NOKIA

5G Smart Sea Port

Hamburg Port Authority

The 5G field trial by the Hamburg Port Authority (HPA), Deutsche Telekom (DT), and Nokia is a perfect demonstration of key 5G use cases that require URLLC, eMBB, MTC, and network slicing. These use cases will improve the productivity of the port authority, as well as provide a series of environmental and social benefits. The fact that this is a field trial and not a lab trial was very important in our scoring, because network slicing can be challenging in such a complex and changing environment.

Judge Glomo Awards 2019

A gateway to the world

Full
7.6
Million TEU

Empty
1.1
Million TEU

Import
4.6
Million TEU

Export
4.3
Million TEU

Degree*
98.3%
* Degree of containerisation

Total
8.7
Million TEU

The Port of Hamburg (German: Hamburger Hafen) is a sea port on the river Elbe in Hamburg, Germany, 110 kilometers from its mouth into the North Sea. It is Germany's largest port and is named the country's "Gateway to the World" (Tor zur Welt).

In terms of TEU[1] throughput, Hamburg is the third largest container port in Europe (after Rotterdam and Antwerp) and 15th-largest worldwide. In 2018, 8.7 million TEUs (20-foot standard container equivalents) were handled in Hamburg.

Some notable statistics:

- 9 million containers/year
- >10k trucks/day
- 1800+ employees
- thousands of sensors
- 50+ barges

1 - Twenty-foot equivalent unit

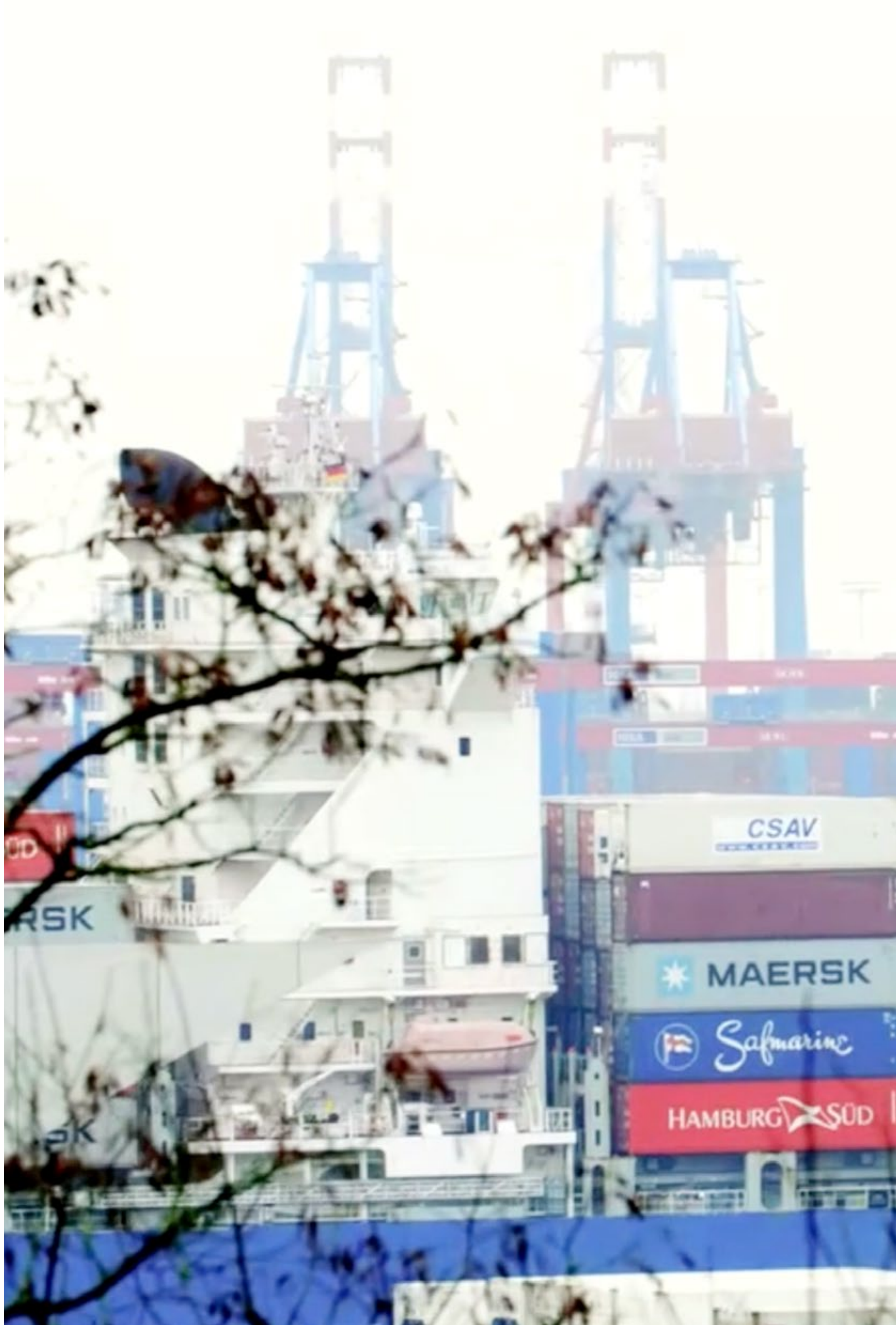
Source: https://www.hafen-hamburg.de/en/

The Hamburg Port Authority AöR (HPA) has been providing future-oriented port management services since 2005. To ensure safe and efficient processes in the Port of Hamburg and to meet the demands of a growing port, the HPA relies on intelligent and innovative solutions. The HPA is responsible for resource-efficient, sustainable planning and the implementation of infrastructure projects in the port. It is the contact point for all kinds of questions concerning the waterside and landside infrastructure, the safety of navigation for vessels, port railway facilities, port property management, and business conditions in the port.

The port covers an area of 80 square kilometres, of which half are land areas. The location is naturally advantaged by the branching Elbe river, creating an ideal place for a port complex with warehousing and trans-shipment facilities.

By 2025, the port is expected to grow to:

- approximately 18 million containers/year
- tens of thousands of trucks/day including self-driving and remote-controlled vehicles
- approximately 100,000 mobile sensors



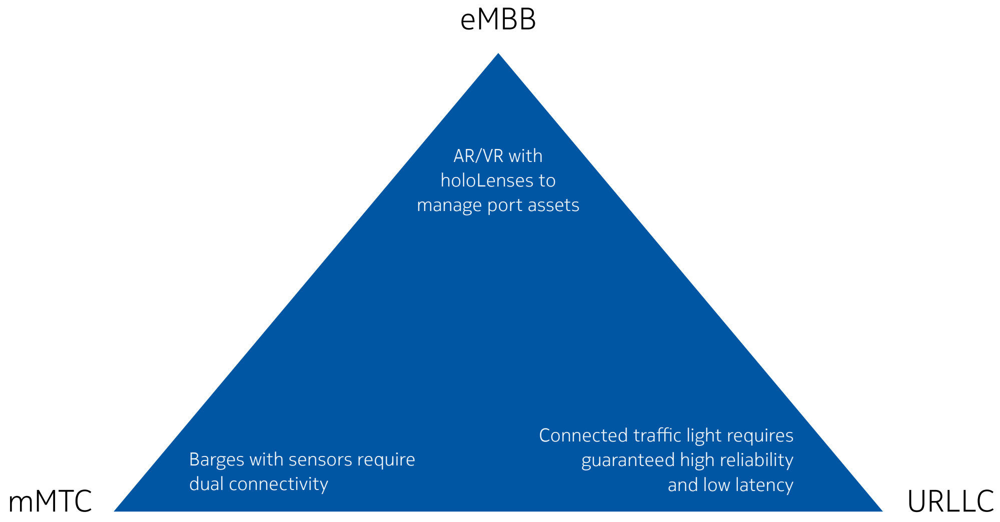
The problem

The Port of Hamburg is a complex and dense collection of transport networks, which includes waterways, roads, 118 bridges, and 300 kms of railways. The HPA needs to manage and monitor all these assets in an efficient way. Does a bridge need maintenance? Is a portion of a road in need of repair? Where do traffic congestions happen frequently?

Further, the current telecommunications network is comprised of 350 km of fiber, a mix of radio technologies used for nautical operations, public LTE, and Wi-Fi for indoor usage in its office buildings. The HPA evaluated LoRa (Long Range) Low Power Wide Area Networks (LPWAN) IoT. However, since these technologies use license-free sub-gigahertz frequencies, they do not offer guarantees regarding interference and quality of service and were hence considered as insufficient solutions for supporting HPA's use cases which require service level agreements (SLAs).

The use of public LTE in licensed spectrum enables better interference management, however the sharing of radio resources among users restricts what a MNO can offer in service level agreements (SLAs) to enterprise customers. Rather, a number of the use cases needed by the HPA require SLAs based on coverage, latency, reliability and resilience, as well as a guaranteed minimum throughput. For example, a connected traffic light requires a high level of reliability which cannot be guaranteed within a public multi-service LTE network. For instance, when the port celebrates its anniversary, up to one million visitors can completely overload the public cellular network, leaving no capacity for the port's use, which may even cause considerably safety issues. Connecting every traffic light with fiber is cost-intensive and does therefore not represent a feasible solution.

Network slicing, as a core feature of 5G mobile networks, is thus needed to isolate traffic for those specific applications and guarantee the required network quality. The 5G triangle below indicates what features of the 5G spectrum are needed for each of the use cases tested in the trial.



Use cases and their respective 5G requirements

The solution and partnership

The Hamburg Port Authority, Deutsche Telekom, and Nokia partnered to deploy a 5G network as a proof of concept (testbed) part of the European funded research project 5G-MoNArch (see 5G-MoNARch box for details). One network slice was created for each use case described below – according to the specific requirements of the services and applications of the use case – with all slices using the same 5G radio infrastructure. Two Nokia Airscale base stations were deployed with one antenna each using a 10 MHz FDD carrier at 700 MHz. The antennas were mounted at an elevation of 180 above ground on the Hamburg TV tower, in order to guarantee a good coverage of the port area. These base stations were then connected to a local data center of Deutsche Telekom ("DT") in Hamburg located about three kilometers from the port, as well as to a regional data center 500 kms away in Nuremberg. The slices requiring low latency rely on the local data center, while slices with higher performance but less strict latency requirements were deployed at the regional data center. Low latencies of less than 20 milliseconds could be achieved in this 5G testbed (see details in results section). Latency results varied according to how close to the edge, the data center used is. In any case, the local data center is also important not only to maintain low latencies, but also to keep the sensitive data on premise.

"The test bed has given us a glimpse of the huge potential that 5G and, in particular, network slicing will offer. I believe the new standard [...] is the last push we need to make a breakthrough in terms of digitization."

Jens Meier, CEO of HPA

Ultra-reliable and low latency communications (URLLC)

The connected traffic light requires very high reliability which is only available so far with fiber connections. The goal is to operate and monitor the traffic lights remotely from the HPA control center to enable a steering of the road traffic as it flows through the port. Trucks, for example, are guided quickly and safely around the site. In the testbed, the traffic light is connected to both 5G base stations simultaneously, using a dual-connectivity feature, thereby achieving the expected high level of redundancy and performance.

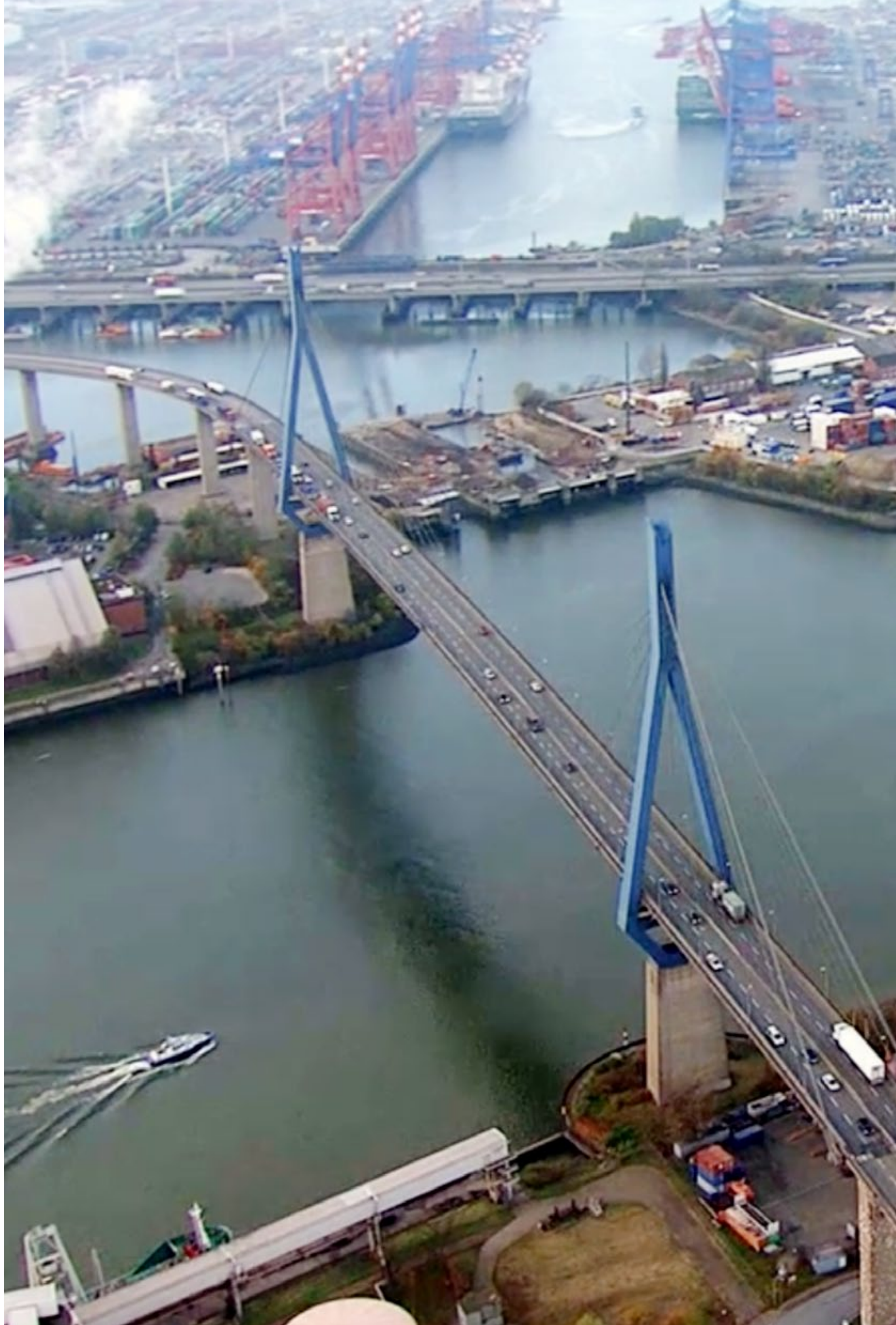
The traffic light control furthermore demonstrates network slice isolation, shown by the difference in latency between best effort (common slice) and a dedicated slice with high reliability and latency requirements, as the status of the local traffic light controller should always be known as guaranteed latency (URLLC).

Enhanced mobile broadband (eMBB)

With the large size of the Hamburg sea port, and its responsibilities, the HPA relies on an engineering team of about one hundred people with the assignment to conduct maintenance, repair, and construction tasks at waterside and landside assets. The goal is to support these engineering teams through applications using augmented and virtual reality (AR/VR), enabling up-to-date key information such as blueprints or construction plans to be available on the spot Buildings, tunnels, bridges, water gate information, and modelling become available in 3D as “digital twins” of the assets for new projects.

Equipped with AR HoloLenses, these engineers are able to see how the project looks like right on the spot and ensure there are no conflicts or inconsistencies to avoid any possible costly mistakes—something they cannot do outdoors today with 4G because the 3D data requires a lot of throughput.

Another application for eMBB is the ability to support the on-site engineering teams with remote experts. For example, many railway switches installed in the port area are rather old, and only few engineers know details about their operation and how to fix them. Instead of physically sending those valuable experts to the site – with one hour travelling forth and back – they can guide the onsite technicians, which are equipped with HoloLenses, through the AR and live video streaming based applications from the headquarter.



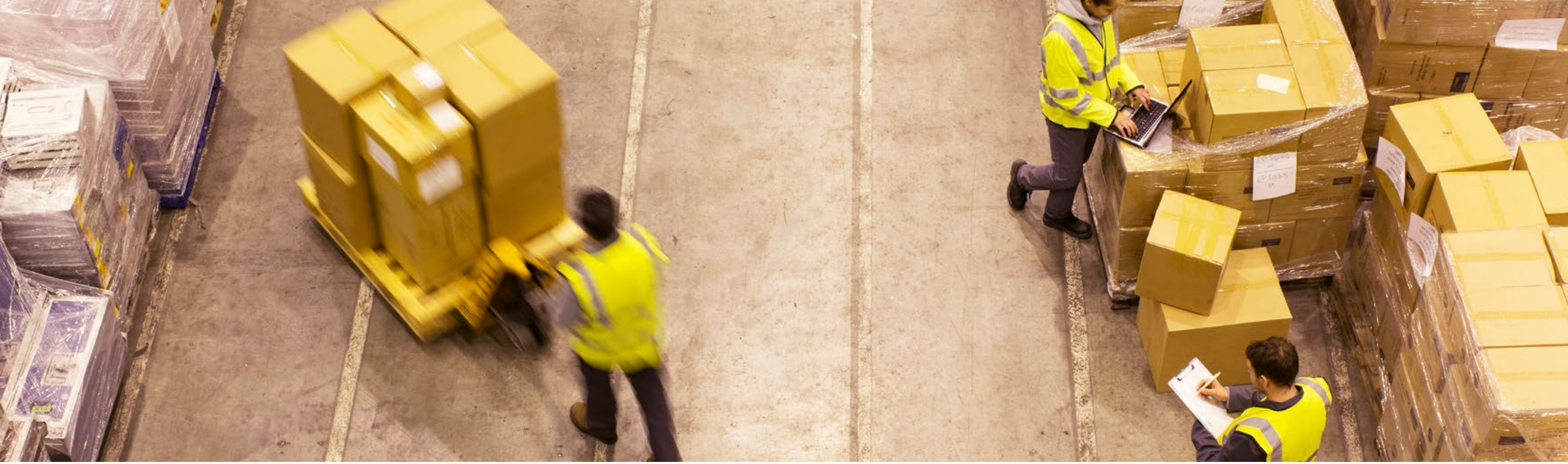
Massive machine type communication (mMTC)

Several barges owned or operated by HPA are already equipped with environmental sensors that measure the levels of carbon dioxide and other gases to gain insights about the emissions of ships. Furthermore, a multitude of fixed and movable assets in the port area are equipped with IoT sensors, for example, bridges, traffic lights, railway switches, locks and water gates, but also assets being part of the maritime navigation such as beacon and fairway buoys or light houses. These sensors gather data continuously to enable a permanent monitoring of the asset status and healthiness, and to enable proactive and predictive maintenance in the future. All these sensors need to be connected to the operations center of HPA, and their number is continuously growing – by 2025, HPA expects more than 100,000 connected sensors being implemented in the port area.

As with the traffic light use case, connecting these sensors via fiber is costly or even impossible. 5G IoT devices will use narrow bandwidth to support tens of thousands of devices per cell, provide deep coverage for challenging locations, and offer more than 10 years of battery life, all in a low-cost package. All the collected sensor “big data” must be transmitted reliably and secure to central monitoring applications and data storage for analysis and input to future artificial intelligence processes.

In addition to deploying dedicated slices to carry the sensor data, the dual-connectivity feature was showcased in the testbed. With dual-connectivity, a terminal (sensor) establishes two connections to two separate base stations simultaneously. Data packets are duplicated, and each base station gets a copy, which reduces the probability of retransmissions and strongly increases the overall reliability of the connection in case of handovers – particularly relevant for scenarios with mobile terminals such as the moving barges.

Besides the requirements of the HPA for connected sensors, also modern ships and containers are increasingly equipped with thousands of sensors, and the shipping companies as well as the cargo terminal operators require a reliable communication infrastructure which is robust enough to handle these emerging requirements.



Testbed use cases and respective requirements

Use case/requirements	Slicing	Latency	Jitter
Sensors installed on mobile barges (mMTC)	Important	Not important	Important
HoloLenses – AR and video streaming (eMBB)	Important	Very important	Occasionally acceptable
Traffic Light (URLLC)	Very important (slice isolation)	Very important	Important

Source: HPA

About 5G-MoNArch

The focus of 5G-MoNArch is about building a flexible, adaptable, and programmable architecture for 5G. 5G-MoNArch's specific technical goal is to use network slicing—which capitalizes on the capabilities of software-defined networking (SDN), network functions virtualization (NFV), orchestration of access network and core network functions, and analytics—to support a variety of use cases in vertical industries such as ports, automotive, healthcare, and media.

Network slicing is a technique where the network is logically (not physically) sectorized, so that separate services are supported by each "separate" logical network. As 5G networks need to support various services simultaneously with different requirements, network slicing will be a crucial aspect of the network architecture, providing flexible and adaptive networks to address the needs of the enterprise/business.

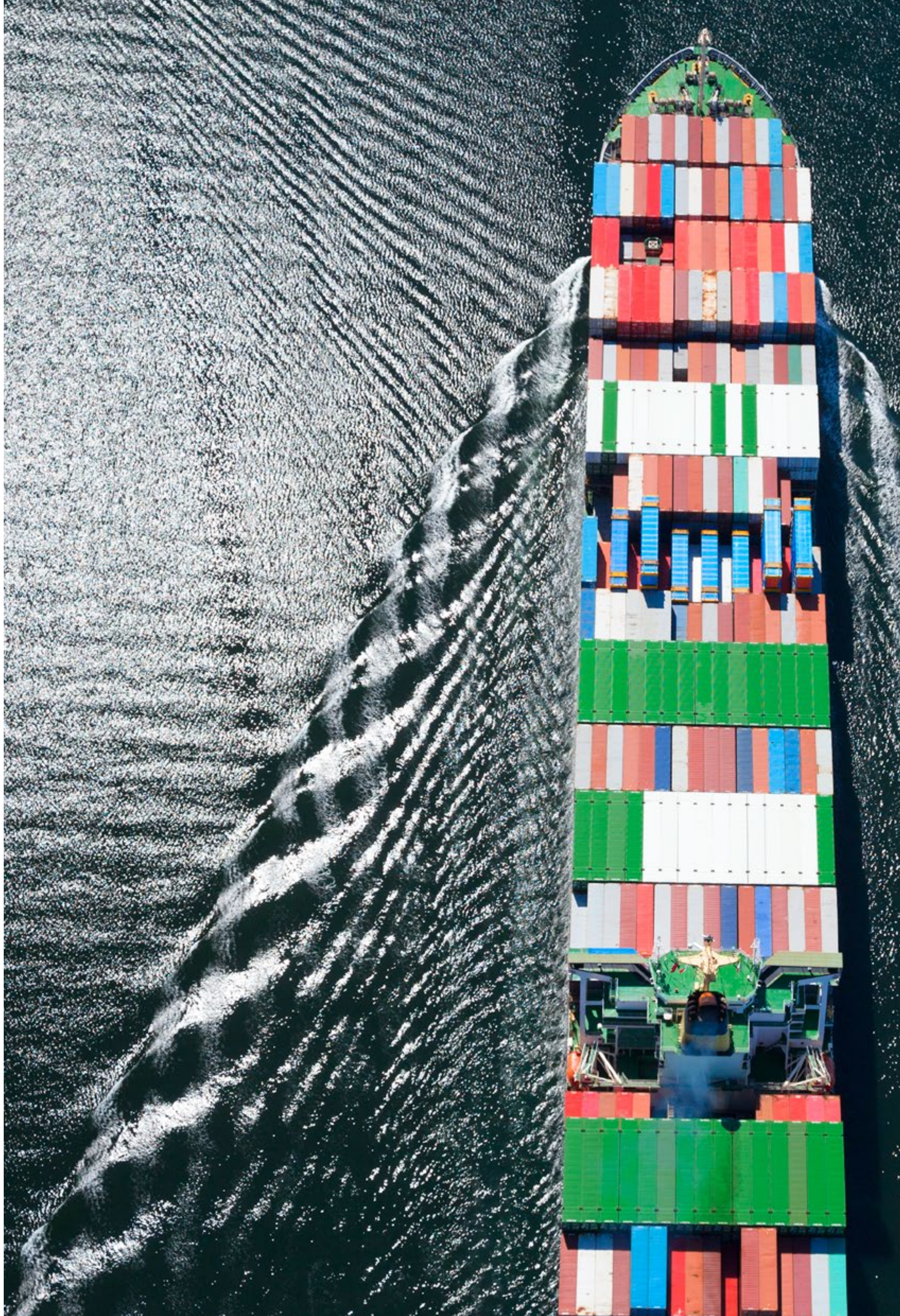
The concepts and enablers are brought into practice through prototype implementations in two testbeds (the Smart Sea Port in Hamburg and the Touristic City in Turin) instantiating slices that include the functional innovations of network resilience and resource elasticity, respectively.

Results and lessons learned

One of the key performance variables the testbed aims at is measuring the level of latency enabled by 5G network slicing. The lower latency for the edge deployments results from the separate user plane running at the Hamburg local data center, and hence shorter distance between data center and terminal. Furthermore, the simultaneous connection of the terminal to two 5G cells results in less retransmissions due to the redundant paths used in dual-connectivity.

The three scenarios tested were:

- central deployment, single connectivity: regional data center in Nuremberg was used and a single connection between one base station and one terminal;
- edge deployment, single connectivity: local data center in Hamburg was used and a single connection between one base station and one terminal;
- edge deployment, dual-connectivity: local data center in Hamburg was used together with dual-connectivity, i.e., two base stations connect to one terminal



Comparison round-trip time

The figure above shows some of the important results from the testbed:

- round-trip time from data center to user terminal and return (measured in milliseconds)
- average latency measured over a period of 12 hours (all latencies have been measured over the same period of time to ensure comparability)

The blue bars are based on 1ms Transmission Time Intervals (TTI) as it is used in LTE (and may still be used in 5G for many services); those values have been measured. The grey bars are estimates based on the 2-symbol TTI numerology introduced in 5G (dedicated to URLLC services).

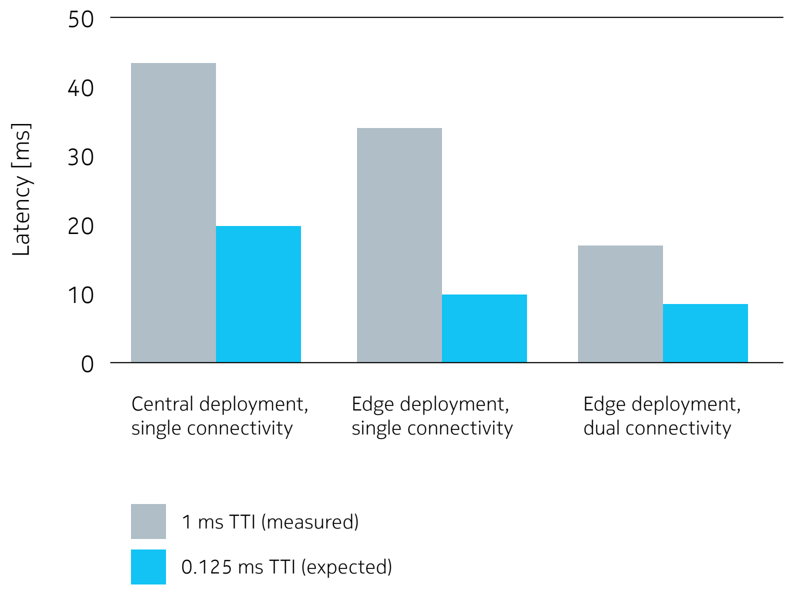
The edge deployment with dual connectivity shows remarkably low latency level of less than 10 milliseconds. It is worth noting that the measurements have been performed in a very large cell with a distance of about 4 to 8 km between base station and terminal!

Another important lesson learned is the importance of the dual-connectivity feature—that is, a user terminal establishes two connections to two different base stations simultaneously. Data packets are duplicated, and each base station gets a copy, which reduces latency in case of handovers – particularly relevant for scenarios with mobile terminals. This feature was tried for the sensors installed on the barges and provided great results in terms of lower packet losses and high reliability.

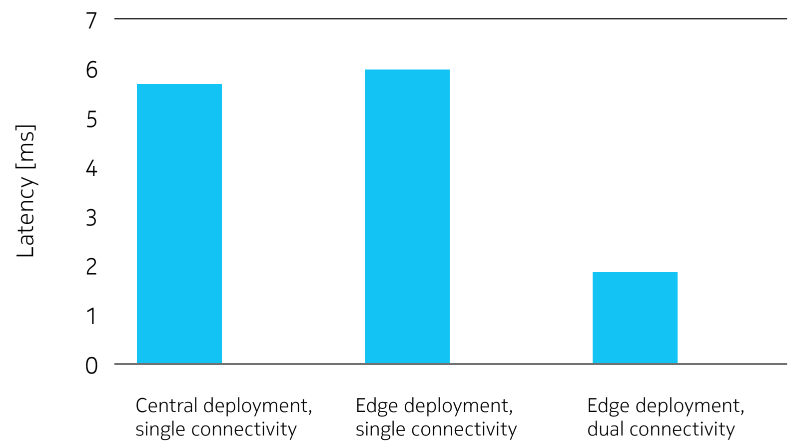
The dual-connectivity feature not only reduces the latency as shown in the figure above (through less retransmissions), but it also reduces the jitter (represented by the standard deviation of the latency). The lower jitter is important for deterministic/predictable services.

This is shown in the figure above where the jitter with single connectivity is three times higher than with dual connectivity (and an edge deployment does not make a difference as the jitter on the wired line part is negligible compared to the wireless part).

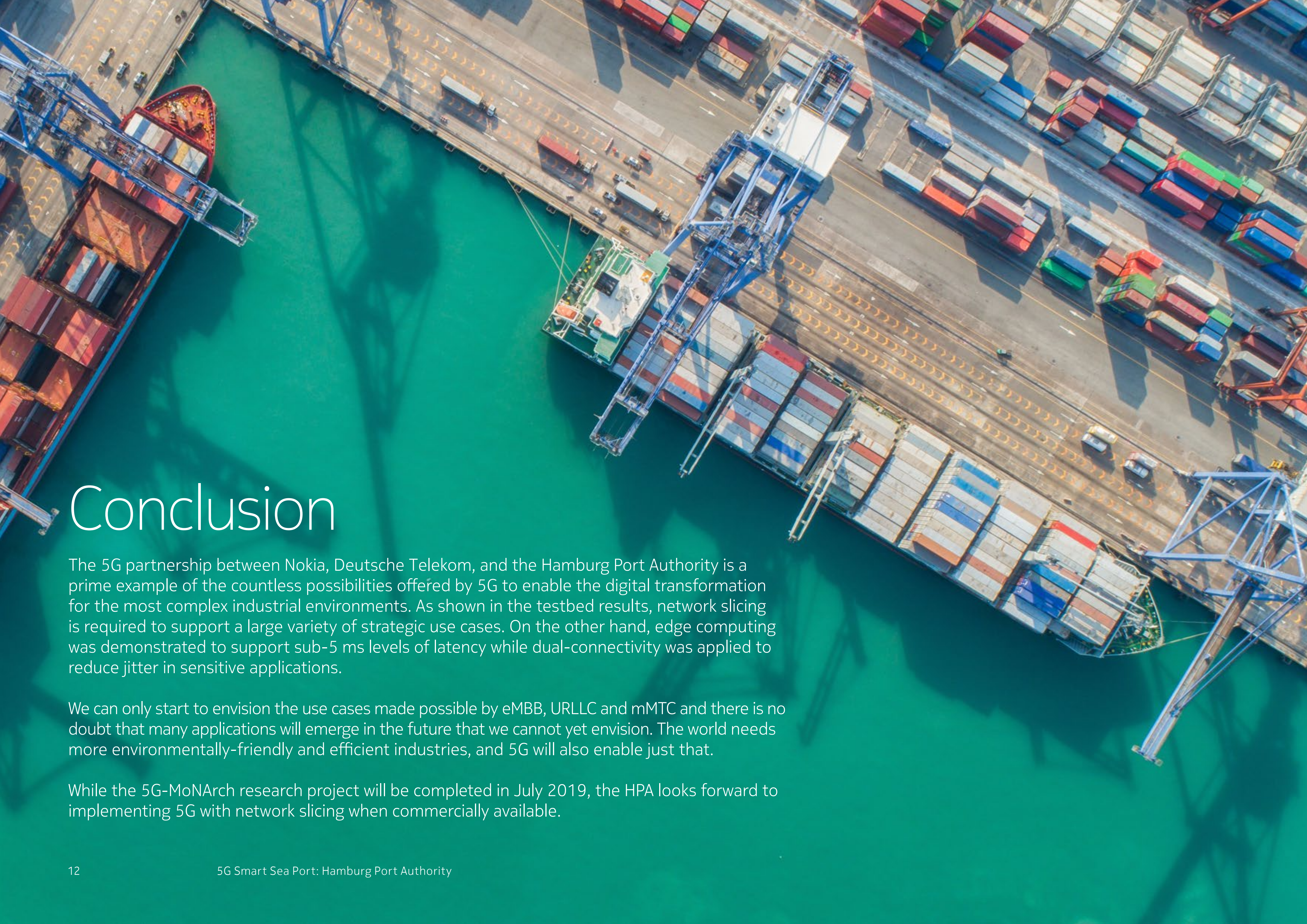
Average round trip time



Standard deviation round trip time



Source: Nokia



Conclusion

The 5G partnership between Nokia, Deutsche Telekom, and the Hamburg Port Authority is a prime example of the countless possibilities offered by 5G to enable the digital transformation for the most complex industrial environments. As shown in the testbed results, network slicing is required to support a large variety of strategic use cases. On the other hand, edge computing was demonstrated to support sub-5 ms levels of latency while dual-connectivity was applied to reduce jitter in sensitive applications.

We can only start to envision the use cases made possible by eMBB, URLLC and mMTC and there is no doubt that many applications will emerge in the future that we cannot yet envision. The world needs more environmentally-friendly and efficient industries, and 5G will also enable just that.

While the 5G-MoNArch research project will be completed in July 2019, the HPA looks forward to implementing 5G with network slicing when commercially available.

About the author
Adlane Fellah, Senior Analyst, is the CEO of Maravedis, a leading wireless analyst firm since 2002. Mr. Fellah has authored various landmark reports on Wi-Fi, LTE, 4G, and technology trends in various industries, including retail, restaurant, and hospitality. He is regularly invited to speak at leading wireless and marketing events and consistently contributes to various influential portals and magazines, such as RCR Wireless, 4G 360, Rethink Wireless, The Mobile Network, Telecom Reseller, just to name a few. He is also a Certified Wireless Network Administrator (CWNA) and Certified Wireless Technology Specialist (CWTS).

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