Imagine being able to turn on a GNSS receiver anywhere (outdoor) anytime and able to achieve centimetre level precision in real-time, without a GNSS base station and without having to connect to a CORS network.
Evolution of High Precision GNSS

- **1980s**: Early commercial single-frequency post-processing around early 1980s; Differential service for marine applications; Commercial dual-frequency around 1988

- **1992**: First commercial Real-Time Kinematic (RTK) solutions followed by Network RTK (NRTK)

- **Late 1990s**: Birth of Precise Point Positioning (PPP)

- **Now**: A hybrid system of “PPP-RTK”

### High Precision GNSS Service Quality Matrix

<table>
<thead>
<tr>
<th>GOOD</th>
<th>FAST</th>
<th>CHEAP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Schrock (2013), ProSurv, Horvath (2012), PPP-RTK Workshop

### Anatomy of PPP

- **Precise Point Positioning (PPP)** allows a dual-frequency GNSS user to determine position at the decimetre / centimetre error level in kinematic / static mode using precise satellite orbits and clocks

#### Standard Positioning Service

- Broadcast orbit and clock information
- User satellite tracking information
- m-level user position estimates

#### Precise Point Positioning

- Precise orbit and clock information
- User satellite tracking information
- Additional error modelling
- dm- to cm-level user position estimates

Source: Schrock (2013), ProSurv, Horvath (2012), PPP-RTK Workshop
Use and Applications

- Commercial applications:
  - Trimble CentrePoint™ RTX™
  - NavCom Global StarFire™ Service
  - Fugro’s Precise (Point) Positioning Service
    - XP, G2
  - Veripos Ultra (Ultra²) and APEX (APEX²) Service

PPP is feasible for positioning and navigation in remote areas or regions of low GNSS reference stations.

Challenges in PPP

- PPP can be most certainly CHEAP and even GOOD, but the challenge lies in the realm of FAST.
- Search for a “sweet spot”, i.e., trade-offs between precision and convergence time.
- Why can’t PPP provide instantaneous centimetre level precision in real-time like RTK?

Source: Bisnath and Collins (2012), GEOMATICA
What is PPP-RTK? (1)

- **Two kinds of RTK:**
  1. **Observation Space Representation (OSR)**
     - rely on "observations" (e.g., observations from a base station)
     - OSR describes lump sum of GNSS errors
     - example: RTK services use network of reference stations and RTK rovers use observations of reference station(s)
  2. **State Space Representation (SSR)**
     - rely on “error states” products (e.g., clock, orbit, atmosphere models)
     - SSR describes each individual GNSS error
     - example: PPP uses observations of single GNSS receiver and state space information (e.g. IGS products) derived from global or regional network

What is PPP-RTK? (2)

- **Distinction between PPP vs RTK**
  - CORS network size
    - RTK service: local, regional
    - PPP service: wide area, global
  - CORS network dependence
    - RTK user: No network = no solution
    - PPP user: What network?

- **PPP-RTK ???**
  - Looks ‘suspiciously’ like RTK
  - Prefer the term RTK-SSR!!
Does PPP Have a Future?

- Low infrastructure
- Computationally effective
- Small data files (corrections) for transmission
- Changing GNSS landscape – Opportunities
  - new systems, new signals, new frequencies, ……
- Transmission of corrections from GNSS satellites, e.g., QZSS LEX (L6/E6) signal
  - similar to broadcasting navigation message

Do We Still Need CORS Network?
Terima Kasih
&
Thank you

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How Good is a PPP Solution?

<table>
<thead>
<tr>
<th>Processing Mode</th>
<th>RMS (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>East</td>
</tr>
<tr>
<td>Daily static</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Hourly static</td>
<td>~4</td>
</tr>
<tr>
<td>Post-processed kinematic</td>
<td>~5</td>
</tr>
<tr>
<td>Real-time kinematic</td>
<td>&lt;10</td>
</tr>
</tbody>
</table>

Source: Geng (2010), PhD thesis
### High Precision GNSS Service Quality Matrix

<table>
<thead>
<tr>
<th></th>
<th>RTK/NRTK</th>
<th>PPP</th>
<th>RTK-SSR/PPP-RTK</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GOOD</strong></td>
<td>Centimetre</td>
<td>Decimetre</td>
<td>Centimetre</td>
</tr>
<tr>
<td>Precision/Accuracy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>FAST</strong></td>
<td>Fast initialisation</td>
<td>Long convergence</td>
<td>Fast initialisation</td>
</tr>
<tr>
<td>Initialisation time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CHEAP</strong></td>
<td>Dense network</td>
<td>Sparse network</td>
<td>Dense network</td>
</tr>
<tr>
<td>Base station</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Dilemma (trade-off):**

- **GOOD** service **CHEAP** won’t be **FAST**
- **GOOD** service **FAST** won’t be **CHEAP**
- **FAST** service **CHEAP** won’t be **GOOD**

Source: Schrock (2013), ProSurv; Horvath (2012), PPP-RTK Workshop

### PPP Scalability

- Broadcast orbits & clocks
  - SPS
- Precise orbits and clocks
  - PPP
- Precise orbits and clocks + hardware delays
  - PPP-AR
- Precise orbits and clocks + hardware delays + local augmentation (ionosphere)
  - PPP-RTK or PPP-ICAR

Source: Collins (2013), PPP Workshop
Will We Need New Rover Equipment?

Real-Time Kinematic Test in Australia

- Date: 23 October 2013
- Location: Centennial Park, Sydney, Australia
- Reference frame: ITRF2008 → GDA94
- Observations: dual-frequency, GPS only
- PPP mode: real-time kinematic
- Orbits and clocks:
  - IGS (CLK11)
  - QZSS MADOCA
    (LEX signal transmission)
- NRTK: CORSnet-NSW
- Ground truth: NRTK solutions
- Vehicle speed: ~20 km/h
Real-Time Kinematic PPP Performance

<table>
<thead>
<tr>
<th></th>
<th>QZSS LEX (PPP)</th>
<th>IGS (PPP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>East (cm)</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>North (cm)</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Up (cm)</td>
<td>8</td>
<td>6</td>
</tr>
</tbody>
</table>

STD | RMS | STD | RMS
--- | --- | --- | ---
2   | 5   | 3   | 9
2   | 3   | 2   | 4
8   | 10  | 6   | 7