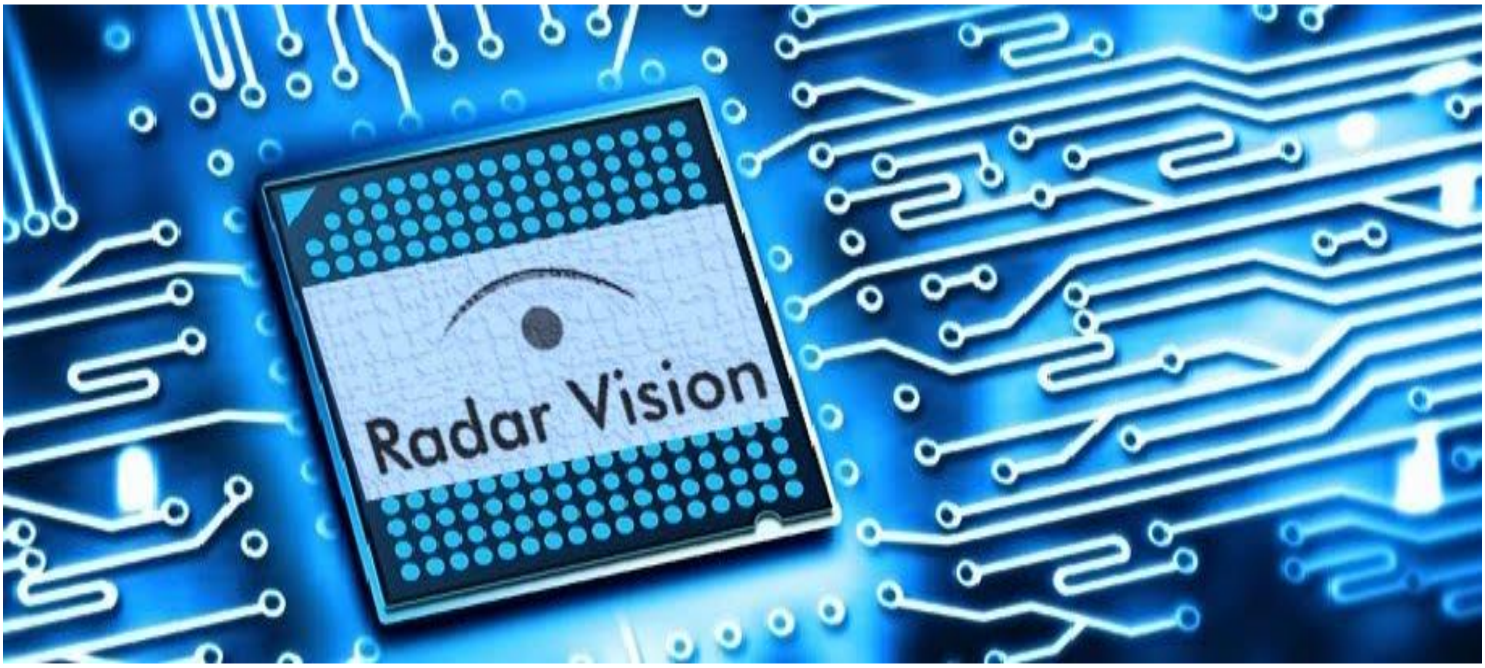
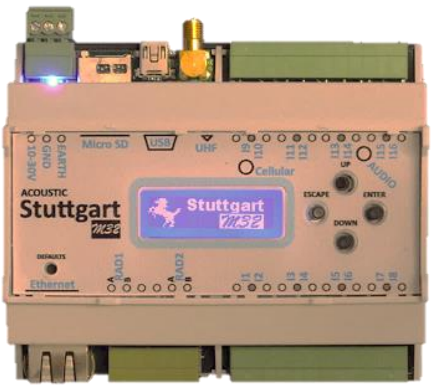


Stuttgart Advanced

Traffic Signal Priority System



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Introduction

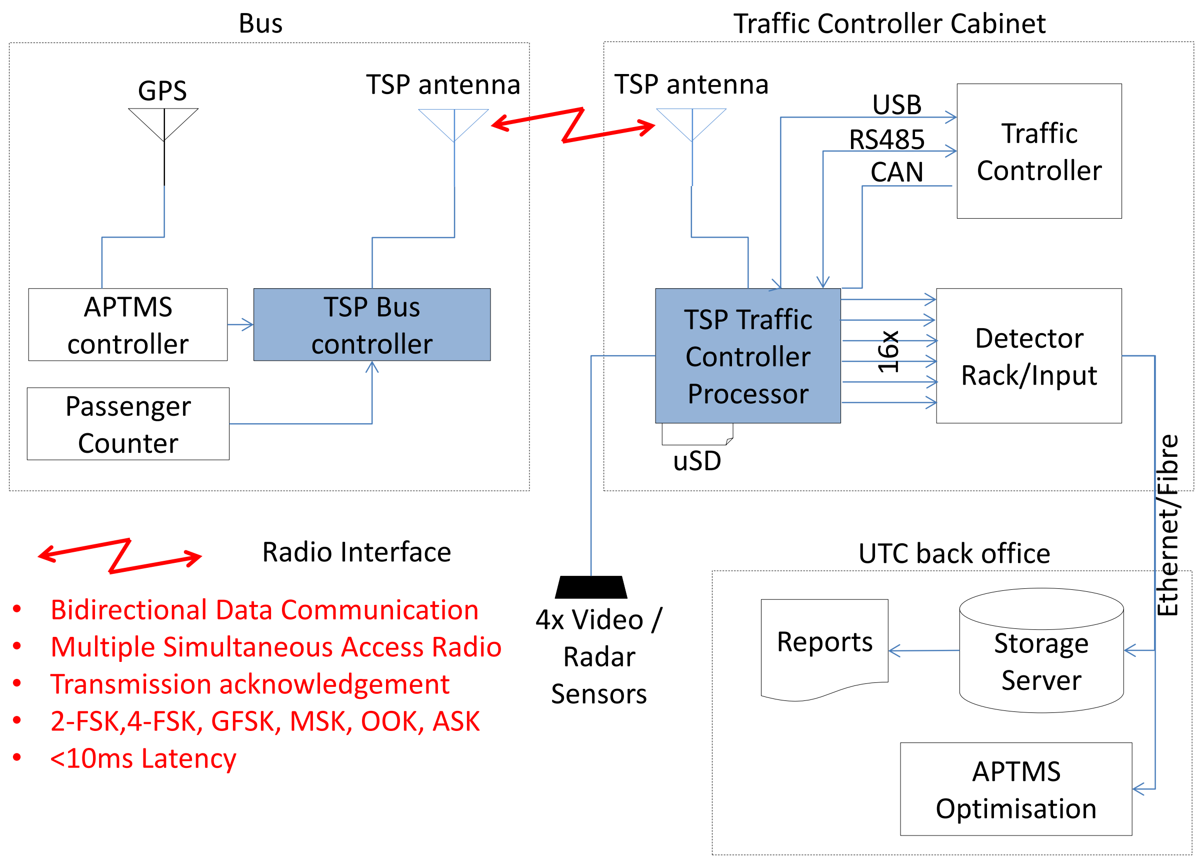
The Stuttgart Advanced Traffic Signal Priority system is second to none in the industry, built on the latest generation radio processors and 32 bit processors.

The system is the product of many years' experience in Urban Traffic Control, and Traffic Controllers in USA, UK and Germany.

The Signal Priority system combines bus priority, remote access, bus alignment, audio announcement and traffic detection in one unit. It also provides features for emergency vehicles or preemption without route planning.

TSP system architecture and operation

The TSP system architecture indicating all the possible interface configurations is shown below. It is possible to activate all the interfaces shown simultaneously.



The TSP Bus Controller receives information from the Advanced Public Transport Management System (APTMS) controller about the route, priority, estimated time of arrival at intersection, approaching intersection and also passenger ridership from the passenger counter. This information is then used to transmit to the correct TSP Traffic Controller processor if the bus is within reach of more than one intersection. The TSP Bus Controller houses a transceiver which is crucial for making certain that the Traffic Signal Controller did receive the request correctly. If not, a collision detection and resolution algorithm ensure that another request is sent, but not simultaneously with other buses. The process repeats itself until the TSP Bus Controller successfully places a TSP request. The TSP Bus Controller considers the estimated time of arrival of the bus during these requests and relay that information also to the TSP Traffic Controller Processor.

The TSP Traffic Controller Processor is responsible for coordinating the following information related to buses:

- Different buses arriving simultaneously
- A bus within radio range of more than 1 intersection
- Different Estimated Time of Arrival (ETA) of each and of different buses
- Different Priority levels for each bus
- Different Approaching Direction as well as Requesting Direction for each bus
- Different Ridership for each bus

The TSP Traffic Controller Processor can calculate calls for each phase based on the following as well:

- Intersection Cycle Time (if fixed, or if variable cycle time is available)
- Current Stage, or Offset if only start of first stage is known
- Congestion Clear Cycle or other special cycles
- Traffic queues up or downstream (to prevent priority requests from causing downstream intersections to be blocked for other bus traffic)
- SCOOT second by second information

A log of the request and request granted events are logged to micro-SD card that is integrated onto the The TSP Traffic Controller Processor. This can be remotely accessed through the Ethernet interface and used in reports in the UTC back office.

Alternatively, the UTC back office may prioritise and de-prioritise certain routes based on time schedules or UTC optimisation objectives.

Should the TSP be used for emergency vehicles, the priority from UTC will be overridden only for emergency vehicles but not for public transport vehicles.

The TSP Traffic Controller Processor also provides support for up to 2 of the 3D tracking radars from Smart Microwave Sensors or up to 4 video detection cameras from Citilog, or a combination of radar and cameras.

The innovative interface for disabled persons is described elsewhere in this document.

Compatibility

The TSP system offers a multitude of interfaces to cater for different system configurations and traffic controller systems in the market currently.

The TSP Traffic Controller Processor offers a number of ways to integrate with current and future traffic controllers:

CAN 2.0B: The latest generation traffic controllers uses Controller Area Network to communicate with the detector rack or detector devices. In some models dry contacts inputs from inductive loop detectors are no longer supported. The TSP Traffic Controller Processor offers up to 2 CAN 2.0B ports.

Ethernet: Many ATC and ITS traffic controllers especially shelf mount controllers support calls over Ethernet. The TSP Traffic Controller Processor can interface over either net through a SOAP, SNMP, Modbus-TCP or VCP connection.

USB: Controllers that run VxWorks, Unix/Linux or Windows Embedded supports USB, CDC profiles allowing calls to be made through USB. The TSP Traffic Controller Processor can interface directly to this through either a CDC profile or a composite device profile that supports 2 * CDC virtual interfaces + 1 * MSD virtual interface that connects to the local micro-SD storage.

RS 485: Some old controllers allow interfacing directly through RS485 or RS232. The TSP Traffic Controller Processor can interface directly to these controllers.

Eurocard: The older controllers offer a Eurocard rack for inductive loop detectors with the inductive loop inputs wired to a terminal strip which is wired to the loops on the road. An optional loop emulator device allows you to connect up any one or more of a 4-channel inductive loop card to the TSP Traffic Controller Processor without having to cut into the connection between the traffic controller and the rack. Alternatively, a 2-channel pedestrian card or 4 channel extension card can be used to access the connections. The TSP Traffic Controller Processor can interface directly to 16 of these inputs and to another 16 through an expander unit.

Dry Contact: Low cost and older generation controllers has digital inputs terminal strips exposed or octal bases exposed to take octal base detectors units. The TSP Traffic Controller Processor can interface directly to 16 of these inputs and to another 16 through an expander unit.

TSP Transmitter

The TSP transmitter is shown below

The transmitter features a low power microprocessor and a 433 MHz/ 868 MHz radio. The antenna connector can be fitted with an antenna as shown, or an external antenna mounted outside the vehicle. The RS232 interface provides a flexible interface from 9600 kbps to 115200 kbps asynchronous interface to the on-board unit or GPS receiver with NMEA output.

Power input is suitable for 12V and 24Vbattery systems with load dumping protection as well as battery boost protection. Battery boosters often apply up to 24VDC to a 12V system or 48VDC to a 24V system. The TSP is able to continuously operate up to 60 VDC and handle surges up to 240VDC.

The LED display provides the technician with a feedback when using the MODE button to cycle through settings and debugging features. Through this interface the device can

- Transmit test signals to test transmission.
- Display the received/transmitted signal strength.
- Configure particular frequencies.
- Configure baud rate and communication parameters.

TSP Receiver

The TSP receiver to be installed in the traffic controller is shown below.

The TSP receiver offers a many state of the art interfaces to many kinds of traffic controllers such as CAN, Ethernet, USB, RS485 and RS232.

In addition, the TSP has a built-in data logger and a graphics display. It is a reliable solid state device that is not running an operating system but supports a full IP stack supporting most popular protocols. Remote access can be achieved through FTP, HTTP, SNMP and many other interfaces.

The Power input is 8-30V DC and power consumption is typically less than 1 Watt so it can be connected to power that is available in the traffic controller.

The user interface is flexible and provide many options to the installer and technician.

16 solid state outputs can be configured for different purposes.

M8 Compact Receiver

The M8 wireless is a compact intelligent wireless controller with RS232/RS485 digital and analog IO. The built-in radio transceiver circuitry support frequencies from 400MHz to 1 GHz and data rates up to 500kbps.

Intelligent devices employ sophisticated control and monitoring algorithms and as such have to provide a rich technician or user interface. As such we provide graphics displays on all our controllers for diagnostics, configuration, trend and graph viewing.

TSP feature summary

- Function
  - Bidirectional Communications between TSP Traffic Controller Processor and TSP Bus Controller.
  - Support for Call request, Call confirmation, Bus arrived, Call cancel requests.
  - Confirmation of requests transmitted back to the APTMS system on the bus for on-board efficiency logging.
  - Time to Arrive calculation to prevent premature call requests causing the bus to arrive just after termination of the required stage.
  - The Receiver is able to monitor the current stage and receive a response from the traffic controller as to when a green can be provided. This can be communicated back to the bus for the OBU to either log or action on.
  - The receiver may receive multiple priority requests simultaneously. The receiver will generate a call on the stage with the highest urgency parameter.
  - The receiver can hold the call until either the ETA is reached or the bus terminate the call.
  - When the bus departs from the stop line, the OBU will signal a terminate signal, resetting the priority call.
  - The bus retransmit the request with a random time interval between transmissions until it receives an acknowledge from the traffic controller

Bus Interface Specifications

- RS232 interface to On Board Computer (OBU).
- USB interface to OBU's that does not support RS232.
- 2 Digit status LED display with Mode button allows configuration and viewing of logs
- 250kbps radio modem.
- Highly customisable and flexible message composition allows advanced Traffic Signal Priority strategies to be implemented.
- Carrier grade 8-48VDC supply with up to 240VDC automotive load dump protection.
- Collision Resolution: The bus receives an Acknowledge response from the controller and backs out communications to allow multiple busses to approach the intersection simultaneously allowing shared air interface.
- On-board temperature sensing can be reported back to the OBU for fan monitoring.
- Bootloader that allows firmware updates directly from the OBU. Physical access to the busses are not required.

Traffic Controller Interface

- Up to 16 dry contact call pulses can be utilised
- Pulses are 100% configurable and programmable and can be synchronised with the current traffic stage.
- Up to 2 CAN 2.0B to interfaces for the latest generation traffic controllers
- Ethernet Interface for remote monitoring of traffic controller with built-in web server, SCADA system or UTC system
- USB interface for new generation controllers
- Up to 16GB local storage logs each bus transaction as well as the traffic controller status. Enough storage to store more than 5 years of data.
- RS232/485 interface for direct connection to older generation traffic controllers
- DIN rail mount
- Support for IO expander to extent to another 16 outputs
- Support for 2 * 3D radar sensors or video detection cameras to sense traffic conditions. Calls can be generated for normal traffic detection whilst queue length is considered for bus priority

Radio Interface

An 868 MHz radio is available but a 433Mz radio is advised. 433MHz has traditionally been used for automotive code hopping and high security remote controls and also other intelligent telemetry devices. With the growth in radio communication technology, many companies moved on to 868 MHz increasingly leaving 433MHz more available. The migration is upwards in search of bandwidth. For traffic signal priority 433MHz provides sufficient data bandwidth. The lower frequencies are more often used for signaling whereas higher frequencies are more often used for continuous data transmission. Therefore, 433MHz offers a quieter radio environment in cities.

- The radio interface supports 2-FSK,4-FSK, GFSK, MSK, OOK,ASK modulation schemes.
- Both the on-board and controller side radio modems are based on <1GHz SOC transceivers that provide extensive customisation and flexibility for the operational, interfacing and environmental circumstances.
- 433 and 868MHz version are available

Advantages of Advanced Signal Priority System

The Radar Vision Advanced Traffic Signal Priority overcome the many issues that traditional discrete input Transmit/Receive pair TSP solutions have such as:

- The estimated time of arrival cannot be sent to the receiver and the call may generate a premature call to priority of the bus stage, causing additional delays on the bus route especially during congested traffic conditions when priority is mostly required.
- Route origin, destination is not sent through, so priority cannot be requested where there is more than one route crossing, because the particular stage to be prioritised is not known
- There is no radio collision detection and resolution mechanism.
- When no priority figure is provided to the traffic controller, the traffic controller would not know which stage to hurry or to extend when more than one bus arrives at the intersection simultaneously with different lateness indicators.
- The bus does not know if the signal was received by the traffic controller. On isolated controllers, the OBU will be able to log the TSP performance and/ or faults.
- When the bus is in traffic and the ETA changes, the simple TSP does not allow for retransmission and recalculation of ETA on the controller.

Transmitted Data

The On-board computer transmits the following information to the TSP on-board Controller

- **Priority 0-15**: Priority 0 means that no preemption is required. Priority 7 means highest priority preemption is required.
- **Approach 0-7**: Direction 0 is North, 2 is East and so on
- **Heading 0-7**: Direction 0 is North, 2 is East and so on
- **Time to Arrive 0-63**: Time in seconds when the bus is predicted to arrive at the stop line.
- **Target Intersection ID**: 0-16383
- **Optional Bus ID**: 0-1023
- **Optional Ridership count**: 0-127
- **Optional authentication**

The TSP on-board Controller will respond with a packet if it receives an acknowledge from the TSP Traffic Controller Unit:

- Start Byte: 0x80
- Reserved Byte: 0x00 or Received Signal Strength Indicator in dB depending on firmware version.
- Count value. For every transmit attempt this value increment. The value roll over after 99.
- Number of retries required for the last transmission.

The on-board unit has communications and storage facility for all other on-board transactions, and should be able to log and automatically download the transaction log above.

In the event that this is not possible the TSP on-board Controller can log the last 128 transactions. This optional feature can be enabled but would require the TSP on-board Controller to be unplugged for data access.

Configuration

The configuration of the TSP Controller interface is achieved through an Excel table, indicating behavior for each relay output:

Intersection ID	101									
Request Output	1	2	3	4	5	6	7	8	9	10
Minimum priority	0	0	3	3	0	0	0	0	0	0
Minimum RSSI (-dB)	110	110	110	110	110	110	110	110	110	110
Input direction	N	N	N	S	S	N	SE	SE	E	E
Output direction	S	S	S	N	E	E	N	W	W	S
Configured as trunk direction	1	0	0	0	1	0	0	0	0	0
Cancel when receiving trunk request	0	1	0	1	1	1	0	0	0	0
Auto activate after prelogon seconds	0	0	0	0	0	0	0	0	0	0
Auto cancel request after time(s)	10	10	10	10	10	10	7	7	7	7
Trigger on Request	1	2	3	0	0	3	0	0	0	0
Bus ID group start	0	0	0	0	0	0	0	0	0	0
Bus ID group end	200	200	200	200	200	200	200	200	200	200
Day of Week to enable TSP function	MTWDF	MTWDF	MTWDF	MTWDF	MTWDF	MTWDF	MTWDF	MTWDF	MTWDF	MTWDF
TSP start time	06:00	06:00	06:00	06:00	06:00	06:00	06:00	06:00	06:00	06:00
TSP end time	21:00	21:00	21:00	21:00	21:00	21:00	21:00	21:00	21:00	21:00
Minimum passengers	0	0	0	0	0	0	0	0	0	0
Stage number	0	0	0	0	0	0	0	0	0	0
Stage offset	0	0	0	0	0	0	0	0	0	0
Adhere to inhibit input	0	0	0	0	0	0	0	0	0	0
Bus route number	0	0	0	0	0	0	0	0	0	0
Radar queue ETA correction factor	0	0	0	0	0	0	0	0	0	0
Minimum ETA to call	5	5	5	5	5	5	5	5	5	5
Target ETA to call	30	30	30	30	20	20	5	5	1	1
Allow Emergency Vehicle Priority	0	0	0	0	0	0	0	0	0	0

General instructions

All the rows for outputs/columns that are not used can be left empty. Do not delete the Request Output row

The most principle business rule based on priority is that if a request is received where another relay is active with the same approaching direction, but a lower priority, then that direction will be cancelled and the new direction (same approaching but asking a different movement) will be activated. If, however the existing relay is a higher priority, the new request will be ignored. If they are the same priority both will be activated.

The TSP may receiver receive an Estimated Time to Arrival (ETA) from the bus, calculated from the current speed of the bus. The TSP receiver will then start its own timer and update the ETA every second. If another request with a new ETA is received the timer will be updated to the new ETA. If the queue function is used, the ETA timer function will be adjusted so the ETA timer will run faster or slower for each direction depending on traffic flow.

The following BUSID's are reserved for special use:

0 = No bus (requests with this Bus ID will be ignored)

999 = Test bus

900 - 998 = Emergency vehicle

Intersection ID

This is the intersection ID of the intersection that the controller is configured for. Only enter one value in this row.

Request Output

Leave number 1 – 16. These numbers are not read by the system. It is only for indication of the columns for the user configuration.

Minimum Priority

Any request with a priority below this number will be ignored. A bus with a priority of 0 will be ignored. This priority may be used by the system when the bus passage must be logged, but a preemption request should not be generated. A cancel request will always be accepted regardless of this configuration.

Minimum RSSI (-dB)

A request from a transmitter with a lower signal strength than the value configured in here will be ignored. This column can be used where intersections are too close to each other and radio noise is created from a certain approach.

Input Direction

The is the approaching direction of the bus. This can be

Direction	Value to be entered (capital letter)	Transmitted Number
North	N	0
North East	NE	1
East	E	2
South East	SE	3
South	S	4
South West	SW	5
West	W	6
North West	NW	7

Do not add any other characters, otherwise the direction will be ignored. Two columns can be configured for the same direction. The outputs are evaluated from 1 to 16 and actions are taken in this order. So, if a direction is configured twice and one evaluation will cause a relay trigger, the relay will turn on during that evaluation and if the second evaluation will cause the relay to cancel, the relay will cancel a few microseconds later.

Output Direction

The is the requested direction of the bus. This can be

Direction	Value to be entered (capital letter)	Transmitted Number
North	N	0
North East	NE	1
East	E	2
South East	SE	3
South	S	4
South West	SW	5
West	W	6
North West	NW	7

Do not add any other characters, otherwise the direction will be ignored.

Configured as Trunk direction

Enter the number 1 if this is a trunk line direction. Trunk lines can be configured to cancel requests from feeder lines. Leave this value 0 if this function is not required or used.

Cancel when receiving trunk call

Enter the number 1 if you want requests to this approach to automatically cancel when a trunk line request is received. Enter the value 0 if you this approach should not be cancelled by trunk lines.

Auto activate after pre-logon seconds

This function is disabled if a value of 0 is configured. An internal timer will be started for each direction after a pre-logon request is received. After the number of seconds configured in this field, the TSP will automatically activate the request relay for this direction once the timer reaches the value configured. If the logon request arrives after auto pre-logon has triggered the relay the relay will remain triggered. The auto cancel timer will start not when the pre-logon request is received, but when the relay is activated either by the pre-login timer or by the logon request.

Minimum Priority

Any request that is below this priority value will be ignored. Valid numbers are 0-7. To allow all requests make this value 0. Priority 7 will always be allowed. A cancel request will always be accepted regardless of this configuration.

Auto Cancel Request after Time(s)

The value in this column is the number of seconds after which a request will automatically be cancelled. It is recommended to always have a number larger than 0 in this column. A 0 value will cause all requests to be held indefinitely or until it is specifically cancelled, or cancelled due to another configuration. Please note that if this value is configured as 0 and radio interference or line of sight occlusion cause the cancel request to be missed, this call will be active until the next bus cancels it, causing the intersection to request priority for every cycle for hours and may cause traffic congestion.

Bus ID group start

This value can be 0 to 999. A BUSID lower than this value will be ignored for both request and cancel operations. These can be used if certain buses are not allowed to preempt certain directions.

Bus ID group end

This value can be 0 to 999. A BUSID higher than this value will be ignored for both request and cancel operations.

Day of Week to enable TSP function

Valid values in this field is shown in the table below:

Value	Description
M	Monday
T	Tuesday
W	Wednesday
H	Thursday
F	Friday
S	Saturday
U	Sunday

The entry must not be delimited. So, all days in the week should be entered as MTWHFSU and weekdays as MTWHF. The TSP will ignore all requests except emergency vehicle requests on days not configured. A cancel request will always be accepted regardless of this configuration.

TSP start time and TSP end time

Valid times from 00:00 to 23:59 can be configured in this column. The TSP will ignore all requests except emergency vehicle requests on times before the start time and after the end time. Ensure to keep the format. Do not use 7:00, instead use 07:00. A cancel request will always be accepted regardless of this configuration.

Minimum Passengers to call

If the number of passengers is transmitted, then requests will be cancelled for all other directions with less passengers. If there is an existing active request with a higher passenger count, this request will be ignored. A cancel request will always be accepted regardless of this configuration.

Stage Number and Stage Offset

This function only works if the traffic controller transmits the start of the current stage to the TSP receiver or if the Stages are configured as inputs to the TSP receiver and hard wired to the 8 inputs. Note that the TSP receiver can be ordered either with 16 outputs or with 8 inputs and 8 outputs. The TSP can either receive the current stage via the 8 inputs or via the CAN/RS485 bus. When the Target Estimated Time of Arrival (ETA) is reached and the current stage is at the stage number and the current stage has been active for the Stage Offset time (in seconds) then the corresponding request relay will be triggered.

Adhere to inhibit input

The TSP receiver can receive an inhibit input if it supplied with 8 inputs or can receive the inhibit input through the CAN/RS485 inputs. The inhibit inputs will not cancel existing active requests but will prevent further requests to be ignored for the duration of the inhibit input. Leave this 0 if not used. Place a 1 in this column if this direction should be inhibited. A cancel request will always be accepted regardless of this configuration.

Detector queue ETA correction factor

Read the introduction on how ETA is calculated first. If the TSP receiver is connected to a Video or Radar Sensor, some outputs can be configured as presence detect outputs or advance outputs. The remaining outputs can be configured for TSP function. The TSP receiver will adjust the timer that count down the ETA depending on traffic flow or queue length to run slower if necessary. This will affect all functions that depend on the ETA. The value configured in here is a number from 0 to 999.

A value of 0 means this function is disabled. A value of 100 means that the timer will be further corrected by a factor of 1.00. A value of 50 will slow down the timer down to 0.5 or half the speed. A value of 200 will double the speed of the timer.

Minimum ETA to call

If the Bus ETA is less than the number of seconds configured in this column the request will be ignored.

Target ETA to call

If ETA is sent through only when the ETA timer reaches this value, will the request relay be activated. If the ETA is already past the target ETA, the request relay will be activated immediately, unless it is later than the Minimum ETA.

Bus Route Number

A value of 0 in this column will disable this function. If the Bus Route is transmitted, then all buses will be ignored except if the route corresponds to the number configured in this field. A cancel request will only be allowed on buses with the correct route number.

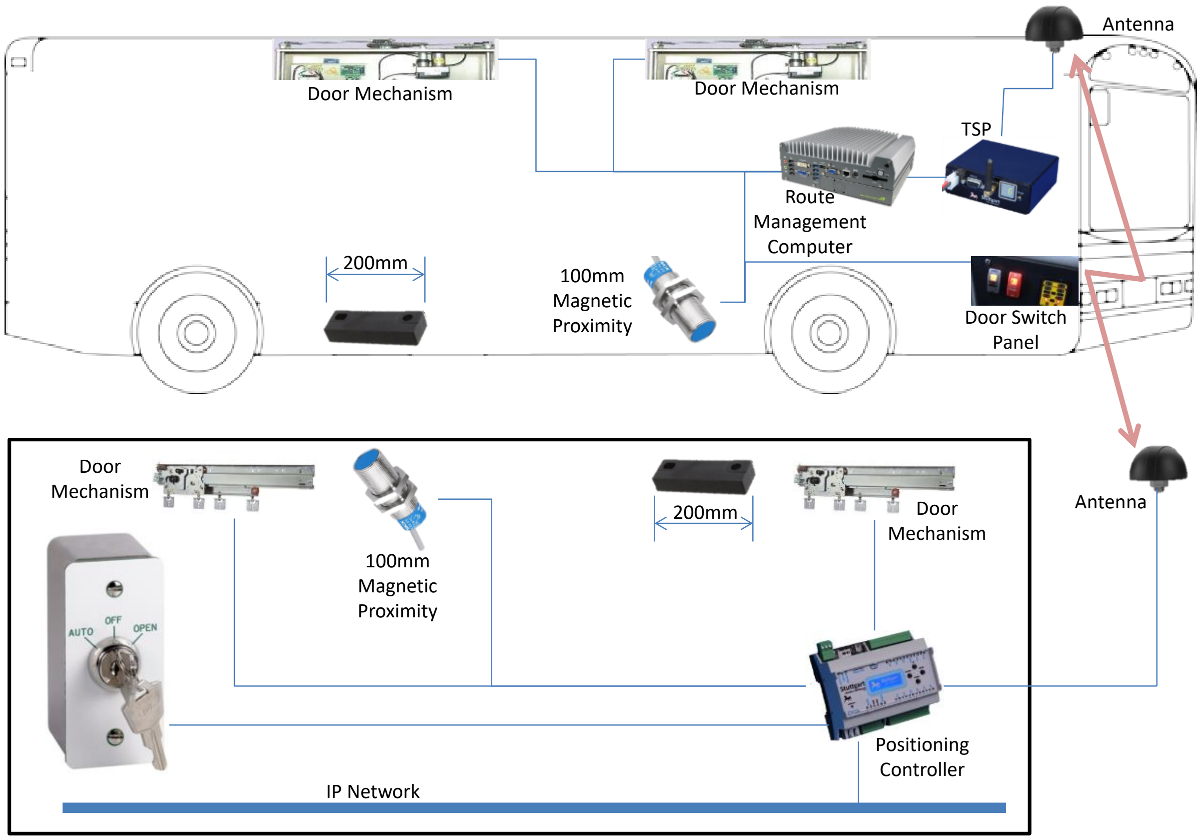
Allow Emergency Vehicle Priority

A value of 1 in this column will allow this this outputs to generate a request regardless of the direction only if the BUSID >= 900, indicating that it is an emergency vehicle.

Bus Alignment System

The TSP bus controller interfaces to a Stuttgart M32 controller, similar to the TSP traffic controller processor at the station to communicate wirelessly the alignment status of the bus and to initiate door synchronisation between the bus and the station. Magnetic sensors or Optical sensors may be used and interfaces directly to the Stuttgart M32 controller.

The sub-system architecture is shown below:

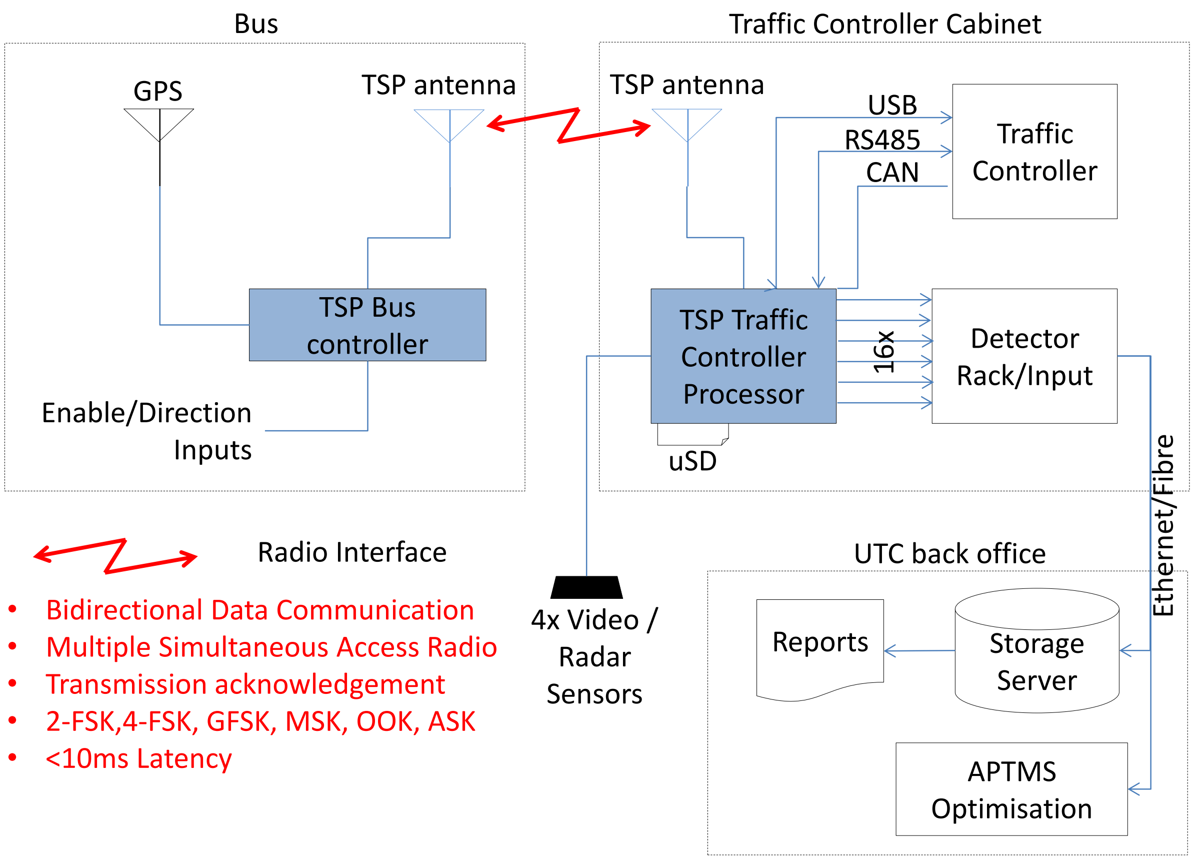


The Door Mechanism in the bus is controlled through the Route Management or Bus computer, and the proximity sensor allows the computer to display a "within range" indication to the driver to assist the driver with positioning. The computer sends a signal via the Traffic Signal Priority Emitter to the Positioning Controller to indicate the BUS ID and request to open the station doors. The positioning controller verify the positioning using its own Proximity Sensor and send a signal to the Door Controller to open the doors. A key switch is available to override the mechanism for maintenance purposes or if the on-board systems fail. Each transaction can be sent via the network to the CCC for logging. Optionally the Positioning Controller can be fitted with a micro-SD card to log all door requests as well and to update the Passenger Information Displays. The Positioning Controller returns a signal to the TSP emitter with an OK status or Fault status from the Door Controller. The Positioning Controller can be instructed from the Control Centre to open the doors or configured in an override mode. The bus driver is also able to initiate an override action through the TSP emitter to the Positioning Controller to open the doors. This can be logged through the Positioning controller with the BUSID and date/time as an exception. The TSP system already employ digital security mechanisms to prevent unauthorised TSP or Door requests.

Emergency Vehicle Support

Emergency vehicles require authentication and can provide a special higher priority trigger to the traffic controller. If there are more than one intersection on the network progression of the emergency vehicle can be ensured from even a further distance than what the radio allows. This is particularly useful in congested traffic conditions where an intersection may be blocked and require more than one cycle to clear the intersection. Under these conditions the 300m warning is not sufficient.

The TSP emitter can also be used without an on-board unit. The emergency vehicle architecture is shown below:



The GPS provide information to the bus controller as to where the vehicle is approaching from. The Enable/Direction inputs provide information to the controller where the vehicle is requesting priority from.

Conclusion

The Radar Vision TSP solution is a future proof and robust system with exceptional expansion and integration possibilities. It prevents supplier lock-in with TSP solutions provided by the traffic controller manufacturers and it allows additional safety and optimisation mechanisms to be implemented.

Contract Radar Vision for more information and datasheets.

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