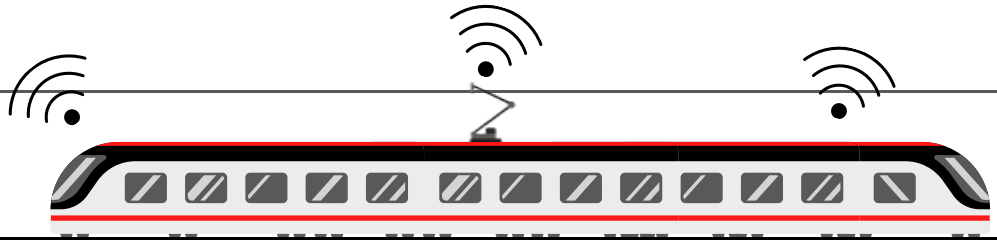
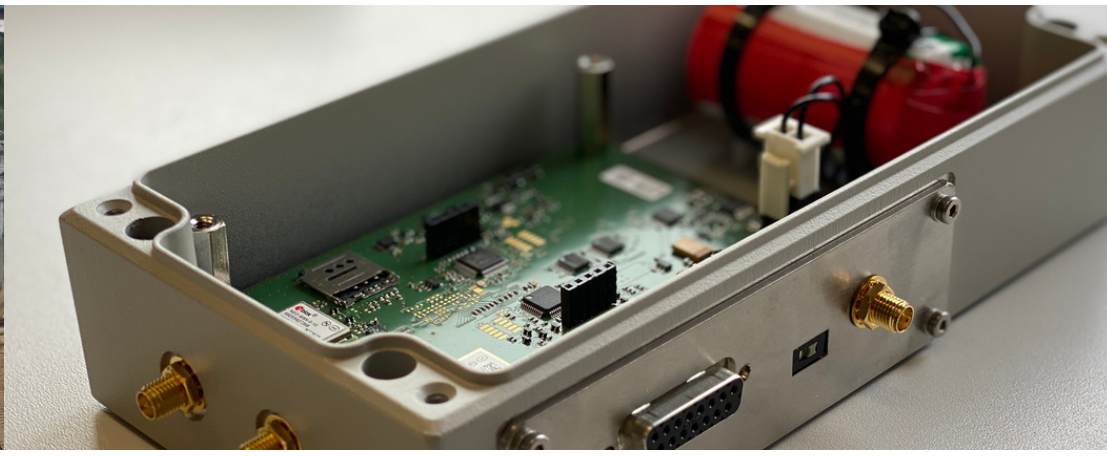


CASE STUDY

Smart sensors for frost protection

Predictive Maintenance - IoT on the tracks

DB EMBEVER



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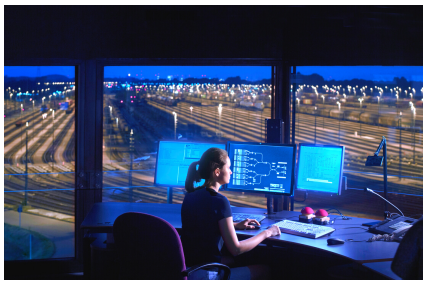
Introduction

After participating in the **DB mindbox 2019** startup cooperation program, Embever is currently working together with Deutsche Bahn to keep locomotives with smart sensors ready for operation in winter.

Class 101 locomotives pull IC trains across the country. To ensure that the vehicles are always ready for operation even at **low temperatures**, they remain under power in the winter months even when not in operation. As a protective mechanism against voltage variations, the locomotive can disarm itself, i.e. take the pantograph off the grid. If the starter battery is then subsequently discharged by the idle consumption of the stationary locomotive, it can happen that the locomotive cannot be started for its next operation: this would cause delays in train traffic.

This is where **Embever's smart IoT technology** comes into play. Wireless, battery-operated sensors continuously check the voltage of the starter battery and inform the responsible control centre directly in case of failures.




Pictures 1: Railway sector. Source: Deutsche Bahn Mediathek

Challenge

Locomotives of older series do not yet have a system that informs the control centres when a pantograph is no longer connected to the grid. If the battery is completely discharged, some of the **locomotive's systems** can literally **freeze**.

Since the locomotives are in service throughout Germany, a complex deployment management system is behind the guarantee of operational capability. The objective is to develop an **automated solution** in order to relieve the personnel of the operations control centers at certain points.

Heroes of the night

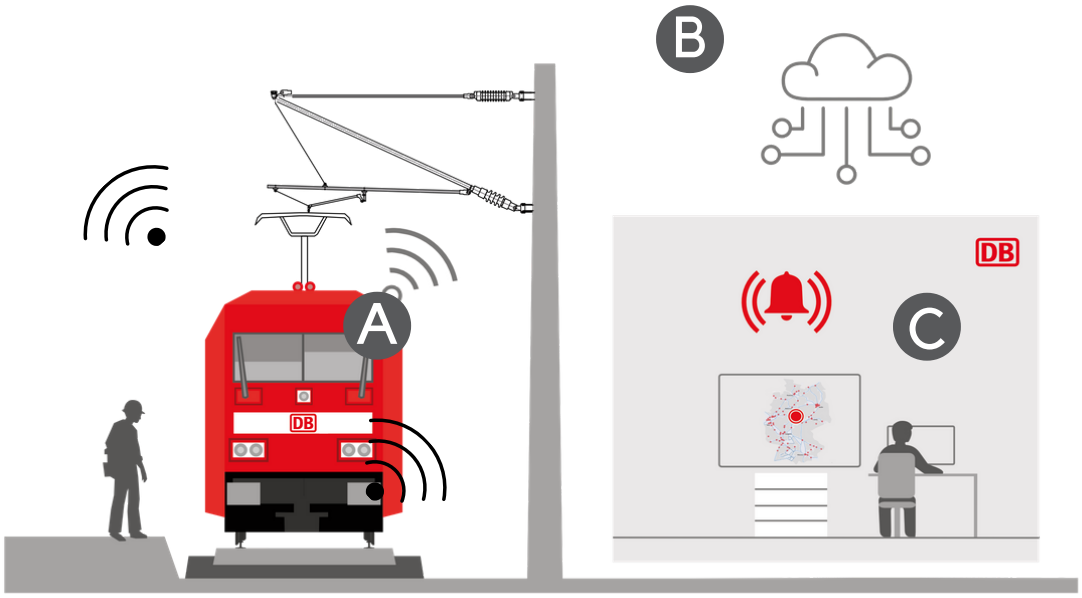
To prevent potential damage to the locomotive and reduce operational delays Deutsche Bahn monitors those locomotives with a workforce called **"Frostwache"**. This group of locomotive drivers and technicians check on-site every two to six hours whether the locomotives are still connected to the grid. The frequency of the inspection interval depends on the type of locomotive and the capacity of the battery installed.

Their activity ensures the vehicles' energy supply and **increases the punctuality of the trains**. The complexity and inconveniences of this preventive process (night shifts, overtime working hours) can be reduced with IoT technology.

IoT Solution

After a successful prototype phase, a **certified system** has been developed and installed in the first locomotive. A **battery-powered gateway** uses **wireless sensors** to determine whether the locomotive is connected to the power supply of the power grid.

This system consists of a complex interaction of **embedded firmware, protocols and a sophisticated cloud architecture** to ensure reliable communication between locomotives and control centres.



Picture 2: Visual Representation of the IoT-Retrofit Solution developed. Source: Deutsche Bahn

A NB-IoT-Gateway

The gateway transmits data from the rail vehicle to an IoT cloud application via mobile radio. The gateway is equipped with a **GPS function**.

Its highlight is that it can communicate with a variety of wireless and battery-powered sensors on vehicle operating equipment. This means that the network can be expanded to include any sensors.

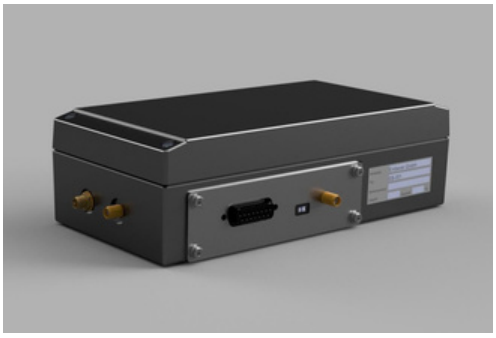
B Cloud

The gateway sends data directly to the cloud. Edge computing allows data to be pre-processed in the vehicles if required and then analysed remotely in the cloud.

C Data Dashboard

The information is available for the DB control centre. An **incident alert** is sent to the technician on duty. Information about the location of the locomotive is also displayed on this dashboard.

System components

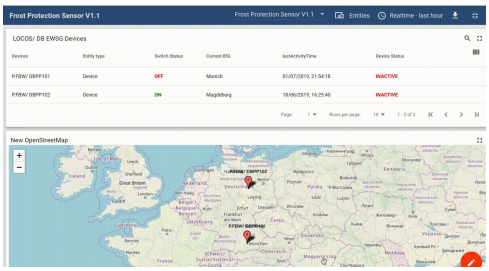


DigiMesh® – NB-1 Gateway

Technical details in Appendix A1 - A3

DigiMesh® Digital I/O Module - 2.4GHz

Technical details in Appendix A4 - A6



Data dashboard

Customer-tailored dashboard using website applications, with GPS location information

Get a quote

Contact us at info@embever.com

Certifications

The system is certified to comply with these norms:

- EN 50155 (Temperature level OT3: -25 until +70°C)
- EN 50121-3-2
- EN 45545-2 (Hazard Level 2)
- EBA EMV-06
- 2014/53/EU (RED)
- 2014/30/EU (EMV)
- 2011/65/EU (RoHS)

See Appendix for more certifications

Project Timeline

February 2019

Participation in DB-mindbox startup program

The 100 Days Accelerator Program from Deutsche Bahn starts and Embever works in the challenge related to the "Future of Maintenance". This is the beginning of the journey.

July 2019

Prototype development

After identifying the challenges and requirements of the DB in the matter of frost protection, a prototype is developed and tested.

January - August 2020

Product development

Learnings are made after testing the first prototype. Required improvements are implemented.

September 2020

Certification

All required tests and certifications for the railway industry are passed and our product becomes a certified product ready to be used in the market.

November 2020

First installation

The first IoT Device is installed in a locomotive in Hamburg. The objective is to retrofit the complete fleet of 145 101 type locomotives that operate in all Germany.

Further applications

Diesel, **electric** locomotives and other rail vehicles for **freight** and **passenger** traffic can be easily equipped with smart sensors that help to implement predictive maintenance and fault detection, even in older vehicles. With this system, data is collected, sent to the cloud and is thus securely available remotely anywhere. The **certified system** can be used in a wide range of applications.

Incident detection

- Autonomous equipment fault report
- Autonomous anomaly detection
  - e.g. equipment consumption increase
  - e.g. equipment is no longer in operation for a certain time period

Predictive Maintenance

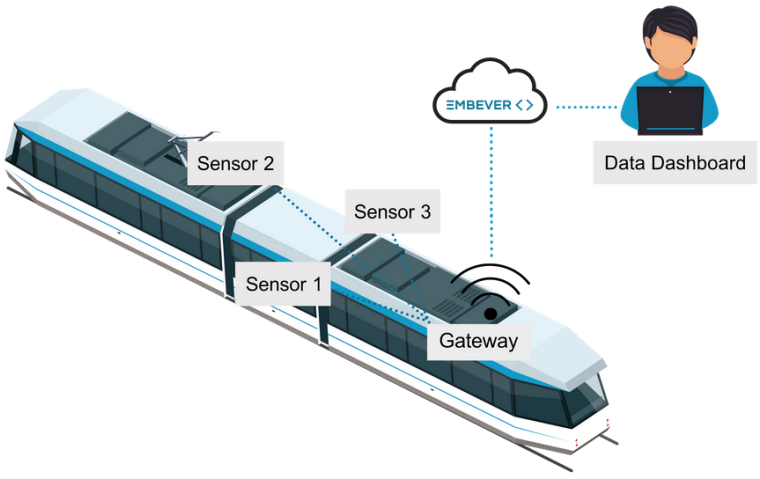
- Flexible maintenance and replacement intervals
- Maintenance/replacement based on use or operating hours
- Early detection and prevention of malfunctions

Data analysis from sensors

- Data processing in the cloud (Cloud Computing) as well as in devices (Edge Computing)

Other inputs or wireless sensors

- Active / Inactive
- Operating hours
- Power meter
- Oscillations / Vibration
- Levels
- Local temperature



Picture 3: IoT-Retrofit System. Source: Own creation

Become an IoT innovator

Would you also like to integrate a Railway Retrofit IoT-Solution into your products or services? Contact us! Our team provides support in the following areas:

- Project planning
- Installation planning
- Sensor module development
- Certification
- Technician training and support
- User training
- System provision and connection

Contact us → info@embever.com

About Embever

Embever is a spin-off of the University of Magdeburg and was founded in 2017. It has a team of experts in the fields of hardware, embedded and cloud systems and applications.

Appendix

Gateway

Identification

Name	DigiMesh® – NB-1 Gateway
Art-Nr. (DB)	EB-001

Product version

Hardware Revision	01
Software Revision	1.0
Datasheet Version	1.0

Application description / Properties

Description	Battery-powered mobile radio gateway (LTE Cat. NB-1, GSM Fallback) for connecting DigiMesh® - 2.4GHz devices

General information

Power supply	Battery, LSH 20 (LiSOCl2), 3.6V Nominal voltage
Protection class	IP20
Enclosure material	Aluminium
Mounting	Screw mounting
Weight	1,24 kg
Dimensions (WxHxD)	100x200x61 mm
Operating temperature range	-25° - 75° C
Storage temperature range	-25° - 85° C

Connections

1x SMA (Mobile Radio)
1x RP-SMA (GPS)
1x SMA (2.4GHz)
1x D-Sub 15-Polig

Gateway

Radio interfaces

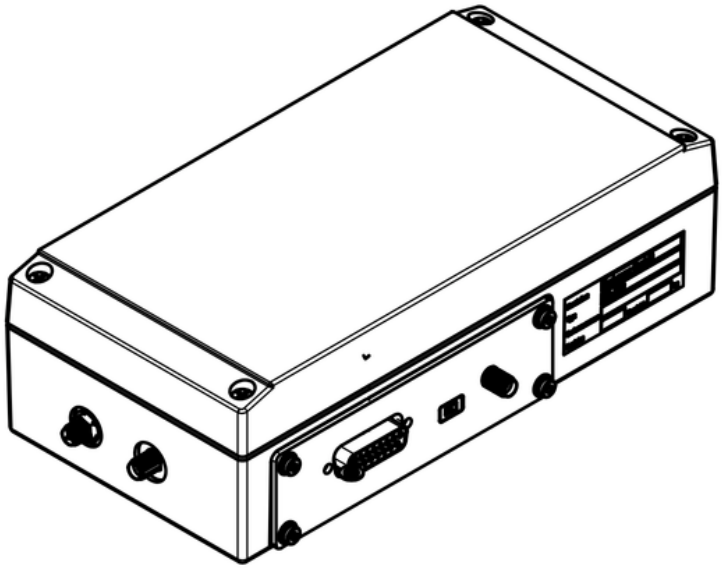
Mobile technologies	2G GPRS / EGPRS LTE-Cat-NB1 Half-Duplex
LTE FDD Bands	Band 8 (900 MHz)
2G Bands	GSM 850 MHz E-GSM 900 MHz
ZigBee / DigiMesh®	2.4GHz ISM Band
GNSS	72-channel GPS L1C/A, SBAS L1C/A, QZSS L1C/A, QZSS L1 SAIF, GLONASS L1OF, BeiDou B1I, Galileo E1B/C

Certifications and norms

EN 62311:2008
EN 62368-1:2014
EN 301 489-1 V2.2.3
EN 301 489-17 V3.2.4
EN 301 489-19 V2.2.0
EN 301 489-1 V2.2.0 (Draft)
EN 301 489-52 V1.1.0 (Draft)
ETSI EN 301 908-1 V13.1.1
ETSI EN 300 328 V2.2.2. (2019-07)
EN 303 413 V1.1.1
EN 301 511 V12.5.1
EN 50155:2017
EN 50121-3-2:2016
EN 6100-6-4: 20177+A1:2011
EN 50155121-3-2:2016
EN 55016-2-3
EN 6100-4-3
DIN EN 61373:2011
EBA EMV 06
DIN EN 45545-2:2016

Gateway

Dimensional drawing



I/O Module

Identification

Name	DigiMesh® Digital I/O Module - 2.4GHz
Art-Nr. (DB) (only for DB)	EB-002

Product version

Hardware Revision	01
Software Revision	300B
Datasheet Version	1.0

Application description / Properties

Description	Battery-powered module for DIN rail mounting with two digital inputs. The value of the input is transmitted via DigiMesh® in a local mesh network. The module supports synchronous and asynchronous sleep modes in mesh networks. Sleep times and modes are configurable.

Input

Digital Input	D1,D2 Voltage-less Not short circuit proof
Threshold Digital Low	0.3xVCC
Threshold Digital High	0.7xVCC
Internal pull-down resistor	1 MΩ (typical)

Output

VCC	2x
GND	2x
DigiMesh®	Digital input transmission via DigiMesh protocol, customisable firmware

I/O Module

Other interfaces

UART	RXD, TXD, !CTS, !DTR
Reset	!RST

General information

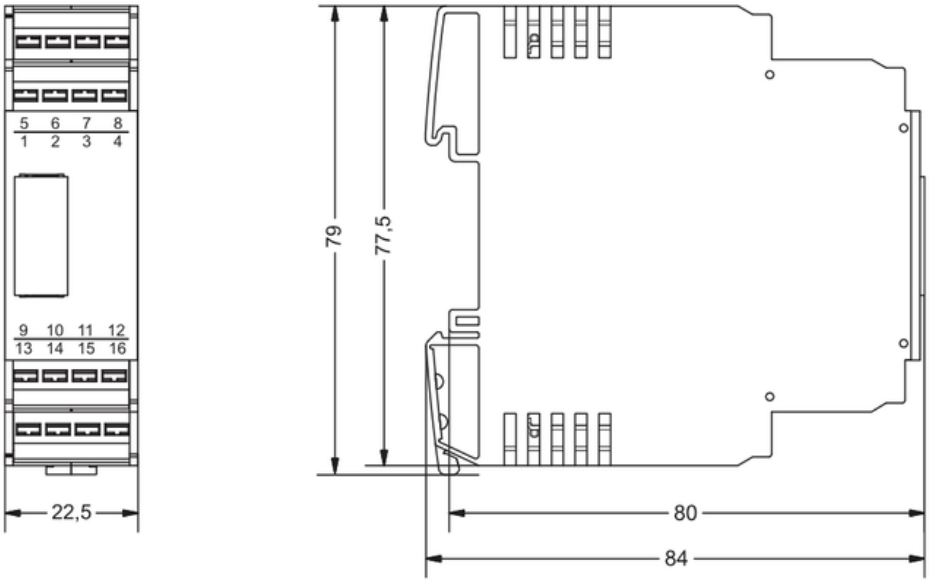
Radio	ISM 2.4-2.4835 GHz, DigiMesh®
Power supply	CR2477N, 3 V, replaceable
Status display LED	Red - activity Green - picking
Connection type	Push-In solid 0.20 - 2.5 mm2 AWG 20 - AWG 14 finely stranded 0.20 - 2.5 mm2 AWG 20 - AWG 12 Stripping length: 8 mm Screwdriver: 3.5 × 0.6 mm
Protection class	IP20
Housing material	PC-ABS
Mounting	can be snapped onto top-hat rail TS35 (EN 60715)
Weight	0.07 kg
Dimensions (WxHxD)	22.5 × 79.0 × 84.0 mm
Operating temperature range	-25° - 85° C
Storage temperature range	-25° - 85° C

Certifications and norms

EN 62311:2008
EN 62368-1:2014
EN 301 489-1 V2.2.3
EN 301 489-17 V3.2.4
ETSI EN 300 328 V2.2.2. (2019-07)
EN 50155:2017
EN 50121-3-2:2016
EN 6100-6-4: 20177+A1:2011
EN 50155121-3-2:2016
EN 55016-2-3
EN 6100-4-3
DIN EN 61373:2011
EBA EMV 06
DIN EN 45545-2:2016

I/O Module

Dimensional drawing



Connection diagram