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WIRELESS CONNECTIVITY IN PORT TERMINALS E-BOOK

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Beth Maundrill
Editor

PORT TECHNOLOGY

WELCOME

Welcome to this exclusive *Wireless Connectivity in Port Terminals* E-Book brought to you by Nokia and Port Technology International.

Through the articles in this E-Book we will explore how wireless connectivity is evolving and enhancing operations at ports and terminals globally.

The need for ports to adapt is more important than ever as the supply chain becomes increasingly demanding and other actors within the industry adapt, such as the shipping lines which are increasing the size of their vessels.

All these factors, and more, demand that ports continue to innovate and implement the latest technologies into their operations to meet demand and optimize.

The use of industrial-grade private wireless networks will be able to provide the secure communications for digital transformation to take place.

They will be used across the board from the equipment, supplied by the likes of Kalmar, which is already testing the use of 5G connectivity in its wireless RTGs.

At the higher level 5G and LTE will be implemented throughout Port Community Systems to make sure that connectivity and date provides the digital backbone needed to overcome the challenges that ports are up against today.

We already know that 5G is coming to us through the latest smart phone technology, but it is now clear that our industry will benefit from this new level of connectivity.

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5G AND THE DIGITAL TRANSFORMATION OF TERMINAL OPERATIONS

Matthias Jablonowski,
Head of Maritime,
Nokia

NOKIA

The container terminal industry needs to evolve rapidly to meet the challenges and complexities of our interdependent global markets. Supply chains are under extreme pressure, routes are shifting and vessel sizes are growing. Adapting ports and terminals to meet these evolving needs calls for innovative thinking and the adoption of digital technologies. A keystone technology in this digital transformation will be industrial-grade private wireless networks based on LTE or 5G.

The digital transformation of terminal operations requires the ability to collect, process and act on data across the entire terminal. Technologies such as machine learning, data analytics and advanced wireless communications technologies are being introduced to the port ecosystem. The convergence of operational technology (OT) and physical assets of ports with information and communications technologies (ICT) is driving innovations and automation that increase operational efficiency.

To connect terminal operations, end to end, requires more than cabling. Robust, secure and reliable wireless communications are essential to share data and enable automated processes, as well as to support remote operations, yard integrity, site and asset surveillance and a host of other use cases that can be digitalised. And, despite the growing complexity of terminal operations, this expansion and integration of digital technologies will actually simplify operations and make them more predictable and efficient.

Most terminal operations in the world have already taken steps towards digital technologies in recent decades. Successive waves of technology have been implemented for specific operational applications. The result is often a bit of a hodgepodge of overlapping technologies, many of them employing a specific flavour of wireless networking.

Talking to each other

These application-specific wireless communications include professional

WHITE PAPER:
LTE/5G pervasive industrial wireless and the digital transformation of port terminals

mobile radio (PMR) for mission-critical voice communications, based usually on TETRA or Project 25 (P25). There are wireless sensor networks (WSN), low-power wide area networks (LPWA) and different proprietary wireless technologies to support machine-to-machine (M2M) communications and industrial Internet of Things (IoT). There are also transponder networks for automatic guided vehicles (AGVs) and, finally, Wi-Fi for general operational data.

These various wireless solutions all have specific strengths and weaknesses, but in general, get the job they were designed for done. They, however, also collectively impose a bigger operational and maintenance toll just to keep them optimised, secure and available. As terminals move towards greater integration of their various digital operational processes, they are finding that these various systems do not talk to each other and do not scale.

Bringing the various operational technologies onto a single wireless network both reduces the maintenance burden of running multiple siloed networks and allows the various digital applications to more easily share their data with each other. It can provide a scalable communications and connectivity platform for an end-to-end digital transformation of terminal operations.

The wireless technologies best suited to replace these legacy systems and provide a single consolidated network for the terminal are 3GPP-based private LTE and 5G wireless. LTE wireless is a good candidate and has been in operation worldwide for the last decade in mobile telephone networks, with a robust ecosystem of devices and interfaces available. 5G offers further capabilities and allows for more use cases. Terminals starting with LTE can easily migrate to 5G when required.

In either case, what is making it possible for private networks to now use LTE and 5G is the recent efforts by governments to make the necessary radio spectrum available to private networks. Until recently, spectrum was effectively monopolised by the world's public mobile phone operators. Although superior for industrial applications to any of the competing wireless technologies, such as Wi-Fi, the unavailability of spectrum made 4G either unavailable or too expensive for most private applications.

This is all changing as spectrum is made available by national governments positioning themselves to enable enterprise to gain from the 5G revolution, which is all about industrial advancement. The advanced capabilities of 5G will enable more applications, especially in the area of automation. Often referred to as Industry 4.0, it will require higher bandwidth and ultra-low latency in a predictable and controlled way.

Remote control and automation

There have been some automated terminal operations in place for several decades, especially automated rail-mounted gantry cranes (aRMGs) working in tandem with AGVs, which are widely

used to provide horizontal quay-to-yard container transfer. There have also been early cases of automated straddle and shuttle carriers and automated rubber-tired gantry cranes (aRTG).

The industry needs to move more aggressively, however, in the direction of freely-moving container-handling machines such as aRTGs, shuttle and straddle carriers, and a freely moving version of the AGV called the automated intelligent vehicle (AIV). Untethering gantry cranes from their rail infrastructure, or AGVs from their complex beacon networks, will require robust and reliable wireless communications. This is where LTE and 5G private wireless hold great promise.

Remotely controlling automated equipment requires very low latency communications because of the need for almost instantaneous response from the remote operator or central control software. LTE can support industry protocols such as Profinet and Profisafe for control and automation applications. 5G, with a number of time-sensitive networking (TSN) features, will support ultra-reliable low latency communications (URLLC) that enable further enhancements.

Remote control of free-moving machines also requires the capacity to carry video from on-board cameras. There can be 15+ cameras for an aRTG and eight for an automated straddle carrier. 5G's extreme mobile broadband (eMB) feature supports the kind of bandwidth required by so many cameras.

Additionally, the industry is testing the use of network-based RF localisation for highly accurate positioning with little or no additional dedicated infrastructure, as is required, for instance, with beacon technologies used by AGVs. This represents another important capability of 5G.

Video analytics and beyond

As with automation and remote-control applications, there is also the possibility of leveraging video analytics to improve yard integrity by having accurate tracking of container locations.

Another example is remote reefer monitoring which can be migrated onto LTE and 5G. They will also support completely new applications, such as worker safety and fatigue monitoring. Drones can be introduced, which are especially useful in terminal and yard operations for remote visual asset inspection, monitoring of dangerous goods and perimeter surveillance, as well as improved situational awareness in emergencies.

LTE/5G can provide a single, highly reliable and secure communications platform for the full digital transformation of terminal operations. From TOS connectivity to high-capacity mobile video for drones, remote-controlled cranes and straddle and shuttle carriers, it is possible to support the terminal from vessel to truck or train.

Viewed on an application-by-application basis, there are already strong business cases for moving to LTE, as many terminals have already done. Viewed systematically, the argument for adopting a private wireless network based on either LTE or 5G as the terminal communications platform is even stronger and it will only strengthen over time.

"TO CONNECT TERMINAL OPERATIONS, END TO END, REQUIRES MORE THAN CABLING."

About the organization

Nokia creates the technology to connect the world, developing and delivering the industry's only end-to-end portfolio of network equipment, software, services and licensing that is available globally.

Private LTE/5G wireless networks will provide terminal operators with the foundation for unlocking new productivity gains, boosting efficiency and achieving operational excellence.

Nokia Industrial-grade Private Wireless supports critical communications and operational applications with a dedicated LTE or 5G network that delivers resilient, secure connectivity to every part of the terminal. These capabilities help terminal operators use digital technologies to enhance operational control, increase automation and improve safety.

The Nokia solution features industry first easy-to-deploy simple plug-and-play connectivity for all the assets.

About the Author

Matthias Jablonowski is Head of Maritime at Nokia and leads its ports program. Being intrigued by the opportunities of connected technologies and digital transformation, he works with port authorities and terminal operators on Port 4.0 and terminal automation projects as they embark on their smart ports journeys. Matthias has been instrumental in the expansion of Nokia into the Transportation industry.

5G ENABLES MISSION-CRITICAL WIRELESS CONNECTIVITY FOR PORTS AND TERMINALS

INTERVIEW WITH
Pekka Yli-Paunu,
Director, Research,
Kalmar

KALMAR

Q A

Kalmar is actively researching the future possibilities of 5G technology in ports and terminals. High-bandwidth, low-latency connectivity is expected to open up significant new possibilities for both terminal operators and system providers over the next few years.

Pekka Yli-Paunu leads Kalmar's automation research team. As one of the research avenues, his team is collaborating with Nokia and Finland's national research institution VTT to research and test 5G technology and its applications for terminal operations.

We spoke to Mr. Yli-Paunu about his current work with 5G technology as well as the reasons why Kalmar is investing in 5G.

WHY IS KALMAR INVESTING IN 5G TECHNOLOGY RIGHT NOW?

Mobile technology really became a potential game changer for us with the advent of private 4G LTE (Long Term Evolution) networks. In public networks, bandwidth and network management can easily create bottlenecks for mission-critical industrial applications. Private LTE networks enable ports and terminals to have their own high-performance mobile networks that can then be administered by mobile operators or other system providers.

The possibilities of private LTE networks were already apparent with the first test deployments that we did with 4G technology, but 5G is really taking things to the next level. Private LTE connectivity is more reliable and secure than Wi-Fi, and 5G is now genuinely enabling the low-latency, high-capacity connectivity and giving possibilities to make edge computing in same server where 5G core is running that is required for time-sensitive critical industrial applications using real-time analytics and multiple high-resolution video feeds.

One of the first use cases for the technology is wireless remote control for container handling machines, but the technology will enable countless other applications as well. Basically, we are now able to build robust digital industrial environments that depend on secure and reliable wireless

"IN ESSENCE, EVEN THOUGH 5G IS A BIT MORE COMPLEX TECHNICALLY, IT JUST IS A BETTER AND MORE RELIABLE NETWORK."

ABOVE
One of the first uses for 5G connectivity will be in enabling wireless control of RTGs.
Photo: Kalmar

connectivity yet are not tied down by a physical cabling infrastructure.

In our own product range, one of the first uses for 5G connectivity will be in enabling wireless control of rubber-tyred gantry (RTG) cranes. Until now, RTGs have been dependent on a fibre-optic cable reel system for remote control, which of course complicates the process of moving the machine between container stacks. The video, control and safety signals for remote-controlled RTGs demand very low latency and high bandwidth to uplink direction, and we have now successfully demonstrated 5G (NSA) connectivity for this application.

HOW DO PRIVATE 5G NETWORKS DIFFER FROM TRADITIONAL MOBILE NETWORKS?

Wireless automation networks have significantly different needs than traditional mobile networks. Consumer mobile connectivity is typically optimised for downlink capacity, while automation solutions send most of their data on the uplink side. Even with private 4G networks, the uplink bandwidth just was not high enough.

Latency is another parameter that is not really a concern for public mobile networks. The latest private mobile networks now enable very low latencies in the millisecond range, so it's no longer a constraining factor for industrial applications like remote control.

Of course, private mobile networks also introduce a different way of thinking about connectivity. Teleoperators have a lot of experience in building consumer mobile networks for large global customers but creating a high-capacity private network for mission-critical industrial applications demands quite a different approach, and a new way of working.

WHAT KIND OF COLLABORATION DOES KALMAR HAVE WITH NOKIA AND VTT AROUND 5G TECHNOLOGY?

We have been collaborating with Nokia on 5G connectivity since 2017 as part of a wider research project involving several industry research units and academic partners. One of our main partners has been Finland's state-owned research institution VTT. In the research collaboration we selected the RTG remote control scenario as our main use case.

In the test yard at our Tampere Competence Centre, we set up different configurations of container stacks, and Nokia conducted measurements to map out how mobile wireless signals propagate in a container terminal. We started this research with 4G technology, which was basically enough to get a single machine working reliably, but the capacity of 4G simply maxes out if you have a terminal full of wirelessly controlled machines. Even though 4G uplink speeds and bandwidth have improved over the last year or two, 5G is the obvious choice for future solutions.

WHAT BENEFITS AND VALUE CAN 5G BRING TO PORTS AND TERMINALS?

There are a lot of things to consider here. From a radio-technical point of view, 5G is simply a superior technology

to Wi-Fi or legacy mobile networks. You do not need to build as many access points, while simultaneously enjoying a significantly more reliable and secure wireless network. With 5G as the core technology, Wi-Fi can be added for those applications that need it.

5G also enables vastly more advanced capabilities for managing and monitoring the network as well as its quality of service. In essence, even though 5G is a bit more complex technically, it just is a better and more reliable network.

Of course, all this is on the technical side, and for terminal operators the real benefits are in how 5G supports the adoption of terminal and process automation. The higher the level of automation in the terminal, the more it will benefit from the capacities offered by 5G. In a manual terminal, a few seconds' drop-out on the terminal's wireless network is likely to go unnoticed in operations. In an automated terminal, bandwidth or latency issues are simply not acceptable, as they might stop machines and disrupt production.

The relationship between automation and wireless connectivity is a discussion that has been going on for years. The first wireless solutions were built over Wi-Fi and then supplemented by mobile networks as the technology improved. Today, we are seeing a strong drive towards standardisation in wireless connectivity, and it would obviously be beneficial if one type of network could serve all the different equipment in a container yard.

WHAT WILL THE FUTURE LOOK LIKE WITH 5G APPLICATIONS?

Private mobile networks have already taken some parts of the wireless applications that have been traditionally run over Wi-Fi, at least at larger terminals. For small terminals, Wi-Fi can still be a viable and cost-effective option, but as automation gains ground in smaller machines and at smaller terminals, it's easy to predict that 5G will follow.

It is my estimate that in the future, all of these technologies will continue to co-exist in various combinations. Maintenance halls might deploy Wi-Fi networks inside the building, while out in the yard automated machines might run over a private 5G network. In fact, one of the great features about 5G is how it can be combined with Wi-Fi.

One of the factors holding back the adoption of 5G is of course the question of radio frequency allocation, which varies from one country to another. It will also be interesting to see how the 5G network operator landscape develops. There will definitely be a market for a range of business models, including smaller virtual network operators serving the IoT field.

For our own projects, we have already been supplying equipment to one of our major terminal customers that are deploying high-performance mobile networks for critical solutions. Our next area of interest will be to extend the capabilities that we have developed in our remote-control RTG project to cover all equipment types. Smaller container-handling machines are more challenging from a radio connectivity perspective due to the restricted lines of sight between container stacks, but this is where the simulation and modelling capabilities that we've developed with Nokia and VTT will be invaluable.

So, we are building from our current know-how to more challenging applications, but it's safe to say that eventually we will be looking to have 5G connectivity on all of our container handling equipment, regardless of type or size. That is the future and what we are working towards.

BELOW
Kalmar has been using its Technology and Competence Centre in Tampere, Finland to test 5G connectivity.
Photo: Kalmar

About the organization

Kalmar, part of Cargotec, offers the widest range of cargo handling solutions and services to ports, terminals, distribution centres and to heavy industry. Kalmar is the industry forerunner in terminal automation and in energy efficient container handling, with one in four container movements around the globe being handled by a Kalmar solution. Through its extensive product portfolio, global service network and ability to enable a seamless integration of different terminal processes, Kalmar improves the efficiency of every move.

About the Interviewee

Pekka Yli-Paunu (Licentiate in Technology, Automation & Hydraulics) has more than 17 years of experience in automation R&D at Cargotec and Kalmar. Before that he was a CEO in an engineering office, as well as worked several years as a research scientist at VTT, The Technical Research Centre of Finland.

A CONNECTED AND DIGITAL PORT ECO-SYSTEM ENABLING SUSTAINABLE SYNCHRO-MODALITY

Mar Chao, Head of Commercial Business Development, **Port Authority of Valencia**; Laura Rodríguez Romo, Digitalisation Specialist and Project Manager, **TiL**; José Andrés Giménez, Port Logistics Director, **Valenciaport Foundation**; and Dr. Oscar Pernia, Director of Automation and Digitalisation, **TIL**

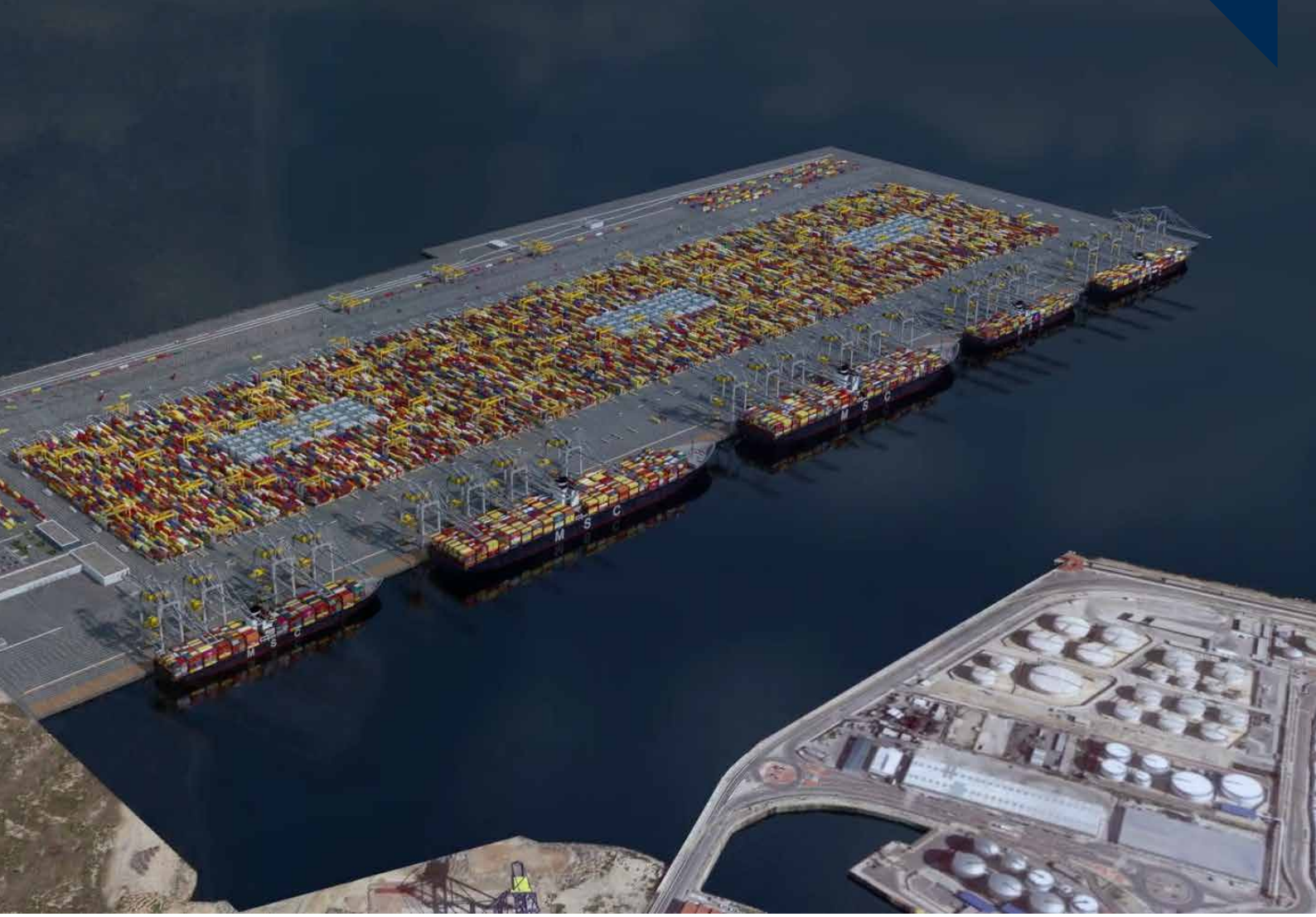
An ever more connected and digital port-logistic industry must still confront fundamental challenges. One such challenge means managing significantly higher cargo volumes while keeping and improving the increasingly exigent and dynamic productivity and competitiveness parameters. This is key for terminals globally responding to intermodal networks needs and for ports truly becoming efficiency partners to the ocean supply chain they are connected to. Trends like:

- Bigger vessel sizes with bigger call sizes
- Shipping lines alliances and associated economies of scale
- Reliability and visibility requirements by new e-commerce logistic models
- New sustainability and environmental decarbonization regulations.

For marine terminals, empowering synchro-modality, bringing decisions closer to real time and making contingency plans more predictable is paramount to enable efficient connection between the different transportation modes. The focus for framing a more efficient and sustainable operations at landside is concentrated for catalysing intermodality:

- The big scale operation at quay side need to be supported by the evolution at yard and gate processes, where systems such as the Gate Automation System or the Vehicle Booking System are important actors to enable the required intermodal 'fluidity'
- But without the required connectivity and integration at Port Community level, those objectives cannot be achieved so Port Community Systems (PCS) are very relevant to overall connect, digitise and integrate the whole port-logistic chain.

This article describes the holistic digital and technology evolution at the port level and the ability to connect processes across the different decision domains. Additionally, sustainability



“DATA GENERATED FROM EACH TRANSPORTATION MODE - MARITIME, AERIAL, RAILWAY OR ROAD – SHOULD BE VISIBLE AND INTEGRATED IN A CORE OPERATIONAL BACKBONE.”

RIGHT
Figure 1 – SmartPorts and IOT platforms
Source: Fundacion ValenciaPort

will be the fundamental driver in the building of a more efficient, safer, and secure port-logistic chain.

The telecommunication technology role on visibility and efficiency

The roadmap to SmartPorts will require new standards with low latency, high bandwidth, and high reliability communication services to effectively support synchro-modality at the port-logistic chain.

Data generated from each transportation mode - maritime, aerial, railway or road – should be visible and integrated in a core operational backbone. The connectivity is key to get there, by technologies widely known in the port logistics sector such as WiFi, Bluetooth and RFID; as well as new actors in the so called LPWAN (Low Power Wide Area Network), like LTE-M and NB-IoT, that benefit from a largest range in geographical zones with 2G, 3G, 4G and shortly 5G.

New communication options will reshape connectivity across the port eco-system. They will enable the

“FOR A REAL PORT ECO-SYSTEM, THE CORE FRAMEWORK ENABLING PORTS TO MOVE FORWARD TO THE DIGITAL TRANSFORMATION AND THE OPERATIONAL EFFICIENCY ARE THE PCS.”

realisation of opportunities today that are only theoretical, such as the traceability benefits that smart containers will bring or the advanced analysis of video by drones.

The end goal is to integrate the data capture and real-time updates into a data system-of-record that applies data consistency models and makes information accessible and reliable across applications. The resulting system architecture is complex but modern open platforms which are enabling the evolution to the required modularity, scalability, responsiveness and robustness to truly support the evolution to SmartPorts.

The process digitalisation and intermodal decision making

With those connectivity and data pre-requisites resolved, the quantum leap for decision making will not take place without taking some steps backwards, as data exchange is still very fragmented.

At the terminal process, automation by Gate Operating Systems (GOS) is key, both in automated gate and rail access terminals to identify the cargo, the vehicle and the driver, together with the entry and exit time and operational, technological or maintenance exceptions. The automation of this process is complemented by Vehicle Booking Systems (VBS) to plan available timeslots for the vehicle to arrive to the terminal and combine import and export to promote double transactions, as well as encourage the access outside peak hours.

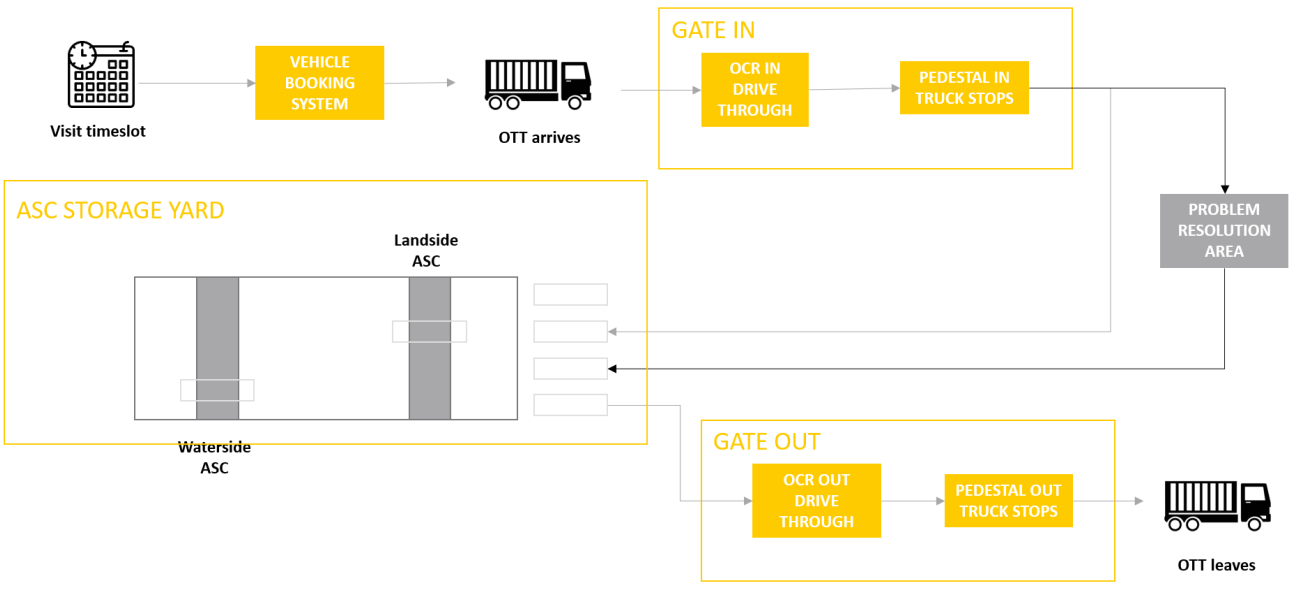
In (semi) automated terminals this is very important, as the timeslot availability needs to be also synchronised with yard cranes scheduling, so the terminal yard schedule capacity and manage buffers efficiently.

A key function of VBS is its predictive data analysis, to achieve a more efficient terminal management through prescriptive planning and, along with gate automation, an optimal truck-turn-around time. Additional relevant benefits are cuts to emissions, less congestion and improved traffic management overall. The VBS function also simplifies documentation management, in collaboration with the Port Authority, resulting on a simpler and more efficient gate process for all actors involved.

A smart port eco-system empowering PCS and TOS

For a real port eco-system, the core framework enabling ports to move forward to the digital transformation and the operational efficiency are the PCS. The integration with Terminal Operating Systems (TOS) is also key, as both applications cover the core functions for supporting planning processes and will continue being the basis for intermodal planning and desired synchro-modality at Ports.

BELOW
Figure 2 – Terminal Gate Process digitalisation and automation
Source: TiL



From here, the introduction of IoT technologies and the deployment of sensor networks at ports enable the generation of new data and new information layers, to integrate the existing ones with richer and more accurate data, overall increasing visibility of port processes:

- In the future, massive data processing (Big Data) and advanced analysis by artificial intelligence and machine learning models will enable prediction tools. These tools will be able to 'look ahead' at planning and to 'learn from the past' at execution, making the cargo repetitive/seasonal patterns and the best performers practices optimizing the connection of all transportation modes.

To consolidate connectivity technology impact and to address operational synchronisation, it is necessary the collaboration and the implication of all port agents, specially between operators and the port authority. It is relevant to share a vision in relation to sustainability and efficiency. This is the case at the Port of Valencia, in which the Port Authority along with Valenciaport Foundation work actively together with key Terminal operators like TiL to achieve the objective of the Port being a more transparent logistic node, more and more sustainable and efficient.

- PCS is the platform that enables the digitalisation of port operations. As a proof of efficiency in Valencia's services to clients, five million messages a month, on average, were transferred through ValenciaportPCS during this COVID crisis, allowing business run under normal standards.

ABOVE
Figure 3 – Port eco-system actors at SmartPorts
Source: Valencia Port Authority

Conclusions

Currently, the transportation and logistics sector is facing challenges on decarbonisation and the added and depth changes originated by the COVID-19 global pandemic. Public and private agents need to collaborate to effectively reframe processes, technology and organization paradigms:

This article touches on the technology evolution, especially by IoT and 5G, and their associated platforms – and SmartPorts efforts in order to make sure connectivity and data creates a digital backbone to ensure the synchronisation of the different operations, reducing waiting and idle times therefore minimizing energy consumption and emissions.

Ports and terminals need to become transparent logistic nodes within the supply networks, and within the overall ocean supply chain: being their efficiency and sustainability strongly depending from the synchronisation across the different transportation modes, as shippers and carriers evaluate the overall network of hinterland, short-sea, and deep-sea, and its connectivity, to select their port of choice.

This article also explores the main applications on the terminal and port side that will help the evolution. PCS acts as the central application and how TOS, GOS and VBS need to act as truly interconnected eco-system to manage landside operations in a much more predictable and digital manner.

In conclusion, the rapid growing of e-commerce and the need of being resilient is accelerating Ports industry transformation, the Port eco-system role is key in our search to find answers to the real-time visibility and reliability requirements from shippers, cargo owners and end consumers: processes, systems and data need to come along in our inevitable focus for reducing the environmental impact, keeping and even incrementing the operational efficiency at our terminals and ports.

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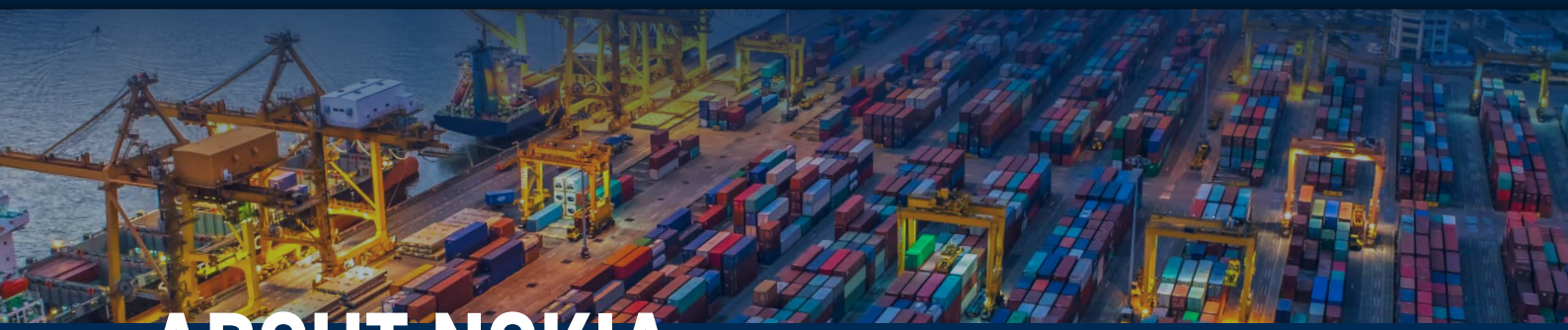

ABOUT NOKIA

We create the technology to connect the world. Only Nokia offers a comprehensive portfolio of network equipment, software, services and licensing opportunities across the globe. With our commitment to innovation, driven by the award-winning Nokia Bell Labs, we are a leader in the development and deployment of 5G networks.

Our communications service provider customers support more than 6.4 billion subscriptions with our radio networks, and our enterprise customers have deployed over 1,300 industrial networks worldwide. Adhering to the highest ethical standards, we transform how people live, work and communicate. For our latest updates, please visit us online **www.nokia.com** and follow us on Twitter **@nokiaindustries** and **LinkedIn**.

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