Deliverable D4.7

Harmonised interface to transmit on-board monitoring data to the traffic control centre

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Executive Summary

The deliverable D4.7 makes a presentation of activities and technical solutions adopted for the development of one specialized interfacing system. This interface is focused on transmitting data acquisitioned by the ABA and SATLOC systems, from the on-board train vehicle to the centralized software application, running on the Control Center.

The development solution necessity resides in the fact the train acceleration sensors, from on-board vehicle, mainly for the ABA measurement system but also the information collected by the SATLOC system, provide a very large volume of data in a short time.

These data, in the present situation, are retained in the train until the end of the measurement trip. In this way, large delays occur in the processing stage and obtaining the results.

In the first part of the report are presented, at the level of functional and technical characteristics, the two existing systems, which will be improved by the development made in the NeTIRail-INFRA Project.

Information related to the both existing systems involved (ABA and SATLOC) and to the new communication system developed are very extensive but documentation presented is focused on the technical interest segment, needed for development in the project.

Both, ABA and SATLOC, are the primary sources of information that will provide inputs to the new communication system.

In the next chapter are presented solutions for developing the interfacing and communication system.

The new communication system mainly aims to add a new functionality to the ABA system, which in the current formula involves acquiring data, for a monitored line, and obtaining the processed results after a long processing period.

With the built-in interface and transmission system, the acquired data will be transmitted in real-time to the control center application and this is a great advantage.

Even if the complete data processing requires a long analysis time, extreme values, which go beyond a certain threshold of interest, can be quickly obtained by applying filtering program modules. In this way, it is possible to obtain timely information about railway sections which could endanger the transportation on the railway line and require immediate maintenance intervention.

And, overall, the transmission of data, would be much faster than in the previous version, and allows for data processing to begin even during the measurement travel and thus to obtain results much faster.

The real-time monitoring of safe condition increases not only the safety and operation availability, but enables the optimization of overall transport quality and better satisfaction of business objectives.

It is considered that the solution developed accomplish the NeTIRail-INFRA stated requirements, but with one deviation which is described in detail in the Conclusions Chapter, where the Grant Agreement stated that the communication would be via the SATLOC system, however, due to restrictions in SATLOC system it would be have been problematic to use that system for communication, so an alternative communication solution has been developed.
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## Abbreviations and acronyms

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<thead>
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<th>Abbreviation / Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSV</td>
<td>Comma-separated values</td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobile Communications</td>
</tr>
<tr>
<td>IoT</td>
<td>Internet of Think</td>
</tr>
<tr>
<td>LAN</td>
<td>Local Area Network</td>
</tr>
<tr>
<td>LTE</td>
<td>Long Term Evolution is a wireless broadband technology for communication of high speed data for mobile phones</td>
</tr>
<tr>
<td>RCCF</td>
<td>S.C. RC-CF TRANS S.R.L.</td>
</tr>
<tr>
<td>Signal R</td>
<td>SignalR is a software library that simplifies the process of adding real-time web functionality to applications</td>
</tr>
<tr>
<td>TU Delft</td>
<td>Technical University of Delft</td>
</tr>
<tr>
<td>WAN</td>
<td>Wide area network</td>
</tr>
<tr>
<td>UML</td>
<td>Unified Model Language</td>
</tr>
<tr>
<td>SATLOC</td>
<td>Satellite Location System</td>
</tr>
<tr>
<td>ABA</td>
<td>Axle Box Acceleration System</td>
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</table>
1. General considerations related to involved systems

1.1 ABA – Acquisitioning Data System. General technical characteristics

Monitoring the track quality over a long time can sense the track behaviour and the rate of wearing. These would be used in a widely distributed ground infrastructure. For managing this, the railway infrastructure contains various and large spread of sensors and actuators to provide information about its structural wear level and maintenance needed. The sensors and actuators operate in real-time or periodically depending on their functions in different components.

The vertical axle box acceleration (ABA) system was developed by TU Delft for detecting defects such as severe corrugation and poor-quality welds.

1.1.1 Rail defects detected with ABA system

Squats

Squat is a type of rolling contact fatigue (RCF). This type of defects appear on the running band in straight track and large curves, independent by type of the track. The origins of squats are diverse. Some of them could be due to corrugation, bad quality welds, and small indentations, see Figure 1.1.

![Figure 1.1 - Squat phenomena result](image)

There are defined three classes of squats: light (squat A), moderate (squat B), and severe (squat C), and there are depending by the dynamic contact between wheels and rails.

The most important variable of a squat is the length of it; it is related to the duration of the impact and provide the wavelength characteristic and therefore the frequency of the dynamic contact force.

Corrugation

Short pitch corrugation (common named as “corrugation”) refers to the corrugation with wavelength falling in the range of 20 – 80 mm, and with amplitudes (peak-to-trough distance) up to 100 µm, (see
Figure 1.2). In the Dutch railway network, the most commonly recorded corrugation has the wavelength of 20 – 40 mm (1) (2).

On the other hand, corrugation can result in rolling contact fatigue phenomenon, e.g. rail squats (3). If still now there is no complete explanation for the corrugation phenomena, the ABA system represent a competitive tool for improving understanding of corrugation.

1.1.2 ABA Equipment and installation description
The ABA system measures longitudinal and vertical vibrations, and it is focused for detection of short wave irregularities. Lateral ABA has been employed in the railway literature in the frequency range below 100Hz.

A vertical track irregularity like a squat causes an impact to a wheel in the vertical direction (y direction), which induces vibration of the wheelset. The vibrations caused by the impact are transmitted from the wheel-rail contact force to the axle. In the case of longitudinal and vertical acceleration (x and y directions) the axial plane of the wheel permits the analysis of some correlation between plane x-y and squats (see Figure 1.3).

In Figure 1.4, a schematic overview of the ABA system is shown. Data is collected from accelerometers but also from one GPS receiver and either a tachometer or speed-sensor for positioning.
For ABA measurements, a number of accelerometers are mounted on the axle boxes of at least one bogie. For mounting the sensors, three small mounting studs have to be glued on each axle box. Therefore, a small spot of approximately 2x2 cm should be cleaned and be free of paint and grease, see Figure 1.5.

Sensor cables are routed from the bogie frame to the measurement box in the train, using an entry cable. If this solution is not available, the cables can be routed through an open window. As it is for temporary use, the cables are attached by cable ties so they can easily be removed after the measurements. The mounting studs are not removed after the measurements.

The measurement box is represented by a process calculator and a number of interfaces and communication channels with sensors, with the Laptop and with other auxiliary devices. One of the
serial interfaces, available on the main board processor, will be used to integrate data from the SATLOC on-board computer (6) (see Figure 1.6).

**Figure 1.6 - Measurement box and laptop/computer**

### 1.2 SATLOC System. General technical and functional characteristics

#### 1.2.1 Importance and innovations of the SATLOC System

The SATLOC system could be considered as result of at least 15 years of satellite applications studies, in the railway applications, which were led by the UIC, ETCS and ERTMS, Regional IFSTTAR and SPIRENT and include many simulations of geo-referenced conditions. Also, other major companies, like SIEMENS, ANSALDO and INVENSYS RAIL, integrate this segment of newest technologies in train control telecommunications and using of the ETCS standards.

The SATLOC System has main characteristic as following:

- Low cost train control solution for regional and low traffic density lines – the same basic functions and high safety target as ETCS.
- Compatibility with ETCS – interoperability on long term.
- Highest flexibility of implementation – to satisfy pragmatic, workable and best options for cost efficiency.
- Application of new technologies for train localization, train completeness, mobile radio communication with trains.
- Improved testability and validation for easier approval of applications.
- Expandability to new functions and services based on IT, UMTS-LTE and GNSS as integration and optimization platforms.

Innovation coordinates for the system:

- Opportunity for using of technologic progress in application: IT, satellite navigation, radio-communication, automation.
- Absolute location of trains with GNSS, route map and virtual beacon.
- Train tracking function to supervise train running by the TCC for high safety target with lower SIL components.
• Use of UMTS-LTE high performance mobile radio in VPN-sec technology for data transport at marginal cost/cab radio on UMTS with IP address.
• Adaptation of operations to maximize the effect of technology and reduce cost (i.e. spring switches for crossing the trains, de-centralized shunting, etc.).

1.2.2 System architecture

The SATLOC system, using SOL databases, provides the train location, speed and precise timing for the train control. The fix integrity and high-level safety are assured by close-loop integration of train traffic and movement authority control from the control center. The high degree of innovation in the integrated train-track behavior enables lower safety integrity components to achieve a very high safety target.

The SATLOC system is built up of at least one TCC (Traffic Control Centre) for train protection and supervision and also trains equipped with SATLOC on-board equipment. Each train registered in the SATLOC area is linked to the TCC via a mobile network.

Figure 1.7 shows the SATLOC system architecture with the TCC and a train in the SATLOC area, linked to the TCC via SATLOC network (7).

One of the great improvements achieved in the NeTIRail-INFRA project is the physical link between ABA and SATLOC system. In this way, data from the both systems are integrated and used more efficiently, especially by the ABA system, on the process of acquisitioning accelerometers sensors values.

According to common specific protocols, was made direct interfacing between ABA and SATLOC; in this way, the Laptop used by ABA system also collects and integrates short messages, from SATLOC on-board equipment (ex.: GPS positioning data, odometer data, in field tag codes), see Figure 1.8.

This interface is presented as detailed solution in Deliverable D4.9.
Figure 1.8 Block structure of the linked ABA and SATLOC systems

Software to collect data from SATLOC on board equipment and also integration of data collected, with TU Delft equipment, was develop by TU Delft.

1.3 The structure of data in systems based on acceleration detection and acquisition

In accordance with the functionality of the measurement equipment, the acquisitioning and collecting of various dynamic parameters are performed. ABA system measure location, speed, acceleration and vibration in the lateral and vertical direction on the axis of the bogie. Inside the cabin we measure vertical and horizontal acceleration - passenger comfort.

Measurements of the dynamic parameters and the speed are carried out with a frequency of 4000 Hz multiplied with installed sensors number and with bytes resolution of the every sensor. That means very large volume of data available for sending, for every second.

In assessing the dynamic characteristics of the rail line for train with tilting, in accordance with EN 14363:2005, the conditions for conventional vehicles are applicable, more specifically for "passenger vehicles with two-axle bogies: $V \leq 200$ km / h: measurement of acceleration on the basket and the bogies of the vehicle" (8).

Accelerometers placed on the bogie provide information about security, while accelerometers mounted in the cabin of the vehicle provide information about the driving characteristics and comfort.

For data processing a simplified method is used: calculations of the measured acceleration.

The results of the measurements are processed according to the measured rail line sections. In addition to the measured speed and the path accelerations values, the minimum and maximum measured values of dynamic parameters, as fast processed values, are shown - the average lateral acceleration, lateral forces and derailment coefficient.

Taking as example, the ABA System developed by TU Delft, has the following characteristics of data structure:

- Collected data is stored in csv (comma-separated values) files in the acquisition and processing computer. Because the volume of data collected is huge, the csv files are generated at the level of a 1-minute session; even so, their size is in range of hundreds of megabytes.
- The files stored are text files, in format of .csv files. In the first column is the GPS location. The next column is a time stamp from the GPS receiver. The next column is the speed of the train. The
last 24 columns are acceleration measurements, from sensor 1 to sensor 24, covering left and right rail, training and leading wheels, one vertical and two longitudinal acceleration directions.

### 1.4 GSM communication support. General and useful technical characteristics

In time of the T4.4.1 task, from the technical point of view, we developed workable interfacing technology for next stages: linking with the on-board data acquisitioned, preparation and data transmission using the existing broadband packet-switched technologies. To achieve this, a two-tier approach is needed:

- building a network architecture capable of transmitting broadband data, over long distances;
- creating a client-server system for real-time synchronization of collected data;

The developed network architecture is presented in the Figure 1.9 underlying the different physical levels (system applications) and connection points.

![Figure 1.9 Network system architecture](image)

From a physical point of view, it consists of a LAN and a WAN. The LAN has the following components:

- 2 endpoints: ABA measurement box and ABA Data Storage local computer
- the connection between above endpoints, through the router’s LAN mode

The WAN has the following components:

- 2 endpoints: ABA Data Storage computer and Central Data Server
- the connection between above endpoints, through the router’s WAN mode

For wireless communication over the Internet, an intelligent 4G LTE router designed for critical infrastructure and industrial applications was acquisitioned and used.

It provides a secure, reliable connection to industrial controllers, process automation equipment and smart grid assets on third party sites or remote locations. Software defined, multi-carrier networking and global LTE and HSPA+ options make it easy to get connected. This drop-in connectivity gives operators a way to reduce downtime and service calls and also increase revenue by bringing faster the distributed online sites (see Figure 1.10).
The principal’s technical characteristics of this router are listed in the following table:

<table>
<thead>
<tr>
<th>Components</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WIRELESS INTERFACES (WWAN)</strong></td>
<td></td>
</tr>
<tr>
<td>LTE 450 - EMEA/APAC (M2)</td>
<td>LTE CAT 3: 450(B31)/800(B20)/1800(B3)/2600 (B7)&lt;br&gt;HSPA+: 900/2100 MHz&lt;br&gt;EDGE: 900/1800 MHz&lt;br&gt;Transfer rate (max): 100Mbps down, 50Mbps up</td>
</tr>
<tr>
<td>GLOBAL HSPA+ (U9)</td>
<td>3G HSPA+: 850/900/1700AWS/1900/2100 MHz&lt;br&gt;2G EDGE/GPRS: 850/900/1800/1900 MHz&lt;br&gt;Transfer rate (max): 21 Mbps down, 5.76 Mbps up</td>
</tr>
<tr>
<td>CONNECTORS</td>
<td>2) 50 Ω SMA (Center pin: female)</td>
</tr>
<tr>
<td>SIM SLOTS</td>
<td>(2) Mini-SIM (2FF)</td>
</tr>
<tr>
<td>SIM SECURITY</td>
<td>Screw-down SIM cover</td>
</tr>
<tr>
<td><strong>ETHERNET</strong></td>
<td></td>
</tr>
<tr>
<td>PORTS</td>
<td>(2) RJ-45; 10/100 Mbps (auto-sensing)</td>
</tr>
<tr>
<td><strong>PROTOCOLS</strong></td>
<td></td>
</tr>
<tr>
<td>PROTOCOL SUPPORT</td>
<td>HTTP, HTTPS, FTP, SFTP, SSL, SMTP, Device Cloud SNMP, SNMP (v1/v2c/v3), SSH, Telnet and CLI for web management; remote management via Digi Remote Manager; SMS management, protocol analyzer, ability to capture PCAP for use with Wireshark; DynDNS, Dynamic DNS client compatible with BIND9/No-IP/DynDNS</td>
</tr>
<tr>
<td>Components</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SECURITY/VPN</td>
<td>IP filtering, State full inspection firewall with scripting, address and port translation; VPN: IPSec with IKEv1, IKEv2, NAT Traversal; SSL, SSLv2, SSLv3, FIPS 197, Open VPN client and server; PPTP, L2TP; (5) VPN Tunnels (upgradable to a maximum of 50); Cryptology: SHA-1, MD5, RSA; Encryption: DES, 3DES and AES up to 256-bit (CBC mode for IPsec); Authentication: RADIUS, TACACS+, SCEP for X.509; certificates; Content Filtering (via 3rd party); MAC Address Filtering; VLAN support</td>
</tr>
<tr>
<td>ROUTING/FAILOVER</td>
<td>IP pass-through; NAT, NAPT with IP Port Forwarding; Ethernet Bridging; GRE; Multicast Routing; Routing Protocols: PPP, PPPoE, RIP (v1, v2) OSPF, SRI, BGP, iGMP routing (multicast); RSTP (Rapid Spanning Tree Protocol); IP Failover: VRRP, VRRP+TM; Automatic failover/ failback to second GSM network/Standby APN</td>
</tr>
</tbody>
</table>

Table 1.1 Principal's technical characteristics of intelligent 4G LTE router
2. Developed solution for transmitting on-board monitoring data

In the following sections, we will focus on the description of the client server system, for linking the on-board data acquisitioned, preparation of data and data transmission, using the existing broadband packet-switched technologies. This is the most important component of system, being responsible for communication management between the storage system and the central server where all the registration data is collected and analyzed.

System requirements are detailed and summarized in the following table:

<table>
<thead>
<tr>
<th>Application type</th>
<th>Application Description</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application for storage data server</td>
<td>Application for storage data server will operate at the Control Centre level</td>
<td>Data is transmitted via the communication module, an application will be build that will contain the following functional components: data communication, processing and storing data received.</td>
</tr>
<tr>
<td>Application for transfer data</td>
<td>Application for transfer data will operate at the Rail Unit level</td>
<td>To achieve a 3G/4G gateway, was needed to be programmed a communication module type Windows Service which will manage data transmission, from remote, to a Control Centre. This module will run in the background and will listen to requests for transmitting information; the amount of data requested will be sent via GSM LTE.</td>
</tr>
</tbody>
</table>

Table 2.1 – System applications requirements

2.1 General presentation of the new interface developed

The main problem to be solved in this application is the realization of a system which is able to ensure the sharing and synchronization of the data provided by the ABA and SATLOC system with a central server, using the GSM 3G/4G communication network.

The constraints on solving this problem are given below:

- the large size of the data files to be transmitted (over 800MB);
- determining the status of the files to be transmitted - because several files are generated at the level of a recording session and some of them are processed for more than 1 minute, the status of these files must be monitored to determine when they were completed and to prepare them for transmission;
- another important aspect is data transmission which should be done during train travel at different speeds and in areas with different network coverage - taking into account these factors, we need to ensure that the data has been correctly transmitted to the destination;

For GSM communication network was chosen private providers, against GSM-R based solution, because only in this way could be achieved necessary performances to send large volume of data in
real time. Also, these private GSM 3G/4G networks can provide high levels of algorithms for safety and reliable communication and also integrity of data. Standards such as ERTMS and ERTMS-REGIONAL have very limited data transmission capability and can’t assure the integrity of software and hardware demanded by the requirements of the system.

The UML Use Case Diagram is the simplest representation of the system user’s interaction and describes the specifications of a usage case. It can have different types of users and different ways of interacting with the system.

Considering these, the implemented system is based on a peer-to-peer network, there is only one actor, this being the data transmitter user. It can only have one role, the only different operation between different users is how they connect to the network.

In our case, the user is represented by the client application that performs the following operations (see Figure 2.1):

- create, modify, and delete files;
- monitors the status of files;
- start synchronization of the files;
- stop synchronization of the files;

In the following sections are presented the solving of the above problems.

2.1.1 The architecture of the large file transfer component

The problem of sending large files over the Internet today has been resolved by large cloud service providers such as Amazon, Azure, Google, etc.
This providers solved the problem in a similar way by fragmenting the files on the source transmitting side and sending them in parallel tasks, followed by assembling them at the destination in a single file, identical to the one sent by the source (see Figure 2.2).

We have done similarly and implemented a pattern based on chunk technology (see Figure 2.3). Our solution is characterized by:

1. Providing 2 REST WebApi endpoints: FileApi/GET and FileApi/POST.
2. Any client app which wants to use the upload service, first has to make a request to GET endpoint.
3. On successful request, client asking would be getting a unique ID to start the transaction.
4. Next, the client application can split the file into chunks (typically Byte arrays) and can send it to POST endpoint. Following are mandatory parameters for this request:
   - File ID => Unique Id from Step (3).
   - Chunk ID => Unique 8-digit Integer (for example - 00000001, 00000002...) to identify which chunk is being received.
   - Is Completed => Boolean value. True in case if last chunk is attached to request. False in case of any other chunk.
5. On successful request, the server will process the request and sends back a message: “200 OK HTTP response”. In case of any error, the message will be: “500 Internal Server Error”. For protecting data integrity, we offer possibility to the client app to RE-SEND the failed chunk request, back to service again.
Another important consideration included in the application design is that it allows to establish a single TCP connection between the client and the server, bidirectional and full duplex communication, resulting in a low latency connection.

In this sense, we used the protocol Class WebSocket. The WebSocket protocol addresses many, if not most of these issues, by enabling fast, secure and two-way communication between a client and a remote host without relying on multiple HTTP connections. WebSockets support full-duplex, bi-directional messaging, which is great for real-time, low-latency messaging scenarios.

Best of all, WebSockets is fully interoperable and cross-platform at the browser level, natively supporting ports 80/443 as well as cross-domain connections.

There are two parts to the WebSocket protocol: client and server. The W3C owns the JavaScript client API and the IETF Hypertext Bidirectional (HyBi) Working Group is responsible for guidelines governing how the server-side protocol should be implemented.

As shown in Figure 2.4, when a WebSocket-enabled browser/client establishes a connection to a WebSocket endpoint, it conducts a handshake over port 80/443 and requests an upgrade to the WebSocket protocol. If the server supports the WebSocket protocol, and the protocol version of the client and server match, the web server will accept the upgrade request and makes the upgrade of the request. From this point, the client and server have a direct socket connection and can freely exchange messages.
2.1.2 Solution for monitoring the status of files

One of the issues is that the ABA acquisition system generates files throughout the acquisition sessions, and for security reasons, the operating system blocks access to the files where data is written. That is why we need to monitor the status of the files and consider only those that have been completed.

To resolve this issue, a service based on File Watch Service has been created through which we identify when a file has been finalized, and can be included in the list of files that can be sent to the central server.

WatchService is a service that tracks recorded objects to detect changes or events. A classic example for using this service is a file manager can use the tracking service to monitor a directory of possible changes.

In order to implement WatchService (see Figure 2.5), it was necessary to create a Watcher for the file system. Every director who wishes to be watched must be registered with this watcher. When registering a directory, have to be specified the type of events for which notifications are requested. For each monitored directory, a WatchKey key is created.

There are four types of events could be tracked:

- "ENTRY_CREATE: this event occurs when creating a new directory entry - a new file, a new directory;
- "ENTRY_DELETE: this event occurs when a directory entry is deleted;
- "ENTRY_MODIFY: this event occurs when a directory entry is modified;
- "OVERFLOW: Indicates that events have been lost or have been deleted; it is not necessary to specify this event to receive the notification.

This service is designed for applications that need to be notified about events related to changing files in a directory.
2.1.3 Solution for data transmission during train travel, at different speeds and in areas with different network coverage

One of the important issues is data transmission, which should be done during train travel at different speeds and in areas with different network coverage; taking into account these factors, we need to ensure data has been correctly transmitted to the destination.

To solve these issues two approaches have been considered:

- in terms of network configuration, through the use of several Internet access providers;
- from a software point of view, by monitoring correct synchronization of transmitted data packets;

So, in order to achieve a dual Internet connection via LTE, the router used is one that allows a dual sim connection (see Section 1.4). We can configure the router to detect a link failure and automatically switch to the second installed SIM.

This router provides the ability to set up WAN access in two ways (see Figure 2.6 and Figure 2.7) (11):

- Both SIM cards/slots have equal weighting. In the event of a problem the router will change over from one SIM to the second one. Once it has failed over it will remain on the alternate SIM until another problem is detected in which case it will change back to the original SIM. This method keeps down time to a minimum. This option should be used when no SIM has preference over the other.
- If one SIM has a higher weighting than the other. After boot-up the router uses primary SIM if possible. In the event that a problem occurs the router will change over to the secondary
SIM. The router uses the secondary SIM for a configurable time or until a problem is detected. When either a problem occurs or the time is up, the router will attempt to change back to the primary SIM. This is useful if one SIM needs to be preferred over another, for example if the data charges are cheaper on the primary SIM. Therefore, attempting to revert to the primary SIM just because the router uses the secondary SIM for the configured length of time, results in an outage. If the router still cannot use the primary SIM, there is a further delay while the router reverts back to the secondary SIM.

Please make the appropriate selection:

- Equal weighting
- SIM 1 has priority over SIM 2
- SIM 2 has priority over SIM 1

Figure 2.6 Dual SIM weighting configuration
Figure 2.7 Configure and test W-WAN models from the web interface

2.2 General presentation of server application for synchronization of collected data

At the acquisition server level, within this task, have been implemented a RESTful API interface used for loading, in asynchronously mode, 5 series of parallel load processes for 5 large files (over 500 MB); this is based on the architecture described in Section 2.1.1.
In fact, the web server side of the file uploader tool is based on ASP.NET Web API version 2.x. The ASP.NET Web API version 2.x is a RESTFUL based API and we use action-based routing to call the methods exposed by the backend web server (see Figure 2.8).

![Figure 2.8 Dependencies Diagram of FileUpload API Controller](image)

The FileUpload API exposes several methods (see Figure 2.9). The "UploadChunk" are POST methods and accept the file uploads. The reason for using multiple "UploadChunk" POST methods is so that we can write to all of the methods in parallel.

In this solution could be selected variant to send one “UploadChunk” POST OR 5 parallel channels as UploadChunks POST (“UploadChunk1” … “UploadChunk5”)

![Figure 2.9 FileUpload API Controller class diagram](image)
The "UploadChunk" POST methods implement the same functionality and this is defined in the "ProcessChunk" method. The "ProcessChunk" method checks to see if we are uploading multipart/form-data encoded data, and that we are not trying to upload a file chunk that is greater than 50MB.

Once we have passed those checks, the next check is to look for the "FT-Encoded" header. If this header is present it means that we are uploading the file chunk as a base64 encoded string. This means that we have to extract the base64 encoded string from the multipart/form-data encoded data and convert it to byte array using the "Convert.FromBase64String" method.

If the "FT-Encoded" header is not present then we read the uploaded data into a byte array. Once we have read the file chunk into a byte array we save the byte array to file in a temporary directory. The temporary directory that is created is based on the name of the file.

Each file chunk is saved as a separate file and we pad the file names so that we can give each file a sequential number. This is important because when we try to merge the file chunks into a single file if the names of the file are not in the right order then we run the risk of creating a corrupt file. The sequential number is created by passing the "chunknumber" to the "UploadChunk" method and appending the "chunknumber" to the file name.

The "MergeAll" is a GET method and is used to merge all of the file chunks that are saved in a temporary folder, into the original file.
Interface of File Upload API must be initialized with 3 mandatory parameters:

- Filename - is the name of the file to be uploaded
- Directory Name - is the name of the directory where the file should be loaded
- NumberOfChunk - the number of chunks in which the file was fragmented at the client application level

The interface of File Upload API definition is shown in Figure 2.10.

### 2.3 General presentation of client application for synchronization of collected data

At the client level, within this task, are implemented 2 applications, which use File Upload API:

- One desktop application through which the data collected by the ABA system is transmitted in real-time.
- One web application through which they can transmit the data collected by the system in a series of 5 files. This application is useful when we did not have GSM coverage and the data could not be transmitted in real time but also is useful for retransmitting the files which generated errors during real-time transmission.

The desktop application was designed to run in the background as a Windows service and has two main functionalities:

- Check the status of the files to be transmitted and prepare them for transmission (see Figure 2.11).

![Figure 2.11 Application form for check status of the files to be transmitted](image-url)

- Fragmentation of large files using the chunk method and their asynchronous transmission (see Figure 2.12).
To build the web client (see Figure 2.13) we have used the HTML 5 API Specifications that include several pieces of interesting technologies, that have been implemented in modern web browsers and these include:

- **The File API specification** - This specification provides a standard way for interacting with local files on personal computer. The specification allows us to place multiple files from computer into an array and also allows us to slice a file into byte ranges.

- **The Web Worker API specification** - This specification allows us to spawn background scripts that run in parallel with the main page. The threads are processed in JavaScript language. The benefit of this is that we can pass off a long running task to a web worker without blocking the UI on the main page or other scripts.

- **The XMLHttpRequest Level 2 specification** - This specification provides new capabilities for transferring data between the web browser and the web server. The capability that we are most interested in it, is to be able to send data to the server in a variety of formats. This will allow us to upload data to the server using FormData objects.

We are combining these technologies together, to be able to upload files greater than GB to a web server, and are described as following:

- Using the File API specification to select one or multiple files in the web browser.
• Passing the selected file or files to one or more web worker that is dedicated to processing the file.
• In the web application, which is dedicated to processing file, it is used the File API specification to slice the file into chunks. This would be similar to splitting a large file into smaller files using a file compression utility. We use the SparkMD5 library to generate the MD5 checksum for the file and then send the chunk back to the main page (parent page form now on).
• In the main page it is send the chunk to a web background page processing, which is dedicated to the task of sending the file chunks to the web server.
• In the web component, which is dedicated to sending the file chunks to the web server, we created a pool of XMLHttpRequest Level 2 objects that use FormData objects to POST the file chunk to the web server as multipart/form-data. In the case where the web browser does not support the FormData object, were manually created the multipart/form-data requests and convert the file chunk to a base64 string.
• At the web server, each chunk from the client is received and saved as an individual file. The web server continues to do this until it receives a command to merge all of the individual chunks into a single file. Once the file is created on the web server, it sends a success message to the web browser that includes the MD5 checksum of the saved file.

2.4 Preliminary tests
There were carried out several tests with the file upload tool, as the most concerning part of Application. The tests with the industrial modem, acquisitioned for this system, were done sending files with 1GB volume, using wireless 50MB WAN link, in 6 minutes, in laboratory conditions.

Also to check if application is not at the edge of the performance, was increased the communication speed, at 100MB with other router modem. It took around 3 minutes to send a 1GB file across a 100MB WAN cable link, to a remote server. It was been able to upload five 9GB files in parallel, across a 100MB WAN link, in 135 minutes; this experiment was done in laboratory conditions.

Using the information from the D4.3 Deliverable, we can compare the speed of raw data collection by ABA System and the transmission speed of the new communication system. If ABA collects data with a sampling rate of 25.6 KHz and if there are installed a number of 24 sensors working simultaneously (3 sensors per wheel, 8 wheels measured), also considering 1 byte for each acceleration value, raw data available for transmission sum a volume of 614.4 Kbytes/sec. (8)

Considering the above tests, comparing with the experiment sending 1GB in around 6 minutes through a 50MB wireless WAN communication speed, ABA system could collect in the same time approx. 614.4 Kbytes x 360 sec = 221 184 Kbytes (221.184 Mbytes). In the theory approximation, the communication system could send faster than ABA raw data collecting.

However, there is a variable that can drastically reduce the communication speed: the quality of the communication support offered by the selected provider. In this aspect, the most important factor is communication interruptions due to insufficiently covered areas. Multiple interruption of the wireless link could appear on the route which involve the re-initiation of the connection and retransmission of the data packets.

Real field tests will follow, for the railway network conditions, on the testing line Bartolomeu- Zarnesti, at our partner RCCF.
Conclusions

Due to the complexity of the components involved, the project developed in this task is itself a complex system for communication interfacing, and is adapted for achieving of specific and necessary functionalities and services for the ABA and SATLOC systems.

In the first part of the report are presented the technical characteristics of the systems involved. From the ABA and SATLOC technical specifications were retained information with importance for development.

On the second chapter is presented the technical (hardware and software) solution for the long range and fast communication system, made in time of the NeTIRail-INFRA project.

The new communication system is based on an advanced GSM modem that works in the LTE Router configuration, with a transfer rate of 100Mbps downlink and 50Mbps uplink. It will work on the GSM 3G / 4G communication network.

Developed system contains, as resumed, two types of applications:

- Application for storage data server.
- Application for data transfer.

The solution was defined from software point of view, through creating two WebApi endpoints: FileApi/Get and FileApi/Post.

This data transfer is achieved by a single TCP connection between the client and the server applications; it is a bidirectional full duplex communication, resulting in a low latency connection.

The used communication protocol is defined by the WebSocket Class, which support fast, secure, two-way communication between a client and a remote host without relying on multiple HTTP connections. WebSockets support full-duplex, bi-directional messaging, and is optimized for real-time and low-latency messaging scenarios.

One very important function is for monitoring the status of files should be transmitted; for this a service based on File Watch Service has been created. Using this service events when a file has been finalized and closed could be identified, and can be included in the list of files, for sending to the central server; WatchService is a service that tracks recorded objects to detect changes or events.

The solution for data transmission during train travel at different speeds and in areas with different network coverage; was to achieve a dual Internet connection via LTE, the modem GSM router, used in the project, allows dual SIM connection (see Section 1.4). The router device could be configured to detect a link failure and automatically switch to the second installed SIM.

For the level of server acquisition of the sent data, a RESTfull API interface has been implemented through which are loaded, in asynchronously mode, 5 series of parallel load processes for 5 large files (over 500 MB); this is based on the architecture described in Section 2.1.1.

At the client level, were implemented two applications which use File Upload API; these are:

- Desktop application for transmitting in real-time the data collected by the ABA system. The desktop application was designed to run in the background as a Windows service and has two main functionalities:
  - Files status checking when have to be transmitted and prepare them for transmission (see Figure 2.11).
  - Large files fragmentation when using the chunk method and asynchronous transmission (see Figure 2.12).
Web application for transmitting the data collected by the system in a series of at most 5 files, with operator intervention. This application is useful for poor GSM coverage and for retransmitting the files which generated errors, during real-time transmission when using desktop application.

Deviation from the project specifications: the NeTIRail-INFRA project Grant Agreement requests to build a solution for fast and long range communication, using the SATLOC implementation of ETCS, which is already at TRL 8 (proven, already in function). Unfortunately, it was not possible to use SATLOC as an integrating platform for getting data at local level, data transmission and evaluation in the traffic control center because of high restrictions imposed by the SATLOC developers. They considered that adding high volume of data on the same communication platform will decrease the performance of the technical defined and closed SATLOC application. Also, changing the firmware and control center application will change the validity of the already certifications and could create issues and delays for in during homologation.

For these reasons, although much more complicated and requiring greater work effort, the variant of one communication platform, independent of that of SATLOC, was adopted. A non-intrusive solution for SATLOC was obtained and more efficient solution for ABA system because entire communication platform and all of its performances are dedicated to ABA transmitting data.

For next steps were planned to embark the communication system and to make in train experiments; for this purpose will be used the testing line Bartolomeu- Zarnesti, from our partner RCCF.
Deliverable D4.7 Harmonised interface to transmit on-board monitoring data to the traffic control centre

References


7. RCCF, Task Leader. D4.9: Interface definition for input of GNSS (or ground-based train odometry) location data to monitoring technology. s.l.: NeTIRail INFRA, 2017.


