Networked RTK using the Internet for Controlled Traffic Farming

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INTRODUCTION

The Department of Sustainability and Environment (DSE) in Victoria has developed a Global Navigation Satellite System (GNSS) Continually Operating Reference Station (CORS) infrastructure called GPSnet™ (Refer to www.land.vic.gov.au/GPSnet). GPSnet™ provides Networked Real-Time Kinematic (NRTK) correction services that are suitable for many high accuracy applications such as surveying and construction. Recent trials conducted with the Department of Primary Industries (DPI), the Balliang Controlled Traffic Farmers Group and several industry partners have demonstrated ±2 cm horizontal navigation capability for controlled traffic farming applications by using NRTK.

This paper describes how centimetre accurate GNSS navigation guidance from Victoria's GPSnet is generated by using the internet and a "virtual" base station at the farm site. Use of GPSnet means not purchasing a local base station on the farm. NRTK corrections from GPSnet provide a range of additional benefits including strict compliance with Australia's national datum GDA required for pass-to-pass precision and year-on-year accuracy.

CONTINUALLY OPERATING REFERENCE STATIONS (CORS)

CORS are stable, monitored GNSS reference points. Combined into a network, CORS provide continual, uninterrupted GNSS satellite information used to compute parameters which determine the national datum, measure continental drift and monitor changes in sea levels.

CORS networks in Australia

CORS networks in Australia are a fundamental component of the nation's spatial infrastructure; position, navigation and time. The Australian Regional GNSS Network (ARGN) is the primary network managed by Geoscience Australia. The Australian Fiducial Network, part of the ARGN, was used to determine the current national datum GDA94 and underpins legal traceability of position (http://www.ga.gov.au/geodesy/).

Geoscience Australia is developing the national CORS network project, AuScope (http://www.auscope.org.au/). Information at the State and Territory scale is summarised as:

GPSnetwork Perth (http://www.gpsnetworkperth.com.au) - private sector operated network with assistance from the WA Department of Land Information.
GPSnet (www.land.vic.gov.au/GPSnet) Victorian Department of Sustainability and Environment
SunPOZ (http://www.nrw.qld.gov.au) Qld Department of Resources and Water
NT CORS (www.ipe.nt.gov.au) NT Department of Planning and Infrastructure
SydNET NSW Department of Lands (http://sydnet.lands.nsw.gov.au/sydnet/login.jsp) (http://sydnet.lands.nsw.gov.au/images/MetroNETCoverage.jpg)

CORS in Victoria - GPSnet™

GPSnet is rapidly growing with the allocation of resources to build 7 new CORS during 2007/8. GPSnet started in 1996 and now has a real time network of 30 stations (Figure 1). The aim is to expand GPSnet to a state-wide ±2cm service available via the internet. GPSnet also aims to develop a CORS network management model that allows other states and territories, such as NSW, SA and even TAS, to share data between CORS networks.

GPSnet is a cooperative model where the department is a custodian that builds, operates and manages the network for all stakeholders. Hosts and contributors include a range of government, research, utility/industry organisations, Landcare groups and independent farmers. Along with the network development, the uptake of new GPSnet users has increased rapidly, particularly with respect to surveyors who require reliable centimetre positioning.

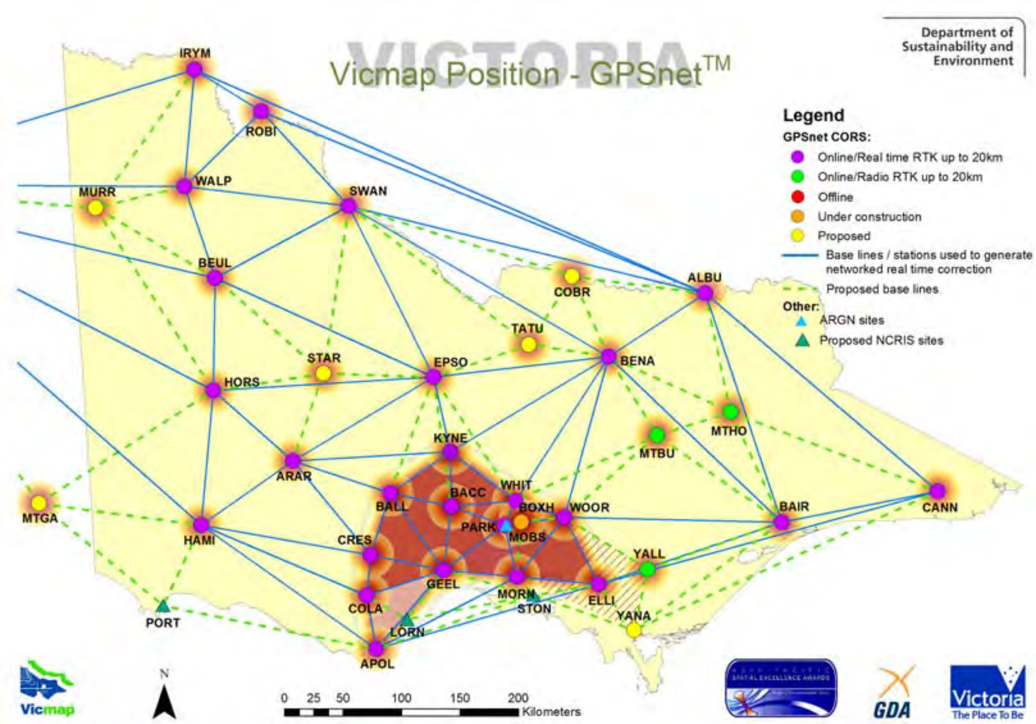

Figure 1. Victoria's CORS network, GPSnet

GPSnet uses a dedicated server processing centre to collect data from all the GPSnet CORS sites. The GPSnet web servers distribute corrections over the Internet using the NTRIP[1]. Users typically access the service using a GPRS enabled mobile phone, which transmits the corrections to a suitable GNSS receiver via Bluetooth. Alternatively, correction signals can be sent to a central location and transmitted to farm equipment using radios.

[1] NTRIP Networked Transport of RTCM Via Internet Protocol – International Standard Refer to http://igs.ifag.de/index_ntrip.htm

GPSnet quality

The GPSnet specifications achieve accuracy, reliability and quality by the use of specialised quality control programs that ensure a target service up-time of 99.98%. Research into the development of real-time quality indicators is on-going (Cooperative Research Centre for Spatial Information www.crcsi.com.au Project 1.2)

NETWORK REAL-TIME KINEMATIC FOR CENTIMETRE POSITIONING

Standard GNSS positions without corrections are typically accurate to 20m, with precision to 5m in ideal environments. However, signal multipath (the reflection of satellite signals bouncing off objects like trees, sheds and machinery) will cause large unwanted errors.

There are several techniques used to achieve greater GNSS accuracy, one of which is Networked Real-Time Kinematic (NRTK) corrections (Table 1). By streaming GNSS observation data from individual reference stations to the processing centre, a reference network is created that models atmospheric (ionospheric and tropospheric) errors and satellite orbit biases over the entire network area. The user receives a more reliable correction model based on their location within the network. The NRTK approach generates a *virtual* reference station (VRS) to imitate a base station close to the users' position. In this way the 15km RTK range limitation for single base is increased to over 70km for the NRTK method.

Table 1. Positioning methods

Positioning Method	Accuracy	Range Limit	Correction Method	Uses in Agriculture
Standard Positioning	20m – 5m	World wide	No corrections	"Where am I" navigation
Differential GNSS	5m – 2m	100 km from base station	Single base via Radio, Internet, or Communication Satellite	Yield mapping, transition between soil zones
Network Differential GNSS	2m – 0.5m	Anywhere in network (500km)	Network via Radio re-broadcast or Internet	Yield mapping, geographic information site surveys, soil zones
Real-time Kinematic	0.2m – 0.02m	15-20km from base station	Single base VHF/UHF Radio	Automated machine guidance, engineering construction surveys
Network Real-time Kinematic	0.05m – 0.02m	Anywhere in network with 70-100km triangles	Network via Radio re-broadcast, Internet and mobile phone	Automated machine guidance, engineering and construction surveys

Creating a Virtual Reference Station (VRS) for a farm location

Victorian farmers can create a VRS using a Personal Computer (PC) or Laptop with access to a Broadband internet connection, free downloadable software (called GNSS[2] Internet Radio) and a transmitting/receiving set of radios/modems.

[2] Note: GNSS Internet Radio software has been developed to support an international standard for streaming of GNSS correction data over the internet refer to http://igs.ifag.de/

The farmer specifies a location to create a VRS by inputting known coordinates (from a map or GPS) into the GNSS Internet Radio software. The farmer then receives real-time GNSS corrections based upon this position within the CORS network. The software then requests corrections by making an automatic connection to the GPSnet service. The corrections are streamed to the PC as real-time data with a choice of formats like CMR+ or RTCM. A radio/modem is connected to the PC comport (COM1) to rebroadcast correction data from the PC and to a receiving radio/modem and GNSS on a tractor or harvester in the field (Figure 2).

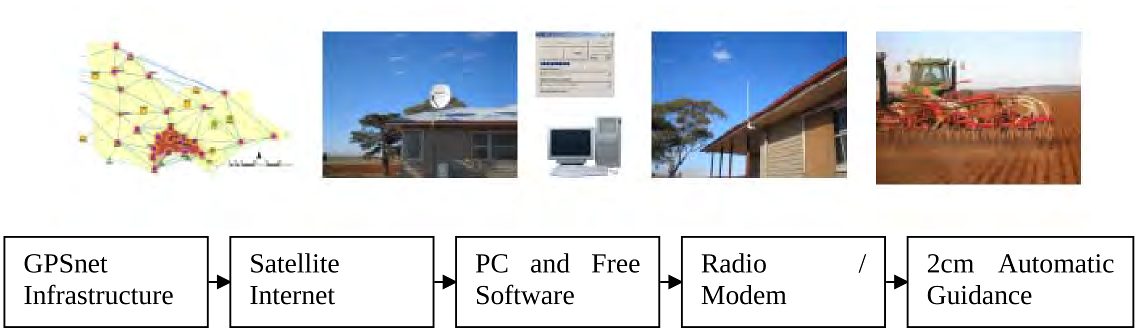

Figure 2. CORS NRTK system for 2cm automatic guidance

BENEFITS OF CORS NRTK

Datum coordination and monitoring

The advantages of using a CORS network include not having to purchase a base station receiver and antenna, and the costs of installing, operating and maintaining this equipment. Also, surveying the base station to the GDA94 datum and creating a reference point with exact coordinates in case the base equipment needs to be moved or changed is not required. Connection to a datum is absolutely necessary if year-to-year accuracy is required on the local farm, within the district, across the state and over the entire nation.

Without uniform coordination there will be distance errors between neighbouring reference stations. At worst, if the WGS84 datum is used to correct roving GNSS equipment, users may experience high precision from pass-to-pass in one season, yet year-to-year accuracy will drift north east along with the Australian continent at about 7 cm per year! CORS networks such as GPSnet are directly connected to GDA94 with Regulation 13 certification provided by Geoscience Australia, eliminating the effects of tectonic plate movement. In this way CORS are the primary means of connection to state and national spatial infrastructure.

Redundancy and efficiency

Unlike a single base local RTK solution, a network solution is founded on at least 6 contributing reference stations. If a CORS station has a problem there are multiple other stations available. The overall network is designed with redundancy for reference stations, with efficient data processing and internet signal distribution.

Connecting a series of GNSS reference stations in triangles generates an accumulative growth in the area covered by the physical reference station sites – a classic effect of networking. For example, 6 connected triangles in an ideal network will cover an area more than double of that of 7 non-connected single base stations. For a large continent like Australia, a well designed network of GNSS reference stations would promise significant cost savings and efficiency gains due to this network effect. For example, Figure 3 displays the current GPSnet coverage area surrounding Melbourne of 27,105km^2 compared to a reduced coverage area of 16,328km^2 for the same number and location of reference stations operating in isolation and not connected as a network.

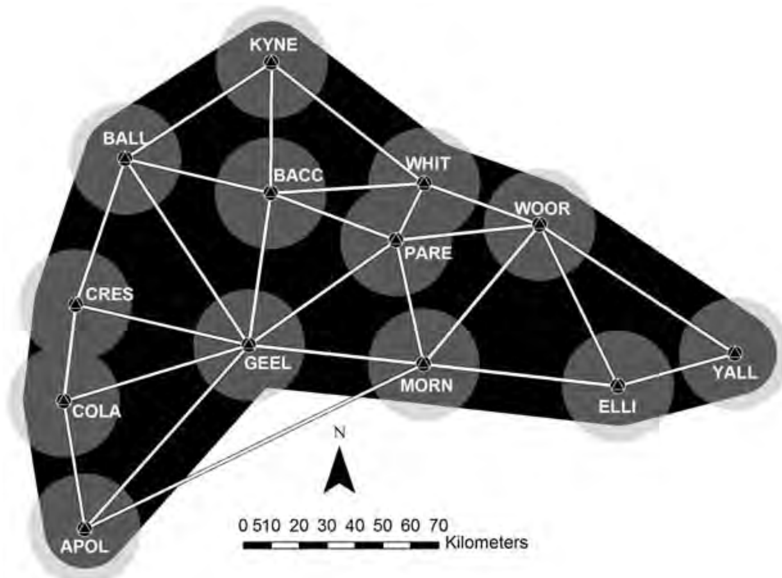

Figure 3. Network RTK compared to Single Base RTK

Reliability and quality

Secure remote access to each reference station and the streaming of data to a central processing centre accumulates additional benefits. Network processing produces a more reliable solution, with better atmospheric models and error corrections. Reference stations are continually monitored for quality, continuity of operation and data completeness, while upgrades and maintenance can be managed over a remote connection, adding to the reliability and quality of the service.

CASE EXAMPLE: NRTK FOR CONTROLLED TRAFFIC FARMING IN VICTORIA

The advantages of controlling farm machinery to 2cm accuracy are well known and discussed within the Precision Agriculture (PA) industry and farming groups such as Controlled Traffic Young Farmer Groups (CTYFG). One of the groups, based around Balliang, north of Geelong in Victoria, has hosted and tested the capability of GPSnet to provide reliable pass-to-pass accuracy. Balliang is within the high accuracy coverage of GPSnet and is an important grain production region. The success of the project was aided by the enthusiasm of the group and the precision agriculture industry at large, without this level of cooperation, testing of the networks capability would be problematic.

Local farmer Chris Sharkey has a satellite broadband connection at his property and saw this as an opportunity to introduce the capabilities of GPSnet to the broader farming community.
Chris said ‘a network of base stations is the only way forward for centimetre guidance, it’s just a waste of money having individually owned and run base stations 15 km apart when we can have GPSnet base stations at 70 km’.

Unfortunately, the Sharkey's satellite broadband connection did not deliver the data required for the project, and Paul Jensz volunteered to host the trials. A specially designed internet connection was installed and tested. The work done has led to the discussion presented in this paper. The Group see networked GNSS reference stations delivering NRTK corrections as the future and a way to remain internationally competitive. Moreover, a state-wide CORS network will be highly valued by sowing and harvesting contractors.

Ultimately, a state-wide GPSnet would mean all users can achieve consistent 2cm guidance in terms of GDA94 anywhere in Victoria. The enthusiasm of the Balliang CTYFG to host these trials is greatly appreciated and demonstrates their belief in the potential of a NRTK correction service. The group is very keen to continue its involvement with the technology and the members are ready to be the first to use GPSnet when it becomes commercially available to the farming community.

FUTURE CHALLENGES - GPS TO FULL GNSS IN TEN YEARS: 2017

There are numerous challenges that users of satellite navigation systems face in the future. Access to new generation satellite constellations and GPS modernisation is paramount to equipment specifications and purchasing decisions over the next 5 years. The unified CORS infrastructure across Australia, equipment costs and interoperability, productivity benefits and the role of commercial partnerships will all be important considerations.

Over eighty GNSS satellites will be commissioned by 2017 with twenty five satellites in view at any time. In addition to satellite availability, industry experts regard CORS and differential techniques as essential providers of the accuracy required for CTF and other applications.

GPS modernisation (www.navcen.uscg.gov/gps/)

Global Positioning System (GPS) from the USA is the best known and fully operational with 30 satellites. GPS modernisation includes a civil L2 and new L5 signal with an overall plan for 30 GPS-III satellites ready for deployment between 2013 and 2018.

Russian GLONASS (www.glonass-ianc.rsa.ru).

The Russian Federation operates GLONASS with a total of 10 operational satellites, two launched in April 07. The intention is to achieve a full 24 satellite constellation transmitting two civil signals by 2010 and GLONASS modernisation by 2017.

EU Galileo (http://ec.europa.eu/dgs/energy_transport/galileo/index_en.htm)

The European Union Galileo program has slipped behind its original deployment schedule with the full operational capacity estimated for 2010. Only one test satellite currently in orbit! A completion date for 30 satellite constellation around 2012 – 2014 is projected.

CONCLUSION

Continually Operating Reference Stations are being established in each State and Territory in Australia as the primary means of connection to the national datum GDA. The connection to GDA ensures year-to-year accuracy between neighbouring farms and across the whole continent. Victoria's GPSnet is well advanced with state wide coverage for high accuracy nearing completion. GPSnet offers a range of services including NRTK that provides centimetre accuracy in real-time. The uptake of GPSnet services for survey and construction has been increasing in metropolitan areas well serviced by wireless internet coverage.

The difficulty in obtaining reliable internet in rural areas was the motivation behind developing a system to re-broadcast a "virtual" reference station solution to a farm using a satellite internet connection. A new approach to 2cm guidance using a CORS NRTK system was demonstrated at Balliang. The Balliang Controlled Traffic Young Farmers Group tested a CORS network that doesn't require individual base station equipment. Additional benefits include a consistent national approach to providing CORS infrastructure. With over eighty GNSS satellites scheduled to orbit by 2017 there are many challenges ahead for GNSS users, CORS network operators and local base station owners to extract the maximum benefits from high accuracy satellite positioning systems.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the collaboration between the Department of Primary Industries and Department of Sustainability and Environment facilitated by Chris Bluett from DPI; the assistance and generosity of A1 Lasers and GPS for supplying and installing Trimble Ag GPS; NewSat for providing satellite internet connectivity; CNG systems for installation and PC; Paul Jensz for use of his farm and John Deere tractor and Luke Pendretti for his driving and patience. Finally, thanks to the Balliang Controlled Traffic Farmers Group for their enthusiasm for continuing the development of GPSnet services.