Göteborgs Stad

SoftPrio

System Overview

Version: A

Göteborgs Stad

General information about the documents

This document is part of the documentation available for the SoftPrio product. The documentation for SoftPrio consists of the following document types:

System Overview (SO)

The System Overview describes how the system works as a whole and how the subsystems interact with each other. A System Overview contains the abbreviation SO in its file name.

Reference manual (RM)

The Reference manual is an encyclopedia that provides a detailed description of each component. A reference manual requires a high knowledge of its readers. It contains the abbreviation RM in its file name. The reference manual is only available in Swedish.

User's guide (AH)

A user's guide is a brief and easy-to-understand description of how to go about performing specific given steps in the operation of SoftPrio. The user's guide presupposes a good understanding of the subsystems. A user' guide contains the abbreviation AH (from Användar-Handledning in Swedish) in its file name. The user's guide is only available in Swedish.

Terminology

The detailed system overview (*SB_SoftPrio_Detalj.pdf*) also contains a section with explanations for terminology, concepts, and abbreviations. This system overview is only available in Swedish.

Versions

PrelA1, PrelA2 PrelA3, etc. are preliminary versions.

A, B, C, etc. are official versions of the document.

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1. Introduction

Gothenburg had its first electrically operated tram in operation in the early 1900s. The tram point switch operations were then all manual, and it took until the late 1950s before the first tram switch was motorised. Since then, the motorisation of switches has continued, and today only a few manual switches remain. Over the years, the technology for tram switch operation evolved, and in the 1990s, Gothenburg introduced a detection system based on inductive communication loops in the ground. The system was costly during installation and maintenance and sensitive to mechanical interference. The technology was also limiting when it came to developing new services based on tram detection. The detection of the exact position of the tram is a critical parameter. The knowledge of the precise location of a tram supports many functions and applications that are possible for the facility's operation and maintenance.

In 2010, a decision was made at Trafikkontoret (City of Gothenburg's Urban Transport Administration) to investigate the use of a more straightforward, cheaper, and more reliable technology for tram detection. In connection with this, Trafikkontoret initiated a project that resulted in the SoftPrio system. Instead of inductive loops in the ground, the SoftPrio tram switch operation system uses RFID technology to detect the tram's location and radio communication between the tram and the equipment rooms. The development of this technology has been ongoing since then in-house and through procured suppliers. It turns out that investment costs and operating costs are significantly lower for SoftPrio compared to other known available technologies.

The technology is used today in Gothenburg not only for tram switch operation but also for traffic signal operation, among other things. Modular structure enables exciting development initiatives in the future.

By spring 2019, all tram switches had the new SoftPrio technology installed, and fitment of the tram fleet was complete by the first quarter of 2020. The SoftPrio system handles approximately 1,400 RFID tags buried in the ground, 270 trams, and just over 100 tram switches. The experience of the new technology is good. The system expects to have a technical life of about 20 years, although reinvestment of specific equipment is anticipated during the period.

Several tram cities in the Nordic countries have expressed interest in building systems based on SoftPrio, including Norrköping, Stockholm, and Oslo. Trafikkontoret has decided to provide its SoftPrio software and make its know-how available to these railway sites under a license. A licensing agreement with the City of Gothenburg is a prerequisite for third parties to use the technology within SoftPrio.

2. About this document

This system overview of the radio-based tram switch operation system aims to provide general information on the design of the system based on SoftPrio. The text also offers references to other materials describing the subsystems in more detail. The hope is that a reader without deep technical expertise will be able to understand how the system is structured and how the subsystems interact. However, to benefit the content of the document, it is an advantage if the reader has a general technical knowledge and an understanding of the challenges that exist in the tram switch operation field.

The document sometimes refers to the term “Licensee”. A Licensee is a public trustee responsible for the tramway facility, which uses the SoftPrio technology in return for a license fee. A signed license agreement with the City of Gothenburg is required to use the SoftPrio technology.

The purpose of this document is to explain in a general way how the radio-based tram switch operation (SoftPrio) works in the system implementation found in Gothenburg.

2.1 Scope of the document

The document covers all subsystems that are part of Trafikkontoret’s implementation of Radio-based tram switch operation - SoftPrio.

2.2 Other documents within SoftPrio

- If you are looking for a more detailed description of the system, read the complete system overview: *SB_SoftPrio_Detalj.pdf* (Swedish only).
- If you are looking for detailed information on a specific component or technical solution, read the reference manual: *RM_SoftPrio.pdf* (Swedish only).
- If you are looking for information on how to handle specific components, read the user manual: *AH_SoftPrio.pdf* (Swedish only).
- If you need explanations of concepts and definitions, read the Terminology chapter in the detailed system documentation: *SB_SoftPrio_Detalj.pdf*.

2.3 Limitations

All examples are related to Trafikkontoret’s implementation and experience. A Licensee may have other requirements and needs that result in different requirements and realisation of the subsystems.

SoftPrio is a modular concept supporting alternative solutions of the subsystems as long as the interfaces between the subsystems are unchanged.

The document focuses on tram switch operation. RFID technology can support other applications in a tramway system, e.g., monitoring of rectifiers, signal priority, etc. Information about these systems is available in other documents. See Trafikkontoret's FTP site for technical documentation of other tram systems *(ftp://softprio.trafikkontoret.goteborg.se)*.

3. Basic concepts - an overview

SoftPrio is using a tram switch control concept from 2003, which is based on the technical detection taking place when a tram enters and when it leaves a switch point area. Before SoftPrio, inductive loops buried in the ground detected the tram passage, a technique that has become outdated. The new technology is more modular and enables the use of significantly cheaper standard electronic components. However, the overall tram switch control concept and the safety-critical core are unchanged. (See description in the detailed system overview: *SB_SoftPrio_Detalj.pdf*. Swedish only.)

In the radio-based tram switch operation system, the tram is detected via RFID tags in the ground, which constitute a detector and the RFID reader mounted in the tram. A registered passage of an RFID tag can initiate an activity, such as changing the setting of a switch point.

The following description of a passage through a switch point area introduces the central concepts.

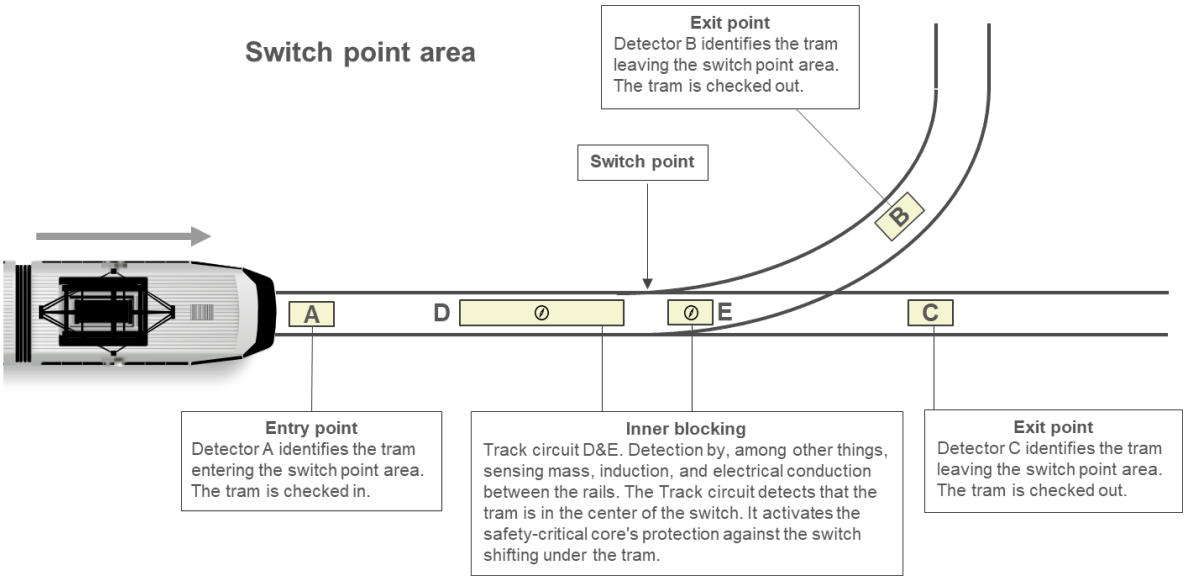

Figure 1. A tram is passing through a switch point area.

When a tram is crossing through the switch point area, it goes through three steps, see Figure 1.

1. **Passage of the entry point**
   When the tram passes detector A, the computer in the track subsystem registers the tram and checks the vehicle in. As a result, the track subsystem receives a request to set the switch point direction. If the tram switch operation system is ready to accept the request, the switch point is placed in the requested position - left, right, or straight forward (in case of a double-switch). The tram switch signal display confirms that the switch point is in control. The tram may pass the switch.
2. **Passing through the tram switch - internal blocking**
   When the tram occupies the track circuit, D or E, the switch point is blocked by fault-safe relay logic (internal blocking). Internal blocking means that no part of the switch system can now affect the position of the switch point. However, the tram driver can still manually change the position of the switch point unit by using an iron skewer.
3. **Leaves the switch point area**
   When the tram passes detector B or C, the tram leaves the switch area, and the computer in the track subsystem is checking out the vehicle. Checking out a tram means that the system is ready for the next tram to pass the switch point area.

Note: If the switch point is in the correct position, you do not have to wait for the signals but can drive immediately. This situation also applies to accompanying train driving.

4. SoftPrio system architecture and its subsystems

4.1 Subsystems in SoftPrio

SoftPrio consists of four subsystems:

- RFID tags
- Tram subsystem
- Track subsystems
- Central system.

The subsystems consist of commercial hardware and in-house developed or customised software for Trafikkontoret.

Note: Products provided under a License Agreement should be used for the realisation of a system according to the system architecture below:

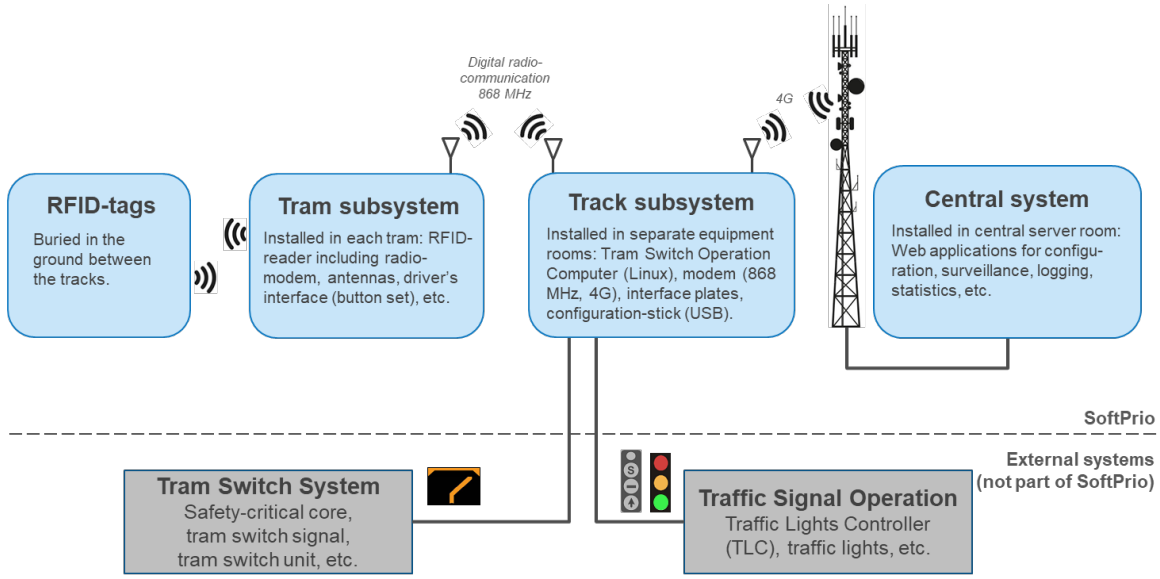

Figure 2. Architecture for the radio-based tram switch operation system. Subsystems and interface to external systems

4.2 Interfaces to external systems

The system uses interfaces to the following external systems:

a) **Traffic Signal Operation**
The Traffic Signal Operation is responsible for controlling the phases red-yellow-green, etc., i.e., signal control of conflicts in the traffic (e.g., pedestrians, cyclists, car drivers, etc.). The Traffic Signal Operation system receives the priority request from a tram, requesting access through a signal-controlled intersection or the like. This system is not part of SoftPrio.

b) **Tram Switch System**
The Tram Switch System is responsible for

   i. the safety integrity of the setting of the tram switch

   ii. the tram switch signal

   iii. to execute the request for a tram switch setting (from left to right and vice versa) safely and with high availability.

The Tram Switch Operation system only allows a new switch point setting when safety-critical blocking circuits can validate that there is no tram within the switch point area. This safety-critical system affects, and is affected by SoftPrio, but is outside SoftPrio's domain.

One absolute condition for a Licensee to use the SoftPrio system is that there must be a safety-critical core installed in each switch based on fail-safe technology. A safety-critical core implements the blocking of the switch point operation and the switch point signal. The fail-safe technology is designed for the event of a failure, so it enters or remains in a safe state.

Note: The modular structure of the system makes it possible to implement each subsystem in different ways as long as the interfaces meet the conditions between the subsystems.

5. RFID-tags

The radio-based tram switch operating system uses passive RFID tags placed in the ground between the rails. A passive RFID tag has neither batteries nor other power supply, and by programming the tag, it carries unique information. Depending on the tag's programming, the track subsystem will perform a specific type of activity, e.g., a request for a new setting of the switch point position.

The information in the RFID tag is transmitted to the tram system when a tram with RFID reader passes over the RFID tag.

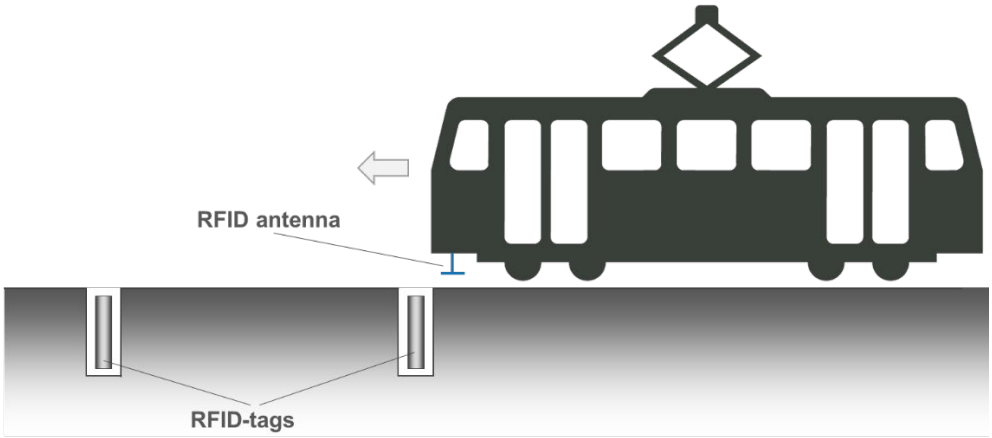

Figure 3. RFID tags in the ground and a passing tram with RFID antenna

The deployed RFID tags have two essential features of the system:

- They provide accurate positioning of passing trams
- Initiate an activity. The information in the RFID tag defines the activity.

Note: Each RFID tag must have the correct information and location for the system to function.

6. The tram subsystem

The tram subsystem has interfaces to the following:

- physical direction request buttons (right, left) operated by the driver
- the track subsystem (located in a nearby equipment room) when within range via 868 MHz radio
- RFID tags when they are within range via the RFID antenna.

The task of the tram system is to:

- detect an RFID tag upon passing such and transmit the tag information along with the vehicle data to the track system via 868 MHz radio.
- detect button pressing from the driver's direction buttons for the setting required for the next switch. (left or right). The selection is transmitted to the track system via 868 MHz radio.

The figure below describes the implementation of the tram subsystem.

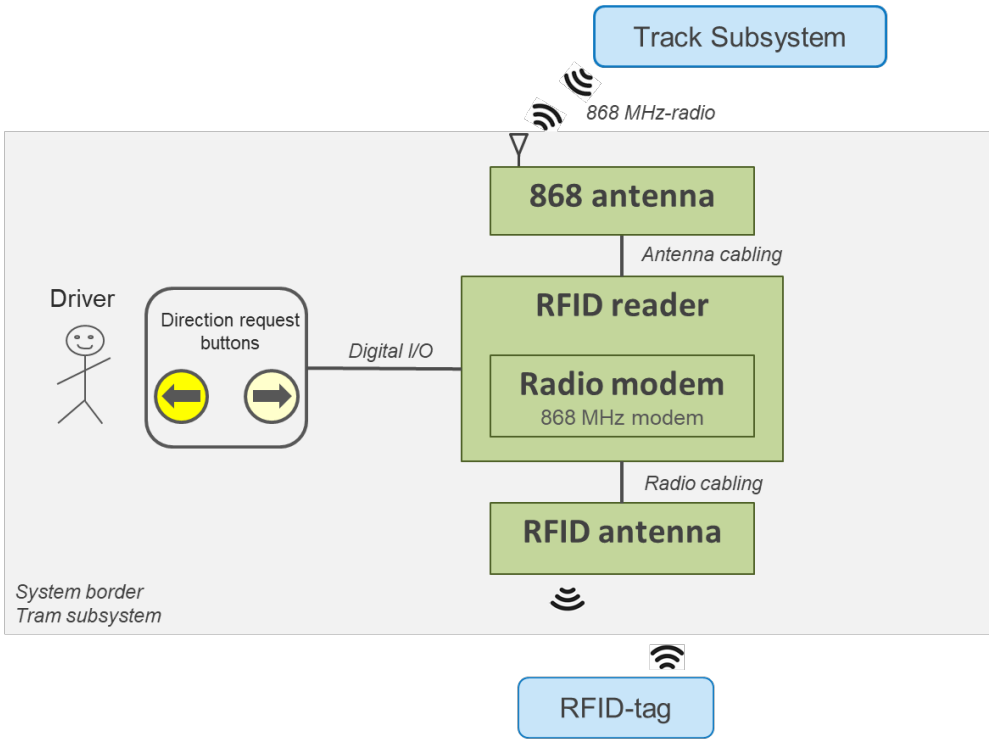

Figure 4. Overview of the realisation of the tram subsystem made by Trafikkontoret

7. The track subsystem

The track subsystem consists of the hardware and software installed in the equipment room. There are several types of subsystems in an equipment room. The SoftPrio track subsystem is one example. Other examples are the Tram Switch Heating subsystem (which controls heating of tram switches) and the SignalPrio subsystem (which controls traffic flow via handling of tram priority requests to pass traffic signals). The equipment rooms are usually located in the vicinity of the switch point area. An equipment room can be a free-standing physical building, a rented space, or a cabinet. The main functions of the track subsystem are:

- **Manage requests on the setting of the switch point direction**: Receive requests on setting the switch point direction (item 2 in Figure 5 below) from the tram when it is passing the entry tag.
- **Setting the direction of the switch point:** When applicable, send a request to the external Tram Switch System to change the position of the switch point (item 3 in Figure 5 below).
- **Handle the checking out when the vehicle leaves the switch point area:** Unblock the tram switch operation system making it possible to handle the next tram (4,5 & 6).
- **Logging all track subsystem events:** Log messages are stored centrally on servers in the central system and allows to recreate event sequences (for monitoring and, e.g., post-analysis of traffic accidents), creating statistics, etc. The logging is very detailed and with a time resolution of a few milliseconds. The system logs any change in the input or output signal to the Tram Switch Operation Computer.

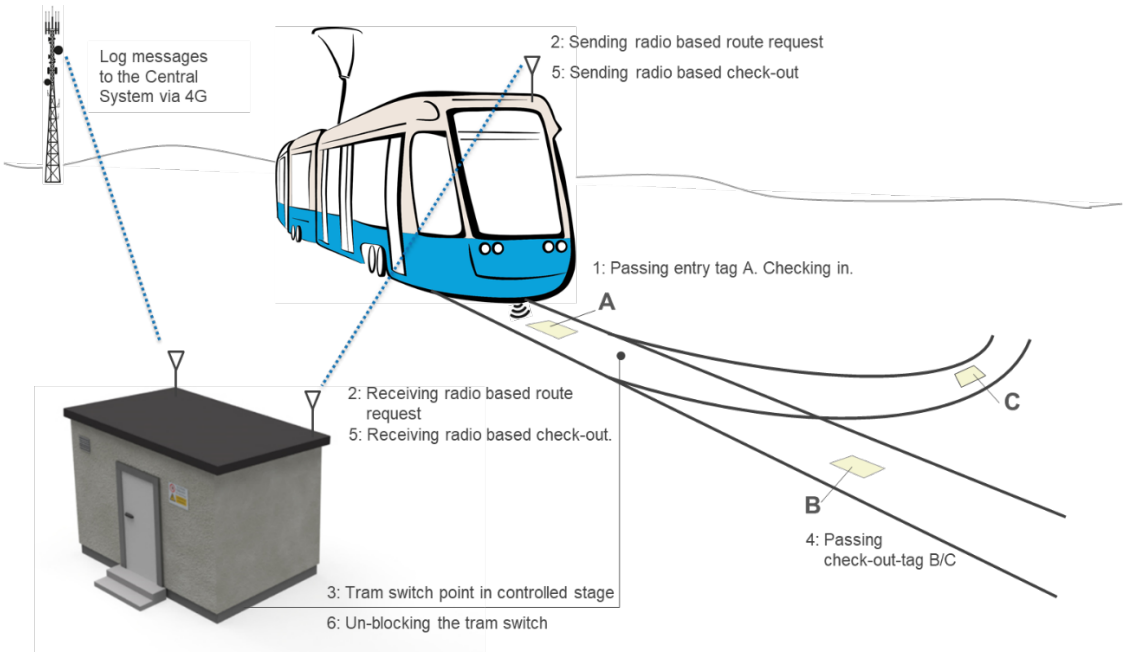

Figure 5. Simplified sketch of the checking in and out, and other events when a tram passing through a switch point area

Trafikkontoret has implemented the SoftPrio track subsystem, according to Figure 6.

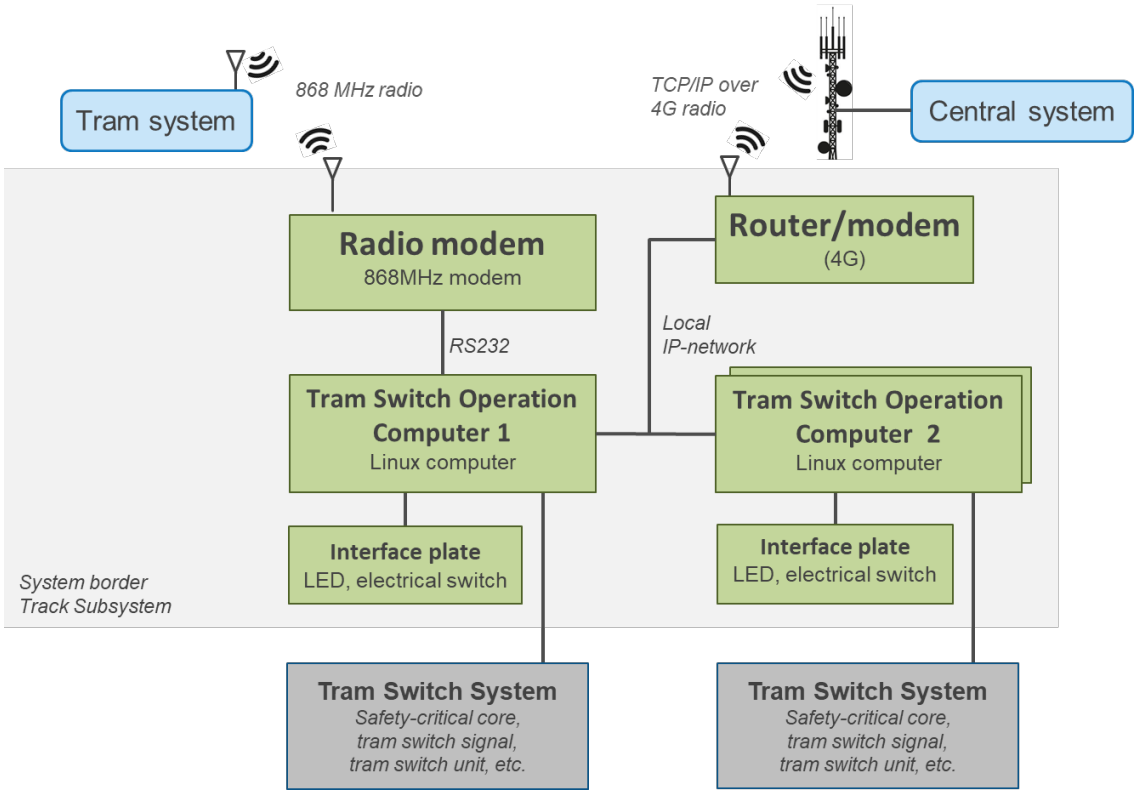

Figure 6. Simplified overview of the implementation of the SoftPrio track subsystem

The track subsystem has the following external interfaces:

1. **Interface to the tram subystem** (868 MHz radio). An encrypted protocol for receiving messages from passing trams, typically containing the request for setting the switch point direction.
2. **Interface for Tram Switch System** (24V I/O signals). Control signals which via the tram switch operation system initiate the Tram Switch System, the tram switch signal, and associated input signals to monitor the condition of the components.
3. **Interface to the central system** (TCP / IP networks and 4G). All events performed are logged and transferred to a log server in the Central System. Trafikkontoret has implemented this interface via 4G radio.

8. Encryption

The communication between the tram and the equipment room should be encrypted. For an encrypted system to work, the same crypto key must be implemented in all systems involved. You install the crypto keys into the Tram Switch Operation Computer and the RFID reader at the configuration steps.

The crypto key must be selected uniquely with the help of the random generator by the Licensee, who is responsible for keeping their crypto key secret. Unique crypto keys also prevent units from one city to be used in another city's system without resetting the crypto key.

9. The central system

The central system consists of centrally located servers. These servers hold several business-related applications for operation and maintenance of the tram switch operation system, such as configuration, monitoring, logging, and statistics. A central system is not strictly a technical requirement for a functional implementation of the radio-based tram switch operation system but provides an overview of the system's function. Trafikkontoret recommends a central system for efficient management.

Trafikkontoret has chosen to create web applications for its system management. These web applications suit different roles in the administration. The applications will be changed and updated to adapt to changes in the Trafikkontoret's organisation and processes or IT environment without assuring backward compatibility. Trafikkontoret provides the web applications outside the license. They should be seen as a proof-of-concept, i.e., before the Licensee has designed its own implementation of the Central System.

The figure below summarises the architecture of Trafikkontoret's implementation of the Central System:

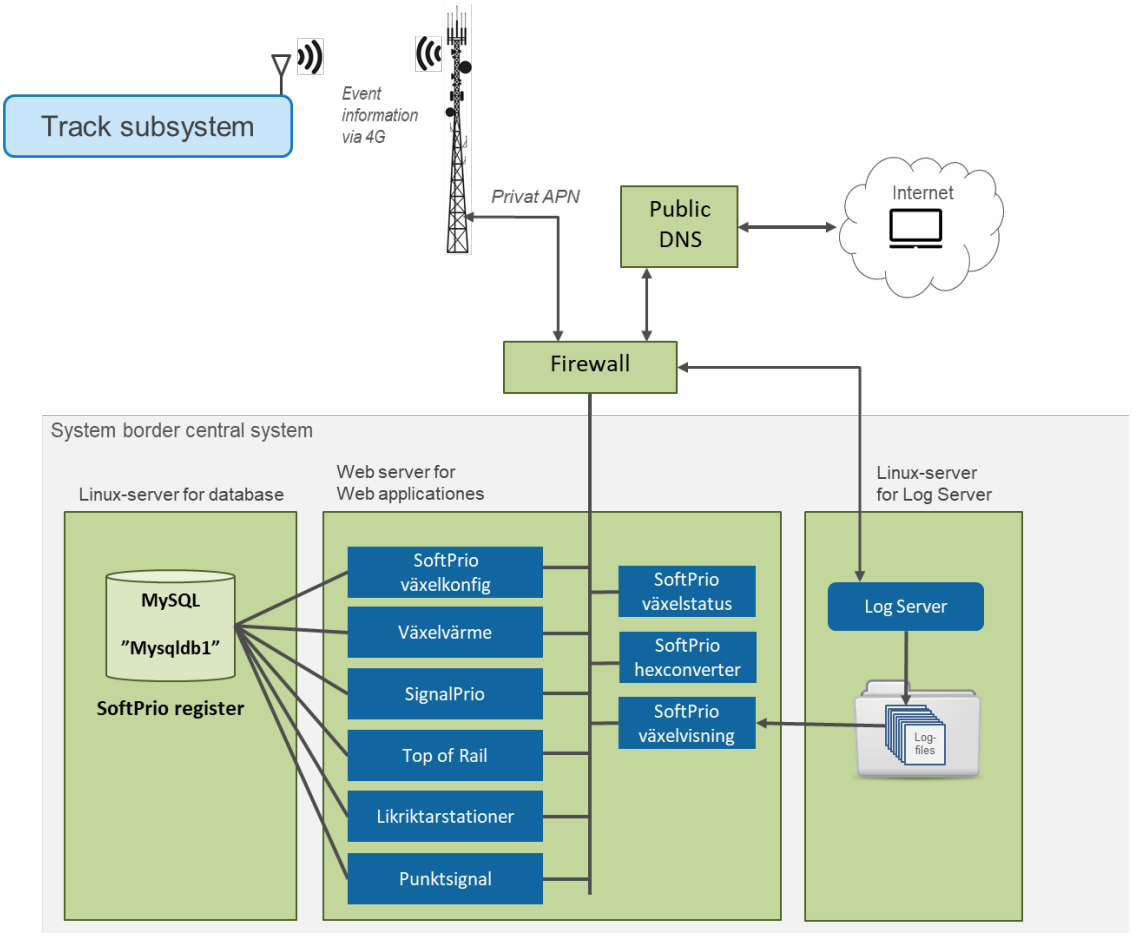

Figure 7. Overview of Trafikkontoret's implementation of the SoftPrio central system

9.1 Log Server

Log messages are sent via the 4G network from the equipment rooms to the central system. The *Log Server* receives them and saves them in a log file. Each traffic day's events are stored in a separate log file. Web applications can use the information in the log files to create services for monitoring, error detection, history, statistics, etc.

9.2 SoftPrio växelvisning [Eng: Switch Viewer]

SoftPrio växelvisning is a password-protected web application (web page) that is accessible from the Internet (outside the firewalls). It shows current and historical events in the tram switch system. The application retrieves data from the log files saved by Log Server.

This web application is in Swedish only

9.3 SoftPrio hexconverter

SoftPrio hexconverter is a password-protected web application (web page) that is accessible from the Internet (outside the firewalls). The application converts decimal values into hexadecimal and vice versa. It is customised to handle the tag ID of the RFID tags.

9.4 SoftPrio växelstatus [Eng: Switch Status]

SoftPrio växelstatus is a password-protected web application (web page) that is accessible from the Internet (outside the Firewall). The application can connect to and display the status of a given Tram Switch Operation Computer.

This web application is in Swedish only

9.5 SoftPrio växelkonfig [Eng: Switch Configuration]

SoftPrio växelkonfig is a web application (web page) that is only available inside the Trafikkontoret firewalls through a Citrix session. You can use this web application to configure and register the various components included in SoftPrio's switch system. It is linked to the database *Mysqldb1* (track register).

A read-only version of *SoftPrio växelkonfig* is available through the web application *SoftPrio växelvisning*.

9.6 Mysqldb1

Mysqldb1 is a MySQL database containing many of the switching system's parameters.

9.7 Other web applications

In Figure 7, there are also examples of other software applications: *Växelvärme* (the heating of tram switches), *SignalPrio*, *Top of Rail*, *Likriktarstationer* (Monitoring of rectifier stations), etc. They are web applications all linked to the *Mysqldb1* database, and they are part of other tram systems belonging to Trafikkontoret.

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10. References

Dokument title	Filename/URL	Information about the document
SoftPrio System-beskrivning	*SB_SoftPrio_Detalj.pdf*	This document is a detailed system description covering the SoftPrio system and its subsystem. Swedish only
SoftPrio Referensmanual	*RM_SoftPrio.pdf*	This document is a reference manual describing individual components of the SoftPrio system in detail. Swedish only
SoftPrio Användarhandledning	*AH_SoftPrio.pdf*	This document holds instructions on how to perform specific steps such as configuration and installation regarding components of the SoftPrio system. Swedish only
Trafikkontorets FTP-site	*ftp://softprio.trafikkontoret.goteborg.se*	Trafikkontoret's FTP site for technical documentation of various tram systems.
SÄO	*http://www.sao.tkgbg.se/*	Trafikkontoret's safety regulations. Swedish only
RFID-tag placement	*21238_Placering-RFID-taggar.pdf*	Drawing of tag placement in detectors
Signal systems	*21356_Signalsystem i banan.pdf*	Overview map of Gothenburg's tramway system. Stops, equipment rooms, etc.

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11. Version history

Version	Author	Reviewed and approved by	Date	Comment
A	Jonas Kolvik	Lennart Englund Kristian Johansson	2020-08-18	First official version