMEA Position
Reference station data streams back to server through LAN, Internet, or radio links
VRS Data Flow

Roving receiver sends an NMEA string back to server using cellular modem. Virtual Reference Station position is established.
VRS Data Flow

Server uses VRS position to create corrected observables and broadcasts them to the rover.
Rover surveying in normal RTK mode but data is relative to the VRS.
### CSVSN: Operation Status: Summary View

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<th>Host Group</th>
<th>Service</th>
<th>Last Checked</th>
<th>Est. Next Check</th>
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<td>Yuba City</td>
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</tbody>
</table>

Service color legend:
- **Unchecked**
- **Good**
- Failed (no alerts sent)
- Failed (alerts sent)
- **Disabled**

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For questions about this server, contact ed@baseline.com
Real-Time Test Setup in the Network

- Operation of rover (32 km from the nearest reference station)
- After each fix the RTK system outputs position data for 30 seconds
- After that the RTK system initializes the ambiguity search again, no data from the past is used
- All position output is stored on an extra PC and analyzed statistically
VRS Performance Analysis

- 90 hours day/night
- Rover 32 km from Ref 3

Ref 1

Ref 2

Rover

Ref 3

Ref 4

70 km
Error in North – 32 km Baseline

Confidence Level
90 %: < 13 mm
99 %: < 26 mm
Error in Height – 32 km Baseline

Confidence Level
90 %: < 25 mm
99 %: < 49 mm
RTK Initialization – 32 km Baseline

Performance:
- 50%: < 40 sec
- 90%: < 80 sec
- Average: 58 sec
Initialisation Times in the SAPOS Network

Performance
516 Initialisations
Average: 57 Sec.
Advantages of VRS/RTN™

- Extended operating range with improved initialisation and accuracy
- Increased productivity
- Eliminates need to establish reference station
  - Set-up, power, physical security become non-issues
- Provides integrity monitoring
- All users in common, established coordinate frame
- Eliminates dependency on single reference station
- Uses established communications Cellular data
GPS Deformation Monitoring

◆ Purpose:
  ◆ To monitor and model the movement of man made and natural structures to prevent and warn against potential catastrophes using GPS and integrated sensors.
  ◆ To monitor the integrity of high order geodetic networks
GPS Deformation Monitoring

- Target Markets
  - Oilfield Subsidence
  - Dam deformation monitoring
  - Landslide monitoring
  - Volcano monitoring
  - Geodetic network monitoring