Communication Solutions

Final Event

Brussels 25th February 2020

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Grant Agreement
Number: 777576

Outline

- Track-Side Communication Solution
- On-board Train Integrity (OTI) Communication Solution
  - OTI Communication Protocol
  - OTI System Prototype and Human Machine Interface (HMI)
  - OTI Power Consumption Analysis
- Conclusions

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Track-Side Communication Solution

State of the Art

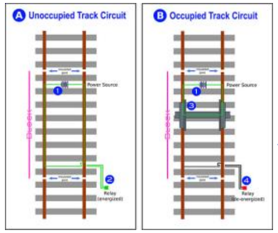
Wired Communications

Lights

Fiber optics

Connected to
the power grid

Fiber optics



Track circuits or other detction systems

Object Controller

Represent an interface between Interlocking and wayside objects.
<u>Receive from objects</u>: state of the object,
<u>Send to objects</u>: commands (required position);
<u>Send to interlocking</u>: data about elements state

Connected to
the power grid

Interlocking

knows all trains position and wayside objects positions on the section.
Interlocking communicates with others Interlockings and with the Command Center.

Level Crossings

Motor for barriers

Track-Side Communication Solution

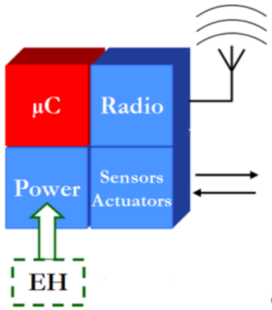
Forecasting

- ✓Less cost
- ✓Less maintenance
- ✓Less infrastructure to deploy

All the communications are Wireless and harvested from the environment.
Protocols employed are energy aware.
Nevertheless, **wayside objects are still feed from electrical network.**

Connected to the power grid

Connected to the power grid



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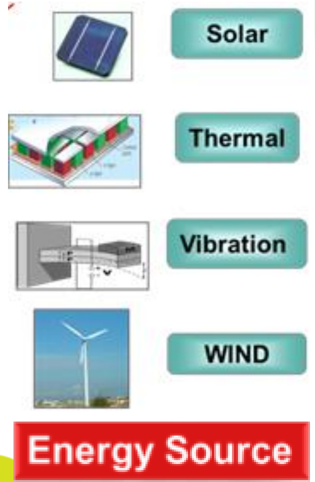


Interlocking

knows all trains position and wayside objects position on the section.
Interlocking communicates with others Interlockings and with the Command center.

Track-Side Communication Solution

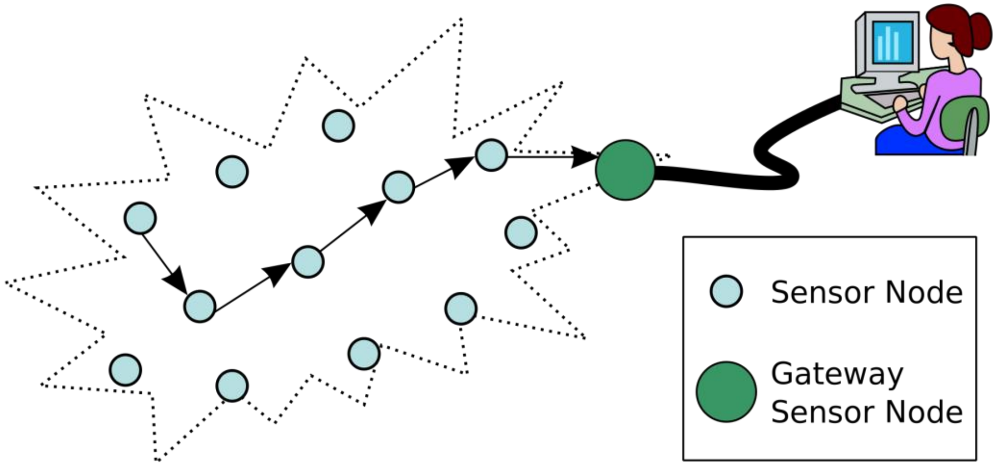
➢ Trade-off analysis (D3.1)

Energy consumption, reliability, availability, security, fault tolerance and fault recovery.

Wireless Technology

- ✓ **Lower cost & maintenance**
- ✓ **Quick real-time status & performance monitoring**

➢ Wireless Sensor Network (WSN) - RF communication



- ✓ **Dynamic network topology**
- ✓ Channel variability
- ✓ Security robustness
- ✓ **No need of network infrastructure**
- ✓ Hight fault tolerance
- ✓ **Low energy consumption**
- ✓ Simple Hardware architecture
- ✓ **Low production and installation cost**

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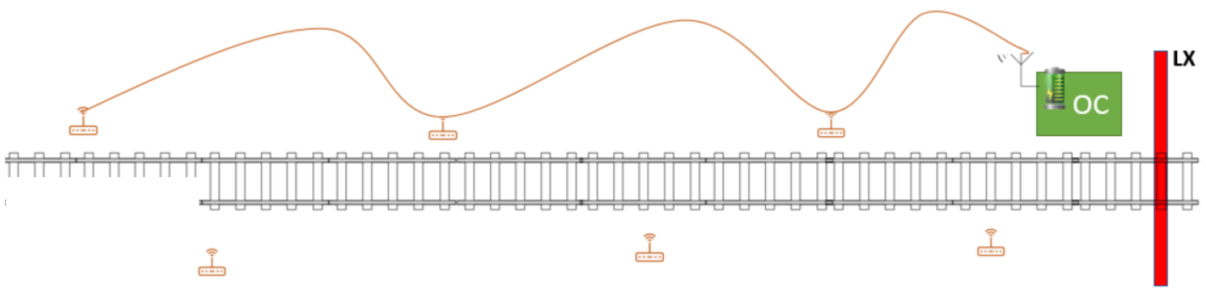
Track-Side Communication Solution

Communication Systems and Wireless Components for Track-side

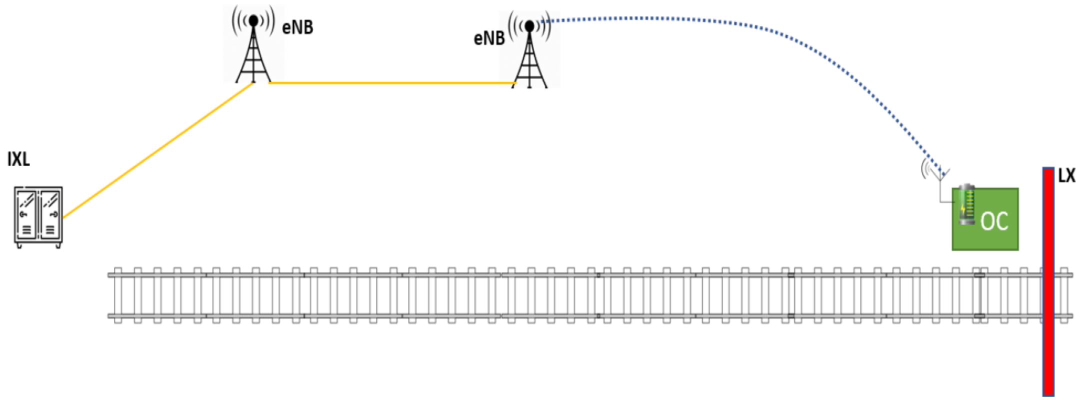
Identify most suitable coomunication solution for track-side object controller

2 main scenarios

WSN based architecture (low/high density areas)



LTE based architecture (low/high density areas)



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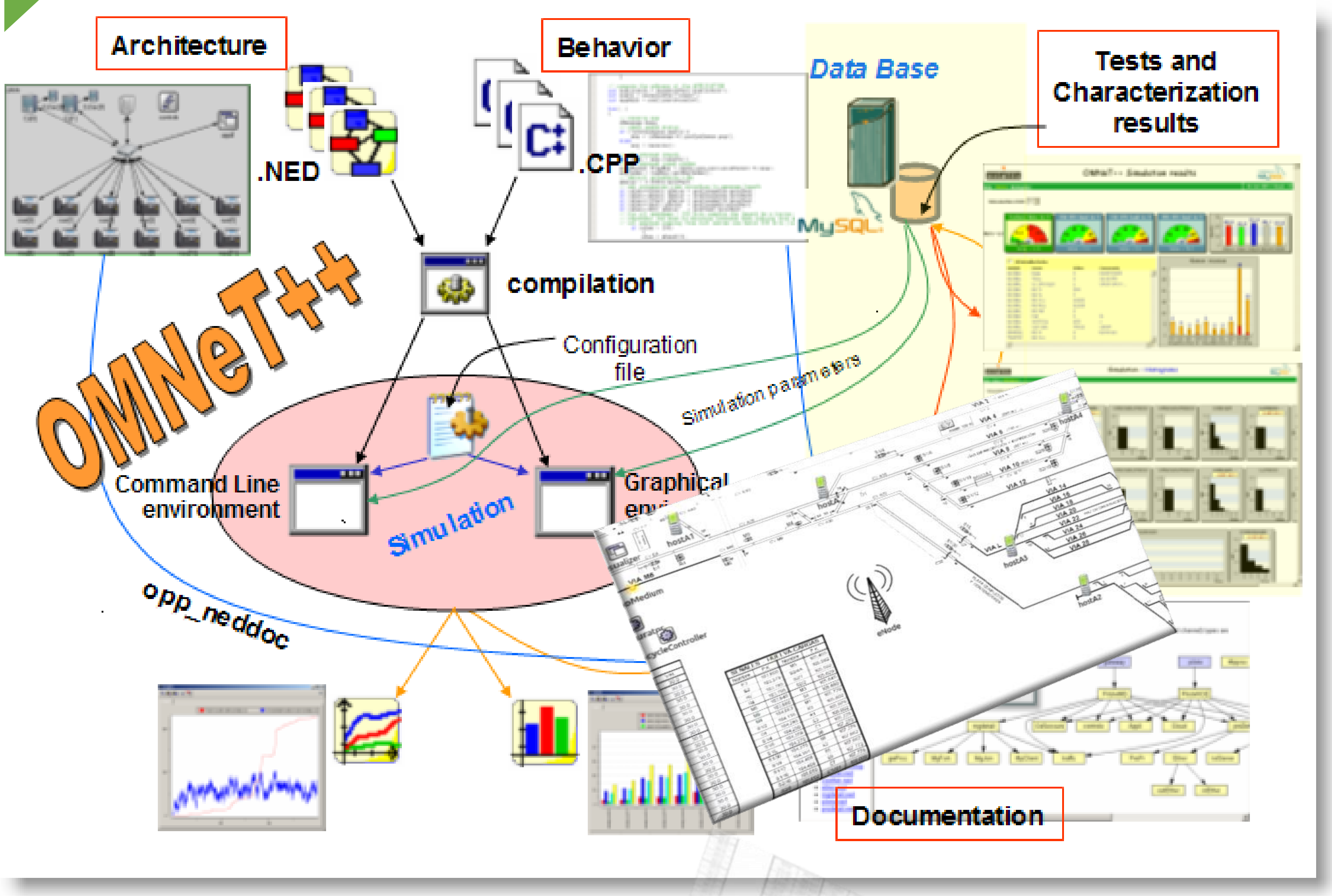
Track-Side Communication Solution

Network simulator - SW OMNeT ++ → **Identify power consumptions and QoS parameters**

Two main technologies: WSN & LTE

- **Distance**
- **Sensivity**
- **Noise power**
- **Transmitted power**
- **SNR threshold**



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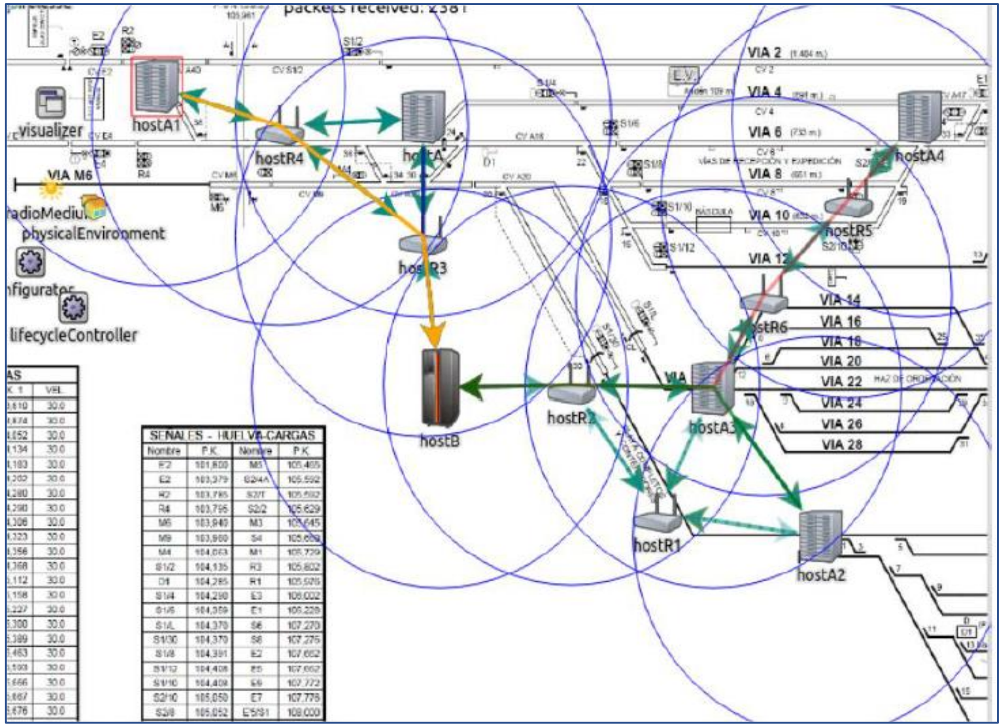
Track-Side Communication Solution

Conclusions

- Scenario 1: WSN-based technology deployed in railway low/high density areas
- Scenario 2: LTE-based technology deployed in railway low/high density areas



- <u>WSN-based</u> devices consume 50% less than LTE based devices
- <u>LTE-based</u> technology: higher consumption but more suitable for safety-critical railway applications

On-board Train Integrity (OTI) Communication Solution

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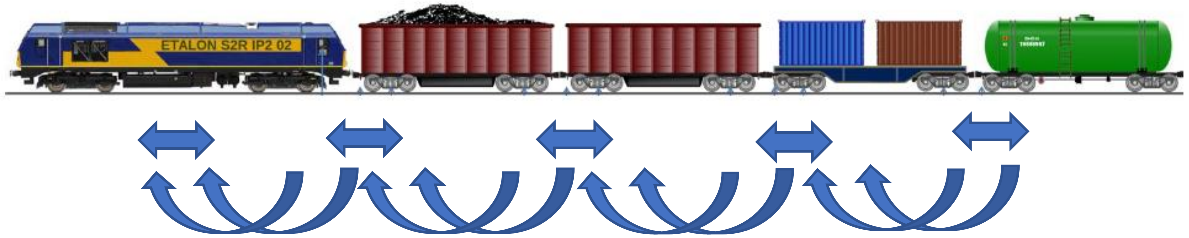
Introduction to the OTI System



Functionalities:

- Able to discover/identify all the wagons composing the train (**Network Discovery** Procedure)
- Able to asses the Train Integrity at a configurable period of time (**Train Integrity** Procedure)

OTI System:

- Multi-hop Communication based on a WSN (@868 MHz)
- Wagon-to-wagon distance sensor based on UWB technology (@6.5 GHz)

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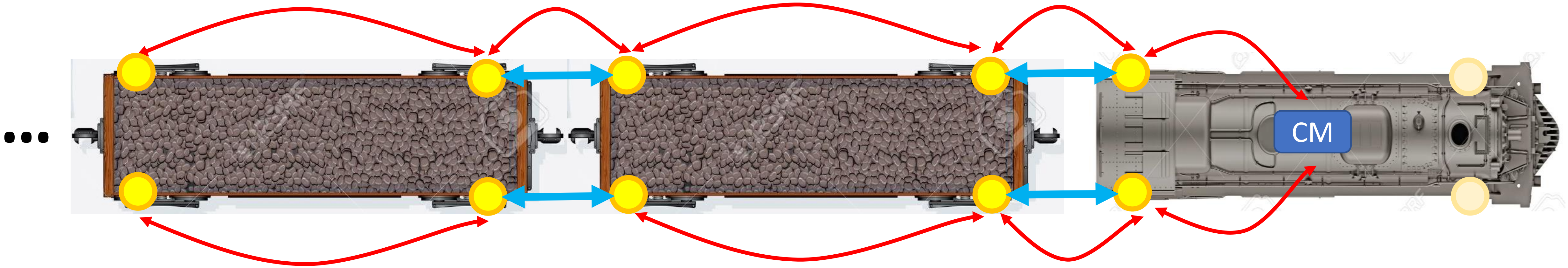
OTI Communication System Scheme

The OTI System is composed of:

- One Control Module (CM) located on the locomotive
- Four Sensor Nodes (SNs) in each wagon and two in the locomotive



Legend

COM (SubGHz)

UWB

Sensor Node

CM Control Module

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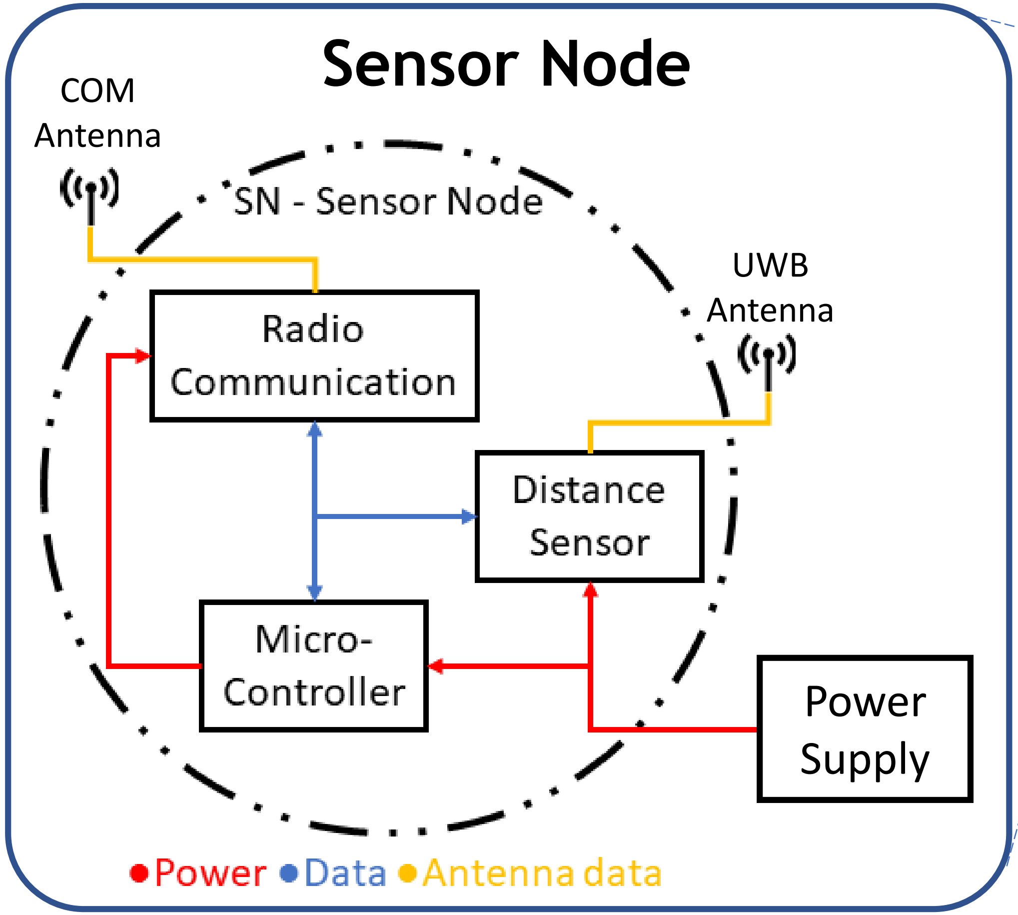
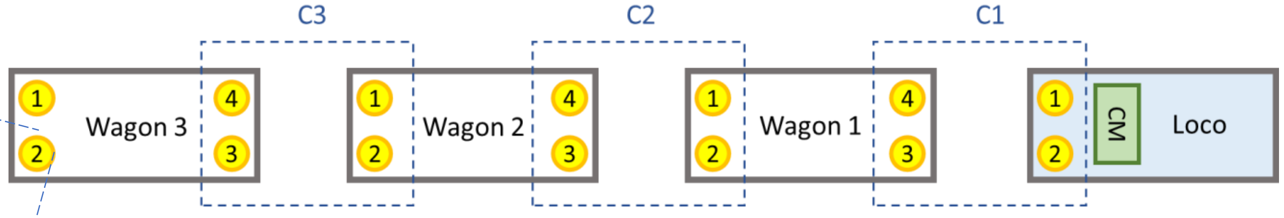
OTI Node Architecture





- **Radio Communication** module
  - based on a 868MHz radio chip.
  - implements the node-to-node communication link
- **Distance Sensors (DS)**
  - based on UWB (6.5 GHz)
  - implements inter-node distance measurement
- **Micro-Controller**
  - implements the WSN communication protocol
  - interacts with the DS module for performing distance measurements
- **Power Supply**
  - EH module

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Network Discovery (ND) Procedure

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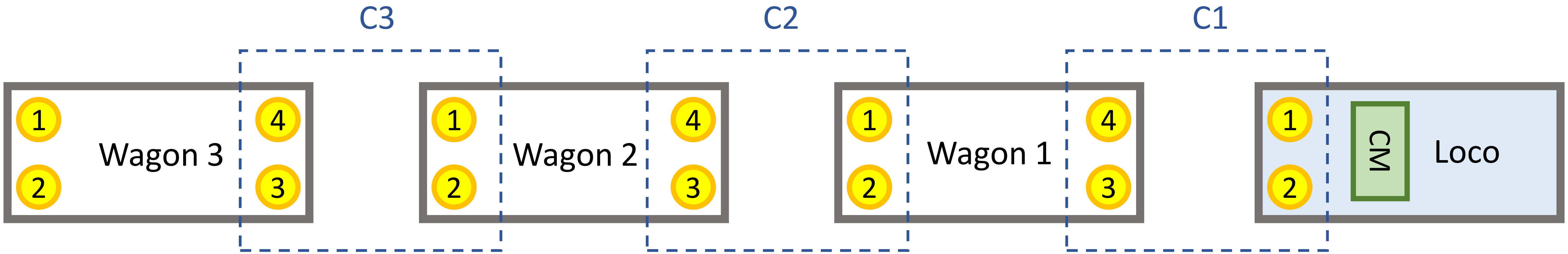
Network Discovery (ND) Procedure



1. Discovery of all SNs and couplings belonging to the train.
2. Assign network short IDs to all SNs.
3. Configure of SNs for proper operation in the network.

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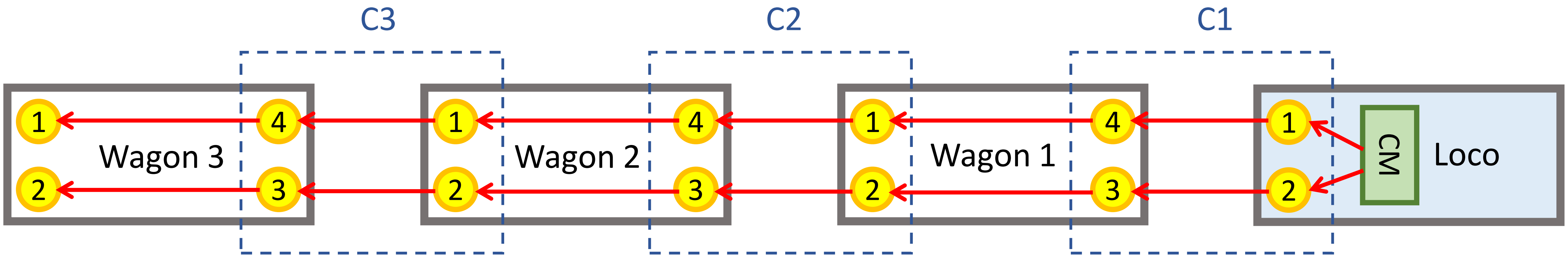
Network Discovery (ND): Message Propagation



1. The CM sends a **ND request** to SNs 1 and 2 of the Loco.
2. SNs 1 and 2 send an Acknowledge **(ACK) message back** to the CM.
3. SNs 1 and 2 use their **Distance Sensor to discover the closest SNs** and configure them.
4. SNs 3 and 4 **propagate the ND request** to the SNs 1 and 2 of the same wagon.
5. The **ND process is iterated** till the end of train.

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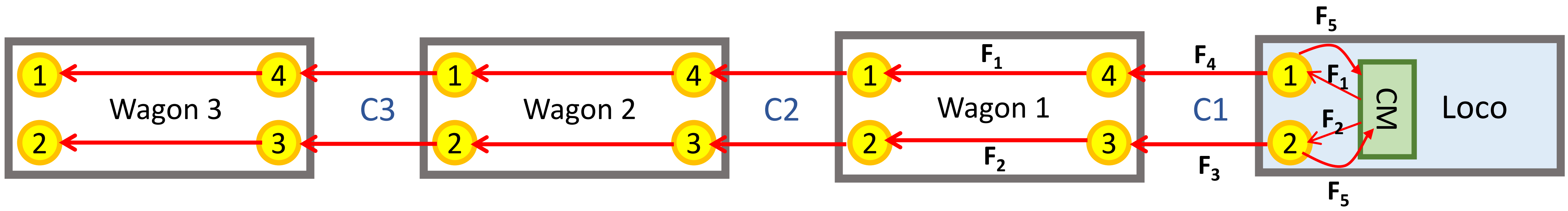
Multi-Channel Hop Optimization



To reduce the number of messages in the radio channel and **minimize interference**:

- The OTI System uses **5 different frequency channels**
- Each SN receives on its own channel and switches to the receiver's channel to send a msg
- All messages are sent using "**Robust MAC Communication**" using "N" repetitions

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Train Integrity (TI) Procedure

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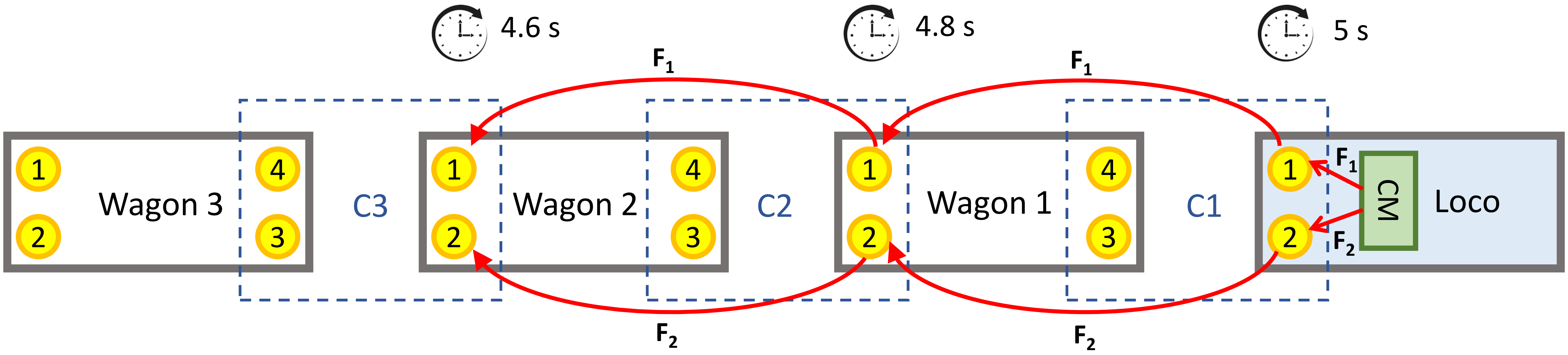
Train Integrity (TI) Procedure (1/2)



- The CM starts the propagation of a **TI Request** toward the last coupling
- Once reached the last coupling, a **TI ACK** message is sent backwards to the CM
- During the backward propagation of the **TI ACK**, “**timers**” are set on each SN.

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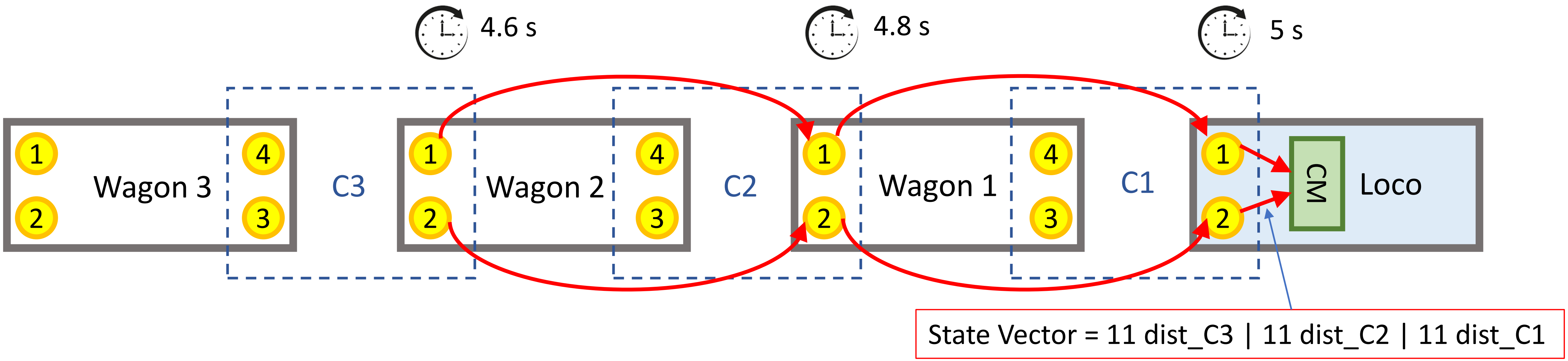
Train Integrity (TI) Procedure (2/2)



- Both nodes of the last coupling start a **TI Backward Propagation**
- The receiving nodes **update the TI message** with their state and propagate back to the CM.
- The **TI is confirmed** if the measured **distances are below a threshold** (which is set during the ND procedure)

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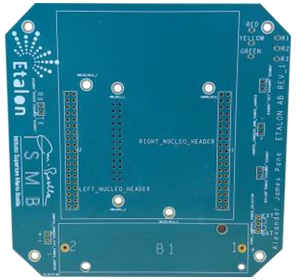
Sensor Nodes Prototype and Deployment

COM module (S2-LP board)

+

Nucleo board

+

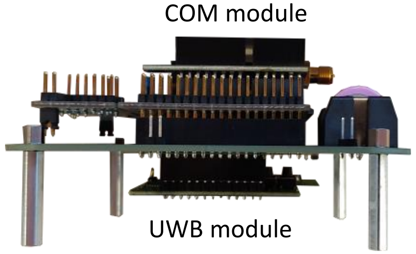


Adaption board

+

UWB module (DWM1001)

=

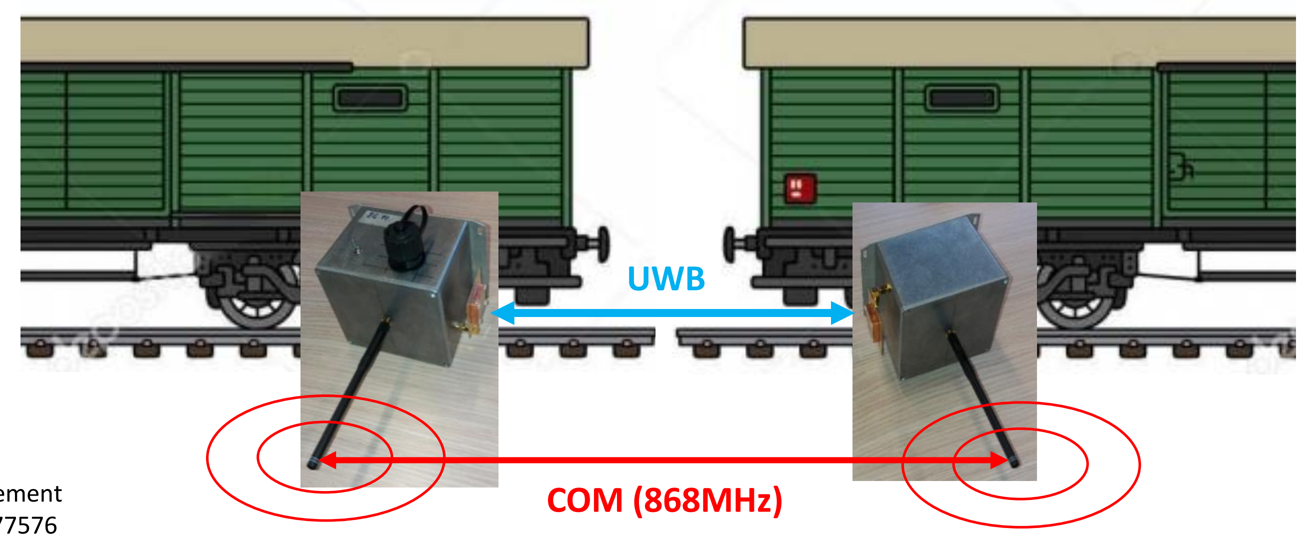


Assembled Node

COM Antenna

UWB Antenna

Example of OTI System Deployment



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Control Module

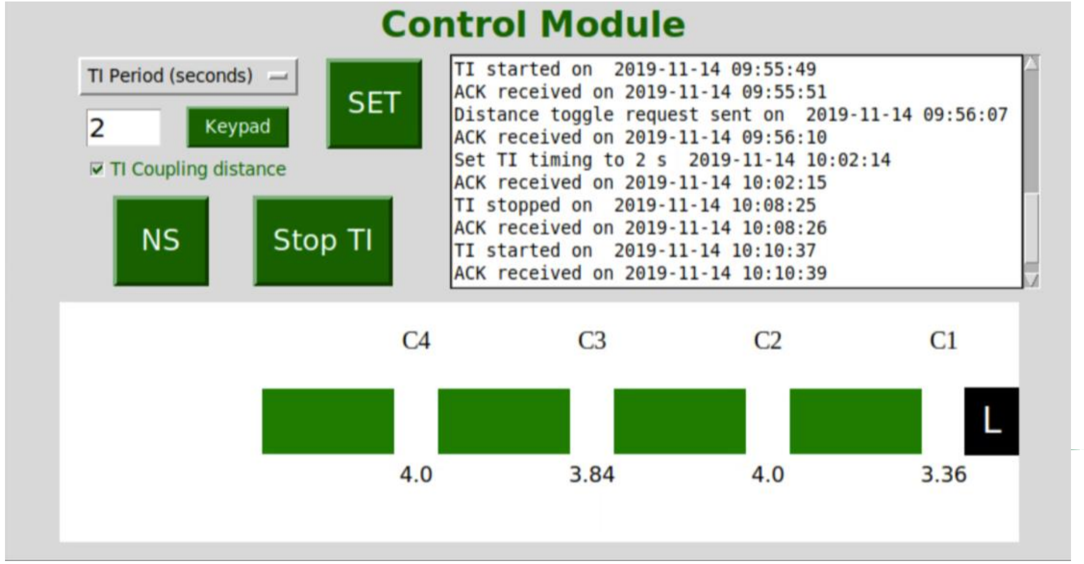
The **Control Module** is able to send requests to the WSN. Type of requests are:

1. Network Discovery
2. Train Integrity

The HMI provides a basic interface for the user to manage the network.

The Control Module

HMI



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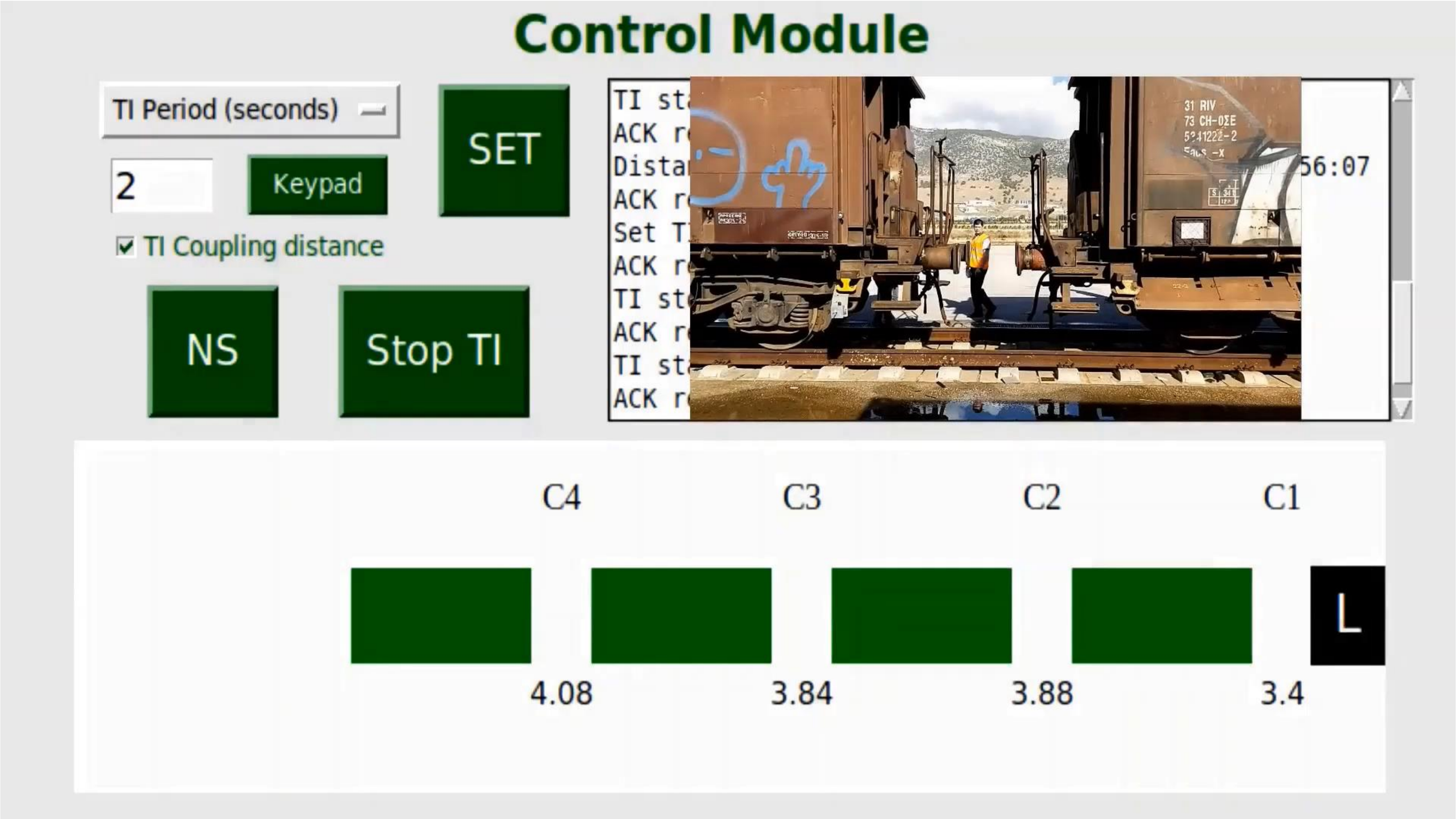
Video of the OTI Communication System



OTI Power Requirements Analysis

Consumer Component	OTI Average Power TI@5s [mW]	OTI Average Power TI@10s [mW]	Source
Microcontroller	0.30	0.30	D3.2 sec 3.1.1
Radio	0.43	0.22	D3.2 Table 3
Distance Sensor	0.30	0.17	D3.2 Table 6
Total	**1.03**	**0.69**	

Note: all the power figures have been taken from datasheets of the selected components

The total power consumption is fully compatible with the one generated by EH module (56mW)

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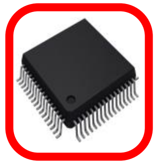
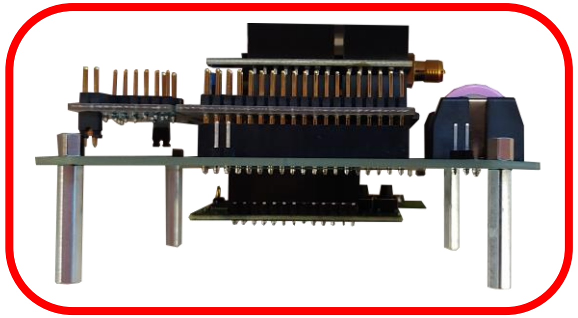
OTI Power Consumption Measurements – TI@5s

Consumer Component	OTI Average Power Southampton tests [mW]	OTI Average Power (Not energy optimised) [mW]
Microcontroller	3	
Radio	25	
Distance Sensor	12	
Total	**37**	**353**



Obtained by

- Isolating HW modules
- no DC-DC, no USB included



Obtained by considering the whole prototype

- COTS boards (no HW optimization)
- includes consumption of not useful HW modules
- no sleep mode mechanisms activated

EH module (56mW)

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Conclusions

- **Trackside Communication** solution based on **WSN** architecture **consumes less** than **LTE** one (tested via simulations)
- The defined **OTI architecture** is based on **WSN** and **Distance Sensors** that use the UWB radio technology
- The defined **Network Discovery** and **Train Integrity (TI)** procedures have been made robust and ready for the tests in the “relevant environments” (WP5)
- The developed OTI system demonstrated to be a very good solution for a **detailed TI monitoring** (in fact it provides the status of each coupling)
- This **OTI communication system** could be **enhanced** to deliver also monitoring data from other systems such as condition monitoring systems, tracking and tracing, etc.
- The **power consumption** of the OTI **could be optimized** in further development activities for a commercial product

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Thank you for your attention!

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