WICE: Data Collection and Fleet Management for Connected Vehicles

Mathias Johanson
Alkit Communications AB

Introduction

The WICE system is a powerful and flexible data collection and fleet management system developed by Alkit Communications AB. It is primarily targeting automotive OEMs and other organizations that have a need to collect data from fleets of connected vehicles, but many other applications are also possible.

The WICE system makes it possible to conduct large scale data collection operations in vehicle fleets, enabling knowledge-driven product development and data-driven innovation. Having access to up-to-date information about vehicle performance and usage patterns is a valuable asset for automotive OEMs, automotive component developers and many other stakeholders.

The WICE system can also be used for focused fault tracing purposes and for verification and validation activities. Moreover, the fleet management functionality of WICE improves awareness and knowledge about the status of connected vehicles and vehicle sub-systems.

The WICE system and application services

The WICE system consists of two main parts:

1. An in-vehicle data logging and monitoring system (also known as a Wireless Communication Unit, WCU), providing connectivity and telematics services. The in-vehicle hardware unit supports communication interfaces for measuring and logging vehicular data (including CAN, LIN and FlexRay buses, analog inputs, digital inputs, USB and Ethernet).

2. A back-end server (cloud) infrastructure including a Data Lake for storing collected data, a database for storing meta-information and application state, a web-based front-end user interface (known as the “WICE Portal”), and a REST-based Application Programming Interface (API).

The following application services are supported by the WICE system:

- A **Data Collection** service, enabling users to collect measurement data of different kinds (signals, frames, logs, video, etc.) from connected vehicles. Measurement tasks can be configured and assigned to connected vehicles through the WICE Portal user interface, and measurement data can be accessed, visualized and processed.

- A **Fleet Management** service, keeping track of the status of connected vehicles, including map-based positioning, mileage, uptime, Diagnostic Trouble Codes, and ECU software version numbers.

- A **Rapid Prototyping** service, enabling emulated execution of ECU services in the in-vehicle WICE unit, for proof-of-concept testing of new automotive functions and services.

- A **Remote Software Download** service, making it possible to remotely re-program in-vehicle ECUs, enabling continuous deployment of ECU software in connected vehicle fleets.

The WICE WCU

The WICE WCU is a special-purpose hardware unit, typically installed in vehicles, which runs the Linux operating system and the WICE WCU software. The unit has the following communication interfaces (some of which are optional):

- a point-to-point (ppp) interface using a 2G/3G/4G mobile data modem,
- optionally, a WiFi wireless LAN interface,
- one to four wired ethernet interfaces,
- two to six Controller Area Network (CAN) interfaces,
- optionally, one or more Local Interconnect Network (LIN) interfaces,
- optionally, a FlexRay interface,
- one to two USB interfaces.

The unit has the following storage mechanisms:

- internal flash memory for persistent storage,
- removable SD card for temporary storage.

The unit has the following power modes:

- running (full functionality available),
- sleep (suspended state),
- deep sleep (low-power suspended state).

The software running on the WCU (both application software and OS/BSP) can be remotely updated from the WICE Portal. All configuration of the WCU is done through the WICE Portal.

The WICE back-end server infrastructure and the WICE Portal

The WICE back-end software realizes the server-side functionality of the WICE system. The design is based on a Service-Oriented Architecture (SOA), wherein the functionality is split up into a number of independent services, each realizing a key function of the complete system. This approach is beneficial in that it allows distribution of the different services on a number of separate server machines, improving the scalability of the system through horizontal scaling, improving performance through load balancing, and providing fault tolerance through isolation of services.

A high-level model of the system architecture is shown in Figure 1.

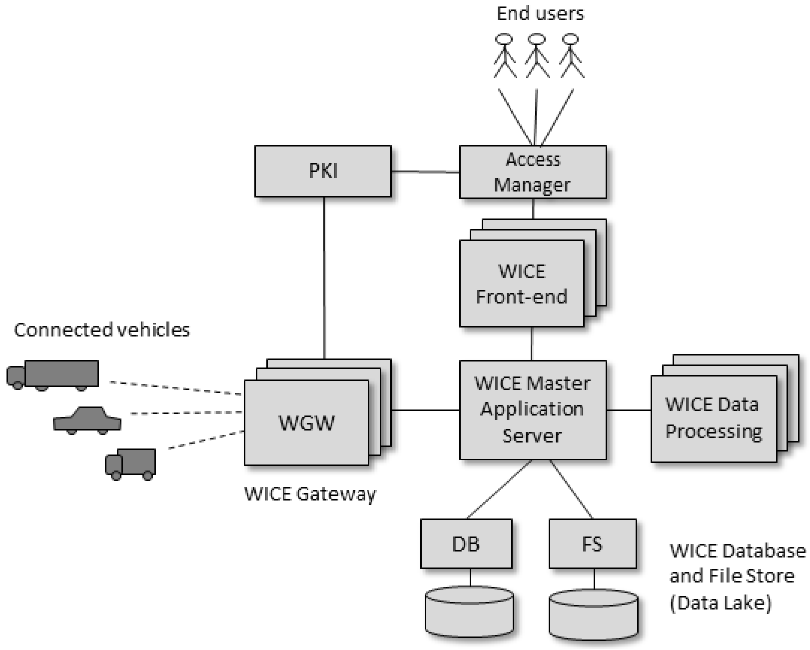

Figure 1: High level architecture of the WICE back-end infrastructure

The WICE End Users interact with the system through a web-based front-end (known as the WICE Portal), typically accessible through a corporate Access Manager (AM). The WICE Master Application Server implements the core functionality of the supported services, including management of measurement tasks and data, fleet management of connected vehicles, user management and administration. An access control framework based on user roles and resources regulates which users have access to particular data sets or application services.

The WICE Gateway (WGW) is the access point for the connected vehicles through the WICE Telematics Services. Each connected vehicle has a WCU (Wireless Communication Unit) installed, which contains the vehicle side of the system, including data capture and monitoring modules, vehicle diagnostics modules, GPS positioning and vehicle status information.

Both the WGW and the AM can be connected to a corporate Public Key Infrastructure (PKI) managing certificates for access control.

The state of the WICE system is kept in the WICE database, which is a relational DBMS. The measurement data uploaded from vehicles is stored in the WICE File Store which is a large volume storage solution based on a Data Lake concept.

Processing of data for different purposes, such as data conversion and analytics, is typically performed in dedicated WICE Data Processing servers. The number of servers can be dimensioned based on the number of connected vehicles, the data volume and the data processing requirements.

The Web-based User Interface

The web-based graphical user interface (GUI) gives users access to the WICE application services and data. Through the GUI, authenticated WICE users can configure and control the connected WCUs, in order to perform data collection tasks and access the uploaded data. The data collection is highly configurable, both in terms of which data should be collected and in which way it should be collected (e.g. which protocols to use, which sampling frequency, etc.). The GUI contains authoring tools to create Measurement Assignments for different types of data collection. The GUI also makes it possible to manage the configuration of vehicle fleets, keeping representations of the data sources available in the vehicles, by using well–established automotive mechanisms (e.g. description files like DBC, A2L, Fibex and Diagnostic Databases).

Other parts of the GUI include User Management and other administration, the Fleet Management presentation (including map-based positioning), measurement data presentation and various data search and access mechanisms.

An example screen-shot of a data visualization component of the user interface is shown in Figure 2.

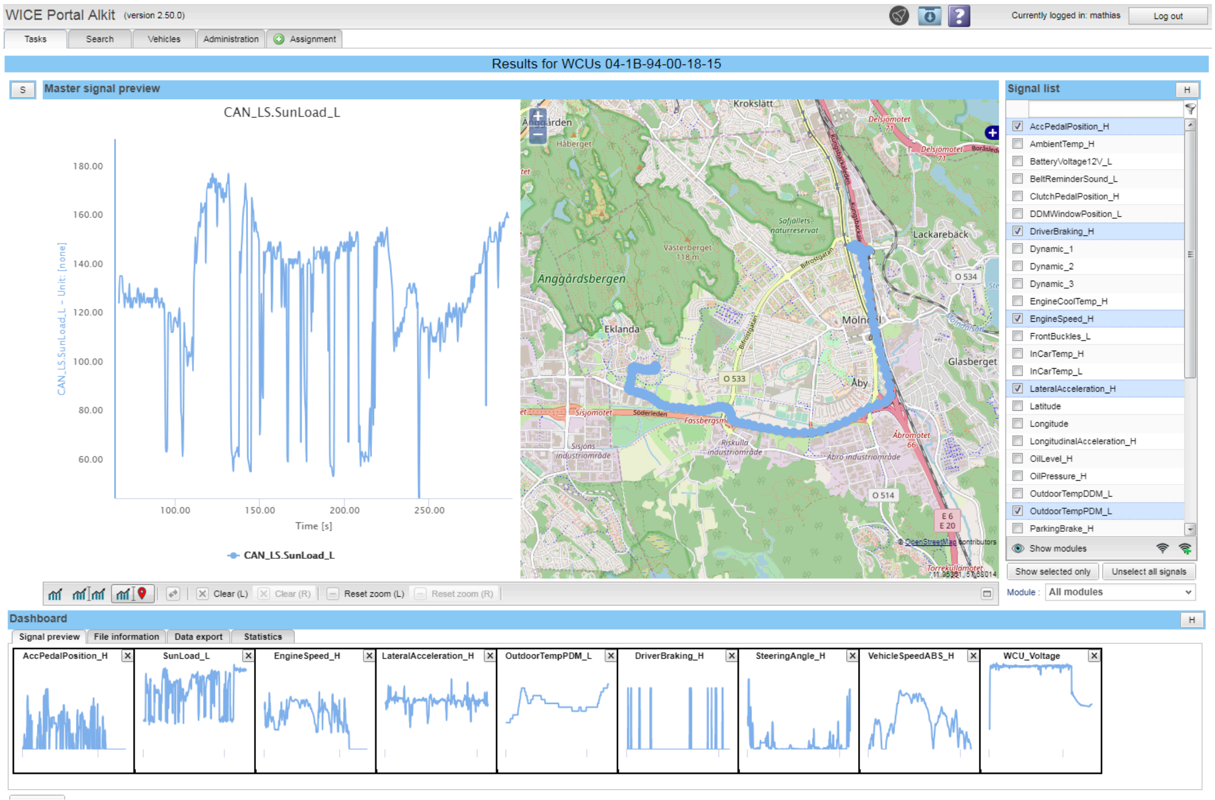

Figure 2: Example screen-shot of the web-based WICE user interface

The M2M API

In addition to the web-based user interface, there is an Application Programming Interface (API), called the M2M (Machine-to-Machine) API for programmatic access to the back-end services and collected data sets. The M2M API is based on the Representational State Transfer (REST) model, implemented using HTTP/HTTPs and JSON.

By using the M2M API it is possible to design automated data processing services for data analytics. It is also possible to realize structured data exchange between different stakeholders by means of the M2M API and the Access Control framework.

The M2M API can also be used to create measurement assignments and access the current state of ongoing data collection tasks.

Measurement data collection using WICE

The WICE Data Collection service is a general purpose service providing powerful data capture mechanisms for many different kinds of data in fleets of connected vehicles. The concept is based on a usage model wherein the data capture activities to be performed in a group of connected vehicles are described by Measurement Tasks, designed by the user in the web-based user interface (the WICE Portal).

Many different Tasks can be defined for capturing different kinds of data, e.g. CAN or FlexRay frames and signals, video, or diagnostics data. When the Measurement Task has been created, and the target vehicles have been defined, a representation of the Measurement Task is downloaded from the WICE back-end to the WCUs installed in the fleet of vehicles, where it executes. The data sets resulting from the Measurement Task are uploaded from the vehicles until the measurement task is terminated. The user can then access the data through the web-based interface of the WICE portal, or programmatically through the M2M REST API.

Each different Measurement Task is supported by a specific measurement Module. The measurement modules are realized as software components on the WCUs installed in the connected vehicle fleet. Some modules are dependent on dedicated hardware installed in vehicles and connected to the WCUs, whereas others are software-only modules on the WCU.

Key data collection modules include the following (see WICE documentation for a complete list):

- **Signal Reader**
  The Signal Reader module enables powerful monitoring and recording of CAN, LIN and FlexRay signals. It also supports UDS diagnostics capabilities, XCP and CCP data collection, advanced trigger conditions with pre-/post-trig recording options, and many additional features. Signal data can, in addition to being stored (in the MDF format) and uploaded, also be streamed in real time for live monitoring in the WICE Portal.
- **IDC - Integrated Diagnostics Client**
  The IDC module gives the opportunity to capture data using ISO14229 Unified Diagnostics Services (UDS) on CAN or Ethernet interfaces.
- **State-of-Health**
  The State-of-Health (SoH) module is used to repeatedly collect information about a vehicle's status and present this for the user in the WICE Portal. The kind of information collected is configurable and may include for instance mileage, battery voltage, uptime, ECU software versions, Diagnostic Trouble Codes and OBD-II PIDs. The State-of-Health data provides the basis for the WICE Fleet Management presentation in the WICE Portal.

- **Video**
  The video module enables capture of video from cameras connected to the WCU. Video recording can be triggered by conditions and events based on CAN/FlexRay signals or digital i/o.

- **Audio**
  The audio module enables capture of audio from microphones connected to the WCU. Audio recording can be triggered by conditions and events, similar to the Video module, and also by a configurable volume level, for voice-activated recording.

Data Visualization and Processing

The WICE system has built-in data interpretation and visualization for many types of collected data, including time series data in the MDF format, Diagnostics data, positioning data, audio and video. WCE also provides the opportunity for users to create custom dashboards or other visualizations of data collected by WICE through the Grafana framework. Grafana is an open source analytics and visualization tool, which can produce web-based plots, charts and graphs of WICE data, when connected to a WICE back-end. WICE provides a Grafana plug-in that makes it possible for authenticated WICE users to build Grafana based front-ends that are accessible from outside the WICE Portal. This is a powerful tool to create customer-specific analytics and customized visualizations of data.

Figure 3 shows an example of a Grafana visualization of WICE data.

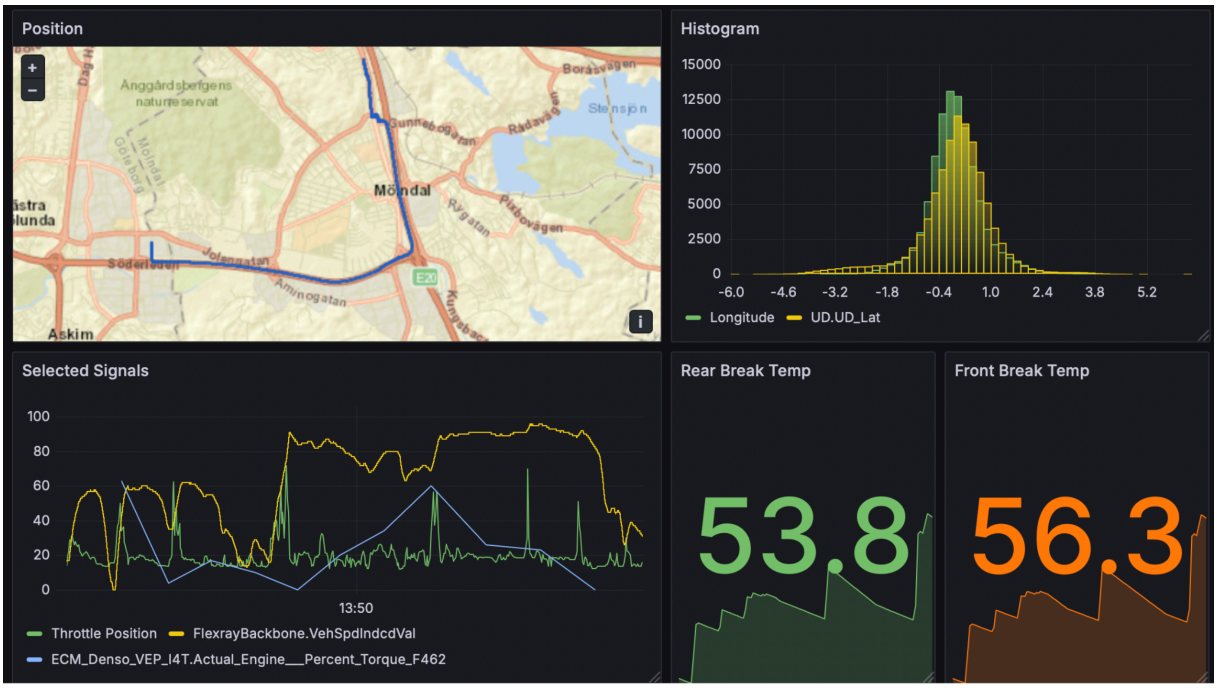

Figure 3: Grafana visualization example

Rapid Prototyping and Edge Computing

When developing new automotive functions and services, there is a need for a powerful platform where prototype implementations can be tested and concepts validated before necessary hardware is available in the target vehicle platform, and before the production cloud infrastructure software is deployed. This can be achieved by using the WICE Rapid Prototyping service, which enables custom software components to be executed on the in-vehicle WICE units (WCUs), supported by WICE back-end services with open interfaces for accessing and processing streaming and bulk data from the vehicles.

To facilitate rapid development of in-vehicle software, the WICE RP concept includes a high-level Signal Broker API that makes it easy to read in-vehicle signals using a publish-subscribe model. The Signal Broker, which is implemented by the Signal Reader module, takes care of the complexities of reading CAN, LIN and FlexRay frames and interpreting them.

The RP module furthermore supports the design of prototype user interfaces based on the Node.js JavaScript runtime environment. This allows automotive Digital User Experience testing to be realized in connected vehicle fleets.

The WICE RP module can also be used for general Edge Computing applications, where some sort of processing of captured data is desired to be performed in the vehicle, before the processed data or events generated by the data are uploaded to the back-end.

Remote Software Download and Continuous Deployment

Using the remote software download (SWDL) service available in WICE, in-vehicle ECUs of connected vehicles can be remotely re-programmed. This enables continuous deployment of ECU software and gives the opportunity to carry out A/B testing in connected vehicle fleets, whereby different ECU software versions are tested, evaluated and compared in a highly efficient and cost-effective way.

The SWDL service is based on a diagnostics module in the WCUs, which handles the re-programming using UDS diagnostics services using either CAN or Ethernet communication with the vehicle. The ECU software packages (including VBF files and meta information) are managed by the WICE back-end infrastructure, and downloaded to the selected WCUs before the re-programming is initiated by the vehicle user, by means of a special-purpose web-based user interface available over Wi-Fi in the vehicle.

WICE Multiplexing Units

A WICE Multiplexing Unit (WMU) is an in-vehicle unit connected to the WCU that performs frame (CAN, LIN) multiplexing and forwarding over ethernet. It runs the WICE Multiplexing Unit software and is configurable through the WICE Portal.

One or more WMUs can be installed in a vehicle in situations where the available CAN or LIN interfaces on the WCU is not enough. This way, up to 30 CAN buses and 10 LIN buses can be handled with one WCU (and 4 WMUs).

The WMUs do not communicate directly with the WICE back-end, but rather through the WCU which manages all communication with the back-end.

Access Control, Privacy and Cybersecurity

The WICE software, both the back-end services and the WCU software, are developed based on the principles of security-by-design. This means that security concerns are addressed already in the development phase of the software and not as an afterthought. This development principle is complemented by following established best practices and processes and recommendations formalized in cybersecurity standards such as ISO/SAE 21434 "Road vehicles - Cybersecurity engineering". A large number of cybersecurity mechanisms are implemented in WICE in response to different threats, including:

- **Access control and access rights**
  WICE includes a comprehensive access right framework which controls what authenticated users are allowed to do. Access control mechanisms are used throughout the system to verify that a certain user has the proper right to a certain resource or function.
- **Authentication**
  WICE authenticates users at log-in and provides authentication mechanisms for identifications purposes throughout the system (back-end and WCU).
- **Strong encryption**
  WICE relies on strong encryption for confidentiality, integrity and non-repudiation.
- **Firewalls and Network Address Translation (NAT)**
  Firewalls, including NAT, are used to prevent intrusions in the WICE operating environment, including both the WCU and the WICE back-end.
- **Secure software updates**
  WICE has mechanisms to ensure secure deployment of new software versions, both for back-end and WCU.
- **Secure communication channel between back-end and WCU**
  The means of communication between WCU and back-end is designed to ensure that only properly authorized endpoints are allowed to communicate and that the communication channel cannot be eavesdropped, corrupted or replayed.
- **Resilience against DoS attacks**
  The WICE system has been designed to provide resilience against Denial of Service (DoS) attacks.
- **Status and performance monitoring**
  The WICE system has status and performance monitoring mechanisms to ensure the proper execution of the WICE services and avoidance of cybersecurity threats.
- **Back-up of important data in the back-end**
  The WICE system supports back-up and disaster recovery mechanisms, protecting the key information storage resources, the WICE database and the WICE data lake, from ransomware attacks, data corruption attacks and similar.

Summary

The WICE system is a powerful and flexible data collection and fleet management system for connected vehicles. It has been designed to be secure, efficient and scalable to large volumes of data and many connected vehicles.

For more information about WICE contact Alkit Communications AB.

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