Presented at GNSS 2004
The 2004 International Symposium on GNSS/GPS

Sydney, Australia
6–8 December 2004

The development and enhancement of GNSS/GPS infrastructure to support Location Based Service Positioning Systems in Victoria

James Millner
LBS Project Manager
Department of Sustainability and Environment
Level 13 570 Bourke Street
Melbourne 3000
Tel: 03 8636 2376 Fax: 03 8636 2813
Email: james.millner@dse.vic.gov.au

Martin Hale[1] Paul Standen[2] and Nick Talbot[3]

[1] GPSnet Project Manager Department of Sustainability and Environment
[2] Manager Ultimate Positioning Victoria
[3] Senior Software Engineer Trimble Navigation

Presenter James Millner

ABSTRACT

Spatial Information Infrastructure (SII), part of the Strategic Policy & Projects Group, Department of Sustainability and Environment has facilitated the establishment, coordination and development of GNSS/GPS infrastructure in Victoria. GPSnet, the state's GPS base station network, has been developed in cooperation with leading Industry organisations and Academic institutions since 1996. Currently GPSnet consists of 20 operational base stations that transmit, record and archive, hourly data files. These data are used for post-processing satellite measurements by a multitude of diverse user groups to achieve greater reliability and certainty of their locations. In addition 8 base stations transmit local code and phase data for Real Time Kinematic applications.

Recently the GPSnet network infrastructure has been upgraded and enhanced to generate a networked Differential GPS (DGPS) correction service for real-time applications in support of Location Based Service (LBS) Positioning Systems. This paper will describe the system architecture, design and implementation stages of the LBS project. The issues relating to connectivity and communications for the distribution of GPS correction streams over the Internet will also be discussed.

KEYWORDS: GPSnet, DGPS, GPS Network, Mobile Internet, NTRIP.

1. INTRODUCTION

The Department of Sustainability and Environment (DSE) was established on the 5th of December 2002 (refer to www.dse.vic.gov.au) and is committed to a future in which all Victorians live in a sustainable way within their natural and built environment. DSE has a vast portfolio which includes: Catchment Management, Spatial Information, Conservation, Recreation and Public Land, Forests and Fire Management, Sustainability Policy and Programs, Biodiversity, Greenhouse and Sustainable Energy, Heritage, Parks and Crown Land.

Spatial Information Infrastructure (SII) is the agency within DSE responsible for the Victorian Government's primary spatial information programs. The mission of the agency is to provide Victoria's authoritative, comprehensive and easily accessible spatial information infrastructure to support effective decision-making. The SII workforce is responsible for developing and managing Victoria's fundamental spatial information and managing the departments' corporate spatial resources. Part of the strategic direction is to deliver and continuously improve its quality of services.

The project to develop a positioning capability to support current and future Location Based Services (LBS) during the fiscal years 2004/05 was identified as an important strategic initiative under this framework.

Satellite-based positioning techniques form an essential part of Location Based Services. Today the Global Positioning System (GPS) is widely used by public and private organisations within Victoria. It is expected that there will be further uptake of satellite-based positioning as new systems are developed and GPS is modernised. It is important that infrastructure is created to support the coordinated and efficient use of Global Navigation Satellite Systems (GNSS).

The Spatial Information Infrastructure agency has endeavoured to provide a leading role within Victoria for coordinating access to GNSS data. An early step in the process involved the creation of GPSnet, a ground-based reference station network. The network was developed with limited resources but delivered on-line access to base station data for post-processing. More recently, radio transmitters have been used at some stations to provide centimetre-level data in real-time. The next step in the process is to generate real-time DGPS corrections to users across Victoria.

Transmission of GPS data from reference stations to a processing facility, and from the processing facility to users presents some technical challenges. Victoria's population is mostly contained within the capital city, Melbourne. Telecommunication infrastructure has evolved out from Melbourne to country towns, through growth corridors and along arterial roads. Some of reference stations are located at DSE offices that are Intranet connected; while other stations are very remote. Finally, some of the reference stations are operated by third party organisations. It is important that data transmission is:

- cost efficient;
- secure;
- high integrity; and
- fast - with low latency.

Telecommunication costs for continuously operating data transmissions are multiplied by the number of reference stations and therefore can be an appreciable component of operating expenses. Access costs for the data is a high concern for users, therefore it is important to minimise these operational expenses. In addition security of computer networks is always a concern for organisations; as such the operation of the GPS data network and connectivity must not compromise existing systems.

It is important to note that GPSnet is not intended for safety of life navigation operations such as aircraft navigation. However it must operate with a high degree of continuity and integrity.

Many errors that affect GNSS/GPS users are temporal in nature. Hence correction services need to deliver data promptly (i.e. with minimal latency), to users in order to maintain the highest level of accuracy.

This paper describes the GPSnet infrastructure and how it has been used across Victoria. The model developed for real-time concentration of base station data, and for delivery of corrections is presented next. Many of the challenges faced during the development of GPSnet are common to similar systems. It is therefore believed that the model proposed for GPS/GNSS infrastructure in Victoria can be used in comparable settings around the world.

2. VICTORIA'S BASE STATION NETWORK - GPSnet

2.1 GPSnet Background

Spatial Information Infrastructure (SII); previously the Land Information Group (LIG), has facilitated the establishment, coordination and development of the GPSnet GPS base station network in cooperation with industry organisations and academic institutions see www.land.vic.gov.au. SII manages and operates GPSnet with the main remote control centre in Ballarat with a secondary centre located in Melbourne. GPSnet commenced operations and network site establishment in July 1996. The first industry site was set up at Geelong in collaboration with Barwon Water Regional Authority as the Host. Significantly, the test facility for the LBS project has been conducted inside the Barwon Water Authority IT facilities in Geelong.

The network of GPSnet base stations is currently specified to:

- establish state-wide infrastructure for multiple end-use GNSS/GPS applications;
- use high standard geodetic standard dual frequency GNSS/GPS receivers, calibrated antennas at secure base station locations;
- supply code and carrier phase data in standard formats for differential post-processing;
- contribute data for scientific research and student projects;
- offer simple access to GNSS/GPS products through the Internet; and
- provide local Real Time Kinematic (RTK) correction signals transmitted over authorised radio frequencies for localised use.

2.2 Vicmap Position - GPSnet

The position correction services that are based on the GPSnet infrastructure is marketed as Vicmap Position - GPSnet which is a part of the Vicmap suite of products and services see www.land.vic.gov.au/spatial. At selected sites, essential position correction data is provided by SII and then re-distributed by Value Added Reseller Agreements (VAR's). ***GPSnet***® is a trademark registered to the Crown in the Right of the State Of Victoria that gives the legal right to use GPSnet within Australia for goods and services for which GPSnet was registered under Class 9: Computer software, surveying and measuring instruments.

SII is enhancing Vicmap Position – GPSnet services by developing a wide area, real time, and differential network correction capability to meet the needs of a broad range of GPS users. To effect this progression, SII has commissioned a 'Milestone Initiative' called the Location Based Services Project (LBS). It is envisaged that the LBS component of GPSnet will generate additional on-line products that will possibly be distributed through an Application Service Provider (ASP) business model as described by Millner *et al*, (2001). The LBS Project is part of a broader strategy called the Geospatial Emergency Information Network (GeIN).

2.3 Geospatial Emergency Information Network (GeIN)

The main objective of GeIN is to provide a single gateway into which state and national agencies can access the structured unitary body of Victorian spatial information. GeIN would operate within an overall policy framework of the Victorian Government's Information and Communication Technologies Infrastructure Strategy to reduce both costs and complexity. GeIN is a practical adoption of the concept 'create once, use many times' that will provide efficient participation for large agency users and many smaller clients with lower transaction volumes.

The information management model is based on custodianship or delegated responsibility. Implementation of GeIN would build on the existing core of eight *Framework* spatial data sets in VicMap, including Vicmap Position - GPSnet. Together with another 64 spatial datasets, GeIN will provide a single authoritative resource of spatial information; with state-wide coverage, fully maintained, documented and secured. Data will be available through both physical media and secured transactions over the Internet to support the needs for emergency management, counter terrorism, environmental management and planning, delivery of infrastructure, major projects, and risk assessments. Notably, the LBS project will provide a principal means of integrating real-time positions with spatial information from GeIN.

3. LOCATION BASE SERVICES (LBS) POSITIONING SYSTEM

3.1 Location Based Services Project Scope

The LBS project is intended to provide a GNSS/GPS positioning capability to support current and future location services in Victoria. The project recognises the need to support the growing diversity of GNSS/GPS users with associated variations in the level of positioning accuracy required; from low-end code only applications to users of precise dual frequency carrier phase data.

The formation of the Cooperative Research Centre for Spatial Information (CRC SI) has recognised the importance of integrated positioning and mapping systems and in particular the need to "…facilitate the development of a low-cost, real-time GPS-based positioning system capable of providing accurate location in any environment to support a range of surveying and mapping applications." See www.spatialinfocrc.org/

Scott-Young and Mowlam (2004) point out that a precision location-based service is the key to exciting new ways of getting where you want to go. Similarly, SII has taken a broad approach to the potential services that will benefit from the LBS project. With this wider user community in mind, the real time, networked Differential GPS correction service (DGPS) will accommodate standard DGPS operational performance from single frequency C/A code only and C/A code/phase receivers, as well as enhanced DGPS through the generation of ionospheric-free DGPS solutions for dual frequency precision applications. Future upgrades to provide a state-wide networked Real Time Kinematic (RTK) service will be supported through streaming all the available observed (dual frequency) data from GPSnet nodes to the Central Server Cluster processing centre.

Initially the LBS server cluster will process a solution using six existing GPSnet base stations to generate a networked Differential GPS (DGPS) correction service. These corrections will maintain an accuracy specification for DGPS that is independent of the distance from a GPSnet base station, available to users in 'real time' with state-wide coverage across Victoria. The DGPS correction service will support contemporaneous access and usage for multiple clients. User access to this service will be primarily through mobile devices connecting to the Internet. Appropriate parameters will also be generated by the LBS application to describe the quality of the data collected at the GPSnet station nodes and for the corrections generated by the DGPS correction service.

Roberts (2003) asserts that the GPSnet infrastructure should move towards providing networked based real-time kinematic solutions in the near future due to the growing demand for these services. The notion of complete state-wide centimetre real-time positioning is subject to solving some unique challenges that are presented in Victoria such as availability of suitable communications infrastructure and the sparse nature of the GPSnet base station spacing.

3.2 Projected LBS User Groups

Currently GPSnet has many different user groups who access the service for various applications and tasks. These include but are not limited to those listed in Table 1.

Mapping Grade Use	Higher Precision Use	Post-processing Use
• emergency response	• precision agriculture	• atmospheric research
• navigation	• machine control	• climate research
• tracking environmental hazards	• intelligent transport	• deformation monitoring
• GIS data capture and asset management	• precise GIS	• control surveys
• general mapping	• surveying & mining	• geotechnical analysis

Table 1. GPSnet uses

It is expected that the LBS project will attract additional and more diverse client usage profiles to those that are listed in Table 1.

3.3 Primary LBS GPS Base Station Nodes

Initially it is planned to stream data from a minimum of six base station nodes located at existing GPSnet sites around the state to the LBS Central Server Cluster processing centre at Geelong. Nonetheless, connecting to all current and proposed GPSnet nodes is envisaged in the future once the LBS application is commissioned and fully operational. Refer to Figure1.

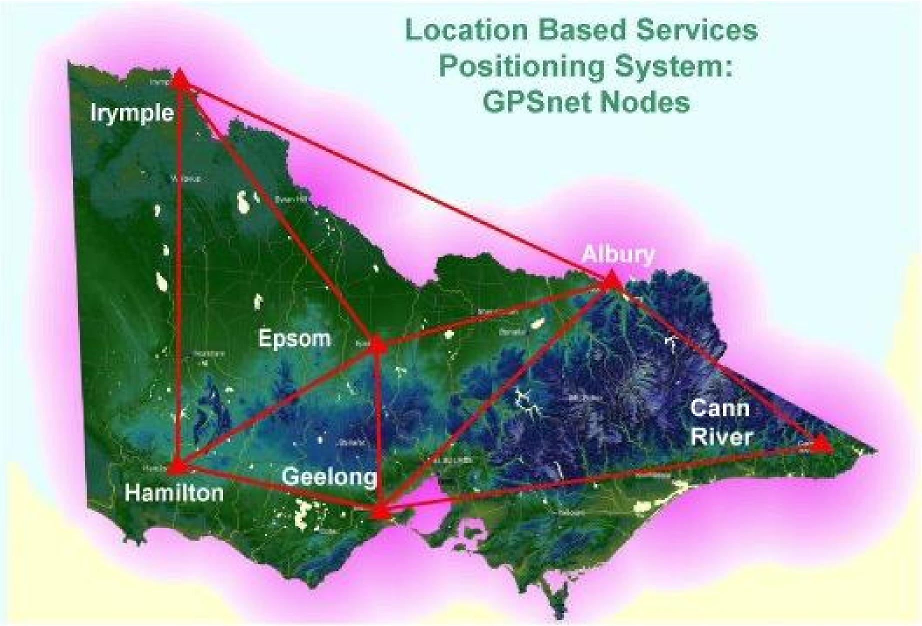

Figure 1. GPSnet LBS Base Station nodes

4 LBS ARCHITECTURE AND DESIGN

4.1 Connectivity

Specifications for GPSnet base stations that are currently required to connect using the Internet and transmit data files to the GPSnet Central Server, located at the Australian Stock Exchange (ASX) Data Centre in Melbourne are explained in the Vicmap Position - GPSnet product description documentation. Refer to www.land.vic.gov.au/spatial.

GPSnet base stations that are linked over the DSE Wide Area Network (WAN) send base files in RINEX format every hour to a the GPSnet Central Server by File Transfer Protocol (FTP) using the Department's existing communications network. Base station sites that are external to the Department WAN, such as Albury, Geelong and Hamilton, send files by FTP over the open Internet with the site Host providing the Internet gateway.

FTP is a recognized protocol that is used in conjunction with in-house software to push files via FTP to the GPSnet Central Server located in a zone secured by a firewall (DMZ). For additional security a file integrity module developed as part of the **GQC** Integrity software by Brown *et al* (2003) is used to ensure that no spurious files are transferred, received, opened or stored on the central server. The FTP file size is reasonably small, about 200kb per hour, hence there are minimal issues relating to bandwidth for transmitting these data files.

The new LBS networked real-time service must generate solutions based on an uninterrupted feed of observed GPS raw data that is continuously transferred from each base station node to the LBS Central Server Cluster. Permanent connectivity from each GPSnet base station node must be provided such that this stream of real-time data can be received at the processing centre located at Barwon Water in Geelong in a secure way with minimal latency. Further, two-way communication (duplex) from the cluster of servers at Barwon Water to each GPSnet base station node is required for operation. Based on an average of 10 GPS satellites, the bandwidth that is determined for the data stream is small, typically in the order of about **500 *Bytes per second*** (Trimble 2004). However data collected during a twenty-four hour period accumulates to over 1 Gigabyte per month per GPSnet node. At more than 7G per month for six LBS nodes, the total amount of data to be transferred over the network requires a sustainable and cost effective solution.

The existing GPSnet architecture was initially designed for straightforward FTP transfer; yet topology for a Virtual Private Network (VPN) was included for added flexibility and capability for future expansion. Currently, the GQC FTP module initiates or ***pushes*** files from within the secure DSE environment to a secured DMZ without the need for more demanding two-way communications. Based on the LBS specifications a number of options were considered to implement a VPN that would fulfil the duplex connectivity requirements of the new real-time data stream.

4.2 Managed Private Network VPN Model

Multi Media Victoria (MMV) is responsible for the supply of Telecommunications Purchasing and Management Strategy (TPAMS) for the procurement of ITC services across the whole of the Victorian Government. AAPT, Telstra, Optus and SPtel, from the TPAMS panel of suppliers, were approached to provide a VPN solution for the LBS project. Typically, a carrier would offer a managed private network that is designed for larger bandwidth than the LBS data stream uses. The advantage of a managed private network model includes guaranteed reliability and low data latencies. However these benefits must be balanced against the high expenditure required for building this type of communication network. The feasibility of connecting all current and proposed GPSnet nodes to a centralised processing centre using a managed private VPN network is also considered.

4.3 Internet Based VPN Model

A Internet based VPN model would incorporate the open Internet as the central medium for delivery of data from GPSnet base stations to the LBS Central Server Cluster. Flexibility would be a noteworthy advantage of using an Internet based VPN model. For example if GPSnet base stations are able to be connected to the Internet, a generic VPN solution could be established which is calculated to be more cost effective than using managed private network. In addition, it would not matter where the GPS base stations are located the only constraint is the method of connection to the Internet. Refer to Figure 2.

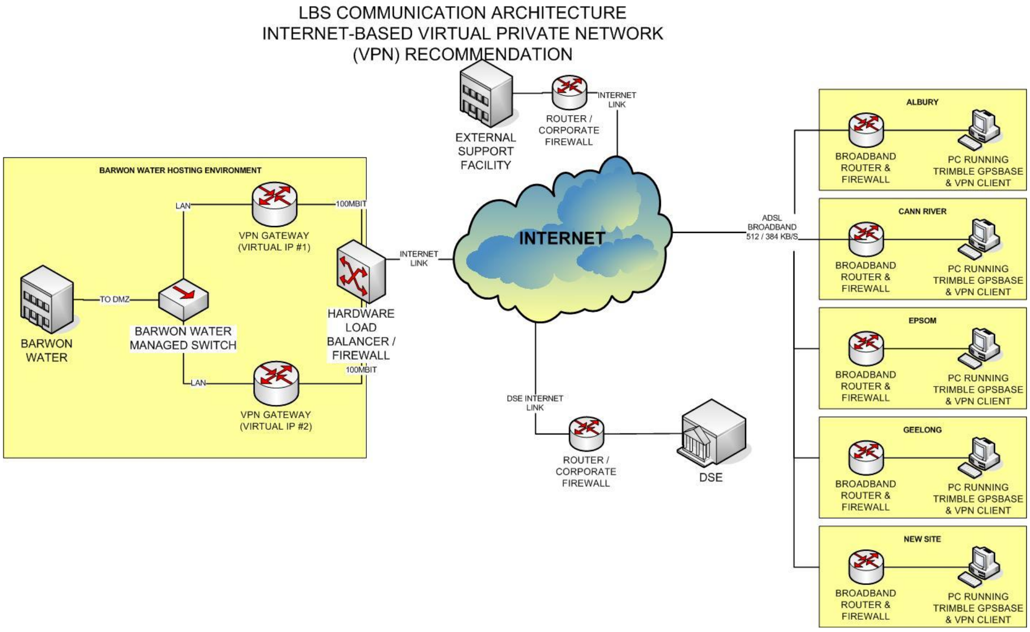

Figure 2. Internet based VPN model (Geomatic Technologies 2004)

4.4 DSE Managed Network VPN Solution

DSE Information & Technology Service (ITS) provides WAN/LAN services to over 87 regional government departments and authorities across Victoria. Recently ITS commissioned a CISCO VPN concentrator at the Australian Stock Exchange (ASX) Data Centre that is capable of including sites from outside the DSE domain into a managed network VPN. The solution provides for GPSnet sites that are outside the DSE network such as Albury, Geelong and Hamilton to be incorporated into the DSE *external domain.* Secure connectivity using the managed network VPN model could be realised through expertly designed architecture consisting of CISCO VPN routers, clients and secure switches. Refer to Figure 3.

Further analysis suggested that the most efficient and economical method for streaming real-time data would be by building a managed VPN network for GPSnet nodes already on the DSE WAN and then adding an Internet VPN model by means of a carrier such as Optus for the non-departmental sites. It was argued that latency would not be a significant issue at a 500 *millisecond* threshold value, given that the end user would be subject to a similar Internet latency by the nature of their mobile Internet connection to the LBS service. Peterzon (2004) has shown latency measurements of around 3 seconds for mobile Internet (GSM/GPRS) users receiving RTCM type 1 stream in Europe.

Initial testing of data rates over the DSE WAN through the VPN using Echo request – Echo reply (ping) that emulated 600 Bytes per second file streams were encouraging. The base time was found to be around 63 milliseconds. Average data delay for actual data streamed from DSE WAN sites via the VPN concentrator at the ASX and over the Internet VPN to Barwon Water are were between 150 and 200 milliseconds.
While average delays for sites using the Internet varied between 200 and 400 milliseconds.

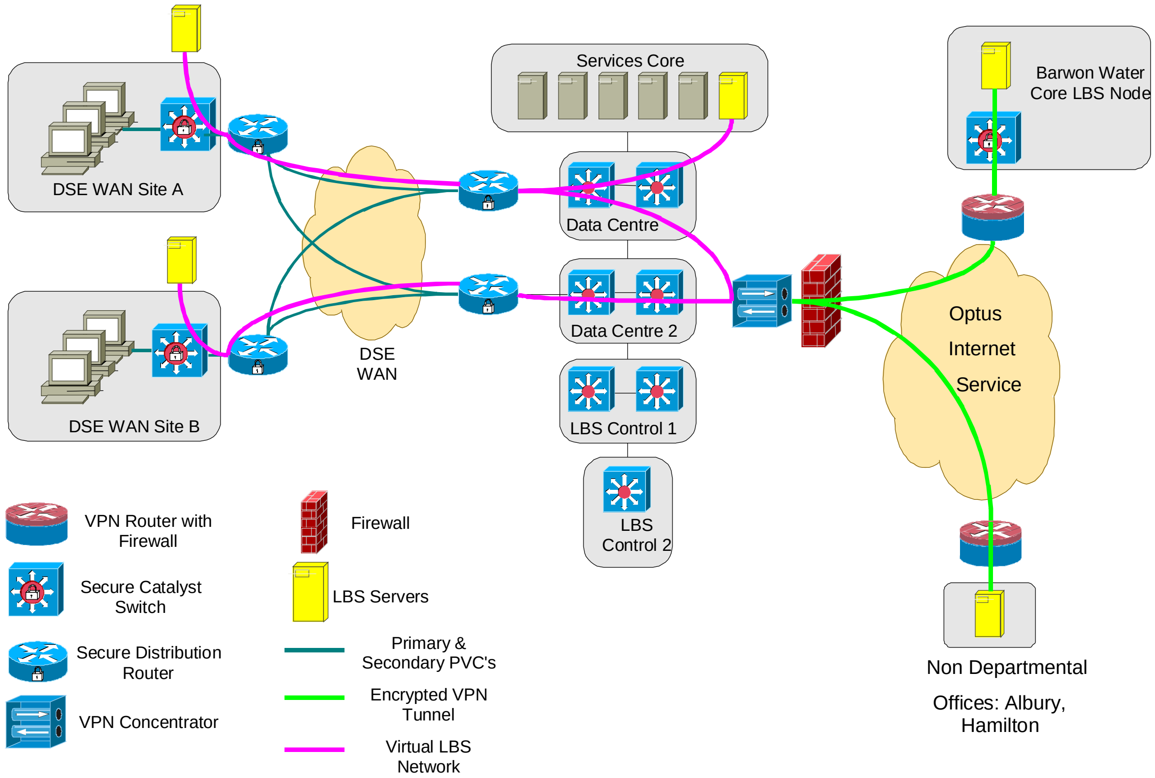

Figure 3. DSE Shared Services VPN model

4.5 Internet Connectivity - ADSL Business Broadband

LBS GPSnet nodes and the LBS Central Server Cluster are connected to the open Internet by ADSL Business Broadband supplied by Optus. ADSL splits the phone line into two frequencies which makes it possible to use the line for phone calls and Internet access at the same time. It is called "asymmetric" because more bandwidth is reserved for receiving data than for sending data. The key to ADSL is that the upstream and downstream bandwidth is asymmetric, or uneven. In practice, the bandwidth from the provider to the user (downstream) will be the higher speed path. This is in part due to the limitation of the telephone cabling system and the desire to accommodate the typical Internet usage pattern where the majority of data is being sent to the user with minimal upload capacity required such as keystrokes and mouse clicks (Optus 2004).

4.6 LBS Data Centre

Engineers from Trimble Navigation designed the LBS data processing data centre situated at Barwon Water ITS facilities in Geelong. The server cluster construction is intended to deliver processing efficiency while providing sufficient system redundancy and the capacity for future expansion. Refer to Figure 4 for a representation of data centre server cluster and associated peripheral equipment, adapted from Trimble (2004).

The server cluster in Geelong is comprised of seven machines that run on Widows XP Professional with specified dual hard-drives, dual central processing units and dual power input.

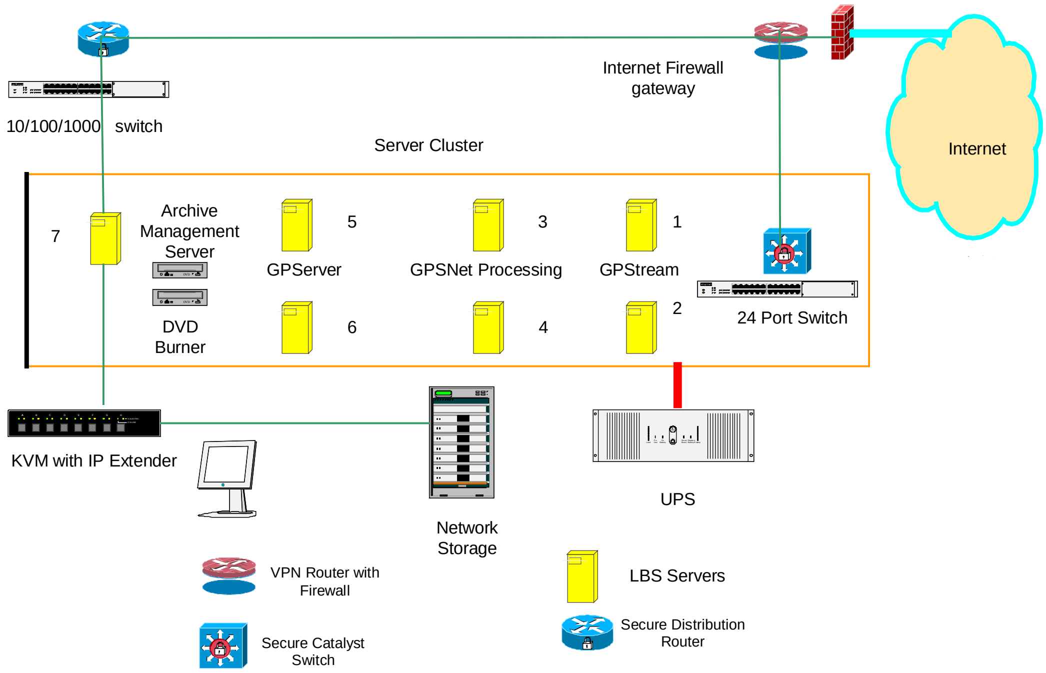

Figure 4. Data Centre Schematic (Adapted from Trimble 2004)

4.7 Server Redundancy

Standen (2004), advises that the GPStream server (server 1 in Figure 4) is essential for system operation so it is built in a dual power supply rack mount chassis and uses RAID hot swap hard disks in order to minimise possibilities of failure. However, should a failure occur, a secondary GPStream server (server 2 in Figure 4) is in 'warm standby' in the cluster. Should the primary GPStream computer go down, that is, not answer the 'hello' requests for more than 5 seconds, GPStream on the secondary server will start and take over functions of the primary GPStream server. This scenario applies to all the servers in the cluster which have a secondary backup server ready in *standby* mode (servers 3&4, servers 5&6 in Figure 4).

4.8 Remote Management

Remote control type management, by gaining control of the remote consol or desktop, allows for remote management by replicating the server display to another output such as the remote management client. The GPSnet team currently use proprietary remote software to manage GPSnet base station computers and GPS equipment over TCP/IP or modem connections. The same remote management software will be used to manage the GPS equipment over the VPN through a management server (server 7 in Figure 4).

For remote management of the sever cluster itself a Video Keyboard Mouse (KVM) that is equipped with an IP remote management extender module will be used. The KVM has the advantage of allowing simultaneous multiple user access via the Internet during the same remote session; which will facilitate remote configuration, instruction, operations and maintenance. This is an important consideration given GPSnets' duplicated control centres and requirement for provision of some 'off shore' support. Refer to Figure 5.

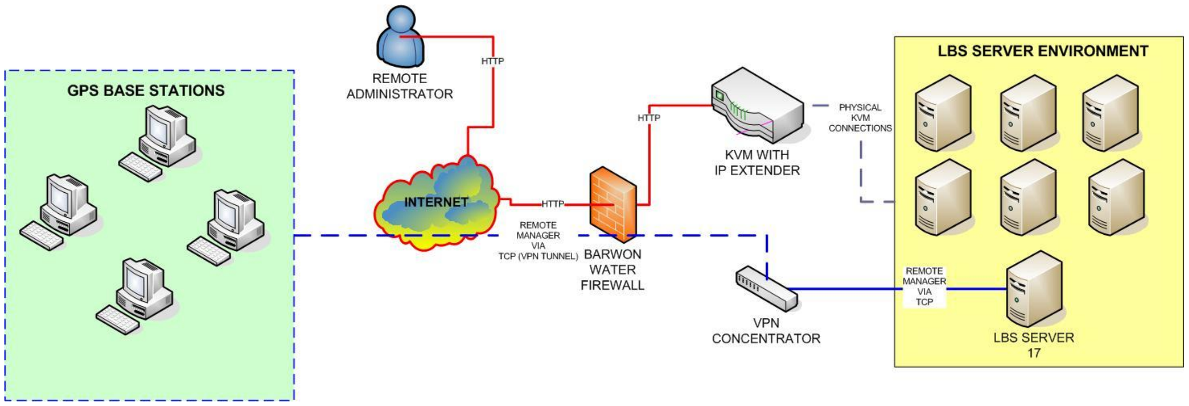

Figure 5. Remote Management (Geomatic Technologies 2004)

4.9 Security

The Location Based Service application is hosted in an external domain; therefore it demands high vigilance to ensure there is absolutely no interference with the hosts' corporate environment and that the LBS system will meet the departments' own rigorous security standards. Particular aspects of LBS security advice, implementation and procedures are subject to intellectual property owned by IT contractors who are currently engaged on the LBS project. However, the interested reader may review public documents from SUN which form the basis of the N-Tier architecture that is proposed for the LBS system. Refer to: http://www.sun.com/blueprints/1000/ntier-security.pdf

A thorough security audit forms an important component of LBS maintenance. Several elements within the LBS system architecture that require regular attention have been identified through a security analysis. Refer to Table 2.

LBS Element	Description
Firewall and VPN	Firewall rules and VPN encryption to restrict access
N-Tier Architecture and reverse proxies	Layer 3 switching to ensure that only pre-specified data flows are permitted
Bastion Hosts	Operating system "hardened" disabling all non-essential services
Operating System Maintenance	Periodical patching of operating system vulnerability's as they are released
Application Maintenance	Servers such as Apache will also need to adhere to periodical patching
Port Scanning	Port-scanning and reporting to show potential vulnerability
Intrusion Detection	Detection of traffic that is not authorised
Virus Detection	Standard enterprise updated anti-virus: eTrust

Table 2. LBS Security Audit and Analysis

5. INTERNET DATA STREAMING

5.1 Communication and Distribution - iGate

The LBS application comprises a set of modules that communicate and distribute GPS data over the Internet. For example files are distributed through an external *World Wide Web* server like APACHE and a client like MS Internet Explorer. Alternatively, GNSS/GPS processing and inquiry systems such as Pathfinder Office and Trimble Total Control from Trimble Navigation can automatically extract data files.

Trimble's ***iGate*** is a module in GPServer which operates as a communication centre between the source for GNSS data and the users of the data by stream-based transmission over the Internet (Trimble 2004). It makes the NTRIP protocol (see section 5.2) available and links the source of RTCM data from the base station network, through the central processing cluster, to the users who request the data over the Internet. iGate is designed to accept multiple simultaneous connections from client hosts. Moreover, a significant task if iGate is to provide a simple interface to the GPS database such that the otherwise tedious task of manually manipulating multiple file sets with different data rates or time spans for post-post processing download is reduced (ibid). Refer to Figure 6.

5.2 Networked Transport of RTCM via Internet Protocol- NTRIP

Networked Transport of RTCM via Internet Protocol (NTRIP) was developed by the Federal Agency for Cartography and Geodesy of Germany to enable the streaming of DGPS or RTK correction data via the Internet (Lenz, 2004). Distribution of streamed data by NTRIP is based on the General Public License software that was originally developed for MP3 media player formats. This appears to be well adapted for GPS streams with data rates between 0.5 and 5kbit/s, as MP-3 was designed for bit rates (music streams) from 32 to 128 kbit/s.

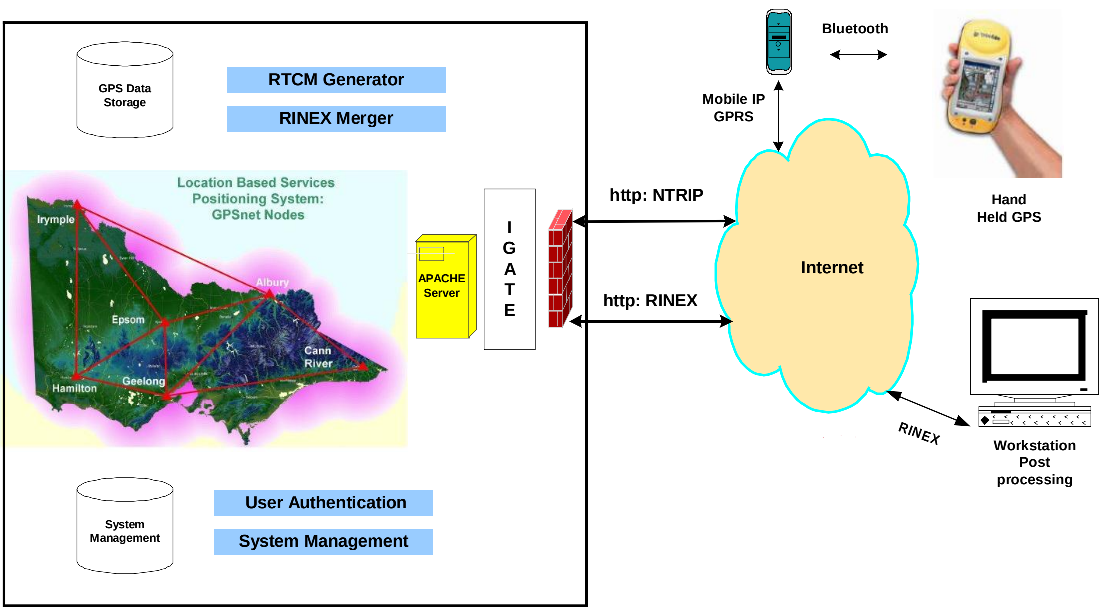

Figure 6. Streaming GPS data over the Internet

Dettmering and Weber (2004) describe NTRIP as a generic, stateless protocol based on Hypertext Transfer Protocol (HTTP/1.1) that is enhanced for GNSS data streams. NTRIP consists of several components namely the NTRIP Source such as GPSnet base stations that generate data; NTRIP Server that transports data streams, NTRIP Caster (Trimble's iGate in Figure 6) which handles the administration of connections between clients and data streams and the NTRIP Client application for a mobile user, (Personal Digital Assistants, Pocket PC or Win CE) or PC/Laptop, Trimble Survey Controller etc. The Federal Agency for Cartography and Geodesy of Germany has freeware NTRIP client tools such as GNSS Internet Radio software for mobile or desktop use that are available from their web site: http://igs.ifag.de/index_ntrip.htm.

5.3 Wireless Internet Connections

NTRIP supports wireless access to the Internet ***cloud*** directly through General Packet Radio Service (GPRS) or General System for Mobiles (GSM) that will ***dial up*** to a local Internet Service Provider (ISP). GSM is a worldwide standard that can provide data in packet mode at speeds up to 9.6 Kbps. GPRS uses the GSM infrastructure with increased speeds of up to 115 Kbps. Generally GPRS is preferable to GSM connections since the users are only charged by the amount of data transferred and not by the duration for call time. Indicative costs for using GPRS to access the Internet for receiving LBS DGPS data corrections range from $2 per hour up to about $8 per hour, depending on the carriers' plan. It should be noted that mobile Internet access is not ubiquitous across Victoria. In this respect NTRIP could be used for broadcasting through other means such as FM radio, digital TV or communication satellites in the future.

When a user wishes to connect to the LBS service, their local NTRIP client running on Windows Pocket PC for example instructs the cell phone, communicating via Bluetooth™, (see www.bluetooth.com) to connect to the Internet. Once on the Internet, a socket connection is initiated to the GPStream NTRIP server. The server then requests a user name and password for authentication.

This socket will be the real IP address of the firewall gateway and the NTRIP socket configured on the GPStream server. The firewall gateway is configured to forward any requests on the NTRIP TCP port to the GPStream server. When first contacted, NTRIP will send the user a menu of available services, such as DGPS or RTK. Once authenticated, NTRIP will interact with the RTCM manager software module and instigate a connection to the next available socket that will stream out GPS correction data to the user (Standen 2004).

5.4 Data Stream Output Formats

The LBS application will broadcast (multiplexed data) from single and multi-station networked corrections for DGPS or RTK use, at different data rates, such as 1, 2 or 5 seconds. The output formats for DGPS include RTCM 2.1 and RTCM 2.3.

The LBS application is also capable of broadcasting network RTK messages in four modes:

1. VRS mode in CMR^+ and RTCM;
2. SAPOS with FKP network corrections sent out in RTCM 20/21;
3. ADVFKP where FKP messages are sent out encrypted in RTCM 20/21; and
4. RAW – code and phase data without network corrections.

Additional output formats allow for RTCM+RTK broadcasts where the primary messages are both DGPS and RTK corrections. Unlike the previous GPSnet configuration, were local real-time RTK corrections are constrained by the limitation of the VHF UHF radio system, centralised access to networked correction allows the user to determine and select the output format that is most appropriate for their application or task.

5.5 User Activity and Connection Status

LBS administrators supervise information regarding current user activity and connection status through the iGate module. Statistics such as a users IP address, user name, service protocol selected, authentication type, service duration and amount of data sent are all available. Service history, total connections and service *up time* are all recorded and can be viewed by the LBS system operator.

User accounting is done automatically from the access to the web servers with NTRIP and iGate logging information to the GPS databases. The time that users are connected, the time when they disconnect and data use while on-line are all recorded. This information can be used for account generation, billing and user activity reports.

5.6 Monitoring, Analysis and Reports

Monitoring and administration tasks for the LBS application are important considerations in order to fulfil the total service up-time requirements of Vicmap Position – GPSnet. With multiple LBS modules running in parallel on a permanent basis it is important that these administration functions are automated.

In addition alarm systems and appropriate warnings are necessary for the LBS administrators and operators to perform early intervention and timely corrective actions. For example, messages can be sent via e-mail alerting when pre-determined thresholds are reached for example: Satellite availability, received data communication links, disk and memory size, correction and coordinate status.

Analysis modules such as GPSnet node single point positions, GPS receiver clock, DOP, raw data, multi-path and ionospheric analysis are important for understanding effects from GPS signals and performance of the base station equipment. Receiver errors such as outliers, cycle-slips are detected and corrected or removed from the data and written into error messages or summary reports. These reports are passed in XML format ready for display and distribution over the Internet. Monitoring, analysis and reporting tasks are essential for efficient and effective system management that will ensure users have viable and complete access to Victoria's spatial information and infrastructure.

6.0 Conclusion

GPSnet has recently become the principal utility for the collection of accurate spatial data in Victoria using GNSS/GPS technology. The LBS positioning system project will further enhance this important sate-wide infrastructure by providing a multi-station networked real-time solution suitable for an interesting range of applications and tasks. Further, the project is part of a broader strategy to integrate a real-time positioning capability with spatial information from the Geospatial Emergency Information Network (GeIN).

A significant factor for obtaining dependable location based services using Vicmap Position - GPSnet are affordable and secure communications for streaming data from the base station nodes to the central server processing centre. After an exhaustive feasibility study and rigorous technical analysis a hybrid managed VPN was built over the departments' WAN which could be extended to include non-departmental sites connected via the Internet. It has been found that the average latency of the data streamed from GPSnet nodes to the central processing facility is less than the threshold value of 500 milliseconds.

The LBS project, once commissioned and fully operational, will endeavour to combine all present and proposed GPSnet nodes into a total network solution. With increasing demand for high accuracy position systems there is a legitimate expectation that the LBS project will provide the primary infrastructure for developing a networked RTK service for all Victoria in the near future.

REFERENCES

Brown N, Kealy A, Millner J, and Ramm P (2003) ***Quality control concepts for regional GPS reference station networks,*** 6th Int. Symp. on Satellite Navigation Technology Including Mobile Positioning & Location Services, Melbourne, Australia, 22-25 July, CD-ROM proc., paper 81.

Dettmering D, Weber G (2004) ***The EUREF Ntrip broadcaster real-time GNSS data for Europe***, Federal Agency for Cartography and Geodesy, BKG, Frankfurt, IGS 2004 Workshop, Bern, March 1-5 2004. http:/igs.ifag.de/ntrip_caster.htm

Geomatic Technologies (2004) ***LBS base station to server infrastructure communication analysis and report,*** LBS Project Documentation, Spatial Information and Infrastructure, Department of Sustainability and Environment.

Lenz E (2004) ***Networked transport of RTCM via internet protocol (NTRIP) – application and benefit in modern surveying systems***, FIG Working Week, Athens, Greece, May 22-27, 2004. Int. paper TS3.2.

Millner J, Hale M, Brown N, Kealy A, Smith J, and Williamson I (2001) ***The influence of emerging location-based technologies and electronic business models on Victoria's Geodetic Strategy***, 5th International Symposium on Satellite Navigation Technology and Applications, Canberra, Australia 24th - 27th July 2001.

Optus (2004) xDSL ***technical sales information***, LBS Project Documentation, Spatial Information and Infrastructure, Department of Sustainability and Environment.

Peterzon M (2004) ***Distribution of GPS-data via internet***, Reports in Geodesy and Geographical Information Systems, Geodetic Research Department, National Land Survey of Sweeden, Thesis LMV-report 2004:01.

Roberts C, Zhang K, Hale M, Millner J (2003) ***Towards real-time networked-based RTK corrections for Victoria's GPSnet,*** 6th Int. Symp. on Satellite Navigation Technology Including Mobile Positioning & Location Services, Melbourne, Australia, 22-25 July, CD-ROM proc., paper 59.

Standen P (2004) ***Ultimate Positioning LBS positioning system product description***, LBS Project Documentation, Spatial Information and Infrastructure, Department of Sustainability and Environment.

Scott-Young S, Mowlam A, (2004) ***Towards Precision LBS***, Position Magazine, December 2003/2004 pp 51- 52.

Trimble (2004) ***GPServer data publication using the Internet***, Trimble product documentation www.trimble.com