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Delivering Precise Positioning Services in Regional Areas

Matt Higgins
Leader Project 1.04, Cooperative Research Centre for Spatial Information (CRCSI),
Principal Survey Advisor, Department of Natural Resources and Water, Queensland, Australia
Phone: +61 7 3896 3754, Fax: +61 7 3891 5168, Email: matt.higgins@qld.gov.au

ABSTRACT

On July 1 2007, the Cooperative Research Centre for Spatial Information (CRCSI) commenced a new research project to investigate the issues associated with extending Global Navigation Satellite Systems (GNSS) precise positioning services into regional areas. Such regional services are required for a growing number of applications in agriculture, mining, utilities, construction, tourism, defence and environmental protection.

Around the world there are now many networks of GNSS Reference Stations delivering real time centimetre accuracy positioning to users. Most of those networks are in areas of high population density with excellent Internet and mobile communications infrastructure. This project will address the issues associated with delivering such GNSS Reference Station networks in rural and remote areas of Australia, which are characterised by sparse populations and lesser quality Internet and communications infrastructure. The project is divided into two parts; the first part addresses business issues and the second part addresses the technical issues.

This paper concentrates on the first part of the project, which is researching and defining the business enablers to service adoption (commercial, operational and institutional) when extending a service into regional areas.

It is intended that Project 1.4.1 will develop a prototype for partnering among the project participants that can more effectively deliver precise positioning services to regional areas. While the prototyping will be based in Queensland, it is possible that such a business and partnership models may also be attractive for application in other states of Australia and to other sparsely populated areas of the world.

KEYWORDS: GNSS Reference Stations, Network RTK, Business Models, Partnership Models, Regional Areas, CRCSI.

1. INTRODUCTION

On July 1 2007, the Cooperative Research Centre for Spatial Information (CRCSI) commenced a new research project to investigate the issues associated with extending Global Navigation Satellite Systems (GNSS) precise positioning services into regional areas. For the purposes of CRC Project and for this paper, the term "precise" is defined as less than 5 centimetres horizontally at 95% confidence. This paper will outline how regional services are required for a growing number of precise positioning applications in agriculture, mining, utilities, construction, tourism, defence and environmental protection. Many of these applications involve so-called "machine guidance" where farming or earth moving equipment is positioned very precisely leading to significantly increases in productivity.

Around the world there are now many networks of GNSS Reference Stations delivering centimetre accuracy positioning to users in real time. The physics behind deriving centimetre accuracy GNSS corrections is such that reference stations need to be spread across the area of interest with maximum spacings of approximately 60 to 70km.

Many existing networks elsewhere in the world tend to be in areas of so-called "thick infrastructure", with high user population density and with good communications for both the reference stations and for the users' roving receivers. In Germany for example, the SAPOS network has been established primarily with Government funding and covers the entire country. Germany is also well served by the very latest in communications technologies.

In contrast to the German situation, the Australian state of Queensland is 5 times the area of Germany with only 1/20th of the population, which means that the per capita cost of establishing such a network across Queensland is 100 times more than in Germany. Therefore, in Queensland and in many other sparsely populated areas of Australia and the rest of the globe, there is a need to devise innovative funding and partnership models to achieve the coverage from the GNSS reference station networks and communications networks required to deliver precise positioning to users in regional areas. The CRCSI project described in this paper will address the issues associated with such service delivery in sparsely populated areas.

The problem and therefore the CRCSI project, can be divided into two parts. This paper concentrates on the first part of the project dealing with the business issues; the other part of the project dealing with the technical issues, for example see Feng, Rizos and Higgins (2007).

The first part of the project is researching and defining the business enablers to service adoption (commercial, operational and institutional) when extending a precise positioning service into regional areas. It is intended to develop a prototype for partnering among the project participants that can more effectively deliver precise positioning services to regional areas. While the prototyping will be based in Queensland, it is possible that such a business and partnership models may also be attractive for application in other states and territories of Australia and indeed, in many other sparsely populated areas of the world.

2. THE GROWING MARKET FOR PRECISE POSITIONING

A study recently commissioned by the Queensland Government and undertaken by Position One Consulting estimated the Australian market for precise positioning to be over $120 million per year and on the cusp of rapid growth. The greatest challenges to the implementation of GNSS and Spatial Information products and services are in regional and remote parts of Australia. In these areas, the agricultural, utilities, mining, tourism, transport, defence and environmental protection industries will all benefit from improved positioning services.

The Position One Consulting report gives examples from Queensland of the economic benefits that can accrue to various industries from precise positioning, including:

- The mining industry reports productivity increases of as much as 30% by adopting GNSS technology. GNSS is used for a variety of tasks including surveying, grading, dozing, drilling and fleet management;
- GNSS machine control in the form of auto-steer is widely used in the grain, cotton, sugar and horticultural sectors of Queensland agriculture. An estimated 15% of grain growers in Australia use GNSS for machine guidance and 9% for auto-steer. Using auto-steer for control traffic farming can reduce input costs of fuel, seed, fertilizer, herbicide and time by 10-20%;
- In civil engineering, by using GNSS machine control and other innovative techniques the Port of Brisbane Motorway was completed six months ahead of schedule (30% reduction in time required), with a 10% reduction in total project costs, 10% reduction in traffic management costs and 40% reduction in lost time injuries;
- By introducing GNSS pilotage systems and improved channel tolerances, 4 fewer buoys were required at the Hay Point Terminal with a cost saving for the Department of Transport of approximately A$4 Million;
- In the spatial market, surveyors using the Department of Natural Resources and Water's SunPOZ precise positioning service, report productivity improvements of 30-50%;
- Photogrammetric surveys in regional Queensland by Main Roads have been decreased from 4 months to 1 week through the use of GNSS;
- Rail track survey costs for Queensland Rail have been reduced by 80% through the introduction of GNSS based automated track surveys, and;
- The time taken for mapping and reporting fire fronts has been reduced from 6-7 hours to 1-2 hours by the Department of Emergency Services.

Even with the promise of such significant benefits, widespread adoption is constrained by the lack of necessary infrastructure to deliver the precise positioning services. One solution has been to implement private systems to cover individual business operations. A disadvantage of this approach is the proliferation of local single station solutions. It is estimated for example that over 1000 cropping farms have purchased GNSS reference stations and private radio solutions over the last 5 years. The total expenditure has been approximately A$20M and this is expected to grow to A$40M over the next 5 years. Many of these private systems overlap with each other and provide no access to other users working nearby. By utilizing all available infrastructures (government and private) a unified precise positioning service could be delivered to regional areas with less duplication of proprietary infrastructures and less need for additional investment. Such an infrastructure would greatly improve performance and efficiency for existing users but more importantly it would enable accelerated take up across major sectors of the economy.

3. PRECISE POSITIONING USING GNSS

Most consumer level GNSS equipment measure how long a signal takes to come from a GNSS satellite to the user's receiver. They measure the "range" using codes modulated onto the radio signals broadcast by the GNSS satellites. By matching codes generated by the receiver to the codes from four or more satellites the user's position can be calculated from the four measured ranges with accuracies ranging from tens of metres to a few metres.

Centimetre accuracy positioning is based around significantly more sophisticated GNSS receivers that measure the phase of the underlying satellite signals carrying the codes. This so-called "carrier phase" measurement technique is based on the fact that modern electronics enable measurement to a few hundredths of the wavelength of the carrier signal. With a wavelength for the GPS L1 signal being 19cm (for example) centimetre accuracy positioning is possible, so long as the errors that affect accuracy can be corrected for each user's location. The most significant errors are in the satellite orbits and in delays to the signals as they pass through the ionosphere and troposphere.

3.1 The Single Reference Station Approach

The simplest way to achieve centimetre accuracy is to use a carrier phase capable GNSS receiver at a known location and use that "reference station" to calculate corrections to the orbits, ionosphere and troposphere and then broadcast those corrections to the users. It is important to note that the user's receiver may be subject to different ionospheric and tropospheric conditions, which means there is a limit to how far the corrections from a single reference station can be extrapolated. Therefore, reliable centimetre accuracy from a single station service is typically limited to a radius of 15 to 20km around each reference station.

Even with this limitation, the approach can be very useful and there are many single station services that have been established on a case by case basis for a given survey, farm or mine. Such systems often use dedicated radios to broadcast the corrections from the reference station to the user's receiver. Other communications technologies such as wireless LAN are also used in some cases. It is also important to note that the corrections can change quite rapidly over time and to achieve centimetre accuracy, the corrections need to be derived and delivered every second.

3.2 The Clustered Reference Station Approach

It is also possible to cluster a number of reference stations and let the user's receiver select which station to use for its corrections. Examples of this approach, include clusters of stations servicing cane farms in the operations area of a given sugar mill. Although the cluster approach has multiple stations, it is important to note that the corrections are derived from the station nearest to the user and are mathematically the same as the single station approach and limited to the same radius of 15 to 20km around each reference station for reliable centimetre accuracy. The clustered approach is more about gaining efficiencies in the communications for delivering the corrections than about efficiencies in the number of GNSS reference stations or in the process of calculating the corrections.

3.3 The Networked Reference Stations Approach

The next logical development after the single reference station and clustered reference station approaches was to develop a network of stations and calculate the corrections based on the multiple stations surrounding the users. In this approach data from all the reference stations are brought together in a central computer which models the errors in the orbits, ionosphere and troposphere across the entire network area. The physics behind deriving those models with centimetre accuracy requires placing reference stations across the area of interest at a maximum spacing of 60 to 70km. Therefore the network approach can cover large areas of land with less reference station infrastructure than the single or clustered station approaches.

Corrections based on the error models are then broadcast to the user's receiver, which then interpolates the correction models for their location at a given time. Interpolation rather than extrapolation (as used in the single station approach) means that the performance for the user is largely independent of the distance between the user and the nearest reference station. In addition to centimetre accuracy, other performance measures important to users are the reliability and timeliness of "ambiguity resolution", which is the carrier phase receiver's equivalent of time-to-first-fix for a mass market receiver. So long as the user is operating in the network coverage, centimetre accuracy and ambiguity resolution performance have been shown to be superior to the single station approach (Ong, 2003).

The other aspect of the networked approach is that it enables the GNSS reference station infrastructure to be more easily separated from the communications infrastructure; for both the reference stations and the user. The requirement for calculating corrections every second (1Hz) means the reference station network needs a communications network such as broadband internet that can deliver the data to the central processing centre reliably and with minimal latency. The availability of broadband communications is a significant technical issue in establishing such networks in regional areas.

The ideal way to deliver the corrections from the central processing centre to the user is using mobile phone technologies. It is increasingly desirable to use internet based protocols, which for GNSS corrections means using Networked Transport of RTCM via Internet Protocol (NTRIP). Where mobile phone coverage is not available, other techniques like wireless LAN or radios can be used. For example in agricultural applications, it is possible to deliver the corrections over an internet connection to the farm house and then broadcast the corrections to the farming equipment in the fields using a local base radio.

The latest GNSS network techniques enable the reference stations, the communications, and the corrections to be de-coupled from each other and delivered in a way that is optimised for the location and for the application. In the farming example, the so-called "virtual reference station" approach allows the corrections to be tailored for a specific position such that the user's receiver thinks there is a reference station in the middle of a particular paddock, even though the physical GNSS reference station might be 40km away and the radio is on the roof of the farm house 5 km away.

Another interesting facet of having users directly connected to the Internet and reliably located is that it opens up the possibility for all sorts of data useful for the application to be exchanged in both directions. Such information could be tailored not only to the user's application but also to their location.

For example, for a bulldozer working on road construction it would be possible for several useful data flows to be happening simultaneously:

- An updated engineering design being sent directly into the guidance computer in the cab;
- A revised work schedule being sent to the driver because the part of the site scheduled for the bulldozer in the afternoon is not ready due to other equipment running behind schedule;
- A collision alert warning being sent to the driver from a safety system monitoring the movement of all equipment and personnel on the site, and;
- Engine and other performance data being sent to the nearest workshop of the company contracted to maintain the bulldozer. It might be that extra data is desirable in certain locations, for example if the machine is on a steep side slope.

4. PRECISE POSITIONING SERVICES IN AUSTRALIA

4.1 Real Time Precise Positioning Networks in Australia

There are a number of networks in Australia already delivering real time centimetre accuracy correction services for GNSS users. They include Government owned networks in Victoria, Queensland, New South Wales and the Northern Territory and a network in Western Australia operated by a private surveying company. In all of those cases real time centimetre accuracy correction services are only available in the metropolitan area around the capital cities. In Queensland for example, the Department of Natural Resources and Water operates the SunPOZ service (Cislowski and Higgins, 2006), the coverage for which is currently limited to south east Queensland (see Figure 1).

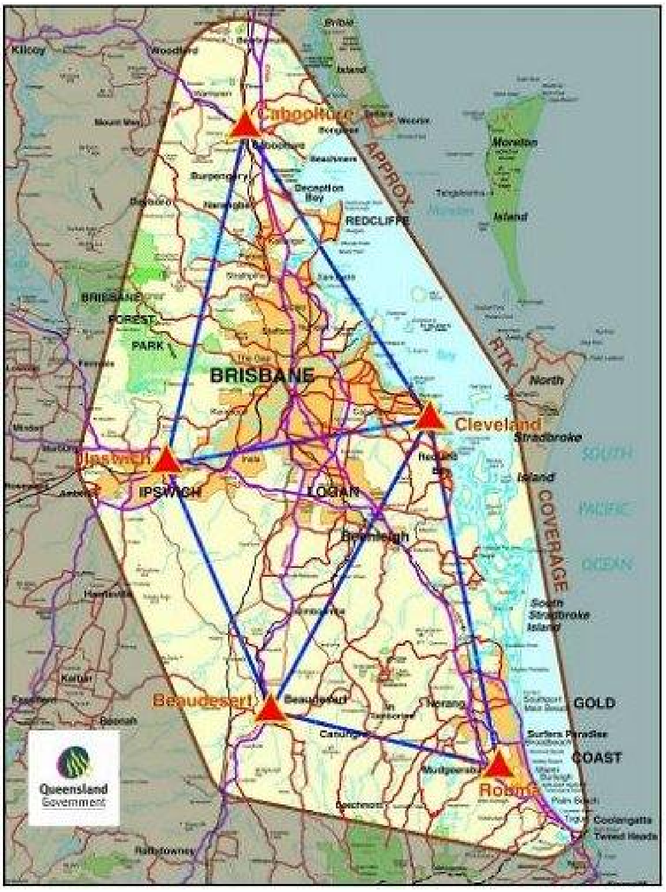

Figure 1 - Current SunPOZ Coverage

4.2 The AuScope GNSS Network

Another significant development is the planned AuScope GNSS network. In December 2006, the Australian Government announced funding for the AuScope project under the National Collaborative Research Infrastructure Strategy (NCRIS). Figure 2 shows the indicative design for the AuScope GNSS reference station network. AuScope will be primarily for scientific purposes. However, there is also interest in demonstrating downstream benefits of the infrastructure beyond the purely scientific base.

Figure 2– Indicative Design for National AuScope Network

Within the AuScope project, there is also a need for State and Territory governments to match the capital expenditure by the Australian Government and to carry the operating costs for the GNSS network. Therefore, the CRCSI project will also investigate the business and technical issues associated with integrating state-based networks into a national backbone infrastructure like the AuScope network. That will require defining partnership and pricing models that meet the public good and science needs of AuScope (as demanded by the NCRIS programme) while also allowing for a revenue stream that can help States and Territory governments meet their ongoing operating costs for the AuScope stations.

The CRCSI project will also investigate technical issues such as communication enablers associated with integrating the AuScope network with networks such as SunPOZ, which have quite different underlying technical architectures and purposes.

5. THE CRCSI PROJECT ON PRECISE POSITIONING IN REGIONAL AREAS

As mentioned at the start of this paper, on July 1 2007, the Cooperative Research Centre for Spatial Information (CRCSI) commenced a new research project to investigate the issues associated with extending GNSS precise positioning services into regional areas. The project is divided into two parts, one part dealing with the business issues and the other part dealing with the technical issues.

The business issues part of the project has been divided into three major tasks
Task 1.- User Market and Requirement Studies;
Task 2.- Evaluation of Commercial RTK Network Solutions in Regional Areas;
Task 3.- Business Model and Partnership Studies.

5.1 Task 1 - User Market and Requirement Studies

Given that all the existing precise positioning networks in Australia are servicing metropolitan areas, the first task in this part of the project is to gain a better understanding of the requirements of users in regional areas. Therefore, a study is being conducted to gain a better understanding of user groups, markets size, performance requirements (accuracy, availability, integrity, reliability, timeliness and affordability), and the preferred operational modes for the positioning services in different user segments.

The study is considering users groups from different industries, which require machine guidance and precise navigation and positioning, including, but not limited to:
- Precision agriculture users;
- Construction users;
- Mining users;
- Spatial positioning in surveying and GIS data collection for asset management, road and rail mapping, etc;
- Maritime and offshore survey (within 200km of the coast);
- Lane-level vehicle navigation;
- Other professional positioning services such as location-based services and mobile mapping.

A contract for the Study has been let to Rob Lorimer of Position One Consulting. Rob conducted a workshop session at the Project kick-off meeting in August 2007. That enabled agreement on the user requirement parameters to be measured and the application areas to be examined in the study. Rob has now commenced the data gathering phase, including interviewing specific user group representatives. Overall, Task 1 is progressing well and Rob is on schedule to deliver his report to the CRC in the first half of 2008.

5.2 Task 2 - Evaluation of Commercial RTK Network Solutions in Regional Areas

Once the requirements of users in regional areas are better understood, there is a need to assess the ability of existing commercial solutions to meet those requirements. That will require the establishment of a test network involving the following steps:
- Establishment of a test network in a regional area covering a large variety of potential application areas, including agriculture and open-cut mining;
- The network will involve 4 reference stations at a spacing typically recommended for current commercial solutions, i.e. no more than 70km;
- The test network will be managed using commercial software packages from two project participants in Leica (Spider software) and Trimble (GPSNet software);
- The network management centre will be the existing SunPOZ management centre in south east Queensland. That will enable testing of the ability to run a second non-contiguous network several hundred kilometres from the network management centre and completely separate from the existing network;
- Several alternative communications approaches (for both reference stations and rovers)

will be implemented and tested;
- Rover testing will be carried out using existing commercial solutions from suppliers such as Leica and Trimble;
- The rover testing will involve as many application areas as practical but will definitely include agriculture and open-cut mining;
- Testing will concentrate on achievable measures of accuracy and reliability and their comparison with the levels identified in the user requirements analysis. For example if a user requirement is identified as “better than 10cm horizontal accuracy at 99% confidence, 24 hours a day and 7 days a week”, then that would form the specification for the testing.

The establishment of the test network is scheduled to begin during 2008 with the rover equipment testing likely to happen during the second half of 2008.

5.3 Task 3 - Business Model and Partnership Studies

A key issue underpinning this task is that the sparsely populated nature of Australia’s regional areas means that it is difficult for any one entity, public or private, to justify the expense of creating their own GNSS Reference station network. This is offset by the fact that many of the key players in Government and Industry interested in developing precise positioning services are participants in the CRCSI project. This raises the possibility of developing a prototype business and partnering model among the project participants to provide such services into regional areas.

The first part of this task (Task 3.1) will examine the options and most appropriate Business Model for delivering precise positioning services to users in regional areas. Task 3.1 will also examine existing business models around the world that involve various mixes of government and privately-owned GNSS infrastructures, including those operating commercial services versus free to air services. This task will also examine what options exist for pricing models, such as flat daily rates versus per second rates. The task will also consider models that place different emphasis on hardware prices versus service prices; which is common among mobile phone service providers. Task 3.1 will also examine what new opportunities might be enabled by server-based positioning, which is being studied in the technical development part of the overall project.

Task 3.2 will examine Business Partnership models. Specifically, Task 3 will investigate what possible partnering models would be best for realising the most viable business models for the key application groups. This task will examine issues associated with a purely open market with multiple infrastructures and multiple service providers compared to having a single infrastructure and a single service provider and the various combinations of possibilities between those extremes; such as public private partnerships, joint ventures and service delivery outsourced by Government.

This part of the project will also examine issues associated with leveraging free data streams (e.g. from the AuScope network) to create value-added services that can generate revenue streams to help support the ongoing operating costs of public good services like AuScope.

Under the official project schedule, Task 3 was not expected to begin until 2008. However, the rapidly developing operating environment for the state based networks and the AuScope network is raising the urgency for answers to the types of questions being addressed under Task 3 and some initial work has already begun. For example, initial discussion at the Project kick-off meeting in August 2007 showed that there is good scope for agreement among government participants on the role of government versus private sector in the provision of precise positioning infrastructure and services. This will be further examined in coming months with a view to seeding more detailed discussions on the role of government versus private sector among the attendees at the IGNSS 2007 symposium.

6. CONCLUSIONS

This paper has outlined the growing market for real time precise positioning with particular attention to the field of machine guidance and its application in major industries, many of which are based in regional areas of Australia. Some of the economic benefits for those industries were also outlined. The various techniques for precise positioning using GNSS were reviewed and the case was made that a networked reference station approach offers the most efficient approach for a large, sparsely populated country like Australia. Existing and planned networks in Australia were also described.

The paper then described a new research project in the Cooperative Research Centre for Spatial Information (CRCSI), which is investigating the business and technical issues associated with extending GNSS precise positioning services into regional areas. The business aspects of the project, described in the paper, hope to set a framework for a unified precise positioning service that could be delivered to regional areas with reduced duplication of infrastructure and less need for additional investment. Such an infrastructure would greatly improve performance and efficiency for existing users but more importantly enable accelerated take up of precise positioning in regional areas, thereby enabling significant productivity improvements across majors sectors of the Australian economy.

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