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CORSnet-NSW: Deploying a CORS Network in a Corporate IT Environment

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ABSTRACT

CORSnet-NSW is an expanding network of Global Navigation Satellite System (GNSS) Continuously Operating Reference Stations (CORS) being deployed in New South Wales (NSW), Australia by Land and Property Information (LPI), the State's lead agency for spatial data infrastructure. It currently consists of more than 70 CORS across NSW and two Network Control Centres (NCC) in two geographically separate data centres, providing a high degree of redundancy. Within LPI, all IT resources are centrally managed by a team of specialists in the Information & Communications Technology (ICT) section. The NCCs for CORSnet-NSW have been jointly designed and implemented by the Survey Infrastructure & Geodesy and ICT sections of LPI. This paper examines the approach taken in designing and implementing a NCC for a CORS network on top of a corporate IT infrastructure. New technologies such as Virtual Private Network (VPN) and server virtualisation – commonly used in the corporate IT environment today – are employed and their specific implementation in CORSnet-NSW will be discussed. The advantages and disadvantages of using such an approach at LPI will also be examined.

KEYWORDS: CORS, IT, CORSnet-NSW, virtual server, VPN.

1. INTRODUCTION

CORSnet-NSW is an expanding network of Global Navigation Satellite System (GNSS) Continuously Operating Reference Stations (CORS) providing fundamental positioning infrastructure for New South Wales (NSW) that is accurate, reliable and easy to use (Janssen *et al.*, 2010, 2011). It is built, owned and operated by Land and Property Information (LPI), a division of the NSW Department of Finance & Services. CORSnet-NSW supports the spatial community across the state and provides stimulus for innovative spatial applications and research. Currently consisting of over 70 reference stations, the CORS network is planned to expand to 120 stations by 2013. Real-time services are provided via the Internet, accessed by users in the field through wireless cellular networks (Yan *et al.*, 2009).

Compared to other spatial data management systems that LPI maintains, the CORS network represents a unique challenge in terms of technology. While the IT designs for those systems are commonly based on spatially-enabled relational database management solutions, the IT system for CORSnet-NSW is an intricate combination of real-time communications and computations using specialised GNSS software that has to operate around the clock. A successful implementation requires the system to meet the business and technical needs set and be in-line with the organisation's standard operating procedure, particularly in the area of Information Communications and Technology (ICT).

This paper presents the process taken to implement the CORSnet-NSW system within LPI's corporate IT environment, focusing mainly on the Network Control Centre (NCC) aspect. Major factors to consider are initial technical and business requirements, the corporate organisation and technology environment, and selection of the CORS network management software. The implementation of the CORSnet-NSW system covers important aspects such as system architecture, communication links, data storage, failover mechanisms and system monitoring.

2. SYSTEM REQUIREMENTS AND ENVIRONMENT

2.1 Technical and Business Requirements

CORSnet-NSW's Network Control Centre is required to handle the full expansion and commercialisation taking place over the lifetime of the project. The following system capacities are expected:

1. Support for up to 132 connected CORS with approximately 500 bytes per second traffic per node with latency better than 200 milliseconds.
2. Support for up to 5000 registered users.
3. Support for up to 1000 concurrent users.
4. Storage for GNSS data at 1 Hertz rate.
5. Long-term archive of GNSS data at 30 second rate.

The system is expected to take advantage of LPI's existing IT infrastructure, with redundant systems to be built at each of LPI's data centres in Sydney and Bathurst.

2.2 Organisational Management

Within LPI, IT resources are centrally managed by the ICT group. The services maintained by LPI ICT cover a fairly broad range of IT from IP telephone system and desktop support to data centre and in-house software development.

The knowledge and expertise in GNSS technology and its survey applications reside within the Survey Infrastructure and Geodesy branch of LPI. The CORSnet-NSW technical team consists of eight technical officers and surveyors, all with extensive knowledge and experience in GNSS infrastructure and applications.

The CORSnet-NSW system has been designed and implemented by the Survey Infrastructure and Geodesy branch together with LPI ICT staff specialising in data centre, network communications and software development.

2.3 Virtualisation Technology

Modern data centres consume significant amounts of electricity. A recent report by the U.S. Environmental Protection Agency states that data centres in the U.S. consume 4.5 billion kWh annually, or 1.5% of the country's total electrical consumption (EIA, 2001). This figure has doubled from 2000 to 2006 (Kumar, 2007) and is likely to double again in the next few years.

Energy use translates into increased costs for organisations. For example, between 2007 and 2012, most enterprise data centres in the U.S. are expected to spend as much on power and cooling as on the hardware itself (Kumar, 2007). It is also predicted that energy costs will continue to rise and could double by 2012. At the same time, hardware in data centres has traditionally been underutilised. A server often uses only between 5% and 10% of its capacity in a typical 24-hour period (Kumar and Mingay, 2008).

Virtualisation technology can substantially reduce power and cooling costs by consolidating multiple server workloads onto a single piece of hardware. By using the latest, more energy-efficient hardware combined with virtualisation, resources can be consolidated, thereby decreasing energy costs while increasing asset utilisation. Spare capacity can also be allocated on-the-fly to respond quickly to changing workloads or business priorities (VMware and Intel, 2009).

Virtualisation allows for multiple application and operating system workloads to run on the same server. Ten server workloads running on a single physical server is typical. Consolidation through virtualisation reduces the number of physical servers required, helping to reduce power and cooling costs, as well as providing more computing power in less space.

Over the past three years, LPI ICT has been testing and deploying virtualisation technology in its data centres in order to reduce energy cost, hardware footprint and maximise workload. The current platform used to host the Microsoft Windows operating system is Microsoft Hyper-V.

2.4 CORS Network Management Software

In late January 2009, a tender was opened to procure commercial software for the management of CORSnet-NSW and provision of required products and services. Concluding a competitive and comprehensive tender process, a contract was awarded in June 2009 to utilise VRS^{3}Net, the latest generation of CORS network management software from Trimble Navigation.

The tender evaluation was a critical process to determine the suitability of the selected software in meeting the initial business and technical requirements mentioned earlier. In turn, the system requirements of the selected software will dictate many aspects of the system's implementation.

In addition to the CORS network capacity requirements, it is also important that the selected software meet certain IT requirements and can be easily integrated into LPI's overall IT infrastructure. As such support for virtualisation technology, redundant data centres and integration with other IT systems through technology such as web services were also important considerations in selecting the required software.

3. IMPLEMENTATION

3.1 System Architecture

The architecture for the CORSnet-NSW system is a 3-tier model that comprises of a production environment, a User Acceptance Testing (UAT) environment and a development environment. The production environment consists of two VRS^{3}Net systems, hosted at each of the LPI data centres in Sydney and Bathurst. Due to the real-time nature of the technology, it is very sensitive to any outages that can occur. The loss incurred to real-time users when the system is not available is higher compared to other types of applications where users can wait until the system becomes available again. Additionally, as with any systems, scheduled downtime for maintenance is always required to keep the system at optimal performance.

To accommodate these requirements, the production environment has been designed for high availability. It involves running two separate VRS^{3}Net systems in separate data centres. Both systems are always online, processing and storing data independently, however only one system (primary) services user requests. In the event the primary system becomes unavailable, due to either maintenance or fault, user requests will be rerouted to the backup system. Both the primary and backup systems are setup with identical configuration. This primary/backup approach has been favoured instead of load balancing due to the additional complexity involved in implementing a load balancing architecture.

The UAT environment consists of a replica of the VRS^{3}Net production system. The UAT environment is used primarily for testing any new changes to ensure they meet user requirements before getting elevated to the production environment.

The development environment consists of a single-server VRS^{3}Net system. It is used for the development of in-house software for integration of VRS^{3}Net with other corporate systems within LPI such as the Spatial Information eXchange (SIX) platform (LPI, 2011) and the SAP accounting system.

Except for the development system, each VRS^{3}Net system consists of multiple virtual servers (or machines) that run on each data centre's Hyper-V cluster. The Hyper-V cluster consists of a series of host machines (physical servers). Live migration of virtual machines from one host to another is possible if the current host experiences a problem. This provides hardware redundancy with zero downtime.

Hardware resources within the Hyper-V cluster can be dynamically allocated to virtual machines. This allows the VRS^{3}Net system servers to be upgraded on-the-fly as the demand grows during the ongoing expansion of the CORS network without being constrained by initial hardware specifications. The use of virtualisation platforms allows better handling of transient surges of CPU or memory consumption due to the larger hardware resource pool available.

The recommended operating system by Trimble Navigation for the VRS^{3}Net software is Microsoft Windows 2008 Server R2 x64. Microsoft SQL database software is also required with Standard 2008 being the recommended version. A VRS^{3}Net system can run over a single or multiple servers. From consultation with Trimble Navigation and other VRS^{3}Net operators, using between three and five servers appears to be a common approach. Generic server specifications were initially recommended by the manufacturer based on the expected size of the CORS network and the extent of products and services. The exact specifications for each server were then further refined using empirical load testing at LPI.

3.2 Communication Links

The communication link between the data centres and each CORS is an important aspect and significantly affects the performance of individual CORS. CORSnet-NSW utilises several different types of communication links for its CORS. With regards to the design of the Network Control Centre, they can be classified into two main categories: those that are part of LPI's corporate Wide Area Network (WAN) and those that are not part of LPI's corporate WAN.

The first category includes CORS that are connected via dedicated link provided by service providers such as SOUL, Telstra and RailCorp. Depending on available coverage, the physical connection to the CORS can be copper wire, fibre-optic or wireless radio. CORS in this category become part of LPI's corporate WAN with a transparent IP address. Having a transparent IP address enables the VRS^{3}Net production system in each data centre to establish a direct, independent connection to all CORS in this category.

The second category includes CORS that are connected to the host's Local Area Network (LAN). These CORS are allocated a private IP address not visible to the VRS^{3}Net system. Connection is initiated by the CORS receiver – functioning as an NtripServer – to CORSnet-NSW's NtripCaster. Under the current design, it connects to the NtripCaster on the primary VRS^{3}Net system. When the failover process is initiated, it automatically gets redirected to the NtripCaster on the backup VRS^{3}Net system.

LPI is currently testing VPN technology that would establish a VPN tunnel between the CORS equipment and LPI's WAN and provide the CORS with a transparent IP address to the VRS^{3}Net system. This would standardise the connection procedure used across all CORS and

eliminate the short outage introduced during failover and failback. The testing is ongoing and has proven to be challenging due to the complex nature of multiple networking protocols and various LAN setups involved in establishing the connection.

Between the two data centres in Sydney and Bathurst, redundant communication links are in place, provided by different carriers.

3.3 SQL Servers

VRS^{3}Net uses a relational database management system to store a variety of metadata including accounting information such as username, subscription and usage history. It specifically requires a Microsoft SQL Server to run. While an Express version is included with VRS^{3}Net, the CORSnet-NSW system uses Microsoft SQL Server 2008 Standard Edition which is the version recommended by Trimble Navigation.

For redundancy, two instances of SQL Server are running, one in each data centre. Because the current version of VRS^{3}Net does not support the use of redundant database servers, one instance is used as the primary server while the other assumes the role of backup server. Both VRS^{3}Net production systems connect to this primary server. The transaction logs from the primary server are then shipped to the backup server. If the primary database server is unavailable due to maintenance or fault, the logs are restored into the backup server and the backup database is brought online for usage.

3.4 GNSS Raw Data Storage

Although a relational database management system is used for storing metadata, a conventional file system is still used to store the raw GNSS data. Storage of these files takes advantage of the dedicated Storage Area Network (SAN) infrastructure at each of LPI's data centres. Similar to the idea of virtual servers, SAN provides an abstraction layer between banks of physical hard disks and virtual partitions or drives that can be presented to different applications. The SAN fabric supports very high storage capacity with high flexibility for growth. Storage capacity can be dynamically allocated and adjusted immediately. This provides significant advantage to the CORSnet-NSW system as no initial storage hardware commitment is needed and capacity can be allocated accurately without over-committing. As storage size grows – mainly due to the increasing number of CORS and GNSS satellites – the storage capacity is adjusted to keep up with the requirement. The current monthly size of data for the network is approximately 21 GB and is growing at an average rate of 8% per month.

In order to support full disaster recovery, in the event that one of the production systems becomes completely irrecoverable, each VRS^{3}Net production system stores a complete set of data at each data centre. A two-way synchronisation procedure has been designed and implemented to ensure both datasets are consistent and complete.

3.5 Failover Mechanism

Under the primary/backup configuration, servicing of user requests is redirected from the primary system to the backup system when the primary system is unavailable. This could be

due to maintenance or fault. The switching between the primary and backup systems is handled by a load balancer and is transparent to users. The domain name for accessing CORSnet-NSW services remains the same.

Figure 1 illustrates the CORSnet-NSW production environment, indicating communication links and data flow between the different components involved.

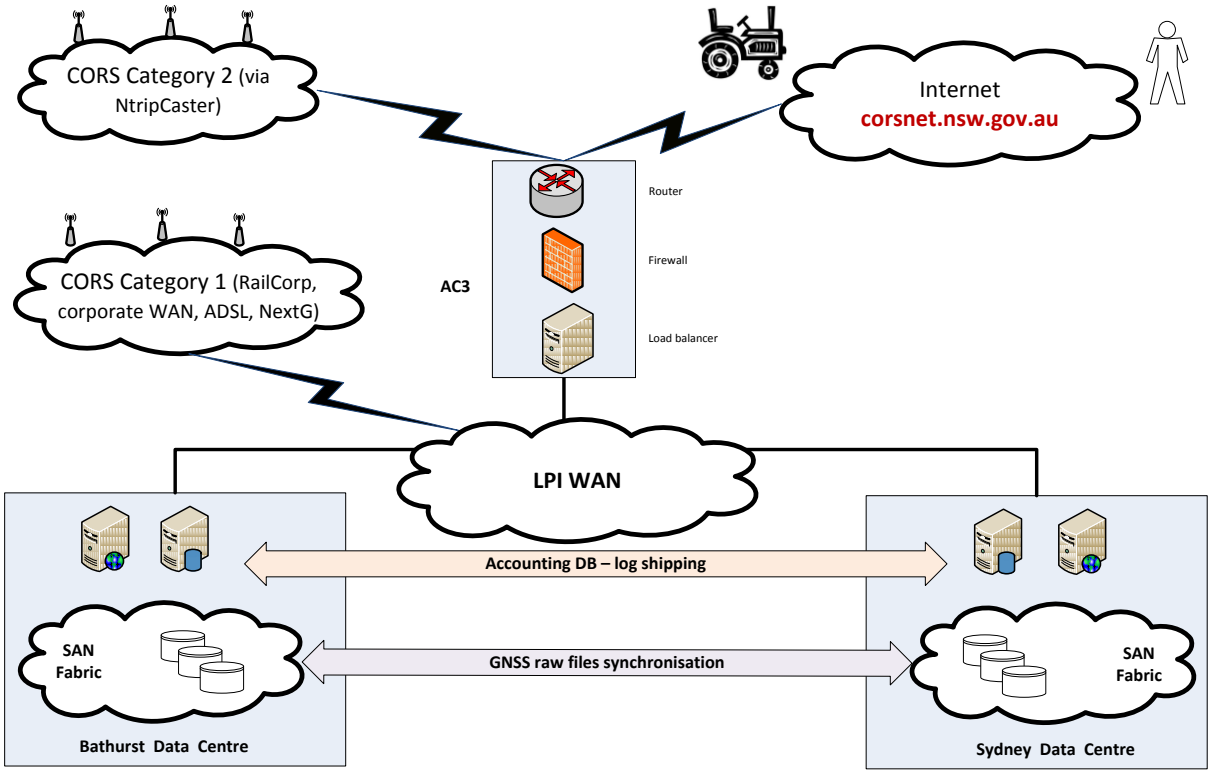

Figure 1: CORSnet-NSW production environment.

3.6 Monitoring and Backup

Following common practice in data centres, pro-active monitoring and regular backups are carried out on the CORSnet-NSW system. All the underlying hosts and virtual machines are monitored on a 24/7 basis using the enterprise monitoring solution Groundworks. Resources such as ping response, CPU utilisation, RAM utilisation, failed components and disk space are checked on a regular basis to ensure they meet the agreed threshold. Alerts are sent to LPI's ICT staff via email and SMS, and acted upon based on the criticality of the issue.

The rapid expansion of the CORS network means that server resource consumption is dynamic and increasing. The expanding network coverage also stimulates user take-up, augmenting the dynamic nature of resource consumption. This requires closer monitoring on the server infrastructure to ensure that the resource allocated continues to meet the demand so that optimal system performance can be maintained.

Based on CORSnet-NSW's observation so far, the increase in server resource consumption – focusing on RAM, CPU and disk space utilisation – is predominantly affected by the increase in the number of CORS connected. In comparison, the increase in the number of real-time users has far less impact in regards to server resource consumption. This is an advantage in

terms of capacity planning since the increase in the number of CORS can be estimated far more accurately compared to the increase in the number of users.

All virtual servers in the system are backed up in accordance with LPI's corporate backup policy. There are two types of backup, incremental and full backups. Incremental backup is carried out on a daily basis, while full backup is carried out on a weekly basis.

4. CONCLUDING REMARKS

The Network Control Centre (NCC) segment is a crucial part of any CORS network. In this paper, the design and implementation of CORSNet-NSW's NCC has been outlined. Major factors that influenced the implementation are initial technical and business requirements, the corporate organisation and technology environment, and the selection of the CORS network management software. The implementation of the system has been discussed, covering important aspects such as system architecture, communication links, data storage, failover mechanisms and system monitoring.

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