

Paper 133 - Smart ICTs for the enhancement of traffic logistics in the Port of Seville

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ABSTRACT: This paper focuses in the optimization of intermodal transport by the development of a freight geolocation and telecontrol platform for intermodal transport. This system, Cooperative Unitized Tracking System (CUTS), is being developed under the project TECNOPORT2025, which is an initiative of the Port Authority of Seville (PAS), co-funded by the European Commission by means of the ERDF (European Region Development Funds), under the Pre-commercial Public Procurement model aiming the “Port of Future”.

1 INTRODUCTION

The Port of Seville is the only inland seaport in Spain, being the waterway from Seville to the coast is part of the TENT Trans-European Transport Network with the name of Guadalquivir EuroWay E.60.20. The Port of Seville is an important logistics hub that serves a population of over one million people and maintains a leadership position in some logistic corridors such as the Madrid-Seville-Canary Islands one. The Port Authority of Seville (PAS) launched in 2014 the TECNOPORT2025 project, conducted by the University of Seville in collaboration with five leading companies in their respective fields. An important subproject within TECNOPORT2025 is called CUTS (Cooperative Unitized Tracking System).

CUTS is aimed at providing an open, public and cooperative infrastructure for container monitoring and tracking that use a heterogeneous communication network, whose most innovative parts are: a) the definition of a set of open interfaces for cargo monitoring and control, b) the development of an autonomous wireless network with low-cost terminals and metropolitan coverage which moves with the containers, and c) the use of an integration platform based on FiWare, which is an open middleware platform promoted by the European

Commission intended for the Internet of Things (IoT).



Figure 1. Partial view of the container yard in the “Batan” dock at the Port of Seville.

This paper presents the CUTS project, its objectives, components and expected results. The TECNOPORT2025 project (and consequently the CUTS subproject) ends in December 2015 with a demonstration of the different systems and tools developed in the project. These systems and tools will be later converted to commercial products that



satisfy the PAS needs, and simultaneously provide innovative solutions to other facilities (and ports) with similar problems.

The CUTS project is being developed by the University of Seville and Isotrol. Worldwide Internet access and the integration platform are provided by Telefónica.

2 TECNOPORT2025

The Port of Seville, with the aim of making a more efficient port that optimizes its services as an intermodal logistics hub, is committed, as part of its long-term planning, to investment and technology development, especially in three key areas: container tracking, railway traffic optimization and improvement of navigation by the Guadalquivir river.

TECNOPORT2025 is an initiative of the Port Authority of Seville, co-funded by the European Commission by means of the ERDF (European Region Development Funds), under the Pre-commercial Public Procurement model. In TECNOPORT2025 the University of Seville is leading a team of four European companies (Telefónica, Thales, Portel e Isotrol) with a leadership in their respective fields with the aim of building the “Port of the Future”. A fifth company, Serviport, provides consultancy related to the activities of the Port. TECNOPORT2025 is conceived as an initiative to enhance existing physical infrastructure by means of an exhaustive use of information and communication technologies (ICTs) in order to optimize their exploitation with the long term objective of increased growth, while ensuring environmental sustainability, and maintaining a leadership position in some key logistic corridors like the Madrid-Sevilla-Canary Islands one.

To this end, an innovative infrastructure for some key enabling technologies (such as a heterogeneous communication network and a platform for service integration) are being deployed, and three subprojects are being carried out, each one targeted to an area of particular interest to the activity of the Port of Seville: “Container Unitized Tracking System” - CUTS (focused in container tracking), “Ferro Port System” - FPS (focused in railway traffic operation), and “e-River information and optimization” - eRIO (focused in sensor monitoring and enhanced navigation in the Guadalquivir River).

The final result of TECNOPORT2025 will be a set of innovative products, designed to meet the needs of different stakeholders and users of the Port of Seville: the port authority itself, logistic operators, shippers, carriers, consignees, stevedores, ancillary companies, and inspection bodies, among others.

The scope of the project is the construction of a full-scale demonstrator of the overall solution and of each of its components in order to test both, their technical feasibility and their effective creation of value.

The overall solution will lead to the development of new products, which will find an application in other areas with similar requirements, so that the results of the project, in addition to meeting the needs of the PAS, will become commercially exploitable products.

3 CUTS Project

3.1 Introduction

Freight transport is one of the business with more presence in the world and crucial to the economy of a country. The fact that the traffic volume is so high makes it a complex problem involving many different actors: from the cargo owner to the insurance company, including also intermediate administrative entities. Therefore a system that provided information about the containers in transit would provide significant added value to logistics systems.

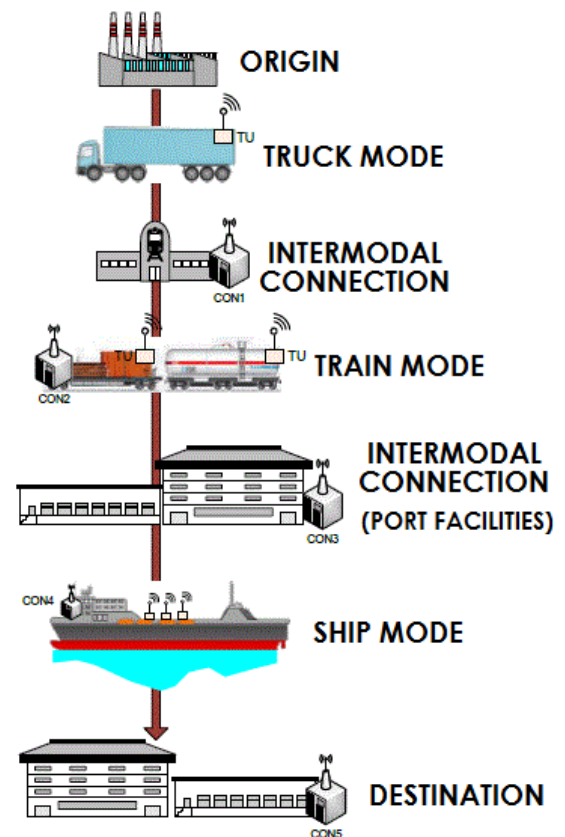


Figure 2. Scheme of multimodal transportation

Road transport has always been the most prevalent in the movement of freight. However, road congestion and the increasing necessity to find



more sustainable modes of transport have encouraged governments to promote multimodality as an alternative. From the supplier, the freight is transported using multiple modes (rail, ship and truck) without cargo handling to its final destination. Thus multimodality combines the cost effectiveness of railways or ships with the flexibility of trucks. However, multimodal transport has several difficulties to overcome to become viable. One of them is a high fixed cost, which explains why multimodality is not suitable for trips shorter than a certain minimum distance, which could be extended if drayage operations were improved.

Optimizing the management of freight is one of the main targets of the multimodal transport. Independently from the selected transportation mode, it is important to monitor the exact location and status of the merchandise in order to ensure its efficient management, at the same time, that goods are not damaged or their quality is not impaired (it is especially important in the case of perishable goods).

A variety of goods tracking systems have recently appeared in the market, although its market penetration is still low. They are usually intended for road transport. The most common tracking systems use RFID tags attached to boxes, pallets or containers, which are read in certain checkpoints along the way. These solutions, though do not require batteries in the tracked element, are limited by the necessity of deploying tag readers in selected checkpoints, with all the drawbacks inherent to such a solution.

More recent solutions offer GPS tracking (despite its high power consumption) attached to a communication terminal (GPRS/GSM or satellite), with widespread need for a SIM card.

Only very recently some solutions have appeared which are based on a set of sensors (including door opening detectors, temperature and humidity sensors, accelerometers, etc.) connected by a wireless network (Bluetooth or ZigBee type) to GSM/GPRS or satellite terminals, allowing cargo tracking in real time in almost any part in the world.

As for communication technologies, those solutions based on local networks solutions are rare; they mainly use the 2.4GHz band, which implies communication problems when there is a high concentration of containers.

One of the most complete examples of these systems is the one called Trecs (which stands for tamper-resistant embedded controllers) developed by Maersk and IBM in 2005. Such solutions usually lead to closed systems and terminals, based on proprietary interfaces. They provide all the services for cargo tracking usually at a high cost, only suitable for high-valued cargo.

3.2 *CUTS Objectives*

The goods are transported by various modes (road, train, boat, etc.) along multimodal corridors, although generally there is not a visibility of their location and state, nor it is possible to act on them. These limitations generate uncertainties (e.g. in the arrival time, or in temperature of the cargo), as well as a reduced ability to react, forcing to accept tolerances and, generally, to assume greater operating costs (e.g. in inventory or insurance premiums). Having more elements for decision-making in real time, and a greater capacity to react should allow optimize the effectiveness of the operations (i.e. reduce logistics costs, increase the reliability of the logistic chain, etc).

The main objective of CUTS System is to develop an open platform for geolocation and for remote monitoring and control of containers and their cargo, giving an answer to the problem of optimization of freight management.

CUTS is a system for remote monitoring and control of containers that integrates data coming from sensors located in the containers themselves and the necessary supplementary information, providing an open environment for the exploitation of these capabilities. CUTS solution transforms the container into an active element of the multimodal corridor, almost comparable to a store asset, increasing the capacity of management of supply chains.

3.3 *CUTS Functionalities*

The proposed system will provide the following functionalities:

- Geolocation: To determine the geographic position of a container and its presence/absence in bounded enclosures.
- Monitoring: To receive readings from sensors installed in containers in transit: both, periodic readings and alarms triggered by events, in almost real time.
- Actuation: To send commands to equipment installed in container traffic in near real time.
- Additional information: To include information on containers and cargo in transit from various systems.
- Services: To facilitate the development of applications. For example, for the management of transportation plans, for alarm management, for "geofencing" applications, etc.

3.4 *Beneficiaries of the system*

The main beneficiaries of the CUTS system are those responsible for the transportation of goods in containers in multimodal corridors (distributors,



producers etc., or specialized agents which operate on behalf of them). In addition, the system will develop new services that will create value for some other actors involved in the Port activity or in the logistic system.

Following Muñuzuri et al. (2015), the expected supply chain impacts of the system could be grouped in 6 categories: visibility, security, reliability, timeliness, cost, and efficiency, as it is shown in Table I.

Category	Requirement Description
VISIBILITY	<ul style="list-style-type: none"> - Transparency and visibility on terminal shipping processes - Earlier information on hinterland transport - Visibility during recovery processes from anomalies (reactive) - Traceability of empty containers for better repositioning strategies - Enablers of exception management - Accuracy of position of container in terminal area
SECURITY	<ul style="list-style-type: none"> - Opening of container only once/as less as possible - Fight counterfeiting - Reduce theft - Avoid cargo damage (liability issue) by knowing the sensitivity of the commodity
RELIABILITY	<ul style="list-style-type: none"> - Decrease lead time variability and capture deviations within margins
TIMELINESS	<ul style="list-style-type: none"> - Reducing total door-to-door time, minimising idle time - Reduce dwell time at terminals by improved availability of information to different actors thus contributing to better process planning - For some users, waiting time can be functional - Enabling companies to go intermodal by reducing complexity and solving interoperability issues - Contribution to e-freight and IoT visions to become a reality
COST	<ul style="list-style-type: none"> - Reducing total door-to-door cost
EFFICIENCY	<ul style="list-style-type: none"> - Reducing administrative burden/single window offering, one stop-shop-service - Pre-announcement of hinterland operators to improve terminal efficiency - Value added services from platform: automatic document generation from users

Table I. CUTS project impacts on the supply chain

4 TECHNICAL APPROACH

4.1 CUTS specifications

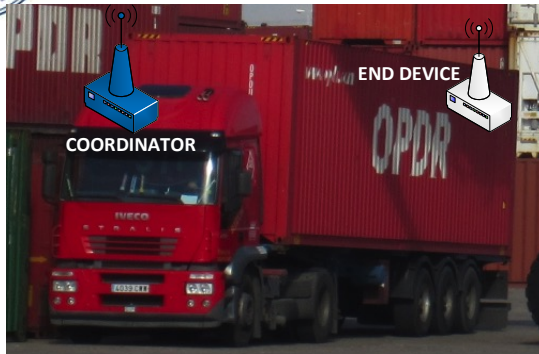
The proposed system is based in a low cost heterogeneous communication network covering the entire port facilities, which is connected via Internet (GPRS/GSM or satellite) to (usually smaller) network replicas deployed in warehouses, trains and vessels, or to single communication terminals installed in trucks. A set of autonomous, low cost, communication terminals interact with this network infrastructure. These terminals, attached to containers, are equipped with a GPS module and a set of optional sensors that monitorizes the container cargo (temperature, humidity, movement detection, etc.), as well as the presence of events that will generate alarms under critical circumstances, such as detection of an open door, fire, gas leakage, etc.

The network infrastructure is based on the recent IEEE 802.15.4g standard. Data measured by the attached sensors along with the location information of the containers are sent to an open and cooperative platform for data analysis, and offered to an integrated service centre based on the Internet of the Future Fi-Ware platform, that will provide specific services to each of the stakeholders in the transport chain. Moreover, using the capabilities of cloud computing, the proposed solution will offer scalability, intensive data processing, flexibility and easy management through web tools.

4.2 Architecture

The network infrastructure is based on the recent IEEE 802.15.4g standard, and it adapts to every stage in the multimodal chain. In the distribution of goods, several transportation modes can apply. Every mode has specific conditions to trace the cargo. The transportation of a container in a truck is much simpler than in others because there is only one container to track at a time, thus deploying a complex Wireless Sensor Network is not necessary, the container has one end device which will be connected to the coordinator terminal in the truck cabin. In the case of a ship or a train, they transport several containers (from only one to several thousands), then a WSN can be deployed to locate every container. In this scenario 3 different modes are identified:

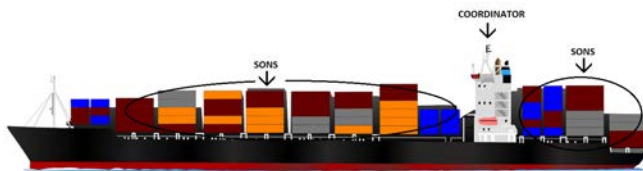
- Train and trucks moving the cargo from the origin to the port,
- Ships travelling between different ports
- Train and trucks that deliver the container to the final destination.



a) Network deployed in a truck: one end device in a container



b) Network deployed in a cargo train



c) Network deployed in a cargo ship



d) Network covering most of the Port of Seville facilities

Figure 3. Network architecture in main scenarios

There are four ways of acquiring the information for container traceability depending on the scenario: trucks, ships, trains and port. Figure 1 depicts the network architecture in every case, being the last two (ships and port) the most challenging ones in terms of technology performances and complexity of the solution.

The Madrid-Sevilla-Canary Islands corridor will be the logistic corridor where this system will be applied for the first time, with Seville port as the strategic point.

Once the cargo arrives to the port, the CUTS system is able to trace containers in the port facilities. It manages every critical piece of information about the goods, and provides alarms and notifications, such as an open door, a significant change in the optimal temperature, humidity, etc. Moreover, the system monitors the amount of time the container is stored in the port facilities, which is very important for the management of the containers in a big port, for calculating the costs of container storing, and to check the delivery time for perishable goods.

5 SUBSYSTEMS

5.1 Wireless Terminal Nodes

In order to achieve the network development a node based on an Atmel microcontroller and a Texas Instruments transceiver in the subGHz band have been chosen.



Figure 4. Designed wireless terminal node

This node consists of two boards, one of them with open interfaces dedicated to data acquisition, and the other one dedicated to manage wireless communications.

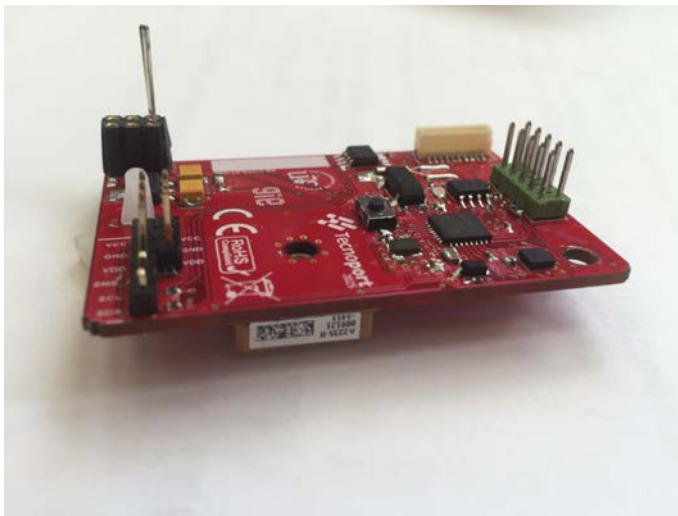


Figure 5: Sensor Interface board with GPS

5.2 Wireless Network Basic Topologies

Two kinds of networks will be implemented regarding the different scenarios explained in previous sections.

The first network, the system on a cargo ship or train, consists of a coordinator with a number of end devices connected directly to it. In this network, all the end devices attached to the containers can

be connected to the coordinator located in the bridge ship. The coordinator sets an 802.15.4 superframe, giving slots to a determined number of end devices, which can transmit their data to the coordinator in the assigned slot. The truck network is a particular case of this network where only an end device applies.

The star network has been designed as a synchronous beamed network with 256 slots. Thus, in 5 minutes of superframe period, 256 end devices have a dedicated slot, avoiding collisions. Every node sends a 25 bytes frame every hour or every assigned slot if an event occurred. The latency of the network depends on the total number of end devices. When the number of end devices is higher than 256 devices the latency increases in 5 minutes steps each 256 extra end devices. This latency is enough to locate the containers and to monitor typical variables in it. Network programming is based on STK600, where a Transceiver Abstraction Layer (TAL) has been designed, to make the design independent on hardware.

For the network deployed in the port facilities, it is necessary to know the area to cover. Usually port facilities have an extensive area to cover. Although a star-network is the optimal solution, it is possible that coverage is not ensured in this way. For this purpose up to 3 levels of routers could be necessary, which can cover distances in a radio of 10km for a typical communication link passing through several building walls.

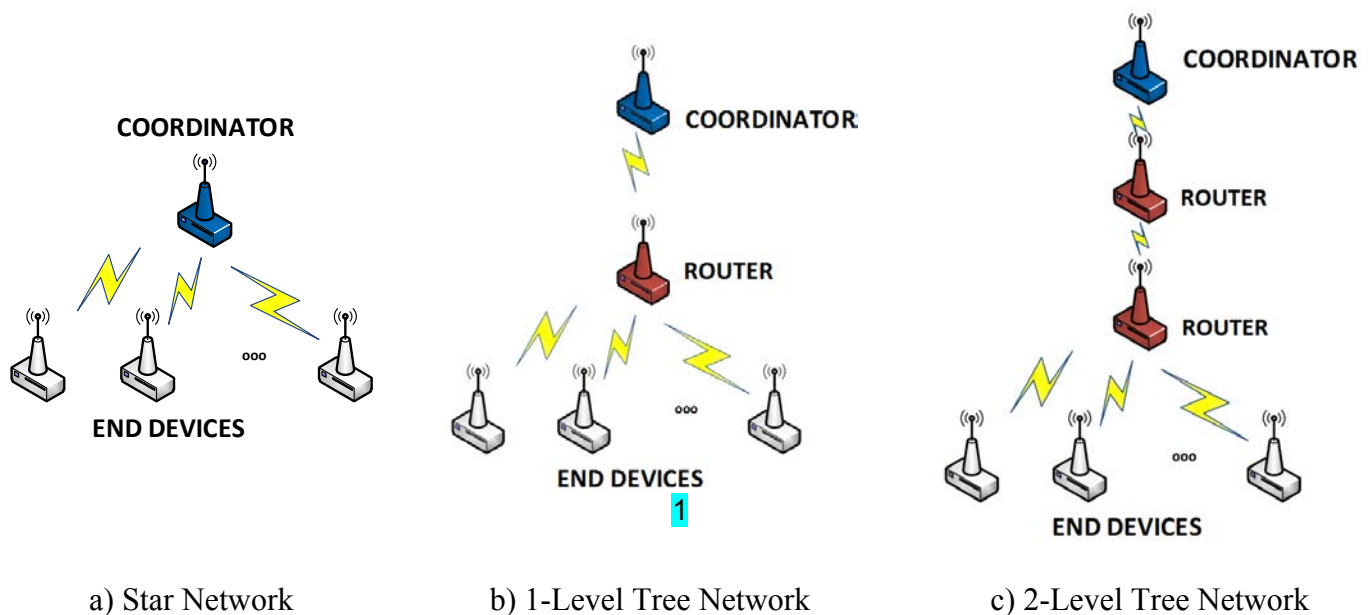


Figure 6. Basic Wireless Network Topologies

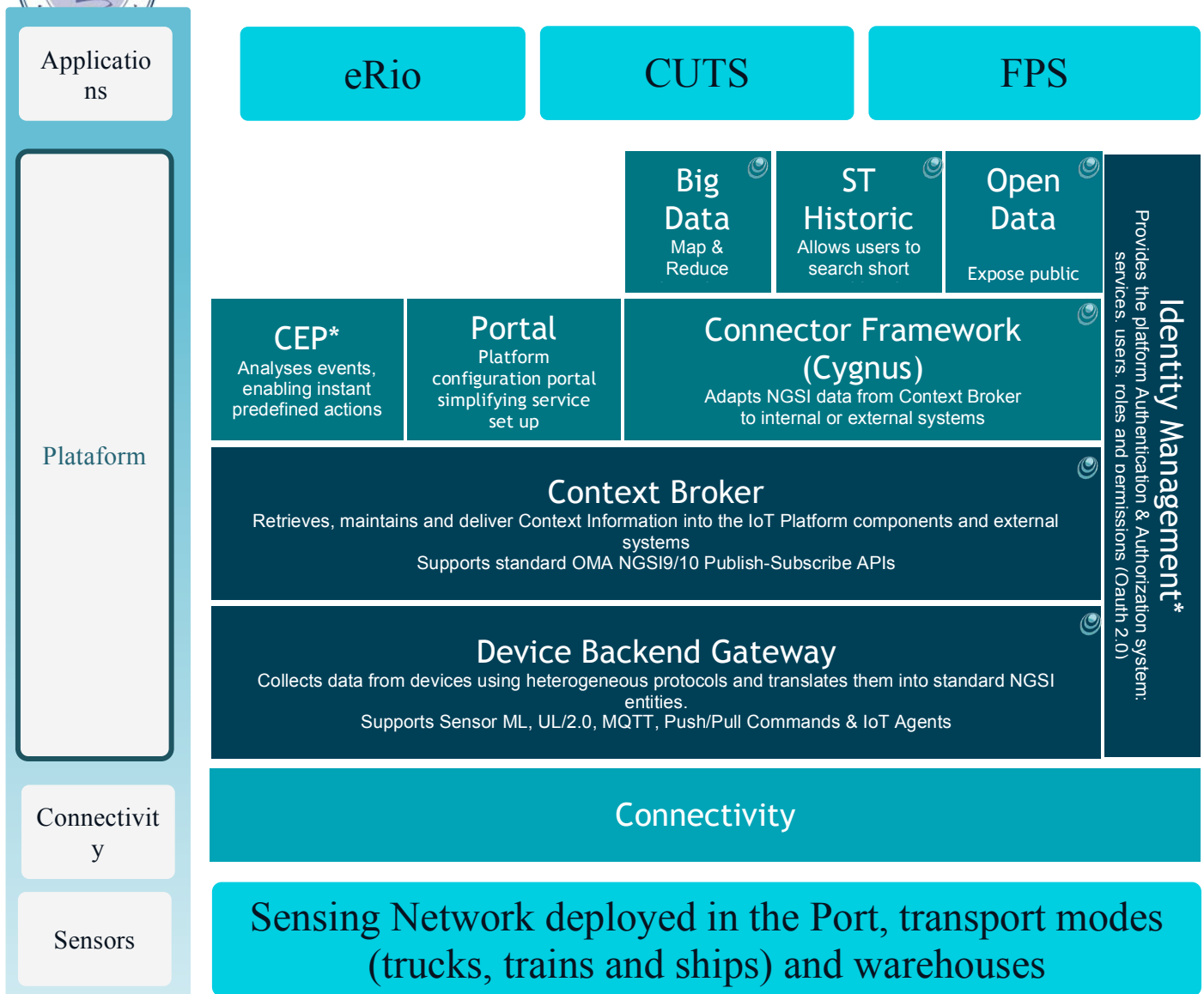


Figure 7. Architecture of the Integration Platform based on FiWare.

5.3 Integration platform and services

5.3.1 Integration platform

TECNOPORT2025 requires an integration platform that collects the information coming from the sensor network deployed in the in the different means of transport (trucks, trains, etc.), stores them in a distributed database and serves them to the different services and applications used in the project. To this end, and innovative platform based FiWare has been chosed, FiWare has been pushed by the European Commission in the Future Internet initiative.

FiWare is an open cloud-based infrastructure for cost-effective creation and delivery of Future Internet applications and services based on the Internet of the Thing (IoT) paradigm. The API specification of FiWare is open and royalty-free, driven by the development of an open source

reference implementation which accelerates the availability of commercial products and services based on FiWare technologies.

5.3.2 Services

CUTS has been designed to provided open interfaces for thirs-party applications, so that only a reduced catlog of services has been considered for CUTS in the TECNOPORT2025 project. Among them we select two of he most significant ones:

a) Geofencing

A service derived from geolocation is geofencing, consisting of detecting the position of a container outside a real or virtual enclosure defined by the geographic coordinates of its perimeter. When this situation occurs, an alarm is generated and reported to all those actors who may suffer

injury or who need to reschedule their operations, in the case of transport delays.

b) Planning of port operations

Since the CUTS system knows with high accuracy the position of the containers, as well as the location of the transport mode that carries it, an algorithm has been implemented that prioritizes the inputs and outputs of the containers in the port so that the overall port operations is optimized.

The aim of this service is to minimize transition times of containers in transit by the port facilities so that effective transport times are reduced in favor of a better service.

To this end the system collects the following input information:

- Estimated time of arrival at the port of different modes of transportation (trains and ships).
- Time required for output of different modes of transportation (trains and ships)
- Information on container transfers between modes.

and provides the following output information:

- Suggested priority for the entrance to the river of different ships, with dock allocation.
- Suggested priority list for the entrance of trains to the container terminal, with track allocation.

A user-friendly interface has been developed for viewing container tracking, with different user profiles (cargo owner, container owner, carrier, etc.).

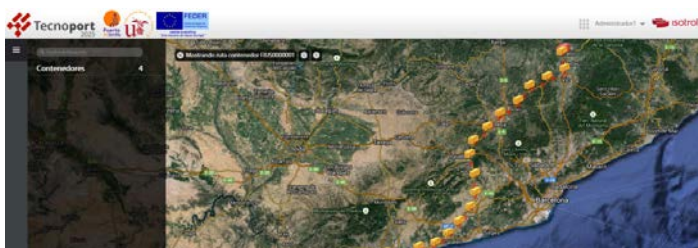


Figure 7. A view of CUTS user interface

A complete demonstration of the CUTS system is presently being deployed that will show the capabilities of different subsystems and tools developed in the project. The demonstration will track about one hundred containers in a real case tracking their position and the state of their cargo along the way from a warehouse in Madrid to another one in the Canary Islands, using different transport modes (truck, train and ship). The demonstration will finish at late November this year.

7 CONCLUSIONS

This paper has presented CUTS: a system for container tracking based on an open, public and collaborative approach, which is the opposite to the closed, proprietary solutions currently existing. CUTS is one of the parts of TECNOPORT2025, which is an ambitious project launched by the Port of Seville with the objective of advancing towards the “Port of the Future”.

In CUTS every transportation mode in a multimodal transportation (including warehouses and Ports) provide a basic ICT infrastructure consisting of a heterogeneous communication network whose most innovative part is a low-cost, high-performance autonomous wireless sensor network especially designed for this application. The end terminals of this network have got open interfaces so that a set of sensors and actuators developed in CUTS, or supplied by third parties, can be attached following simple connection rules based on standards.

The Port Authority also provides an integration platform based on FiWare, the solution pushed by the European Commission to become the de-facto standard for the Internet of Things. A reduced set of basic services are maintained by CUTS and offered to a community of users (which include all the entities interested in the activities of the Port, each one with a different user profile), and to interested developers, so that very complex applications can be designed, in an open way, to increase the efficiency of freight management, while reducing management costs, and increasing the competitiveness of the Ports.

CUTS capabilities and functionalities are being presently demonstrated in the Port of Seville.

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