5G and MEC can significantly improve smart port operations

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Shipping ports are central to global trade in goods; 793million[1] twenty-foot equivalent (TEU) containers passed through them in 2018, an increase of 4.7% from 2017. These containers must be offloaded from cargo ships onto handling areas in ports until container trucks or trains are in place to remove them. A large number of cranes of different types are used around the ports and each is operated on a 24/7 basis because containers must be moved to and from freight ships in a timely manner. Any significant delay would result in substantial economic losses to the shipping companies.

Crane controllers, however, work in hazardous conditions, which leads to high labour costs, including insurance premiums. This comment will discuss some of the challenges that port authorities face and the reasons why 5G plus multi-access edge computing (MEC) technology should present these authorities with the first real opportunity to significantly improve controllers' working conditions, overall automation and deliver cost savings to ports.

Ports must operate like clockwork; any delays or staffing problems can be costly

The volume of the world's seaborne trade reached an all-time high of 11 billion[2] tons in 2018 of which 7.8 billion tons were classified as dry cargo, transported via containers on freight ships. A total of 793 million TEUs were transported by sea in 2018. The rest consisted of crude oil and other tanker trades. The world's top three container ports – Shanghai Singapore and Shenzhen – shipped 42.0[3], 36.6 and 27.7 million TEUs, respectively, in 2018. Port operations will come under increasing pressure to improve efficiency in order to remain competitive.

Efficiency is the cornerstone of port operations and to meet targets, a wide variety of cranes operate around the port on a 24/7 basis. Quay cranes are used on the quayside to offload containers from the freighter and onto the cargo handling area where other types of cranes, such as rail mounted gantry cranes (RMGs) and rubber tyre gantry cranes (RTGs) move the containers further along the container yard and onto container trucks or railways to transport them to their destinations.

The whole operation must run smoothly to avoid additional operational costs or potential law-suits against the port authorities. In passenger airline operations, airport gates are leased on an hourly basis to enable passengers to embark and disembark, and to allow the plane to refuel. Ports adopt a similar model. A cargo ship's time at the port is billed on an hourly basis as needed to offload and load new containers. Inefficient port operations can cost cargo carriers hundreds of thousands or millions of dollars.

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[1] For more information, please see UNCTAD 2019 Handbook of Statistics

[2] For more information, please see UNCTAD 2019 Handbook of Statistics

[3] For more information, please see World Shipping Council

Port authorities find it difficult to recruit crane operations staff and face general efficiency pressures. There can be up to 60 gantry cranes in a 1km-square area and to maintain continuous operations, with three rotations every 24 hours, the ports must employ a large number of crane controllers. The controllers work in hazardous conditions given that they operate heavy equipment and move around areas where large and heavy loads are continuously transferred. The harsh working environment makes employee recruitment difficult.

A typical crane controller works in a small cabin at the top of the cranes, at a height of between 30m and 70m above the ground. Furthermore, these controllers are prone to injuries because they sit a small place for long periods. For these reasons, the comprehensive labour costs such as compensation and insurance subsidies at traditional ports account for a large proportion of port operational costs.

The port authorities are investing in automation and remote control systems to reduce costs and staff injuries

Creating smart ports is not easy

Port authorities have been trying to automate operations and create remote control systems particularly for cranes and other vehicles, for over 20 years with limited success. Multiple HD-quality cameras and programmable logic controllers (PLCs) are required to remotely control the gantry cranes from a control room elsewhere in the port, instead of having a controller sit in the cabin at the top of every crane. Controllers remotely control the cranes to load and offload containers from freighters by watching camera feeds. The number of cameras installed on cranes can vary depending on the crane size. Typically, 6 to 27 cameras are required on each crane, which would use a total uplink bandwidth of between 30Mbps and 120Mbps. However, a controller can only watch up to 5 video streams simultaneously, so a maximum of 30Mbps uplink bandwidth per crane will actually be required.

Port authorities explored and verified a mix of fixed and wireless networks, using fibre-optic cables together with Wi-Fi and 4G technologies. Following the latest 5G trials, we can conclude the advantages and disadvantages of each of these technologies for this type of use case and environment is shown in Figure 1.

Figure.1: Technology comparisons

Comparisons	5G	Wi-Fi	Fixed network
Mobility	High	Limited	None
Coverage	High	Limited	Limited
Latency	Ultra-Low	Low	Ultra-Low
Uplink bandwidth	Very High	High	Very High
Interference improvement	High	Low	N/A
Security	Very High	Low	Very High

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In container ports, RMG and RTG cranes are the two most widely used types of gantry cranes. The former moves on pre-set tracks in a container yard, while the latter is equipped with tyres and flexibly moves containers across the container yards. However, even the very heavy cranes, such as quayside cranes, have high mobility requirements. They usually need to move horizontally on a 100m to 200m track, depending on the port size, while the smaller RMG cranes need to move on a 200m to 400m track. The connectivity in traditional ports on both the quayside cranes and RMGs is delivered by fibre on reels with a diameter of between 3m and 4m, installed on the cranes.

Other container handling machines, such as the RTG cranes and intelligent guide vehicles (IGVs), however, have a greater range of mobility and move at higher speeds up to 40km/h, around the whole port area. Wi-Fi, however, only delivers a coverage area of tens of meters with limited quality of service (QoS) guarantees even if outdoor high-power access points (APs) are used. Switching between multiple APs can take several seconds and may be required even in low mobility scenarios, such as in the 200m covered by the quayside cranes. This can lead to signal loss and reduced QoS.

5G plus MEC will deliver the communications technology necessary for smart-port use cases and will reduce operational costs

The new 5G mobile technology, unlike 4G, will provide significantly higher bandwidths, both in the downlink, but more importantly in the uplink. In a typical remote control scenario requiring 20 or more cameras installed on a single quayside container crane, an average 5Mbps bandwidth (compressed data to reduce additional bandwidth requirements) per HD camera working at 30 frames per second, will generate 100Mbps or more uplink bandwidth from a single crane. The total bandwidth requirements for the whole port quickly add up if HD camera on all cranes, other vehicles and intelligent video surveillance (IVS) devices are all taken into consideration.

To properly control vehicles and avoid injuries in locations where heavy objects and machinery are in use, the controller will require a system with rapid response rate. 5G delivers significantly lower latency, that is the delay between sending a command and receiving a response from the server, than 4G networks and this will ensure precision crane control or allow the controller to stop a vehicle in case of an emergency. For example, with a 1-second latency, a vehicle travelling at 40km/h will have moved 11m, which is far too long a distance in an emergency situation. The end-to-end latency requirements to control vehicles and gantry cranes is less than 30ms.

5G networks on their own will not, however, deliver such low latencies. All data communications that use a mobile network must by definition travel the length of the operators' transport network before reaching an external data network. This will significantly add to the overall latency. The advent of MEC deployed at the local gateway will have a twofold advantage: through user plane and control plane separation, MEC ensures the data is kept to be processed locally within the port networks, thereby reducing the overall latency. Furthermore, MEC can create a private local network, improving data security. Given that ports are independent enterprises, the port authorities will not want their data to interact with the mobile network operators' (MNOs') external infrastructure.

The availability of local computing resources as part of MEC can improve data processing and reduce the machine vision system cost. Machine vision is used for container ID identification for smart tally at ports. The existing machine vision system is expensive due to the dedicated monolithic architecture that consists of tightly coupled HD camera and image processing server (installed on the container identification nodes). A more cost-effective machine vision system would offload the image processing capability from local servers to the central MEC servers. Furthermore, the use of MEC will future-proof the port's networks, making future upgrades and daily maintenance easier and facilities the AI and big data algorithm training by breaking the data silos.

Private and public network separation using 5G will enhance network security

5G networks provide much higher network security features compared to Wi-Fi, such as two-way device authentication and the use of licensed spectrum instead of unlicensed, which reduces interference and tampering. 5G's 256-bit enhanced cryptographic algorithm, compared to 4G's 128-bit, delivers additional security improvements. Integrity protection implemented on the 5G user plane, through MEC deployment, effectively prevents tampering and improves air interface security.

Port authorities in partnership with their mobile network operator (MNO) partners can also create multiple sub-networks in order to enhance network security and separate different users. A public sub-network for consumer mobile communications and a private sub-network for cameras and the remote control of cranes and other vehicles can be setup by using SIM cards (or eSIMs) with different public land mobile network (PLMN) numbers. Traffic from the different devices can be routed to the appropriate destinations based on access point name (APN), PLMN or tracking area code (TAC) through the mobile base stations and the port's MEC gateway.

5G smart ports worldwide

To compete in the global economy, port authorities must embrace digital transformation. The advent of 5G networks, AI and other Industry 4.0 digital technologies, has prompted the world's top 20 ports by annual container shipments to engage with MNOs, such as Deutsche Telekom and LG U+ and network equipment providers (NEPs), such as Ericsson, Huawei and Nokia, to trial new solutions.

The port of Qingdao in China and Ericsson launched a partnership programme at Mobile World Congress 2019, following a technical trial in late 2018, to develop a 5G smart port solution. One of the key goals was to demonstrate the advantages and labour cost savings that could be possible if 5G networks were used for automation compared to a traditional port with no automation. It is, however, unclear that progress is made beyond the trial stage.

In the Italian port of Livorno, which handles 780 000 containers per year, together with Telecom Italia, Ericsson and ENI Enrico Mattei Foundation, the port authority has defined an innovative model to assess the introduction of new technologies such as 5G in the port processes and explore how digital transformation can drive sustainable development and meet the United Nations set goals for Sustainable Development for 2030.

Given China's export market and number of containers that pass through its ports, China would seem to be a huge market for this kind of automation. Huawei has therefore engaged in a number of trials with all the top 10 ports authorities including Nansha, Ningbo, Qingdao, Tianjin and Yangshan to trial 5G technologies. The engagement with the port authority at Ningbo port, one of the world's largest, with over 550 gantry cranes, successfully demonstrated the use of 5G together with MEC technology, delivering high data throughput needed to serve a large number of HD camera feeds, together with latency of less than 20ms for vehicle remote control. A further trial between Huawei and the Qingdao port served as proof that 5G can address the needs of gantry cranes for remote control. Huawei and Nansha port have trialled 5G to test next-generation IoT sensors, big data analysis, and AI, to build a smart, environmentally friendly port for use by 2021.

In Shanghai Yangshan port, the world's largest port, and the 32.5km long Donghai bridge that connected the port to the mainland, Huawei successfully deployed 35 5G base stations to deliver full 5G coverage in the port and to ensure that remote control and unmanned driving can be implemented in the port and the connected bridge area. In the other ports, including Tianjin, Huawei has focuses on delivering 5G and AI as the key to port digitalisation.

The port of Rotterdam also hosted a collaboration between Huawei and KPN to establish a 5G network using latest antenna technologies to increase network capacity and reliability, becoming the first port in the Netherlands to trial 5G networks and test AR and HD camera use cases.

The South Korean operator, LG U+ partnered with Seoho Electric, the nation's major producer and developer of port crane control systems and the world's second-largest, in August 2019, to enact demonstrate smart port operations based on 5G networks. Once installed, 5G's ultra-low latency feature will smoothly and flexibly operate the unmanned cranes to load and unload containers.

In June 2019, the Hamburg port authority (HPA) together with Nokia and Deutsche Telekom completed an 18-month trial of 5G network with network slicing. The trial explored different network slices for different applications, including sensors used for environmental monitoring, traffic control and analytics, together with maintenance support and augmented reality. HPA announced that the port was ready to automate many of the port's operations as soon as the 5G network was live. Deutsche Telekom's goal was to demonstrate that operators can serve the industrial space with campus networks, separately from their everyday network setups.

Good network connectivity has become a fundamental infrastructure need for ports, however, port authorities must understand that the benefits will not be delivered using 4G or other wireless technologies, such as Wi-Fi. Port authorities should partner with NEPs and MNOs to trial and invest in 5G networks.