Products description

CP560 DVB-T2 Gateway

TNS541 Seamless SFN switch

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1. Acronyms

Acronym	Interpretation
ASI	*Asynchronous Serial Interface*
BB-Frame	*Baseband Frame. (A frame with a header and payload containing a large number of TS packets. BB-Frames are used for transport of MPEG-2 TS in DVB-S2 and DVB-T2)*
DVB	*Digital Video Broadcasting*
HD	*High Definition (television)*
IP	*Internet Protocol*
MFN	*Multi Frequency Network*
M-PLP	*Multiple Physical Layer Pipes. (TDM multiplexing of multiple Transport Streams in DVB-T2)*
MPTS	*Multi Programme Transport Stream*
PCR	*Program Clock Reference. (MPEG-2 clock and time synchronisation is based on PCR)*
PLP	*Physical layer Pipes*
PSI	*Program Specific Information, ISO/IEC 13818-1 2000*
QoS	*Quality of Service*
SFN	*Single Frequency Network*
SI	*DVB System Information*
STB	*Set Top Box, home receiver decoder*
T2 (DVB-T2)	*DVB 2nd generation standard for terrestrial broadcasting*
T2-MI	*DVB-T2 Modulator Interface*
TS	*MPEG-2 Transport Stream as defined in MPEG System ISO/IEC 13818-1 2000*
TX	*Transmitter*
TXP	*T-VIPS XML configuration protocol*
XML	*Extensible Mark-up Language*

2. Executive Summary

This document describes T-VIPS' range of products for adaptation of DVB-T2 and covers mainly the DVB-T2 Modulator Interface (T2-MI) generation and adaptation Equipment DVB-T2 systems.

2.1 T-VIPS Technology Platform

T-VIPS AS is a technology company specializing in providing Intelligent Solutions for Terrestrial Broadcasting as well as for Contribution and Primary Distribution of television. T-VIPS products are used in applications such as terrestrial broadcast networks, contribution, studio-to-studio media exchange, primary distribution from play-out to transmitter, in-house signal distribution and routing, post-production, live event coverage, general video transport and primary distribution. This is illustrated in Figure 1. T-VIPS has delivered systems and products world-wide.

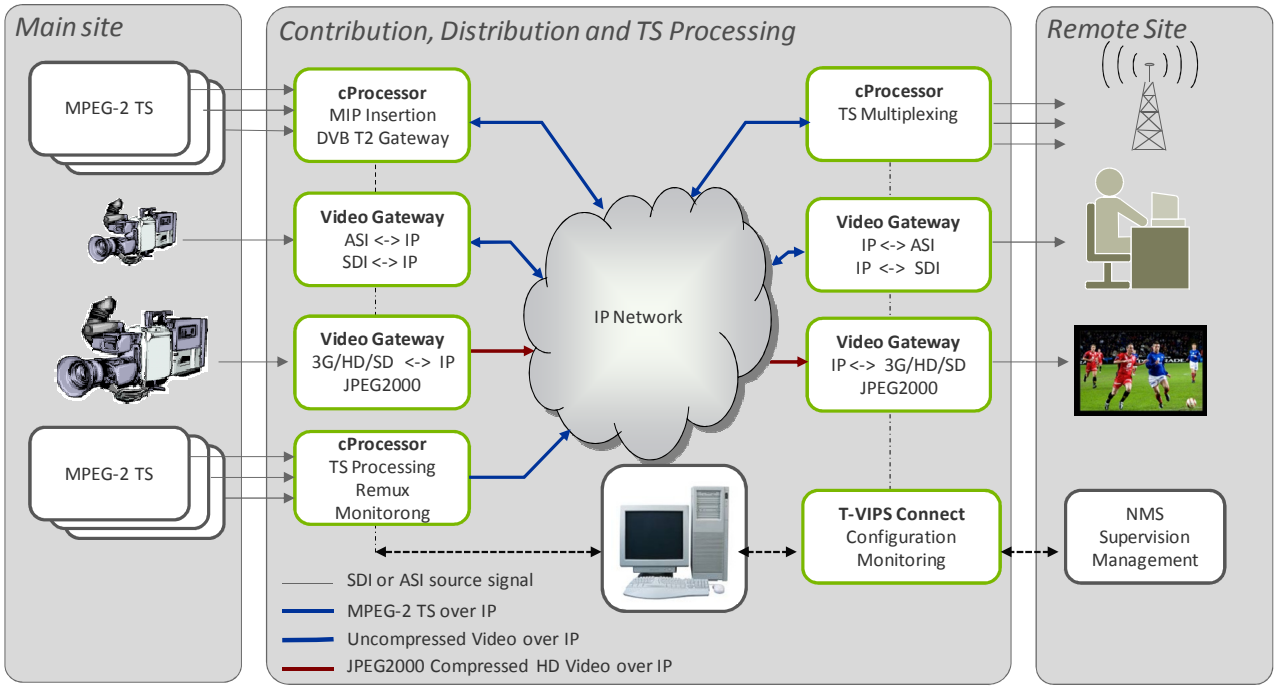


Figure 1: T-VIPS product overview for processing and transport of television.

2.2 T-VIPS Solutions for Terrestrial Broadcasting

T-VIPS has supplied system solutions for regional adaptation of the Norwegian and United Kingdom terrestrial broadcast networks that have allowed the broadcasters to maximize the payload capacity in the network, thereby providing space for additional services.

T-VIPS is a leading vendor of equipment for distribution of DVB-T over IP such as ASI-over-IP gateways, TS processors and Multiplexers currently in use worldwide.

The T-VIPS product family for MPEG-2 processing and monitoring consists of:

- CP510 TS Processor
- CP511 SFN Adaptor
- CP515 UK SI Manager
- CP525 TS Re-multiplexer
- TNS540 Monitoring TS switch
- TNS541 Seamless TS Switch
- TNS546 Multichannel TS monitor
- T-VIPS Connect Management System

Figure 2 shows an example how T-VIPS equipment can be applied in a terrestrial broadcasting chain.

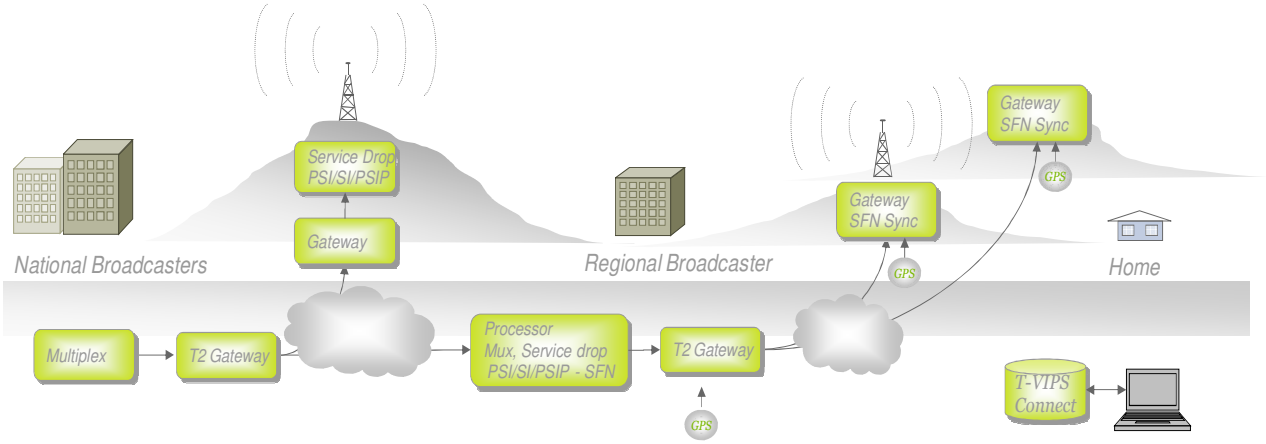


Figure 2: T-VIPS solution for terrestrial broadcast chain

2.2.1 T-VIPS Solutions for Video Transport

T-VIPS pioneered JPEG2000 encoding technology for broadcast application and delivered the first JPEG2000 contribution system in 2006 for live backhaul of hockey in Finland. Since then T-VIPS has delivered JPEG2000 solutions to a large number of broadcasters on all continents.

The benefits of JPEG2000 for contribution and primary distribution are low latency, 10 bits video resolutions, 4:2:2 sampling, no reminiscence from DCT block structure, graceful degradation at lower bit rates and no error propagation from one image to the next.

The T-VIPS product range for contribution and distribution of television over IP networks consists of:

- CP560 DVB-T2 Gateway
- TVG415 SD JPEG2000 Gateway
- TVG430 SD/HD JPEG2000 Gateway
- TVG450 3D/HD/SD JPEG2000 Gateway
- TVG480 Digital Cinema Gateway
- TVG420 ASI – IP Gateway
- TVG425 Transport Stream Gateway ASI – IP Gateway

- TVG410 SDI –IP Gateway
- T-VIPS Connect Management system

T-VIPS has specific expertise in making tailored solutions for operators in the backhaul and distribution market satisfying their requirements for QoS. T-VIPS offers high-quality and cost-effective products and solutions, with special focus on avoidance of network jitter, low latency, effective error-correction, transmission over IP, SFN Synchronization, regional adaptation of local programming and other distribution-related subjects.

For more information, please visit our website: www.t-vips.com

3. CP560 DVB-T2 Gateway

3.1 This section describes the technical features and the functionality of T-VIPS's CP560 DVB-T2 Gateway. General

The CP560 DVB-T2 Gateway provides the Baseband adaptation for DVB-T2 systems by encapsulating the incoming Transport Stream packets (input TS) into Baseband Frames (BB frames). In addition the Gateway generates the DVB-T2 time stamp frames required for SFN operation and the L1-signalling frames to control the modulators. These frames are building the DVB-T2 Modulator Interface (T2-MI) used as distribution interface to the transmission sites.

The T2-MI stream can be distributed over ASI or IP.

3.2 Mechanical Design

The unit is delivered in half-width 1 RU form factor. Two units may be mounted side by side in 1 U in 19 inch racks. The rear (connector side) of the unit is shown below. The power supply is 110/240 VAC and the power consumption is less than 35W. Alternative PSU solutions are DC power supply or dual AC supplies.

The CP560 DVB-T2 Gateway is delivered with 10 ASI ports, two Data Gb Ethernet ports, one management Ethernet port and one SFP port.

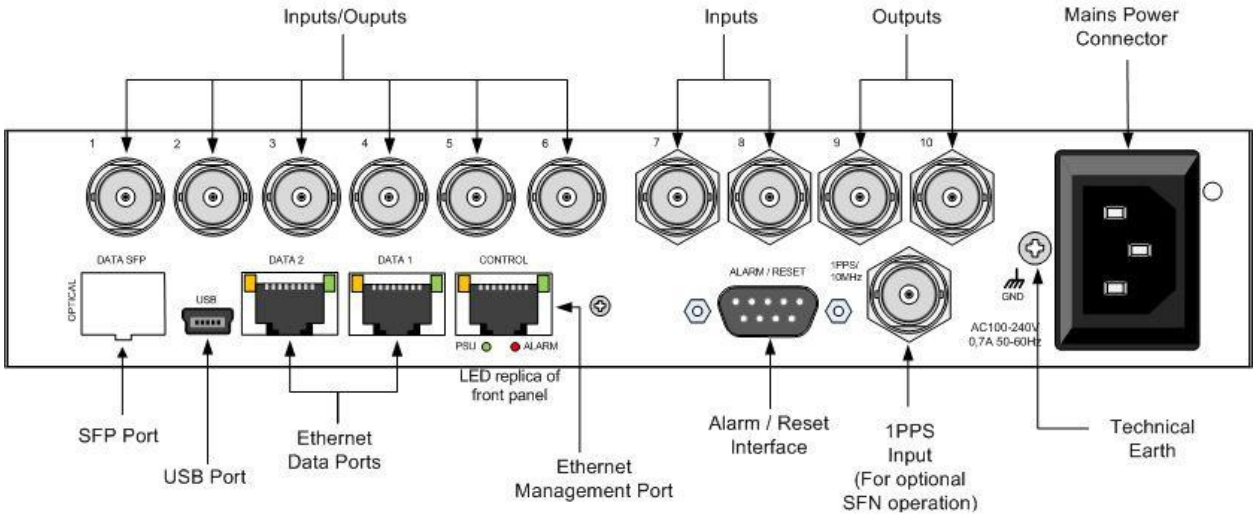


Figure 3: CP560 back panel with 10 ASI ports. In this version 2 ports are input only, 6 ports are configurable as either input or outputs and 2 as outputs only.

3.3 Main functionality

The CP560 generates the T2-MI interface used to feed, synchronize and control the modulators. This T2-MI interface is then piped into MPEG2-TS packet and distributed over ASI or IP.

The following diagram shows the main functional modules of the CP560 DVB-T2 Gateway

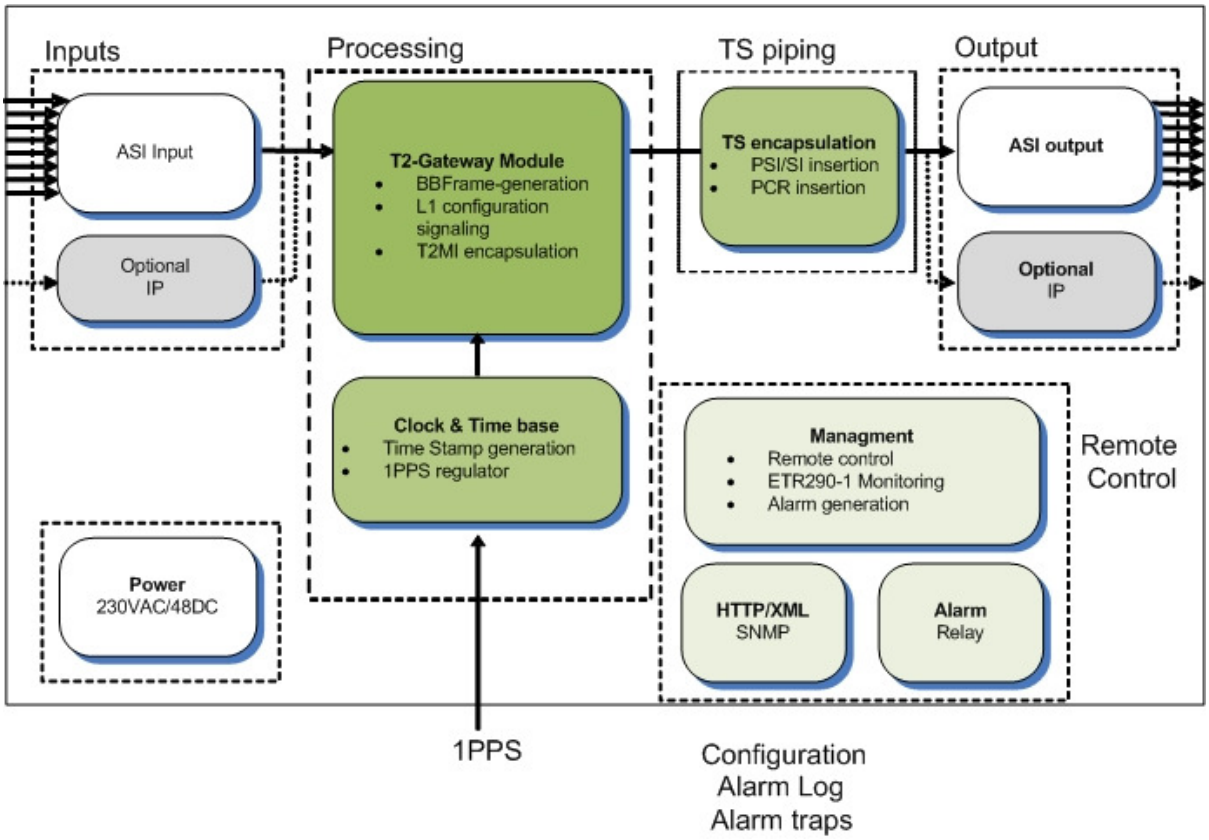


Figure 4: CP560 functional block diagram. Several modules perform the required processing for the T2-MI generation.

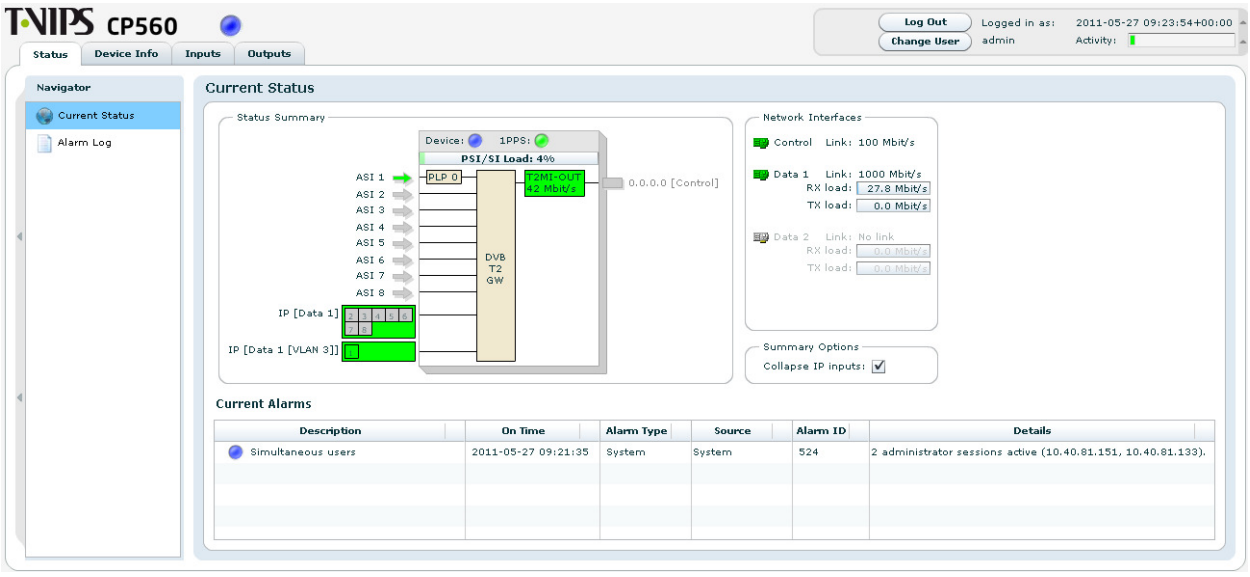


Figure 5: The CP560 User interface is based on Adobe Flash Player and can be accessed using every browser (IExplorer, Mozilla FireFox, Google Chrome, Opera …). The Main GUI shows the overall status of the unit, alarms and active interfaces.

3.3.1 Baseband adaptation

The incoming TS packets are encapsulated in Baseband frames according to the DVB-T2 operation mode. Both Normal Mode (NM) and High Efficiency Mode (HEM) are supported. To increase the bandwidth efficiency of the RF signal it is possible to use the Null Packet Deletion (NPD) feature in combination with the Input Stream Synchronizer (ISSY). This feature removes Null Packets (up to 255 per DVB-T2 frame) from the incoming MPEG2-TS. Each time a packet is removed, the Deleted Null Packets (DNP) counter is incremented and an ISSY field is inserter. This mechanism allows the receiver to reconstruct the original MPEG2-TS by inserting Null Packets at the corresponding position.

In case of Multiple Physical Layer Pipes (M-PLP) operation, the ID of the PLP containing a number of TS packets is written in the header of the BBframes. That way each BBframe can later be modulated using different schemes at the modulator.

In case off-air re-synchronization is required, the CP560 will insert DVB-T2 Modulator Information Packets (T2-MIP) into the incoming stream. Since the T2-MI time stamps are dropped at the first modulator, this measure will allow the daughter sites to synchronize on valid timing information.

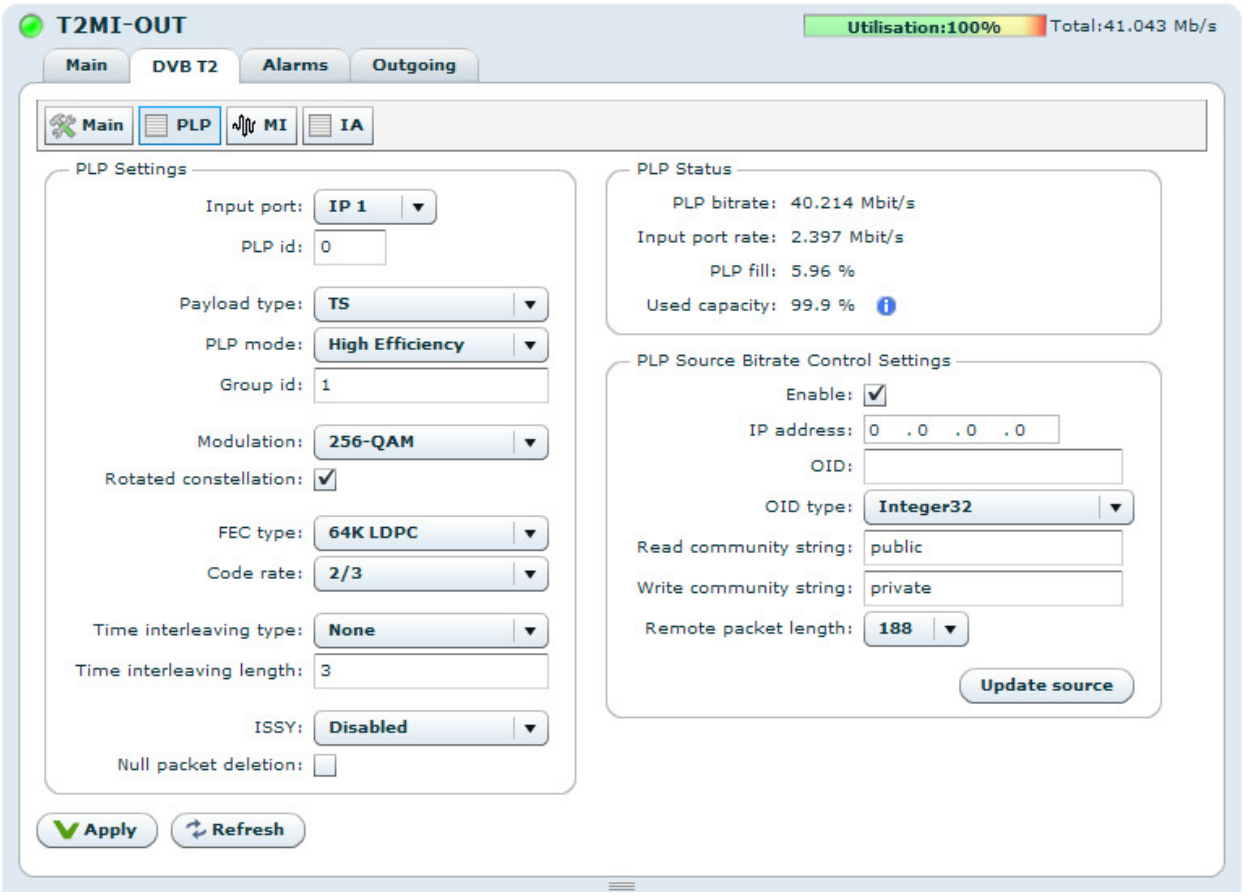


Figure 6: Single Layer Pipe (single-PLP) settings on the CP560; configuration of the modulation parameters, code rate and signal protection. The GUI shows the bit rate of the PLP on the status field. In addition the PLP fill level and used signal capacity are displayed.

3.3.2 Physical Layer Pipes

The CP560 supports both single-PLP and multi-PLP operation.

3.3.2.1 Multiple PLP (multi-PLP)

The CP560 DVB-T2 Gateway supports up to 16 Physical Layer Pipes (PLP). The adaptation is done by mapping input Transport Streams into PLPs according to a fixed one to one relationship. The implementation uses the static PLP allocation model with fixed bit rate and no de-multiplexing of the input. Accordingly to the static model, no Common PLP is used.

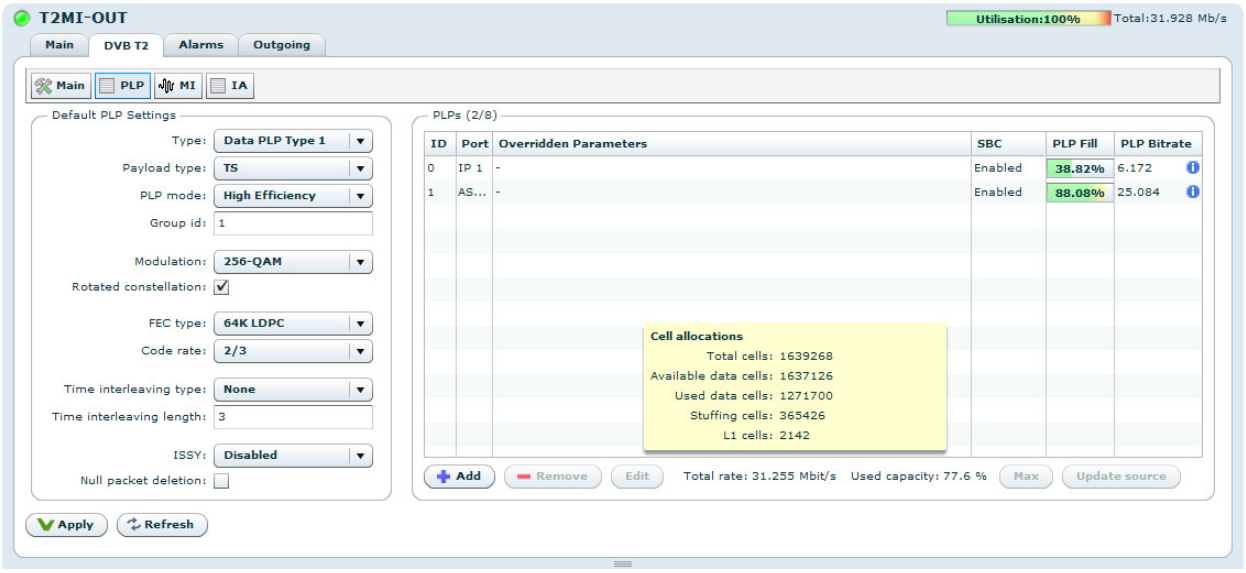


Figure 7: Multiple Physical Layer Pipe (M-PLP) settings on the CP560. Each PLP can be configured by opening the settings menu on the PLP table.

3.3.2.2 Experiences

Since the implementation of M-PLP, T-VIPS distributed this feature to several of its customers.

MediaBroadcast, the DTT network operator in Germany has deployed a test system with eight PLPs in the scope of the DVB-T2 trial project in north Germany („Modellversuch DVB-T2 in Norddeutschland“). Multi-PLP has been deployed in order to test different modulation schemes and signal protections at the same time. Using multi-PLP for testing saves the time and efforts during the network planning and design phase since the system does not need to be reconfigured for each test. Another aspect is to test and evaluate the reception diversity (in-door antenna, roof top antenna) using different modulation schemes and code rates.

The feedback from MediaBroadcast on multi-PLP for testing purposes was very positive and they highlighted the flexibility and the ease of testing. As per today, no concrete commercial plans using M-PLP have been decided.

ORS, the DTT network operator in Austria, is deploying multi-PLP in their DVB-T2 pilot project. The motivation behind the multi-PLP mode is the same as in Germany; however the number of PLPs used was limited to four. Again no concrete plans for a commercial M-PLP deployment have been communicated. The actual planning activities are focusing on the use of single PLP.

The actual commercial deployments in Europe, including Sweden (Teracom), the United Kingdom (Arqiva) and Finland (DNA), are operating in single-PLP mode. The focus was put on other features as SFN, SFN redundancy and IP distribution; however a later migration towards M-PLPs networks is not excluded.

A plausible use case for M-PLP is the use of a dedicated service PLP for set-top-boxes (STBs). A main PLP could carry the video and audio data while a very small PLP could carry software updates for the DVB-T2 set-top-boxes. Other scenarios include a hierarchical protection of the services, where customers can choose different signal robustness for their services. A third option is to use multi-PLP for a hierarchical geographical coverage of the signal. In this case a PLP with high bit rate could covers a large city or agglomeration whit HD services. A second PLP with lower bit rate but larger coverage could be transmitted in neighbouring locations as shown in the figure below.

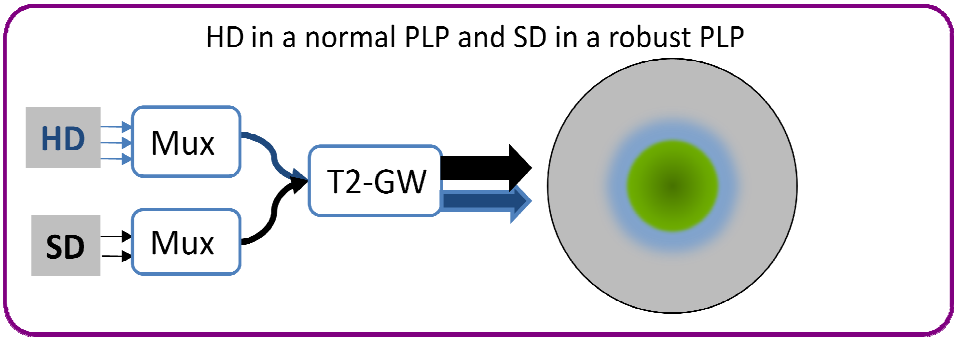


Figure 8: Hierarchical coverage using multi-PLP.

3.3.3 DVB-T2 Time Stamps generation

The CP560 generates a very accurate time stamp used for the SFN synchronization. This Timestamp includes information about:

- Signal Bandwidth
- Elapsed number of seconds since 01.01.2000
- Elapsed sub-second in the current second
- Leap seconds correction (UTCO)

The CP560 can generate both relative and absolute time stamps. In addition the CP560 offers the possibility to configure the network delay by setting the estimated transmission time in the GUI.

A feature for the management of Leap Seconds has been implemented to handle addition or removal of Leap Seconds. This feature will assure that the UTCO filed is always signalled correctly. Even in case the unit was not operating at the time of the leap Second transition.

To generate the timing information described above, the CP560 must be connect to a SNTP server (in order to calculate the absolute time since 2000) and to a 1PPS source (for the sub-seconds). The CP560 has an internal time regulator that adapts to the 1PPS pulse and adjusts the internal time of the unit accordingly. After the adaptation period (around an hour) the regulator can maintain the time of the unit after loss of 1PPS for at least 24 hours. After 24 hours the time can start to drift in microsecond range. Performed tests

showed that the SFN operation can be maintained for more than 24 hours on free run (loss of 1PPS) with modulators from different manufacturers.

As defined by the DVB-T2 specifications every DVB-T2 frame includes a time stamp. The value of the time stamps is updated for each super-frame (that might include several DVB-T2 frames).

3.3.4 L1-signalling

The CP560 generates L1-signalling frames containing the information about the signal to be generated at the modulator (RF signal). This information is configurable through the Graphical User Interface (GUI). One L1-Signalling frame is generated for each DVB-T2 Frame.

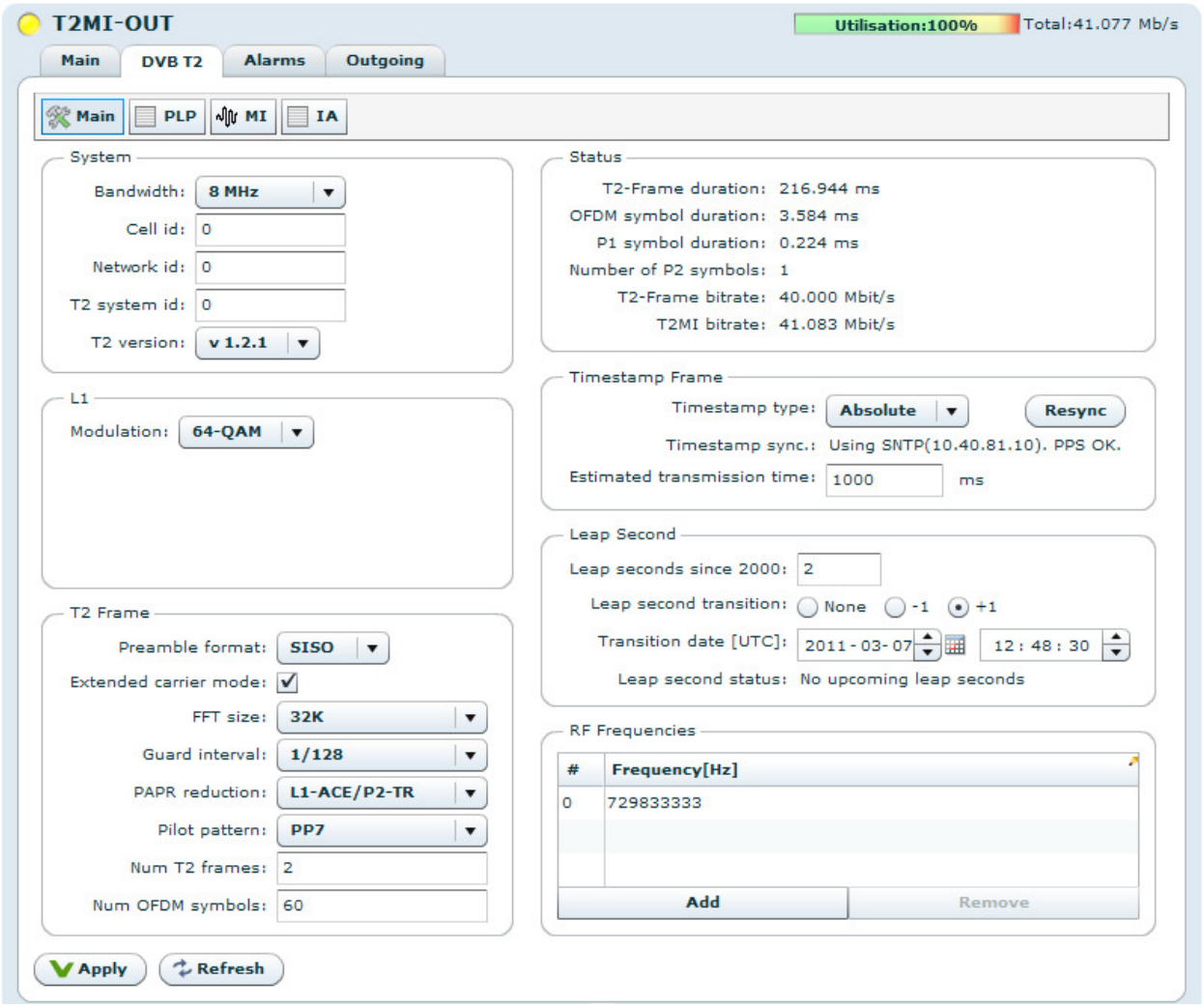


Figure 9: L1-Signalling and Time Stamp settings. The signal properties (FFT, Guard Interval, Pilot Pattern …) and Time Stamp settings (type relative/absolute, estimated delay, leap second…) can be configured on the GUI as shown above. A status field gives information about the signal (bit rate, frame length …).

3.3.5 MPEG2-TS piping

Once the T2-MI is generated, the CP560 fragments the T2-MI frames and encapsulates 184 Bytes segments in the payload of MPEG2-TS packets with the same PID. In addition simple SI information (PAT, PMT) is generated and inserted in the outgoing TS.

An optional functionality of the MPEG2-TS piping module is the insertion of PCR packets in the outer TS layer. The spacing between PCR packets and their PID are configurable. This feature can be useful for equipment that base their bit rate calculation on PCR.

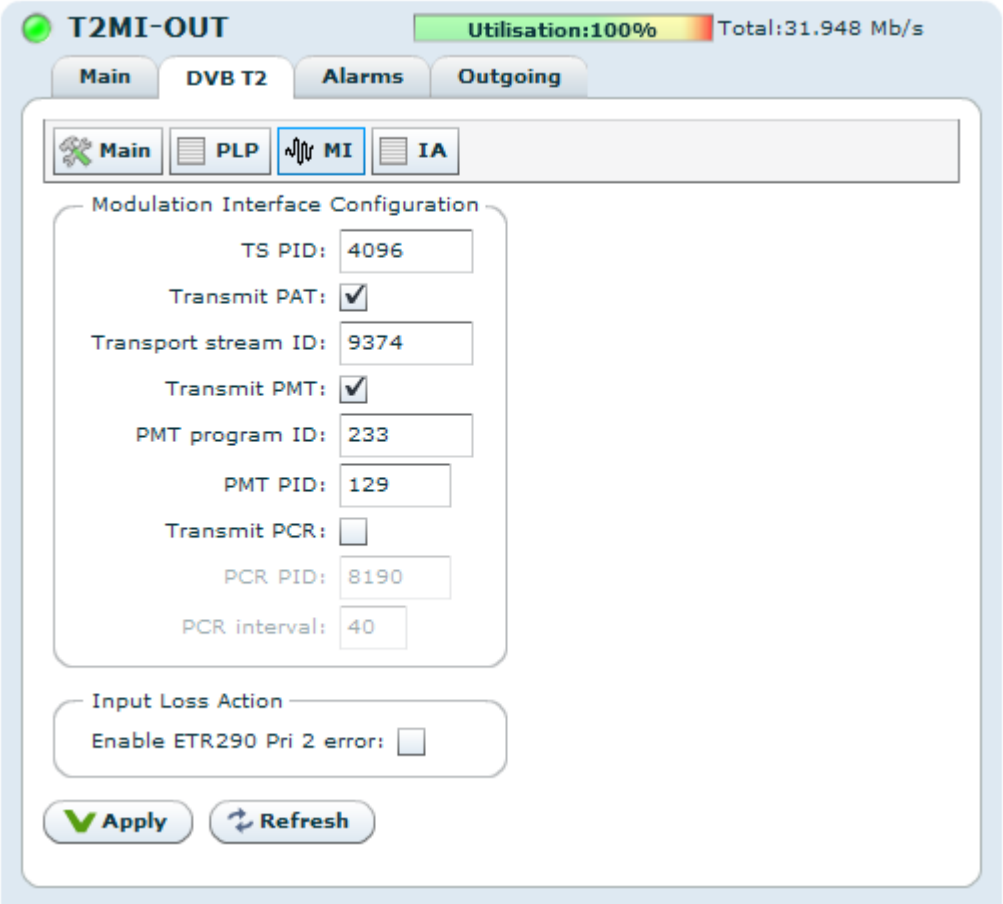


Figure 10: T2-MI stream transport layer settings. The PID carrying the T2-MI stream, the PAT and PMT can be set for the MI interface GUI. In addition PCR packets can be sent on the outer TS layer.

The following diagram shows the encapsulation layers required for the T2-MI generation

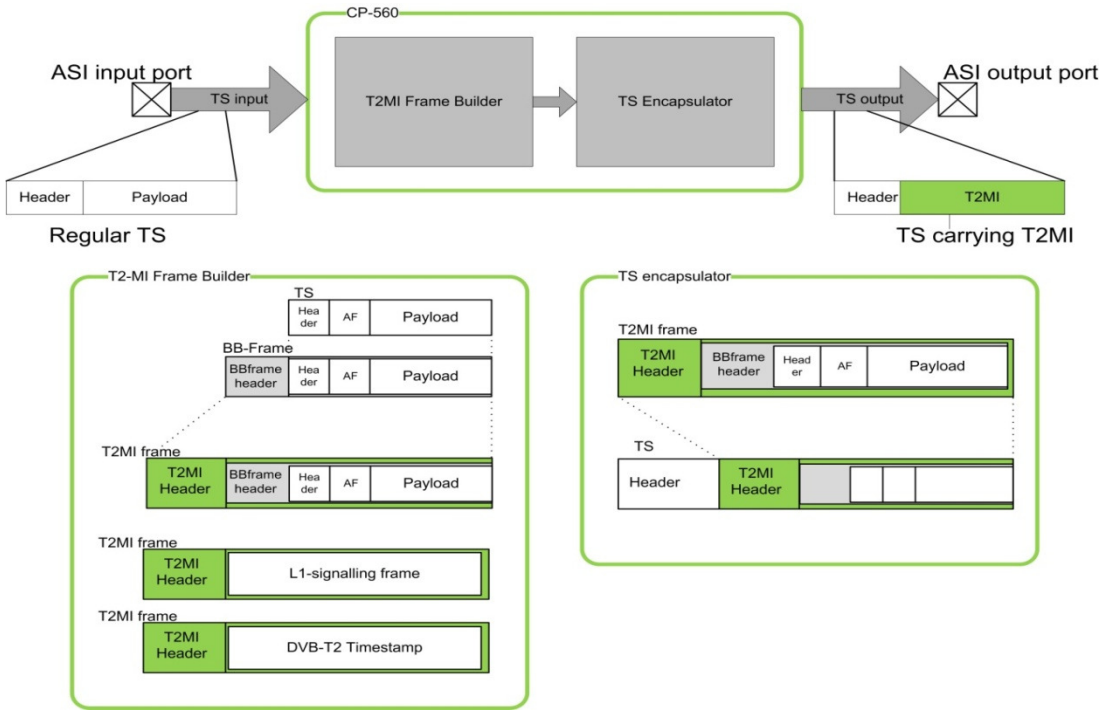


Figure 11: Transport Stream packets encapsulation into T2-MI.

3.3.6 Distribution formats

The CP560 DVB-T2 Gateway supports both ASI and IP distribution formats. Both interfaces can be used simultaneously.

3.3.6.1 ASI outputs

The CP560 has 10 BNC connectors, where the two rightmost ports are configured as output copies, the seventh and eighth ports are configured as inputs while the six remaining ports can be configured as inputs or copies of the output. For ASI both 188 and 204 Bytes are supported. Reed-Solomon FEC is used for error correction on ASI.

It is possible to set the outgoing ASI bit rate manually or to select an automatic bit rate adjustment that will transmit a saturated stream allowing bit rate saving on the T2-MI link

3.3.6.2 IP outputs

The CP560 has two electrical Ethernet physical interfaces and a SFP interface. In operation the two electrical ports can be used simultaneously, alternatively one electrical and the SFP interface can be used.

The CP560 supports up to eight IP inputs and can transmit the T2-MI on eight IP outputs as well using the same or different physical interfaces (smallcast). Both Unicast and Multicast modes are supported in addition to VLAN tagging.

For increased Quality of Service (QoS), Forward Error Correction (FEC) is implemented according to SMPTE2022-1 with a limitation of L+D <=32.

Both SMPTE2022-2 and UDP only encapsulation methods are supported.

The saturation of the IP stream is configurable; it is possible to select the number of Transport Stream packets per frame (from one to seven).

3.3.7 Bandwidth efficiency

The CP560 supports Null Packet Deletion (see clause 5.1.5 Null Packet Deletion of the DVB-T2 specifications [1]) and is able to remove null packet from the incoming Transport Stream (input). For each removed null packet the Deleted Null Packets counter (DNP) is incremented and appended to the original User Packet (TS). In addition to DNP the CP560 generates Input Stream Synchronizer (ISSY) that carries information like Input Stream Clock Reference and required buffer size for the receiver (BUFS) to reconstruct the original Transport Stream by inserting Null Packets at the correct position (see Annex C of [1]).

The CP560 is able to perform mode adaptation in Normal Mode and High Efficiency Mode (HEM) as described in clause 5.1.7 and 5.1.8 of [1] respectively. These mechanisms can increase the bandwidth efficiency of the DVB-T2 signal.

An additional feature is the optimization of the bandwidth on the T2-MI layer. The CP560 is able to reduce the necessary bandwidth on the T2-MI link by sending a saturated Transport Stream carrying the T2-MI on its output.

3.3.8 Synchronization

The CP560 uses an algorithm based on deterministic frame alignment and 1PPS to place the T2-MI time stamps in the T2-MI stream. This mechanism allows redundant units to be synchronized and send the same T2-MI time stamps at the same time. When the configuration of the two units is identical, they will generate and send identical L1-signalling frames synchronously. These measures allow the TNS541 Seamless SFN Switch to perform seamless switching on T2-MI layer (see section 4.4.3”SFN Seamless switching“).

The synchronization is software based and does not require any communication or wired connection between the CP560 Gateways, this allows each unit to operate independently.

3.3.9 Error situation

The DVB-T2 specifications require the Gateway to produce a syntactically correct stream at all time. This implies the generation of a correct T2-MI in error situation like loss of sync on the input. In this case the T2-MI will contain valid Time stamps and L1-signalling frames, but the BBframes will have valid headers and only padded payload. This might lead the modulator to generate empty T2-frames on air and thus cause black screens on the reception side for MFN, or the destruction of the signal when SFN is used.

The CP560 has a built in mechanism to signal such error and inform the TNS541 Switch by setting an ETR101 290 error flag on the outgoing TS packets on the outer layer. The TNS541 will perform a switch to the healthy source preventing the modulators from receiving invalid data.

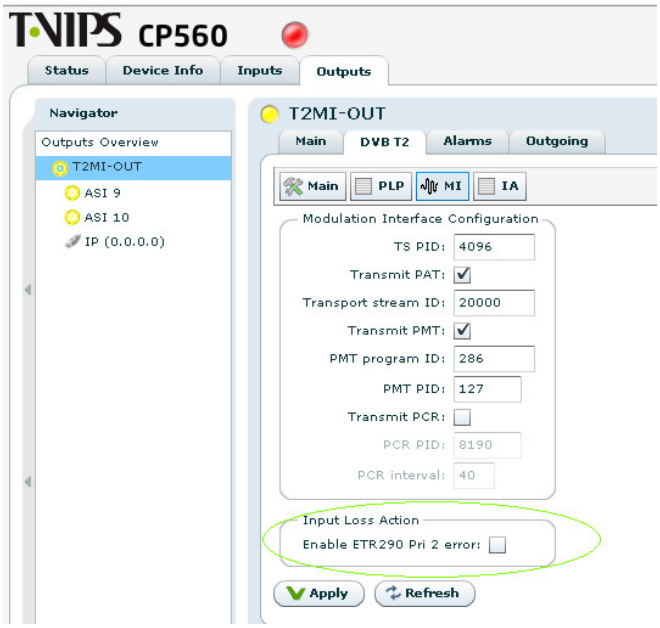


Figure 12: Transport layer settings. When enabled, the Input loss option will signal an ETR101 290 priority 2 error. This error can be then caught by the redundancy switch that will perform a switch to the healthy source.

3.4 CP560 DVB-T2 Gateway main features:

- DVB-T2-MI interface to the DVB-T2 modulators
    - L1-signalling insertion
    - SFN Time Stamp insertion

- Seamless SFN/MFN DVB-T2 switching

- Support for deterministic DVB-T2 frame alignment

- Single and Multiple Physical Layer Pipes (PLP)
    - Encapsulating the incoming Transport Stream in DVB-T2 Baseband frames
    - Null packet deletion (NPD)
    - Mapping input Transport Stream into individual PLPs

- DVB-T2 MIP packets insertion

- Transmitter signature (tx_sig) using FEF frames and AUX streams

- Individual signalling of DVB-T2 modulators
    - Multiple Input Single Output (MISO)
    - Peak to Average Power Ratio (PAPR) parameters

- ASI and IP input/output interfaces

- User-friendly configuration and control
    - WEB/XML based remote control
    - SNMP agent for easy integration with NMS systems
    - Integrated with T-VIPS Connect

3.5 Applicable standards

The CP560 DVB-T2 Gateway complies with the following applicable standards and guidelines:

- [1]: ETSI EN 302 755 v.1.2.1; Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for a second generation digital terrestrial television broadcasting system (DVB-T2).
- [2]: ETSI TS 102 773 v.1.2.1; Digital Video Broadcasting (DVB); Modulator Interface (T2-MI) for a second generation digital terrestrial television broadcasting system (DVB-T2)
- [3]: Draft ETSI TS XXX XXX; Digital Video Broadcasting (DVB); Structure and modulation of optional transmitter signatures (T2-TX-SIG) for use with the DVB-T2 second generation digital terrestrial television broadcasting system

Note: The T2-TX-SIG specification is not yet published by DVB, but is in a very mature stage and is also expected to become an ETSI standard. T-VIPS is aiming at implementing the latest and most useful features for its customers tries therefore to fulfil the requirements of the latest DVB specification version, even if it is not yet formally approved as an ETSI standard.

- [4]: CENELEC EN 50083-9; Cabled distribution systems for television sound and interactive multimedia signals; Part 9 Interfaces for CATV/SMATV head-ends and similar professional equipment (ASI).
- [5]: ETSI TR 101 290 v1.2.1; Measurement guidelines for DVB systems.
- [6]: IEEE 802.3-2005 1000 Mbps Ethernet port (GigaBit Ethernet/GbE) port (especially 1000Base-TX)
- [7]: IEEE 802.3-2005 100 Mbps Ethernet port (Fast Ethernet) port (especially 100Base-TX)
- [8]: IETF Simple Network Management Protocol (SNMP) version 1 and 2 (SNMPv1 RFC1155 – RFC1157 and RFC1213, SNMPv2 RFC1441 – RFC1452)
- [9]: IETF NTPv4 (Network Time Protocol version 4) and SNTPv4 (Simple Network Time Protocol version 4) for synchronising local time to distributed UTC over IP according with RFC 4330.
- [10]: Adaptation of MPEG2 TS to IP/Ethernet and belonging FEC in accordance with MPEG Pro Forum Code of Practice #3 and SCTE 2022.
- [11]: RFC-2616 Hypertext Transfer Protocol -- HTTP/1.1 or later

3.5.1 Latest experience

The CP560 includes the results of the latest experience in field (commercial deployment and trials) and is subject to continuous enhancements and improvements. All the new implementations, including new features and enhancements, will be communicated to customers with the appropriate documentation. The result of the implementations will be provided via a software update.

4. TNS541 Seamless SFN Switch

4.1 General

The TNS541 Seamless SFN switch provides efficient real-time monitoring and capability to switch between two ASI Transport Streams with dedicated HW designed to operate in a broadcast environment. The product is a powerful tool for redundancy handling and continuous extensive monitoring of video and audio services in live transport streams with PID and PSI/SI/SI table analysis.

In an increasingly complex broadcast infrastructure, the TNS541 provides an essential tool for error detection and switching with fast diagnostics of erroneous signals.

The TNS541 unit is delivered with two switches in a 1RU, where one switch is active by default. To enable the second switch a software license key is required. There are two ASI input ports per switch. The unit provides one secured ASI output port per switch that always provides an output signal even in case of power loss. In addition each switch provides two configurable active monitoring outputs.

4.2 Versions

The TNS541 unit is always delivered with two physical switches and can be operated in three different modes. The operational modes of the switch are controlled by software license keys.

4.2.1 Single Switch

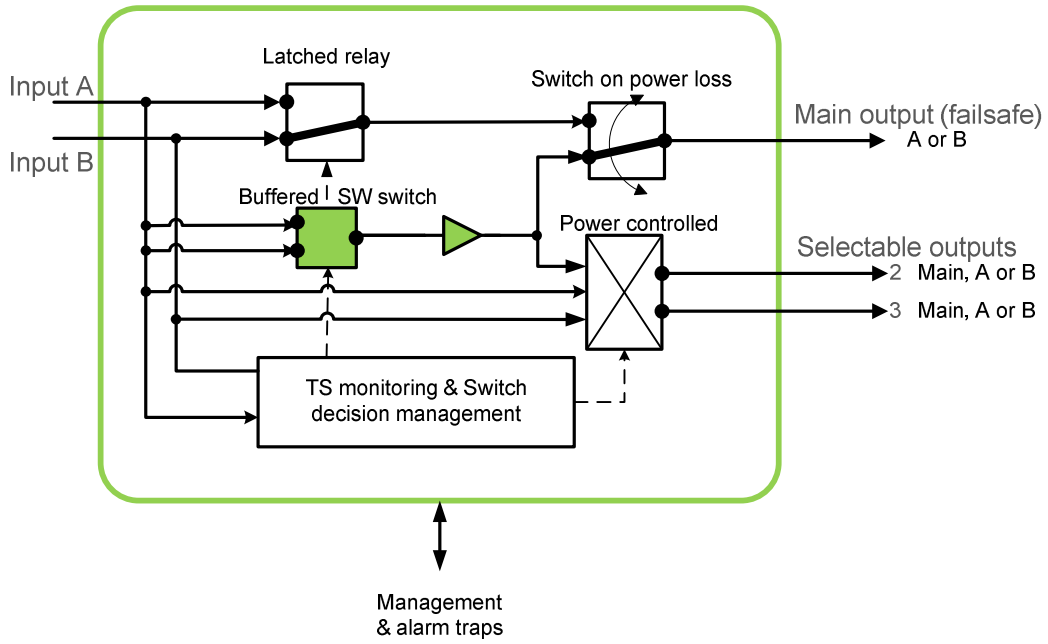


Figure 13: Block diagram of the TNS541 single switch. In active mode (power up) the switch performs TS analysis and streams matching to decide on the best source. In passive mode (configured setting or power failure) a galvanic relay will bypass the last selected input and transmit correct TS.

This is the basic version of the TNS541 operating a single switch. This version can assure redundancy between two identical MPEG2-Transport Streams. These streams may be time shifted. It offers one secured output, operational even on power loss, and two configurable outputs.

Figure 14 Shows the main user interface of the single switch version of the TNS541

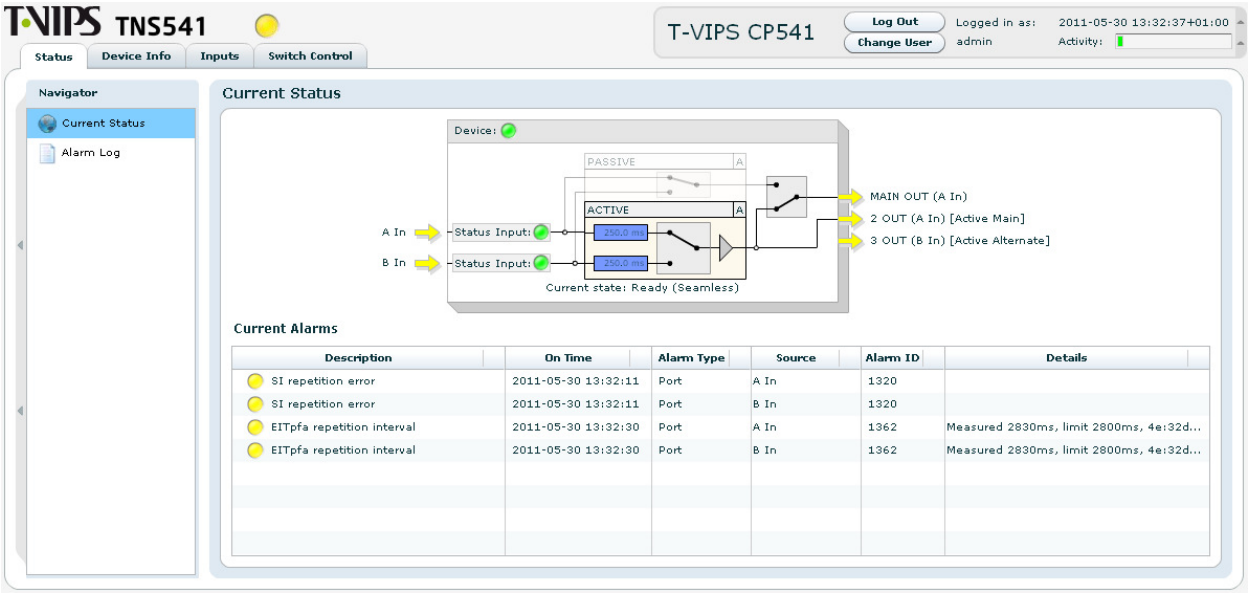


Figure 14: Main GUI of the TNS541 single switch. Alarms, buffer size and switch position are displayed. The coloured LEDs are status LEDs showing the status of each module of the TNS541.

4.2.2 Dual Switch

After unlocking the second switch with a license key, the TNS541 can operate two individual switches. These two switches operate independently. This operational mode can ensure the redundancy between two pairs of Transport Streams. Each switch has a secured output and two configurable outputs.

This variant can be used to monitor and switch between main and spare streams of two multiplexes.

Figure 15 shows the block diagram of the TNS541 in the dual switch version.

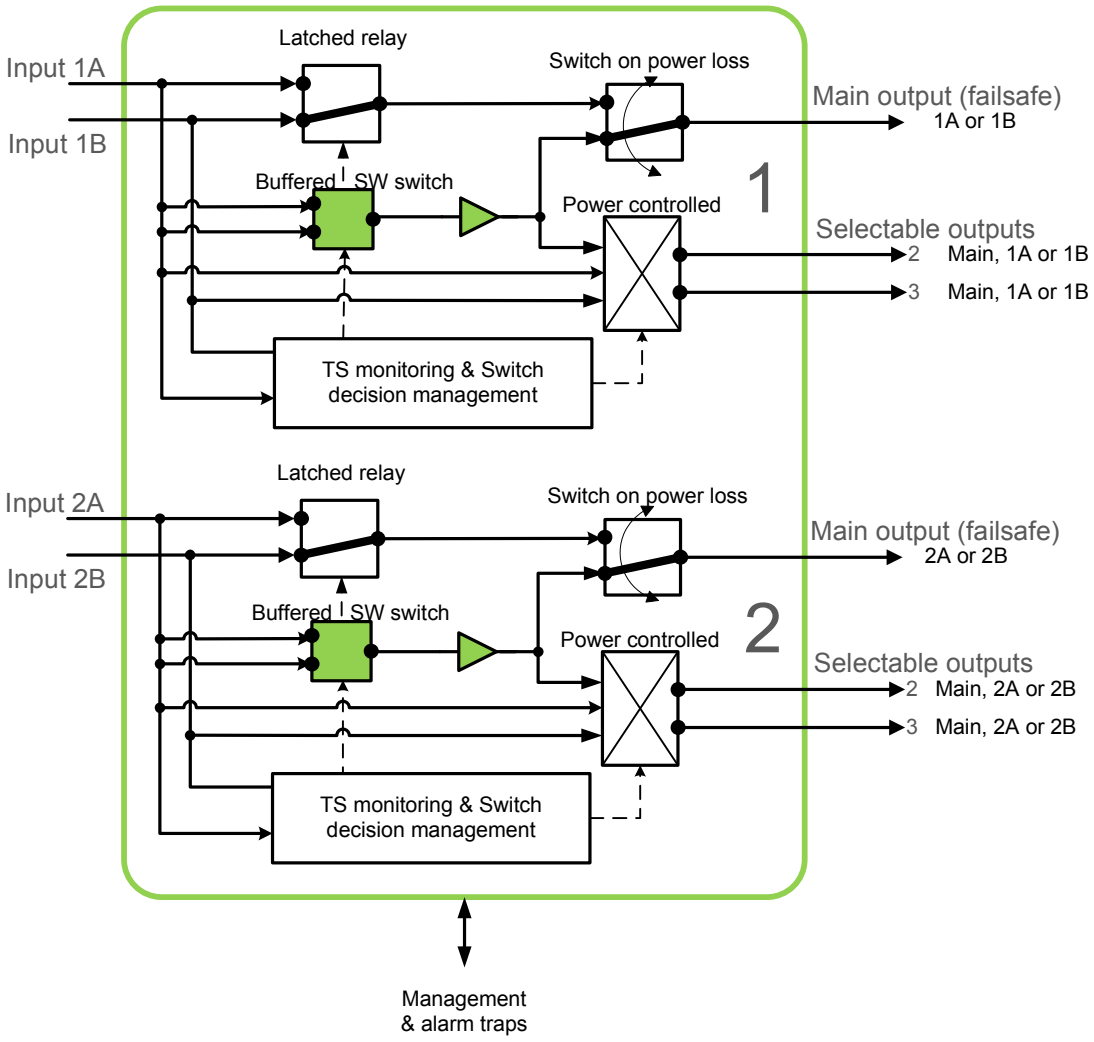


Figure 15: Block diagram of the TNS541 dual switch. In active mode (power up) each switch performs TS analysis and streams matching to decide on the best source. In passive mode (configured setting or power failure) a galvanic relay in each switch will bypass the last selected input and transmit correct TS.

In dual mode, each switch can be operated and monitored individually. The two switches will have their own alarm management, traps and switching criteria.

Figure 16 shows the main GUI for the TNS541 dual switch.

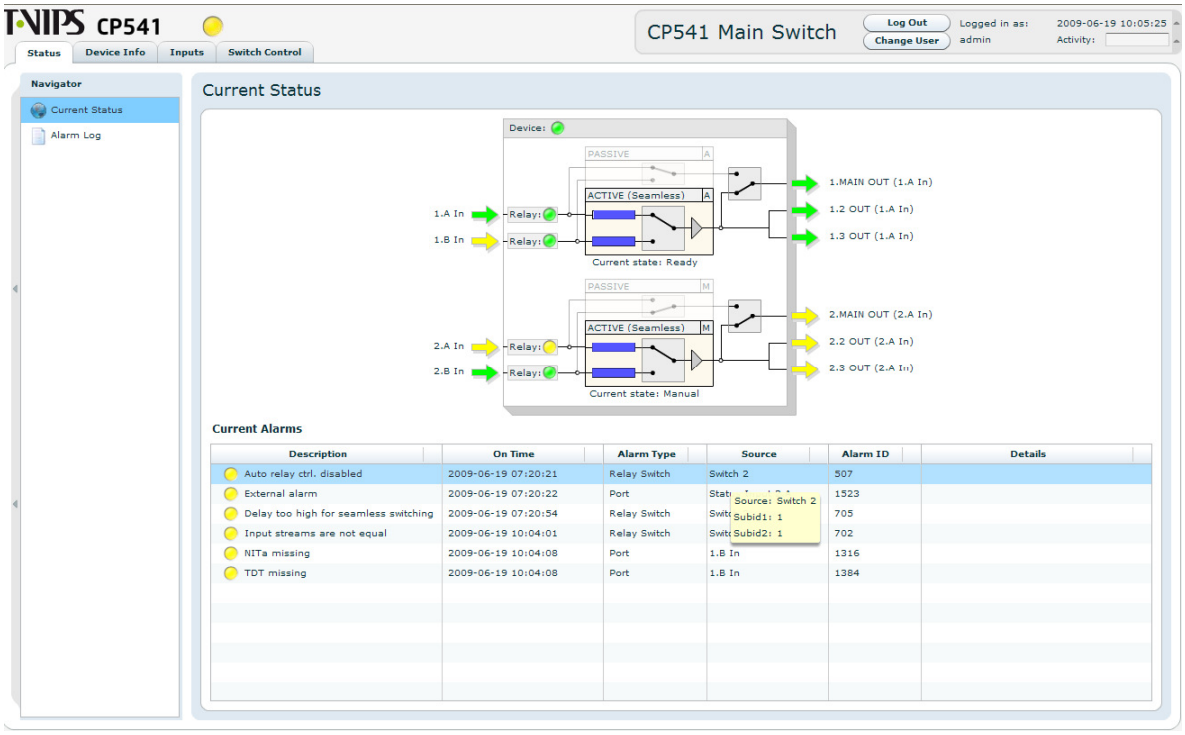


Figure 16: Main GUI of the TNS541 dual switch.

4.2.3 Ganged Switch

The ganged switch version of the TNS541 offers a master-slave operation, where one switch monitors and makes the switching decision. The second (slave) switch only monitors the input streams and follows the position of the first switch.

This version of the TNS541 is recommended in case a total 1+1 redundancy of the system is wished. It guarantees that the secured outputs of both switches carry **the identical signal at all time**, even on power loss. This solution is deployed in several commercial projects in Europe.

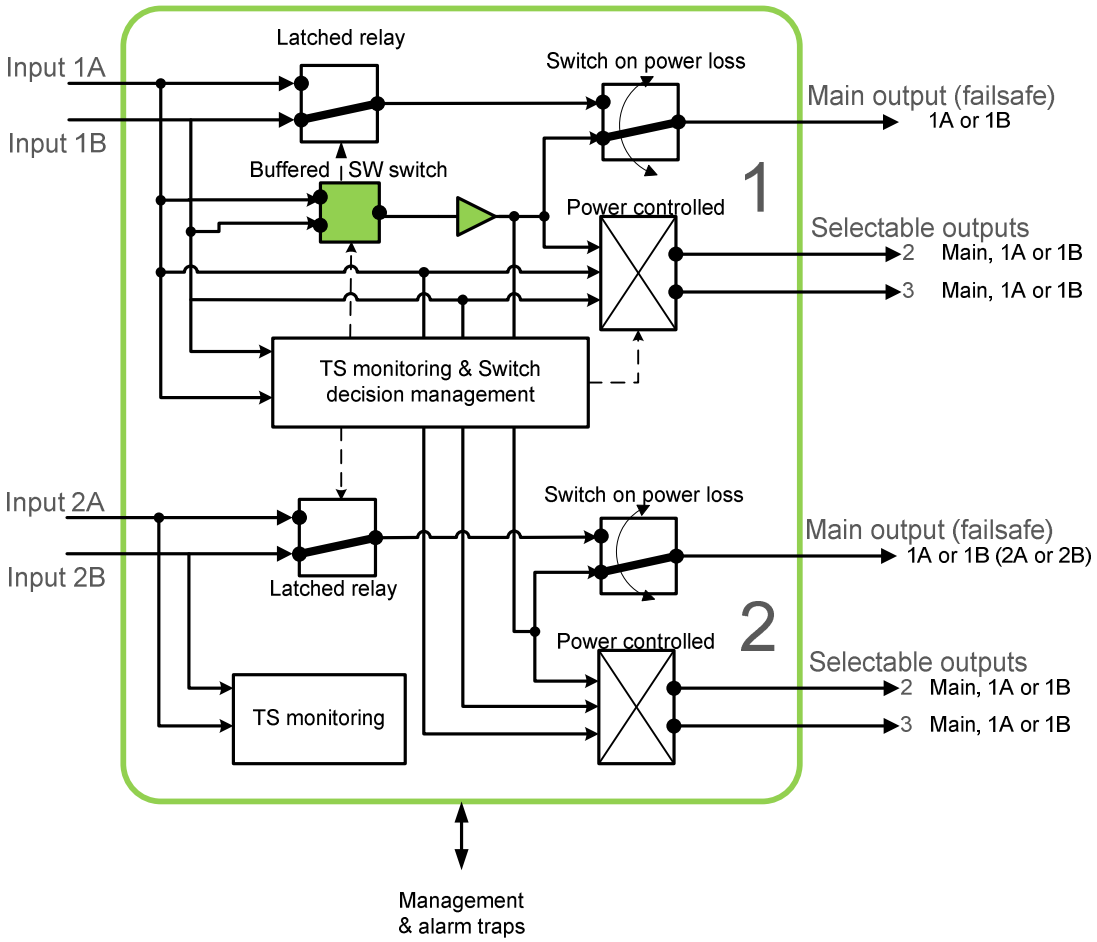


Figure 17: TNS541 ganged switch block diagram. The second switch follows the first one and has the same position as the master switch at all time.

The Ganged switch is operated a single switch as shown on the user's interface below.

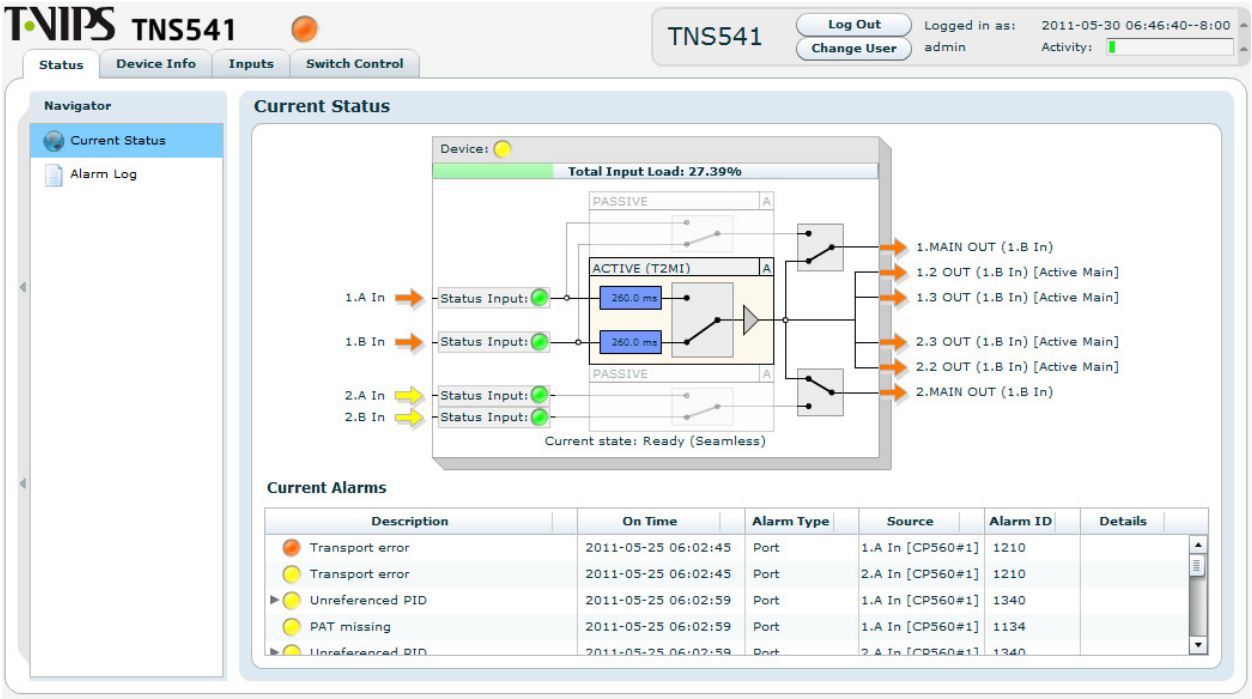


Figure 18: Main GUI of the TNS541 ganged switch.

4.3 Mechanical Design

The unit is housed in a full-width 1 RU enclosure. It is equipped with dual power supplies with load sharing under normal operation. The state of each power supply is continuously supervised and an alarm is raised in case of failure in one of the power supplies. Figure 19 shows a rear panel view of the dual switch TNS541. The TNS541 may be configured as a single 2x1 switch or a dual 2x1 switch. The switches are independent. Each switch has 2 ASI inputs and 3 ASI outputs. 1 ASI output is protected by a relay which will make a passive connection to the current selected input in case of power loss. Alternatively it may be set to a select either input A or input B. The 2 active outputs are configurable to A, B or copy of main or the alternative input. TNS541 has also two pairs of alarm inputs that may be connected to external devices. The power consumption of the unit is below 35W.

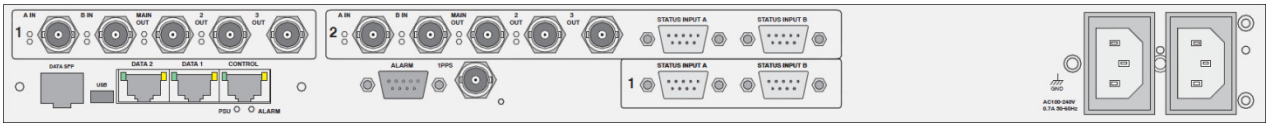


Figure 19: TNS541 rear. Each switch has two inputs, a secured output and two configurable outputs. The unit has an Ethernet control interface, two Ethernet interfaces (not in use), a SFP interface (not in use), a USB port, an alarm relay port (dry loop), a 1PPS port (not in use) and status inputs for each input. On the right side are the connectors for the dual power supply.

4.4 Redundancy Switching

TNS541 provides three operational modes:

- TS Seamless switching
- Packet aligned switching
- SFN seamless switching

These modes allow the TNS541 to behave according to the network's needs and offer more flexibility.

4.4.1 TS Seamless switching

In seamless mode the TNS541 will buffer and synchronize two identical input streams and there will be no break in the output stream in case of switching. The TNS541 can handle 1 to 12 seconds of difference in delay between Input A and Input B, depending on the input bit rate. This means e.g. that it can handle redundancy switching between two signals; one arriving via satellite and the other arriving via an IP or a fibre optic network.

In order for the seamless mode to work flawlessly the two Transport Streams have to be identical in content and in packet order. If one of the Transport Streams at some stage has been reordered, e.g. by passing through a multiplexer, some artefacts may be visible, but there will be no ASI sync loss.

4.4.2 Packet aligned switching

In this mode the TNS541 does not align the input streams and perform a switch at the TS packet boundary (at the end of a packet). This means that in contrast to a regular ASI switch, a TS packet will not be cut or interrupted, however the result of the switching is not seamless.

4.4.3 SFN Seamless switching

This mode has been developed to ensure the flawless switching between streams carrying SFN information, as MIP packet for DVB-T or T2-MI time stamps for DVB-T2. These DVB-T MIP and T2-MI time stamps are used to align and evaluate the matching of the streams.

In MIP (DVB-T) matching mode the TNS541 will align the input stream by parsing and evaluating the MIP packets. This mode requires that MIP analysis is enabled; the TNS541 will automatically enable MIP analysis if not already enabled. The MIP packets are automatically detected and parsed and no specific setting configuration is required. The MIP alignment works for identical inputs with different delays. The MIP alignment also works if two different T-VIPS CP511 SFN Adapters are connected to each input, given they are both synchronized to the same SNTP server and 1PPS reference.

In T2-MI matching mode the TNS541 aligns the input streams by looking at the time stamps of the TS packets carrying DVB-T2 time stamps. This requires that the T2-MI PID is set by the user, and that this PID contains a valid T2-MI stream. This T2-MI PID has to be set manually since this same PID encapsulating the T2-MI can be set manually on the CP560 DVB-T2 Gateway (see setting on **Figure 10**). As for the MIP mode, The T2-MI alignment works for identical inputs with same or different delays. The T2-MI alignment also works if two different T-VIPS CP560 DVB-T2 Gateways are connected to each input, given they are both synchronized to the same SNTP server and 1PPS reference.

The TNS541 Seamless SFN Switch aligns the two T2-MI streams coming from the Gateways and runs a matching algorithm between these streams. The TNS541 will select the best stream as active source and transmit it on its outputs. The switch continuously analyzes the streams and assures the continuity and

order of the DVB-T2 time stamp Frames. When a switch is performed the order and continuity of the SFN information (time stamps) is not interrupted nor duplicated. The modulators will receive the next time stamp frame as expected. This measure avoids the modulators from loosing lock to the time stamp frames and prevents a re-synchronization that will cause a considerable loss of service.

Monitoring of the streams coming from the DVB-T2 Gateways, allows the TNS541 to detect a distortion of the streams and perform a switch to the “healthier” source. As mentioned in section 3.3.9, the DVB-T2 specifications require the Gateways to produce a syntactically correct stream at its output at all time. If one of the Gateways looses synch on its input, it will still produce a clean T2-MI stream containing null packets This will prevent the modulators from loosing synch, but will lead to a signal carrying null packets only and thus to a loss of SFN and black screen on the reception side. The TNS541 is able to detect such failure (loss of input on the CP560) and perform a switch to the redundant source and transmit the stream containing valid data.

The TNS541 can be seen as an active unit that always generates a valid T2-MI stream containing continuous and correct time stamps, signalling consistent signalling information and valid payload data.

4.5 Management Interface

The management sub-system consists of several modules that supervise all the interfaces to monitor and control the operation of the TNS541.

The management sub-system communicates with the users, either humans or machines, via the following interfaces:

- Front panel and back panel LEDs for status
- Graphical user interface (using Flash player) on WEB browser
- SNMP traps on alarms
- SNMPv2c Agent
- Alarm relays on alarms
- SNTP client for real time clock synchronization
- FTP server for direct file system access

4.5.1 Graphical User Interface

Human operators monitor and control the TNS541 mainly via the Adobe Flash GUI application served from the embedded web-server. The GUI application can be accessed with a WEB browser and communicates with the configuration framework via an HTTP/XML based protocol.

A comprehensive set of status information is extracted from the device and made available for system monitoring.

The user interface can be used to control all device parameters. It also allows partial or complete configuration files to be extracted and loaded.

An example of a graphical user interface page Shown in Figure 18 displays the “Current status” page. This provides the current status of the device in the form of a functional diagram and a list of current alarms with severity indication.

4.5.2 Control of Redundancy Switching

There are two mechanisms for redundancy switching:

- Automatic redundancy switching based on configured switching criteria.
- Manual redundancy switching (operator controlled)

When automatic redundancy switching is selected the user can choose to switch on a certain alarm state e.g. critical alarm on the active input. The alarm level of an event is configurable according to the ITU-T X.733 specification.

Alarms from external devices may also be used to control changeover by connecting the alarm outputs to the TNS541 external alarm input. If included in the switching criteria an alarm from an external device may trigger a changeover. Alternatively the external alarm can be wired to a remote control panel. Figure 20 shows the user interface for configuring redundancy switching.

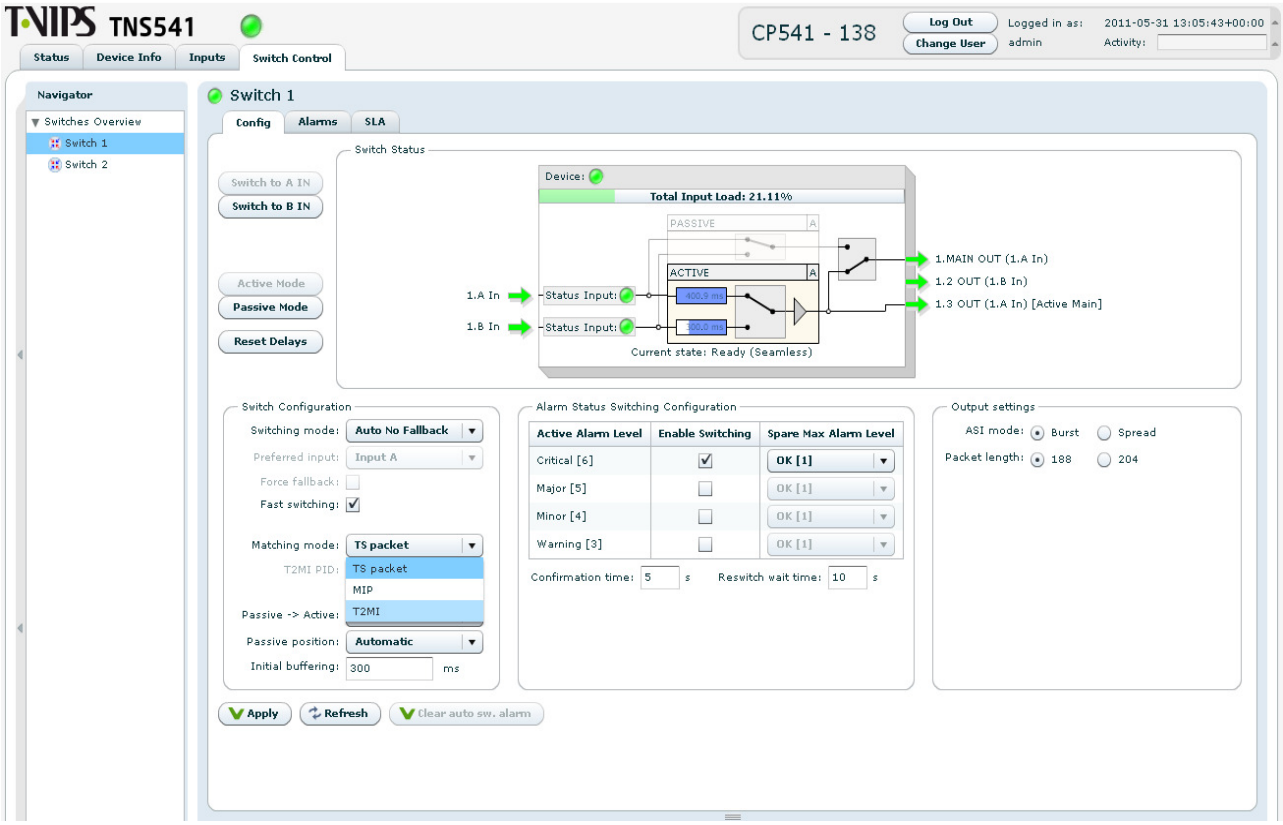


Figure 20: Redundancy switching control. The switching mode can be selected between TS packets, DVB-T MIP and T2-MI frames.

Figure 21 shows the configuration of an alarm level for specific events. This could e.g. be a triggering event for switching action.

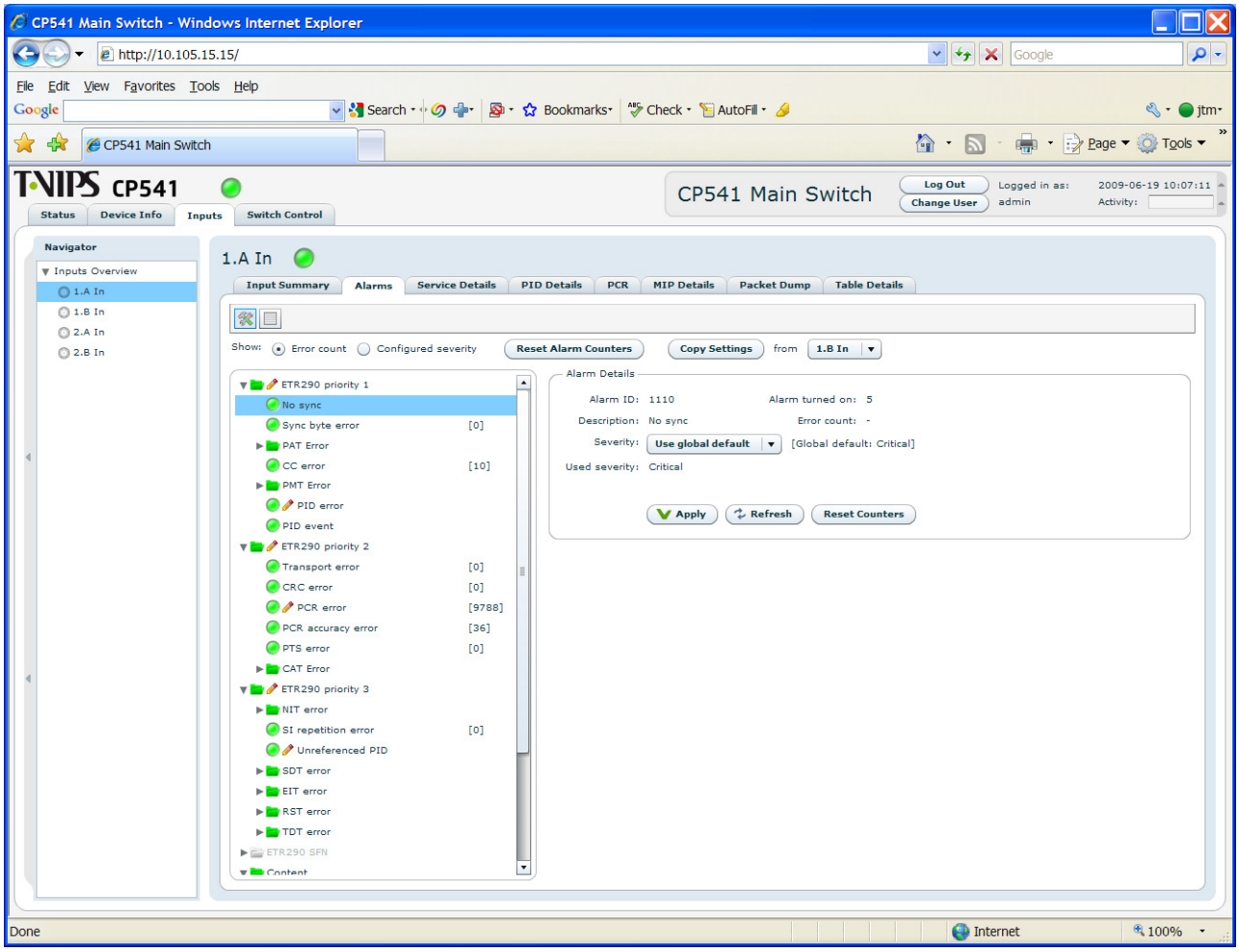


Figure 21: Alarm severity level configuration. Each event has a default severity level that can be overridden to suit the requirements of the network.

4.5.3 Alarm Handling

The TNS541 has a well integrated alarm manager ensuring that the current alarm status is displayed consistently in the various interfaces.

The user can override the default severity level of every single alarm to match his system environment as indicated in Figure 21

A large number of alarms is available to give system feed-back. The “Device Alarms” are not tied directly to any port but are classified as System alarms.

The above classification is reflected in the GUI pages for alarm configuration. The alarms are presented in a tree structure, where status and configuration is combined. Every port has its own alarm tree. The units alarms are represented in an individual tree under “Device Info” describing the system alarms.

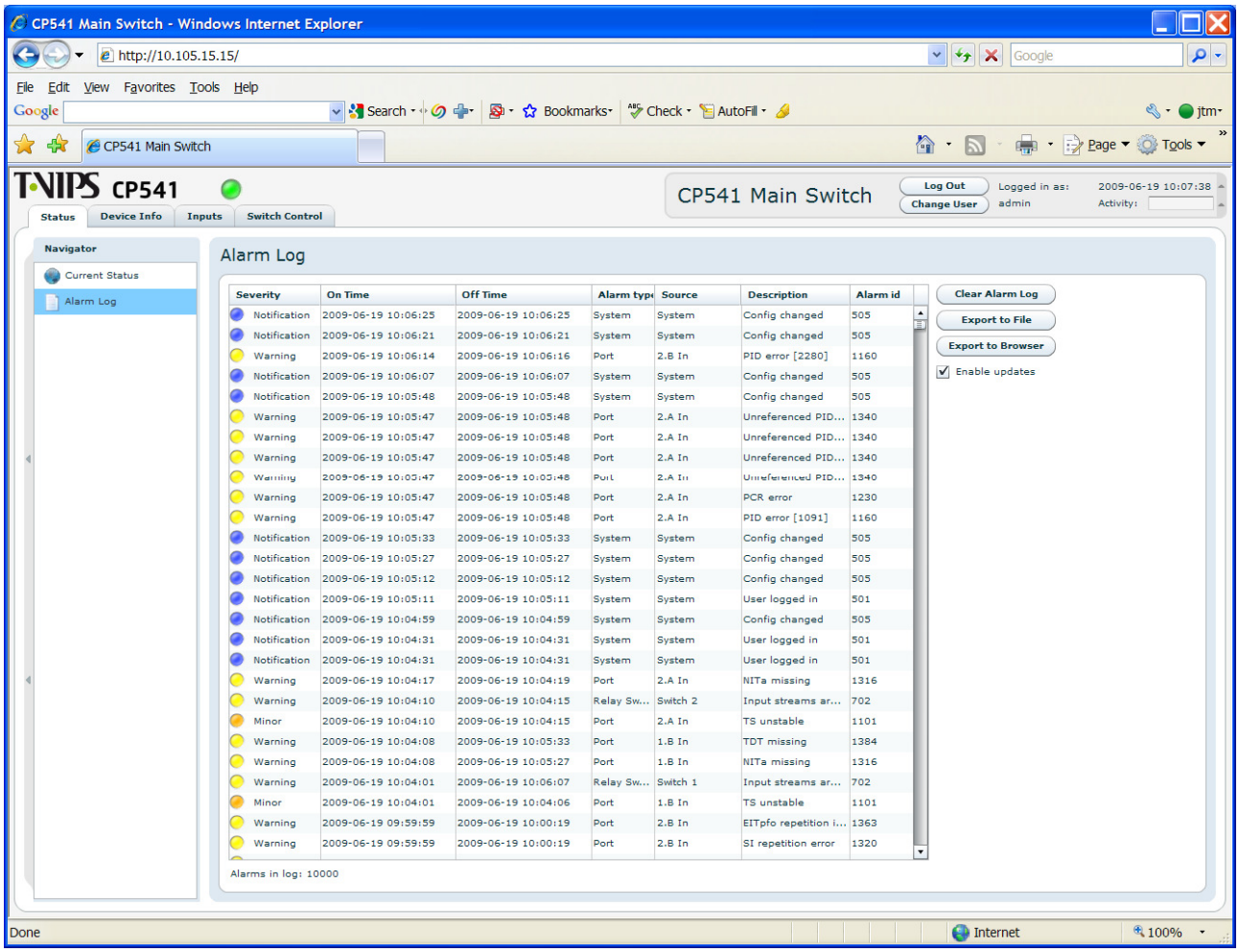
The alarm manager always keeps track of the highest severity alarm in the unit and on each port, and makes this information available in the external interfaces.

SNMP traps are dispatched to registered receivers whenever there is an alarm status change.

Alarm relay 1 and alarm LED are configured to signal whenever there is a critical alarm present.

Alarms are stored in a circular alarm log of up to 10 000 entries. The alarm log is stored in non-volatile (Flash) memory and can be exported to a file or browser.

Figure 22 shows an example of the alarm log.



Severity	On Time	Off Time	Alarm type	Source	Description	Alarm id
Notification	2009-06-19 10:06:25	2009-06-19 10:06:25	System	System	Config changed	505
Notification	2009-06-19 10:06:21	2009-06-19 10:06:21	System	System	Config changed	505
Warning	2009-06-19 10:06:14	2009-06-19 10:06:16	Port	2.B In	PID error [2280]	1160
Notification	2009-06-19 10:06:07	2009-06-19 10:06:07	System	System	Config changed	505
Notification	2009-06-19 10:05:48	2009-06-19 10:05:48	System	System	Config changed	505
Warning	2009-06-19 10:05:47	2009-06-19 10:05:48	Port	2.A In	Unreferenced PID...	1340
Warning	2009-06-19 10:05:47	2009-06-19 10:05:48	Port	2.A In	Unreferenced PID...	1340
Warning	2009-06-19 10:05:47	2009-06-19 10:05:48	Port	2.A In	Unreferenced PID...	1340
Warning	2009-06-19 10:05:47	2009-06-19 10:05:48	Port	2.A In	Unreferenced PID...	1340
Warning	2009-06-19 10:05:47	2009-06-19 10:05:48	Port	2.A In	PCR error	1230
Warning	2009-06-19 10:05:47	2009-06-19 10:05:48	Port	2.A In	PID error [1091]	1160
Notification	2009-06-19 10:05:33	2009-06-19 10:05:33	System	System	Config changed	505
Notification	2009-06-19 10:05:27	2009-06-19 10:05:27	System	System	Config changed	505
Notification	2009-06-19 10:05:12	2009-06-19 10:05:12	System	System	Config changed	505
Notification	2009-06-19 10:05:11	2009-06-19 10:05:11	System	System	User logged in	501
Notification	2009-06-19 10:04:59	2009-06-19 10:04:59	System	System	Config changed	505
Notification	2009-06-19 10:04:31	2009-06-19 10:04:31	System	System	User logged in	501
Notification	2009-06-19 10:04:31	2009-06-19 10:04:31	System	System	User logged in	501
Warning	2009-06-19 10:04:17	2009-06-19 10:04:19	Port	2.A In	NITa missing	1316
Warning	2009-06-19 10:04:10	2009-06-19 10:04:15	Relay Sw...	Switch 2	Input streams ar...	702
Minor	2009-06-19 10:04:10	2009-06-19 10:04:15	Port	2.A In	TS unstable	1101
Warning	2009-06-19 10:04:08	2009-06-19 10:05:33	Port	1.B In	TDT missing	1384
Warning	2009-06-19 10:04:08	2009-06-19 10:05:27	Port	1.B In	NITa missing	1316
Warning	2009-06-19 10:04:01	2009-06-19 10:06:07	Relay Sw...	Switch 1	Input streams ar...	702
Minor	2009-06-19 10:04:01	2009-06-19 10:04:06	Port	1.B In	TS unstable	1101
Warning	2009-06-19 09:59:59	2009-06-19 10:00:19	Port	2.B In	EITpfo repetition i...	1363
Warning	2009-06-19 09:59:59	2009-06-19 10:00:19	Port	2.B In	SI repetition error	1320

Figure 22: Alarm log containing up to 10000 entries stored on the non-volatile memory of the unit.

4.5.4 In-depth Monitoring and Analysis

4.5.4.1 ETR290 Checkpoint and Template Monitoring

The TNS541 provides monitoring according to TR 101 290, previously known as ETR290. The severity level of each alarm event can be individually configured as shown in Figure 23

In addition, the monitoring can be tailored to the actual stream; for example Continuity Count error checking of specified PIDs can be masked.

The unit can also perform content or template monitoring as shown in Figure 23, e.g. monitor that a certain component does not have a bit rate above or below user-defined values. In addition, the unit can check that all services in a user-defined list are included in the stream.

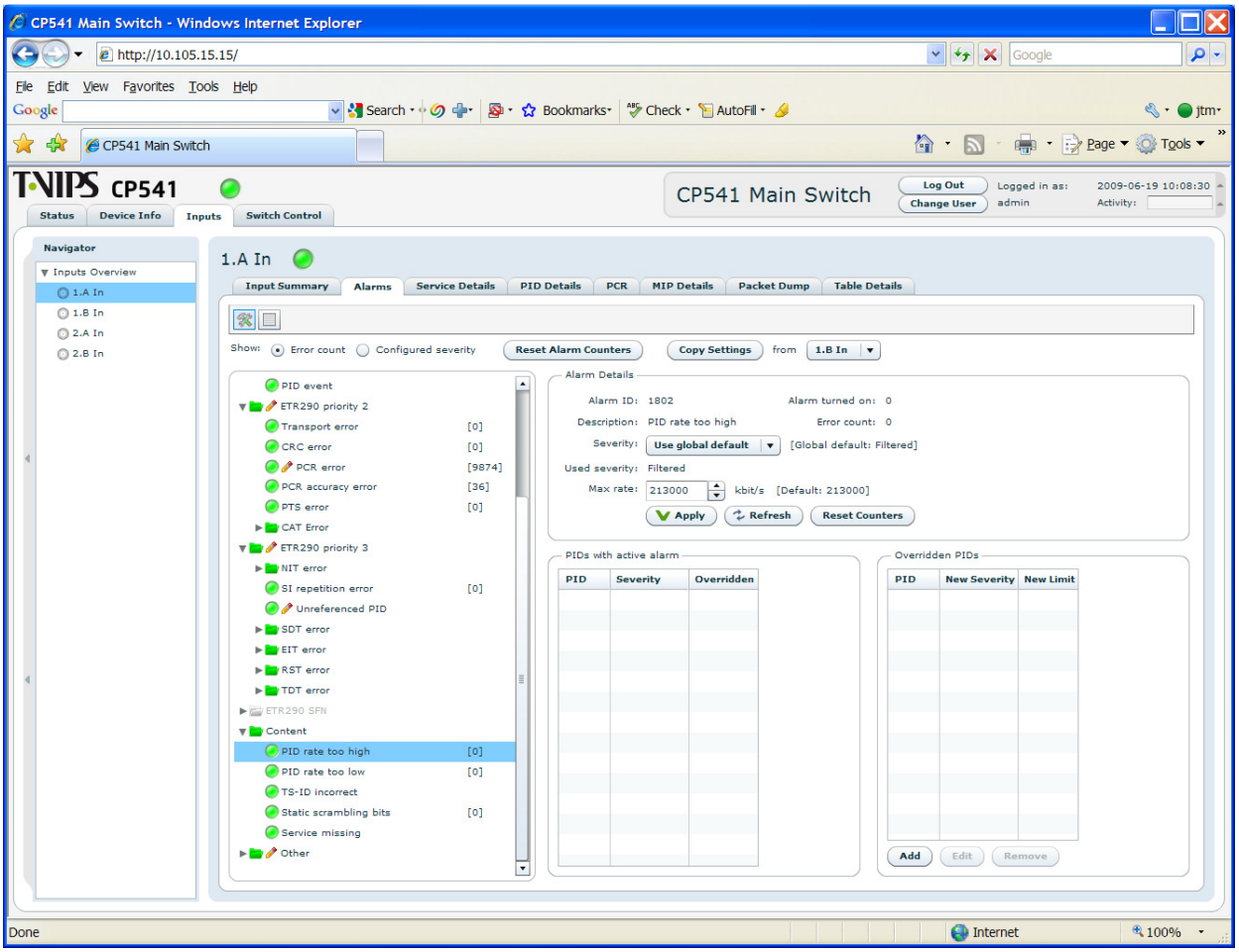


Figure 23: Template monitoring can be used to monitor user configured events.

4.5.4.2 Transport Stream Overview

The unit provides overview of the stream content. The content can be displayed in several ways. Figure 24 shows the Transport Stream overview page which gives an overview of all the services and PIDs in the stream. Figure 25 shows the page displaying the packet rates of the streams' components in a bar graph. The packet rate display is updated in real time.

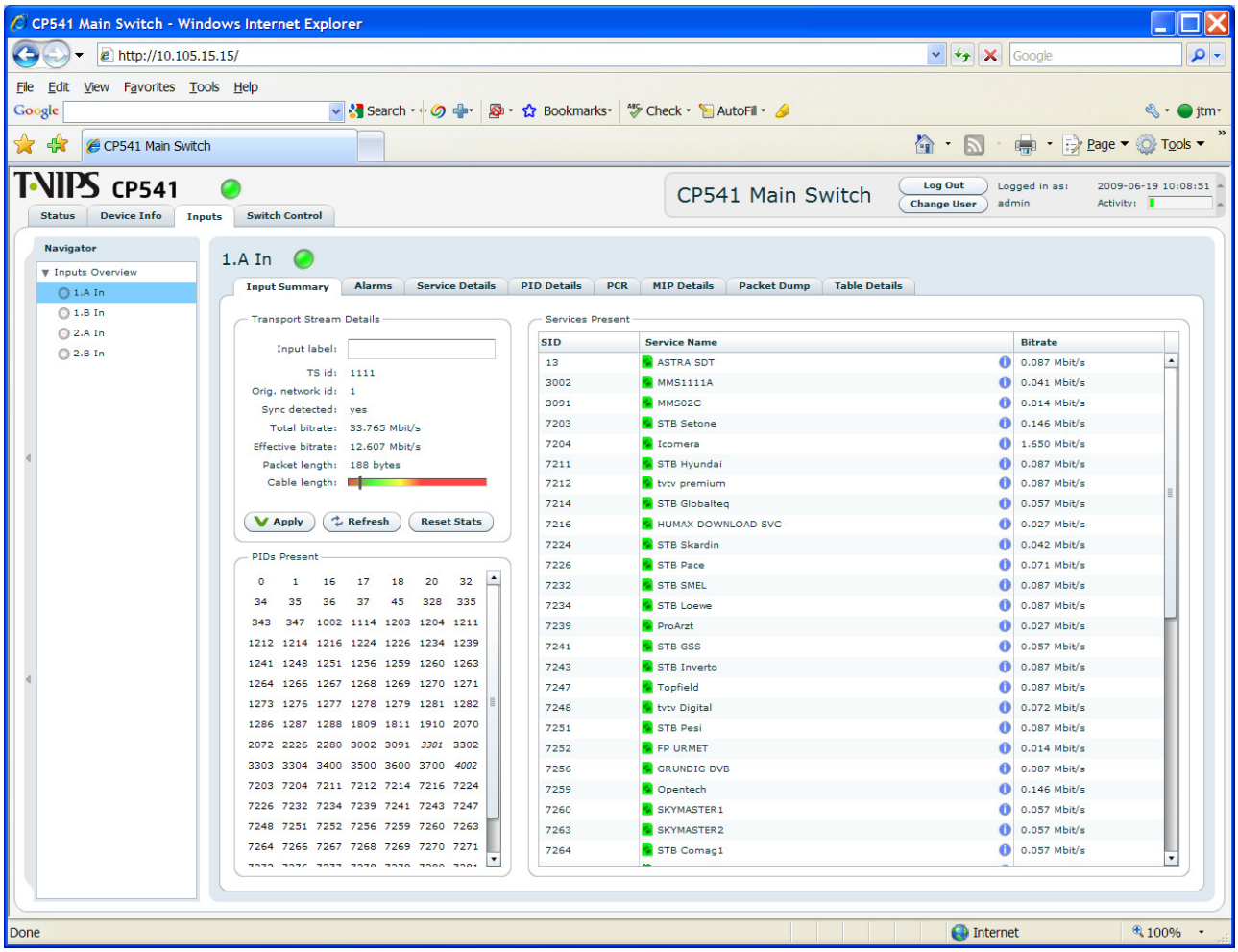


Figure 24: Transport Stream overview showing the present PIDs and services in the stream. The Transport Stream bit rate is shown in the status field.

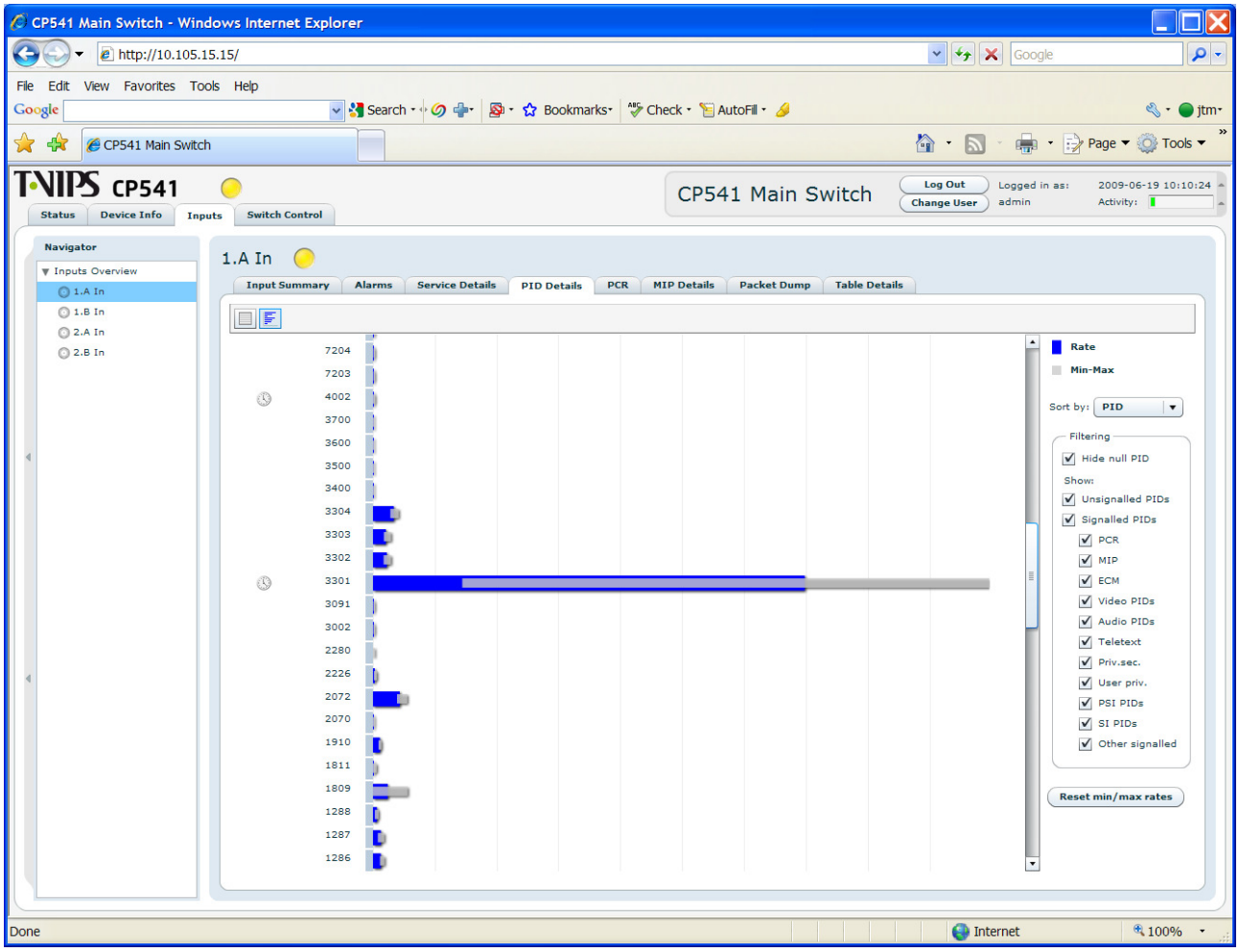


Figure 25: Rate overview page showing a graphical representation of the bit rate for each PID present in the Transport Stream.

4.5.4.3 PCR Analysis

The TNS541 provides PCR analysis. Figure 26 shows a graph display of PCR jitter distribution for a specified PCR PID. The display is updated in real time.

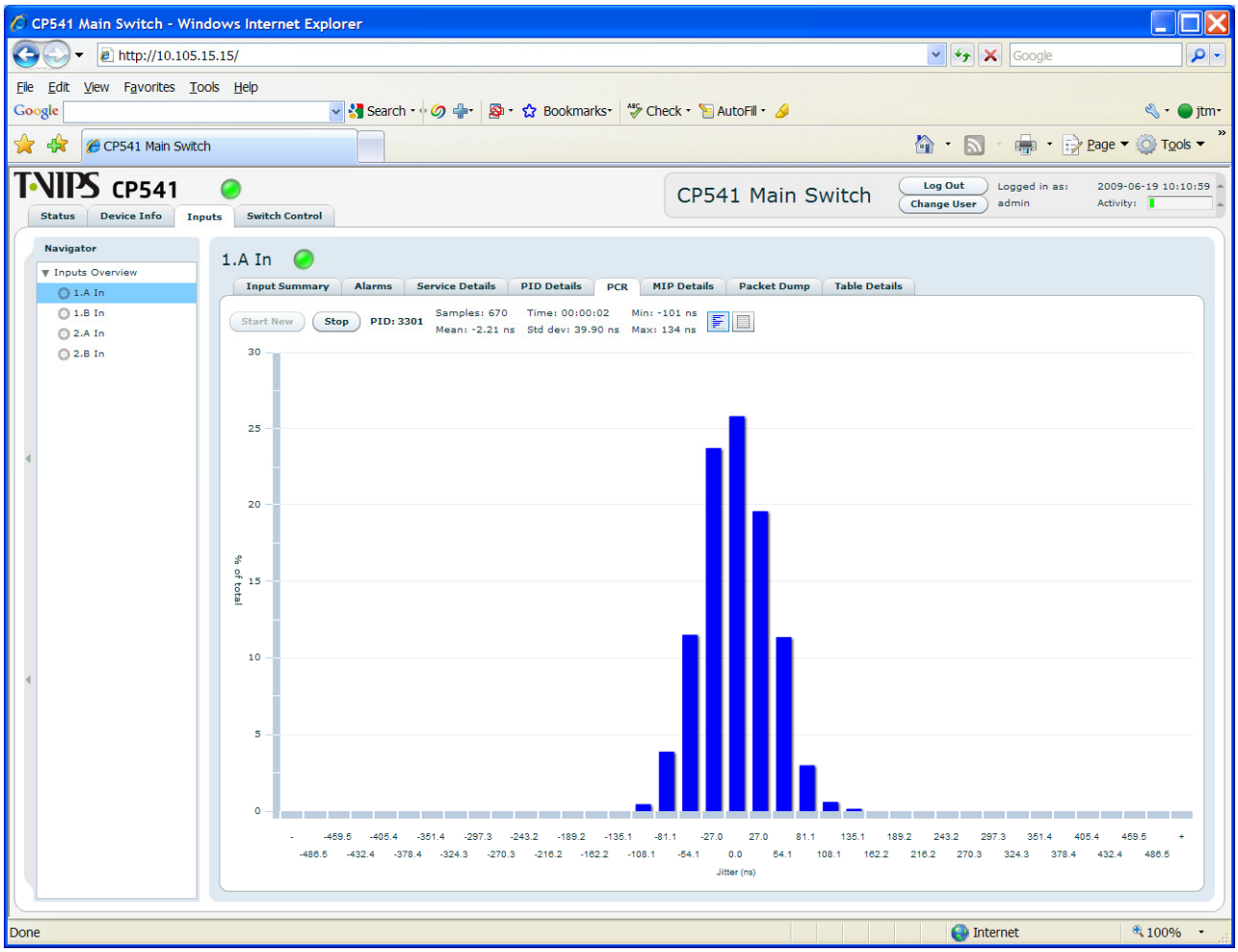


Figure 26: PCR analysis page showing a graphical representation of the PCR jitter distribution.

4.5.4.4 TS Packet Dump

The TNS541 can perform a dump of several consecutive packets belonging to a specified PID. For each packet the unit can perform decoding of the TS packet header. Figure 27 shows the packet dump display containing packet header byte values in hexadecimal notation and interpreted according to the specification.

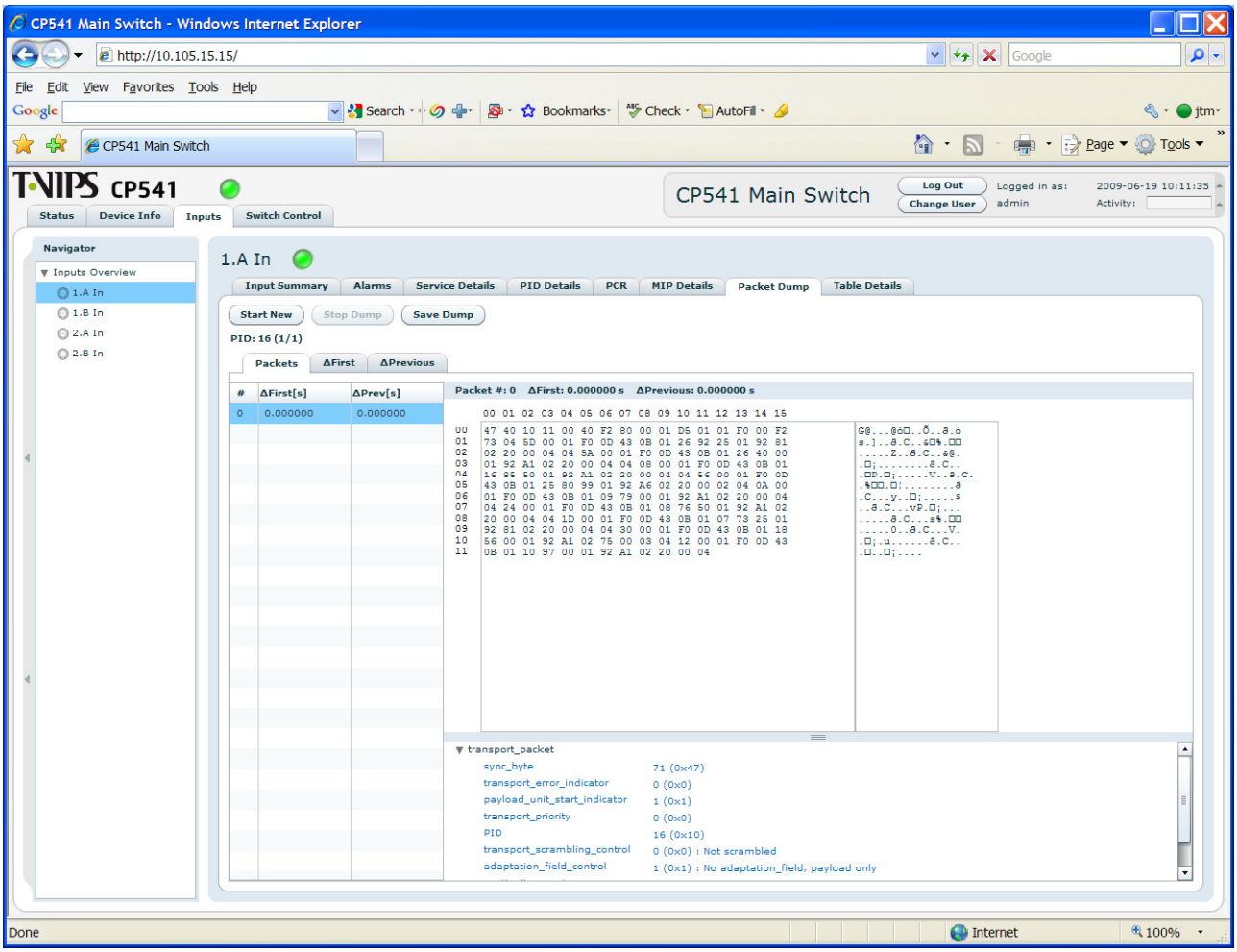


Figure 27: Packet dump page showing decoded TS packet headers.

4.5.5 PSI/SI/SI Table Reception and Decoding

The TNS541 performs PSI/SI/PSIP decoding. The unit gives a hex dump of the table sections in addition to decoding of the table fields and descriptors. Figure 28 shows the table decoding page.

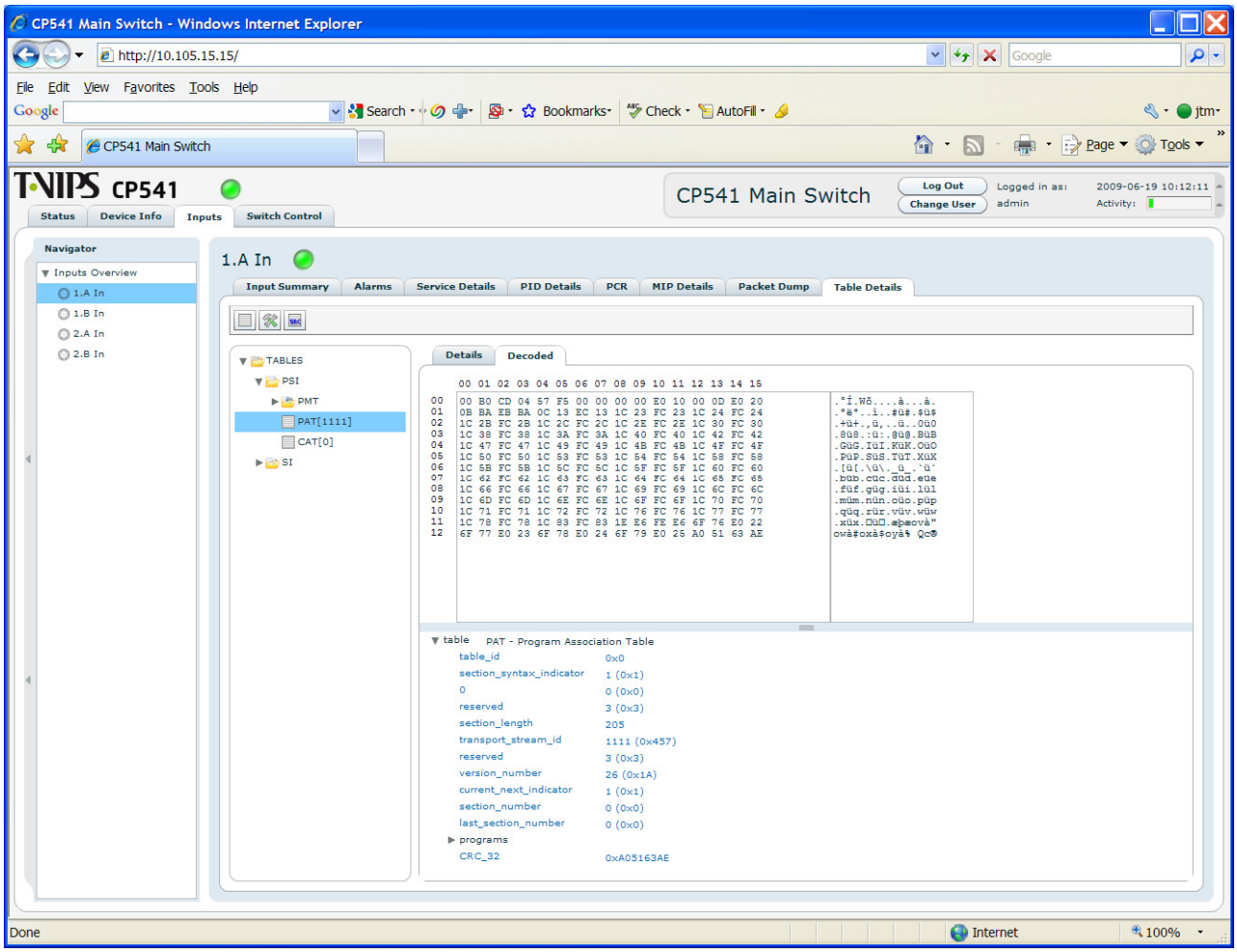


Figure 28: Table decoding page showing decoded table sections.

5. T-VIPS Connect Management System

T-VIPS Connect is a software application providing a flexible concept for configuring and supervising contribution and distribution in broadcast networks. The functionality of T-VIPS Connect covers four areas that are relevant for network operation and monitoring:

- Supervision and Logging
- Configuration Management
- Inventory Management
- Scheduling

In addition T-VIPS Connect may be used to set up IP connections. Figure 29 shows an example of the T-VIPS Connect user interface, showing the status of connections and devices for a small contribution system.

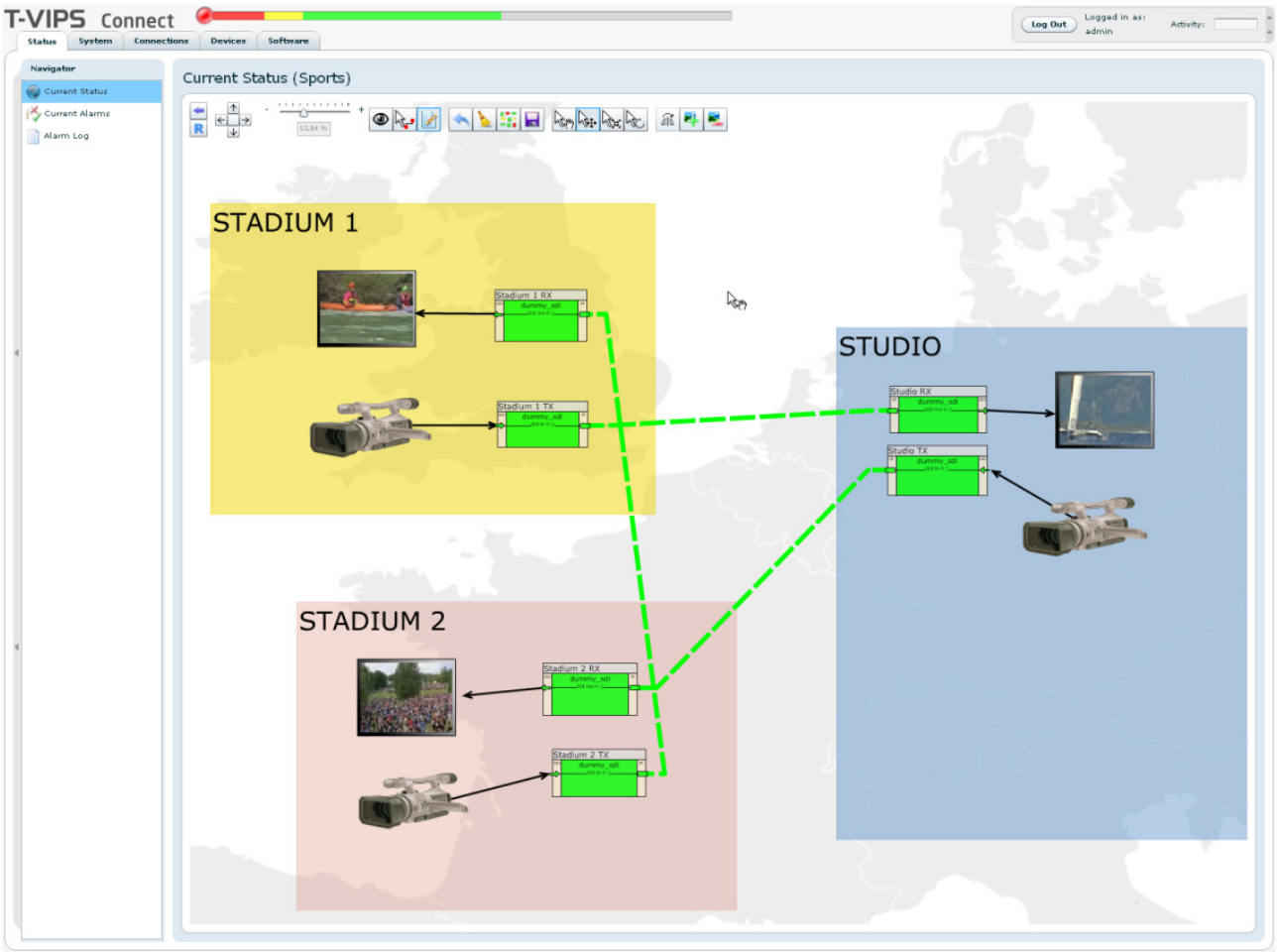


Figure 29: Example of the user interface of T-VIPS Connect showing a small contribution system.

5.1 General

The main purpose of T-VIPS Connect is to provide efficient device supervision and connection management for "video-centric" devices in a broadcast network, with primary focus on equipment from T-VIPS.

T-VIPS Connect is a server application including a central database with WEB-based remote control typically placed centrally. The application provides WEB based clients meaning there is no need to install client software on the PCs operating the server remotely; only a standard WEB browser, such as Internet Explorer or Firefox, is required. In order to provide a fast and user-friendly user interface the GUI of T-VIPS Connect is based on Rich Internet Application (RIA) technology using Macromedia FLASH.

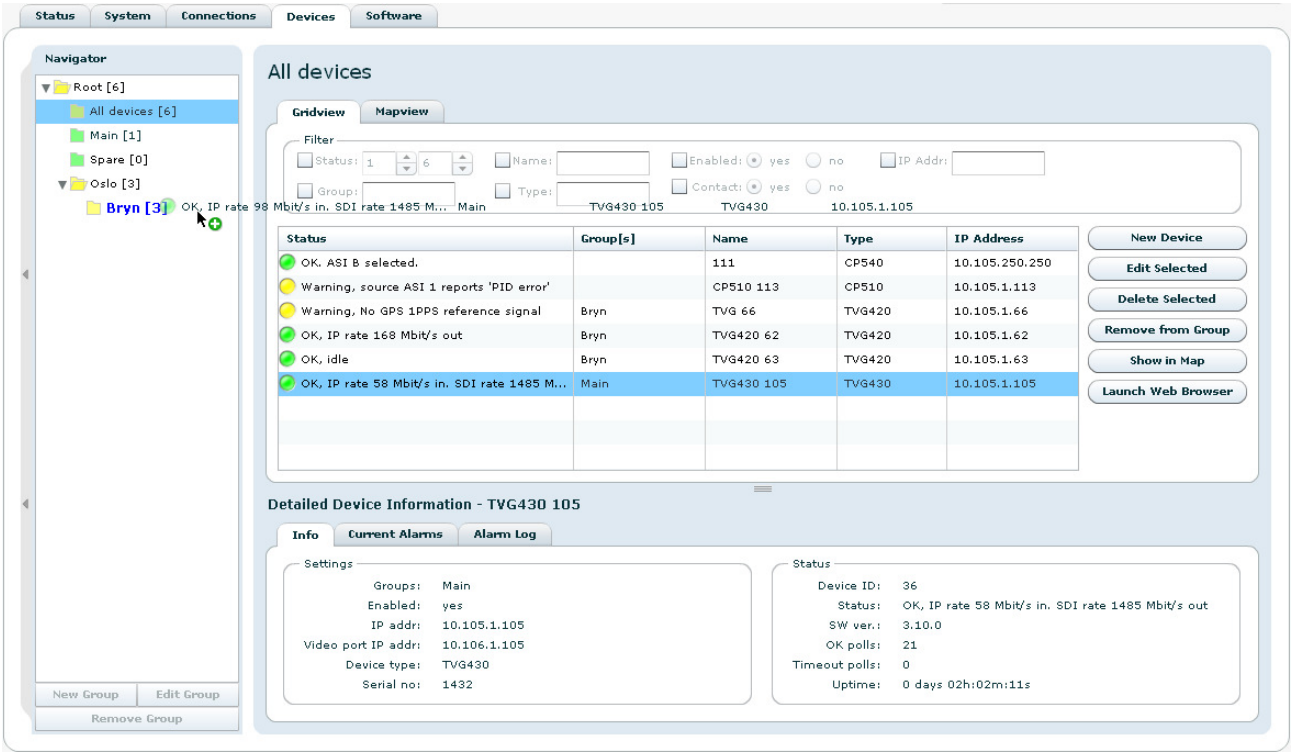


Figure 30: User interface of T-VIPS Connect showing the status of the monitored units.

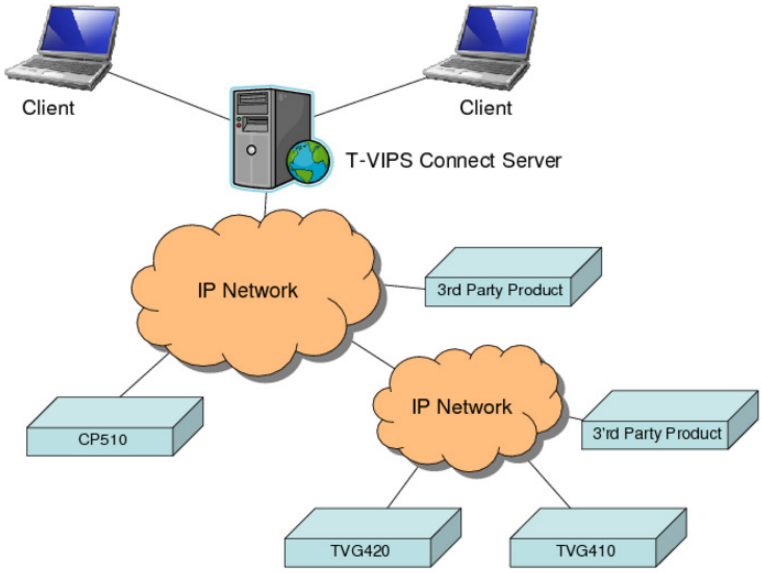


Figure 31: T-VIPS Connect system overview

The main functionality of T-VIPS Connect for the system is device management, device supervision and maintenance. All sites and devices are registered by the application. In order to provide a simple overview of the total system, each piece of equipment is registered as belonging to a site. The T-VIPS Connect application will monitor all devices and show equipment status and health. In case of an alarm from any of the devices, the application will immediately notify the operator by raising an alarm. The application will provide both a tree view and a graphical view of all installed equipment. Figure 32 shows the textual status view of installed equipment.

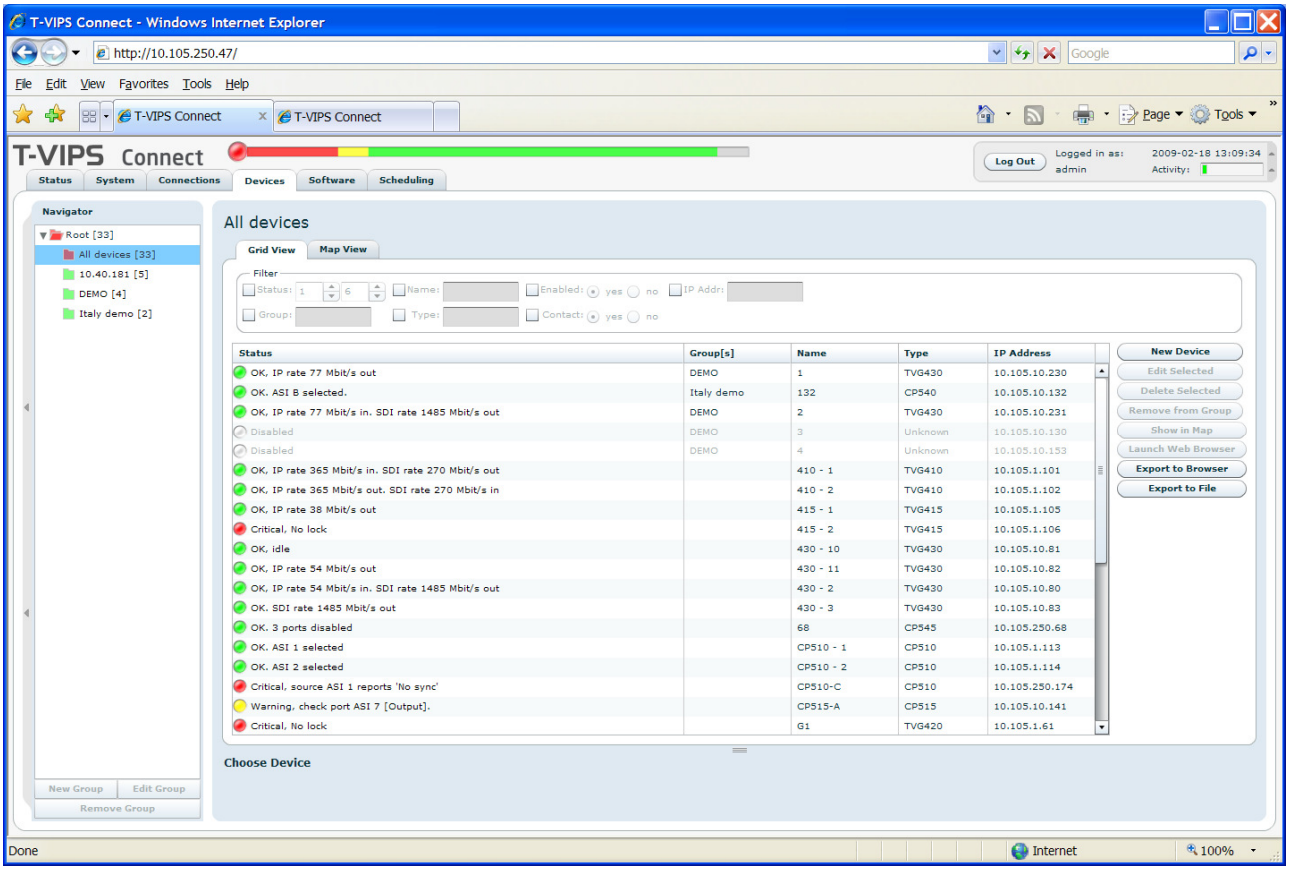


Figure 32: Connect status all devices

The current status can also be shown in a map view as on Figure 33.

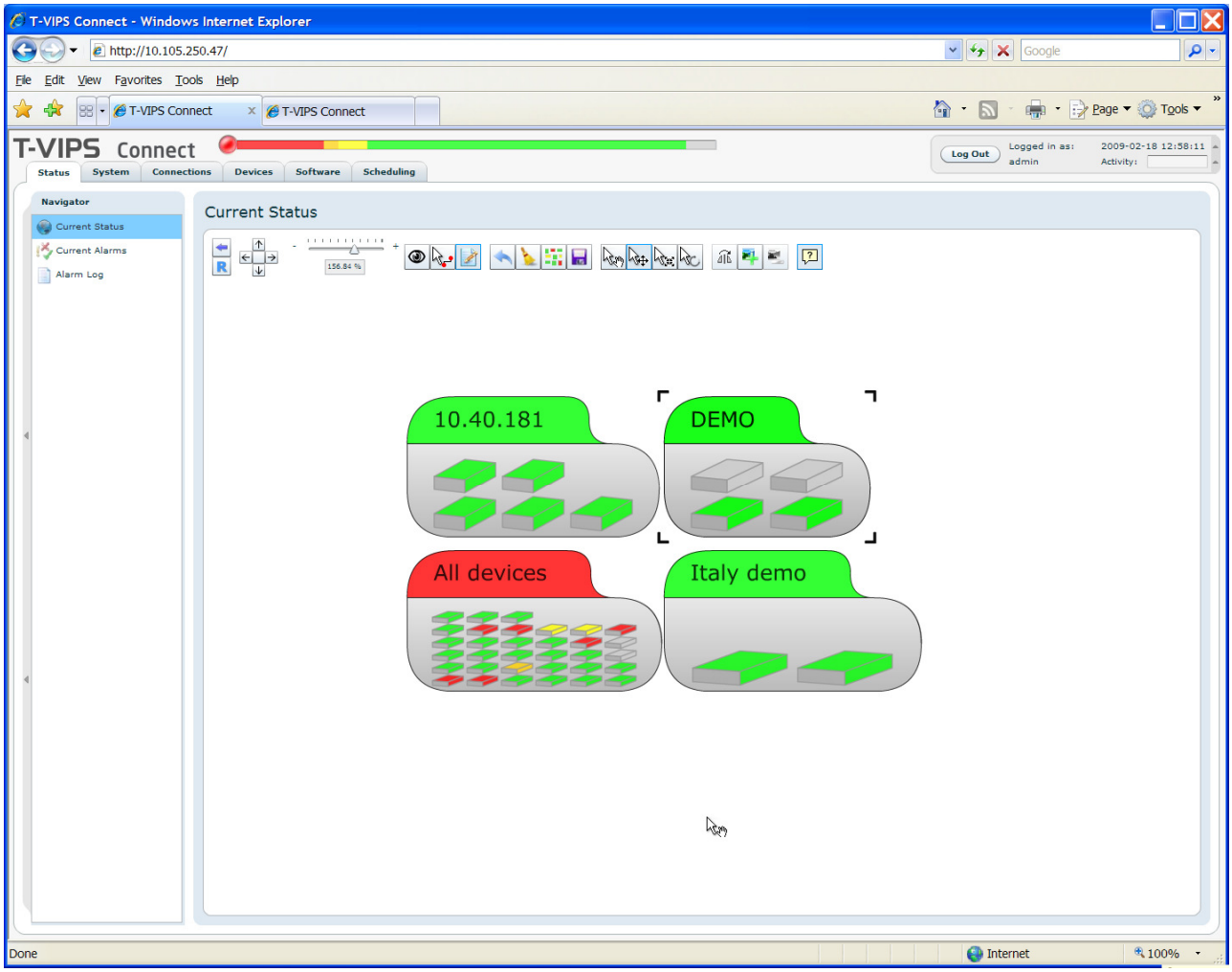


Figure 33: Connect status overview showing a map view of the system.

5.2 Supervision and Logging

The core part of T-VIPS Connect is the device management module aiming at helping the operator to:

- Supervise the status of the entire system
- Easily check device alarm conditions
- Easily check the alarm history for each device

T-VIPS Connect keeps track of the history of the system providing logging of all types of events. All alarms reported from equipment will be logged including user interactions.

Figure 34 shows the Connect alarm log.

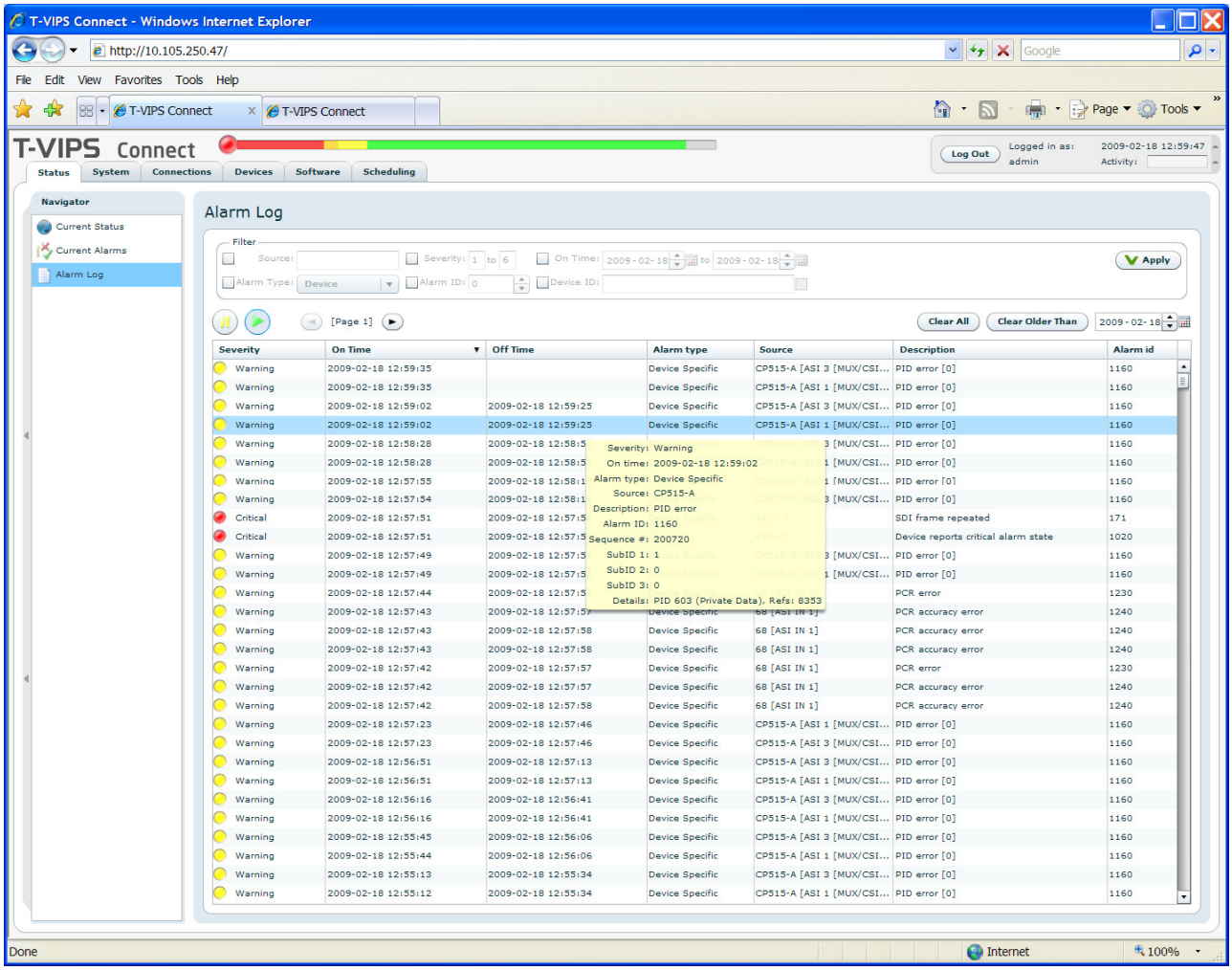


Figure 34: Connect alarm log showing all events registered on the managed units.

T-VIPS Connect offers an easy entry to the configuration interface of the T-VIPS devices. The WEB-interface of a T-VIPS device is launched directly from T-VIPS Connect without having to type in the IP address of the equipment. This allows easy configuration and diagnostics of devices.

5.3 Graphical View

It is possible to define graphical views of subsystems and equipment defined in T-VIPS Connect. The layout of the graphical maps must be defined by the system administrator.

The GUI provides a basic set of icons according to the following list:

- Each device type in the system
- Network clouds
- Geographical sites

The task of defining a map is very similar to any ordinary vector graphics drawing program allowing zooming in and out on a map. It is also possible to upload graphics that can be used as background pictures on the maps. For example, a city map may be uploaded on the server to clearly show where equipment is located.

5.4 Grouping of Devices

In the simplest case, the system is a sequential list of devices. For a small system (below 10 devices) this might be a useful approach. When a system, includes a large number of units, a grouping of devices is recommended. T-VIPS Connect provides a very flexible functionality for this approach.

A group may be a logical grouping of a set of devices, or it might represent a geographical site. A device may be member of multiple groups as for example transmitter site “Broadcast Hill” and “Standby group”. Examples of group definitions are:

- All devices of a certain type
- All devices installed at a particular location.
- All devices that participates in processing of a specific signal
- All main devices /all standby devices

Nesting of groups is possible so that a group may have subgroups and so on.

Figure 35 shows an example of grouping where unit ‘CP540 A1’ is a member of both the ‘CP540 Devices’ group and the ‘City A’ group.

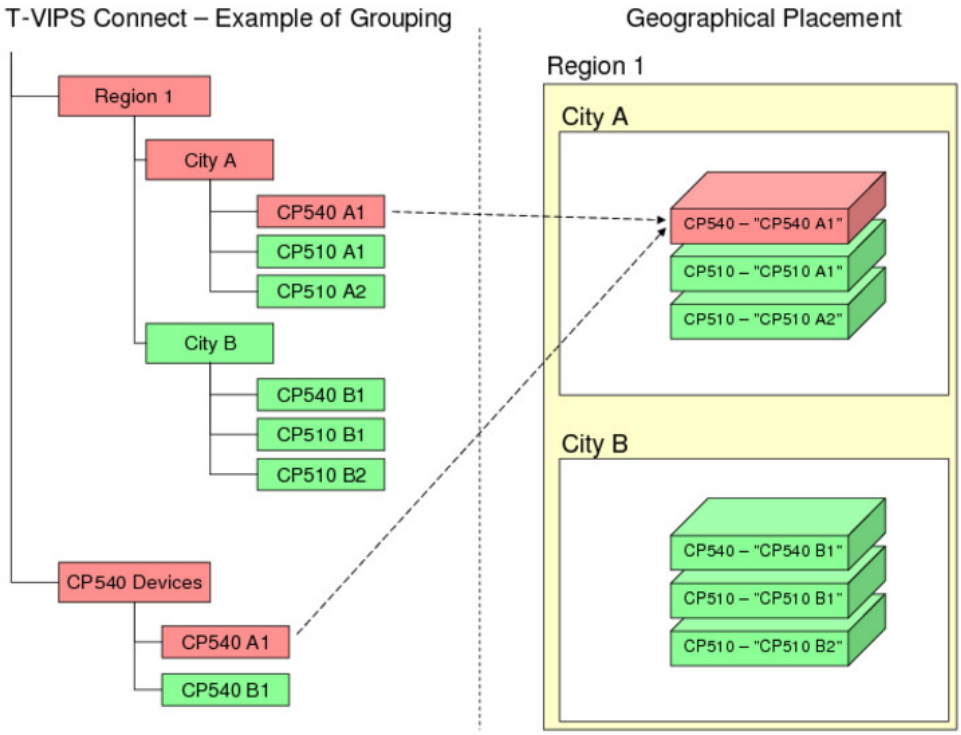


Figure 35: Grouping example. Units may be grouped according to different criteria.

A group has its alarm status clearly visible at any time. A group's alarm status represents the most severe alarm status of any of its children.

5.5 Connection Management

Connection management is an important aspect of T-VIPS Connect. The application keeps track of all installed devices and their ports and modules. Connections are easily made by selecting a port (e.g. an IP port on a transmitting device in a city) and dragging a connection line over to a destination port on a receiving device in another city as illustrated in Figure 36.

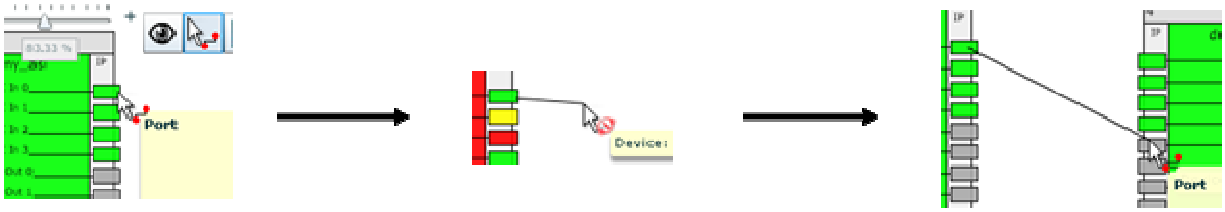


Figure 36: User interface details for setting up a connection using graphical menus

Once a connection has been made the connection details such as Unicasting or Multicasting, bit-rate, Forward Error Correction parameters etc. may be configured or simply selected from a previously stored user defined connection profile.

For a large system the graphical user interface may become too crowded when making connections by dragging as outlined above. Alternatively a connection may be set up by using the IP ports' right-click context menus. Use the context menu to set a port as transmitter, then navigate the map to the receiver port and use the context menu again to finalize the connection.

5.6 Inventory Management

Equipment inventory management is another feature of T-VIPS Connect. The application keeps track of the serial numbers and software versions of all installed devices.

5.7 Software Upgrade

It is possible to perform device software upgrades using T-VIPS Connect. A software upgrade can be performed on a single device or on a group of devices.

New software revisions are downloaded to, and stored on, the server. Upon download, the server verifies that the actual downloaded file is valid for the specific device type. Figure 37 shows a unit being upgraded.

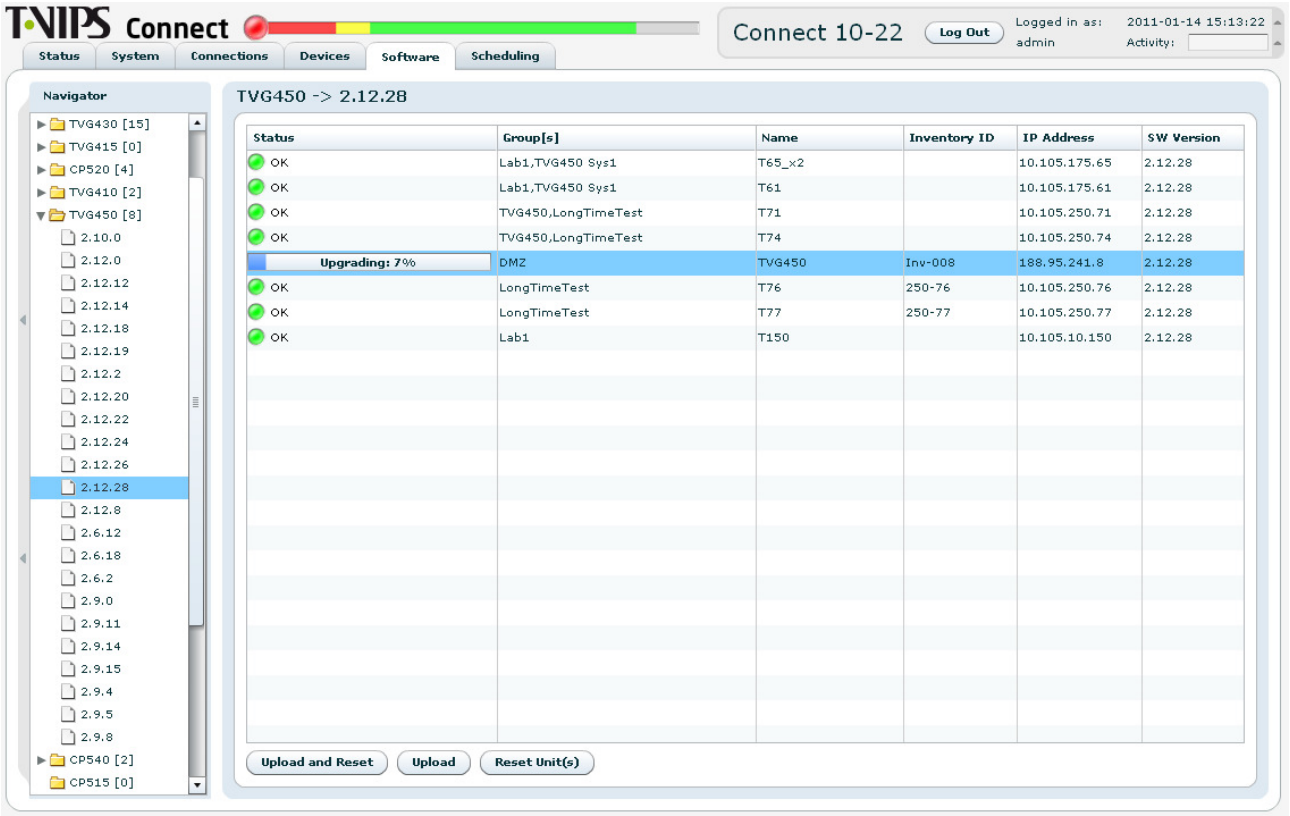


Figure 37: Connect software upgrade showing the software versions for specific devices.

5.8 Configuration Management

T-VIPS Connect will be able retrieve and load configurations to the devices under its control and continuously monitors configuration changes of the devices. When a device configuration is changed, T-VIPS Connect makes a back-up of that configuration for future use. The automatic back-up feature can be switched off.

During normal operation, T-VIPS Connect does not actively do a configuration change of a unit. Upon request from a user, for example during maintenance when a device is replaced by a new unit, T-VIPS Connect may download the last cached configuration to this new unit. In this way, the operator does not need to change the configuration parameters manually.

For configuration support Connect will handle both the default configuration and the specific station configuration generated by the configuration wizard.

Configuration management support will become available Q2 2011.

5.9 Northbound Interface

T-VIPS Connect incorporates an SNMP agent that allows communication with a T-VIPS Connect server from a top level Network Management System. The SNMP MIBs contain information and descriptions of the system and top level alarms status.

T-VIPS Connect is able to send SNMP trap messages to at least 5 external listeners. The trap destination addresses are configurable from the standard GUI.

5.10 User Management and Authentication

The T-VIPS Connect application supports a high level of security including user access control. The product provides three user levels:

- Guest: Allows monitoring only
- Operator: Allows configuration of equipment and monitoring
- Administration: Allows any operation within the system such as installation of new equipment, add new user, define groups, remove old entries from databases, perform maintenance etc.

Figure 38 shows the user management interface.

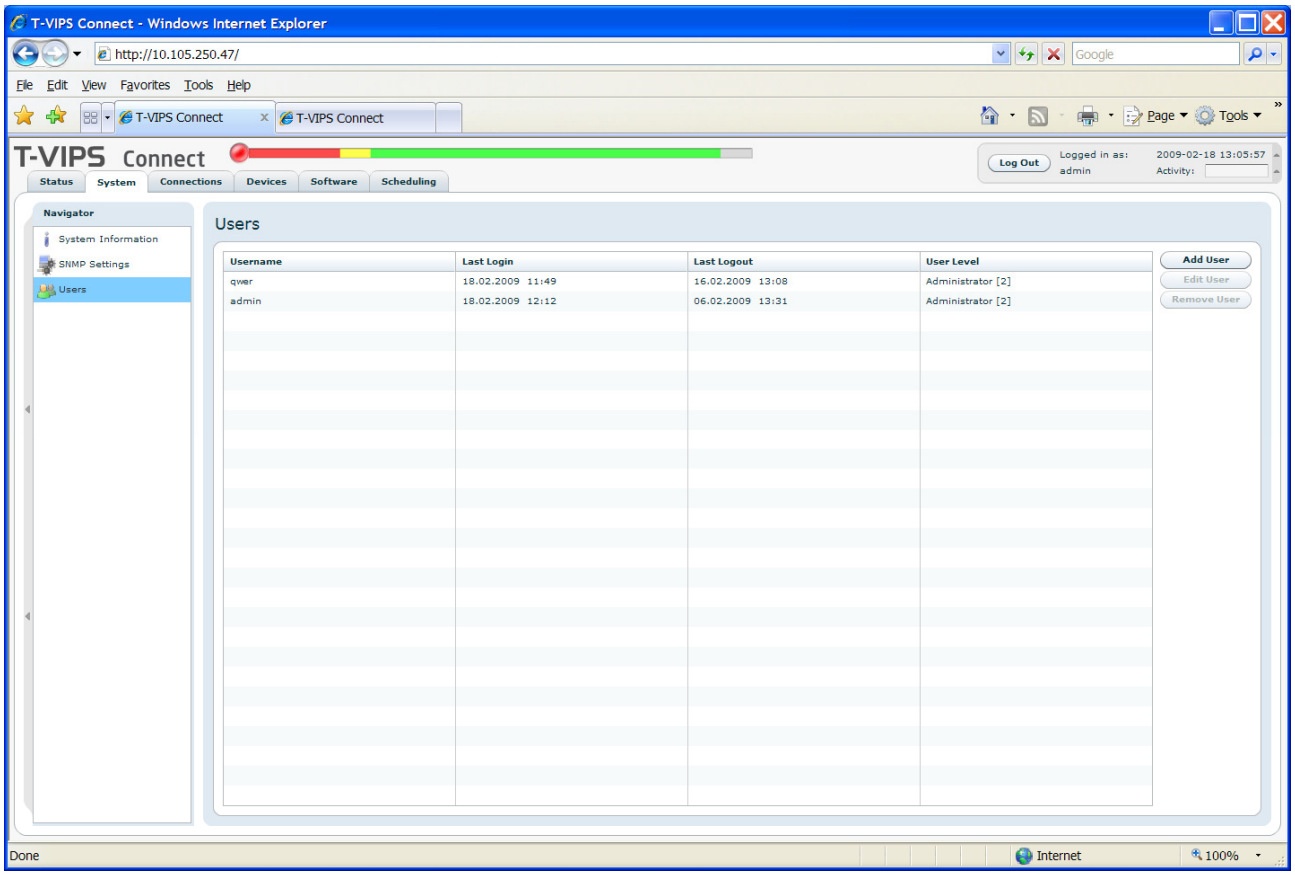


Figure 38: Administration interface for user management.

5.11 Connect Server Redundancy

A main and standby server solution can be deployed for redundancy purposes. The main server will be active and the standby server passive. In case the main server is out of operation, an operator may transfer the active operation to the standby server. Both the active and standby servers will receive SNMP traps and status information from supervised and managed devices. Thus the standby server will be up to date on system status at all times. Scheduled connections and other changes in the network will be entered on the main unit and the information may be manually transferred to the standby unit by data base backup. The main and standby server may be located in different locations. Separate Connect servers administrating a subset of devices might also be used, but care must be taken in order to avoid conflicting configurations.

5.12 Connect Server Requirements

The T-VIPS Connect server application is shipped together with a PostgreSQL database. Therefore the application might have an increasing need for hard drive space over time and it is recommended that no other applications are running on the server machine. The machine to run the T-VIPS Connect server application must fulfil the following minimum requirements:

- Hard disk size: 40 GB or more
- CPU: Minimum Intel Pentium 4, 2.6 GHz or equivalent
- RAM: 2 GB
- Network card: 1 Gbit/s Ethernet network interface
- Operating system: Windows XP Professional or newer, Windows Server 2003 or newer

T-VIPS recommend that a solution exceeding the minimum requirements is used in order to serve the large number of units of the system.

6. General Compliance

All T-VIPS equipment complies with existing international recommendations (ITU-R, ITU-T, IEC, ISO, EN and ETSI). The equipment is tested and approved for sale within international markets in accordance with applicable directives, such as Low Voltage Directive 73/23/EEC and EMC Directive 89/68/EEC and aims at fulfilling international standards and the highest environmental requirements.

6.1 Quality norms

T-VIPS production partners are compliant with ISO 9000/14000.

6.2 MTBF

The MTBF is 100 000 hours. The field proven MTBF for the cProcessor platform is >500 000 hours. The estimate is based on failure rate for CP525. More than 700 units have been in operation for more than 30 months. 2 Failures have been reported (2 750 000 hours).

6.3 Electrical Safety

The equipment in all respects conforms to the latest edition of IEC publication: Electronic equipment IEC 950 (=EN 60950, =SS EN 60950).

6.3.1 Protective earth

In case of 230 V/400V AC, all accessible metal parts, such as front panels, racks and frames etc. are connected to one common terminal for connection of protective earth. The cables for protective earth have green and yellow isolation. The AC power connector have protected earth conductor.

6.3.2 No closed loop

The earth conductor does not form a closed loop anywhere.

6.3.3 Protection for accidental contact

All live parts which under normal operation or fault condition may cause danger to human life are so protected that they cannot be accidentally touched.

6.4 Dangerous materials

6.4.1 Polychlorobiphenyl

T-VIPS equipment does not contain Polychlorobiphenyl (PCB) in any form.

6.4.2 RoHS

All units comply with the EU-directive RoHS 2002/95/EG. The directive has the objective to minimize the use of mercury, cadmium, lead, chromium six and the flame-retardants PBB and PBDE.

6.5 Electromagnetic Compatibility

6.5.1 EMC emission

The units fulfil standards EN 50081-1 for installations in office or light industrial environments.

6.5.2 EMC immunity

The equipment fulfils standards EN 61000-6-2 or EN 50082-2 for installation in heavy industrial environments.

6.5.3 Static electricity discharges

The equipment cannot be damaged or disturbed by static electricity discharges inflicted by touching the cabinet or other objects in the system.

6.6 Continuous operation

The equipment is designed for a constant 24/7 operation.

6.7 Dimensions

T-VIPS devices are mountable in standard 19” rack with 1U height (44mm), and are built to allow for connectors at the back.

6.8 Cooling

It is possible to install many units on top of each other without space for air circulation between cabinets. It is also possible to mount two units side by side, as the air flow is going from left to right when seen from the front. Two fans are used with supervised operation; in case of failure an alarm will be raised.

All equipment has temperature monitoring and an alarm will be generated if the temperature exceeds the preset alarm value.

6.9 Indicators

Two LEDs are mounted in the front panel. The green LED indicates an error-free operation while the red LED indicates an error in the unit. Similar LEDs are present on the rear of the device.

6.10 Rubber and plastic materials

6.10.1 Stability

All rubber and plastic materials are of an ozone resistant quality. They will not become brittle or soft nor show ageing in the specified environment.

6.10.2 Gases

Plastic materials do not give off gases that may have harmful effects.

6.11 Metallic parts

All metallic parts are protected from corrosion by surface treatment and choice of material.

6.12 Power Supply

T-VIPS equipment can be delivered with 230 V AC or 48 V DC power supply.

6.12.1 Power consumption

The unit power consumption is around 30 Watts.

6.12.2 Power supply connector 230 V AC

The power connector for 230 V AC is according to IEC 320 (CEE-22 IEC publ. 83) and located at the rear. Locking facility for securing the plug from accidental disconnection can be included.

6.12.3 48 V DC

Units operate from 48 V DC (nominally) battery supply with the positive pole earthed, according to ETSI EG 201 147. The positive pole shall be isolated from the chassis, racks and frames.

6.12.4 Current surge

Inrush current is less than 2.5 A, compliant to ETSI EN 300 132-2 V2.2.2

6.12.5 Power supply connector 48 V DC

48V DC connector parts:

- Harting 0969 200 033 (housing) and 3x 0969 181 7423 (female)

Cable connector parts:

- Harting (housing) 0967 015 0343, (connector body) 0969 200 0033, (male pins) 3x 0969 181 7423, cable TVC1010.

6.12.6 Power supply redundancy

All units can be delivered with dual power supply for 230V AC. A power share module secures even load distribution in normal operation.

6.13 Environmental Conditions

The following ambient conditions apply:

6.13.1 Temperature

Temperature range -5°C to +50 °C

6.13.2 Humidity

Relative humidity 5 - 95 %

6.13.3 Air pressure

Air pressure 86 - 106 kPa

6.13.4 Solar radiation

Solar radiation 700 W/m²

6.14 Transportation and storage

During transportation and storage the units (non-working) can withstand the following ambient conditions without damage:

6.14.1 Temperature

Temperature range -40 - +55 °C

6.14.2 Relative humidity

Relative humidity 0 - 100 %

6.14.3 Air pressure

Air pressure 30 - 106 kPa

6.15 User documentation

All units come with a product CD containing an English written electronic documentation in .pdf format. The user manual includes operational, security and environmental guidance.

A list of alarms and traps is appended in the annex A of the user manual.