



TransPOD™

Transit Priority On Demand
TransLink Contract 0516-06
Main Street Transit Signal Priority Project

System Design Specifications

Final Draft

Standard

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TransPOD™ System Design Specifications

I have carefully assessed the TransPOD™ System Design Specifications for the Main Street Transit Signal Priority (TSP) Project.

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Overview

The Novax TransPOD™ traffic solution has been designed to allow transit operators to significantly improve their operations in terms of efficiency and reliability, reducing operating and capital costs while delivering better service, resulting in net gains in increased revenues and public service. TransPOD is a feature-rich, user-configurable system where interaction between autonomous components is made possible through interactive machine-to-machine wireless communication.

TransPOD improves the flow of buses and other transit vehicles operating in a mixed traffic environment by giving them preference through signalized intersections. Research has shown that Transit Signal Priority (TSP) is the lowest cost operational improvement strategy available.

The Priority Request Generator (PRG-E) onboard a bus uses real time positional information to request priority at an upcoming TSP enabled signalized intersection as it crosses a predetermined line (check-in). A Priority Request Server (PRS-E) located at the upcoming TSP-enabled signalized intersection receives the priority request. The PRS-E in turn, through its connection to the Traffic Signal Controller at the intersection, continues the priority request until the bus's PRG-E indicates that the bus has entered the intersection (checkout). As a backup, both the PRG-E and the PRS-E have built-in programming to terminate the priority request after a user-defined period of time.

TransPOD can dynamically determine a priority level for each bus based on its variance from schedule in keeping with user-defined thresholds. When a number of buses, some with different priority levels, approach an intersection the system arbitrates between the various priority requests giving preference to buses with higher levels of priority.

Unique to TransPOD is that it communicates through a broadband wireless mesh network providing real-time remote logging, remote telemetry, asset tracking, and remote system configuration and reconfiguration.

The broadband wireless mesh network facilitates real-time remote logging by making it possible for each TransPOD component to augment its onboard logs by sending the onboard logs to a central element management system that can be accessed through a secure web browser interface.

The broadband wireless mesh network provides a communications framework making it possible to remotely update firmware on individual components; the only restriction being that mobile components must be within network coverage. Service and maintenance issues are streamlined as the operational health of individual components can be accessed remotely at any time.

Unlike many other mobile systems, TransPOD's mobile components power down with the bus and as such do not create a parasitic drain on the vehicle battery.

In addition to service and operational improvements, TransPOD-generated data and information can be used to provide up-to-date information to travellers.

Utilizing the same TSP-based infrastructure, the Novax emVeePOD™, an extension of TransPOD, can expedite the movement of emergency vehicles through signalized intersections.

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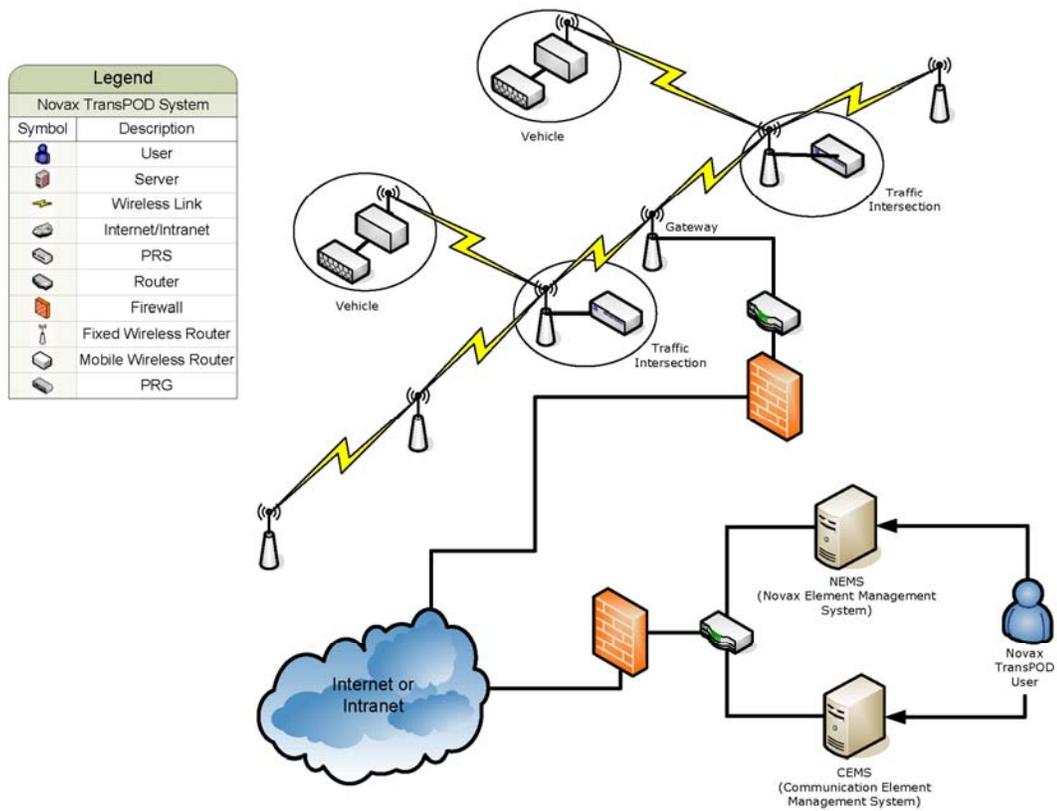


Figure 1. Diagrammatic representation of the TransPOD solution.

TransPOD's primary components are:

1. Wayside infrastructure and network
 - a. Backhaul
 - b. Intersection or Signal Activated Pedestrian Crossing
 - i. PRS-E Wayside Cabinet
 - ii. Fixed Wireless Mesh Router
 - c. In-Fill
 - i. Fixed Wireless Mesh Network Router
2. Wayside Electronics
 - a. Priority Request Server (PRS-E)
3. In-vehicle equipment
 - a. Priority Request Generator (PRG-E)
 - b. Mobile Wireless Mesh Router
 - c. Antenna
 - Positioning System
4. Element Management Systems
 - a. NEMS to manage the TSP system
 - b. CEMS to manage the wireless mesh network

Main Street Transit Signal Priority Project

The Main Street Transit Signal Priority Project was developed to improve the flow and timing of bus traffic along the Main Street corridor in Vancouver by implementing TSP at 31 selected intersections and signal activated pedestrian crossings. (The intersection at 1st Avenue will be added at a later date, resulting in TSP installation at 30 initial locations.)

In addition to the 30 current and one future TSP locations, there is a requirement for a number of in-fill wireless mesh routers to maintain a continuous network between intersections and signal activated pedestrian crossings resulting in a total of 38 wayside installation locations. While a TransPOD-equipped bus is within this network, it will be able to send a request for signal priority to the upcoming TSP-equipped intersections and signal activated pedestrian crossings.

For the Main Street Transit Signal Priority Project, the dynamic position of the bus will be determined by an existing onboard positioning system. This Automatic Vehicle Location (AVL) device is supplied by the Init CoPilot and the location is passed onto the PRG-E. It is assumed that the positional information provided by the AVL device will be accurate to within ± 2.5 meters without latency.

1. Wayside Infrastructure

The wayside infrastructure is the backbone of the TransPOD solution which is installed at all locations involved in the project. It is comprised of three components:

- ❑ Backhaul
- ❑ Wireless Mesh Network
- ❑ PRS-E Wayside Cabinet

“In-fill” locations contain only a fixed wireless mesh router and are not TSP equipped.

Appendix A contains site plans, detailed drawings, and reference sheets supplied by DMD Engineering outlining the installation plans for all locations.

Appendix B contains Novax generic installation drawings that detail the four types of installation variants.

1.1 Backhaul

The backhaul design is currently being finalized with TransLink. However, the Gateway locations for the wireless mesh network that will connect to the backhaul have been identified.

The Gateway provides the connection between the wireless mesh network and a backhaul network infrastructure, which in turn connects to the Element Management Systems (EMS).

Proposed Gateway locations under consideration are:

- ❑ **Pender**
Propose a pole-top extension of 6ft minimum to improve RF path to location.
- ❑ **Terminal**
Propose the Skytrain station rooftop as the preferred location for wireless router and backhaul radio.
- ❑ **Broadway**
Propose the southwest pole as the best location for a wireless router path to 5th Ave and RF path for backhaul.
- ❑ **21st or King Edward**
Both locations suitable for backhaul. Locating at King Edward would balance the router count between clusters.
- ❑ **41st**
Propose the southeast pole. Possible pole extension required due to trolley strain wires.
- ❑ **57th**
Propose the southeast corner pole for backhaul wireless radio.

Novax has also identified two cellular site locations along the route. Novax will be exploring the potential of fixed wireless links with the cellular carriers from the cell site to the gateway locations located on Main Street.

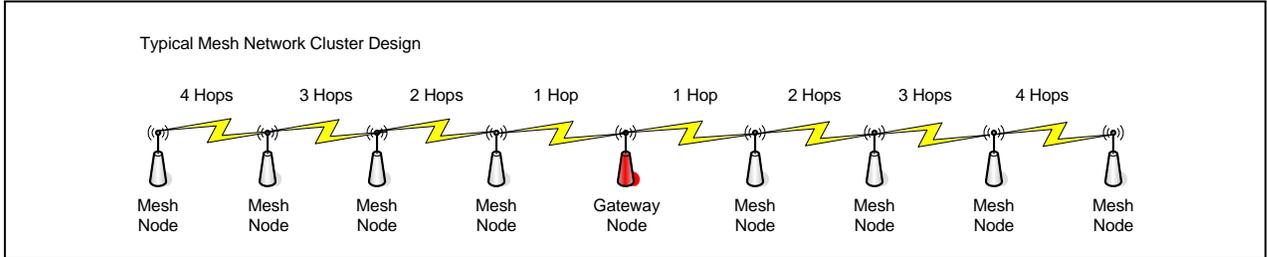
Cell Site Locations (proposed):

- ❑ **288 E. 8th Ave**
Located one block east of Broadway and Main.
- ❑ **206 W. 49th Ave**
Located on the southeast corner of 49th & Main.

1.2 Wireless Mesh Network

The Tropos nodes in the mesh network receive the signal from the oncoming vehicle's PRG-E (via an onboard Tropos wireless mobile router) and route the information via Ethernet cable to the PRS-E. This in turn sends a priority signal to the traffic controller as needed to enable signal priority.

1.2.1 Mesh Network Design Summary



1.2.1.1 Design Target

- ❑ Achieve 1 Mbps of throughput at last node or hop.
- ❑ Typical hop performance will affect data at $1/n$, where n = number of hops.
- ❑ Specific details regarding mesh network design, interference & noise can be found in Appendix G.

1.2.1.2 4-Hop Cluster

| Link | SNR (min) | Data rate (Mbps) | Throughput (Mbps) | Latency (ms) | Round Trip Latency (ms) |
|-------|--------------|------------------|-------------------|--------------|-------------------------|
| Hop 1 | $8 + 5 = 13$ | 12 | 4 | 10 | 20 |
| Hop 2 | $5 + 5 = 10$ | 6 | 3 | 10 | 40 |
| Hop 3 | $5 + 5 = 10$ | 6 | 2 | 10 | 60 |
| Hop 4 | $5 + 5 = 10$ | 6 | 1 | 10 | 80 |

1.2.1.3 3-Hop Cluster

| Link | SNR (min) | Data rate (Mbps) | Throughput (Mbps) | Latency (ms) | Round Trip Latency (ms) |
|-------|--------------|------------------|-------------------|--------------|-------------------------|
| Hop 1 | $5 + 5 = 10$ | 6 | 3 | 10 | 20 |
| Hop 2 | $5 + 5 = 10$ | 6 | 2 | 10 | 40 |
| Hop 3 | $5 + 5 = 10$ | 6 | 1 | 10 | 60 |

| Typical 802.11g data rate (Mbps) vs SNR (dB) | |
|--|----------|
| Data Rate (TCP) | SNR (dB) |
| 6 | 5 |
| 9 | 6 |
| 12 | 8 |
| 18 | 10 |
| 24 | 13 |
| 36 | 16 |
| 48 | 21 |
| 54 | 24 |

1.2.2 Fixed Wireless Mesh Router

For full details of wireless conformance and specifications, refer to the Tropos Networks Metro Mesh Router Outdoor Installation Guide in Appendix C.

NOTE: Please see Appendix E for detailed installation information.

1.3 PRS-E Wayside Pole and Cabinet Detail

Two possible configurations for each of the 30 TSP-equipped intersections involved in the Main Street Transit Signal Priority Project are described in Appendix B:

1. TSP intersection installation mounted on street light davit arms (TSP Intersection Davit Arm NDWG000026D1, Sheet 1 of 2)
2. TSP intersection installation mounted on street pole (TSP Intersection Pole NDWG000026D2, Sheet 2 of 2)

Appendix B also contains a detailed layout of the PRS-E Wayside Cabinet (NDWG000028D1).

1.3.1 PRS-E Wayside Cabinet Components

The TransPOD Main Street TSP project has been designed to provide a wayside housing to incorporate several components of the TSP system as detailed below.

- Power distribution equipment
- TSC signaling terminations
- TSP indicator lights
- LAN cable terminations
- PRS-E mounting location

1.3.1.1 Power distribution

Continuous 120V power is derived from a switched source in the existing Traffic Signal Controller. This supply is limited in the Traffic Controller to a 3Amp load.

The power is distributed through a conventional isolator switch and is used to provide a permanent supply to the wireless mesh router.

Spare terminals are provided to connect future equipment which shall interface into or provide functions associated with the TransPOD TSP system.

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The power distribution is fused and connected to a dual socket receptacle for plug-in power adapters.

1.3.1.2 TSC Signaling Terminations

The cabinet provides a secure location for the termination of a signal cable which is connected to the Traffic Signal Controller.

Three wires are terminated at a 10-pin pluggable connector which connects to the PRS-E component.

These signal wires activate the pre-emption inputs on the Traffic Signal Controller.

1.3.1.3 TSP indicator lights

A remote indicator panel is provided to allow visual confirmation of the operation of the signals connected between the PRS-E and the Traffic Signal Controller.

The panel consists of five indicators which are arranged in a cross pattern to intuitively provide directional feedback of the active signals from the PRS-E.

A central status indicator is provided that illuminates RED or GREEN depending upon the operational status of the PRS-E.

1.3.1.4 LAN cable terminations

The LAN cable provides PoE (Power over Ethernet) and data communication between the PRS-E and the fixed wireless mesh router.

1.3.1.5 PRS-E mounting location

Mounting screws are provided for the installation of the PRS-E.

1.3.2 Technical Specifications of the PRS-E Wayside Cabinet

(Refer to PRS-E Wayside Cabinet NDWG000028D1 drawing in Appendix B for installation notes.)

| | |
|--------------------------------|--------------------------------------|
| Environmental Characteristics: | NEMA 3R housing with lockable access |
| Electrical Rating: | HiPot tested to 1200V DC |
| Dimensions: | 16" (w) x 20" (h) x 6" (d) |
| Mechanical Mounting: | Steel Banding to Street Pole |

2. Wayside Electronics

The PRS-E is installed in a pole-mounted, NEMA-rated enclosure at 30 intersections along the Main Street route.

2.1 Priority Request Server (PRS-E) unit

The PRS-E (Priority Request Server) is a fully self-contained component of the TransPOD system. The PRS-E is designed to minimize the human-machine interaction with plug-n-play features. The PRS-E performs all TSP functions autonomously and has no user controls or local management features.

The PRS-E consistently communicates with the remote NEMS through the wireless mesh network and will automatically receive the commands from NEMS to reload the new configuration data.

In the event of the requirement to update or modify the software, such changes will be effected by operations remotely.

2.1.1 Operating Environment

The PRS-E software operates on a Linux-Gentoo Distribution and PC/104 platform with integrated Ethernet Ports, 8 GPIO lines and on-board Watchdog chip.

Other installed software packages include an SSH Server, HTTP Server, Logging Server, and a Watchdog Monitor Package which enables recovery from critical software or operating system failure.

2.2. External Interface Requirements

2.2.1 User Interfaces

Although the PRS-E requires minimal user-machine interactions, the following user interfaces are accessible for system configuration and maintenance purposes.

2.2.1.1 Configuration Interface

The initial configuration of the PRS-E is accomplished via a local web server during the Staging and Configuration Phase.

Subsequent configuration is achieved using the NEMS PRS-E Configuration screen. (Please refer to Section 4.1.2 for details.)

2.2.1.2 Maintenance Interface

The remote NEMS maintenance interface is comprised of the PRS-E Dashboard screen, Performance Monitor screen, and Performance Data screen. (Please refer to Section 4.1.1.3 for details.)

2.2.1.3 Hardware Interfaces

The hardware interfaces of the PRS-E are comprised of the following:

- ❑ TSC output connector
- ❑ PoE Ethernet Port

Refer to Section 2.7 for a description of the Hardware Interfaces.

2.2.1.4 Software Interfaces

The PRS-E main program communicates with the PRG-E and the central NEMS system using a TCP/IP secure protocol.

2.2.2 Communications Interfaces

The communication interface of the PRS-E is comprised of the following:

2.2.2.1 TSP Transaction Interface

This interface is assigned to TCP port 16001, for TSP transaction communication with the PRG-E.

2.2.2.2 Logging Interface

This interface is assigned to TCP port 1514, for sending remote system log messages to NEMS.

2.2.2.3 Update Interface

This interface is assigned to TCP port 16002, for receiving firmware and configuration updates from NEMS.

2.2.2.4 HTTP Service Interface

The service interface is assigned to TCP port 80 for initial device configuration and factory setup.

2.2.2.5 Remote Novax Diagnostic Interface

This interface is assigned to TCP port 22 for Secure Shell diagnostic access.

2.3 Functional Requirements

Each PRS-E receives simultaneous TSP requests from multiple PRG-Es and prioritizes them in real time.

The following standard features are provided for each PRS-E:

- ❑ Responds to a priority request from a PRG-E.
- ❑ Signals a service requests to a Traffic Signal Controller.
- ❑ TSP requests are handled using either FIFO or Priority Level.
- ❑ Provides priority outputs for each intersection approach for a specific period of time.
- ❑ Logs priority service requests.
- ❑ Uniquely identify all transactions with the PRS-E.
- ❑ Has real-time clock synchronization with the NEMS Network Time Protocol.
- ❑ Provides a secure remote configuration facility.
- ❑ Is uniquely addressable and identifiable on the communications network.
- ❑ Provides software and hardware watchdog functionality and application state monitoring.
- ❑ Logs all TSP transactions and watchdog or application state errors/warnings.
- ❑ Interfaces with existing wayside equipment in compliance with the current TS2 specifications applicable to the Traffic Controller industry.

2.4 Electrical requirements

2.4.1 Operating Voltage and Parameters

- ❑ The operating voltage is 12V DC (supplied by Power over Ethernet).
- ❑ The operating current is less than 1 Amp.

2.4.2 Electrical Interface

- ❑ The installation utilizes 600V-rated insulation on all wires.

2.4.3 Lightning Protection

- ❑ Transient protection devices are provided on the output signals to the Traffic Signal Controllers and power supply lines.
- ❑ A secure ground connection is provided inside the PRS-E Wayside Cabinet.

2.5 Environmental requirements

The PRS-E is designed to operate within the confines of a NEMA 3R weatherproof cabinet.

2.5.1 Temperature

- ❑ The PRS-E is designed to operate in the temperature range specified by NEMA.

2.5.2 Mechanical requirements

- ❑ The PRS-E is installed in the PRS-E Wayside Cabinet and is tested to withstand exposure to shock and vibration.

2.6 System Commands and Displays

The PRS-E has no hardware user interfaces to facilitate field management or control of its functional features.

Management functions of the PRS-E are handled by the remote NEMS.

2.6.1 Front Panel Indicators

The PRS-E is equipped with three front panel indicators to assist in determining functional performance.

The functionality of the indicators is described in the sections below:

2.6.1.1 Power Supply Indicator

The DC supply indicator monitors the applied power to the PRG-E from the Power over Ethernet interface from the fixed wireless mesh router. It has three states:

- ❑ GREEN – Indicator is illuminated whenever DC Power is applied to the PRS-E.
- ❑ NONE – If the power to the PRS-E is at any time removed, the indicator will extinguish. A power fail alarm will be logged and the internal standby power supply allows the PRS-E to perform a safe shutdown of any active software processes.
- ❑ RED – Illuminates if the polarity of the incoming supply is reversed.

2.6.1.2 Internal DC Power Indicator

The status of the internal regulated DC supply is monitored by the DC Power indicator.

The regulated DC-DC converter is provided with an automatic power management process that enables the regulated DC output after a start-up delay of 10 seconds to minimize the possibility of intermittent starts when power is first connected. There are two states:

- ❑ GREEN – DC regulated supply is operating.
- ❑ NONE – Is in a restart mode. The PRS-E contains features that enable it to generate a Power Recycle mode whereby the DC power will turn OFF for one second and then Reset to the ON State.

2.6.1.3 Status Indicator

An indicator is provided to monitor whether the PRS-E is operating. There are two states:

- ❑ RED – Either a fault has been detected or the processor is booting up.
- ❑ GREEN – The PRS-E is operating.

2.7 Description of Hardware Interfaces

2.7.1 TSC Output Connector

The PRS-E has capacity for isolated solid state circuits to control four TSP outputs.

The outputs consist of normally open contacts with a common return signal. These outputs are configured for steady state output. They are fully isolated and meet NEMA TS2 performance requirements.

The outputs are conventionally assigned to the TSP functions for north, east, south, and westbound approaches to an intersection.

Two isolated inputs are available for accessory functions.

2.7.2 PoE Ethernet Port

Power for the PRS-E is derived from the applicable terminals of Connector C1 or via a Power over Ethernet (PoE) connection from the fixed wireless mesh router.

PoE is a selectable option and requires the setting of jumpers inside the PRS-E cabinet.

3. In-vehicle Equipment

The Priority Request Generator (PRG-E) is the source of the signal which initiates the priority request at each intersection. The PRG-E is installed on each participating vehicle and is interfaced with the onboard Init CoPilot unit already existing on each bus. The PRG-E collects the information it needs (bus route, direction, speed, GPS location, etc.) to send a priority request ahead to the TSP-equipped intersection as it approaches.

All system commands are handled through the EMS.

The in-vehicle equipment to be installed is comprised of:

- ❑ PRG-E unit
- ❑ Mobile Wireless Mesh Router
- ❑ Antennas

NOTE: Please see Appendix E for detailed installation information.

3.1 Priority Request Generator (PRG-E)

The TransPOD PRG-E generates priority requests based upon the inputs of data from the Init CoPilot system (i.e., positional data, schedule variance, and door status).

The PRG-E has built-in processing capabilities to determine the correlation of the set or sets of intersection data with the computed location so that the required signaling can occur at the correct instance between the PRG-E and PRS-E components of the system. This is achieved through the communications network.

The typical requirements of the PRG-E are:

- ❑ Mobile computing platform
- ❑ Vehicle positioning system (supplied by Init CoPilot)
- ❑ Inertial navigation/dead reckoning components, including an odometer/wheel rotation sensor and an accelerometer/rate-of-turn sensor (supplied by Init CoPilot)
- ❑ Mobile wireless communication network
- ❑ AVL system with schedule adherence data output (supplied by Init CoPilot)
- ❑ Event logging and file management database
- ❑ Remote EMS configuration and software upgrading
- ❑ Door Status signal (supplied by Init CoPilot)
- ❑ Fused switched 12V DC power supply (supplied by CMBC)

The requirements detailed below identify the desired parameters of each subsystem described.

3.1.2 Operating Environment

The PRG-E software operates on a Linux-Gentoo Distribution and PC/104 platform with integrated Ethernet ports, 8 GPIO lines, and on-board Watchdog chip.

Other installed software packages include an SSH Server, HTTP Server, Logging Server, and a Watchdog Monitor Package which enables recovery from critical software or operating system failure.

3.2 Functional Requirements

The functional requirements of the PRG-E are as follows:

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- ❑ Determine absolute position to an accuracy of ± 2.5 Meters.
- ❑ Receive priority need message from the vehicle AVL system, or
- ❑ Receive a priority request and level of priority from Vehicle Logic Unit.
- ❑ Generate a TSP signal from the PRG-E over the mobile wireless mesh network to the PRS-E.
- ❑ Determine the upcoming TSP-equipped intersection.
- ❑ Determine the check-in position as to when to issue the priority request to a PRS-E.
- ❑ Log messages locally and on the remote NEMS server through the mobile wireless mesh network.
- ❑ Log all system-related messages.
- ❑ Determine PRG-E position, time, heading, and speed based on position updates from the Init CoPilot system.
- ❑ Determine from the Init CoPilot system the specific route it is traveling on.
- ❑ The signaling, monitoring and configuration data communicated with the PRG-E is NTCIP compliant.
- ❑ Interfaces with existing vehicle AVL equipment using an Ethernet connection as defined by the Init ISI specification.
- ❑ Automatically update system software and configuration data from the NEMS server when the vehicle enters the wireless mesh network.

3.3 Electrical requirements

3.3.1 Operating Voltage & Parameters

The PRG-E is designed for the harsh environment of a vehicle's power system. The 12V DC power inputs provided to the PRG-E are protected against transient surges, reverse polarity, load dumping, and intermittent power on initial application. The PRG-E is further equipped with its own short-term internal backup power to enable the recording of vehicle power interruptions and ensure no loss of performance data when power is removed.

The power supply to the PRG-E and associated equipment is protected by a replaceable 10 Amp in-line fuse.

3.3.1.1 Power

| | |
|-----------------------------|--|
| Operating Voltage: | 12.0V DC (Min 8.0V – Max 30V) |
| Supply Current : | 800 milliAmp quiescent (12.0V DC Supply) |
| Power up delay : | 10 Seconds after switch-on |
| Protection: Transient/Surge | 33V limiting device |
| Reverse Polarity | Diode protected with Red indicator |
| Internal Current Limiting | Preset – 3Amp input |
| Thermal Shutdown | Preset - 120°C on internal circuitry |

3.3.2 Control IO interfaces

The PRG-E has capacity for four solid state output circuits and two isolated inputs for accessory functions.

3.3.3 Lightning Protection

No direct exposure to lightning discharge is anticipated but the PRG-E will withstand the application of a continuous discharge of 1200V positive or negative between earth and any unused output terminals.

3.4 Environmental requirements

The Vehicle Resident Hardware is designed to operate inside a vehicle with natural convection cooling.

3.4.1 Temperature

The PRG-E is designed to operate in the temperature range specified by NEMA.

3.4.2 Mechanical requirements

The device is provided with independent mounting plates, brackets, and fasteners, which are resistant to vibration.

All fasteners will be provided with self locking nuts and or thread locking cement to prevent fixtures working loose over extended periods.

3.5 External Interface Requirements

3.5.1 User Interfaces

Although the PRG-E requires minimal user-machine interactions, the following user interfaces are accessible for system configuration and maintenance purposes.

3.5.1.1 Configuration Interface

The initial configuration of the PRG-E is accomplished via a local web server during the Staging and Configuration Phase.

Subsequent configuration is achieved using the NEMS PRG-E Configuration screen. (Please refer to Section 4.1.3 for details.)

3.5.1.2 Maintenance Interface

The remote NEMS maintenance interface is comprised of the PRG-E Dashboard screen, Performance Monitor screen, and Performance Data screen. (Please refer to Section 4.1.1.3 for details.)

3.5.1.3 Hardware Interfaces

The hardware interfaces of the PRG-E are comprised of the following:

- DC power from vehicle
- Ethernet LAN to mobile wireless mesh router
- Ethernet LAN to Init CoPilot

3.5.2 Communications Interfaces

The communication interface of the PRG-E is comprised of the following:

3.5.2.1 TSP Transaction Interface

This interface is assigned to TCP port 16001, for TSP transaction communication with the PRS-E.

3.5.2.2 Position Display Interface

This interface is assigned to TCP port 16010, for streaming positional information to NEMS for the Map Display.

3.5.2.3 Logging Interface

This interface is assigned to TCP port 1514, for sending remote system log messages to NEMS.

3.5.2.4 Update Interface

This interface is assigned to TCP port 16002, for receiving firmware and configuration updates from NEMS.

3.5.2.5 HTTP Service Interface

The service interface is assigned to TCP port 80 for initial device configuration and factory setup.

3.5.2.6 Remote Novax Diagnostic Interface

This interface is assigned to TCP port 22 for Secure Shell diagnostic access.

3.5.2.7 Init ISI Interface

This interface is assigned to TCP port 51001 for communicating with Init CoPilot.

3.5.3 Mobile Wireless Mesh Router

For full details of wireless conformance and specifications, refer to the Tropos Networks Metro Mesh Router Installation Guide. (Please refer to model 9422 in Appendix C.)

3.5.4 Mobile Wireless Antennas

The antennas selected below have been selected for optimum performance of the wireless mesh network.

3.5.4.1 Vertical 2.4 GHz Antenna

Features:

- Designed for use as a high gain mobile antenna or medium gain access point
- Spring loaded base is flexible for mobile use minimizing breakage
- 802.11b and 802.11g compatible
- Male N-connector for easy installation
- Compact gain antenna for point-to-multipoint applications
- Heavy duty fiberglass
- Weather proof for indoor or outdoor installation
- See Appendix D for additional product documentation.

3.5.4.2 Vertical 4.9 GHz Antenna

Features:

- ❑ Feed point is elevated above its mounting surface, easily clearing the overhead light bars in police and ambulance vehicles which often obstruct the RF signal.
- ❑ Quiet, closed coil tri-linear rod.
- ❑ Excellent VSWR performance on or off a ground plane.
- ❑ Rugged molded polymer elevated feed housing and stainless steel spring and rod, for maximum resistance to every day wear and tear. Mates with all 1-1/8"-18 thread mounts, including 3/4" mounts.
- ❑ High frequency microwave mounts utilize Pro-Flex™ Plus 195 low loss coaxial cable for optimal performance at microwave frequencies.

See Appendix D for additional product documentation

4. Element Management Systems

The Element Management System (EMS) configures and administers the TransPOD network by way of custom built graphical user interfaces (GUI).

There are two EMS programs used by TransPOD:

- ❑ The Novax Element Management System (NEMS), and
- ❑ The Tropos Element Management System.

4.1 NEMS

NEMS™ is a tool for collecting data and configuring and managing the TransPOD system, which includes a GUI for intuitive system access.

NEMS is a server which is typically located in a network operations center (NOC). Authorized users can access NEMS to remotely view the system via a standard web interface, make configuration changes, and read or download logs.

Data is logged to NEMS in real time. Logged data can be displayed on a remote PC using NEMS, enabling system managers to remotely monitor TSP activity and transit vehicle flow within TransPOD.

Through NEMS, software can be updated remotely on every PRG-E or PRS-E in service, along with vehicle and intersection configuration changes. NEMS also allows the performance of each system component to be monitored.

4.1.1 Specifications

4.1.1.1 Hardware:

The following minimum hardware specifications are recommended for NEMS:

- ❑ A dual-processor (X86) with 64-bit computing capability and processor speed higher than 3.0GHz.
- ❑ 4 GB memory.
- ❑ A RAID disk array.
- ❑ Hard disk with useable capacity greater than 200 GB.
- ❑ High RPM hard disk for fast Disk I/O accessing (preferably > 7200RPM).
- ❑ Dual Ethernet cards.
- ❑ DVD R/W or tape drive for data upload and backup (optional).

4.1.1.2 Software

NEMS is built on a LAMP platform (Linux Apache MySQL PHP) to ensure adherence to open standards, along with the flexibility and cost-effectiveness of using open source software. Built on an N-Tier architecture, TransPOD utilizes Linux as the underlying operating system and Apache and PHP for its user interface. All system data is stored in a robust MySQL database for information storage and analysis. The open architecture has both generic and Novax-specific components.

4.1.1.3 NEMS Modules

Apache Web Server Setup Specifications

NEMS is accessible through a web browser.

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The NEMS HTTPS server is enabled with mod_ssl/2.0.54. OpenSSL/0.9.7e modules serve the HTTPS connections between NEMS and the clients while a PHP/5.05 module serves the web interface preprocessing.

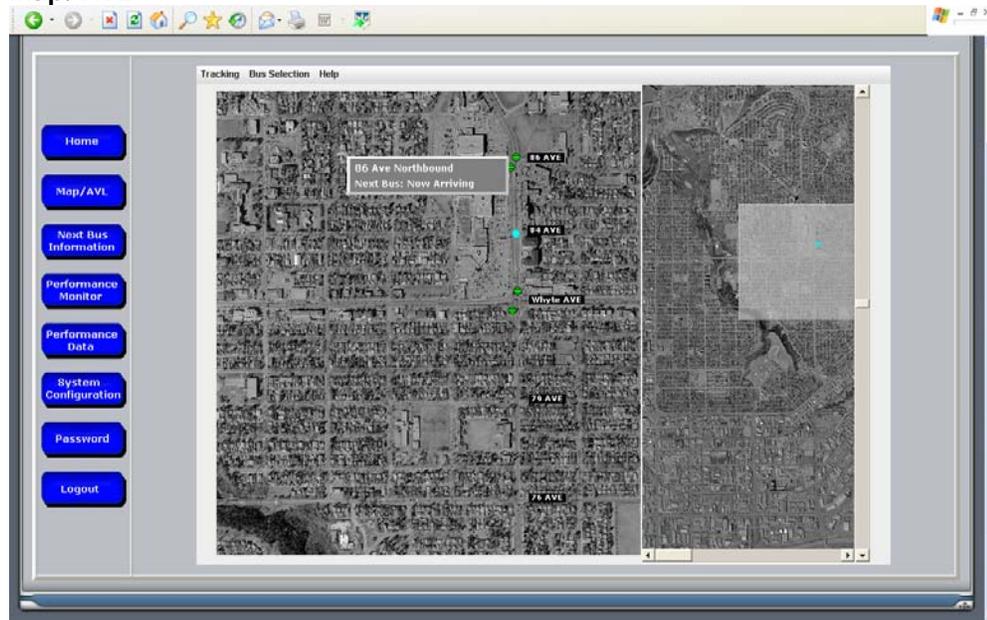
Novax Web Interface Design Specifications

The NEMS web user interface is implemented in standard HTML which is generated by a PHP module (web preprocessor).

To view the map application, you must have Java installed on your local machine.

The web interface, in general, is divided into nine different areas:

1. **Map/AVL**

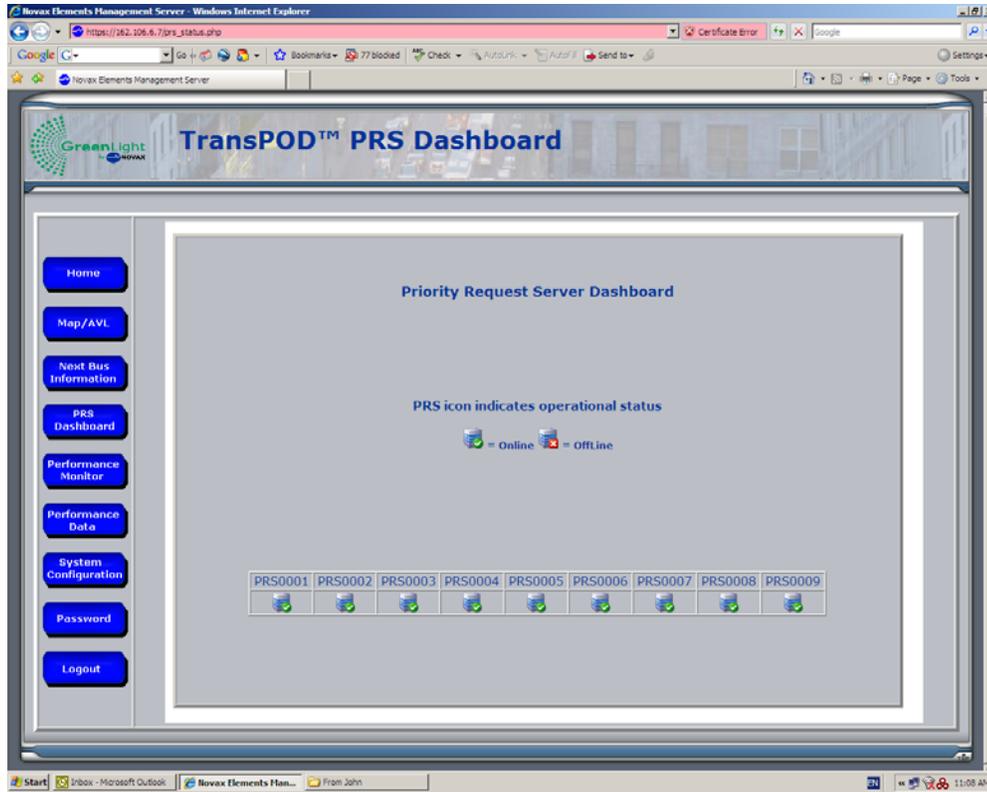


This screen is the Map/AVL (Automated Vehicle Locator). This opens a Java™ application, which displays a real-time map showing TransPOD-equipped vehicles travelling within the wireless network area. Check-in and check-out status is also displayed.

As a visual feature, the bus icon colour is coded to correspond to different levels of priority. A unique colour is always used to signify that the vehicle is located between check in and check out position.

2. PRS-E Dashboard

The PRS-E Dashboard provides a quick and easy way to check the status of PRS-E units and to display basic information of each device.

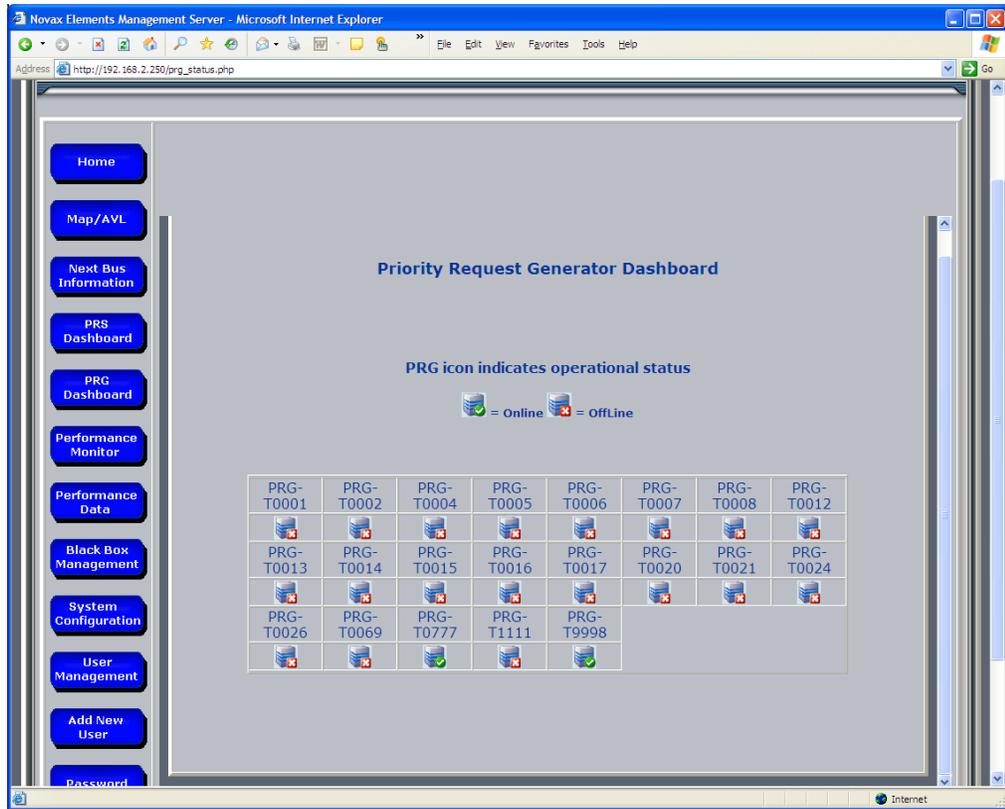


Icons indicate whether a particular PRS-E is online or offline.

Mousing over an icon gives details of the PRS-E, such as:

- Location
- IP Address
- Uptime (in minutes)
- Downtime (in minutes)
- Last Reboot
- Status
- Version (of PRS-E software)

3. PRG-E Dashboard



The PRG-E Dashboard provides critical information on each PRG-E in the TransPOD system. Information available includes:

- Vehicle ID
- Last Seen
- Status

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4. Performance Monitor

The TransPOD Performance Monitor is a display of the most recent 500 log entries. This data is also stored in the NEMS archive, where it is available for historical performance reports.

The log is a record of TSP events related to the PRG-E and PRS-E devices, and includes information on date, time, Bus ID, intersection, approach direction, bus priority, and action performed.

NOTE: This screen is updated every 10 seconds.

| Timestamp | Source | BusID | Intersection | Approach | Priority | Sequence # | TSP Transaction # | Action |
|---------------------|--------|-------|-------------------------------|------------|----------|------------|-------------------|------------------|
| 2006-09-12 10:11:07 | PRG | N0003 | 83 St and Argyll Rd | NULL | 1 | 3387844 | | CHECKOUT |
| 2006-09-12 10:11:07 | PRG | N0003 | 83 St and Argyll Rd | Northbound | 1 | 3387845 | 666 | PRIORITY_CLEAR |
| 2006-09-12 10:11:07 | PRS | N0003 | Engineering Test Intersection | Northbound | 1 | 3387861 | 666 | PRIORITY_CLEAR |
| 2006-09-12 10:10:59 | PRG | N0002 | 86 St and Argyll Rd | Northbound | 1 | 3387830 | | CHECKOUT |
| 2006-09-12 10:10:59 | PRG | N0002 | 86 St and Argyll Rd | Southbound | 1 | 3387831 | 49 | PRIORITY_CLEAR |
| 2006-09-12 10:10:59 | PRS | N0002 | Engineering Test Intersection | Southbound | 1 | 3387859 | 49 | PRIORITY_CLEAR |
| 2006-09-12 10:10:59 | PRS | N0002 | Engineering Test Intersection | Southbound | 1 | 3387860 | 49 | CLEAR IGNORED |
| 2006-09-12 10:10:51 | PRG | N0002 | 86 St and Argyll Rd | Southbound | 1 | 3387828 | | CHECK-IN |
| 2006-09-12 10:10:51 | PRG | N0002 | 86 St and Argyll Rd | Southbound | 1 | 3387829 | 49 | PRIORITY_REQUEST |
| 2006-09-12 10:10:51 | PRS | N0002 | Engineering Test Intersection | Southbound | 1 | 3387856 | 49 | PRIORITY_REQUEST |
| 2006-09-12 10:10:51 | PRS | N0003 | Engineering Test Intersection | Northbound | 1 | 3387857 | 49 | SERVICE_CURRENT |
| 2006-09-12 10:10:51 | PRS | N0002 | Engineering Test Intersection | Southbound | 1 | 3387858 | 49 | REQUEST IGNORED |

Information available:

- ❑ **Timestamp:** Timestamps are truncated to the second and represent the time the event took place at the PRG-E or PRS-E.
- ❑ **Source:** Either PRG-E or PRS-E.
- ❑ **BusID:** The ID number of the bus that has requested priority.
- ❑ **Intersection:** Location of the PRS-E handling the priority request.
- ❑ **Approach:** Direction of the transit vehicle approaching the intersection. This may be displayed as North, East, South, or West.
- ❑ **Priority:** Priority ranking of the vehicle. TransPOD can handle more than 200 levels of priority. The higher the number, the greater the priority. The highest priority numbers are reserved for emergency vehicles.
- ❑ **Sequence Number:** A unique number identifying each logged event in the database.
- ❑ **TSP Transaction Number:** Each PRG-E device allocates a sequential transaction number to all logs associated with a specific TSP request. All logs associated with a specific TSP request by a specific PRG-E thus have the same transaction number. This simplifies data interpretation.
- ❑ **Action:**
 - i. **PRIORITY REQUEST** – Indicates receipt of the priority request message from the PRG-E.

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- ii. **SERVICE REQUEST** – In response to the priority request from the PRG-E, the PRS-E sends a service request to the TSC.
- iii. **PRIORITY CLEAR** - Indicates receipt of a priority clear message from the PRG-E.
- iv. **SERVICE CLEAR** – This log message indicates that a priority clear request has been received from the PRG-E and was relayed to the TSC.
- v. **PRIORITY CANCEL** - In response to a priority cancel message from the PRG-E, the PRS-E echoes the request.
- vi. **SERVICE CANCEL** – This log message indicates that a priority cancel message has been received from the PRG-E and relayed to the TSC.

5. Performance Data

The Performance Data screen provides access to archived data which can be retrieved and sorted in a variety of formats to create historical reports on the TransPOD system.

| Timestamp | Source | BusID | Intersection | Approach | Priority | Sequence # | TSP Transaction # | Action |
|---------------------|--------|-------|-------------------------------|------------|----------|------------|-------------------|------------------|
| 2006-10-11 12:55:17 | PRS | N0003 | Engineering Test Intersection | Southbound | 1 | 3430129 | 91 | PRIORITY_CANCEL |
| 2006-10-11 12:52:49 | PRS | N0003 | Engineering Test Intersection | Southbound | 1 | 3430122 | 91 | SERVICE_TIMEOUT |
| 2006-10-11 12:53:19 | PRS | N0003 | Engineering Test Intersection | Southbound | 1 | 3430121 | 91 | SERVICE_REQUEST |
| 2006-10-11 12:53:19 | PRS | N0003 | Engineering Test Intersection | Southbound | 1 | 3430119 | 91 | PRIORITY_REQUEST |
| 2006-10-11 12:52:10 | PRS | N0003 | Engineering Test Intersection | Northbound | 1 | 3430114 | 90 | SERVICE_CLEAR |
| 2006-10-11 12:53:10 | PRS | N0003 | Engineering Test Intersection | Northbound | 1 | 3430113 | 90 | PRIORITY_CLEAR |

Data fields available are:

- ❑ **Date Selection:** Input a range of dates during which the data is to be analyzed.
- ❑ **PRG-E/PRS-E Selection:** The options are to view PRG-E data, PRS-E data, or both.
- ❑ **Bus Selection:** Choose to view individual bus data, or data for all buses at once.
- ❑ **Intersection Selection:** Select a specific intersection, or all intersections in the TransPOD system.
- ❑ **Approach Selection:** Choose to report logs for a direction of approach to an intersection.

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- ❑ **Download CSV File:** The file downloads as Comma Separated Values (CSV) format to be saved on a local drive.

6. Black Box Management

Logged GPS locations are stored in the PRG-E until they can be transmitted to the NEMS. This information can provide transit managers a clear picture of where a particular vehicle was at any given time – including how much of that time was spent moving or stationary.

The frequency of recording the GPS location is a configurable parameter.

The files are compressed CSV files in GZIP format. There is a limit to the number of files stored in this archive. This limit is a configurable parameter.

Novax Elements Management Server - Microsoft Internet Explorer
Address http://192.168.2.250/blackbox_report.php

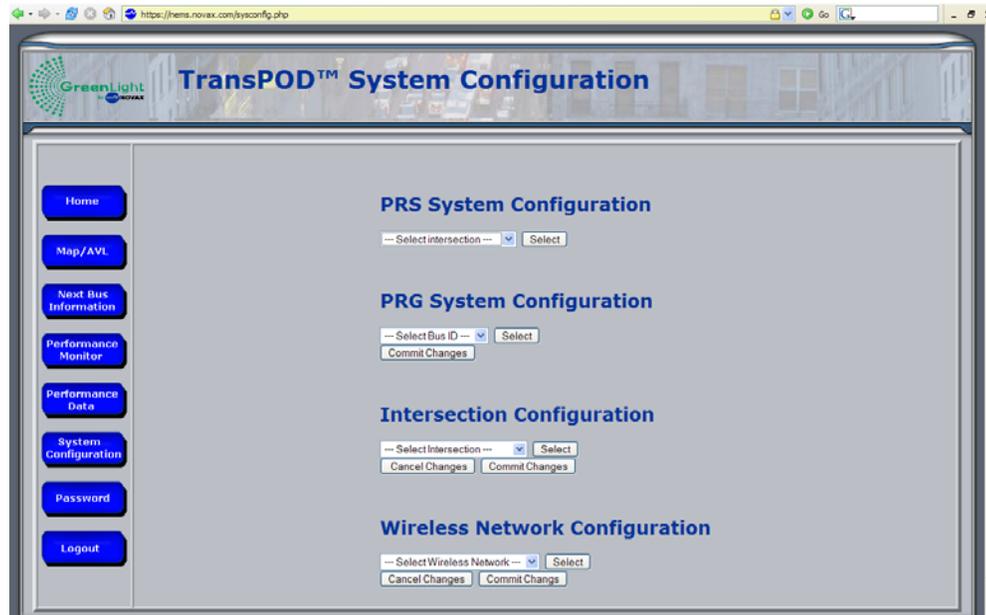
All files are zipped with *gzip* extension. They can be unzipped with most file archiver programs available (e.g. Winzip, 7-zip, etc.).

Index of /blackbox

| Name | Last modified | Size | Description |
|---|-------------------|------|-------------------------|
| Parent Directory | | - | |
| N0009_2008_01_07_05...> | 07-Jan-2008 13:33 | 44 | GZIP compressed docume> |
| N0009_2008_02_27_05...> | 27-Feb-2008 16:57 | 20 | GZIP compressed docume> |
| N0009_2008_03_06_05...> | 06-Mar-2008 10:35 | 20 | GZIP compressed docume> |
| N0009_GPIO_2008_01_0...> | 07-Jan-2008 13:33 | 82 | GZIP compressed docume> |
| N0009_GPIO_2008_02_2...> | 27-Feb-2008 16:57 | 56 | GZIP compressed docume> |
| N0009_GPIO_2008_03_0...> | 06-Mar-2008 10:35 | 56 | GZIP compressed docume> |
| N0032_2007_05_08_05...> | 15-Jan-2008 10:52 | 559 | GZIP compressed docume> |
| N0032_2007_05_22_05...> | 15-Jan-2008 10:52 | 44 | GZIP compressed docume> |
| N0032_2008_01_07_05...> | 18-Feb-2008 16:06 | 14K | GZIP compressed docume> |
| N0032_2008_01_08_05...> | 15-Jan-2008 10:52 | 132 | GZIP compressed docume> |
| N0032_2008_01_14_05...> | 15-Jan-2008 10:52 | 4.1K | GZIP compressed docume> |
| N0032_2008_02_12_05...> | 18-Feb-2008 16:06 | 140 | GZIP compressed docume> |
| N0032_2008_02_13_05...> | 18-Feb-2008 16:06 | 1.9K | GZIP compressed docume> |
| N0032_2008_02_14_05...> | 18-Feb-2008 16:06 | 188 | GZIP compressed docume> |
| N0032_2008_02_15_05...> | 18-Feb-2008 16:06 | 1.0K | GZIP compressed docume> |
| N0032_2008_02_16_05...> | 19-Feb-2008 12:07 | 1.0K | GZIP compressed docume> |
| N0032_GPIO_2008_01_0...> | 18-Feb-2008 16:06 | 82 | GZIP compressed docume> |
| N0032_GPIO_2008_01_1...> | 15-Jan-2008 10:52 | 82 | GZIP compressed docume> |
| N0032_GPIO_2008_02_1...> | 18-Feb-2008 16:06 | 111 | GZIP compressed docume> |
| N0032_GPIO_2008_02_1...> | 18-Feb-2008 16:06 | 148 | GZIP compressed docume> |

7. System Configuration

NEMS comes pre-configured from Novax. It enables authorized system managers to view a broad range of operating conditions within TransPOD and makes it possible to re-configure limited features of the PRG-E and PRS-E as circumstances change in the transit system. Note that each PRG-E is configured for a specific transit vehicle, while each PRS-E is configured for a specific intersection.

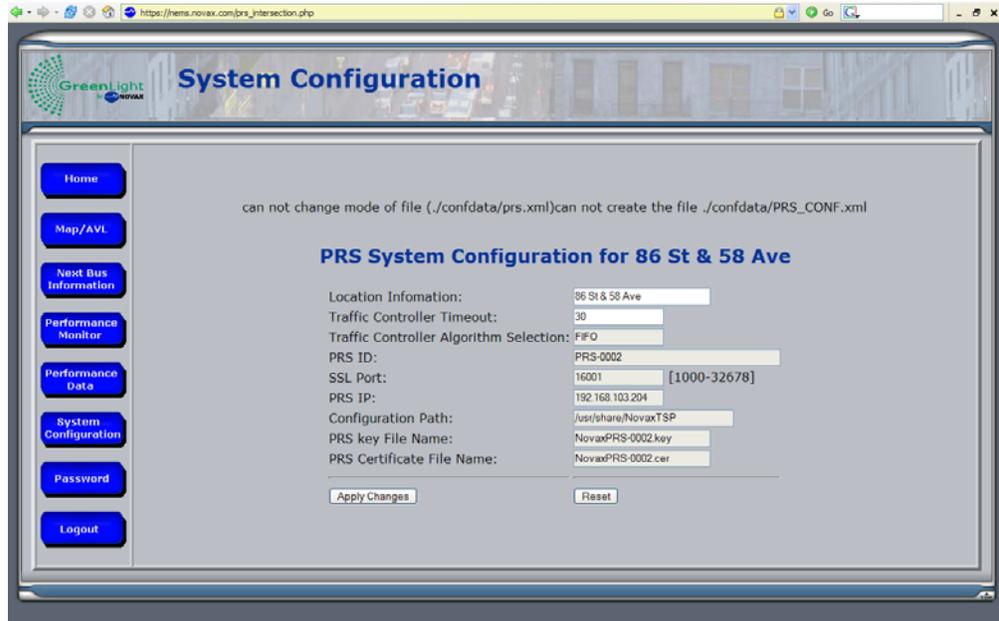


- ❑ **PRS-E System Configuration:** Use the dropdown menu to select an intersection, then click the “Select” button to open the PRS-E configuration screen.
- ❑ **PRG-E System Configuration:** use the dropdown menu to select a vehicle, then click the “Select” button to open the PRG-E configuration screen.
- ❑ **Intersection Configuration:** Use the dropdown menu to select an intersection, then click the “Select” button to open the Intersection configuration screen.
- ❑ **Wireless Network Configuration:** Use the dropdown menu to select a wireless network if there are two or more for the TransPOD system. If there is only one wireless network, simply click the “Select” button.

NOTE: Changes made on the configurations screen don't take effect until the “Commit Changes” button is clicked, either on this screen or on the configuration screen.

7.1 PRS-E Configuration

This screen allows a number of parameters for the PRS-E to be configured.



- ❑ **Location Information** is normally only changed if the PRS-E is replaced or removed and re-installed at a different intersection.
- ❑ **Traffic Controller Timeout** shows the maximum interval the PRS-E can hold a Priority Request from a PRG-E. The default is 14 seconds. If the transit vehicle has not reached the intersection within that interval, the PRS-E cancels the priority request.
- ❑ This timeout value can be individually changed for each PRS-E. It can be changed to reflect traffic conditions that vary for different times of day, or to reflect temporary changes in conditions, such as construction that slows traffic for several days or weeks.
- ❑ **Traffic Controller Algorithm Selection** is preset to FIFO (First In First Out).
- ❑ **SSL Port** is the Secure Socket Layer port through which the PRS-E communicates with the PRG-E.
- ❑ **PRS IP** is the IP address of the device.
- ❑ **Configuration Path** is the directory where the configuration data resides.
- ❑ **PRS Key File Name** contains the filename for the SSL key.
- ❑ **PRS Certificate File Name** contains the filename for the SSL certificate.

7.2 PRG-E Configuration

This screen allows a number of parameters for the PRG-E to be configured.

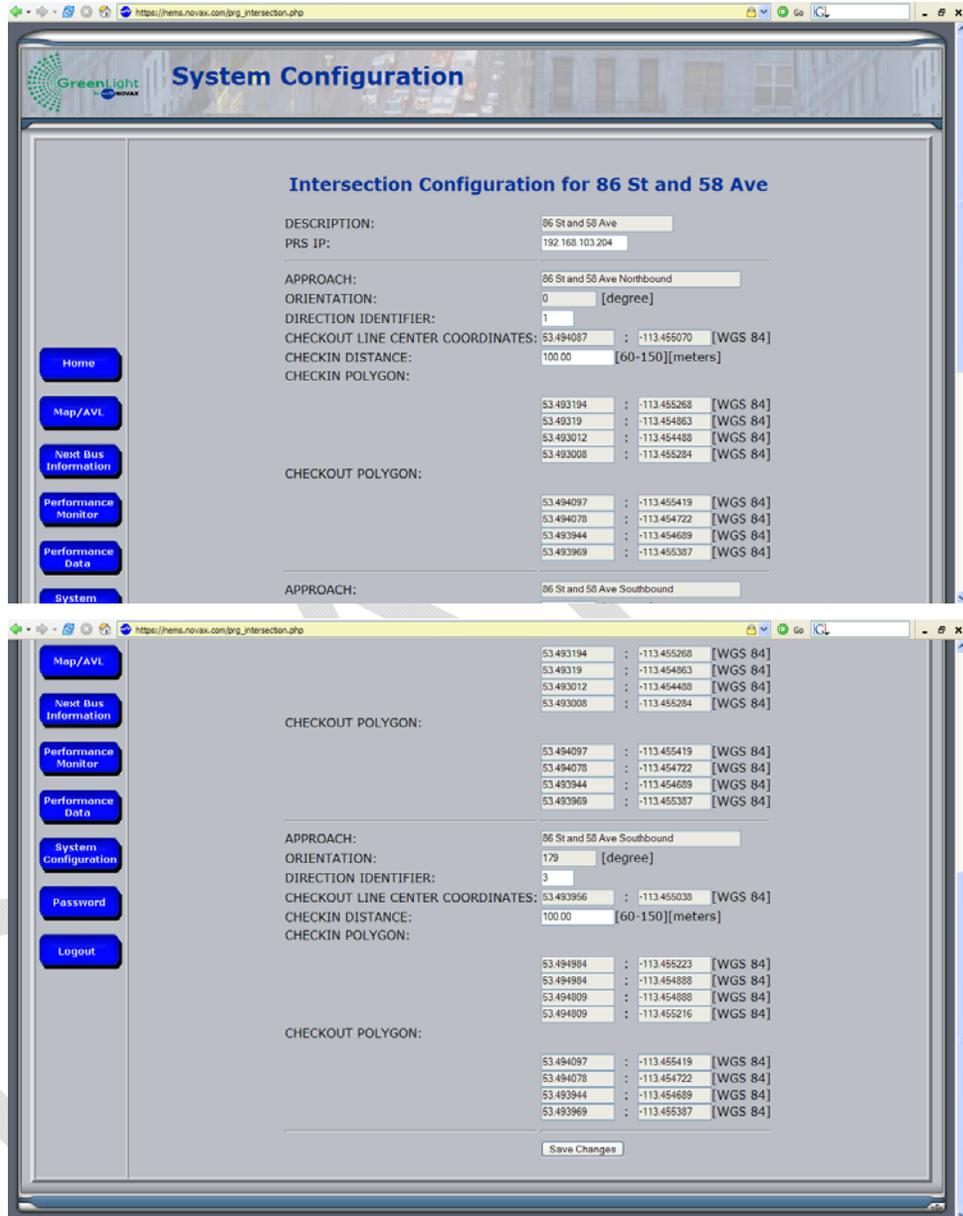
The screenshot shows a web browser window with the URL https://hems.novax.com/prg_systemconf.php. The page title is "PRG System Configuration for E4452". On the left side, there is a vertical navigation menu with buttons for "Home", "Map/AVL", "Next Bus Information", "Performance Monitor", "Performance Data", "System Configuration", "Password", and "Logout". The main content area displays various configuration parameters for the PRG system, each with a text input field and a unit indicator. The parameters are: PRG ID (E4452), Intersection Data File (/usr/share/NovaxTSP/I0006_2003.xml), Wireless Network File (/usr/share/NovaxTSP/W0006_2001.xml), SSL Port (16001 [1000-32678]), CA File (/usr/share/NovaxTSP/ca.cer), PRG Certificate (/usr/share/NovaxTSP/NovaxPRG-0003.cer), PRG key File (/usr/share/NovaxTSP/NovaxPRG-0003.key), Position Report Interval (1 [seconds]), Position Report Server IP (192.168.101.3), Position Report Server Port (16098 [1000-32678]), GPS Track Upload Server IP (192.168.101.3), GPS Track Upload Server Port (16099 [1000-32678]), Heading Margin (30 [degree]), Priority Timeout (120), SSL Session Timeout (60 [seconds]), Activation Time (15 [seconds]), Uplink Server IP (192.168.101.3), and Priority (1). At the bottom of the configuration area, there are three buttons: "Save Changes", "Cancel Changes", and "Commit Changes".

The majority of the fields are pre-configured by Novax in the Configuration and Staging process. The following fields are reconfigurable:

1. **Priority Timeout:** The maximum amount of time the priority request can be held, from the time the transit vehicle checks in, until it checks out at the intersection.
2. **Priority:** This configurable field determines whether the vehicle derives its requirement for priority from the Init CoPilot system or from a value inserted in this field. Default value = -1.

7.3 Intersection Configuration

The intersection configuration data is critical to system performance. Prior consultation with Novax is strongly recommended before any changes are made.



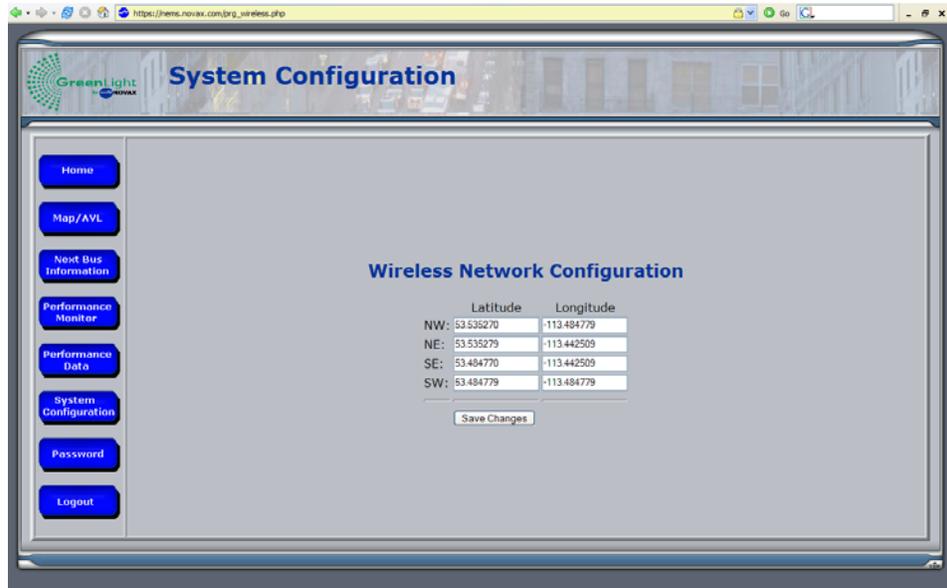
- ❑ **Check-In Distance:** the distance (in meters) from the check-in line to the Checkout line. The PRG-E establishes communication with the PRS-E at check-in and submits a priority request. The distance can be different for each intersection and can be changed if circumstances warrant. (Please refer to the above note about making changes to this screen.)

7.4 Wireless Network Configuration

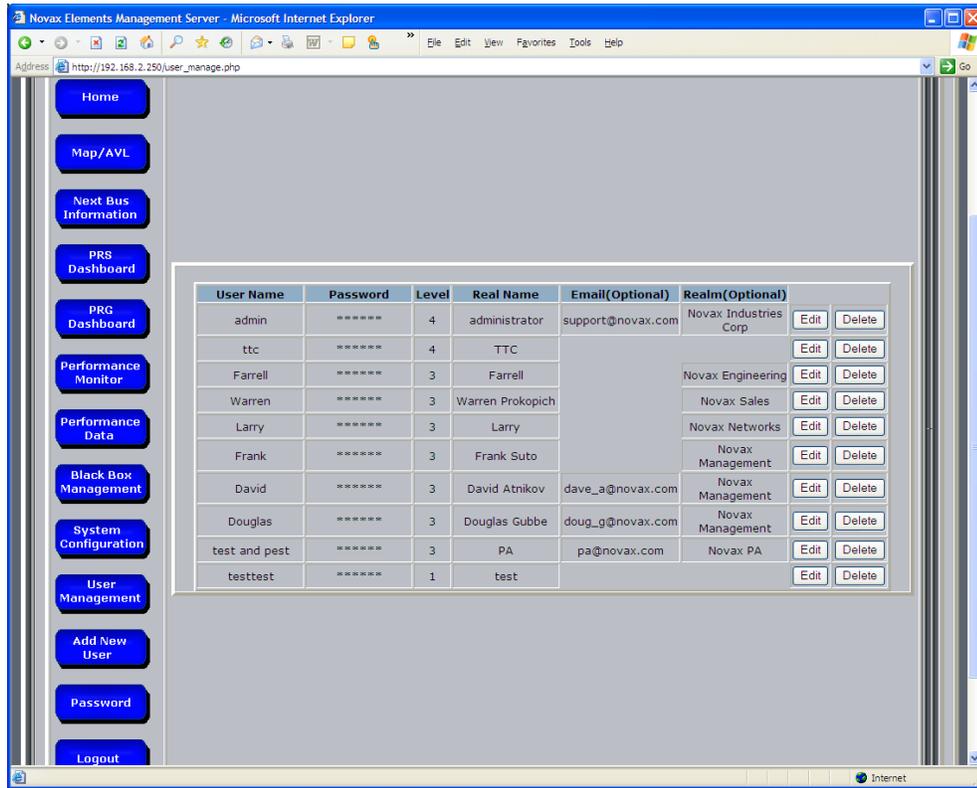
The **Wireless Network Polygon** is a set of latitude and longitude coordinates that define the wireless coverage area, for the TransPOD system.

The latitude and longitude coordinates are preconfigured by Novax, but may be reconfigured by authorized users.

Prior consultation with Novax is strongly recommended before any changes are made.

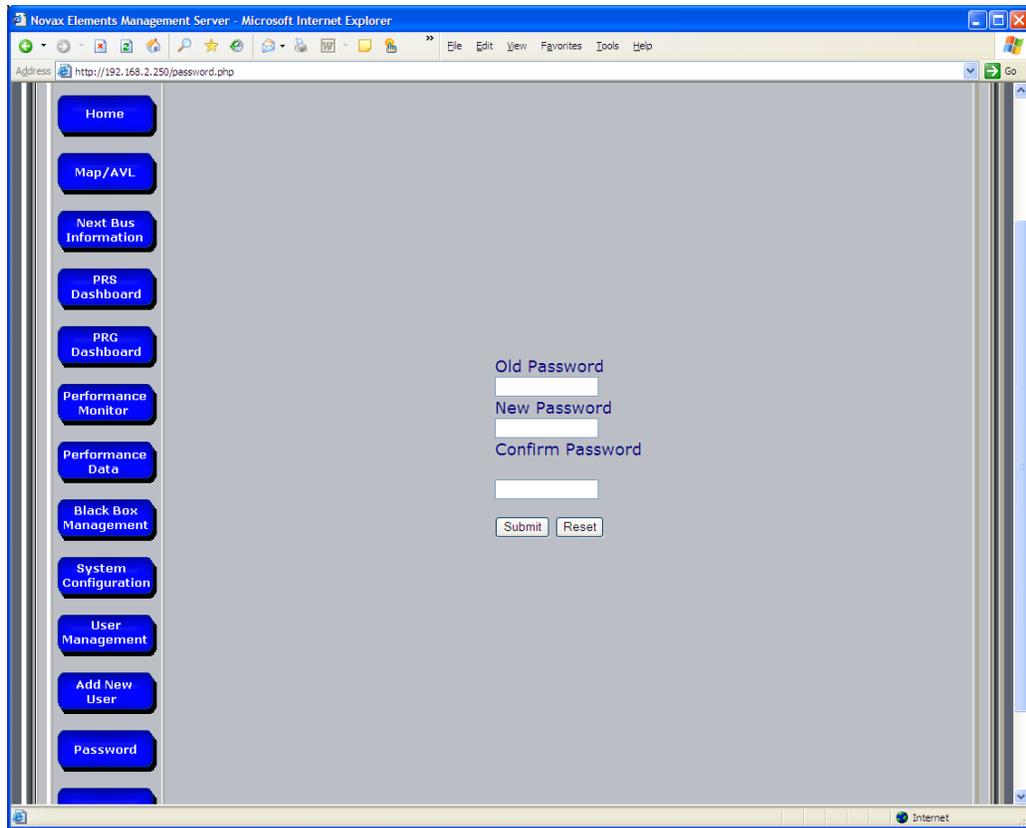


8. Account Management



This screen provides access to modify user account information. Access to this screen may only be achieved by users of a higher account level.

9. Change Password



This screen allows users to change their login password.

4.2 Tropos EMS

The Tropos EMS is comprised of Tropos Control and Tropos Insight.

4.2.1 Tropos Control

The Tropos Control EMS is a comprehensive, real-time management tool for Tropos wireless networks which provides network wide control and management and which administers and configures the mobile and fixed wireless routers used throughout the Main Street TransPOD solution. Tropos Control uses a central management station to view the status of all Tropos Wireless Mesh gateways, as well as fixed and mobile routers, modify configurations, and to assess network performance.

Tropos Control is a powerful management tool, enabling network operators to remotely perform configuration and updates of Tropos Mesh routers, whole network performance monitoring and statistical capture — including simple point-and-click graph creation, real-time link state, and client connectivity.

Tropos Control includes the following features:

- ❑ Network health check with point-and-click graphs
- ❑ Mobile node support
- ❑ Reporting of global positioning system (GPS) location data in network maps for mobile nodes
- ❑ Multiple views of network capacity and wireless link quality
- ❑ Web interface for client reports, network health, and alarm information
- ❑ Point-and-click access to configuration and security information
- ❑ Link state and client connectivity monitoring
- ❑ MAC address filtering
- ❑ Continuous alarm and event monitoring
- ❑ Automatic collection and monitoring of performance data
- ❑ Performance reporting
- ❑ Remote configuration and software updates
- ❑ Network control from a single management station
- ❑ Bulk provisioning of router configurations and security settings

4.2.2 Tropos Insight

Tropos Insight is an application that works with Tropos Control to provide advanced reports on network health as well as a comprehensive performance measurement application for network performance tuning and troubleshooting.

Numerous conditions influence mesh network performance as packets travel to and from client devices through the Tropos wireless mesh and to the wired network and beyond. A performance bottleneck in any link can result in reduced end-to-end performance as measured by client devices.

Tropos Insight takes data that is collected from each Tropos gateway and node and generates an extensive set of reports and graphs with all the information needed to isolate network performance bottlenecks down to individual links and equipment. Report generation is performed once per day at a pre-determined time (default is approximately 3am local time).

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The Tropos Insight advanced analysis and optimization tool is intended for use by network engineers and administrators who are responsible for setting up and administering Tropos wireless networks. Some familiarity with local area networking and wireless networking concepts is assumed.

These are the Tropos Insight Report Categories which describe the general report categories for executive and advanced reports.

| Category | Description |
|---|--|
| Missing Data | Number of routers that have not provided data because they are inactive or unreachable |
| Mesh Links | Number of active links that are below the set threshold. Threshold parameters for individual reports: <ul style="list-style-type: none"> • Packet success probability (PSP); values range from 0 to 1 |
| Node Throughput, Latency, Packet Loss | Measurements for assessing the ability of active routers to transmit data within the mesh. Threshold parameters for individual reports: <ul style="list-style-type: none"> • Upstream and downstream throughput (Mbps) • Noise (dBm) • Latency (ms) • Node loss (percent) • Counts |
| Backhaul Throughput, Latency, Packet Loss | Measurements for assessing the ability of active routers to transmit data to the wired network. Threshold parameters for individual reports: <ul style="list-style-type: none"> • Upstream and downstream throughput (Mbps) • Noise (dBm) • Latency (ms) • Node loss (percent) • Counts |
| Clients | Measurements for assessing the activity of associated clients. Threshold parameters for individual reports: <ul style="list-style-type: none"> • Client signal-to-noise ratio (SNR) • Bytes received by the client (RX rate) • Bytes transmitted by the client (TX rate) |

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|--------------------------------|---|
| Concurrent Subscriber Capacity | Advanced reports only. Threshold parameters for individual reports: <ul style="list-style-type: none">• Count of routers• Count of clients• Mbps |
| Automatic Channel Allocation | Record of channel changes in response to changes in ambient conditions. Threshold parameters for individual reports: <ul style="list-style-type: none">• Noise• PSP• Message• Missed Message |

For detailed information on System Commands and displays for Tropos Control and Tropos Insight, please see Appendix F.

Appendices

Appendix A – DMD drawings

Appendix B – Novax drawings

Appendix C – Tropos

Appendix D – Bus Antennas

Appendix E – Installation Guides

Appendix F – Tropos EMS

Appendix G – Mesh Network Design

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