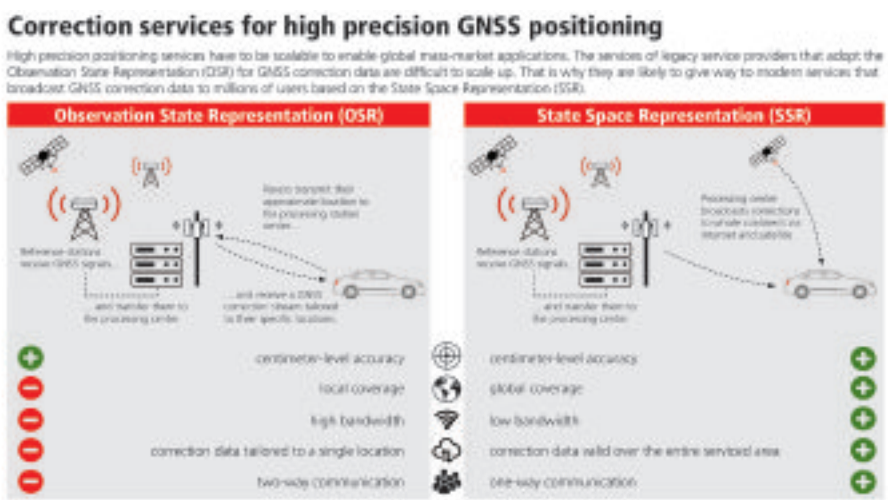

Figure 1. Observation space representation (OSR) versus state-space representation (SSR)

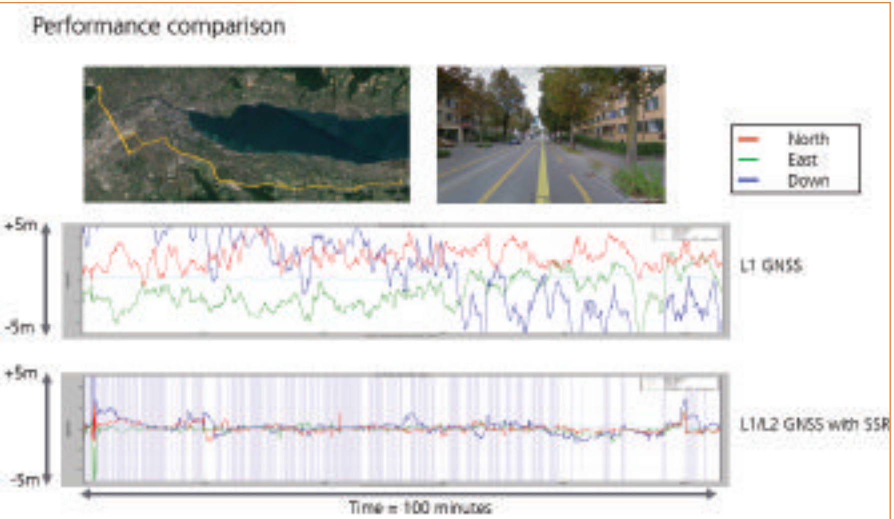

Figure 2. Performance comparison between single-band GNSS and dual-band GNSS with SSR correction data

High-precision GNSS systems dramatically improve precision using GNSS correction data to cancel out errors. One way to obtain this data involves monitoring GNSS signals from a base station at a known location. Deviations from the base station's position are observed and sent to a rover (a manned or unmanned vehicle equipped with a GNSS receiver) allowing it to obtain a more accurate position reading. In favourable conditions, this approach can be used to achieve centimetre-level accuracy, provided that the base station and the rover are not too far apart.

But not all GNSS errors can be eliminated using this approach. Because satellite signals that reach the base stations are subject to many of the same errors as those that reach the rovers, correction data can be used to eliminate satellite position and clock errors, as well as atmospheric errors. Multipath errors, however, which are caused by the local surroundings of the rover (such as high-rises), must be addressed by the receiver itself.

High-precision GNSS isn't new. Surveyors, for instance, have had access to the technology for decades. But high device cost and reliance on expensive correction services have prevented the technology from expanding out of this niche market. What's new is that we now have technologies that make high-precision GNSS attractive to the mass market, enabling applications such as lane-accurate navigation; augmented reality; aerial drone precision flights and landing; unmanned lawnmowers and tractors; and vehicle-to-everything (V2X) communication (in which connected vehicles communicate wirelessly with other vehicles and infrastructure for collision avoidance). Many more applications will undoubtedly emerge as the technology is adopted.

Future high-precision GNSS will be composed of multiple elements: on the ground, reference stations will monitor signal errors in real time; and correction services will broadcast the error components via the internet and geostationary satellites.

Bringing high-precision positioning to the mass market

There are two ways in which correction service providers can transmit GNSS error data to rovers, but only one of them can be scaled up to meet the needs of the mass market. In observation space representation (OSR)-based approaches, correction service providers compute the expected observed errors at the location of each individual rover and transmit this information to them wirelessly. Conversely, in approaches based on state-space representation (SSR), observed GNSS signal errors are used to physically model the errors across an entire region as a state-space model. The parameters describing the state-space model at any given time are then broadcast to rovers across the modelled region.

OSR is adopted by real-time kinematic (RTK) and network RTK satellite navigation, which are used today in settings requiring centimetre-level or even millimetre-level positioning accuracy. These approaches are accurate when the base station and the rover are within 30 kilometres of each other. OSR-based approaches require two-way communication between the rover and the correction service provider. Because mobile communication networks would struggle to reliably sustain this level of communication (were it to be widely adopted), this makes them poorly adapted for mass-market applications. SSR-based approaches get around this by broadcasting a single stream of correction data for the entire serviced area to all rovers. This simplified means of communication – and the fact that it can deliver robust service at a relatively low reference station density (150 to 250 kilometres) – makes it the only feasible approach for mass-market applications, such as highly-assisted driving.

Improved performance will also come from advanced receiver hardware, capable of receiving more information from the satellites. While the first generation of GNSS satellites only transmitted its signals in a single frequency