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RTPORT: the 5G-based Model-Driven real Time Module for General Cargo Management

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Abstract: *Major maritime carriers are globally demanding improvements in the efficiency of port operations. Cargo carried by ships must be loaded and unloaded quickly with minimal stopover time in the port. This is driving the implementation of more efficient processes and the reorganization of technologies at the terminals: connected platforms, cloud-based services, service-oriented architectures (SOA), sensors and other IoT technologies (M2M), augmented/virtual reality (AR/VR), autonomous transportation, next generation mobile networks (5G) and blockchain-based technology. RTPORT, the 5G-based Model-Driven Real Time Module, will allow a better management of general cargo resulting in faster throughput compared to traditional human-driven communications. A full reorganized mobile network (5G), connecting smart sensors with cloud resources will be used in order decrease environmental impacts by optimizing trucks movements in the port area as well as improving workers' safety and enhance their skills with digital tools. The effectiveness of RTPORT will be evaluated in the Port of Livorno for EU Horizon 2020-funded Capacity with a Positive Environmental and Societal Footprint - Ports in the Future (COREALIS) project and it represents the starting point for the deployment of the Physical Internet.*

Keywords: *IoT, 5G, M2M, Automation, General Cargo, Physical Internet, Supply Chain, Augmented Reality, Sustainable Development, Virtual Reality, Container Terminal.*

1 Introduction

The performance of the port and the quality of its services are closely linked to technological innovation applied to the processes involving the whole Port Community. The digitization, sensorization and telematization of the port, enable the Port Community to be a Smart Community. The emerging technological innovations in the ICT (Information Communication Technology), ITS (Intelligent Transport System), IoT (Internet of Things) and PI (Physical Internet) fields allow an overall redesign of the logistic chains, which become increasingly smart and compliant with the concept of Logistics 4.0. The new digital revolution, involving many national and international ports, implies a more innovative, faster, safer and more reliable way of conceiving information exchange. From the value-added services perspective, 5G-based technology is discussed for the fast and huge data transmission, distributed networks for the vehicular communications, photonic radars for the timely detection of data, cyber-security to ensure secure access and historicization of information and blockchain to allow the secure exchange of information and certifications on the origin of data. In this context, the digitalization and integration, facilitated through the adoption of innovative information technology, have enabled a high degree of automation and streamlining in port procedures, especially in Container Terminals (CT). In fact, one of the most important roles of ICT is the ability to connect container terminals with other subjects in the port community, enabling a high level of interoperability and data sharing with the existing IT networks (i.e: Port Community Systems, Port Monitoring Systems, National Single Windows, Terminal Operating Systems, etc.). If for the case of containerized cargoes this proves to be absolutely true, since optimized tools are used (such as the Terminal Operating Systems), for the case of general cargo adequate solutions have not yet been found. The context of general cargo management, still suffers from a very low level of automation and digitization. Obviously this generates inefficiency that spreads over the entire supply chain and that in any case must be filled to guarantee the possibility of preparing the port environment for the deployment of Physical Internet (PI). This is the first requirement to enable the Physical Internet, an open and global logistic system founded on physical, digital and operational interconnectivity.

2 Problem Statement

The general cargo sector is an area that still suffers from the absence on the market of adequate management and monitoring solutions that can guarantee an acceptable level of automation and digitalization, effectively eliminating the operational inefficiency that derives from it. This problem finds its origins in the nature of the general cargo. Unlike the cargo transported in containers, the general cargoes are in fact characterized by irregular and non-standard geometries (i.e. pipes, components for industrial machinery, cars, etc.). The physical dimensions of the cargo constitute one of the main problems for terminal operators: often, this information is incorrect or even completely absent. This leads to many evaluation errors both during the loading phase of the ship and during storage and handling operations. In many situations the cargo taken from the crane according to the loading plan of the ship's captain is inadequate if compared to the space available in the hold of the ship. This means that it is necessary to put the cargo back on the apron, select another available cargo that meets the captain's requirements and load it onto the ship. It is clear that the unreliability of the information regarding the physical dimensions of the specific cargo, in this case produces inefficiency and waste in terms of time, actually slowing down the entire loading process of the ship. Another problem that arises is represented by the storage and handling of the cargo. Since the arrangement of the cargo in the storage area is performed without taking into account any storage optimization procedure (based only on the amount of available space), the movement of a given cargo leads to not always efficient maneuvers, with negative consequences in terms of time needed to find a certain cargo on the apron. To conclude this scenario, we must also consider the problem related to the forklift call. Currently, the control room operator executes manually the forklift call via radio communication systems. The terminal operator does not have a real-time visibility of the distribution of the vehicles on the apron and consequently runs the risk of making an inefficient call (choosing for example a forklift with a greater distance from the selected cargo). All these aspects highlight the fact that the management of the general cargo is still affected by a great inefficiency that affects the entire management and handling process, from the moment it arrives at the terminal to the moment it is loaded on the ship. In this context, RTPORT is proposed as a possible solution to the problems that have been presented, providing an automated and efficient system for monitoring and managing the cargoes on the apron.

3 RTPORT: Model-Driven Real Time Module

Digital transformation is having high impact in port handling and logistics providing new opportunities to enhance the productivity, efficiency, sustainability and port capacity. Although, in the last years there has been an acceleration in the automation and digitalization of ports; general cargo handling is still manual. The Model-Driven Real-Time Control module (RTPORT) fits this context in with the aim to optimize port operations thanks to disruptive technologies, including IoT, data analytics, and emerging 5G networks. RTPORT will allow better and faster handling of general cargo (e.g. storage optimization, yard-vehicles call optimization, loading/unloading phase optimization) if compared to traditional human-driven communication. It allows real time ports operation control by collecting data via yard vehicles and implanted sensors (including cameras) and taking operative decisions based on on-line analytic processing. A 5G mobile network, connecting smart sensors with cloud resources, will be used in order to allow the transfer of massive and high demanding bandwidth data. In the following, the general cargo logistic use case is described; moreover, an analysis of the use case using the structured analysis approach is reported.

3.1 General Cargo Logistics Use Case

The proposed use case focuses on the implementation of a system for the management of the general cargo analyzing both unloading (from the truck) and loading (to the ship) operations. More specifically, the general cargo logistics use case can be divided into three main phases (*Figure 1*):

- **Tracking and Storage** - this phase concerns all operations related to the handling of the goods from when they arrive in the port until they are placed in the yard;
- **Loading Operations** - this phase comprises of the selection of goods to be loaded on the ship and the transfer to the crane.
- **Yard Vehicle Call** - this phase concerns the forklift/stacker call during the general cargo handling operations.

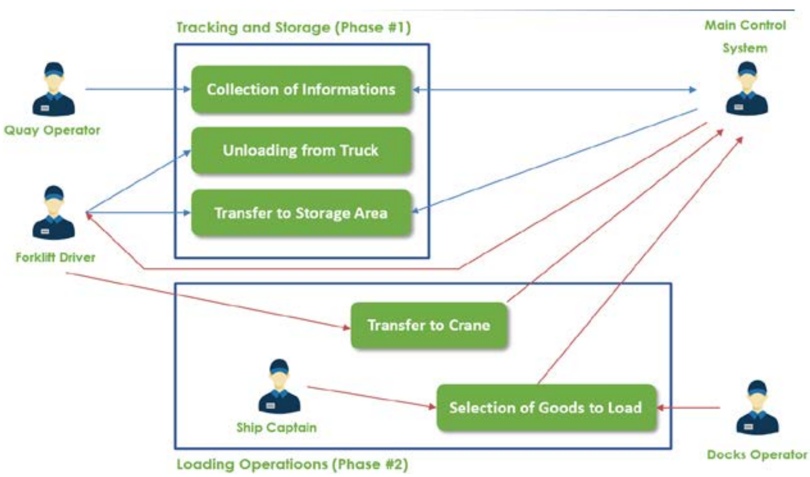

Figure 1: Functional Diagram

3.1.1 Tracking and Storage

The Tracking and Storage phase includes three operations:

- Collection of information;
- Unloading from truck;
- Transfer to the storage area.

The collection of information refers to the goods acceptance procedure. Two actors are involved in this activity: the quay operator and the main control system. The latter is the software managing the sequence of general cargo operations. When a truck arrives, the quay operator checks all the goods that are going to be unloaded. For each object he has to get the information on the waybill and check if the size of the object is already reported, as shown within the procedure diagram in *Figure 2*. If not, he proceeds with the size acquisition using the measurement device based on the LIDAR technology. Once the size is available, the quay operator, using a dedicated application running on a tablet, writes down all data on a dedicated form and sends it to the main control system via the mobile network. Once the main control system receives the information about the incoming object from the quay operator, a record is created in the relational database, where the goods data is stored, inserting the waybill information and the size of the object.

Figure 2: Procedure Diagram – Collection of Information

The unloading from the truck is a manual operation and precedes the size measurement, if required. The forklift or reach stacker picks the object out of the truck and stops waiting for the size measurement and/or the indication for the storage place.

The main control system after having created in the relational database the record associated with the incoming o ie incomk(/P TD [(t)-.14 -(t)-.114((r)4 0.134 ,Tw 0.38 0 Td [(i)1-26(h)1.64(g)-4(-

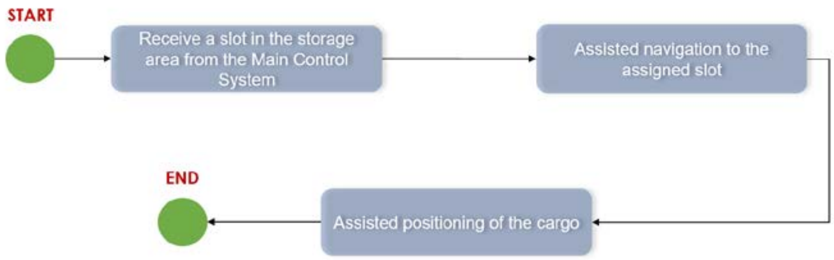

Figure 3: Procedure Diagram – Transfer to storage area

The storage area is equipped with cameras pointing to the stored goods. These cameras are used for stereoscopic vision of objects to detect their position. The same cameras are also used for getting the image stream to send to the driver to show him in augmented reality where to pick or place an object or which objects have to be moved and where, in order to accomplish the target. The object detection and localization functions in the main control system will provide the data description about each object. The main control system will then update the position and status of each object in the relational database.

3.1.2 Loading Operations

This phase includes the following operations:

- Selection of the cargo to load
- Transfer to crane

When goods have to be loaded onto the ship, there is a loading plan prepared by the captain. This plan can be changed runtime, if an object of different size or weight is needed (e.g. to balance the load on the ship). When an object has to be transferred from the storage area to the loading area in front of the crane, the docks operator, using an application, requests the next object to load from the main control system. The object can be identified in more than one way, depending on if it follows the loading plan or not. Once the main control system receives the request it searches for the proper object in the database (selection of the cargo to load phase).

When the main control system has selected the object to transfer, it chooses a free forklift and informs its driver about the object to be picked and where to place it (transfer to crane phase). The driver has an application on which he receives the data from the main control system (*Figure 4*). After having accepted the request from the main control system, he goes to the storage area where the object is located. The location to reach and the current position is shown on a virtual map on the driver's tablet. The application on the tablet, exploiting its GPS, will guide the driver to the location. When approaching the area, the driver can commute to the assisted positioning. By using AR, he could see an image of the area captured by cameras mounted in the storage area, that will highlight the position where the object to pick is located. If there are other objects to be moved to reach the target object, the main control system, through the driver's application, will give indication in AR about the objects to move and where to place them. Once the target object is picked, using the application, the driver has to send to the main control system a message stating the completion of the picking operation. When he discharges the object in front of the crane he sends a further acknowledgement to the main system to state the operation is completed. Then, the main control system updates the object record in the relational database, modifying its status as "transferred for loading".

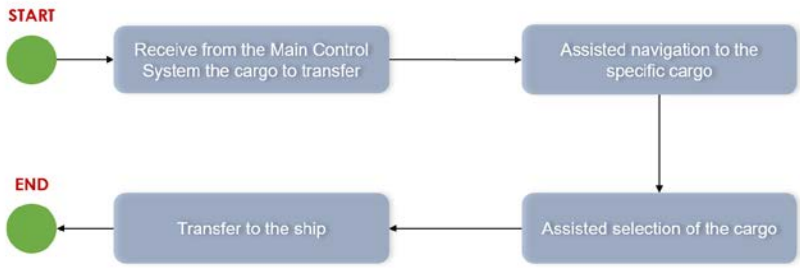

Figure 4: Procedure Diagram – Transfer to crane

3.1.3 Yard Vehicle Call

This phase is based on the use of the 3D rendering module (called MonI.C.A.) of the Port Monitoring System used at the port of Livorno. The idea is to provide the possibility to the container terminal's operators both to trace and monitor the vehicles present on the general cargo area, involved in the operations of loading/unloading/handling of goods, and to monitor its status with the purpose to be able to move/call vehicles optimally, in relation to the disposition of the goods. The vehicles involved in the loading/unloading of the general cargo will be equipped with a tablet to perform the operations as described in the previous sections. The tablet is a built-in GPS tablet and will periodically send data about the position of the vehicle. These data represent the starting point for vehicle tracking and are transmitted, through a 5G network, to the machine-to-machine platform (OneM2M). Then these data are processed and consumed by the local Port Monitoring System. Through a graphical interface, the operator will be able to see (in real time) where each vehicle is located in relation to the general cargo's position that needs to be loaded, unloaded or moved. In this way it will be possible to make the most appropriate vehicle-call in relation to the disposition of the general cargo.

3.2 Structured Analysis of the Use Case

The proposed use case has been analyzed using the structured analysis approach, that helps in defining all data flows, data structures and processes required to comply with the required task. According to the structured analysis approach, a hierarchical set of data flow diagrams (DFDs) have been defined, describing data processing , the data flows and the data structures used in the system. In *Table 1* an explanatory list of the graphic elements used in the DFD diagrams is reported.

Table 1: DFD Legend

Graphic Element	Meaning
Green Box	Actor interacting with the system. It could be a machine or a human being.
Orange border rounded box	Process describing the transformation of the input data flows into output data.
Magenta Bar	File or database.

Arrow	Data flow describing the information exchanged between two processes.

The context diagram in *Figure 5* shows how the actors (green boxes) interact with the general cargo logistics control system (orange box). The arrows represent the dataflows exchanged among the actors and the system. The diagram includes two main sequence of actions, corresponding to the general cargo logistics main phases (Tracking, storage and Loading operations). Except for the camera, green boxes represent humans and interact with the system via a HMI (Human-Machine Interface) made, using a dedicated application running on a tablet/smartphone.

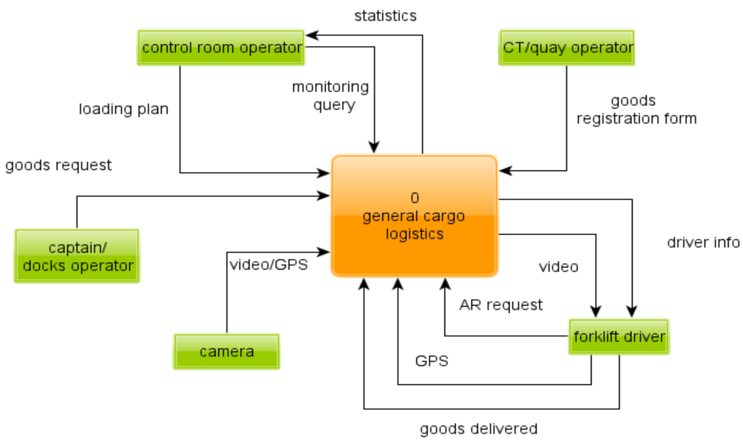

Figure 5: General cargo logistics context diagram

When a truck arrives, the quay operator registers the goods filling a goods registration form with all goods data, using a dedicated application running on a tablet. Then, the system (general cargo logistics) will register goods in a database. During the loading operation the control room operator provides the loading plan prepared according to the loading list provided by the captain in advance. However, this plan can be changed runtime, if an object of different size or weight is needed (e.g. to balance the load on the ship). In this case, the captain or the docks operator, using an application, can send a goods request specifying the next object to load. The control room operator, sending a monitoring query, can also visualize storage area statistics to monitor the yard's operations. When new goods arrive and when goods have to be transferred to the crane the system will identify the location where to place/pick goods and will send the forklift driver indications where the object has to be placed /is located (driver info).

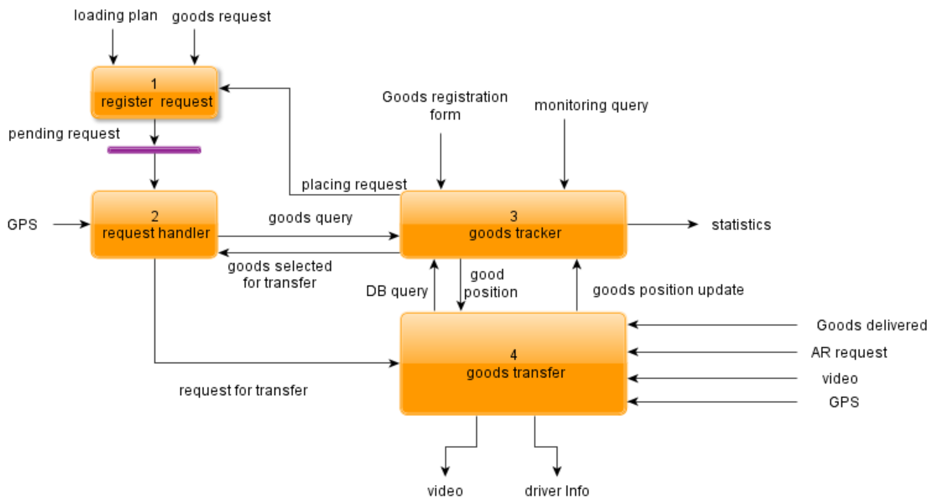

Figure 6: General cargo logistics context diagram

The application on the tablet, exploiting its GPS, will guide the driver to the location. When approaching the area, the driver could commute to the assisted positioning, sending an augmented reality request. By using AR, he could see an image of the area captured by cameras mounted in the storage area, that will highlight the position where the object must be placed/picked. The same cameras are also used for stereoscopic vision of objects to detect their final position. When the transfer is completed, a freight delivered message is sent and the object's status is updated. The "general cargo logistics" process is composed of a set of interacting sub-processes as shown in *Figure 6*. Moreover, it includes a file "pending requests" that queues the pending goods requests during the loading phase.

The processes involved are the following:

- **Process #1** - has the purpose of registering an incoming request for goods transfer into the requests file;
- **Process #2** - handles the next request to serve and the positioning of new accepted goods. During the loading operation, it sends a "goods query" to *Process #3* and, based on the goods selected for transfer, identifies the storage area to reach. Then, it chooses a free forklift and informs its driver about the object to be picked up and where to place it. For new accepted goods it chooses an optimal storage area and creates a request for transfer to send to *Process #4*;
- **Process #3** - manages the goods database;
- **Process #4** - guides the driver to the storage location. It is also able to provide assisted positioning by using AR.

3.3 Technical solutions

This paragraph reports the main technologies that will be used to implement the enhanced general cargo logistics use case.

3.3.1 Cargo size measurement

The size of general cargo goods is not a-priori well defined. The knowledge about their size is fundamental for loading operations and for optimizing storage. For this reason, a method based on laser range finders or laser distance measurement devices will be studied to create a volumetric model of the object consisting of the rectangular cuboid including it. A laser range finder is a laser sensor for area scanning. The light source of the sensor is an infrared laser with laser class 1 safety. The principle for the distance measurement is based on a calculation of the phase difference of the reflected beam, which makes it possible to obtain a stable measurement with minimum influence from object's color and reflectance. The laser range finder scans the environment along a plane, like a radar, computing the distance of an object from the emitter and getting a sliced view of the object on a specific plane. To get the complete model of an object several slices have to be combined obtaining a points cloud describing the object. The laser range finder has typically an opening of more than 90° on each side with respect to its front, scanning an area of more than 180° in total. A single scan lasts typically between 30 and 100 ms. Ten scans or less should be enough for the definition of the cuboid. The size computation should take around one second. In our case for the detection of the size of the goods a measurements system based on 3D LIDAR technology has been used. This device, instead of using a single photodiode for reception, adopts a camera sensor, an array of receptors, to speed up acquisition.

Figure 7: 3D laser range scanner

The SICK Visionary-T 3D laser range finder shown in the *Figure 7* will be used. The sensor will be interfaced with a small portable computer or a tablet/smartphone on which the processing software will reside. The points cloud got by the sensor will be integrated and processed by the software displaying the cuboid size related to the scanned object. This software will allow the worker to introduce additional data, like the ID code of the measured object and other required data, and to transfer, via mobile network, all the information regarding the object to the logistics control system that will then store the data in its database.

3.3.2 Cargo localization

Goods localization is required to optimize storage and allow a fast and optimized retrieval of the proper object to be loaded on the ship. General cargo is typically picked from a truck by a forklift or a reach stacker and placed in the storage area waiting for the ship's arrival. The area where goods are stocked is monitored by a set of cameras. A specific software will be able to identify each object and its position. When an object is picked from the truck, it is identified and registered by the main control system in its database. Then the forklift moves it to the storage area. As soon as the camera can detect the forklift, the object is tracked by the cameras and the location where it is placed is registered. In case an object is moved, the cameras recognize the object, track its movement and register the new position. To get a precise positioning stereoscopic vision will be used. This method should allow to achieve a high localization accuracy. Operating in outdoor environment, we must take care of lighting conditions that can change continuously due to the weather and the time of the day. For this reason, Wide Dynamic Range (WDR) cameras are adopted (*Figure*).

Figure 8: Example of WDR surveillance cameras

The HANWHA TECHWIN TNU-6320 camera is a candidate. Dynamic Range is the difference in light levels in an image, between the darkest and the brightest areas (*Figure 9*). On an overcast day, there will be a low dynamic range without areas of deep black and extreme bright spots. On a sunny day, instead, in an image with distinct shadows, there will be a greater difference between the brightest and darkest areas, and this is what it is called a wide dynamic range or WDR (also known as High Dynamic Range, or HDR).

Figure 9: Difference between a non WDR (left) and a WDR camera (right)

WDR mode is a technology that extends the camera’s range, to cover a greater span between the bright and the dark areas in the image. There are several ways to increase the dynamic range, and many solutions are used in combination to achieve the best result. Several cameras will be placed in the storage area to cover it completely. Each point must be covered by two cameras at least to allow the application of stereo-vision to compute the position of the object. Apart from positioning, the camera will be also used for identification of goods. To achieve this, their images will be processed remotely to recognize and identify the monitored object. For the image processing and recognition open source image processing libraries will be used like OpenCV. For image recognition the possibility of applying technologies based on the analysis of an ensemble of preprocessed image patches using Approximate Nearest Neighbour and Bayes network techniques will be evaluated for identifying the seen object.

3.3.3 Main Control System and its database

The main control system of the logistic application will make use of a relational database in which all the information related to each object will be stored (e.g. ID, destination, size, weight, location). This database will contain all the data needed to manage the object from its arrival to its departure. The same database will be used by the personnel, for instance, either to query the status of goods or to know what is stocked or to find a specific goods fitting some requirements for the loading onto the ship. MySQL is a candidate for this part of the system. An example of its usage can better explain how it will work and how it will be handled by the main control system. When an object arrives on a truck, it is registered with its data and a record is created in the database. When the object moves and reaches the storage area it is tracked by the camera system and its position is detected and added to the record. When the personnel on the ship asks for an object with certain characteristics to be loaded, via a specific application, the main control system identifies the object in the database that matches with the request and informs the harbor worker operating on the forklift which object to pick. The main control system and its database can be also used by the terminal employees to preplan the loading of the ship, optimizing both storage and loading operations. The main control system will be a program, written in python, running on a virtual machine in a local cloud installed in the terminal premises.

3.3.4 Applications on devices

Some softwares and applications, needed for handling the logistics operations in an optimal way, will be developed. The applications will be developed for Android platform, that is one of the most used operating system for tablets and smartphones. The Android Studio development platform will be used for developing the code. This environment includes all the functionalities needed to develop and test the application both with an emulated and real device. Specifically, to provide the required level of automation and integration three applications will be developed. The first application will be used by the worker registering the entrance of a new general cargo. This application will be connected to the tool for capturing the size of the goods. There are two main options: the measurement system is connected directly to the tablet or the measurement system is connected to the tablet via a miniPC. The application will collect the information about the size of the object managing the measurement process and showing the corresponding result to the worker. Then it will allow the creation of the information record about the arrived object sending it to the main control system for registration. A second application will be used by the worker on the forklift. It will provide information in virtual reality (VR) and/or AR to show where the object to be picked is placed in the area or where to place it. In case augmented reality will be used, the OpenCV library for Android could be adopted for the image processing. The application will make use of the GPS inside the tablet/smartphone for localizing the worker. This information could be integrated with more precise positional data provided by the environmental cameras, detecting the worker in the operation area. Then a VR map of the operational area will show the worker where he is, where the cargo he has to move is positioned and where it should be placed. The map will be updated by the remote main control system based on all the information gathered from the different sensors. The same application will provide additional information to the worker about his task and will be used by him to inform the main control system about the completion of the task. A third application could be provided to the stevedore on the ship. Using this application he will be able to send a request to get the next item in the loading plan or send information about the characteristics (size and weight) of an item that needs to loaded onto the ship not in accordance with the loading list. This request will be handled by the remote main control application in the cloud, that will look for an object satisfying the request, will start the search and transfer process, selecting a free forklift and sending the details of what to do to the worker on his application (the second application described previously) and, finally, will send a feedback to the stevedore on his application.

3.4 Use Case requirements

The real time handling of the goods, the continus exchange of massive information between sensors (i.e., cameras) and the control system and the use of AR poses tight requirements in terms of bandwidth and latency enabling the need of a 5G network on-site. *Table 2* details the main use case requirements.

Table 2: General 5G, Network and End Device requirements

Requirement	Value	Details
E2E Latency	<10ms (target 5ms)	time budget is < 100 ms for AR: target 50 ms to provide a smooth feedback to forklift driver; AR processing done in a local cloud close to the terminal area; 90% time budget must be reserved for AR processing.
Speed	>15Mbps/Camera	Cameras for AR and positioning check.
Reliability	More than 99%	-
Mobility	Yes (10mph)	Speed limit in harbor operational area.
Broadband Connectivity	Yes	-
Network Slicing	Yes	-
Security	Yes	-
Capacity	400Mbps (UL) and 100Mbps (DL)	-
Coverage rea	15.000 square meters	-
Number of Devices	5-20	-
Density of Devices	1-3	-
Bitrate per Device	10-20 Mbps	-
Acceptable Jitter	5ms	-
Class Service (1-8)	2-3	-
Type of Device	Camera, PC, Tablet, Smartphone	-
IPv4/IPv6 Support	IPv4	-
Connection of Device	Wired/WiFi	-
Type of Connection	Ethernet/WLAN	-

3.5 5G E2E Network Architecture

IoT devices (e.g. HDR cameras, LIDARs) installed in the area of the trial and supporting forklifts and operations are connected via 5G infrastructure to the local cloud running the application level. Local processing will be used to run the distributed applications needed for image processing and pattern and context recognition while AI processing will support workers' activities to guide drivers and workers with real time augmented reality info. In *Figure 10* the high-level solution of the 5G network infrastructure is reported.

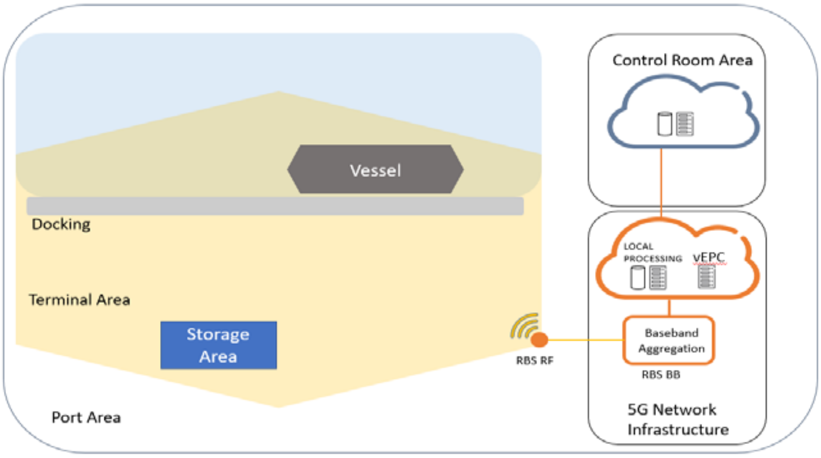

Figure 10: 5G Network high level solution

The overall setup is based on 3GPP R15 Option 3.x architecture. In this option, the 5G NR (New Radio) for user plane coverage is supported by LTE radio access supporting both user plane and control plane. This architecture called NSA (Non Stand Alone) is a reasonable choice for an initial deployment of 5G network where the operator has already a 4G nationwide coverage. Starting from the Radio Access Network section, the RBS RF function is installed at antenna site and will provide dedicated coverage in the test area identified in the Port and Terminal Area. As per NSA architecture the RBS RF will provide both NR and LTE radio coverage. The RAT BB function will be installed at a proper site where also the local Cloud Infrastructure will be hosted. The local cloud infrastructure installed in the same cabinet than the radio equipment will support Core as well as the application level. More specifically, this infrastructure will run all VNFs instances supporting the virtual Core (virtual 5G EPC, including vEPG and vMME and vHSS) to provide User Plane (UP) and Control Plane (CP) functions, in line with Distributed Cloud framework (equivalent 3GPP declination of the MEC paradigm). The UP function will be interconnected to local processing infrastructure through an application server with computing capabilities necessary for the use cases described in the previous paragraphs. The choice of a local 5G EPC co-located with the radio equipment and the NR radio interface is technically related to ensure latency and throughput requirements. More specifically, the local termination of the user plane allows the application to be as much close to the user application as possible, eliminating the transport section contribution to overall latency. In addition, the 5G NR radio interface is designed to reduce the radio access latency contribution in the end to end delay budget. High throughput levels in the radio access section are assured using wider spectrum portions dedicated to NR coverage in accordance to available LTE radio channelization. As a possible alternative implementation some or all functions governing the network control plane can be centralized in the MNO centralized Core Network, leaving locally just the functions dedicated to user plane handling. The result will not affect user plan latencies. Local user plane termination in addition to 3GPP radio cyphering of data and the intrinsic resilience coming for the adoption of MNO licensed spectrum on a dedicated local coverage together with a local termination of user plane (critical data remain on premises) provides additional benefits to reliability and security with respect to other unlicensed solution.

From a general perspective, the proposed solution can be considered making part of Private Network solutions to be used in similar application to the one defined for the COREALIS Project in Livorno, where low latency and high throughput communications as well as security and resilience are required for advanced use cases (including enhanced logistics, industrial automation and automated guided vehicles).

3.6 Transferability Issues

The experimentation of the RTPORT module in a container terminal of the Port of Livorno (chosen as the test bed) aims to instantiate a pervasive 5G network and to demonstrate how the interconnection of IoT devices, through machine-to-machine standards (ie: OneM2M Standard Platform), is in line with the ITU IMT-2020 technical requirements regarding mMTC communications (massive Machine Type Communications) or, which is the same, mIoT (massive Internet of Things). Despite this, the functionality of the RTPORT module is closely related to the radio technology in use: the 5G allows to reach a high data rate, higher throughput, lower latencies, high service availability, very high user density and high energy efficiency, compared to fourth-generation technology such as 4G (LTE) and its evolution. If in some cases, such as Virtual Reality, these requirements are indispensable, for the others (i.e: Augmented Reality, vehicles tracking.) this does not appear to be true. In fact, the initial solution for prototyping the RTPORT module involves an overlap with the existing 4G technology with the possibility to switch when needed. This means that radio technologies of generations preceding the fifth can be used to provide similar services even if in a limited and not always optimized way (4G technology is not able to support, for example, a high number of connections per unit area or even advanced features such as Network Slicing with a differentiated quality of service). In light of these aspects it is possible to state that the transferability of the RTPORT module (with its full functionalities) to other container terminals is closely linked to the availability of a fifth generation network even if it is not a necessary condition. It is clear that this also depends on the context in which each container terminal operates: for example, some terminals may not be interested in having a real-time assistance service during the cargo's handling phases, delivered via viewers and / or tablets with Virtual Reality. In this case a last generation, low latency and high availability network may not be strictly necessary, even if it would penalize the efficiency of operations. Another container terminal could have a very limited network of sensors (made up of a limited number of sensors) and a mMTC communication may not be strictly necessary. With all this, we simply mean that the RTPORT module is designed to work on fifth-generation mobile radio technology, which is why the problem of its transferability is closely linked to 5G coverage in the terminal area, but does not represent a limitation for the use of the module on 4G technology even if with significantly lower performance.

4 Societal Footprint

C*apacity with a p****O****sitive envi****R****onm****E****ntal and societ****AL*** *footpr****I****nt: port****S*** *in the future era*, namely COREALIS, is an EU-funded Horizon 2020 project which aims at supporting digital transformation within international cargo ports. It proposes a strategic, innovative framework for the ports to handle upcoming and future capacity, traffic, efficiency and environmental challenges thanks to the Internet of Things (IoT), data analytics, next generation traffic management and emerging 5G networks. When it comes to topics on ports, socio-economic development and competitiveness are inevitably tied to the minimization of the transit time of goods. 5G networks and digital technologies can shorten idle times for ships, while addressing workplace safety, environmental issues and sustainable development for the surrounding area. The Livorno Port Authority, the public authority in charge of managing port of Livorno, together with the non-profit R&D National, Inter-University Consortium for

Telecommunications – CNIT – and Ericsson, a private company and one of the leading providers of Information and Communication Technology (ICT) to service providers, are developing together a technological experience on COREALIS to qualify the associated benefits from all perspectives including and caring about sustainability issues. The Port of Livorno is facing growing challenges mainly connected to a steady increase in the flow of goods and people in the medium and long term. This phenomenon inevitably demands for an improvement in the operational efficiency of the port. The deployment of an innovative solution combining 5G and Augmented Reality to optimize cargo operations in the port of Livorno will constitute a reference point far across Europe. The Sustainable Development Goals (SDGs), as depicted by the "UN Agenda 2030", combine all of the different aspects of sustainable development by harmonizing economic growth, social inclusion and environmental protection. As the fruitful result of one of the most innovative as challenging policy making and partnership initiative of our time, their immense value lies within the fact

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between networks and IT applications for logistics, 2) Full visibility of the cargo through the supply chain (intelligent and standardized containers) and 3) Open logistics networks. With the reference to the scientific literature, the container terminal could be seen as the π-node, within the Physical Internet infrastructure, consisting of the main elements such as transporters (i.e. forklifts, trucks and ships) responsible for the transporting, conveying, handling, lifting of the cargo and the cargo in itself. Since the general cargo is characterized by not standard physical dimensions, it is not so simple to compare it with the concept of standard and smart container within the Physical Internet (so called π-container). Furthermore, it is not possible to apply a specific tag to the general cargo like for the case of containers, with the capacity to guarantee the traceability, identification, routing and other fundamental aspects for the implementation of the Physical Internet. This limitation must lead to exploring alternatives solutions. One of these could be to analyze the historical data regarding the general cargo (different types of cuboids acquired from the LIDAR system), identifying the most common types of cargo with the aim of being able to obtain a mapping according to the ratio of 1 to 1 between a specific cargo and its relative cuboid. At this point it could be possible to map the cuboid with a specific standard π -container's layout, extending the range of containers' types provided within the Physical Internet (0.12m, 0.24m, 0.36m, 0.48m, 0.6m, 1.2m, 2.4m, 3.6m, 4.8m, 12m and 18m) in order to include all cargoes that exceed the maximum standard dimensions. Of course this is a vary huge job that should be done in collaboration between all the container terminals around the world that manage the general cargo, collecting and processing all the acquired information. In this sense, the RTPORT module is representing the first needed step to explore and assess this possibility on the field, providing at the same time a cloud platform that could be used in order to share this kind of information within all involved stakeholders. Moreover, RTPORT aims to reduce: the empty trips in container terminals, the total number of movements per general cargo unit, the vessel operation completion time, the unnecessary yard equipment movements and more. This produce a significant reduction in fuel consumption, as well as CO^2 emissions reduction. Since Physical Internet is based on the main objective to allow a more sustainable way to manage and transport cargoes, RTPORT certainly allows us to move in this direction.

6 Conclusions

In this paper, a concrete implementation solution, based on the use of emerging technologies such as 5G, has been presented with the aim to address the problems that currently affect the general cargo management sector with the special attention to the Physical Internet. More specifically, it has been shown and discussed how the combined use of IoT sensors, innovative mobile radio technologies and process management/optimization software can provide an effective tool for managing cargoes on the apron, effectively eliminating operational inefficiency that derives from it. The implementation of the RTPORT module has been also addressed from the point of view of sustainable port development and the impact on the surrounding environment in line with the current United Nations 2030 Agenda, showing how it is possible to increase operational efficiency, increase the use of existing infrastructure and reduce operational costs. All these aspects have also been contextualized in the concept of the Physical Internet, showing how the processes of standardization, digitalization, integration and data sharing (enabled by the RTPORT module in the context of the management of the general cargo) are perfectly in line with those that are basic requirements of the Physical Internet.

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