# Can ports change the world – again?

## Connectivity requirements, small cells and private networks

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# About this paper

This paper flows from Small Cell Forum's (SCF's) recent work on private cellular networks (SCF235). That paper concluded that private networking technology is a significant opportunity for service providers, enabling new business models, and tailored services. It allows users and customers to integrate diverse sensors, machines, people, vehicles and more across a wide range of applications and usage scenarios.

One of the paper's most important conclusions is that private networks are not a use case waiting for 5G to happen. There are plenty of current commercial deployments based on 4G-Era technologies. Private LTE (4G) solutions are already available today that can seamlessly migrate to private 5G networks when standards and ecosystem support full commercial deployment. Looking ahead, where enterprises have more demanding performance requirements – e.g., availability, reliability, latency, device density, higher data rates etc – 5G will bring a significant uplift in the potential of private networks.

Our work to date on private networks and cellular connectivity for enterprise represents the telco industry's view of how cellular technology can support business requirements – with many real-world examples of how this has worked in practise. This paper is the first step in what we hope will be on-going engagement with ports, where the focus is on a deep dive into the sector's evolving business requirements and how these must be supported by the 5G-Era technologies. To this end, SCF engaged with a dozen ports and ports organizations in EMEA of various sizes and at quite different stages of their digital journeys.

This is very much a first step and the initial conversations captured here aim to provide a snapshot of business and operational priorities, perceptions and challenges. It's clear digital transformation is an inevitable part of the future of ports and the industries and transport networks that serve them or use them. But what form will it take? What needs will it meet? And how closely aligned are the views and plans of the world's ports on how this transformation will evolve?

The views reflected here are very much from the perspective of the port authorities and our next steps include gaining a better understanding of how these reflect and align with the requirements of the diverse range of port tenants. Our endgame here is to consider the commonalities of current and future requirements and the extent to which a scaleable, baseline blueprint for cellular connectivity can be developed for the sector that reduces the need to reinvent the wheel for each port, reduce costs and speed deployments.

At the request of the ports, the contributions have been anononymized.

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# 1. Introduction: Priorities and focus

Ports were always big business – but in the past few decades they have become bigger than anyone could have imagined in the early 20th century. The advent of containerization in the 1960s slashed the cost of transporting goods around the world and made possible the boom in global trade.

It also changed the make-up of ports, which no longer needed thousands of dock workers and instead invested in improved road, river and rail transport to move containers seamlessly to other parts of a country or continent.

This development changed the world. However, this apparently inevitable change was delayed by a decade of struggle before it was widely adopted.

Some observers of ports believe that the next big change will be digital transformation of the sector. However, this is a complex evolution, involving everything from autonomous cranes to tracking of goods via IoT; from onsite security to onsite communications between staff. And not everyone has a clear vision of how it will happen or what it will involve.

For instance, priorities and the focus will vary a great deal depending on the size, position and activities of a port.

That said, the money-and-time-saving potential of smart or autonomous shipping is a focus of a number of ports and port authorities.

Projects in areas as far apart as China and western Europe are moving facilities ever closer to complete autonomy, with ships loaded and unloaded by automatic cranes, and containers driven away by self-driving trucks, all co-ordinated from a central remote-control room and contributing not only to efficiency but to lower emissions.

And remote-control cranes don't just bring operational efficiencies. Because they're unmanned, the port can continue to run when high winds make it too dangerous for traditional cranes to operate and force other ports to close. Such an evolution may lessen the need for crane drivers but it will usher in upskilling, a trend towards more highly skilled and safer jobs.

The Internet of Things (IoT) will, most obviously, benefit more efficient tracking of goods. However, IoT sensors could also collect data around tidal streams, wind strength and visibility, helping to reduce vessel waiting times and automatically guiding crewless ships into berth, saving tens of thousands of dollars each time a vessel is docked.

Another technology being trialled by some ports is the digital twin. This virtual version of the port enables operators to run different scenarios, using real-time information to improve decision-making and problem-solving, and support predictive planning.

Blockchain is also gaining a lot of interest: it offers a way of securely linking the disparate systems that shippers, port operators and hauliers use to record and track goods, also reducing the time spent manuall re-entering data.

All these applications are predicated on robust, secure and, in most cases, mobile connectivity.

## 1.1 The role of 5G

Our discussions with ports aimed to be technology agnostic – the focus was on requirements, not delivery mechanisms. However, almost without exception the ports we worked with chose to frame requirements and their evolution in the context of 5G availability and capabilities.

**"I'm not convinced it has to be 5G. What we need is high-quality coverage for the whole site – how that's delivered we don't mind."**

A recent report on 5G for ports from Deloitte notes that the majority of the largest seaports have fixed machinery and equipment that can connect to networks over cables. However, port operators also need to track and communicate with hundreds of straddle carriers and vessels – not to mention thousands of employees in a complex ecosystem.

For this a reliable, secure, and private network is needed. Further, port managers need to track multiple data points for tens of thousands of goods such as containers: the exact location, whether a container has cleared customs, whether it is at the right temperature, whether anyone has moved

or opened it, and so on. Moreover, all this must be realized in areas within several square kilometres, filled with moving metal objects and radiofrequency-emitting devices.

5G can – or will be able to – work in these demanding environments of radio frequency interference sensitivity, low latency/real-time/tactile, high density & high reliability needs, whereas for other communication technologies, such as 4G and Wi-Fi, there are latency, bandwidth and resilience considerations. Furthermore, privacy, security, flexibility, and price considerations will likely drive these organizations to want to control their own networks. Deloitte predicts that ports, airports, and similar logistic hubs will generate about a third of the 2020–2025 private 5G market and they will be among the early adopters of this new technology.

**"Today our 4G network is not working well for us in the container yard and things in our sector are generally starting to move to 5G."**

5G could transform the way enterprises work – in particular, alongside IoT, which will add connected sensors and actuators to everything from small tools to large machinery and deliver new levels of insight and automation.

## 1.2 Making it happen

But to make all of this possible requires a greater focus on infrastructure and connectivity in ports as well as bandwidth and ability to share data between ships and ports. And just about everyone agrees that the need for fast, secure bandwidth will only increase.

In addition, some areas – like cybersecurity and electronic handling of documents – are relatively new for ports. In other words, something that is normal in truck cargo is a new development for inland navigation.

The promise of digital transformation may be clear but there's still the question of which technology will be required to enable it, including which connectivity will support it, which type of networks can be rolled out and when and where public networks might be adequate; that is nowhere near resolution yet. Many ports seem to operate through public networks, while in the inland shipping sector there is not yet much talk about private networks.

That said, interest undoubtedly exists and, if spectrum and networks are available, ports and port authorities are beginning to see the potential benefits of greater connectivity in general, with 4G, 5G and private networks in particular.

Reliable coverage is an important driver. For example, data from cranes on discharge and productivity could be useful but if cranes are not attached to the network it becomes difficult to guarantee that such data will be available in real time. Public networks might not meet the ports' privacy and network visibility/control requirements, have a strong enough, or reliable, signal and capacity may be saturated. Multi-generational cellular technologies may be needed, and currently it's not unusual for equipment to only be 3G-compatible. Standard Wi-Fi is a possibility, but it requires large number of access points with a lot of infrastructure and the use of unlicensed spectrum is always an RF challenge.

While 4G is already successfully enabling many port connectivity requirements, many digital transformation frontrunners are trialling 5G initiatives and these are fuelling interest across the sector.

However, it's worth emphasising 5G spectrum is still being auctioned in many countries and rollout won't happen overnight; it could take years for the necessary spectrum to become available globally. For example, in the Netherlands the 700MHz spectrum band was only auctioned in July 2020; and higher-capacity frequencies – 3.5GHz – is to be auctioned during 2022. Finally, the auction of millimeter wave bands offer the most bandwidth with revolutionary 5G characteristics might take several years as well.

On the upside, a number of countries, including the Netherlands, France, Germany and the UK, all have spectrum available for private networks.

## 1.3 Multi-port initiatives

But connectivity-related activity is definitely underway, as visible in the numerous multi-port initiatives. Take the Connected Ports Partnership, a collaboration between several major operators and ports to which seven ports have signed up, with more are likely to follow. Although at a relatively early stage, its (fairly simple) aim is to share data to increase efficiencies and cut costs in the world's busiest ports and trade lanes, as well as to reduce emissions. A shared logistics system will allow participants to pool data and resources with the aim of, for example, adopting shared technology to co-develop a mutual platform for monitoring shipping and environmental data.

**"All the elements of the port community need to communicate with one another. The port authorities, the maintenance crews, the tenants, the trading communities, logistics. Everyone."**

This activity is regional as well as global. The UK-based North East Smart Ports Testbed sees five regional ports band together to explore applications of satellite-based technology and digital programs. The program will involve digital and industry experts, academia and regional authorities as well as a number of ports.

The testbed will examine technologies such as artificial intelligence, data analytics, unmanned marine vessels, and airborne drones to enable ports to become more 'intelligent'. It will also examine ways of speeding up trade, increasing efficiency and reliability, reducing costs, tracking cargo and improving security.

Long-term collaboration projects on industry and trade logistics technology are also being enabled in the UK by what is known as the 2050 Innovation Hub, with port automation and real-time information a potential benefit as well as trial and implementation of appropriate open data systems such as blockchain.

While this is not quite as ambitious as, say, efforts to enable autonomous ships or vehicles (of which more later), the groundwork of improving ports' trading efficiency and environmental impact – and encouraging a move towards a paperless workplace – is essential to the connected ports future and being enabled here.

Satellite communication is also being assessed, through the UK's Situational Awareness Information National Technology Service (SAINTS), which

brings together experts from business, universities and the public sector, to find ways of using artificial intelligence (AI) to harness data and develop digital solutions.

The UK's north-east region has been chosen as an ideal location for a testbed, with the local economy strongly connected to the ports and a tight-knit business community serving as the perfect catalyst for collaboration.

Digitization initiatives, as part of SAINTS, will involve the testing of scalable, satellite-based solutions for ports, providing new business opportunities and hinterland engagement, accelerating the growth of green energy, improving customer experience, and achieving operational efficiency.

**"We're not fixated on any particular platform but if we invest in tech we'd rather invest in the newest tech."**

In addition to this, the testbed will examine technologies such as data analytics, unmanned marine vessels, and airborne drones, allowing ports to become smarter, speeding up trade and reducing operational costs.

As a ke part of the initiative, technology firms are being invited to test their technology at a number of ports.

Connectivity will work alongside, and enable other drives: green energy, health and safety, and more. However, real-time information, faster through-put and greater efficiencies require a strong connection and a decent backbone to get information to people at the right time – and ideally in real time.

But how do you get quayside cranes, mobile cranes, mobile hoppers and other items to talk to each other – and ensure the connectivity needed for track and trace? And how aware are decision-makers of enabling technology, like small cells? These are questions that often still need to be addressed.

## 1.4 Every port is different

The other, more obvious, factor is that every port is different. And in some cases, 'port' feels like an overly constrictive descriptor. The vast majority of ports do much more than just load and unload; they also offer the

warehousing, transport networks and raw materials that attract industries to work on or near a port site, turning it into a hub for production and processing as well as delivery and transport. And one company may be the economic operator, developer and authority for a number of ports and adjoining industrial sites.

This isn't unusual. One organization may provide a complete package of port services to its industrial and commercial clients, from logistics and infrastructure services to the issue and maintenance of the sites in a number of port regions. And many ports are linked, geographically and economically, with industrial sites.

**"Cybersecurity and electronic document handling are relatively new concepts for ports. What's normal in truck cargo is new for inland navigation. Today we need systems secure from the ground up."**

Thus, a port with multimodal access and quays as well as public roll on roll off (RoRo) facilities, ramps, a jetty and various logistics service providers may also have the required facilities for transhipping goods. But, as we have noted, various clustered business sites may be located nearby, using the capacity and diversity of the port to develop chemicals, energy, and related offerings such as wind or wave power. This attracts other businesses, like data center providers, that may consume energy and, beyond this, fixed connectivity such as fibre optics, in turn attracting energy and optic fiber providers.

And that's not all. Green energy can be provided by wind turbines, biomass and hydropower. In some cases, the opportunities offered by nearby agricultural enterprises can feed off biobased locations that in turn may house the recycling and waste industry.

It goes almost without saying that there will be good rail, road and water connections to and from both seaports and land available to attract new business.

The result: something that is much more than a port but with a port as its centre.

## 1.5 Automated shipping

As we have mentioned, a key application for 5G is likely to be autonomous shipping. For example, a number of technology companies and ports are part of a 5G autonomous shipping pilot within the 5Groningen initiative, which is transforming North Groningen into what is referred to as the ultimate testing ground for the latest generation of mobile internet – with a particular focus on autonomous shipping.

For this trial, a five-metre-long vessel was equipped with sensors and cameras, which provided real-time data transmission to a head office. It was thus able to navigate autonomously – though with an on-board crew – within port waters.

Its location, course and speed were measured by sensors, while the vessel was equipped with a 360-degree camera, a high-resolution camera and a thermal infrared camera. Together, these devices were able to monitor the water, the quay and objects such as other ships, creating 'situational awareness' – an awareness of the environment. This pilot aimed to gather

real-time data, as well as to share it as efficiently as possible with operators, vessel traffic controllers or a harbor master.

Elsewhere in the world, another project has brought together a port authority with a global commercial vessel designer and tugboat firm to develop the world's first fully unmanned autonomous commercial marine tugs.

One of the primary advantages of the innovative design includes greater capability, as shifting the human element from on board to onshore will allow such vessels to operate in far more adverse weather conditions. The new technology will also help increase efficiency and enhance operational safety.

As such projects make clear, 5G can offer the possibility of interconnecting sensors and technologies, thus enabling real-time transmission of vast amounts of data. Positioning – at present largely carried out by GPS – is a key aspect of autonomous shipping that could be better resolved by 5G.

**"Autonomous shipping means good bandwidth and the ability to ship data between ships and ports, also between ports. Going forward, our need for fast, secure bandwidth will only increase."**

The reward for getting it right would be far from negligible. The advantages of autonomous shipping are not just smaller crews but potentially an increase in the port's level of safety and efficiency as well as accessibility. Of course it's early days yet. However, automatic docking of freight ships, yachts and autonomous ferries is now also being examined in many parts of the world.

## 1.6 Drones and boats and lanes

As well as the experiments with autonomous ships, some European initiatives have been using drones to measure the depth of ports. While 4G networks could take this on, 5G is better able to offer the speed and bandwidth required. That's even more the case with autonomous ships, where a vast amount of environmental information needs to go from the vessel to the control room – with low latency guaranteed.

Smart shipping is part of an ongoing drive to develop connectivity for ports but it also extends to central systems and of course intra port connectivity across countries and regions. Some of the wish list items already cited by ports and authorities include administrative handling of documents, cooperation between pilots and coastguards, connectivity at sea, dialogue with coast guards and bigger ports and assets management.

Doing this using traditional cabling would be expensive and, at least as importantly, highly disputive. What is needed is a high-quality – and stable – network to help operate sensor systems, surveillance cameras (for security and safety purposes), and central management. Energy grids on site as well could be more efficient with the help of sensors and wireless connectivity.

To support these use cases, a private network would no doubt be better than a public one – especially for security. This is even more the case for port authorities and trade associations, some of which may be in touch with more than 100 ports, and have a wide focus, extending from a vast range of everyday business concerns to sustainability and security.

And now, of course, connectivity. It is not unusual to hear that there is an increased need for ports to talk to each other, but it's also important for the organizations within a port to talk to each other. There may be different tenants in a port and a port authority too, so it's important that interconnectivity is there.

But connectivity of this sort is not always high on the agenda, although it's always in the background when the conversation turns to smart ports and enabling technologies – although who meets the costs is clearly an issue.

Connectivity will be even more of an issue where multiple ports operate under the same banner, as happens in regions like the Middle East where busy shipping lanes require multiple ports.

Thus a deepwater port may be a semi-automated container port that handles general cargo, container, and break-bulk activities as well as roll-on and roll-off (RoRo) that could involve vast terminals for cars.

It may also be part of a network that includes commercial ports, accommodating warehousing and cold storage facilities as well as general and bulk cargo services and cruise ports. In fact, depending on location, cars, containers and cargo may operate alongside cruise tourism and the vast vessels this can involve. Let's not forget support for the oil and gas sector, which inevitably requires special facilities – and which may involve processing or refining not far from the port itself.

**"A baseline requirement is to track anything that's moving – people, goods, vehicles. And we believe 5G is needed for this sort of reliable real-time information."**

Important too is size. It's not uncommon for water depths of terminal to go to depths of 16.5 metres or more, allowing them to accommodate mega-vessels typically carrying in excess of 20,000 TEU.

One of the ongoing issues as ports grow in size is managing these many concerns and ensuring they work together relatively seamlessly, especially where sea travel is a quicker route to multiple destinations, which takes us back to connectivity.

## 1.7 Digital investment and going mobile

Some port authorities have moved quickly to invest significantly in technology and infrastructure. This means a focus on the provision of smart and innovative digital solutions to traders and port communities to accelerate development and trade, increase the efficiency and productivity of maritime business interactions, and encourage transparency and access to real-time information.

The opportunity here is a wide-ranging one. For example, as we have noted, semi-automated ports, designed to handle the next generation of ultra-large container ships among other duties, will be a high priority for many port owners and authorities over time.

However, in some cases digitized solutions have translated into a larger number of services for key clients. This list, from a major regional port authority, is an impressive one and includes:

- Gate Management System (GMS) to reduce downtime from 30 to eight seconds on average for transaction or movement of vehicles
- Remotely programmed gantry cranes and digitized container stacking
- Provision of business intelligence and customer support
- IT communications and rack hosting services

There's also the Port Community System (PCS), a digital platform solution that acts as a single window provider, facilitating information flow between all stakeholders, port authorities and traders. It can be integrated with different government and private entities, in addition to shipping agencies and international shipping lines.

Mobile applications are growing in importance, inevitably. It's not uncommon for smart services to be offered through mobile applications, allowing for real-time updates of the status of shipments as they reach their destination, as well as tracking transactions with more than five integrated entities.

More down to earth perhaps, but equally important, are mobile applications that allow customers to access information and services provided by logistics and industrial hubs.

Another efficiency-enabling concept now in use is VTS Centralization. This aims at integrating all port VTS systems, thus providing a reliable solution to operate all ports from one location. It also contributes to enhancing the work environment by reducing noise levels and providing peaceful environments for operators to reduce fatigue.

Mobile operators are also getting involved, notably in regions where sea lanes dominate and multiple ports operate. While the widespread rollout of private networks is still some way off, many regional operators are delivering digital services like cloud computing, IoT and big data, paving the way for a new era of digital transformation in the maritime sector and enabling connectivity and digital innovation across port facilities.

But this isn't one-way traffic. The focus is on building shared electronic projects and networks, exchanging knowledge, simplifying procedures, securing fixed and wireless telecommunications coverage, and managing operational risk.

This isn't happening in a vacuum, of course. Growth of 5G traffic is expected to be more rapid in some parts of the world than others. In regions where the 5G opportunity is seized, there may be opportunities for ports operators and oil and gas firms, among others, to enhance

productivity by switching to 5G (rather than Wi-Fi) to operate machinery and gather crucial data.

And yet the sheer scale of many of these port operations means care must be taken in rolling out solutions. A port may not just be a port but a geographical spread of a medium-sized town, with industrial zones for oil and gas. It may function as a government entity to maintain supplies at a time of crisis. Dedicated warehouses and a business that spans shopping carts, jet skis and container ships need the ability to connect and to communicate effectively. Cloud may help, but bandwidth can be a problem. This, again, implies a role for 5G rather than 4G but the private networks that would enable this securely are not yet available.

## 1.8 Hubs and networks

**"Competitiveness and efficiencies depend on automation – which depends on connectivity. Even if there isn't a direct ask from customers, ports need to think about this."**

Let's turn to a major port that acts as a European hub – meaning that not just seaways but rivers, rail and road are important parts of the offering, which ranges from wet or dry bulk, project cargo, RoRo, cocoa, non-ferrous metals, containers or off-shore. How does connectivity aid its operations?

Here there is a favorable location, space, expertise and infrastructure, which makes the port region the ideal location for offshore activities in the field of wind, oil and gas, and repair and decommissioning. That in turn has inspired an interest in the way that digitisation is changing the logistics playing field and opening up a world of opportunities. This port is investing in technological developments through the Digital Port programme, with a view to optimizing the logistics and other processes of both clients and the port.

How does this port digitize? Firstly, it continually assesses real needs – together with clients and partners. As a link in an international chain, it helps clients the most when its applications can also be used in other ports. That's why it develops open source whenever possible.

So what does this mean in practice? Well, take Poseidon, a unique platform for digital tracking systems on push barges. Poseidon collects location information from trackers on barges. This data are input for the development of smart services that reduce time, fuel and administrative actions.

With Poseidon users have up-to-date insight into the occupation of mooring facilities; pusher tugs can navigate to freely available places in order to position the barge efficiently. In the future there will be more and more mooring facilities exclusively for pushed barges with trackers.

On the basis of tracker data, Poseidon recognizes when a push barge calls at a harbour basin with mooring facilities. The stay-time is automatically registered as soon as the barge crosses the virtual check-in and check-out border. The visits are invoiced via a clear invoice. This saves on administration resources and costs.

Another system running here is Easydock, which makes it easier to make reservations, eliminating the need for submitting separate statements for

Inland Harbour Dues, and giving users an overview of the allocation and status of their reservations. The declaration of Day Tourist Tax for river cruise ships is also carried out via Easydock.

The app can be downloaded and used by captains, crew, tour operators, bus drivers and other parties involved in the river cruise operational process.

There's also a Cyber Security Program, a network of key public and private stakeholders aimed at making the port ecosystem in the area more resilient in the field of cyber security.

Not surprisingly, drones are also involved in helping to aid efficiency. In 2019 a pilot tested how a sailing drone can be used to optimize the draught control process for the areas locks. In this way experience is gained with new technologies that have an impact on nautical processes.

**"Our single biggest issue is adequate bandwidth. 5G? I'm not sure it's on the radar and right now I don't think private networks are available."**

Again, apps play a significant role in enabling efficiencies. The new digital web app Arrivals gives its users access to information about all ship movements in the port – not just information about arrival and departure times, but also detailed information about the ships themselves. This port has worked with shipping agents and other users on the development and design of the application. The application contains a search function that not only makes it easier to find ships, but also berths and harbour basins.

## 1.9 The 5G-Monarch project

A port of similar size is the home of one of the best-known port-related digital initiatives. While this is by no means the biggest port in Europe, it is by no means negligible. It is conveniently located between the North Sea and the Baltic Sea. Around 8,000 ships call per year, occupying almost 300 berths and a total of 43 kilometres of quay for seagoing vessels. There are more than 2,300 freight trains per week, four state-of-the-art container terminals, three cruise terminals and around 50 facilities specialized in handling roro and breakbulk and all kinds of bulk cargoes, along with about 7,300 logistics companies within the city limits. This one of the world's most flexible, high-performance universal ports.

It's also a very big container port, with handling facilities suitable for every type of cargo. Cargo that cannot be containerized, above all heavy goods, over-sized packing units, or cargo on wheels, are all handled at one of seven multi-purpose facilities. As in our earlier example, this is also a leading centre for cruise shipping.

And 5G may soon support these operations. 5G is frequently promoted as an enabler of smarter working, but also offers potential socio-economic benefits for industrial and public sector users of mobile services.

That's why, as part of the two-year EU Horizon 2020 5G-MoNArch project (5G Mobile Network Architecture for diverse services, use cases, and applications in 5G and beyond), reliable techno-economic cost benefit methods were developed to quantify costs and benefits of 5G deployments, which were then applied to this port.

The goal of 5G-MoNArch is to implement concepts for 5G mobile communications architecture in practice. This test field focuses on the integration of 5G into traffic and infrastructure control. A second test field of the project, elsewhere in Europe, deals with multimedia applications.

The focus of the project was on network slicing – the idea that multiple virtual networks can run simultaneously on the same common infrastructure and each network (or slice) can have different characteristics tailored to meet the specific requirements of a particular application or user group.

Three use cases with different network requirements were tested in the port. In the first use case, the partners installed sensors on three ships. These sensors enable the real-time monitoring and analysis of motion and environmental data from large parts of the port area.

The second use case demonstrated the remote control of traffic flows in the port via a traffic light connected to the mobile network. This should help, for example, to guide trucks faster and more safely through the port area.

The third example tests high bandwidth availability. With the help of the new standard, 3D information is transmitted to an augmented reality application. The 3D glasses allow maintenance teams on site – for example on a construction site – to call up additional information such as building data or receive remote interactive support from an expert.

The project partners were able to demonstrate that complex industrial applications with diverging requirements can reliably work over a common physical infrastructure – an important factor in enabling connectivity in the sort of ports we have seen, where cars, cruise ships and wind farms, for example, could all be seen.

But these efforts did throw up a question: private or public in and around ports? Evidently, there's no one answer to this. There are scenarios where private works best and some in which public does. However, even where the spectrum is available the range may be limited. Thus it may be ok to automate a container yard and thus have a secured yard. But to cover a wider port area and reach anchorage points (some 40kms out at sea) isn't

easy. In other words local connectivity going quite some way is certainly possible, but beyond a certain point some sort of hybrid solutions may be necessary.

Cloudification, private networks and security are other considerations, many of them requiring a level of reliability – notably low latency – that LTE cannot deliver. In tests, network slicing with 5G had no major issues with latency despite a very loaded network.

As we have noted, VR and augmented reality were tried out to support maintenance in this port. A fascinating example involved the use of a 'hollow' head set, with which an engineer on site talked to an expert at the main office. In this case a large railway is part of the port and VR could have a role in, say, building a bridge, to ensure construction has avoided an obstacle, or to check that construction is not deviating from the plans. VR could also be useful for inspecting structures for damage, checking if there is any movement at key sites. Of course this would require low latency, high bandwidth and no interruption if it were to be integrated into port operations – an obvious benefit of private 5G.

One issue that did come up in this project was the role of the port authority. How does it balance with the needs of the groups that use a port – of which there are many? Ports need to stimulate interest in these many users in more effective forms of connectivity to serve their needs – but how will they be delivered and by whom? If a container terminal wanted to deploy a wireless network it could. So too could the port itself, perhaps by becoming an operator and offer wireless connectivity as service. But would a port want this? Mobile services are not seen as their core business by ports. They prefer network operators to be involved.

Nevertheless network slices supplemented by small cells for extra reliability are clearly attractive and could involve different templates for different ports, for example a localised network and spectrum for container terminals.

## 1.10 The biggest ports in the world

Taking things up a notch, we now turn to one of the world's biggest, and by its own description, smartest, ports, one through which goods pass on way to and from destinations throughout the world – from pineapple juice to paper and from computers to chemicals.

It's more than just a port, however. Factories and processing plants add value to the services it offers and help to make it even bigger. In fact, reminding us of the sheer size of modern ports, this is a port that stretches over an area of about 42 kilometres extending from the sea into a major city, with docks so deep that they can accommodate even the largest vessels.

Again, like our earlier example, this is more than just a transit port. Numerous goods are processed into other products here. The goods and services produced in the port and industrial area have a total added value of approximately 45.6 billion euros annually. In all, nearly 385,000 people work in and around this port. It's even a tourist destination, with a cycle route network, nature areas with fascinating plants and animals, and impressive industrial areas.

Tens of thousands of vessels call here every year. Shipping is monitored and controlled using advanced radar systems. On the water, patrol vessels equipped with fire-fighting equipment keep an eye on things – 24 hours a day, seven days a week. The area's Port Authority also has an inspection service for the close monitoring of the transport of hazardous substances. And the area's Port Authority is always collaborating with companies in the port to find ways to make the port even smarter: to transport goods even faster by sharing information about vessels, quays, containers, trains and so on.

Oil, gas and petrochemicals are a big part of this port's work. In fact the port's chemical/petrochemical cluster is one of the largest in the world. It's also a major port for imports and exports of LNG (liquid gas). Tankers deliver crude oil to one of the terminals. From there, the oil is pumped by pipeline to local and regional refineries, where all kinds of fuels and raw materials are produced for the chemical industry before being transported by pipeline, ship, rail or car to the end customers.

**"As our port becomes increasing automated, more and more bandwidth is needed for communication with the moving parts of the plant, such as autonomous vehicles."**

Dry bulk is transhipped everywhere in the port area. The two largest flows of dry bulk are iron ore and coal, but the port also handles biomass, agriproducts such as maize and soya, scrap, building materials and industrial minerals.

Containers and general cargo carry almost everything from computers to frozen fish. Containers fit exactly on trucks or freight wagons. Inland navigation vessels transport about half of the containers to and from the hinterland. The port has several refrigerated warehouses for the storage and inspection of food moving on to supermarkets.

But in order to make all this work smoothly a lot of planning has to be done – and ideally automated – which is why this port aims to be the smartest port in the world. The goal is to create one of the smartest, most sustainable and most accessible logistical hubs, where there is room for national and international companies to grow.

Digitization initiatives therefore either concern the better control and management of the port and port infrastructure (its core tasks) or a focus on an improved insight into, or an improved efficiency of, logistics processes.

A number of opportunities offered by digitisation for improved control and management are being embraced by this port.

A system known as Portbase manages the digital infrastructure of a number of ports and supports all stakeholders in the port and logistics chain via a variety of services. Portbase provides a Port Community System (PCS), which we have mentioned before. This is a digital solution for the administration and document flow that are part and parcel of freight transport, creating greater efficiency, lower planning costs, better and more transparent planning, faster cargo handling and fewer errors.

Then there's an information system shared with another major port. The Harbour Master Management Information System (HaMIS) works as a digital network. It is an interactive system in which all shipping traffic is planned, monitored and administered.

There are a number of other initiatives under way that are specific to the port itself – an Internet of Things (IoT) platform for instance. The port authority uses this cloud platform to collect and process data from sensors located throughout the port. In this way, real-time information about infrastructure, water and air comes in, enabling the port to improve its services. The ultimate aim is the one mentioned earlier in this review – to create a 'digital twin' of the port in 4D – a digital representation of the actual, physical port.

Another plan is one platform for port communities, a single data entry point that is secure for all players in the port: customs, terminals, agents, shipping lines and more. This can reduce phone calls and emails needed to keep parties informed about the status of cargo and ensure better scheduling for nautical service providers and terminals, all leading to a faster turnaround time for ships, more berth capacity and fewer costs caused by delays.

Adding further levels of efficiency is an application called PortXchange. Each ship's visit to a port – a port call – requires numerous parties to carry out various coordinated activities at the right time. With PortXchange, shipping companies, agents, terminals and other service providers can plan, execute and monitor all activities during a port call based on standardized data exchange.

PortXchange combines public data, data retrieved directly from participating companies and forecasts from artificial intelligence applications to generate highly accurate information about a port call. PortXchange does not share any information about the cargo.

**"Our requirements? Real time information, fastest throughput, bigger efficiencies. To achieve all this you need to make sure you have a strong connection backbone to get the information to people at the right time."**

Users can easily filter the available data on their own dashboards and zoom in on the timeline of an individual port call. They can use this information to efficiently access and plan the activities related to a port call. The progress and status of the events is continuously updated on a dashboard.

The results include shorter port call turnaround times, better predictability, better terminal occupancy and shorter waiting times, lower bunker and charter costs and lower $CO_2$ emissions during each port call. Agencies have more time for services to clients. Logistical and maritime service providers benefit too.

Supporting such efforts is Cargo Tracker, a track and trace system for import cargo – a complete picture of the status of ships expected in the port, when containers are unloaded and when they depart the sea terminal on a single screen.

Cargo Tracker is available via the web and as an API. From autumn 2020 users can upgrade Cargo Tracker to a system called Cargo Controller, which will, says this port, really put users in control of their cargo. Based on the track and trace information, users can quickly and easily initiate the subsequent customs procedures in Cargo Controller or authorise others to do so.

Let's not forget rail transport. For many ports, rail transport is a vital component of an extensive network of hinterland connections. With the

OnTrack system, all users share a single point of reference for all trains that are moving to and from the port.

Users get the most accurate information available – such as a train's location, destination, expected and actual time of arrival and departure, time slot and progress at the terminal. Smart filters based on relevant parameters allow users to zoom in on specific information. Real-time progress and status updates help users adjust their operations accordingly.

And then there's scheduling at sea. Timetoport is an application that offers a reliable solution to accurately predict arrivals. This enables port authorities and port communities to optimise planning and maximise the utilisation of berths, assets and people.

Predictions are based on AIS signals from all vessels heading to a port, or on MMSI numbers of the vessels provided by a port management system, a port community system or another operational system.

In fact Timetoport provides accurate vessel predictions up to seven days ahead. This allows ports to better plan the deployment of pilots, tugs, linesmen and other service providers. The terminals and operators in a port can also optimise the use of resources such as berths, assets and people.

And no, we haven't forgotten asset management. On shore, many ports manage their own assets. This involves high costs, investments and risks. This port authority has developed digital tools for optimum asset management, including tools for:

- Deterioration models for quays and assets
- More efficient and smarter dredging
- Database with complete information on the assets
- Repair and maintenance schedules with clients
- Planning budgets and risks for asset management

Like so many other digital initiatives mentioned here, the benefits of Port Asset Tooling, as it is known, are better planning and reduced costs, in this case less expenditure on maintenance, dredging, repairs and investments and less disruption through optimum coordination with clients regarding repair and maintenance work.

As for port management, the online port management system Portmaster integrates scheduling, monitoring and administration tools and modules in a single system. Convenient dashboards provide an up-to-date, detailed overview of the port, allowing users to respond rapidly when dealing with specific events. Portmaster offers extensive options and can be fully adapted to the needs of a port. There's a real-time overview of vessel arrival and departure times and the user experience is optimized on desktop, tablet and mobile devices. It's a modular system to enable easy expansion with additional functionality. And it's cloud-based, safe and secure.

# 2. Private networks: The questions that need answering

Size and complexity differ but all the ports under review have embraced connectivity and digitization to a greater or lesser extent. However, innovations like private networks, which to an untutored eye seem ideal for ports, are seen as interesting but have not been embraced – yet.

So how viable are private networks for ports?

There's little doubt that, at a port, container terminal operators will be attracted by the security of a private network. When it comes to wider scale private networks, it will be a question of budget.

A balance needs to be struck between private networks that are localized and those that are managed by the operators. There is space for both. Some ports have larger areas than others. Some are in cities where infrastructure is stronger than in rural locations. There's also the question of how wide the services are that you want to deploy.

**"Full connectivity is the keystone to everything we want to achieve – we need to make sure everybody is working off the same information."**

There is also going to be a role for small cells. Localized spectrum stimulates the small cell industry in a country, potentially putting the ownership of the network in the hands of the industry sector such as the automotive industry in Germany, where companies can play a part in the decision to determine spectrum policy (although private networks need regulatory approval in some countries – France, for example).

Much of this can be best enabled by 5G – but there is a risk in waiting for 5G. Operators too will need to be convinced that there is a revenue opportunity; they will look for ways to increase their revenue lines especially when they may have to invest in network dimensioning if they are repurposing their networks.

If there are service benefits, then this might translate into user willingness to pay. For example, container terminals could be very lucrative, offering good ROI to operators. By contrast, for services like smart cities, environmental management and even intelligent traffic management, willingness to pay isn't there; they are perceived as public services. New payment models – government-led perhaps – may be needed.

And where will the money come from? Ports often have five-year plans. However, a lot of the competitiveness and efficiencies they need depends on automation, which depends on connectivity. Even if there isn't a direct ask from customers, ports will need to think about this.

The roles of integrators and neutral hosts or even operators with a hybrid offering need to be considered. At the moment, it's not clear how operators feel about this.

Another view to consider (as shown by the variety of ports and businesses they serve) is that one size doesn't fit all. Luckily there are enough solutions

so that all the needs can – potentially – be addressed, both indoors and out of doors.

However, with all that said, private networks are here and now – but not network slicing; that is yet to come. Also much existing 5G is not standalone. It works with 4G core.

And for ports there are still more solutions to consider, like satellite and SAT 5G. Can satellite be integrated into a connectivity approach that suits ports?

There is, however, an established interest from ports around the world in digitally led concepts that would make their job easier. It's no surprise that the private network concept has garnered some interest.

# 3. What ports need and why

It's difficult to overstate the diversity of the dozen or so ports we engaged with in the first stage of this project. Diversity in terms of size, resources, progress and ambition in the context of digital transformation, and diversity in the place connectivity has in the service offering port authorities provide to tenants.

This paper has set out the framework of requirements that emerged from our conversations with ports. We thought it would be useful to summarize the key elements of those requirements in one place, along with the commercial drivers and perceived challenges.

In the next stage of this work we will consider the requirements of port tenants, the technical requirements associated with common clusters of applications and potential delivery mechanisms.

## 3.1 Requirements

- Coverage
- AR and VR applications
- Digital 'twins'
- Autonomous shipping
- Automated or self-driving cranes, trucks and everything else
- Digital tracking systems
- Reservation systems
- Security programmes
- Drone-based services
- Access to information about all ship movements
- Services that attract new business
- Tracking anything that moves and using the data to improve efficiency
- Real-time monitoring and analysis of motion and environmental data
- Remotely controlled traffic flows
- Administration and document flow
- Real-time information about infrastructure, water and air
- Standardised data exchange to manage all activities during a port call
- Track and trace system for import cargo
- Support system for rail and other transport
- Accurate prediction of arrivals
- Digital tools for optimum asset management
- Online port management systems

## 3.2 Drivers

- Massive financial savings and safety benefits – notably from self-operating or self-driving equipment
- Multiple ports need to be networked to communicate more effectively
- Multiple cargoes need to be tracked and monitored
- Multiple businesses – from cargo to cruise tourism may be at one port. How can they be managed efficiently?
- Big ports attract industries that set up there: chemical production, energy production, waste and recycling, data centres and more
- Growing pressure to use technology to address the needs of the environment and sustainability
- Companies attracted by the security of private networks and the efficiencies IoT can offer
- There is an interest from ports around the world in digitally-led concepts and a desire to know more

## 3.3 Challenges

- Interconnected solutions may be needed: wireless (including Wi-Fi), satellite and fibre
- Is there enough bandwidth?
- Private networks are currently not available
- Private networks are currently not understood
- LTE not reliable enough
- Low latency high bandwidth requirement
- Issues and silos, especially at overall management level
- Need to interest users in more effective forms of connectivity
- Who decides what? Port authorities or port users?
- Spectrum policy,
- One size doesn't fit all
- Mobile services are not seen as their core business by ports
- Network slicing is not here yet
- Budget considerations
- Localised private networks or managed by operators?
- Risk in waiting for 5G

# About Small Cell Forum

Small Cell Forum develops the technical and commercial enablers to accelerate small cell adoption and support the digital transformation of enterprises and communities.

Broad roll-out of small cells will make high-grade mobile connectivity accessible and affordable for industries, enterprises and for rural and urban communities. That, in turn, will drive new business opportunities for a widening ecosystem of service providers.

Our focus and work program reflects two key areas of diversification in the small cell ecosystem – the emergence of alternative deployment models such as neutral hosting and private networks, and Open RAN specifications enabling disaggregation of small cells at both component and network level.

We have driven the standardization of key elements of small cell technology including Iuh, FAPI, nFAPI, SON, services APIs, TR-069 evolution and the enhancement of the X2 interface. These specifications enable an open, multivendor platform and lower barriers to densification for all stakeholders.

Today our members are driving solutions that include:

- 5G components, products, networks
- Neutral host & multi-operator requirements
- Open RAN small cells & disaggregation
- Private networks & enterprise requirements
- Deployment and regulation
- Edge compute with small cell blueprint
- End to end orchestration



The Small Cell Forum Release Program website can be found here: www.scf.io

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