The Institution of Railway Signal Engineers
Australasian Section Inc.

WestNet Rail – Building Resilience and Redundancy into a Centralised Train Control System

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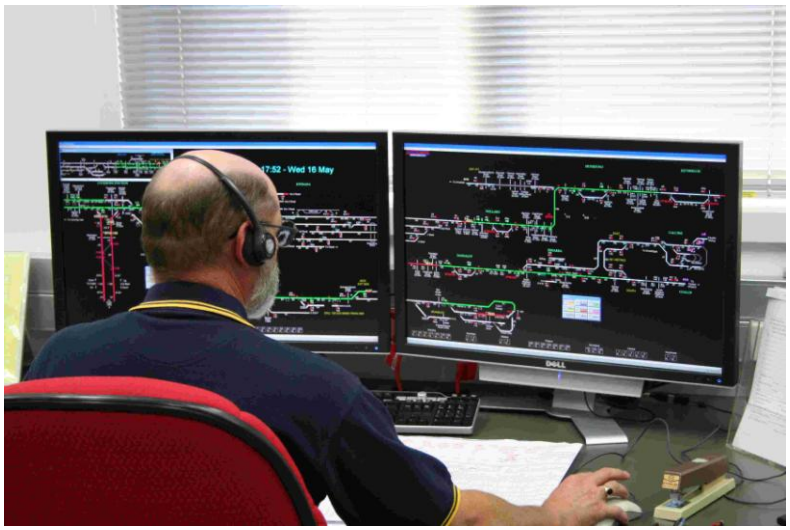


Summary:

Westnet Rail is in the process of centralising its Train Control Operations in Western Australia. Given the strategic importance of the new facility, a significant effort has gone into ensuring that the new system utilises high level resilience and redundancy strategies, whilst maintaining a flexible platform for business needs. This paper describes how this was achieved in an environment of high technical and commercial risks, tight timeframes and constrained resources.

INTRODUCTION AND OVERVIEW OF THE WORK

The WestNet Rail (WNR) railway network comprises rail infrastructure for the regional areas of Western Australia over approximately 5,300 km of track. Of this approximately 4,000 km is non-signalled territory where safeworking is effected using computer assisted proceed authorities (train orders). The balance is remotely controlled signalled territory based on various generations of field based interlocking equipment which provide vital safeworking.

Figure 1 below shows the current WNR Train Control areas.

Prior to the implementation of the first stage of the TCCP the WestNet Rail train control facilities comprised three different and separate train control systems, installed over four Train Control Centres. The existing train control systems and centres were;

- Union Switch and Signal (US&S) original Phoenix Train Control System (located at the Public Transport Centre, East Perth)
- In house developed versions of "Paragon based" Train Control System located at Merredin and Avon Train Control Centres.
- In house developed Interlocking Control System based Train Control System [ICS-TCS] located at Picton Train Control Centre.
- Computer Assisted Train Order System [CATOS] (across all Train Control Centres)

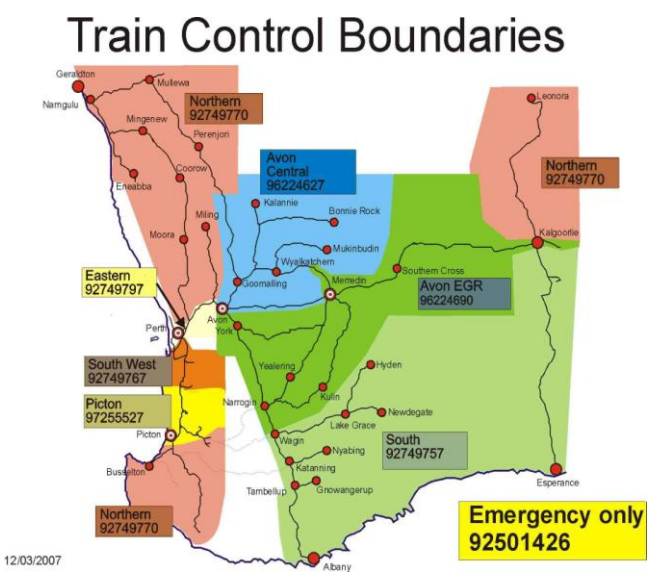


Figure 1 - WNR Train Control Areas

The existing Phoenix, Paragon and ICS-TCS are all regional centralised train control systems, which interface to field based interlockings via various telemetry equipment. Vital safeworking is undertaken locally at each interlocking.

CATOS is a dark territory, computer assisted train order system which is used to validate the issuing of train proceed authorities.

In 2003, WestNet Rail identified a need to rationalise their train control systems and centralise train centre operations to improve operating efficiencies and make better use of resources. The concept of rationalising train control to allow operation of all areas from a single centre was seen as a strategic move in the growth of the Westnet business and a preliminary design was undertaken to identify the feasibility of this proposal.

The preliminary design identified significant issues with data and voice communications and the business undertook enabling works to improve the underlying communications infrastructure. The enabling works included the installation of a backbone fibre from Picton to Perth and Perth to Kalgoorlie and a progressive rollout of an SDH over fibre bearer system

Two main areas of work were identified as core to the centralisation project these were the centralisation of the control for all CTC areas and the replacement and integration of the Train Order Working system. WestNet Rail viewed the two contract packages as a single integrated project ("the Project"), but due to internal timing, the works were initiated as two separate contracts.

WestNet Rail's vision was to implement a system which would allow an integrated environment for all of their train control requirements, in a manner which would provide tolerance to hardware failure, loss of communications, physical disruption to key locations (including MidCon) and to provide multiple potential disaster recovery locations. In essence, WestNet Rail view train control as an application, capable of being run on a laptop, if required, and at any location were train radio can be obtained.

PROJECT MOBILISATION AND DESIGN ISSUES

WestNet Rail commenced negotiations with Union Switch and Signal in late 2003 and after some delays contracts were signed early 2006.

WestNet Rail were highly conscious of the possibility of a single disruption at the new centre having a significant impact on train operations and the issues of resilience, redundancy and disaster recovery became key design parameters. These requirements gave rise to an architecture where application servers would be duplicated and located at multiple locations with the ability to connect to I/O servers at both the same and different locations. This approach necessitated the establishment of a Wide-Area LAN to facilitate the communications between servers. This architecture was novel in that few manufacturers had implemented such designs. With the control centre located in Midland and the I/O servers located as far away as Picton and Merredin, the system would need to look like a LAN and provide resilience in communications to ensure failure of equipment or loss of communications would not compromise the train control function.

In addition, the architecture provides redundancy in train control workstations and allows for any workstation in any location to control any part of the network. This provides a highly flexible operational platform which will accommodate disaster recovery or operational flexibility as the business needs change. This necessitated a radio bus system design which would allow radio take-off points at all major nodes within the WNR network.

Given the technical risks, a 'Proof of Concept' was mandated as the 1st stage of work, such that failure to meet key performance and resilience technical parameters, the remaining contract deliverables would not proceed.

Market conditions also provided significant risk with competing projects in WA and in other parts of the world putting significant pressure on the Contractor to ensure competent and sufficient resources could be retained to complete the works in a tight timeframe.

During the early part of the Project WestNet Rail also upgraded the old Midland Signalling facility (MidSig) at Midland to house the new system. The facility is now called Midland Control (MidCon).

The original timing of the two contract works; CTC control and Train Order Working, necessitated separate Contracts. This introduced its own problems in that the two had to be controlled and managed as separate commercial agreements but WNR desired a single integrated solution with coherence across each controlled area.

PROJECT STRUCTURE: TRAIN CONTROL CENTRALISATION PROJECT

The TCCP works were arranged as six separable portions:

- Technical Proof of Concept
- Relocation of PTC control to Midland
- Relocation of Picton control to Midland
- Relocation of Avon control to Midland
- Relocation of Meriden control to Midland
- Integration and control of Kalgoorlie from Midland

The works include the delivery of a disaster recovery site. The Contract was awarded as a Design and Construct under the AS4300 Conditions of Contract.

PROJECT STRUCTURE : TRAIN ORDER WORKING TOS 2006

The TOS works were arranged as a single delivery with train order permissions being based on the existing WestNet rules. The Contract was awarded as a Design and Construct under the AS4300 Conditions of Contract.

RISK MITIGATION STRATEGIES AND MANAGEMENT PROCESSES

A risk management approach has and is being used to develop the methodologies and implementation strategies for the Project. This has ensured that the Project is managed in a manner that does not conflict with the requirements and operations of the WestNet Rail business.

The fundamental philosophy of this approach has been to ensure that all risks are managed to a level such that the risk is either low, or the risk is reduced to a level that is as low as reasonably practicable.

No risks in the Project are seen as intolerable.

In order to establish the framework for the Project, up to and including final award of the contracts, risk workshops were convened to identify risks and management strategies and to establish controls at key points in the Project.

These key points were identified as:

- Scope definition and clarification including implementation methodology and stages
- Specification and contract document preparation
- Contract terms and conditions development
- Award Process
- Change management and regulatory issues
- Commissioning and commencement of operation

In order to mitigate against project management and contract administration risks, WNR engaged Australasian Railway Consulting Services (ARCS) to undertake both Project Management and Superintendence for both the TCCP and TOS Contracts. ARCS had been involved in the original WNR Phoenix system and are also involved in the Public Transport Authority train control system rollout. WNR seen the commonality of the arrangements across TCCP and TOS as a way of maintaining the focus of one Project and not two contracts and also allowing interface issues to be more easily co-ordinated.

WNR put in place a strong management processes overseeing the Project. These include regular technical, progress and management meetings. Monthly progress meetings for the two contracts and a common joint management meeting are held on the same day to allow cross dialogue between the two contracts and the Joint Management meeting is used to oversee progress and manages commercial and co-ordination issues across both contracts. The management group consists of two senior representatives from both WNR and US&S, the Project Managers from each organisation and the Superintendent.

Both WNR and US&S have maintained a policy of 'no surprises' in meetings. This process has ensured that issues are known to all parties prior to discussions and greatly assists in maintaining relationships within the Project.

TECHNOLOGIES AND TECHNICAL RISKS

The Union Switch and Signal train control system provides WestNet Rail with a proven train control system framework on which to develop a network wide redundant operational platform. Both WestNet rail and US&S however were both aware that the architectures required to ensure that this could be achieved in a highly resilient manner came with technical risks which would need to be overcome before launching into the full project. The main areas of technical risks were seen as:

- The LAN/WAN data communications arrangements to allow redundancy across multiple sites
- The radio bus concept and design
- The integration of the two safe working systems into a common train control platform

The distributed nature of the topology was largely untried and while we were confident of a successful outcome, in order to mitigate against the technology risk a 'Proof of Concept' was included as the first cab of the rank.

The notion of a proof of concept allowed both organisations some time to examine the technical behaviour and performance of the systems in manner which would provide hard performance numbers and a go, no go gate which would limit further commercial exposure. Overall this would provide a risk reduction and improve the confidence in the correct operation of the final arrangements.

PROOF OF CONCEPT

The final system topology was a joint design effort from WestNet Rail technologists and US&S specialist engineers. The proof of concept involved setting up two 8Mb Ethernet links between Kwinana and Midland and Midland and Northam ustilising 4 E1 circuits from the SDH over fibre. Aggregation of the available bandwidth was managed by external Crocus E1 to Ethernet conversion units. Backup links were provided using Telstra ISDN dial up circuits. Cisco routers were used to control and manage the communications links and backup circuits to provide alternate paths on failure of the Ethernet.

While all equipment was co-located for the testing, the LAN/WAN and backup circuits were arranged to route data traffic through Kwinana and Avon and back to the test site.

The testing included failing primary communications links, failing operational logic servers and front-end processors, measuring fail-over times and observing system behaviour.

In addition, cold start-up testing confirmed the level of system resilience during various communications disturbances.

The proof of concept testing confirmed acceptable performance was achievable under comprehensive failure conditions, including scenarios, where the Workstation, Applications Server and the I/O Server were all at different locations. The proof of concept testing also confirmed that the overall system would be capable of being powered up from cold under various fault conditions.

The resultant system would effectively allow control of any area of the State from any of the WestNet Rail major sites. The voice communications infrastructure; Digital Radio System, was also arrange to provide a high level of flexibility such that voice communications could be obtained for any area from multiple sites. This provides WestNet Rail with a very high level of flexibility.

A block diagram of the system architecture is shown in Figure 4 - System Architecture.

CTC CONTROL SYSTEM

The US&S Phoenix system provides an integrated control environment for all WestNet Rail CTC areas of control. It allows any desk in the network to assume control of any control area, whilst other desks can view train operations.

The system is based around duplicated applications servers (Data Processing Units) interfaced to train control workstations and front end processors (Code Servers).

Functionality provided includes:

- Graphical display of network activity
- Display of train numbers
- Interface to RAMS for obtaining train numbers
- Interface to TOS for seem less transfer of train numbers
- Manual routing and route stacking
- Fleeting of automatic signals
- Operator note
- Blocking
- Alarms
- Etc

Overall the functionality provided meets the needs of the WNR operation.

COMPUTER ASSISTED TRAIN ORDERS

In 2002, WestNet identified that the existing Computer Assisted Train Orders System was life expired and was starting to exhibit higher rates of failure than WestNet could tolerate. At this time, WestNet engaged ARCS to investigate the current failures of the CATOS as well as provide ongoing maintenance services until such time a new system could be implemented. WestNet Rail commenced a process to examine a number of different approaches for its replacement. A key design parameter was that the new system be configuration based and provide a level of integration with the CTC system.

ARCS put forward concept designs and in association with US&S and WestNet rail developed a design philosophy based on the US&S Phoenix platform

The US&S solution offered advantages in that integration commonality of operational behaviour and maintenance.

The synergy between the TCCP and the TOS projects also provided WestNet Rail the integrated solution they were seeking for the centralisation of train control.

The level of integration of the two safe working control systems within the same operational environment provides significant flexibility in operations. The system implementation means that the same ‘look and feel’ can be achieved across both safe working systems and serves to reduce operator training, maintainer training, staffing and shift rosters and the like.

The implementation of the proceed order rules has also been formalised in that the rules have been created in a logic table format akin to that of the CTC control tables. This allows easy checking and testing and introduces a more formal and visible change management.

DIGITAL RADIO SYSTEM OVERVIEW

The digital radio system provided by US&S is a Zetron DDS. The radio system is controlled from an operator touch screen and is arranged to allow monitoring of multiple channels concurrently and easy selection of required operation.

The Zetron console is shown in Figure 2 - Zetron Radio Console.

The DDS sits on a radio bus which effectively allows radio channels to be picked out at a number of nodal locations. The purpose of the Radio Bus is to consolidate 30 selected radio channels from the various isolated PDH bearer radio networks into a single 2Mbps tributary, to be carried within the existing STM-1 stream across the entire WNR network. When the Radio Bus is complete, an operator will be able to access any of the 30 channels from anywhere in the network.

Figure 2 - Zetron Radio Console

An overview of the Radio Bus is shown in Figure 3 – Radio Bus below. Each site contains a Radio Bus node, which consists of Nokia DB2-LP muxes for the adding/dropping of individual timeslots, and a configuration of audio bridges to interface and combine the VHF and UHF radio channels carried on the local PDH systems.

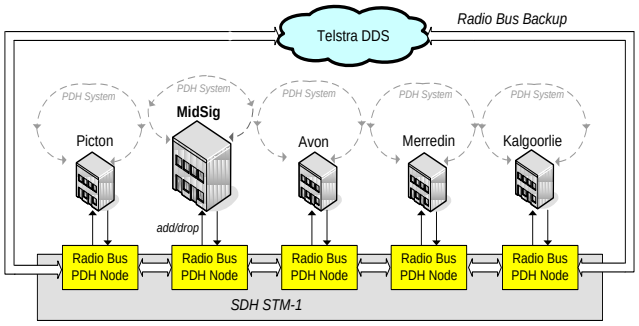


Figure 3 – Radio Bus

The Bus is carried between sites on the SDH STM-1 stream. A Telstra Digital Data Service (DDS) backup path will be implemented between the PDH network terminations at West Kalgoorlie and Picton. The DDS will provide backup for nominated radio channels carried on the radio bus.

The Radio Bus and DDS path are currently being implemented and will be operational as part of the Picton works. Additional Radio Bus Nodes will be added as each stage of work is completed. On completion of the project, the entire radio communications network will be operated from the MidCon.

The advantage of the radio bus concept is that it will allow the train control function to be easily replicated at any node. It will be possible to relocate operations entirely from Midland to Avon if Midland should need to be evacuated. Similarly train control functionality will also be available at Picton or any other nodal location.

Operationally WNR have chosen to allow two disaster recovery sites; one at Avon for the eastern and northern lines, and one at Picton for the south-west. The limiting factor for complete site redundancy is space for operator stations.

DDS Backup

The initial design allowed for a selected group of 8 voice channels to be backed up with individual Voice Link T circuits. During the early design, it was decided to implement a full E1 (2Mbps) backup path between Picton and Kalgoorlie as this offered a technically superior solution. After careful costs and risk assessment by WestNet Rail, the design was changed to Telstra Fastway DDS nx64kbps backup paths. This was due to the high ongoing operational costs associated with the full E1 backup strategy. The Telstra Fastway DDS nx64kbps maintains the technical advantages of the E1 proposal at an affordable operational cost.

The DDS service will initially be installed to provide backup for six nominated train control radio circuits. In the event of a 2Mbps fault on the backbone network, the major train control radio circuits will be automatically looped around the backup path. Transition to the backup path will occur in a few hundred milliseconds and will appear seamless to the operators at MidCon. All reconfiguration of the network will be achieved through the use of Nokia DB2-LP multiplexers using conditional branching tables.

Depending on the location of the fault, some train control radio systems not utilising the backup path may lose operability from MidCon. This situation applies to shunting yards and lightly trafficked areas and is seen as tolerable as these areas generally be able to be operated locally using a local operator console.

A feature of the network design is that allowance is made to scale up the number of radio channel circuits possible to be carried on the DDS backup. If necessary the DDS may be scaled to operate as a full 2Mbps service allowing all 30 channels to be backed up. (It should be noted however that no new equipment is required by WestNet Rail or Telstra to bring about this upgrade).

DISASTER RECOVERY

The MidCon facility at Midland is the location of the main WestNet Rail communications hub, where several train radio circuits are intercepted and added to the radio bus. In the event of Midland becoming inoperable, these systems may become isolated from the network. A measure has been put in place where these systems can be reconfigured to connect to the radio bus at Picton and Avon. This system reconfiguration requires manual intervention and would require approximately half a day to reconnect.

Disaster Recovery of this nature would usually only occur in extreme circumstances such as the Midland facility is burnt out and remaining inoperable for an extended period of time. In such a situation it would be possible to reconfigure the network to initially work between two sites, Picton and Avon without loss of functionality.

A more permanent longer term solution has been allowed for involving splicing the required optical fibres to bypass Midland allowing full operations to be managed from Avon. Alternatively the Telstra DDS could be upgraded to full E1 (2Mbps) and offer the same outcome.

It should be noted that while this section is specifically referring to the radio bus and the associated train control radio circuits carried on it, the same principles apply to the signalling circuits allowing full train control functionality at the alternate DR sites mentioned.

RESILIENCE AND REDUNDANCY

Overall, the new system provides a high level of resilience to hardware and communication disturbances. The ability to move operations to the two nominated disaster recovery sites provide a great deal of flexibility in operational strategies and fault recovery. It effectively allows train control to be located at any WNR node and will provide a good deal of future-proofing including allowing the relocation of the MidCon facility should business needs change.

PROJECT TIMELINES AND MARKET CONDITIONS

The TCCP project is currently in the process of delivering Separable Portion No. 3; Picton relocation to MidCon, with Separable Portion No.1 and No.2a being completed in a timely manner and without incident. SP2a was considered to exhibit the greatest technical risk as the TCS was moved to run on the new distributed communications WAN/LAN, an upgrade to the server and workstation operating systems and an upgrade to the Phoenix versions.

WNR anticipate bringing Picton control online and implementing the Picton disaster recover site by mid September 2007. This reflects a modest slippage over the contract programme.

The programme for the TOS is also running late and we anticipate delivery in the 1st quarter 2008.

Market conditions are such that experienced resources are in high demand and both WNR and US&S have put in significant effort to procure and keep their experienced staff. The current Market is buoyant and skilled people are in short supply. Signalling Engineers in particular are in such demand that the Project timeline is being driven by availability of this discipline.

The availability of suitable resources caused by the current market conditions has and continues to put significant pressure on the Project delivery dates. The use of the Joint Management group allows these issues to be discussed in an appropriate forum, allowing strong views to be aired within a spirit of co-operation and focus on Project delivery. This management group has been pivotal in maintaining a good working relationship between the two parties.

CONCLUSION

The Project is now starting to deliver real benefits to the WNR business with the closure of the PTC facility and the brining into service the new MidCon facility. Progressively over the next year, the remaining control centres will be brought back to MidCon, whilst still allowing local control

centre functionality where operational needs dictate.

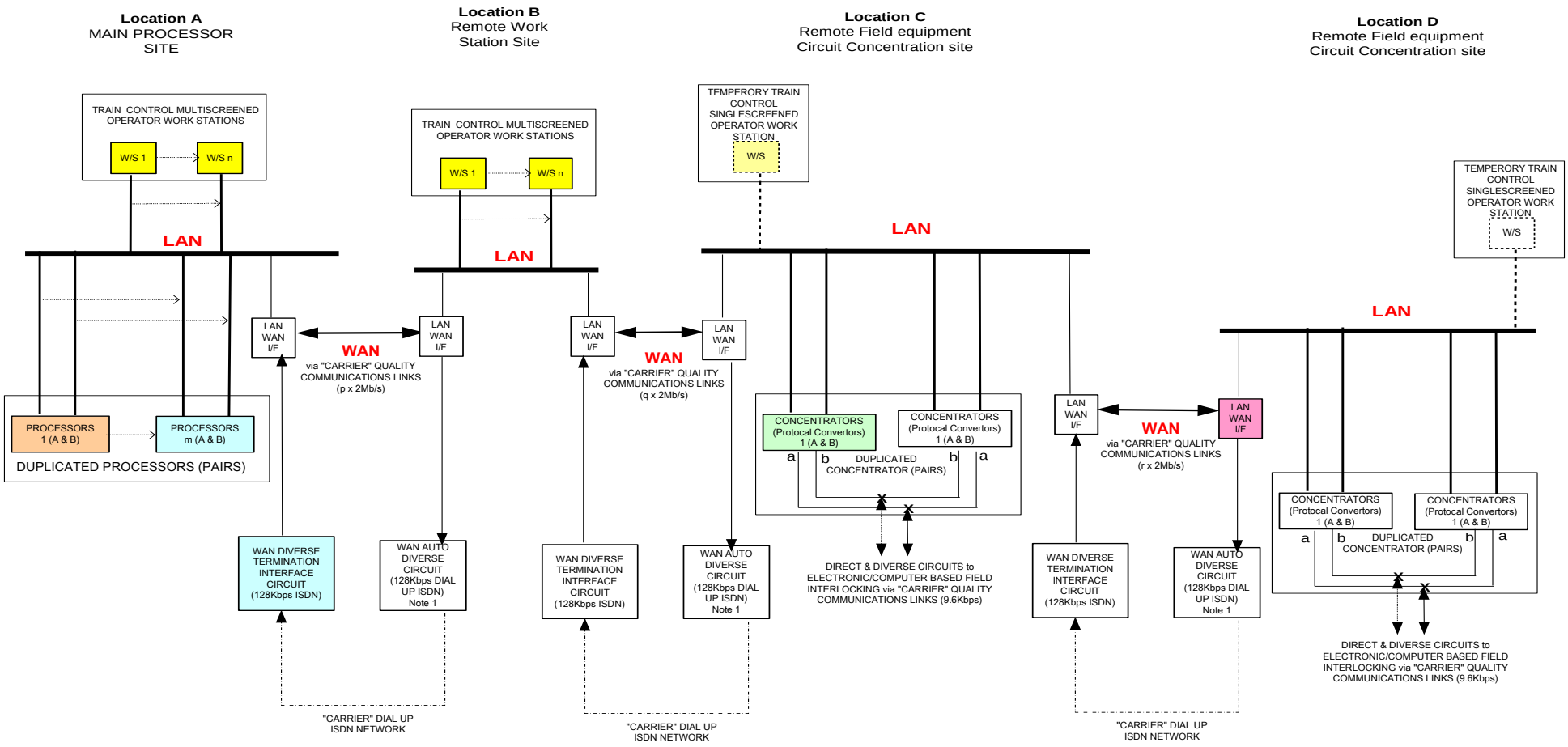
The Project design provides a high level of flexibility for technical the operational aspects of the WNR business as well as support, maintenance and staffing.

The commercial and contract risks continue to be managed with strong project management and steering from both WNR and US&S and all are comfortable with overall achievements and deliverables arsing from the project thus far and the manner in which risks have been managed.

The technical risks seen as; the LAN/WAN data communications arrangements to allow redundancy across multiple sites, the radio bus concept and design and the integration of the two safe working systems into a common train control platform, have been managed through a process of design and prototyping to eliminate the delivery risk arising from the inappropriate use of technology.

WNR are now on the cusp of achieving a centralised train control environment capable of being deployed in a number of locations quickly and with little further expenditure.

Overall the approach taken in the delivery of this Project has been pivotal to the current and future success of these works.



NOTE 1 WAN DIVERSE CIRCUITS OVER "CARRIER" DIAL UP (ISDN) ARE INITIATED, SETUP, MONITORED AND RESTORED AUTOMATICALLY IN THE EVENT OF NORMAL WAN LINK OR TERMINAL EQUIPMENT FAILURE.

Figure 4 - System Architecture

Acknowledgements

WestNet wishes to thank the many contractors and consultants who have actively contributed to the success of this project including:

Contractors
Union Switch and Signal
Zetron

Consultants
Australasian Railway Consulting Services

WestNet Rail Technologists
Communication Manager - Wayne Belstead
Rick Festa - Manager Signals
Kevin Bulger – Manager Compliance and Standards