SECTION 735 – COMMUNICATION SYSTEM NETWORK

##This section cross-references Sections 731, 732, 733, 734 and 736.
If any of the above sections are relevant, they should be included in the specification.
If any of the above sections are not included in the specification, all references to those sections should be struck out, ensuring that the remaining text is still coherent:
##Sections 731, 732, 733, 734 and 736 should be included in the specification.

735.01 DESCRIPTION

(a) Scope

This section relates to the requirements for the Communications Network to support objectives for Managed Motorway Devices including, but not limited to:

i. Freeway Ramp Signals, including Freeway to Freeway Ramp Signals.
ii. Lane use Management System
iii. Variable Message Signs
iv. Real Time Information Signs
v. Freeway data Stations and
vi. CCTV cameras.

This document shall be read in conjunction with contract specific requirements and drawings.

The actual contract document will cover the Communication Systems Scope of Works that The Contractor will be required to complete. This Communication Systems specification provides The Contractor all the Communication systems requirements and process including, but not limited to;

vii. Selection of equipment
viii. Network design
ix. Network topology
x. Network configuration
xi. Installation
xii. Integration into the existing ITS communication system
xiii. Testing and Commission of the Communication System/network.

The Contractor shall refer to Contract for the obligations on installation and commission of the communication network.

The required Communication Network Works include connectivity of the Intelligent Transport Systems (ITS) equipment and Communication network installed on the freeway as part of this project into the existing VicRoads ITS Communication Systems.

The ITS Communication System shall be based on the design principles listed below.

xiv. High speed and resilient IP over Multi-Protocol Label Switching (MPLS) network based on industry standard technologies.
xv. The extension of and integration with an existing end to end managed network allowing monitoring and control of the whole network, reducing system down time and monitoring the network for security breaches.
xvi. Support for any-to-any communications, as opposed to point-to-point, in line with an ITS environment that requires sharing of intelligence available in individual systems to optimize freeway management.
xvii. A system architecture which is scalable to allow integration of future services.
xviii. A communication network which is easy to upgrade and maintain
xix. Maintain existing VicRoads network security.
xx. Provide connectivity for ITS devices.

(b) Details of Works by Others

Penetration tests shall be carried out by third parties to check the Security System of the Communication Network/System installed by the Contractor and the entire system after integration.

(c) Asset Ownership

The Principal will retain ownership of the Communication Network. The Contractor is not authorised to sign and document with any party which transfers ownership of the installation to any other party.

735.02 REFERENCED AND RELATED SPECIFICATIONS, STANDARDS AND DRAWING

All works associated with the installation and commissioning of all devices covered under this specification shall conform to all relevant VicRoads specifications, VicRoads Standard Contract Sections and Australian Standards.

Any associated electrical works shall conform to the requirements of Standard Section 734.

All works associated with the installation and commissioning of all devices covered under this specification shall conform to the general requirements of:

- VicRoads 'TCS' series specifications
- VicRoads 'TC' series standard drawings
- Relevant Australian Standards in Table 735.021
- Drawings included in the Principal Preliminary Design
- Technical Specification included in the appendices.

Standards referred to in this section are listed in Table 735.021 below.

Table 735.021 List of Standards

Australian Standard	Title
AS/ACIF S008:2006	Requirements for customer cabling products
AS/ACIF S009:2006	Installation requirements for customers cabling
AS1307	Surge arrestors
AS1319	Safety Signs for the occupational environment
AS1768	Lighting protection
AS1939 – 1990	Degrees of protection provided by enclosures for electrical equipment
AS/NZ 2211.1:2004	Safety of laser products – Equipment classification, requirements and users guide – IEC 60825 – 1:2001, MOD- (Labels) 01 December 2016
AS/NZ 2211.2:2006	Safety of Laser products – Safety of optical fibre communication systems OFCS) IEC 60825 – Ed3.0 – 2005 (Labels)
AS2967	Optic Fibre Communication Systems safety
AS4142	Fibre Ropes
AS4383	Preparation of documents used in electrotechnology
AS 60529	Degrees of protection provided by enclosures (IP Code)
AS/NZ 60950.1 – 2011	Information Technology equipment – Safety – General requirements (IEC 60950.1, Ed 2.0 (2005), MOD)
AS 61000	Electromagnetic Compatibility (EMC)
AS/CA S008 – 2011	Requirements for authorisation cabling products

TS-SP 013	Telecommunication Installation Version 5.0
IEEE 802.1ad	Provider Bridges
IEEE 802.1D	MAC Bridges
IEEE 802.1p	Traffic Class Expediting and dynamic Multicast Filtering
IEEE 802.1Q	Virtual LAN's
IEEE 802.1s	Multiple Spanning Trees
IEEE 802.1X	Port Based Network Access Control
Extended 802.1X	Authenticated VLAN (Multiple MAC, multiple VLAN's per port)
IEEE 802.1v	VLAN Classification by Protocol and Port
IEEE 802.1w	Rapid Reconfiguration of Spanning Tree
IEEE 802.3	Carrier Sense Multiple access and Collision Detection (CSMA/CD)
IEEE 802.3a	Local and Metropolitan Area Networks (10BaseT)
IEEE 802.3ab	Gigabit Ethernet over Twisted Pair Copper (1000BasedT)
IEEE 802.3ac	VLAN tagging
IEEE 802.3ad	Link aggregation (Dynamic)
IEEE 802.3ae	10 Gigabit Ethernet
IEEE 802.3af	Power over Ethernet (PoE)
IEEE 802.3x	Ethernet Flow control
IEEE 802.3u	100BaseTX and 100BaseFX Fast Ethernet
IEEE 802.3z	1000BaseX Fibre Optic Gigabit Ethernet
IEEE 802.11	Wireless LAN and Mesh Wi-Fi
TIA/EIA-568-C	Generic telecommunications cabling for customers premises

VicRoads Specifications and Technical Notes referred to in this section are listed in Table 732.022 below.

Table 732.022 List of Specifications and Technical Notes

Spec Number	Title
TCS 003	Supply of Ramp Control / Metering Signs
TCS 015	Variable Message Signs
TCS 036	Freeway Help Phones
TCS 037	Electronic Speed Limit Signs
TCS 048	Freeway Data Stations
TCS 056	Lane Use Signs
TCS 061	ITS Field Cabinet
TCS 063	Installation of Freeway Ramp Signals
TCS 067	Digital CCTV Camera
TCS 068	Over-height Detection System
TCS 069	Supply and Installation of Bluetooth Data Stations
TCS 070	Travel Time Signs

VicRoads Standard Sections referred to in this section are listed in Table 732.023 below.

Table 735.023 List of Standard Sections

Std Section	Title
732	ITS Devices Installation
733	Conduits and Pits for Underground Wiring and Cabling
734	Electrical Network Installation
736	ITS Device Testing and Integration

VicRoads Standard Drawings referred to in this section are listed each device specific clause within this section.

NOTE: VicRoads Standard Drawings, Specifications and Guidelines are available for downloading from VicRoads website.

735.03 GENERAL REQUIREMENTS

(a) General

The installation of a new Communication Network or additional works at an existing Communication Network by the Contractor shall include:

(i) supply and installation of all civil works including, but not limited to, trenching, under road bores, conduits, conduit bends, cable pits and lids, draw strings, slabs and cabinet foundations.

(ii) supply, installation and connection of all hardware, equipment and materials including, but not limited to, communications cabling, equipment, fittings and all materials and equipment necessary to complete and commission the installation.

(iii) liaison with the local power distribution company and relevant authorities for the installation of the works, and the obtaining of all necessary approvals and permits from the relevant authorities

(iv) re-instatement of all works.

Unless otherwise specified, equipment and materials used shall be VicRoads type approved, (refer to VicRoads website for type approved products) and comply with the requirements specified in the VicRoads Standard Specifications.

The Contractor shall submit a data sheet of all types of equipment to the Superintendent for review prior to ordering. When requested by the Superintendent a sample of the equipment shall be submitted.

(b) Durability

All structural components shall have a nominated service life as specified in Table 735.031. All other components shall have the nominated service life as specified in VicRoads Specifications or if not so specified, as indicated in Table 735.031.

Table 735.031

Component	**Nominated Service Life**
All structural components/supports including pedestals, conduits and pits	50 Years
All other components not specified in VicRoads Specifications	15 Years

(c) Warranties

VicRoads requires The Contractor to provide warranties for the Cabling Systems and Network Equipment.

i. Cabling System

The Contractor shall provide a warranty to cover the failure of the cabling system, as specified in Section 735.26 – CABLING SYSTEM, to operate the application(s) the system was designed to support. The warranty shall be valid for a minimum of 20 years from the date of Practical Completion with a certificate provided for each Separable Portion.

ii. Network Equipment

The Contractor shall provide a warranty to cover the failure of any electronic network equipment for a period of 24 months from the date of Practical Completion. This shall include the procurement and supply manufacturer warranties and maintenance services contract.

(d) Compliance with Laws, Rules, Regulations and Codes

The Contractor shall give notice to authorities and shall comply with all local laws, rules, regulations and orders of any public authority bearing on the installation or performance of the Works.

These authorities, rules and regulations shall include the Australian Communications Industry Forum

(e) Permits, Licenses and Fees

The Contractor shall obtain all permits and licences, and pay all fees required for completing the Works. The Contractor shall perform all work in accordance with these permits and licences.

735.04 ACRONYMS

The following is a list of acronyms used in this Section:

ACL	Access Control List
ANSI/TIA	American national Standards Institute / Telecommunication Industry Association
AP	Access Point
ASW	Access Switch
BER	Bit Error Rate
BGP	Border Gateway Protocol
CCTV	Closed Circuit Television
CoS	Class of Service
CSIP	Combined System Integration Plan
CWDM	Coarse Wavelength Division Multiplexing
DGN	MicroStation Drawing Format
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name Service
DRC	Disaster Recovery Centre
DRE	Disaster Recovery Equipment
DVMS	Digital Video Management System
DWDM	Dense Wavelength Division Multiplexing
EMS	Element Management System
EOL	End of Life
ELV	Extra Low Voltage
EVC	Ethernet Virtual Connections
FAT	Factory Acceptance Test
FDS	Freeway Data Station
FRP	Fibre-reinforced Plastic
FRS	Freeway Ramp Signals
FTP	File Transfer Protocol
GARP	Generic Attribute Registration Protocol
GMRP	GARP Multicast Registration Protocol
GRP	Glass Reinforced Plastic
GUI	Graphical User Interface
GVRP	GARP VLAN Registration Protocol
HSRP	Hot Standby Router Protocol
ICMP	Internet Control Message
IEC	International Electrotechnical Commission

IFC	Issued For Construction
IOS	Internetwork Operating System
IP	Internet Protocol
IPS	Intrusion Prevention System
IS-IS	Intermediate system to intermediate system
ISO	International Organization for Standardization
ITP	Inspection and Test Plan
ITU-T	International Telecommunication Union-Telecommunication
ITS	Intelligent Transport Systems
LACP	Link Aggregation Control Protocol
LAN	Local Area Network
LC	Lucent Connector (Little Connector or Local Connector)
LOW	Limit-Of-Works
LSZH	Low Smoke Zero Halogen
LUMS	Lane Use Management System
LUS	Lane Use Sign
LV	Low Voltage
MAC	Medium Access Control
MARS	Monitoring and Reporting System
MEN	Multiple Earth Neutrals
MP BGP	Multi-Purpose Border Gateway Protocol
MPLS	Multi-Protocol Label Switching
MPPS	Million Packets Per Second (Mpps)
MSTP	Multi Spanning Tree Protocol
MTU	Maximum Transmission Unit
NBN	National Broadband Network
NMS	Network Management System
NTP	Network Time Protocol
NRFU	Network Ready of Use
O&M	Operations and Maintenance
OFN	Optical Fibre Network
OPT	Operational Performance Test
OSP	Outside Plant
OSPF	Open Shortest Path First
OTDR	Optical Time Domain Reflectometer
PDF	Portable Document Format
PMC	Pole Mounted Cabinet
POP	Proof of Performance
POS	Packet Over Synchronous Digital Hierarchy
QoS	Quality of Service
RCB	Roadside Cabinet
RCCB	Residual Current Circuit Breaker
RCBO	Residual Current Breaker with over-current protection
REP	Resilient Ethernet Protocol
RIP	Routing Information Protocol
ROM	Read-Only Memory
RTIS	Real Time Information Signs
RSTP	Rapid Spanning Tree Protocol
SAT	System Acceptance Testing
SC	Subscription Channel Connector
SDH	Synchronous Digital Hierarchy
SFF	Small Form Factor
SFP	Small Form-factor Pluggable
SIT	System Integration Testing
SNMP	Simple Network Management Protocol
SRW	State Returned Works
SSL	Secure Sockets Layer
ST	Straight Tip Connector
STP	Spanning Tree Protocol
TACACS+	Terminal Access Controller Access-Control System Plus
TCP	Transport Control Protocol
TMC	Traffic Management Centre
UDP	User Datagram Protocol
UTP	Unshielded Twisted Pair

UPS	Uninterruptable Power Supply
VEN	Video Encoder
VLAN	Virtual Local Area Network
VMS	Variable Message Sign
VPLS	Virtual Private LAN Service
VPN	Virtual Private Network
VRRP	Virtual Router Redundancy Protocol
VSLS	Variable Speed Limit Signs

735.05 DEFINITIONS

Title	Description
Communication Network	A collection of new routers, switches, optic fibre, Cisco SFPs, Amplifiers, DWDM, CWDM, patch panels and necessary accessories which connect together, with all configuration, software and firmware required to enable data communication between ITS equipment.
Communication System	Communication Network with NMS, Security Systems and other requirements to produce a fully functioning system.
Cutover	Connection of devices into the new and/or existing communication network for an integrated end to end solution. This includes patching and network configuration for devices and/or communication equipment. Cutover may also include disconnection and all change management required from an existing network.
Datacenter	Computer Room at VicRoads 60 Denmark St, Kew VicRoads Racks at NextDC – M1 Port Melbourne.
Disaster Recovery	Computer Room at VicRoads IRS Office Corner of Cook St and Todd Road, Port Melbourne and VicRoads Racks at NextDC – M2 Tullamarine
Downstream Device	Represents a device in the path on the access layer or on the Local Network
End point	The termination point/s is the boundary on the limit of works. Refer to the relevant drawings within the Contract documentation.
Existing Communication Network	Reference to the 'existing' or 'current' Communication Network or similar or any part thereof to the Communications Network Specification in this section is a reference to the existing or current Communication Network or similar or any part thereof as at the data of signing Contract.
Existing Communication System	Reference to the 'existing' or 'current' Communication System or similar or any part thereof to the Communications Network Specification in this section is a reference to the existing or current Communication System or similar or any part thereof as at the data of singing Contract.
Freeway Management Devices	Intelligent Transport Systems Devices and/or Freeway Management Devices.
Functionality	All functionality that is currently used on the existing VicRoads ITS Communication System shall be implemented on the Project's Communication Network
ITS LAN	VicRoads LAN for the operation of Freeway Management Devices on roads and freeways

Kew	VicRoads Head Office at 60 Denmark Street, Kew
Network Management System (NMS)	The hardware and software platform for the network management system. This includes the hardware servers, the Operation System and the applications running it. These include the DNS, NTP, DHCP, Authentication, Wireless NMS and other NMS applications.
Network Utilization profile calculations	This is a set of calculations/report that The Contractor must carry out to understand the data loadings on the current communication system and the data loading on the network as a "before works" system and "after works" system.
Outside Plant	Continuous conduits for power and communications along the freeway including pits, separate for communication and power
Redesign	Review the current design and determine the changes required for the Contractor, to comply with requirement of this Contract or improve the network/link.
Security Systems	The firewalls, IPS, Splunk
STREAMS	VicRoads ITS platform
Upstream Device	Represents a device in the path towards the Data Centre or DC
VicRoads O&M Contractor/Provider/ O&M provider	Existing Operation and Maintenance Contractor for existing VicRoads Communications System
Communication Patch Cabinet	VicRoads Roadside Cabinet delivered in accordance with VicRoads Traffic Control Series Specification TCS 061 suitably sized for multiple 96 core fibre patch panels, Door Alarm and Access Switch. Not to be used for Freeway Management Devices.

735.06 THE EXISTING VICROADS ITS COMMUNICATION SYSTEM

The existing VicRoads ITS Communication System is described in the following Clauses. The Contractor will be given access to view the secure document regarding the existing Communication Systems refer to section 735.16(a). This includes documentation, design, architecture, security and protocols that are used in the VicRoads ITS Communication System. The new Communication System shall fully, seamlessly and completely integrate into the existing ITS communication system and scalable to allow future integration.

In the event that any devices mentioned on this VicRoads Communication Network Specification shall be affected by manufacturer product refresh or life-cycle programme, the Contractor shall propose alternatives as per the manufacturer's upgrade path or other suitable alternatives.

735.07 BACKBONE NETWORK ARCHITECTURE OF THE EXISTING ITS COMMUNICATION SYSTEMS

The existing core MPLS Network and Communication System is based on a number of nodes (backbone routers) connected together in a ring architecture.

735.08 ACCESS LAYER OF EXISTING VICROADS ITS COMMUNICATION NETWORK

The access layer of the network provides Layer 2 Ethernet network connectivity to Freeway Management Devices. It consists of local access layer switches connected to network nodes. Access switches are positioned along the Freeways to provide local connectivity to Freeway Management Devices.

Drawings of the existing network architecture can be obtained from the superintendent.

735.09 INTEGRATION WORKS

A reference to *configuration* in this section 735.06 is a reference to software configuration required to commission each communication network device and, also as required for integration and testing of all new communication network, including the integration and testing of all new communication network with existing

communication system.

A reference to new communication network is a reference to all the newly-installed communication network, any temporary communication network and any existing communication network device migrated to the new communication network installed as part of this new Project Section.

735.10 INTEGRATION BY VICROADS AND VICROADS O&M NOMINATED CONTRACTOR

This section 735.10 shall provide information to the Contractor on the VicRoads O&M nominated Contractor's responsibilities within this project.

A reference to *configure* in this section 735.10 is a reference to the activity of loading the software configuration onto the compact flash card or communication device directly.

A reference to *integrate* in this section 735.10 is a reference to the implementation of any additional configuration required on new and/or existing communication network device required to provide the same functionality of ITS communication system. This is also a reference to configuration that was not part of the configuration loaded on to the compact flash card, or on elements of the existing communication system where compact flash cards shall not be produced or used.

A reference to *test* and *commission* works mentioned under this section 735.10 refers to SIT, SAT & OPT and commissioning tasks where VicRoads O&M nominated Contractor shall provide reasonable cooperation to the Contractor to complete each task.

The VicRoads O&M nominated Contractor shall be responsible for any aspect of this project integration Works, which shall include developing and applying configuration on new and/or existing Communication Network devices to form a functional Communication System. The Contractor will engage VicRoads O&M nominated Contractor to produce the configuration required for communication network devices, including existing communication network devices that may require changes, as part of this project Works including all required integration works.

All the configuration for Communication Network will be developed by the VicRoads O&M nominated Contractor.

All the integration and testing work regarding the communication system, as a part of this contract shall be in accordance with detailed Communication Network design developed by the Contractor and also in accordance with VicRoads Communication Network specification as described in Section 735.10, Section 735.11.

The following Works shall be delivered by VicRoads O&M nominated Contractor and shall consist of, but not be limited to, the following:

(a) Develop configuration, configure, integrate, test and commission of all new communication network equipment systems including all new ASW, DWDM devices and NMS configuration for door alarms;

(b) Develop configuration, configure, integrate, test and commission of all new communication network devices to the existing Communications System;

(c) Develop configuration, configure, integrate, test and commission new edge ring(s) required Between backbone nodes including all required changes on the existing backbone nodes;

(d) Develop configuration, configure, migrate, test and commission all the existing Communication Network equipment between relevant Communication huts as the case maybe;

(e) Develop configuration, configure, integrate, test and commission backbone routers required;

(f) Develop configuration, modify, configure, integrate, test and commission the existing DWDM devices where required;

(g) In situations where it is required to redesign the entire MPLS topology since the introduction of a new road Section, develop configuration, configure, test and commission all the changes relevant to redesign of MPLS;

(h) Develop configuration, configure, integrate, test and commission new edge ring(s) required between backbone nodes including all the required change on the existing backbone nodes;

(i) Where required, migrate, integrate and test connection of existing Communication Network and Freeway Management devices to the new Communication Network;

(j) Configure the upgrade of the existing NMS and security systems including all hardware, software and licenses where required to complete the integration of the new Communication System into existing VicRoads ITS Communication System;

(k) Configure all the Security systems with necessary policies to ensure full operation and integration of the new road section communications Network to the existing Communication Systems;

(l) Configure all the relevant Communication Network devices to ensure full operation of the freeway management system;

(m) Monitor, manage and control all the new Communication Network devices commissioned under the new project Works;

(n) Upon handover from the Contractor, maintain all the new Communication Network commissioned under the new road Section;

(o) Maintain all the existing Communication Network equipment transitioned to VicRoads Communication Network from temporary works and/or upon completion of Business Continuity plans of new road section Works;

(p) The VicRoads nominated O&M Contractor shall be responsible for any aspect of integration works that shall include developing and applying configuration on new and/or existing Communication Network devices to form the functional Communication System.

735.11 INTEGRATION BY THE CONTRACTOR

(a) As a minimum, the Contractor shall be responsible for any aspect of integration that shall include all the works involved in establishing physical connections between:

- Any assets that make up the New Communication Networks
- New Communication Networks and existing Communication Networks
- New communication network and freeway management devices under the new project Section Works.

(b) The Contractor is also responsible for any aspects of all integration not explicitly excluded under clauses 735.07. The following list outlines other responsibilities of Contractor whilst carrying out the integration and testing of the relevant road section communication network, including integration responsibilities on the Contractor on the existing Communication System:

i. The Contractor shall cooperate with VicRoads and its nominated O&M Contractors for the integration of new communication network built as part of the project to existing Communication System;

ii. Prior to commencement of CSIP, the Contractor shall be responsible to lead and produce a report that shall identify each task with its owner and responsibilities where a task will require VicRoads and/or VicRoads nominated O&M Contractors' input or involvement in order to commence and complete the integration and testing of the relevant road Section Communication Network, including tasks required on existing Communication System. This report shall be prepared in agreement with VicRoads. This report shall be submitted to VicRoads nominated O&M Contractors through VicRoads, for review and comments. The Contractor shall inform VicRoads throughout various stages of this contract when the VicRoads nominated O&M Contractor shall be required to be involved and VicRoads will engage and facilitate the engagement. VicRoads shall also engage its nominated O&M Contractors to carry out review this report;

iii. The Contractor shall be responsible to uniquely identify the compact flash card with labels. The label shall contain equipment name or other mechanism to uniquely identity the compact flash card and shall be prepared in accordance with section 735.31(a).

iv. The Contractor shall be responsible to supply and deliver each uniquely identified compact flash card to VicRoads' nominated O&M Contractor;

v. The Contractor shall be responsible to coordinate and collect the compact flash card from VicRoads' nominated O&M Contractor, with configuration loaded. VicRoads nominated O&M Contractor will accept receiving compact flash cards only after IFC has been issued for a design package. The Contractor shall provide the compact flash cards 6 weeks prior to date for date of practical completion. From the date of receiving the

compact flash card, the VicRoads nominated O&M Contactor shall require 20 working days per compact flash card or communication network device to develop and load configuration and hand back the compact flash card of each communication network device to the Contractor;

vi. The Contractor shall be responsible to install compact flash cards with the configuration into the respective Communication Network devices; VicRoads nominated O&M Contractor will be responsible to directly configure existing communication system, in situations where the communication network device has no capability to support a compact flash card or it is not available for use;

vii. The Contractor shall be solely responsible for all testing of fibre-optic systems including the functional and performance aspects of fibre optic system during FAT, ITP, POP, SIT, SAT, OPT and Commissioning. The fibre-optic system consists of Optical Fibre Network (OFN) comprising fibre optic cables/cores, fibre tube arrangements, splice enclosures, patch panels, connectors, pigtails, CWDM/DWDM devices, fibre optic terminations and other fibre optic accessories that shall be required to form a fully functional fibre-optic system;

viii. The Contractor shall be responsible for FAT, ITP and POP tests for any communication network device that shall be supplied and installed by Contractor;

ix. The Contractor shall be responsible for commissioning and handover of the relevant project's Communication Network and shall cooperate with VicRoads and its nominated O&M Contractor for the integration and testing of the communication Network during the SIT, SAT and OPT tests.

x. The Contractor shall be responsible to produce the Integration Test Plan. Where VicRoads nominated O&M contractor is required to provide inputs into the Integration Test Plans, the Contractor shall engage VicRoads to obtain those inputs.

xi. The Contractor shall be responsible to create a change management plan that shall outline the process to collect information from VicRoads nominated O&M Contractor relating to a change. The process shall also outline the necessary documents required from relevant nominated O&M Contractors. VicRoads nominated O&M Contractor will provide communication network device configurations required for integrating and testing with existing communication system, which shall be an input to method statements.

xii. Any testing works related to physical aspect of the new and/or existing Communication network under SIT testing shall be the responsibility of The Contractor.

735.12 DESIGN REVIEWS

The Contractor shall produce the following stages of documents/drawing with respect to the ITS works packages. They include;

(a) ITS layout drawings
(b) ITS architecture drawings
(c) ITS Connections drawings including Fibre layout plans, including splice joints, Core by Core layout (Core allocation) and network design of backbone links and access rings.
(d) Electrical single line drawings from the Cabinet switchboard to the devices.
(e) Cabinet layout drawings.

These packages should be provided to VicRoads for comment at three stages as follows;

(f) Preliminary Stage which provides details about the contractor designs expected to be 30% correct.
(g) Detailed Stage which provides a very good clear picture for the design that will be delivered at about 80% accuracy.
(h) Issued for Construction stage provides direction on what to build and how to build it. This should be 100% accurate.

The Contractor shall allow 3 weeks for VicRoads to review and provide responses for each document during various stages of design.

735.13 ACCEPTANCE

For acceptance of a section or the entire Project Works by VicRoads, the installed system shall be demonstrated to be installed in accordance with this Section Communications Network Specification and all the reference standards be fully commissioned and working.

735.14 COMPONENT CONFORMANCE

(a) Certificates

The Contractor shall submit copies of component conformance certificates before the components are incorporated into the Works.

(b) Changes to Equipment

The Contractor shall advise VicRoads, in writing, of any changes to the components specified and components proposed. Approval for the change shall be sought before alternate components are used. A three (3) week minimum authorisation period will be required by VicRoads.

(c) Optical Fibre Reels

To show that the performance of the cable complies with the fibre optic standards detailed in this document the Contractor shall obtain a uniquely numbered test certificate for each reel of optical fibre cable delivered to site. The Contractor shall retain these test certificates for inspection at any time during the installation of the Works and include them in the O&M Manuals.

The Contractor shall satisfy themselves, of the integrity of all delivered cable prior to installation.

735.15 METHOD STATEMENTS

The Contractor, in collaboration with the Principal's nominated O&M Contractor (if required) shall submit to VicRoads, method statements for the particular activities required to implement the Works including installation, inspection, testing and commissioning of the Works. The method statements shall indicate the time required and the number of personnel that will be employed to carry out the tasks on site.

Method statements shall be submitted for approval a minimum of four (4) weeks prior to commencement of the particular activity required. Work shall not proceed until the submitted method statement is fully approved. A two-week minimum authorisation period will be required by VicRoads.

735.16 DESIGN REQUIREMENTS

(a) General

The Contractor in its design shall consider the principles, guidelines and requirements as specified in this Section and other relevant VicRoads specification sections. Furthermore 'Safety in Design' concepts must be considered in the preparation of the design and construction methodologies.

The Contractor shall design a solution that has redundancy and resiliency that is the same or better than existing design as per VicRoads FMS Communication As-Is Design, **VS(VRG)-OM-DES-0021-4 Issue -5**, which shall be shared with the Contractor at the time of tendering stage in a secured VicRoads location. Contractor shall not be allowed to take copies or photos of this document at the time of review.

(b) Performance Requirements of Service

The performance requirements of the communication services between the TMC / DRC and Freeway Management devices are detailed in the table below. The Contractor shall take into consideration the latency figures for the relevant existing components in the design to ensure the total combined latency is not exceeded.

End A Central Servers (at TMC or DRC)	End B (Freeway Management Device or Other)	Bandwidth per Stream (min)	Latency (max)*

Servers	Device name		
NMS & STREAMS Servers	Wireless access point for wireless vehicle detectors	100kbps	10ms one way
NMS & STREAMS Servers	Field Processor for LUMS	100kbps	10ms one way
NMS & STREAMS Servers	Field Processor for freeway ramp signal site	100kbps	10ms one way
NMS & STREAMS Server	Field Processor for variable message sign	100kbps	10ms one way
NMS & DVMS Servers	Encoder for existing analogue CCTV camera	5Mbps per stream	10ms one way
NMS & DVMS Servers	Digital CCTV camera	5Mbps per stream	10ms one way
NMS, STREAMS & DVMS Servers	Freeway Management Devices (Wireless Locations)	5Mbps per stream	40ms one way

* Latency shall be measured between the network parts End A and End B.

For all services in the table above, the bit error bit and packet loss rate shall comply with ITU-T standard and/or the relevant IEEE standard.

(c) Infrastructure and Use of Existing Assets

The Contractor shall, wherever possible, utilise existing VicRoads assets in the design of the Communication Network. Existing assets include, but are not limited to the following:

- Conduits, pits, cable tray, cable ladder;
- Existing roadside cabinets – a proposal to determine their suitability must be submitted for approval;
- Communication Huts – equipment huts located on the freeways and
- Existing Communication System – including routers, switches, NMS servers, firewalls, Splunk, IPS, Dark-fibre services and the CWDM/DWDM systems.

The Contractor shall ensure that all existing systems remain operational throughout the life of the Works, or until replacement systems are commissioned for operation excluding NMS servers, Splunk, Firewall, CWDM/DWDM systems and VicRoads backend control system.

For further detail of the existing VicRoads ITS Communication System refer to the Superintendent for access to the VicRoads FMS Communication As Is Design document.

(d) Fibre-Optic Cable

The design shall include the installation of new fibre optic cables as specified in individual contract documents.

(e) Conduits and Pits

In some areas existing trunk conduit network may be retained to form a part of new trunk and tails conduit and pit network which forms part of the work under the contract.

(f) Existing ITS Field Devices

The Principal's nominated O&M contractor shall only responsible for network configuration part of the cutover and Contractor shall be responsible for physical connection aspect of cutover.

For the type and quantity of existing ITS field devices that need to be cutover please refer to Contract documentation for the scope of works and associated drawings.

(g) Freeway management Devices for Freeway Ramp Signals

A Freeway Ramp Signal site (FRS) typically consists of the following Freeway Management Devices:

i. Access Point (AP) and Repeater Points (RP) for in-pavement Wireless Vehicle Detection (WVD);

ii. Field Processor(s) (FP);
iii. Video Encoders (VEN) for CCTV video cameras, or IP-enabled CCTV cameras;
iv. Ramp control signs, including RC1, RC2 and RC3/RTIS;
v. Variable Speed Limit Signs (VSLS);
vi. Ramp Signal Controller; and
vii. Signal Lanterns.

The Contractor shall supply, allocate and manage a minimum of 16 IP addresses for Freeway Management Devices at each FRS site. The IP address blocks shall be obtained from VicRoads.

(h) Design of Modification to Existing ITS Communication System

The Contractor shall develop an end to end solution design which covers any works on the existing Communications system and the new Communications System delivered by this contract. The design must identify the works required to be delivered by third parties. The design shall cover the requirements of tender: scope of work.

(i) Integration

Design required for Integration of the new road Section Communication System with the existing VicRoads Communication System is part of the Works. The following defines the integration responsibilities included in the Works.

The Contractor shall supply and install the Communication Network and test it as a standalone system before any integration with the existing VicRoads ITS Communication System. The Contractor shall produce a Combined System Integration Plan (CSIP) and submit it to VicRoads for approval prior to commencing any pre-integration tests. VicRoads may seek third party opinions on the CSIP.

The CSIP shall detail all upgrades and changes to the existing VicRoads ITS Communication System that are required for successful integration of the Project's Communication System. The Contractor shall not perform any work on the existing VicRoads ITS Communication System unless otherwise agreed with the Superintendent. The Contractor can find the information on the existing VicRoads ITS Communication System that may be is required to prepare the CSIP. Information of the VicRoads existing communication system can be supplied by the Superintendent.

The CSIP shall cover, but not be limited to, the following, aspects of the VicRoads ITS Communication System:

- bandwidth upgrades;
- firewall upgrades or modifications;
- reconfiguration of network equipment;
- network management system upgrades/modifications;
- network node upgrades;
- interface drawings detailing all connections and interfaces between the VicRoads and the relevant project section
- Integration and Testing plan
- Roles and Responsibilities per device per task between the Contractor and VicRoads nominated O&M contractor.

Communication Network

- Specification and bill of quantities for VicRoads ITS Communication System equipment required for integration.

The Contractor shall design all communication links required to integrate the new project's Section Communication System into the new and/or existing Communication system.

The Contractor is required to coordinate the integration of the Project's Communication network with existing Communication Systems.

The Contractor shall produce a responsibility report showing the responsibility matrix with their method of procedure document that clearly spells out each step in the process to ensure a successful integration.

735.17 ELECTRICAL WORKS

Any electrical works associated with the installation of the Communications Network shall be carried out in accordance with Standard Section 734.

The Contractor shall supply UPS for each location that has an access switch or network node. As a minimum, The Contractor shall supply a four hour rated UPS also required to satisfy the required system availability as specified in section 735.19. Each of the supplies for Network Nodes shall be provided with its own isolator switch.

735.18 NETWORK DESIGN PRINCIPLES

(a) System Architecture

A conceptual architecture in contract documents and drawings. The architecture is indicative only. The Contractor design, installation and testing aspects of the new Communication Network shall be provided in accordance with this Specification. Details of the existing VicRoads ITS Communication System are available from the superintendent.

The Contractor shall ensure that the supplied parts for Backbone Node or Access switches or SFP's shall be Cisco products but not contain any refurbished components or any 3rd party components.

All the design and works carried out on the fibre optic network shall confirm to VicRoads practices.

(b) Backbone Network

The Backbone Node supplied shall be made of in-life hardware same model as the existing VicRoads Backbone nodes. For any part of hardware and software in those models which had been issued with end-of-life notices, the replacements must be as recommended by the Manufacturer hardware and software life cycle and replacement notices.

The Contractor shall supply appropriate type and quantity of small form-factor pluggable Cisco (SFP/SFP+) Lucent Connectors (LC) in accordance with the Communication Network Design.

The Contractor shall confirm and obtain VicRoads approval on hardware and software configuration prior to placing the order. The Contractor shall ensure the supplied node shall not contain any refurbished equipment or parts. The contractor shall ensure the Backbone Node is installed and operated in accordance with Manufacturer Hardware Installation Guide.

The bandwidth of all connections between Backbone network nodes shall be at least two 10Gbps. Connections between all backbone network nodes shall be both fully physically and logically diverse by using fibre optic cables running along both sides of the freeway.

The bandwidth of all connections between Backbone Network nodes shall be at least two 10Gbps.

Every road device shall be connected to the nearest access layer switch which shall be connected to the backbone and must have two or more paths to different nodes on the backbone.

Each of connections between Backbone node – Backbone node shall be formed through geographical diverse conduit on each side of the carriageway and diverse fibre trunk. In any section of the freeway where conduits runs along only on one side of the carriageway the design shall follow methods which provide best level of resiliency, as an example, using fibre cores from different tubes within the trunk, etc., In event, where a backbone fibre optic trunk is used to connect more than one pair of Backbone nodes, the connection shall be formed by utilising diverse conduits and different Backbone tubes.

Any connections made to Backbone nodes located at VicRoads Datacentre and Disaster Recovery Centre from existing Backbone nodes located at the freeway shall use DWDM technologies, and it shall follow the corresponding ITU-T standards. Any connection made between Backbone node to Backbone node which are not located at VicRoads Data Centre and Disaster Recovery Centre shall use the direct fibre cores.

(c) Network Access Layer

A minimum of one access layer switch shall be installed in each cabinet requiring Ethernet connections to

LUMS, VMS or FRS controlling equipment Freeway Management devices. Freeway Management Devices shall be connected to the Network Access Layer and not directly to the Backbone Router network.

Each access layer switch shall connect to two different Backbone Routers via connection with a minimum bandwidth of 1 Gbps. The Contractor shall be responsible for determining the bandwidth requirements of connections.

If a Freeway Management Device (either CCTV camera or FDS) is not in the same cabinet as an access switch, a set of media converters may be used to connect the device to the nearest access switch. Two media converters (one at each end) are necessary to connect a single Freeway Management device to the access switch. The fibre-optic cable between the two device media converters shall be a separate 12 core cable single mode fibre and must not use the backbone trunk cable. Media converters shall only be permitted for remotely located CCTV camera or FDS or as otherwise approved by the Superintendent.

There shall be no more than ten (10) access switches within each access ring. Total number of access rings shall be determined at detailed design stage.

(d) Network Function

The existing VicRoads ITS Communication System has functions as described in FMS Communication As Is design Document which is available from the Superintendent. The Project's ITS Communication Network shall have the same functionality.

(e) IP Addressing Scheme

The Contractor shall determine an appropriate IP addressing scheme in consultation with VicRoads and VicRoads nominated O&M Contractor for all network equipment installed or changed as part of this Contract. The Contractor shall:

i. Coordination with VicRoads to ensure that the existing network equipment is configured to allow integration with the new equipment supplied under this Section;
ii. Ensure that the IP addressing scheme reflects the policy currently in place on existing ITS Communication Network; and
iii. Ensure that there is no duplication of existing IP addresses for the new equipment.

(f) Scalability

The Communication Network shall be scalable to accommodate an increase in network traffic and an increase in capacity between Communication Network equipment including the backbone of the network as well as all backbone systems, including the NMS.

The Contractor shall demonstrate that the addition of communication equipment or field devices can be accomplished with minimal disruption to the VicRoads ITS Communication System.

(g) Network Management System

VicRoads will use the existing Network Management System to monitor existing, new and future Freeway Management Devices. The Contractor shall ensure that all the devices, equipment, materials, cabling and any other items that will be used in this Contract Works are able to be integrated and configured into the existing Network Management System to allow the whole of the Network Management System to be operated and controlled.

The detailed Communication Network design developed by Contractor shall provide all the necessary information to integrate and configure the new devices into the existing NMS;

The VicRoads nominated O&M providers shall follow the detailed Communication Network design; configure the new devices into the existing or new NMS systems, which control the VicRoads ITS Communication Network during integration.

(h) Communication System Security

System security shall be implemented to meet or exceed the performance criteria of the existing VicRoads ITS Communication System.

System security shall conform to the requirements of IEEE 802.1X; it shall support ACL and SSL encryption.

System security shall support the rules of associating any combination of the following: IP address, MAC address, Port or VLAN.

The Contractor shall coordinate with VicRoads to ensure correct implementation of the security system in line with VicRoads policies and procedures. These shall be ratified prior to detailed design by the VicRoads.

(i) Open Standards

The Communication Network shall ensure that all network elements are compliant with industry standards and are commercially available off the shelf. Connectivity between network equipment shall not be based on proprietary protocols unless otherwise directed by the Superintendent.

(j) Capacity

The bandwidth capacity of each backbone router interface to each neighbouring Backbone router shall be not less than 20Gbps (2 x 10 Gbps).

The bandwidth capacity of each backbone router interface to each neighbouring access switch in the access rings shall be not less than 1 Gbps.

The bandwidth capacity of the link between an access switch to another access switch shall be not less than 1 Gbps.

The bandwidth capacity of the link between each access switch to each Freeway Management device shall be not less than 100 Mbps.

The capacity of the network core shall be determined as follows;

i. Switching Capacity

Switching capacity describes the switching ability of the switching module, switching card or backplane. Sufficient switching capacity for the applications using the ITS Communication System shall be provided on the switching module of the communication equipment. A minimum of 50% spare capacity shall be provided.

ii. Bandwidth of Communication Links

Sufficient bandwidth for the applications using the ITS Communication Network shall be provided on all communication links in the Communication System. Minimum bandwidth capacity requirements are detailed in Clause 735.18(j).

iii. Interfaces

The number of interfaces shall meet the requirements for all new and existing Freeway Management devices. Additionally, a minimum of 30% spare ports (30% of all ports on the equipment) shall be provided for future requirements. The 30% spare capacity shall be provided for each Access Switch and each Backbone Router.

(k) Redundancy and Fail-over

The ITS Communication Network shall support a redundancy mechanism to provide protection as described below.

(i) For multiple 10 Gbps backbone links between two backbone routers:
If one 10 Gbps backbone link is down, the data traffic shall be automatically switched onto another 10 Gbps link. The switch over time shall be no more than 50 milliseconds.

(ii) For backbone links on one backbone router:
If all backbone links toward a neighbour backbone router are down all data traffic in this direction shall be switched over automatically to the backbone link towards the neighbour backbone router in the other direction. Switch over time shall be no more than 50 milliseconds.

(iii) For each access ring between two backbone routers:

The two backbone routers shall provide a redundancy gateway function and corresponding routing function for the whole access ring.

For data traffic between each access ring and backbone routers traffic balance shall be applied. Access switches on each ring shall be divided into two sequenced, as far as possible of equal quantity, groups. The data traffic from the one group will use backbone router 'A' as the primary gateway and backbone router 'B' as the secondary gateway. The second group will use backbone router 'B' as the primary gateway and backbone router 'A' as the secondary gateway.

If the access switches and Freeway Management Devices on the access ring lose their connectivity to backbone router 'A', backbone router 'B' will take over the gateway and routing function. If the access switches and Freeway Management Devices on the access ring lose their connectivity to backbone router 'B', backbone router 'A' will take over the gateway and routing function.

VRRP or equivalent protocol shall be used for this gateway redundancy function.

(iv) For each access ring between two backbone routers:
The two backbone routers shall use the MPLS tunnel (MPLS Pseudowire or other suitable technology) function to support the access ring for maintaining the access ring topology.

The backbone network shall provide primary and backup MPLS Pseudowire (or other suitable technology) for access rings; the primary and backup MPLS Pseudowire shall have full diversity. If the primary MPLS Pseudowire is 'failed', the time for failover to back up MPLS Pseudowire shall be no more than 50 milliseconds.

(v) The access rings shall use Resilient Ethernet Protocol (REP) or other protocol with similar functionality as approved by the Superintendent to maintain the topology and the redundancy. The layer 2 MPLS tunnel shall be provided on backbone routers to support access rings to maintain the topology and recovery.

(vi) The time for failover of each access ring shall be no more than 10 seconds. This means, during an access ring failover, the down time of connectivity between Freeway Management Devices and backend server (ITS server and NMS server at TMC or DRC) shall be no more than 10 seconds.

(l) General Topology

The following topology principles shall be used for the connection of the network.

i. Access switches between two backbone routers shall be connected as several chains with each end of a chain connected to a backbone router. For each chain, the two ends of the chain connect with each other through the tunnel of backbone routers so that each chain becomes an access ring.

ii. In all roadside cabinets containing a field processor or multiple devices, an access switch shall be installed. For a single device such as a CCTV or FDS a pole mounted cabinet can be used.

iii. All interconnections between access switches shall use fibre interfaces. All interconnection between access switches and backbone router shall use fibre interfaces. All interconnection between backbone routers shall use fibre interfaces.

iv. All devices within the same cabinet as an access switch shall be connected to the access switch by CAT6 cable. When media converters are used, CAT6 cable between the media converter and the access switch shall be used.

v. There shall be no more than ten (10) access switches within each access ring. Total number of access rings shall be determined at detailed design stage.

735.19 FUNCTIONAL REQUIREMENTS

(a) General

To ensure compatibility among network devices, all backbone and access layer hardware equipment shall,

where possible, be supplied by a single manufacturer.

i. New Freeway Management Devices

For the type and quantity of Freeway Management Devices refer to the Contract Documents. Any new ITS field devices to be installed as part of these Works shall be operationally and functionally fully compatible with the existing ITS field devices.

ii. New Communication Equipment

All new communication system equipment to be installed as part of these Works shall be fully compatible with the existing communication system, including the NMS and Security System. The Contractor shall prove, by testing, that the equipment they select is fully compatible with the existing system. The existing system shall remain operational for the applications it supports for the duration of the Works.

Equipment listed in the Table 735.191 shall be used as it is already in operation on the existing VicRoads Communication System. This list is current at time of this document. For the latest approve models refer to VicRoads Guideline TCG 018, Register of ITS Approved Products.

Table 735.191

Item	Manufacturer	Model
Backbone Router	Cisco	Cisco ASR-9006
Access Switch	Cisco	IE3000

Any alternative access switch communications device proposed by the Contractor shall only be implemented as agreed with the VicRoads. As a minimum it shall provide the same functionality and compatibility as the equivalent device used on the existing Communications System, except as agreed with the VicRoads.

In event, where the devices mentioned on VicRoads Communication Network Specification shall be affected by manufacturer product refresh or life-cycle program, the Contractor shall propose alternatives as per manufacturer upgrade path or other suitable alternatives The Contractor must demonstrate to VicRoads that the proposed alternative equipment provides the same functionality as the current device used on the existing Communication Network and shall only be implemented with the VicRoads approval.

735.20 NETWORK BACKBONE NODES

Network nodes (routers) shall support the IEEE 802.3z Gigabit Ethernet standard.

The processing ability of the Processor Card shall be equal or better than the Processor Card of the existing backbone routers. Each card will have a 40 Gbps switching ability, when a Distributed Forwarding Card is used.

The backbone routers shall be fully compatible with the current Authentication System in TMC and DRC. The configuration of each backbone router shall be fully compatible with existing access management and authentication system and consistent with the configuration of existing backbone routers.

Each backbone router shall have an Access Control List (ACL). The VicRoads nominated O&M Contractor shall review the ACL on existing backbone routers and develop the ACL relevant for the routers in scope of the Project. The ACL shall follow the same concept as described in the FMS Communication document in section 735.16 Design Requirements – General.

The configuration of NTP on the backbone router shall be compatible with the current NTP server. The clock on all backbone routers shall be synchronised with the current NTP server, the time stamp for the event and alarm sent by the all backbone routers shall follow the same NTP system.

The configuration of backbone routers shall be fully compatible with existing NMS servers. The new backbone routers shall be configured to provide the same information as is now reported to the NMS from the existing

backbone routers (like alarm, event, log, trap, polling response, etc.).

The configuration of DNS on the network backbone routers shall be compatible with the existing DNS system. All Backbone routers shall use the same Quality of Services (QoS) policy and the QoS/CoS configuration shall be consistent with the configuration of existing communication systems.

The existing VicRoads network uses TACACS+ as authentication. Backbone routers shall be fully compatible with the existing authentication system at the TMC and the DRC. The Contractor shall ensure the configuration of each access switch is fully compatible with the existing access management and authentication system and is consistent with the configuration on existing backbone routers.

(a) Basic Requirements

A Network Node shall include the following components as a minimum:

i. Availability of each backbone router shall be 99.999%
ii. Multi slot chassis configuration with a minimum of six (6) slots;
iii. Multi-function network modules and a common bus or back plane;
iv. Switch fabric capable of supporting a minimum of 480 Gbps bandwidth including required operating system;
v. MPLS capability with up to three (3) label stack levels, MPLS VPN, and VPLS supporting point-to-point, point-to-multipoint, and multipoint-to-multipoint;
vi. Two power supply connections;
vii. All required processing functions, including software, to manage internetworking operations in both a master and hot standby mode;
viii. Support for interchangeable fibre-optic modules;
ix. Support for link aggregation on connections between Network Nodes;
x. Support for IEEE 802.1p Class of Service (CoS);
xi. Support for Simple Network Management Protocol (SNMP) versions 1, 2, and 3;
xii. Layer-3 distributed forwarding performance on the processing module up to 240 MPPS;
xiii. Replaceable fan tray;
xiv. Removable memory cards for configuration backup and restore;
xv. Capability to support dual supervisor or switching engines;
xvi. Network Nodes shall be suitable for mounting in a 19” rack arrangement.

(b) Interfaces

Network Nodes shall include the following interfaces as a minimum.

i. A console port for local access.
ii. (2) x 10 Gbps connections between core network nodes directly connected to each other.
iii. One (1) 1 Gbps Ethernet links with appropriate modules to connect to access layer switches.
iv. No modules that use contended access of greater than 1:2 to the backplane shall be used;
v. All other modules, cables and parts relevant and necessary for network operation including appropriate CISCO SFP which shall be able to support at least, but not limited to, the following connectors and cabling:

    1) 1000BASE-SX;
    2) 1000BASE-LX;
    3) 1000BASE-LX10 or 1000BASE-LH;
    4) 10GBASE-LR;
    5) 10GBASE-LW, and OTU2/OTU2e;
    6) 10GBASE-xWDM;
    7) 10GBASE-ER; and
    8) 10GBASE-ZR.

(c) Environmental Requirements

Network Nodes shall be capable of operating in the following environmental conditions:

i. AC power supply for nodes operating within Datacentre;
ii. DC power supply for nodes operating within Communication Hut;
iii. Four Power source with each power supply on separate and dedicated branch circuit;
iv. Operating temperatures from 0ºC to 40ºC;
v. Humidity from 10% to 85%. (non-condensing)

The Contractor shall ensure all huts containing backbone routers within the limit of Works satisfy ambient conditions to suit the operating conditions stated above. However, as a minimum there shall be air conditioning control.

The Contractor shall ensure backbone router inside the hut within the Works Areas shall be installed in accordance to the Manufacturer Hardware Installation Guidelines.

(d) Redundancy

Network Nodes shall have the following redundancy features.

i. Dual Processor Card, 1+1 backup, both cards shall be hot swappable.
ii. Four Power supply modules, n+1 backup, both cards shall be hot swappable.
iii. Dual fan modules shall be provided.
iv. Dual line cards.

(e) Layer 2 Functions

Network Nodes shall have the following Layer 2 Functions:

i. LACP for aggregation.
ii. Ethernet Channel.
iii. All the backbone routers shall be capable of handling sufficient MAC addresses, at least 50% spare capacity for MAC address process ability shall be provided.
iv. All network interfaces shall support flow control (IEEE 802.3x).
v. Port based VLAN (IEEE 802.1Q).
vi. VLAN management protocols (e.g. GVRP/GMRP/GARP or equivalent protocol).
vii. For each backbone router, sufficient VLAN IDs shall be supported (at least 4096).
viii. STP, RSTP and MSTP.
ix. MAC and ACL.

(f) Layer 3 Functions

Network Nodes shall comply with the requirements of IEEE 802.1X and have the following Layer 3 Functions:

i. Supporting static and dynamic routing protocols, as a minimum RIP1, RIP2, OSPF, IS-IS and BGPV4, MP, BGP.
ii. ARP, DHCP and IGMP.
iii. VRRP or HSRP.
iv. QoS and CoS.
v. ACL.
vi. Multicasting

(g) MPLS Function

Network Nodes shall have the following Layer MPLS Functions:

i. MPLS LDP.
ii. Up to 3 label stack levels.
iii. MPLS VPN.
iv. MP BGP.
v. Traffic Engineering.
vi. MPLS Pseudowire.

735.21 ACCESS SWITCHES

(a) General

The configuration of access switches shall be fully compatible with existing NMS servers. The new access switches shall be configured to provide equivalent information as that reported to the NMS by existing access switches, such as alarm, event, log, trap, polling response.

Each access switch shall have an Access Control List (ACL). The Contractor shall review the ACL on existing access switches and develop the design for the relevant Project Section Communication Network. The ACL shall follow the same concept as described in the FMS Communication document in section 735.16 – Design Requirements – General.

The configuration of DNS on the access switch shall be compatible with the existing DNS system.
All access switches shall use same Quality of Services (QoS) policy; the QoS/CoS configuration shall be consistent with the configuration of existing access rings.

The existing VicRoads network uses TACACS+ as Authentication. An access switch shall be fully compatible with the existing Authentication System at the TMC and the DRC.
The configuration of NTP on the access switch shall be compatible with the current NTP server. The clock on all access switches shall be synchronised with the NMS which is synched with the current NTP server, the time stamp for the event and alarm sent by the all access switches shall follow the same NTP system.

(b) Configuration and Security

The VicRoads nominated O&M Contractor responsible for the configuration shall review the configuration of existing backbone router in the context of the security function of the access switch. It shall follow the security policy and rules of the existing network including but not limited to the following items.

i. The availability of each access switch shall be 99.99%.
ii. Shutdown of all spare ports.
iii. Set up port security for single MAC address per port.
iv. Incoming and outgoing Block Spanning-Tree Traffic on access ports
v. Control of broadcasting.

(c) Basic Requirements

Access switches capable of delivering 10/100 Mbps Ethernet speed to Freeway Management devices. In addition, each access switch shall provide the following minimum requirements:

i. Support for up to a theoretical maximum of 1000 VLAN segments.
ii. An appropriate quantity of equipment from the following list.

- 10/100 Mbps full duplex Ethernet switched ports for connectivity to field equipment over CAT6 copper cabling.
- Gigabit Ethernet Fibre uplink and CISCO SFP uplink modules, as necessary, to provide connectivity to Network Nodes and other access switches.

iii. A minimum of 16 Gbps switching fabric.
iv. A stack-forwarding rate of at least 6.5 MPPS for 64-byte packets.
v. Be configurable up to 8,000 MAC addresses.

A configurable Maximum Transmission Unit (MTU) of up to 9000 bytes, with a maximum Ethernet frame size of 9018 bytes (jumbo frames) for bridging on Gigabit Ethernet ports and up to 1546 bytes for bridging and routing on Fast Ethernet ports.

Be configurable up to 255 IGMP groups.

Provide Software Image with support for QoS, VLAN and multicast capability.

Have all other modules, cables and parts that are relevant and necessary for network operation, including

appropriate CISCO SFP – (1000BASE-SX, LX/LH).

Support Simple Network Management Protocol (SNMP) versions 1, 2, and 3. The Contractor shall review the configuration with respect to SNMP on the existing access switches and develop the new configuration accordingly.

Be able to accept up to two (2) expansion modules.

(d) Physical Interface

Access switches shall include the following interfaces as a minimum.

i. All interfaces for interconnection with backbone routers or other access switches shall be 1 Gbps. All optical ports, including all spare optical ports, shall support Small Form Pluggable (CISCO SFP).
ii. All Ethernet interfaces (RJ45) for connection to ITS field devices shall be 100 Mbps or better.
iii. A console port for local access.
iv. A minimum of 30% spare capacity Ethernet interfaces (RJ45).

(e) Environmental Requirements

Access Switches shall be capable of operating in the following environmental conditions:

i. Operating temperatures from -40ºC to 70ºC;
ii. Humidity from 10% to 95%. (non-condensing)

The Contractor shall ensure all huts within the Works containing access switches (Cisco IE3000) have ambient conditions suitable to the operating conditions above.

(f) Layer 2 Functions

Network Nodes shall have the following Layer 2 Functions:

i. All the access switches shall be capable of handling sufficient MAC addresses as required by the ACL
ii. All network interfaces shall support flow control (IEEE 802.3x).
iii. Port based VLAN (802.1Q).
iv. VLAN management protocols (e.g. GVRP/GMRP/GARP or equivalent protocol).
v. For each access switch, sufficient VLAN IDs shall be supported (at least 4096).
vi. STP, RSTP, MSTP, REP.

(g) Layer 3 Functions

Access switches shall comply with the requirements of IEEE 802.1x and have the following Layer 3 Functions:

i. CoS.
ii. IP ACL.

(h) VLANS

A number of VLANs are required to segregate traffic on the network. Network nodes and access switches shall comply with IEEE 802.1Q – Virtual LANs.

The Contractor shall review the current VLAN allocation on the existing VicRoads Communication System and develop a VLAN allocation for the Project Section Communication System. The VLAN allocation shall follow the same format as the existing system configuration, engineering rules and be resource effective.

The Contractor shall design the necessary number of VLANs to support the services and devices on the LAN. The Contractor shall coordinate the allocation of devices into the appropriate VLAN and shall coordinate with VicRoads to have the access ports accordingly.

A new set of VLANs shall be created for the relevant Road Section Communication System data traffic. The number and device allocation policy shall continue on from that of the existing VicRoads ITS Communication

System. The Contractor shall be responsible for coordinating with VicRoads to implement the new VLAN policy.

(i) Media Converters

The Contractor may seek Superintendent's approval to utilise media converters to connect single CCTV and/or FDS devices. The Superintendent is not obliged to approve any proposed use of media converters.

Media converters, when required, shall comply with the relevant standards and be able to be integrated and configured into the communication system. It may be single mode or multimode fibre.

The fibre connection to media converters shall be a separate fibre cable.

(j) Door Alarms

All cabinets containing communication equipment, including routers, access switches and media converters shall have a Door Alarm that is integrated into the NMS. These door alarms shall activate when the door is opened and report this alarm to the NMS.

735.22 PERFORMANCE REQUIREMENTS

(a) System Availability

The Communications System, with the exception of wireless components, shall be designed to provide a resilient infrastructure with an availability of 99.99% as measured for continuous operation 24 hours a day 365 days a year excluding scheduled down time and outages, or delays caused by third parties. Adequate resilience and redundancy shall be built into the core and access layer of the network. Wireless components of the Communications System shall meet the requirements of Section 735.16.

The network design shall ensure that the following requirements are supported:

(i) Tolerate a failure to any equipment in the backbone network (i.e. routers) such that no ITS services are denied to any users after any network self-healing process.
(ii) Tolerate an access equipment failure such that at most, the maximum number of Freeway Management devices that can be connected to an item of access equipment, taking into account the number of spare ports, are denied access to network services.

Downtime to update the device flash image or repair a component shall be acceptable reasons for downtime, but at no time shall more than one core switch/router be non-operational. The following reasons are acceptable for downtime:

(iii) Routine maintenance or device update required – each device shall be shut down individually to be updated or maintained such that there never is more than one device down at any time.
(iv) VicRoads may allow maintenance or updating on devices if the particular device is or will become non-functional without having the maintenance or updates done.

All maintenance and update activities shall be scheduled to take place during non-peak hours.

The Contractor shall provide an analysis of the network in accordance with ITU-T Recommendation G.911 to demonstrate that the availability requirement is achieved. The Contractor shall provide scenarios of failure events and demonstrate that network element failures or sequences of network element failures do not affect the availability of the network.

The Contractor shall obtain certification from a third party to demonstrate that any transport links (dark fibre) have a systems availability of at least 99.5%.

(b) System Response Time

Response time criteria shall be met under maximum loading conditions. The transmission delay for a real-time or critical transmission (e.g. video) shall not exceed the latency measurement as stated in clause 735.16. The time to restart the network from a cold start or rebootable start after a fault shall not exceed ten minutes.

(c) Network Capability

The Communication System shall be capable of supporting voice, video and data applications through the use of the following:

- Prioritisation of applications using a Quality of Service (QoS) strategy;
- Multi-layer switching;
- Multicast support and VLAN configuration.

VLAN configuration shall be used to logically segment workgroups on the network. VLAN configuration shall be designed, configured and commissioned to ensure that its concept meets the existing VicRoads communication System functionality. Refer to section 735.16 Design Requirements – General.

VPN configuration shall be designed, configured and commissioned to ensure that its concept meets the existing VicRoads Communication System functionality. Refer to Section 735.16 *Design Requirements – General.*

The network shall be designed to support the operational, functional and performance requirements specified. The network utilisation shall not exceed 40% of total available bandwidth under normal load conditions, when there are no faults on the Communication System. The utilisation shall not exceed 70% of total available capacity at peak load, generally when there is a fault on the Communication System.

The Communication System shall be capable of supporting QoS, multiple priority orders, data queuing and transmission to ensure immediate delivery of higher priority and time sensitive voice, video and data packets including but not limited to CCTV video streams and access control alarms.

Minimum QoS requirements shall be as follows:

(i) The QoS scheme shall be made up of a minimum of six queues; these could be video data, FDS data, LUMS/VSLS data, VMS data, FRS data and NMS data.
(ii) Latency criteria shall be met under maximum loading conditions during normal operation. The latency time criteria shall be the same as that for the System Response Time in Clause 735.22(b).
(iii) Jitter shall not exceed 1 millisecond 99.9% of time and shall not exceed 10 milliseconds maximum more than 0.1% of time.
(iv) The Contractor shall ascertain from VicRoads the list of applications and their priority on the network to enable them to configure the Quality of Service.

The Contractor shall liaise with VicRoads to obtain the information necessary to establish an estimate of the network traffic utilisation profile.

The Communication System shall support IP traffic for TCP/IP as well as UDP packets.

The Contractor shall coordinate with VicRoads to review any specific requirements of applications and systems to run over the network and configure the network accordingly.

735.23 LABELLING OF INSTALLED ASSETS

(a) Labelling and Identification

i. Equipment Labelling

The Contractor shall produce full details of the equipment and cable labelling scheme for every cable, patch panel, cabinet, termination frame, and piece of active equipment in the Works. The labelling system shall be submitted to the Superintendent for review and approval before affixing labels.

All equipment, patch panels, outlets, cabinets and racks shall be clearly labelled in accordance with the approved label list.

ii. Cable Identification

Cables shall be labelled at the following points as a minimum:

- All entry/exit points of a building and cabinet.

- Cable pits.
- All cable termination points.

Cable cores shall be identified separately and individually.

Actual label samples for all conditions and cases shall be submitted to VicRoads for approval a minimum of three weeks prior to installation. The cable labelling convention shall be as follows:

i. Upstream Cabinet or Device (alphanumeric characters of varying length) e.g. CC23, RCB25610, LG11E, LUS40113, etc.
ii. Cable Type (single letter)

P = Power Cable (including VAC, VDC, LV and ELV)
C = Coaxial Cable
N = Ethernet/Network Cable
S = Serial Cable (RS232, RS422, RS485, etc)
L = Loop Feeder Cable
T = Traffic Signals Cable
F = Fibre Optic Patch Cable
B = Fibre Optic Backbone Cable
A = Access (Tail) Fibre cable

iii. Identification Number (two-digit number) e.g.01, 02, 03, etc.
iv. Downstream Cabinet or Device (alphanumeric characters of varying length) e.g. CC23, RCB25610, LG11E, LUS40113, etc

The fibre cable shall contain VicRoads custom print on the cable every 1 meter for the full length of the cable delivered under this project. The print shall contain the following text “VICROADS <xx>C – M80: NEL:EASTERN FWY – Project Name Trunk: <MMM-YYYY> and <mmmm> M”

- <xx>: Number of Cores
- <MMM-YYYY>: Date of Manufacture: e.g. “APR-2017”
- <mmmm>M: Sequential length in meters starting at zero (0000) at the inner end of the drum e.g. “0001M

Cable and print labels not in line with this convention will be rejected. The scheme shall be utilised for all record drawings and entries to the cable management system.

Labels shall use an agreed typeface size and font in permanent ink or laser print. Hand-written labels will not be accepted, except on a temporary basis during installation and will not be acceptable for cable testing purposes.

735.24 DRAWINGS AND DOCUMENTATION

All documents shall be prepared in accordance with Australian Standard AS4383.

The Contractor shall provide the following documentation of the network installation as indicated below.

(a) Drawings

The Contractor shall provide the following types of drawings as required for approval at the various stages of the design, as well as, ‘as constructed’ drawings upon completion of the Works. As constructed drawings shall be produced accurately and comprehensively with copies in a DGN compatible format and PDF format;

i. Backbone and tail cable layout. These drawings shall detail the quantity, type and routes of cables throughout the Works including location and detail of all splice locations, cable transitions and cable entries where applicable;

ii. Equipment layout. These drawings shall detail termination frames, panels and cabinets, clearly identifying the equipment in the room or cabinet;
iii. Network schematic. These drawings shall identify equipment type, location, and how the equipment is connected.
iv. Electrical schematic drawings. These drawings shall indicate the electrical cabling and connection of the electrical supplies to internal and external equipment of the Communication System

VicRoads will supply conduit and pit 'as constructed' drawings when each section's drawings become available.

(b) Documents

The Contractor shall provide the following types of documents as required for approval at the various stages of the design and installation.

i. Full network physical and logic design (including connectivity);
ii. Procedures for 'Temporary Sections';
iii. Business continuity plan;
iv. Management plan;
v. Environmental plan;
vi. Combined system integration plan (CSIP);
vii. Implementation plan used;
viii. Test plan;
ix. Training plan;
x. Test results;
xi. Hardware information;
xii. Configuration details;
xiii. Operation and maintenance details;
xiv. Support information.

735.25 AS CONSTRUCTED DRAWINGS AND DOCUMENTATION

(a) Documents

The Contractor shall submit, to the client for approval, as constructed documentation, produced accurately and comprehensively within eight weeks of the completion of each Separate Section of the Works. The documentation shall include but not be limited to:

i. Component conformance certification, indicating manufacturer and component reference, for all items supplied;
ii. Manufacturers literature for products installed in the Works;
iii. Uniquely numbered test certificates for each reel of optical fibre cable;
iv. Electronic schedules (Microsoft Excel format), one for each equipment room or cabinet, of cable terminations;
v. Electronic schedule (Microsoft Excel format) of each cable installed including comprehensive routing and numbering detail;
vi. Electronic records of all cable test results including software required to read test results unless supplied in Microsoft Excel format;
vii. IP Address Schedule for all equipment network equipment and devices installed under this Contract;
viii. Copies of calibration certificates for all test equipment used, valid on all dates where testing was completed;
ix. Configuration files for each piece of network equipment installed including software required to read test results, unless readable in Notepad format;
x. Electronic records of all network test results including software required to read test results unless supplied in Microsoft Excel format;
xi. Communications cabling system application and product warranty issued by the Contractor for a minimum of 20 years after the date of Practical Completion;
xii. Communications system electronic equipment application warranty and product warranty documentation;
xiii. Warranty against defective parts and workmanship for a minimum of one year after the date of Practical Completion;

xiv. Cable routes using pits label.

(b) Drawings

The contractor shall submit all drawings revised to ‘as constructed’ upon completion of the Works. ‘As constructed’ drawings shall be produced accurately and comprehensively with copies in a .DNG format in addition to a .PDF format.

(c) Manuals

All documentation listed above shall be submitted properly assembled into an Operation and Maintenance Manual as required by the Contract Document.

(d) As Built Network Document

The Contractor shall submit, to the client for approval, as constructed documentation, produced accurately and comprehensively within eight (8) weeks of the completion of each Separate Section of the Works.

i. Network architecture
ii. MPLS, BGP, VPN, MPLS Pseudowire
iii. OSPF, BGP, Static Routing
iv. REP topology, Traffic balance; VLAN
v. IP addressing application table and description
vi. QoS and CoS policy and assignment
vii. Port Allocation, network equipment ID, Freeway Management Devices ID
viii. CWDM/DWDM wavelength allocation
ix. Gateway Redundancy (VRRP or HSRP allocation)
x. Access Control list rules
xi. Multicast solution
xii. Authentication

(e) Network Management Systems and Security Solution

The Contractor shall submit, to the client for approval, as constructed documentation, produced accurately and comprehensively within eight weeks of the completion of each Separate Section of the Works.

i. Architecture and solution
ii. User accounts and privileges
iii. Remote access method
iv. Authentication solution
v. Firewall Rules and security policy.

(f) Fibre Cabling

The Contractor shall submit, to the client for approval, as constructed documentation, produced accurately and comprehensively within eight weeks of the completion of each Separate Section of the Works.

1) Fibre route

- Number of cores
- Fibre route
- Location of joint points
- Termination points
- Splicing points
- Location of pits
- Location of associated cabinets
- Distance between pits,
- Length of fibre form one joint point to the next joint point, splicing or termination points
- Listing the pit numbers that each fibre cable passes through.

2) Fibre core allocation

- Fibre patch panel allocation
- Splicing details of each splicing or termination point
- Connection schematic

(g) Fibre design package details shall cover the following:

The Contractor shall submit, to the client for approval, as constructed documentation, produced accurately and comprehensively within eight weeks of the completion of each Separate Section of the Works.

i. Cable ID
ii. Splicing diagrams
iii. Slack fibre length
iv. Fibre allocation or occupation
v. Pits ID of and distance to the next joint point.

735.26 CABLING SYSTEM

(a) General

Fibre optic cabling shall be installed to provide connectivity between core network nodes, between access layer switches as well as between access layer switches and core network nodes. Patch leads shall be supplied and installed between the fibre patch panel and the access layer switches. The exception to this is where Media Converters are used to connect to remotely located ITS field devices.

Where required the Contractor shall also connect into the existing system via patch panels installed by the Contractor.

This section outlines the functional and performance requirements of the cabling system including installation and testing procedures.

All cabling products supplied under this specification shall conform to AS/ACIF S008 and the cabling system installation shall conform to the requirements set out in AS/ACIF S009.

Copper cabling shall be protected by appropriate lightning surge protection. Copper cable conductors shall be directly terminated at each end with a RJ45, 8 pin keyed plug as defined by ANSI/TIA 568.0-D.

(b) Unshielded Twisted Pair Copper Cable Properties

Specific characteristics shall include the following.

i. Unshielded Twisted Pair cable shall conform to Category 6 standards.
ii. External grade shall be used where the cable is exposed to weather and/or wet conditions.
iii. Low Smoke Zero Halogen (LSZH).
iv. Patch cords shall have the same characteristics as above.

(c) Fibre-optic Cable Properties

The use of single-mode fibre throughout the network is preferable.

The Contractor shall seek approval from the Superintendent for the use of multimode fibre for any specific application.

(d) Single Mode Fibre-Optic Cable

Specific characteristics shall include the following.

i. Sheath suitable for installation in conduits. Conduits may be prone to intermittent flooding.
ii. Rodent proof. This may be achieved using ‘rigid FRP’ armouring on the cable.
iii. Non-metallic moisture barrier/ water blocking tape.
iv. Rigid central strength member.
v. Single tube construction for cables up to 12 fibre cores.
vi. Multi tube construction for cables of more than 12 fibre cores.
vii. Easily identifiable tubes in multi-tube constructed cables compliant with EIA 359A.

viii. Individual coloured fibres in each loose tube compliant with EIA 359A.
ix. Non-metallic construction that shall be Glass Reinforced Plastic (GRP).
x. Compliant with ITU-T recommendations.
xi. Where the backbone trunk fibre optic cable is a single 48 cores cable, the Contractor shall use tube-4 for the access rings purposes. In the situation where the access ring needs more than one tube, tube-2 can be used.
xii. Where the backbone trunk fibre optic cable is made of single 96 cores cable, the Contractor shall use tube-8 for the access rings purposes. In the situation where the access ring needs more than one tube tube-6, 4, 2 can be used.
xiii. Where the backbone trunk fibre optic cable is made of two 48 cores cable, the Contractor shall use tubes for the access rings purposes as advised this section 735.26
xiv. Where the backbone trunk fibre optic cable is a single 48 cores cable, the Contractor shall use tube-3 for the backbone node links. In situation where the backbone node links needs more than one tube, tube-1 can be used;
xv. Where the backbone trunk fibre optic cable is a single 96 cores cable, the Contractor shall use tube-7 for the backbone node links. In situation where the backbone node links needs more than one tube, tube-3, 1 can be used;
xvi. Where the backbone trunk fibre optic cable is made of two 48 cores cable, the Contractor shall use tubes for the backbone node links purposes as advised this section 735.26

(e) Patch Panels - Copper Cable

RJ45 patch panels shall have the following characteristics:

i. Fixed using securing bolts and captive nuts at either side.
ii. Enough finger space around connectors to allow patch cables to be connected and disconnected and to allow individual connectors to be mounted and dismounted without disturbing adjacent connectors.
iii. Able to accommodate full labelling of every connector.
iv. Cable support at the rear or front for dressing individual cables with due consideration for minimum bend radii of cables.

(f) Patch Panels – Fibre Optic Cable

Fibre optic patch panels shall have the following characteristics:

i. 1U panel suitable for mounting in 19" racks and street/road side cabinets.
ii. 1U or 2U panel for mounting in 19” racks in a Communication hut/ Data Centres/ Disaster recovery centre.
iii. Fixed using securing bolts and captive nuts at either side.
iv. Fully enclosed with lid, front mounted with no more than 400 mm front to back.
v. Terminate and present all cores of fibre optic cable.
vi. Duplex LC/ST/SC single-mode bulkhead adaptors installed where required complete with port covers to prevent ingress of dust and moisture.
vii. Enough finger space around connectors to allow patch cables to be connected and disconnected and to allow individual connectors to be mounted and dismounted without disturbing other adjacent connectors.
viii. Able to accommodate full labelling of every connector.
ix. An internal area for cable management, splicing and cable support, fully accessible for installation
x. Maintenance purposes by sliding or pivot splice module.
xi. Cables entering enclosed panels protected by appropriate protective glands or grommets.
xii. Management of fibres must meet the bend radius of 30 times the fully loaded optic fibre cable diameter or to the manufacture’s advice.
xiii. Provides facility to secure strain relief at each fibre optic cable gland entry.
xiv. Compatible with traditional or blown fibre optic cable technology.

(g) Fibre Optic Splice / Joint Enclosures

Termination housings shall be used for presentation of cables in cable pits. The enclosure shall have the following characteristics as a minimum:

i. An appropriate number of circular cable entries, as a minimum.

ii. Two (2) circular ports for main cable entry, compatible with blown core or standard cable systems.
iii. One (1) oval cable entry for mid-span loop through/break out applications.
iv. Integral splice tray for heat shrinkable splice protectors.
v. Splice trays hinged allowing full access without disturbance of spliced fibres in adjacent trays.
vi. Present terminated fibre cores to Duplex LC Connectors.
vii. Cable management to maintain at least the minimum bend radius at all times.
viii. Loop manager for storage of through loose tube elements without the need for splicing.
ix. IP68 rated.

(h) Cable Terminations

i. Fibre Optic Connectors

Fibre optic connectors to communication equipment (i.e. Cisco 7606/Cisco ASR 9006 or access switch) shall be small form factor (SFF) Lucent Connectors (LC). The average loss for connector pairs shall be less than 0.3 dB, including the loss due to splicing. Termination on patch panels may be either ST in RCB/PMC, LC/ST/SC within the Communication Huts or Data Centers and Disaster Recovery Centre.

ii. Fibre Optic Pigtails

Fibre optic pigtails shall be made from the same fibre type as the fixed cabling. The colour of the pigtail element coating shall match the colour of the fixed cable element coating. Cables shall only be terminated by fusion splicing to Small Form Factor (SFF) LC connectors unless terminated on a patch panel where ST connectors may be used.

iii. Fibre Optic Splices

Splices shall be retained within a protective sleeve by either friction or adhesive bonds to the optical fibre and additional strain relief for the completed joint shall be provided. All splice joints and their strain relief shall be fixed within the optical fibre management system of the patch panel or splice enclosure. The insertion loss through any splice shall not be greater than 0.1 dB.

735.27 INSTALLATION

(a) General

The following shall apply in relation to the installation of cable, multi-tube or multi-conduit assemblies.

i. The cable installation shall be done in accordance with the manufacturer's requirements and instructions.
ii. Use proper lubricants that are approved for use with the cable jacket type. Apply liberal quantities of recommended cable lubricant as the cable, tube or multi-conduit assembly enters the primary conduit.
iii. Personnel shall be positioned at intermediate positions along cable routes to assist feeding cables into conduit and to prevent snagging. Installation aids shall also be deployed to protect the cable or assembly from sharp edges and other abrasive features where required.
iv. At each pit location where there is no splice 30m of excess cable shall be provided, where there is a splice joint 15 m of excess cable shall be provided on each side of the splice. The excess cable shall be managed on cable supports. The largest loops possible shall be used inside the pit within the limitations of product bend radius restrictions.
v. Each rectangular Pit should be a P9 pit in line with VicRoads Standards drawings.

(b) Cabling installation

Accepted methods for cable installation shall be by pulled or air blown techniques. Pushed cable installation will be accepted for links shorter than 30 metres.

(c) Conduit Seals

The Contractor shall be responsible for sealing any utilised conduits at huts, cabinet entries and pits after installation of cables.

The Contractor shall be responsible for re-sealing utilised conduits entering pits after installation of cables where an existing seal is broken.

Seals shall prevent the ingress of noxious fumes, inflammable or explosive gases and water. A rodent and termite proof product is required.

(d) Fibre Optic Cable Terminations

All terminations to either join or terminate fibre cores shall be by means of fusion splicing methods. Mechanical splices and the use of direct connection techniques shall not be used.

When splicing any stripped cable shall be protected by a splice enclosure or patch panel. When the cable is installed all fibre optic splices shall be housed in splice trays or organisers inside the housing or patch panel. The correct splice tray shall be selected based on the use of fusion splices. Protection and strain relief of the splice shall be by heat-shrink sleeves.

Fibre cores shall be prepared for fusion splicing and the fibre cores cleaved before application of a heat shrinkable splice protector to one core and insertion to the fusion splice unit. The fibre ends shall be aligned and joined in accordance with the fusion splice unit procedures.

The Contractor shall comply with the safety requirements of AS/NZS 2967.

(e) Tail Fibre Inside Road Side Cabinets

Where applicable, the Contractor shall connect the tail fibre from each roadside cabinet to the backbone fibre optic trunk in the following manner:

i. As a minimum, the roadside cabinet shall contain a 12-core single mode tail fibre, connecting to the backbone fibre optic trunk;
ii. On the roadside cabinet, the 12-core tail fibre shall be terminated on fibre patch panel;
iii. Only selected cores from the 12-core tail fibre shall be spliced into the backbone core fibre trunk;
iv. This splicing is done at the pit which is closer to roadside cabinet and where the backbone trunk runs through;
v. The fibre optic cable and associated components along with installation, splicing and testing shall be done in accordance with this section; and

(f) Tail Fibre to backbone Fibre Splice

Where applicable, The Contractor, shall splice the tail fibre cores to backbone fibre cores in the following manner:

i. The same fibre core shall be selected from within the same tube of the backbone fibre cores to splice into the tail fibre of the roadside cabinet;
ii. Each access ring shall be on different pair of backbone fibre cores (for example: Ring-1 on cores 37 & 38, Ring 2 on cores 39 and 40) of 96 core fibre trunk.
iii. As a minimum 4 cores from tail fibre shall be spliced into backbone fibre towards the A-end and another 4 cores shall be spliced to the B-end;
iv. As a minimum, 2 cores spliced towards each end (A & B) will be active and remaining 2 cores shall be maintained as spare; and
v. Each access ring shall remain on the same cores of the fibre trunk.

(g) Fibre Optic Cables for Crossover

Where applicable, The Contractor, shall provide fibre optic cables to crossovers in the following manner:

i. As a minimum this shall be 24 core fibre cable, between the opposite roadside cabinets;
ii. Both ends of the 24 core fibre shall be terminated on patch panels inside the roadside cabinets;
iii. Only selected cores from the 24 core fibre shall be patched into the upstream patch panel, via patch cords;
iv. The fibre optic cable and associated components along with installation, splicing and testing shall be done in accordance with this section;

(h) Installation of Communications Equipment

The installation of all communication equipment shall be in accordance with manufacturer's requirement/directions.

735.28 TESTING AND COMMISSIONING

(a) General

The Contractor shall provide an Inspection and Test Plan (ITP) for all of the Works to cover the requirements of this Specification and those required by the Contractor's own QA Procedures as approved by the Superintendent. The Contractor shall carry out the inspections and tests in accordance with the ITP from prior to energising of the related part of the work and as described below for all test procedures up to and including commissioning tests.

The Inspection and Test Plan (ITP) shall include the following information:

i. Objectives of the inspections or tests
ii. Identification of all inspections and tests required
iii. Location of the inspections or tests
iv. Inspections or testing responsibilities?
v. Possible resultant actions from and depending on the test results
vi. Work method statements to carry out difficult or dangerous testing

Electrical and communication inspections and tests shall be conducted in combination where necessary for full operational acceptance. Electrical tests shall be in accordance with AS 3000. An approved Test Report format shall be used to record all inspection and test results. The completed Test Report shall be submitted to the Superintendent.
The Contractor shall arrange for the attendance of an 'authority' inspector if such an inspection is required.

(b) Notice of Testing and Commissioning

The Contractor shall advise the Superintendent at least fourteen (14) days prior to all inspections and tests. The Superintendent reserves the right to attend site to witness testing and request random sample testing upon completion of tests. Witness testing and random sample testing will be agreed with the Contractor prior to commencement of testing. Witnessing of inspections or tests shall not relieve the Contractor of their responsibilities under the terms of this Contract.

The Contractor shall give the Superintendent at least fourteen (14) working days written notice of when Works are ready for commissioning. The Works shall be commissioned under operating conditions in accordance with the Superintendent approved program.

Information submitted with the notice of test shall include:

i. Fully detailed method statements, identifying the manufacturer of test equipment and procedures to be followed for all tests.
ii. Details of fibre optic cable and equipment testing documentation procedures and samples of the test documentation.
iii. Sample signatures of all personnel authorised to carry out fibre optic cable tests.

(c) Test Equipment and Recourses

The Contractor shall provide all testing apparatus, equipment and labour required to carry out the testing and commissioning. The Contractor shall provide a physical and a logical plan of the test equipment arrangement in PDF format. Test equipment shall include, but not be limited to the following.

i. At least two network test units which shall be used to pass packets to each other in order to check for successful data transmission across the relevant sections of the network.
ii. A network protocol analyser that can transmit appropriate background traffic, such as video, voice or data to simulate network loading.

Copies of current calibration certificates for all test equipment held or intended to be used on site shall be maintained by the Contractor.

(d) Factory Acceptance Test (FAT)

All manufactured items, cabinets and switchboards shall undergo a Factory Acceptance Test (FAT) whereby they shall be inspected and tested before leaving the factory. The Superintendent may request to attend these tests. The Contractor shall inform the Superintendent, four weeks before when these tests will take place.

Tests shall be performed in accordance with AS 3439 or another relevant standard as applicable. The Contractor shall check that the equipment or cabinets are suitable for the application and comply with the specification.

Tests shall include an operational test of equipment and circuits, simulating remote signals where necessary.

Correct operation of all automated circuit breaker functions, including open, trip and close functions shall be included in the tests.

At the completion of the FAT test, inspection and test shall be carried out using the following Acceptance checklist and any defects identified should be rectified prior to the commencement of POP;

Acceptance Checklist are as follows:

i. ATC-FMS-735.20.4.1.1 – FAT for Fibre Optic Cables
ii. ATC-FMS-735.20.4.1.2 – FAT for Access Switch
iii. ATC-FMS-735.20.4.1.3 – FAT for Backbone Node
iv. ATC-FMS-735.20.4.1.4 – FAT for Fibre Optic AMPLIFIER
v. ATC-FMS-735.20.4.1.5 – FAT for Fibre Optic DWDM Multiplexer/Demultiplexer

(e) Inspection Test

Inspections of the whole installation shall include, where appropriate:

i. verification of all equipment correctly installed,
ii. labelling, wire and terminal numbering verification,
iii. tightness of screwed and bolted electrical connections,
iv. security of termination of conductors within terminals,
v. completion of correct compression of crimped connectors and terminal lugs,
vi. completion of correct termination of fibre optic cable, including at splices,
vii. integrity of conductors and insulation adjacent to terminals,
viii. proper installation of shielding where required,
ix. correct labelling of all equipment
x. Verification of labelling and warning notices.

At the completion of the network equipment's and/or fibre optic cable installation, inspection and test shall be carried out using the following Acceptance checklist and any defects identified should be rectified prior to the commencement of POP;

Acceptance Checklist are as follows:

i. ATC-FMS-735.20.4.2.1 – ITP for Fibre Optic Cables
ii. ATC-FMS-735.20.4.2.2 – ITP for Access Switch
iii. ATC-FMS-735.20.4.2.3 – ITP for Backbone Node
iv. ATC-FMS-735.20.4.2.4 – ITP for Fibre Optic AMPLIFIER
v. ATC-FMS-735.20.4.2.5 – ITP for Fibre Optic DWDM Multiplexer/Demultiplexer

(f) Proof of Performance (POP) Test

Proof of Performance tests are completed once the equipment has been installed. These tests are necessary to prove that the equipment as installed will perform, in situ, as stated in the Specification and manufacturer's information. POP testing shall be completed on each and every item of equipment. Electrical POP testing consists of two stages, pre- and post-, refer to the Standard Section 734 Electrical Network Installation for details. POP testing for ITS equipment shall be done in accordance with the approved ITP.

A signed certificate of Electrical Compliance (Certificate of Electrical Safety) shall be required before any mains

electrical power is switched on to the system.

For testing of communication equipment and similar refer to the communication equipment specification and the ITP.

At the completion of the network equipment's and/or fibre optic cable installation site inspection validations, test shall be carried out using the following Acceptance checklist and any defects identified should be rectified prior to the commencement of SIT;

Acceptance Checklist are as follows:

i. ATC-FMS-735.20.4.3.1 – POP for Fibre Optic Cables
ii. ATC-FMS-735.20.4.3.2 – POP for Access Switch
iii. ATC-FMS-735.20.4.3.3 – POP for Backbone Node
iv. ATC-FMS-735.20.4.3.4 – POP for Fibre Optic AMPLIFIER
v. ATC-FMS-735.20.4.3.5 – POP for Fibre Optic DWDM Multiplexer/Demultiplexer

(g) Sub-System Integration Test (SIT)

Once the POP tests are complete for all ITS items a SIT shall be done to confirm that the items can be communicated with from the central communications node.

The SIT for ITS equipment and the Communication System shall be done in accordance with the approved ITP.

At the completion of the network equipment's and/or fibre optic cable installation POP validations, Site inspections and test shall be carried out using the following Acceptance checklist and any defects identified should be rectified prior to the commencement of SIT;

Acceptance Checklist are as follows:

i. ATC-FMS-735.20.4.4.1 – SIT for Fibre Optic Cables
ii. ATC-FMS-735.20.4.4.2 – SIT for Access Switch
iii. ATC-FMS-735.20.4.4.3 – SIT for Backbone Node
iv. ATC-FMS-735.20.4.4.4 – SIT for Fibre Optic AMPLIFIER
v. ATC-FMS-735.20.4.4.5 – SIT for Fibre Optic DWDM Multiplexer/Demultiplexer

(h) System Acceptance Testing (SAT)

The SAT shall be completed by the Contractor once the SITs have been completed and integrated into the central software. The SAT is an end to end test that tests the functions of the software against the specified performance requirements to demonstrate the proper communication to each device.

The SAT for ITS equipment and the Communication System shall be done in accordance with the approved ITP.

At the completion of the network equipment's and/or fibre optic cable installation SIT validations, and SAT test shall be carried out using the following Acceptance checklist and any defects identified should be rectified prior to the commencement of SIT. SAT checklist has to be completed for each separable portion where the Contract contains separate Practical Completion Dates for each separable portion;

Acceptance Checklist are as follows:

i. ATC-FMS-735.20.4.5.1 – SAT for Communication Network

(i) Operational Performance Test (OPT)

The OPT is a 30-day performance test that shall be completed by the Contractor. The OPT is initiated once the SAT has been completed and operation has commenced. The OPT tests the system under full operational loading to ensure the system reliability, availability and performance requirements are met.

At the completion of the network equipment's and/or fibre optic cable installation SAT validations and when all the ITS assets are commissioned, OPT test shall be carried out using the following Acceptance checklist and

any defects identified should be rectified prior to the commencement of SIT. OPT checklist has to be completed for each separable portion where the Contract contains separate Practical Completion Dates for each separable portion;

Acceptance Checklist are as follows:

i. ATC-FMS-735.20.4.6.1 – OPT for Communication Network

(j) Tests to be Performed

Testing shall include, but not be limited to the following items.

i. The Communication Network shall be tested for operation by connecting test equipment to appropriate ports and passing information between the ports under test.
ii. The tests shall simulate each type of traffic expected to operate across the network (e.g. video, data, etc.).
iii. Tests shall be conducted under normal conditions as well as under fault conditions or high traffic levels.
iv. The Contractor shall develop a series of network tests to test each level of quality of service. This shall include packet loading of the network.
v. A minimum of 10% of all access ports of each communication device shall be tested.
vi. Each item of networking equipment shall be checked for functionality by transferring test traffic between units connected to output ports both within the same switch as well as on different switches. All resilience features shall be tested, by creating localised faults.
vii. The Contractor shall develop a test procedure to test the operation of the network under simulated fault conditions. This shall also demonstrate self-healing capabilities for events such as cable failure, port failure or power supply failure.
viii. 'Dead-on-Arrival' and 48-hour burn-in testing shall be undertaken prior to loading any configuration files onto the network equipment.
ix. Any other tests that is required to ensure completion of all test reports.

The purpose of testing is to demonstrate that installed cables meet the appropriate standards of performance.

(k) Copper Cable

A level III or IV field tester shall be utilised to carry out Category 6 Unshielded Twisted Pair cable tests. For each test the unit shall produce a measured result and determine whether the result is within the specified limits of ANSI/TIA-568.0-D. The unit shall be configured to store enhanced plot data within the electronic test record. The tester shall be certified for the level of test to be used.

An overall pass/fail for each test and the measured result for all pairs shall be provided. For each test, the worst-case value or margin to a limit and the frequency will be reported.

The Contractor shall carry out 'Permanent Link' testing to 100% of the Category 6 circuits installed. The method of test equipment utilisation shall be strictly in accordance with the manufacturer's instructions. Connecting test leads will be supplied by the connector block or test equipment manufacturer and terminated in an RJ45 connector for connection to the test instrument.

(l) Cable Testing

Tests for all cables, including fibre optic cable and any other communication cable, shall be carried out and recorded for every cable installed unless otherwise specified.

(m) Multi-Tube and Multi-Conduit Assemblies

Where blown fibre installation is used the tube assemblies shall be tested before installation of fibre optic cores or cables. The testing shall confirm the integrity of the tubes in preparation for cable installation activities.

Tests to be undertaken on each tube or conduit shall verify:

i. Tube air tightness.
ii. No water in tubes.
iii. Tube clear of blockage.

Tests shall be undertaken in accordance with the Cabling System Manufacturer installation guidelines.

(n) Fibre-Optic Cable

Each fibre optic cable shall be tested to confirm that it meets the attenuation/insertion loss requirements, as detailed in ANSI/TIA-568.0-D.

Before testing each connector face, it shall be examined with a microscope for cracks, scratches or dirt. If contaminants are detected the face shall be cleaned or the connector replaced.

All cables shall be tested to verify performance.

A cleaning regime shall be established for cables and the port connector under test before commencement of each certification test.
Single-mode fibre optic cables shall be tested at both 1310 nm and 1550 nm wavelengths.

Tests shall be made in both directions for every core of the installed cable.

For each optical fibre core the following test results shall be recorded:

i. Power Meter Measurements:
   - Overall attenuation/insertion loss to the nearest 0.1 dB.

ii. OTDR Measurements

   - The length of the cable in meters.
   - The loss of each connector and splice in the core.

(o) Failures

Cables that fail testing shall be pulled out and replaced by complete runs of new cable.

(p) Integration Testing

The Contractor shall supply, install, test, and commission all communication links required to integrate the relevant road Section Communication System to the existing VicRoads ITS systems.

(q) Commissioning

The Contractor shall submit a detailed commissioning program and pro-forma commissioning sheets for every system or item of equipment to be commissioned.

The Contractor shall carry out commissioning in accordance with the main project program and ITP.

The Contractor shall submit reports indicating observations and results of tests and compliance or non-compliance with requirements.

The Contractor shall give notice for witnessing of the commissioning works in accordance with the contract.

The Contractor shall provide a commissioning sheet for each cabinet and any other item of equipment as listed in the ITP.

(r) Test Records

Test results shall be recorded and submitted in electronic form on USB flash memory as well as hard copy as specified. The Contractor shall free issue any software required to read test results.

Test records shall identify cables under test using the same cable identity to that installed.

Electronic copies of OTDR test results shall be scaled to allow measurements of insertion loss across all splices and connectors on the link to the nearest 0.1 dB. The location of all splices and connectors shall be clearly indicated, along with the measured insertion loss. These requirements may be generated by the OTDR tester in the form of an event table.

The Contractor shall provide signed test certificates to the Superintendent at least seven working days after the completion of the commissioning of the Works.

A certificate of compliance shall be provided for all components, cables and accessories. This could include type test reports, manufacturer's or supplier's test reports.

(s) Test reports to be Submitted

i. The test reports to be submitted shall cover the following aspects:

1) POP testing Report
2) SIT Testing Report
3) SAT Testing Report
4) OPT Testing Report

ii. The lab testing report shall cover but not be limited to the following areas:

1) MPLS, BGP, VLAN
2) MPLS Pseudowire
3) BGP and OSPF
4) QoS and CoS
5) Failover between 2x10Gbs backbone links within backbone routers
6) Failover of Gateway
7) Failover of one backbone router
8) Failover of different direction of Backbone link
9) Failover of access ring link
10) Failover of access switches
11) Security function
12) VLAN
13) Throughput.

iii. The SIT testing result before interconnection with existing network shall cover but not be limited to the following areas:

1) MPLS, BGP, VLAN
2) MPLS Pseudowire
3) BGP and OSPF
4) QoS and CoS
5) Failover between 2x10Gbs backbone links within backbone routers
6) Failover of Gateway
7) Failover of one backbone router
8) Failover of different direction of Backbone link
9) Failover of access ring link
10) Failover of access switches
11) Security function
12) VLAN
13) Throughput.

iv. The SIT testing results after integration with existing network shall cover, but not limited to, the following areas:

1) MPLS, BGP, VLAN
2) MPLS Pseudowire
3) BGP and OSPF
4) QoS and CoS
5) Failover between 2x10Gbs backbone links within backbone routers
6) Failover of Gateway
7) Failover of one backbone router
8) Failover of different direction of Backbone link
9) Failover of access ring link
10) Failover of access switches
11) Security function

12) VLAN
13) Throughput.
14) Latency from end to end.
15) NMS