WHITE PAPER

LoRaWAN™ CONNECTIVITY

HOW LoRaWAN™ WIRELESS CONNECTIVITY BENEFITS THE TRANSPORTATION INDUSTRY

LoRa Alliance Member™

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HOW LoRaWAN™ WIRELESS CONNECTIVITY BENEFITS THE TRANSPORTATION INDUSTRY

Improving passenger experience and satisfaction is obviously a main focus for train operators: the promise of the Internet of Things inside trains is to reduce delays and out-of-service time by turning reactive maintenance into a predictive mode.

Freight transport can as well benefit from IoT technologies, checking appropriate conditions during the ride, location of carriage, cost and time reduction of operations, thanks to comprehensive fleet supervision.

CONTENT

THE PROMISE OF IOT IN TRANSPORTATION

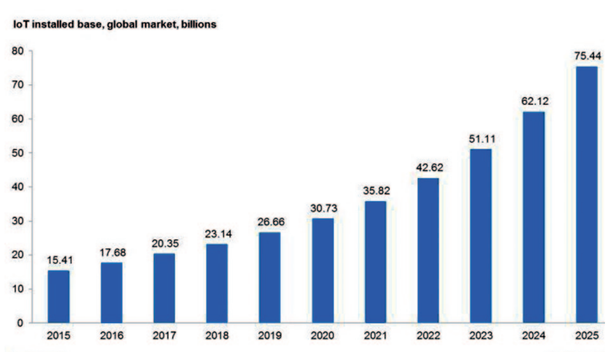
The digital revolution has changed the way we use and implement connected systems and devices on public or commercial transportation. The growth of information technology along with the Internet of Things (IoT) has significantly multiplied the opportunity for new potential services. It is now possible to seamlessly connect devices, related gateways/servers and passengers even when travelling. All market studies addressing IoT foresee a dramatic growth both for passengers and professional applications, thanks to the huge amount of data gathered on-line on these connected systems. Using data analytics in real time helps to solve complex logistic services in the field of asset management, preventive maintenance, passenger information, passenger experience, security improvement, energy saving, finally improving travel security and reliability.

> THE USE OF IOT IS EMERGING IN TRANSPORTATION WITH THE PROMISE TO DELIVER MORE VALUE, IN THE FIELD OF ASSET MANAGEMENT, PREVENTIVE MAINTENANCE, PASSENGER INFORMATION & PASSENGER SATISFACTION, FREIGHT MANAGEMENT, AND SECURITY

GENERAL CONTEXT OF IOT TODAY

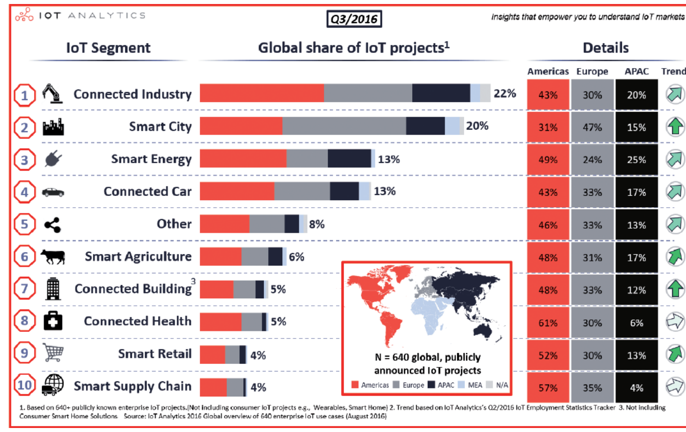
IoT Global Market

IHS market study indicates that the number of IoT devices installed today is about 20 billion and will reach 75 billion by 2025.



Global Share of IoT Projects

According to the IoT segment ranking reported by IoT Analytics, in Q3/2016, transportation projects are lagging behind and are not listed in the top 10 ranking segments, except for connected car applications.
The exceptional 4th ranking held by the car industry can be explained, as opposed to other public transportation segments like train, tram, bus, ships, by quick adoptions of new technologies used as a commercial differentiator for eager adopters of new media technologies.



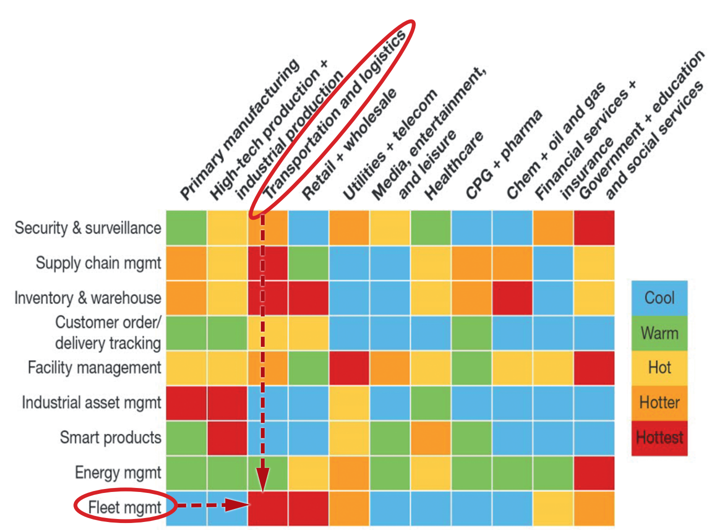
Source: https://iot-analytics.com

Transportation Share of IoT Projects

Looking at the hottest IoT applications reported by Forrester, one can notice that Fleet Management for the Transportation and Logistics area is pointed out and identified as "hottest".

The numerous projects emerging in transportation confirm the adoption of IoT technology. Nevertheless, IoT solutions have been mostly designed so far for other application segments with different constraints.

Products developed for Connected Industries, Smart Cities, Smart Energy or any other top ten applications segments are not 100% aligned with the transportation needs: transportation is a demanding industry which requires certifications, extended temperature range support, availability and serviceability for the long term often exceeding 20 years.



Source: https://www.forrester.com

Last but not least, the connection to the Cloud or the Internet is not guaranteed in mobility. This raises specific exploitation constraints regarding data analytics.

THE MARKET IS THERE BUT THE STANDARD IOT OFFER NEEDS TO BE BETTER ALIGNED WITH THE TRANSPORTATION INDUSTRY WHICH REQUIRES CERTIFIED PRODUCTS WITH RUGGED HARDWARE FOR A HARSH AND DEMANDING ENVIRONMENT (SHOCK, VIBRATION, TEMPERATURE, LIFESPAN, CERTIFICATIONS …).

MOVING FORWARD WITH IOT IN PUBLIC TRANSPORTATION

The world is all about being connected, other application segments have already moved forward taking advantage of these new connectivity trends. Transportation is now ready to adopt the same trend.

The "Connected Train" services, offering Internet to travelers or tailoring on-board digital services are not new. This type of connectivity is already adopted by the operators and driven by the fact that travellers expect the same level of Internet service they can enjoy at home. Train operators generate new revenue streams from this demand. Digital data is already being processed to inform and entertain passengers, drive trains, control traffic and communicate with stations.

Nowadays a "Connected Train" is not only targeting passenger device connections but also sensor devices. More and more devices are generating vast amounts of data which transportation operators monitor and control to improve the performance of their services. This stage from passenger to connected objects is already happening in modern trains with sensors often directly cabled to the Ethernet Train Backbone. But what about aging trains which represent the biggest part of the existing rolling stock? What about freight carriages which are seldom connected, do not have a local power source and are generally old?

This under-exploited application field based on new "smart" connected objects can reduced maintenance cost. Maintenance business model for freight carriages or infrastructure can evolve from being reactive to preventive. A preventive maintenance strategy optimizes both the cost of maintenance and the availability; it has also a direct positive impact on passenger experience and satisfaction. Passengers can better be informed, their feedback taken into account, and vehicles can operate more efficiently with accurate schedules.

IN TRANSPORTATION, THERE ARE MULTIPLE NEW POSSIBILITIES WITH IOT APPLICATIONS WHERE "SMART" CONNECTIVITY COMBINED WITH EDGE COMPUTING AND CLOUD-BASED SERVICES CAN GENERATE NEW REVENUE STREAMS.

LPWAN FOR TRANSPORTATION

LPWAN (Low-Power Wide-Area Network) is a type of wireless telecommunication that allows long range communications at a low rate with connected devices, such as sensors operated on a battery. The LoRaWAN™ protocol is one such type of LPWAN relying on the LoRaWAN radio physical layer.

LPWAN technology is perfectly suited for connecting devices (sensors) that need to send small amounts of data over a long range, while requesting very little power consumption, e.g. allowing very long battery life-time. Some IoT sensors only need to transmit tiny amounts of information; some of them will only transmit in case of anomalies (i.e. temperature, humidity or fluid leak…). The low power consumption of such devices allows that task to be carried out with minimal cost and battery draw.

The figure below presents the main characteristics of LPWANs for IoT.

LPWAN Features		
Long Range	Low Data Rate	Low Power Consumption
End-nodes can be up to 10 kilometers from the gateway.	Less than 5 Kbits/s, generally only few bytes (20-256) per messages are sent only several times a day.	Long Battery Life, often five to ten years, possible.

A LPWAN may be used to create a private wireless sensor network to cover high speed or commuter trains, freight trains, tram, buses or simply a depot of several thousand square meters.

Challenges using a LPWAN in transportation

Transportation covers infrastructure (stations, depots) and rolling stock crossing areas that are often not covered by a LPWAN infrastructure, especially in the countryside far away from Smart Cities or Industrial areas where an LPWAN IoT network can be accessible.

LPWAN connectivity when vehicles are moving is probably one of the biggest challenges. A LPWAN communication has been optimized for long distance, with a long time in the air, between end-nodes and gateways. A sensor installed inside a vehicle can easily communicate with a gateway when it stands in a train station under LPWAN coverage. But it will be quickly impossible to decode the sensor data when the vehicle is moving beyond 10 to 20km/h). The gateway is no longer able to decode the received messages, with a risk of sensor data loss.

In principle, sensors using an LPWAN should live for 10 years or more simply on a tiny battery. The communications are mostly unidirectional from sensors to Gateway at the initiative of the sensors. The energy consumed by the sensors is hence maintained at very low level with a reliable LPWAN communication. Downlink communication to the sensor is yet possible.

LPWAN COMMUNICATION CAN ALSO OPERATE DIRECTLY INSIDE MOVING VEHICLES WITH AN ON-BOARD GATEWAY

WHY ADOPT LoRaWAN™ TECHNOLOGY?

There are several available LPWAN technologies like Sigfox, Narrow-Band (NB) IoT or LTE-M which are all intended to connect low cost, low power, and low bandwidth devices. However LoRaWAN has some differentiators for a railway application due to open standardization with unlicensed frequencies, low power, low cost, and high communication range.

Comparing LPWAN Technologies

Technology	Frequency	Data Rate	Range	Power	Cost
LoRaWAN	915 MHz	< 5 kb/s	15 km	Low	Low
LTE-M	Cellular Bands	1 Mb/s	Several km	Medium	High
NB-IoT	Cellular Bands	250 kb/s	Several km	Low	Medium
SigFox	< 1 GHz	100-1000 b/s	Several km	Low	Medium

What is the LoRaWAN™ standard and what are its key benefits?

- LoRaWAN protocol is a Low-Power Wide-Area Network (LPWAN), for connected devices allowing long range communications at a low bit rate. This is built on top of the LoRa® radio physical layer which is especially designed for low-power sensors operated with a battery, e.g. long life-time due to a very low consumption of devices. LoRaWAN devices are therefore very easy to install since they do not require direct wiring for power or connectivity, and the cost of installation is low.
- The LoRaWAN protocol is not the unique LPWAN wireless technology, but it is the only one supported by an open industry alliance, the LoRa Alliance™, adopted by 500+ industrial members.
- LoRaWAN technology is perfectly suited for connecting devices and sensors that send data over a long range, up to 15 km, while maintaining long battery life (for example: localization/GPS, temperature or shock detector, passenger counting, presence detection, failure detection, etc.)
- LoRaWAN networking topology can accommodate private wireless networks sub-systems of interconnected devices such as in stations, in industrial premises indoor or outdoor, as well as in high speed or commuter trains, freight trains, tram, buses or cargos.

The LoRaWAN wireless connected topology relies on a LoRaWAN based-gateway converting LoRaWAN messages into UDP and TCP frames to feed a LoRaWAN-based server, and finally application servers in the cloud, where all data analytics are supported as a service or by application. This generally goes along with a TelCo provider, also offering IoT-related services. This type of topology is accurate for classical industries and consumer/home/office applications. However, when it comes to mobile or rugged/outdoor environments, such as high speed trains, freight trains, and outdoor industrial areas, it is not possible to rely on a permanent cloud connection, as the Internet access (through 3G/4G, Wi-Fi or fixed networks) is not always available. It is then necessary to handle a private local network with local edge analytics in order to monitor all the connected devices in real-time.

Another concern involves data privacy: even if encrypted or protected, some users refuse to send their data to the Cloud.

Examples of such situations in transportation include:

- Asset management for fleets of vehicles, trains, containers, cargos, etc.
- Monitoring of large operation sites (outdoor) in harsh environment
- Application requiring local On Premise Network and Edge Analytics

The LoRaWAN network topology and platform must then provide a simple private network capability and the MQTT messaging protocol over TCP/IP helps dispatch the messages to users having subscribed to their respective topics.

The LoRaWAN™ STANDARD IS THE PERFECT WIRELESS TECHNOLOGY TO CONNECT OBJECTS FOR ASSET MANAGEMENT IN MOBILITIES SUCH AS TRAINS, TRAMS, CARGOS, BUSES AS WELL AS STATIONS, DEPOTS OR ANY PREMISES

CYBER SECURITY ASPECTS

The following cryptographic technics are used in a LoRaWAN network, providing high level of confidentiality and integrity to the data exchanged with the devices.

The payload of LoRaWAN wireless messages are encrypted with AES128 encryption at the device, and stay encrypted up to the application or analytics server, thus ensuring end-to- end robust protection for the application data. Another key, the network key, is used to protect the access of a device to a particular network. Those keys are essentially static for devices connecting in APB mode (Activation By Personalisation), while they are renewed as session keys at each pairing if OTAA (Over The Air Activation) is used.

After the gateway, when the messages are leaving the gateway to a data broker or an application server, eventually in the Cloud, then traditional IT security applies, such as TLS connections. TLS connections authenticate the parties intending to communicate with asymmetric cryptography (RSA, ECC …) and certificates, before sharing AES session keys used to encrypt the link.

PASSENGER TRAINS USE CASE

The first use case is for an Electric Multiple Unit high-speed train that transports several hundreds of passengers, eighteen hours per day, over long distances across countries. Passenger experience is sensitive to premium on-board services, hence the train operator's strategy has evolved from a traditional periodic maintenance to a predictive maintenance strategy based on LoRaWAN connected sensors and on-board LoRaWAN-based MQTT gateway.

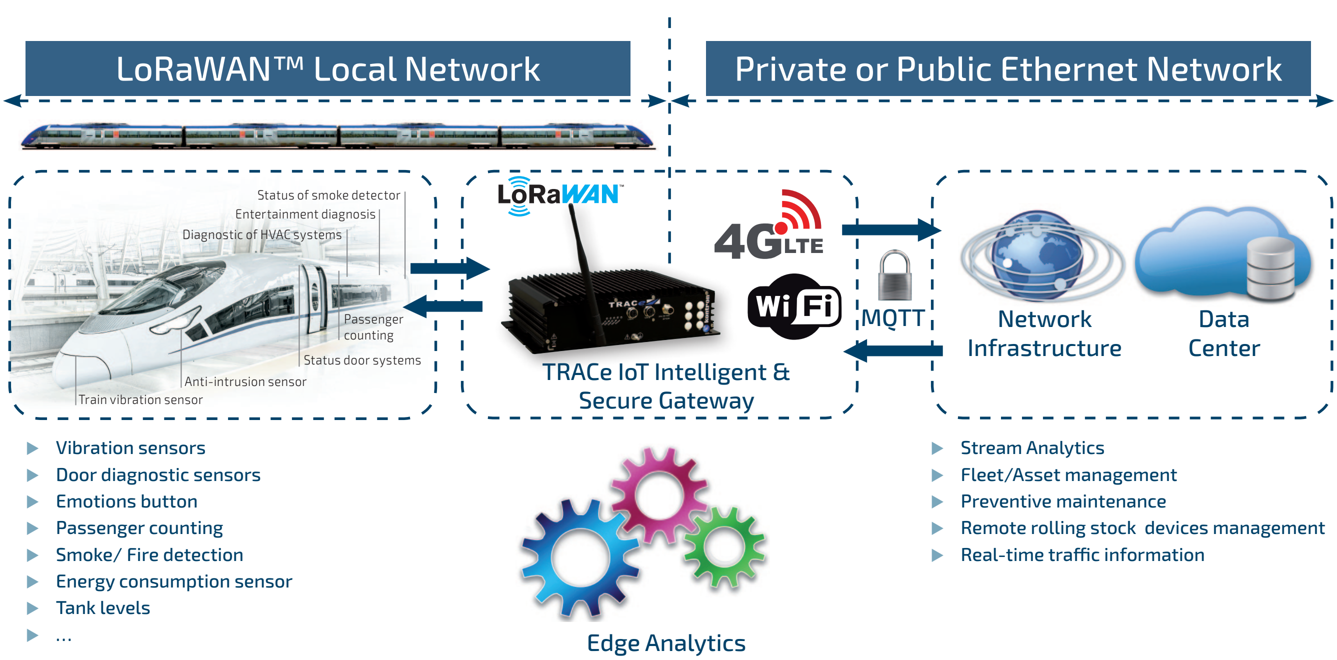
The train operator has accumulated millions hours of operation. Who else knows best the strengths and weaknesses of his fleet and sub-systems? He knows, even better than the original train builder the symptom of a failure, he can anticipate the replacement of an air conditioning unit, define which sandbox needs to be refilled or which water tank is nearly empty.

In addition to preventing failures and potential delays on train schedule, operators can drastically reduce the down-time of a train; they can prepare a quick fix in the next station or decide to refill some tanks. They can also use the LoRaWAN wireless network to accommodate passenger sensors to collect feedback on the service quality or the toilets cleanliness.

The on-board LoRaWAN-based MQTT gateway enables a reliable LoRaWAN wireless network that is moving with the train and will not suffer from coverage issues as opposed to a typical train-to-ground communication, even when the train is travelling at high speed.

In this use case, a Kontron TRACe LoRa-MQTT gateway is installed in an appropriate area in the second car with an internal whip antenna directly mounted on the gateway. Among the LoRaWAN end devices installed in each carriage, air conditioning sensors are installed below the chassis. For example, a train with ten carriages and one LoRaWAN communication works perfectly even in the last carriage, located at more than a hundred meters from the gateway.

More than acting as a LoRaWAN concentrator, the gateway is converting LoRaWAN messages to MQTT streams which are sent to a data broker in the cloud using the 2G/3G/4G/LTE connectivity. The TRACe LoRa-MQTT can react immediately thanks to its Edge Analytics capabilities and report alarms online to the driver or the crew without any Cloud connection.



FREIGHT TRANSPORT APPLICATION

Freight transport is another interesting use case with the objectives to improve the efficiency of transporting goods.

Localization of the goods and carriages is critical yet not easy to collect since the wagons are not permanently coupled nor powered. Goods carried by a wagon can be "on the move", pulled by a locomotive or somewhere in a depot station waiting for coupling to a freight train.

The carriage conditions like temperature, humidity but also vibration, tilting are very important. By nature, a freight carriage has no local energy and can be connected to any other carriages. Locomotives with their local energy can accommodate the Kontron TRACe LoRa- MQTT Gateway while wagons host autonomous LoRaWAN sensors.

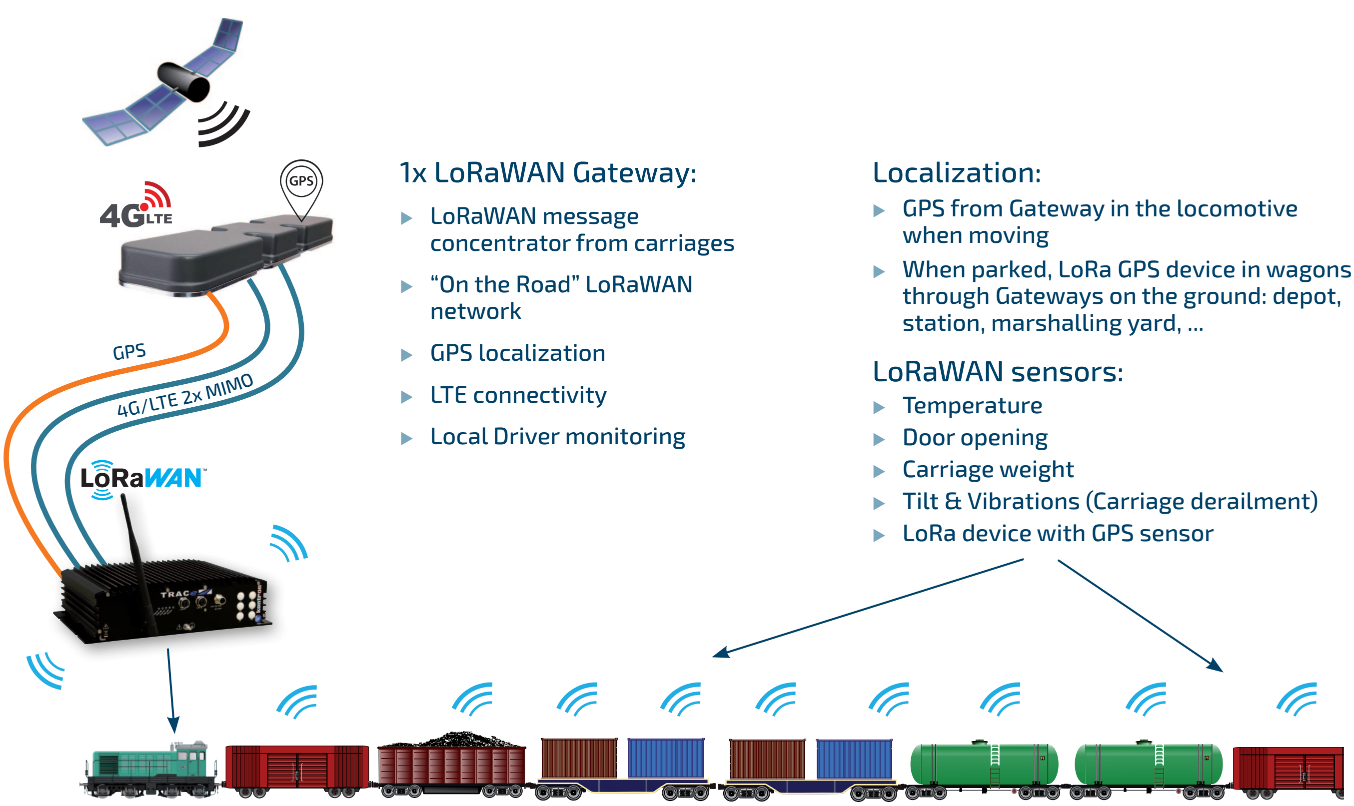
The locomotive acts here as a private LoRaWAN network concentrator to aggregate sensors data coming from the coupled carriages. The GPS module, embedded in the gateway, provides a precise locomotive geo-localization, and the 2G/3G/4G/LTE radio enables the transmission of all sensor data and positions in real-time. When the GSM connexion is not available, the gateway buffers the data appropriately and can handle locally the most urgent processing, like alarms for the driver. Thanks to its multiple SIM support, the locomotive can cross different countries and communicate using different mobile operators.

While pulled by a locomotive, sensors in wagons can provide critical data like temperature, humidity, shock and vibrations but also door opening, intrusion, location of carriage or containers, etc. Even the weight of the freight can be monitored and significant changes will be detected.

Tilting or derailment (vibration) can be reported immediately to the driver for emergency actions thanks to the edge computing capability of the Kontron TRACe LoRa-MQTT.

While still, in a depot, the same wagon sensors can communicate with a ground based TRACe LoRa-MQTT gateway or any existing LoRaWAN network infrastructure, providing the same information including the GPS position.

Freight wagons and carriage conditions can be tracked whether they are moving on the tracks or still in a depot. In marshalling yards, confirmation that the wagon is on the right track targeting the expected destination is reported through a LoRaWAN GPS device.



KONTRON MOBILE LoRaWAN™ CONNECTED DEVICE PLATFORM

Kontron, a leader in embedded computing, has extended its gateway product portfolio and is the first to deliver a rolling stock secure, all-in-one, LoRa-MQTT gateway.

The recently introduced TRACe™ LoRa-MQTT allows a secure and reliable data transmission with connected LoRaWAN devices. Already operational on high-speed trains and freight transport, the TRACe LoRa-MQTT utilizes a quad core processor and 2 Gbytes of main memory to power the LoRaWAN gateway, and the edge analytics part when necessary. This new Gateway platform complements the existing Kontron TRACe portfolio of railway certified computers.

By supporting continuous communications from LoRaWAN devices to a cloud or on premise server, this IoT gateway enables highly-secure data collection and remote analysis. This approach gives operators the essential security from a private local LoRaWAN network infrastructure that is exclusively reserved for intra-vehicle communication. Security is iron-clad as the LoRa-MQTT Gateway supports advanced security features, both at software and hardware levels. Associated server communications are also secured by TLS connections that use authentication on both sides.

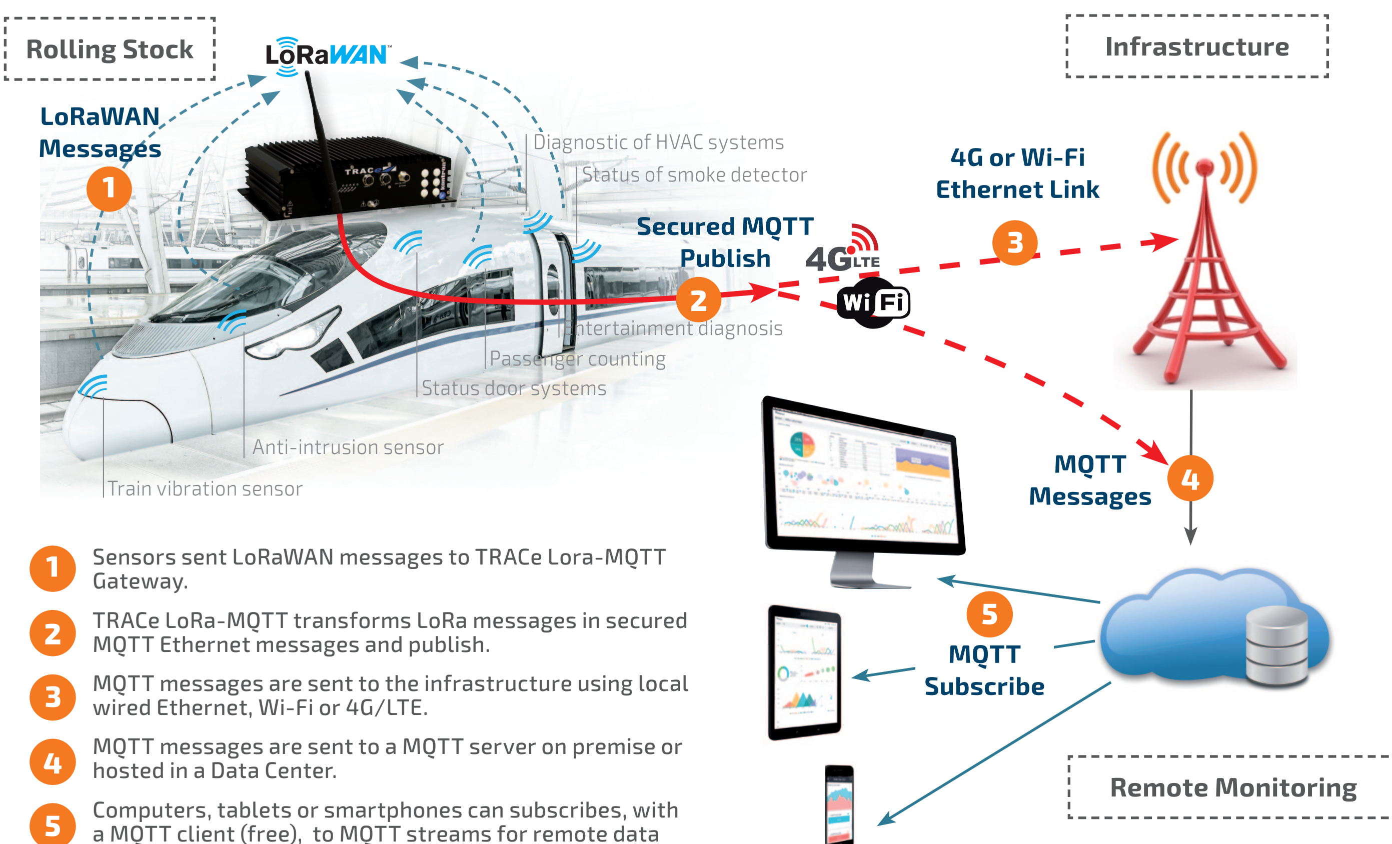
TRACe™ is a field proven product line compliant with EN50155 railway certification standards, designed to sustain a wide range of temperatures (-40 up to 70°C), it offers Ethernet connectivity with two gigabit Ethernet (GbE) ports using rugged M12 connectors.

TRACe LoRa-MQTT can be directly installed on the train to create a private local LoRaWAN network infrastructure reserved for intra-vehicle communication, with no message loss. It has been demonstrated that a single gateway at one end is enough to cover connected devices inside a whole double length high speed train, without using external antennas. This private network infrastructure interconnects all mobile LoRaWAN sensors and supports edge analytics and connection to the Cloud (private or public).

Thanks to its rugged design, the Kontron TRACe LoRa-MQTT is also being used in unprotected locations such as smart-cities, smart-harbor, agriculture, and generally speaking in all outdoor environments with weak connectivity to the Cloud, thanks to its edge-analytics capabilities and instant possibility to create a private LPWAN network.

LoRaWAN™ COMMUNICATIONS IN MOBILE OR OUTDOOR APPLICATIONS REQUIRE AN ALL IN ONE GATEWAY FEATURING ROBUST ENVIRONMENT SUPPORT AND PROVEN SECURITY, SUCH AS KONTRON TRACE LORA-MQTT GATEWAY.

Typical block diagram for a passenger train:



1. Sensors sent LoRaWAN messages to TRACe Lora-MQTT Gateway.
2. TRACe LoRa-MQTT transforms LoRa messages in secured MQTT Ethernet messages and publish.
3. MQTT messages are sent to the infrastructure using local wired Ethernet, Wi-Fi or 4G/LTE.
4. MQTT messages are sent to a MQTT server on premise or hosted in a Data Center.
5. Computers, tablets or smartphones can subscribes, with a MQTT client (free), to MQTT streams for remote data monitoring and analysis.

SUMMARY AND CONCLUSION

The LoRaWAN standard is a major wireless technology to manage large clusters of connect devices. The beauty of LoRaWAN protocol allows the genesis of low power devices, with long life time, running a robust protocol, based on a fully open protocol, license-free. LoRaWAN devices are connected to the Cloud via gateways. Most of these gateways are designed for home-office or classical industrial environments.

For Transportation where mobility and outdoor conditions are common, and with no connection to Internet nor the Cloud, the new gateway offered by Kontron brings an innovative answer, certified in transportation, with real time and faster performances thanks to its edge analytics capabilities. On premise and embedded computing is made possible for large fleet of vehicles like trains, buses, metro, trucks, and lower dramatically the cost of asset, fleet and freight management.

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About Kontron – An S&T Company

Kontron is a global leader in IoT/embedded computing technology (ECT). As a part of technology group S&T, Kontron off ers a combined portfolio of secure hardware, middleware and services for Internet of Things (IoT) and Industry 4.0 applications. With its standard products and tailor-made solutions based on highly reliable state-of-the-art embedded technologies, Kontron provides secure and innovative applications for a variety of industries. As a result, customers benefi t from accelerated time-to-market, reduced total cost of ownership, product longevity and the best fully integrated applications overall.

For more information, please visit: **www.kontron.com**

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