Chapter

Mapping the Applications of Vehicular Communications in the Context of Smart Maritime Ports

El Idrissi Ayoub, Haidine Abdelfatteh, Ait-Allal Abdelmoula, Dahbi Aziz and Aqqal Abdelhak

Abstract

The maritime transport networks play a critical and major role in an increasingly globalized world economy. Within these networks, the maritime ports play the role of hubs. Any disturbances in these hubs will negatively affect the worldwide economy. Therefore, economy players are transforming the ports through an evolutionary process to become smart maritime ports. These smart ports are built through an ensemble of smart domains that adopt sensing, data transmission, and data intelligence to support intelligent decision-making processes. Examples of such smart domains include smart grid/microgrids, smart container management, and smart/automatized terminal operations. In each of these domains, optimal decisions must be met to optimize the use of resources, increase the economy efficiency of the ports, and increase the safety and security for assets, goods, and people. In smart maritime port environment, vehicular applications are adopted everywhere, such as automated guided vehicles to transport containers, unmanned aerial vehicles for different port operations, etc. In this work, we discuss some concrete examples of these vehicular applications in the smart port environment and suggest the adequate and optimal vehicular communication technologies to be deployed to support a reliable data transmission for these applications.

Keywords: smart maritime ports, vehicular communications, unmanned aerial vehicles, intelligent transport system, mobile communications

1. Introduction

In today's maritime world, numerous pressures are exercising on ports; so many things have been changed deeply. Therefore, ports worldwide face challenges every day. Nowadays, we assist to more goods and services that are being shipped, resulting in ship's traffic that is increasing permanently [1]. Ports are crowding because of the growth of population in the world, accentuated by the globalization and the growing maritime industry. So far, the maritime world has been impacted by the global trade, sustainability, and digitalization.

A simplified configuration of maritime transport networks is depicted in **Figure 1**, showing that such a network can be modeled as graph network G = (V, E), where the set E constitutes the maritime routes, which must be secure, cost-efficient, short-delay, and reliable. The set of nodes (or vertices) is constituted by the world maritime ports/seaports. These nodes must also be secure/safe, cost-efficient, short-delay, reliable, environment friendly, and energy-efficient. Any disturbances in these nodes, that is, ports, will result in dramatic scenes and negative impact on the economy, nationally and as well as internationally in more globalized economy/industries. Such a concrete example is depicted in **Figure 1** (bottom) showing an increasing queuing of jam in front of maritime ports. More concretely, port authority recorded shattered 73 container ships stuck waiting off California port [2].

All these maritime challenges and so more could be reduced or even deleted if we focus on the solutions proposed by the new technologies that convert all the drawbacks into opportunities. Nowadays, and in a competitive world, being attractive or even exist needs to innovate with more intelligence and by using the digital way to care more for the future of the industry. Thus, the maritime ports should follow this evolution.

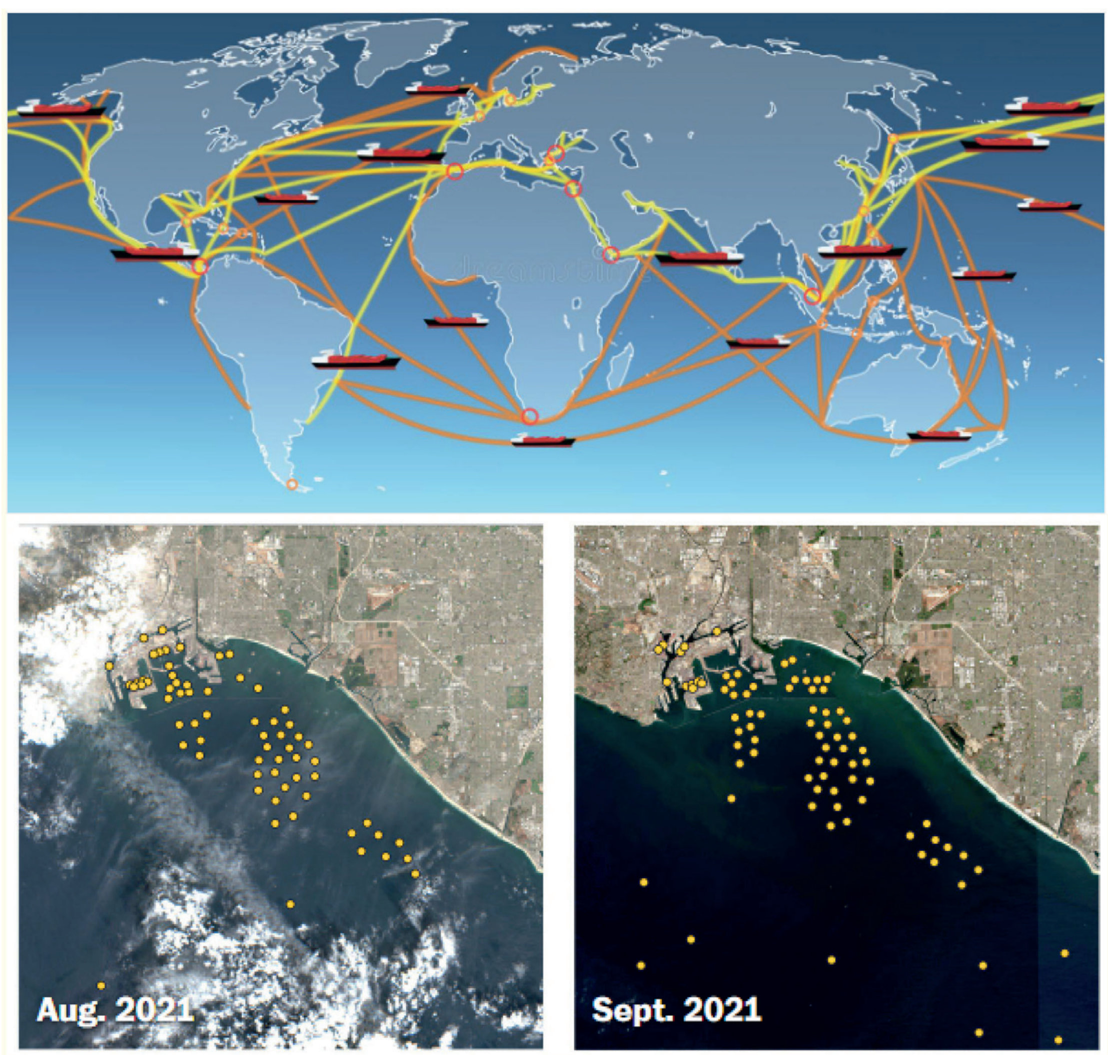

Figure 1.
Simplified presentation of maritime transport network (top, Credits: Dreamstime) and Jam of containerships in front of Los Angeles port resulting in a long delay of containers and goods delivery (bottom, Credits: Washington Post).

According to this context, and including the intelligence to ports, a new concept has emerged, which is called smart port intended to care for the maritime environment in order to be more effective and performing. Smart ports lead to provide more with less. This means saving time, resources, and money. Furthermore, smart ports is aiming to achieve a better connection for stakeholders using the automated ships, to massively reduce pollution and congestions, while increasing time/economic effectiveness and safety.

Smart ports' solutions and strategies can be integrated to solve most of the maritime challenges. The use of new technologies and intelligence is a way to transform the traditional practices of ports and their weaknesses to smart ports with more benefits. Smart technologies, such as big data, artificial intelligence (AI), Internet of Things (IoT), blockchain technology, and fifth-generation (5G) connection, are means to change the maritime industry. They are used as a decision-making system and a way to monitor processes with developing more security and safety in the working environment.

In this chapter, we discuss the main components for the realization of smart maritime ports; then, we focus more on vehicular applications. These applications should lay on a strong performing and reliable communication layer. Therefore, we analyze different possible transmission technologies for vehicular communications through a qualitative evaluation of different performance criteria, which are more relevant for smart maritime port environment.

2. Smart maritime ports and IoT model

2.1 Smart ports: definitions and objectives

Smart is a new concept adapted to the technology setting to follow the modern world. It is a word that contains digital information, computer development, and a way to innovate. According to [3], smartness is defined as the application of automatic computing principles such as self-configuration, self-protection, self-healing, and self-optimization. Smartness has found its way into many industries, especially in urban areas, as a solution to a number of problems such as pollution, increasing cost, problem of congestion, and preservation of historical sites.

Smart ports provide digital port solution consultancy for new and existing ports. Smart ports combine new technologies, automation, and digitalization to optimize the port operations. The use of smart ports is a way to boost digital transformation and make it effective in practice; also, it gathers technology, innovation, and digital tools. Smartness relies on information and digital technologies to become more efficient, sustainable, and collaborative. It encompasses different types of technologies such as big data, artificial intelligence (AI), Internet of Things (IoT), blockchain, and 5G.

Finally, a smart port is a port facility using information and communication technologies (ICT) to increase efficiency and ensure the safety of transshipment operations.

The objective of smart ports is to provide solutions to four key issues: economic issues, ecological issues, energy issues, and social issues. Today, many ports seek to use technology to achieve these objectives and to become a sustainable port responding to economic, ecological, and citizen issues:

- Concerning the economic aspect, the objective of the smart port will be to reduce the costs linked to the increase in flows and goods; many smart ports use artificial intelligence. For instance, AI can be used to predict the arrival of ships or to know the activities of each in real time.

- As for the ecological aspect, and to meet this challenge, smart ports seek above all to reduce their greenhouse gas emission, which also increases the air quality of their city.

- Smart ports aim to address the challenge of energy in two main ways. The first is through the development and use of renewable energy sources, such as solar, wind, and wave power. The second is by reducing overall energy consumption in the ports through the use of energy-efficient technologies and processes.

- From the perspective of the social aspect, ports generally adopt two solutions: education and participatory democracy.

2.2 Smart domains in smart maritime port environment

The evolution of the traditional port into a smart maritime port is complex and involves various research activities. Therefore, the smart maritime port can be seen as a set of (also known as "vertical" domains) smart domains, as depicted in **Figure 2**. In the following, we describe some of these smart domains.

Smart grid: Smart grid technology represents the next major advance in power grid management. With the help of various technological means, it allows an intelligent control of energy flows, enabling an adequate balance between energy supply and demand, resulting in savings for both consumers and producers. Smart grids also play an important role in the development of renewable energies. However, the high implementation costs and certain data protection issues remain major challenges against this technology.

The major applications and roles of the smart grid can be summarized as follows:

- Balance: It allows for better management of the energy produced and the energy delivered.

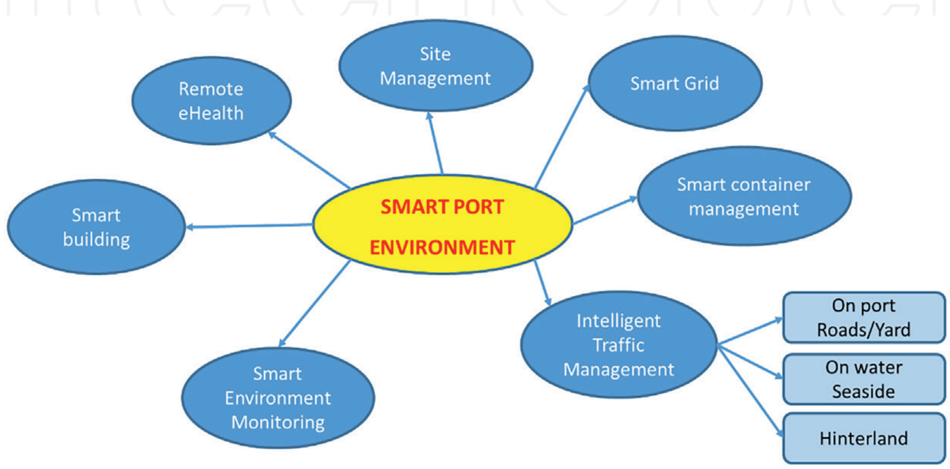

Figure 2.
The smart port environment is constituted of a set of smart domains.

- Security: The smart grid improves the stability of the electrical network, reducing the risk of overloads or outages, which can have negative impacts on both individuals and industries.
- Ecology: The smart grid allows a better use of renewable energies in the global energy consumption and, thus, avoids very important losses.
- Economy: A more stable network management allows a drastic reduction of production and consumption costs and lower losses.

Intelligent transport system (ITS): The state-of-the-art solution for the management of truck flows is based on an innovative concept of an intelligent parking lot, which makes it possible to put an end to port congestion and to fluidify the adjacent road traffic.

In this context, having an access permit is no longer sufficient for gaining access to the port. Access to the port is subject to an appointment with the operator through its online software system connected to automated gates and cameras; trucks accessing the port have the option of using the physical parking lot or the virtual online parking schedule. They will only be allowed into the parking lot after a mission has been created and the port operator has confirmed the scheduling of an imminent operation.

The Internet of Things (IoT) and artificial intelligence (AI) are enabling a new class of intelligent transportation systems (ITS) for road, air, rail, and sea. These solutions connect vehicles, traffic signals, toll booths, and other infrastructure to help reduce congestion, prevent accidents, reduce emissions, and make transportation more efficient. Examples include fleet management, intelligent traffic management, vehicle-to-everything (V2X) communication, electric vehicle charging, electronic tolling, and a wide range of other mobility solutions.

Terminal operations: In a nonmechanized seaport, operator travel can take up to 40% of their working time, resulting in a significant drop in productivity, soaring costs, and deterioration in customer service. However, with the multiplication of intelligent solutions, the connection of machines to each other, and the development of information systems as well as the network of connected objects, it is very easy and often less expensive than one might think to automate all or part of its flows.

Today's port professionals need to have a thorough understanding of container terminal management, the developments that impact their development and the challenges and opportunities for container ports: growth in container traffic requiring additional container capacity, ever larger ships calling at your port and terminals, alliances between container lines, automation of port terminal operations, growing importance of intermodality, and increased competition focusing on profitability and service.

Smart container management: The automated container terminal is not a futuristic view. For over a decade, automation has been implemented in terminals, and this trend is continuing. Today, in some terminals, the management of container fleets (including storage and movement) is done with fully automated equipment. Automated vehicles such as automated guided vehicles (AGVs) and straddle carriers are used in some terminals for transporting containers between storage areas and dock gantries.

For terminals, IT management is an element of activity management (storage and movements) in relation to ship planning and inland service tools. The tools for inland services. With the total automation of the terminal, we can imagine totally autonomous terminal managing flows: positioning and provisioning. The "smart terminal" will become, over several hectares, what is done in some logistics warehouses. The future would then be a terminal with artificial intelligence for total management.

2.3 IoT model for smart maritime ports

The deployment of smart environment, such as smart city, smart home, etc., uses the approach of Internet-of-Things (IoT) models. In such models, a set of sensing nodes (or IoT end-devices) is dispatched in this environment to collect different types of measurements/data. These data are transmitted over different communication links and networks and then stored somewhere for further real time or offline treatment, exploration, and exploitation. The large success of the IoT leads engineers to adopt different IoT models, mostly a three-layer model, a four-layer model, or a five-layer model. Because this chapter focuses on vehicular applications in the port environment, we adopt the model presented in **Figure 3**, which is sometimes called "IoT value chain" and used in the literature to point out the services related to vehicular applications. This includes six levels:

- Sensing layer: This layer is constituted by different end-devices known as sensors/actuators, which sense the environment and collect data. These data can be either sent directly to the upper layer or be submitted to some local but limited processing, such as compression and/or filtering.

- Transport/communications layer: The data collected locally by the sensing layer are given to this layer to be transmitted, generally to far locations where we have some advanced data processing equipment. This layer can be built by different alternative technologies. This can be wired technology like optical fiber and cables, or wireless using IEEE technologies (WiFi, WiMAX, long-range Bluetooth, or ZigBee) or 3GPP transmission technologies, which are categorized in second generation (2G), third generation (3G), fourth generation (4G), or 5G.

- Data layer: The data collected by the sensing layer and transmitted arrive to this destination where they are stored for advanced processing. This layer is comprised of data centers or clouds where advanced big data operations are executed.

- Analytics layer: This layer is characterized by a higher level of intelligence, where algorithms or processes related to artificial intelligence and/or machine learning treat the stored data.

- Control layer: Based on the insights and knowledge gained from the analytics layer, this layer should meet optimal decisions to control the processes or the infrastructure monitored through the considered IoT system.

- Business layer: The IoT system is foreseen to be deployed in industrial and/or professional environments. Therefore, the objective remains generally the achievement of some economic benefits. The responsible processes to guide the entire processes to achieve these objectives and benefits must be englobed in this layer.

Figure 3.
Simple horizontal model for the IoT value chain in vehicular applications.

3. Vehicular applications/systems in smart maritime port environment

3.1 Vehicles in maritime port yard

The maritime ports is a very active area, where heavy goods mostly encapsulated in containers must be handled in different processes, namely, loading, unloading, storage, delivery toward hinterland, received from hinterland, controlling through customs, etc. These operations require the use of different vehicular machines such as cranes, mobile cranes on wheels or rails, cranes operated by drivers, automated cranes, trucks on port yard, hinterland trucks, trains from hinterland, etc. **Figure 4** shows some examples of vehicles on port yard, including unmanned aerial vehicles (UAV) or drones. Some ports also use underwater unmanned vehicles (underwater drones) for different control and environment supervising tasks or control the part ship container underwater.

Automated guided vehicles (AGV): An automated guided vehicle (AGV) or automatic guided vehicle is a vehicle used to transports containers (and other items) in the port's area. These vehicles are remotely controllable, but also have an advanced level of intelligence to execute self-driving and other optional decisions, as depicted in **Figure 5**. Several advantages are guaranteed through the use of AGVs, such as economic/cost effectiveness, time efficiency, increased efficiency of the overall processes in the ports, considerable reduction in accidents, and reduced injuries due to the absence of human traffic, etc.

- **UAV or drone-assisted operation:** Drone or unmanned aerial vehicles (also unmanned aircraft systems—UAS) are gaining a large application fields. Maritime ports are already testing drones for their operation, such as [4]:

- inspections of physical structures and patrolling of security rounds;

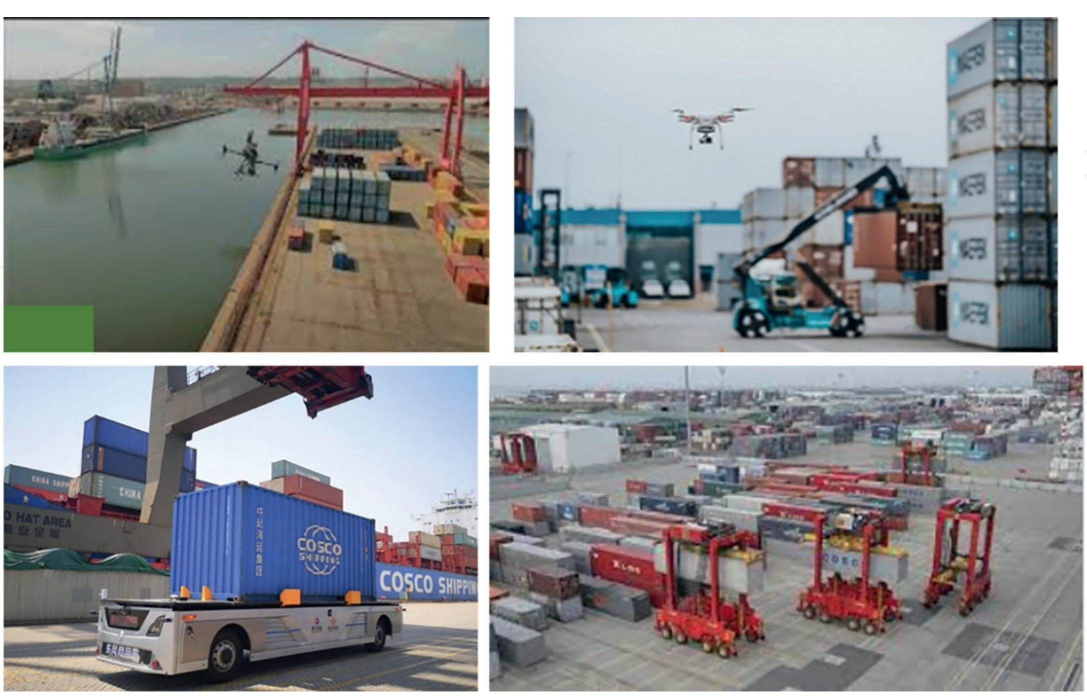

Figure 4.
Examples of vehicular applications in smart maritime port environments.

Figure 5.
Fleet of AGVs as part of port operations automation (Credits: wikiwand.com).

- routine inspections for maintenance of buoys, pipes, docks, breakwater cranes, roof ships, and other structures that are conventionally difficult to access;
- stock measurement to calculate (bulk) volumetric mass inventory. Inventory volume tracking of outdoor bulk material storage areas;
- detection of irregular situations, leaks, or abnormalities through (thermal and gas) sensors, as supplemental emergency support without the need to expose people to the affected areas;
- measurement and control of environmental aspects, detection of contamination, and tracking and monitoring those responsible for the environmental breaches. Environmental and ecological monitoring of both on-site processes and surrounding areas.

3.2 Levels of intelligence in vehicular applications in SMP

The different types of vehicles used in the port yard have the objective of facilitating the port operation through the optimization of processing time, safety of goods and personnel, and achieving cost and energy efficiency. However, higher levels of optimization are only reached through the automation of different operations, even also through the operation of vehicles in maritime ports. Therefore, we talk about autonomous or intelligent vehicles. The transition from traditional/classical vehicles towards autonomous port vehicles cannot be done in one transition. Thus, there are different levels of autonomy of vehicles, as illustrated in **Figure 6**. These intermediate levels allow a smooth transition, where the research and development works can be accompanied with the proof of concepts in the real life of maritime ports. This will allow the engineers get feedback from the practice to adapt their systems to any existing or new challenges in such a harsh and critical infrastructure. Higher autonomy signifies higher intelligence that requires the collection of larger amount of

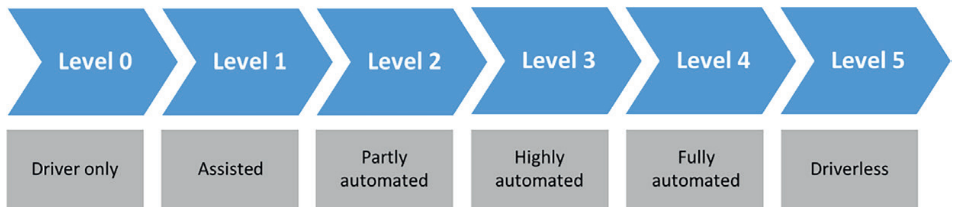

Figure 6.
Generic model for autonomy levels of vehicles in port operations [5].

data, which in its turn must be treated and/or transmitted in very short delay and in high reliable manner. In other words, these vehicles will need ultra-low latency and ultra-reliable communications links.

In a general context, the introduction of autonomous vehicles has three main objectives [5]:

- increased efficiency of transport, which brings alongside better capacity;
- utilization;
- less negative environmental impact;
- increased safety.

4. Vehicular communications in maritime ports

4.1 General hierarchical architecture/infrastructure in the smart port

From the economic point of view, it is worthy to select communication technology that can support all (or at least the maximum of) customer services. However, in practice, this is not possible. On the one hand, the diversity in services and the generated traffic have different quality-of-service requirements. On the other hand, each developed technology has its strengths and weaknesses, as can be seen in **Figure 7**, where only two performance criteria are plotted for different transmission technologies, namely, coverage and throughput. In reality, operators and engineers of the network must take into consideration further performance criteria such as delay, reliability, deployment as well as operational costs, etc.

An optimal design of the networking layer consists in having a networking infrastructure, which can support a variety of services from different vertical smart domains. A simplified topology of communication infrastructure in the area of a smart maritime port is illustrated in **Figure 8**. In such architecture, we recognize three levels, as discussed first in [6]:

- Level of low band or low bandwidth: This connects to the end-devices of the sensor layer (built through sensors and actuators). These nodes are dispatched in wide areas and transmit, in general, short and few parquets. Therefore, these nodes are not very requiring concerning the quality of services. The networking technologies to build this level must be very energy efficiency (low energy consumption) while offering low bit rates. Generally, wireless technologies such as Bluetooth, Bluetooth energy (BLE), ZigBee, Z-wave, low-power wide area

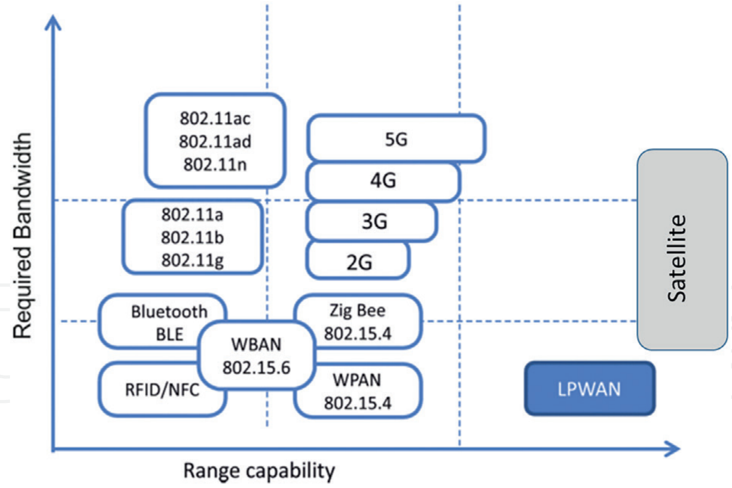

Figure 7.
Classification of wireless communications technologies in a two-dimensional plane (coverage and throughput).

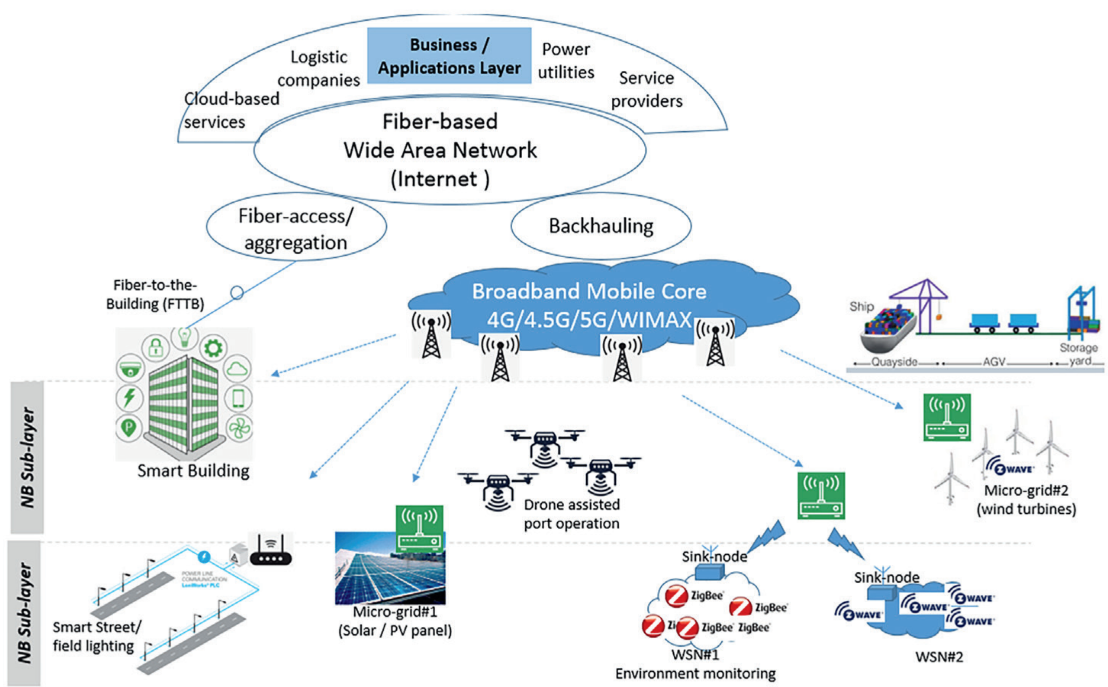

Figure 8.
Sublayers of communication architecture in a smart port.

(LPWA) networks (SigFox or LoRa or WightLess). As we remark, the wireless solutions are advantageous in this level, as they are easy to deploy and to maintain.

- Level of medium bandwidth: This level must transmit the traffic aggregated from the nodes of the lower level. Normally, for each node pool (or cluster of nodes), there is a gateway that collects and aggregates the traffic outgoing from these nodes. Because of that, the demand of the transmission capacity is relatively higher. The determination of the size of the clusters is subject to optimization under different constraints. But, we can consider that a bit rate of 2 Mbps a good compromise.

- Level of broadband technologies: In its turn, the level of medium bandwidth must be aggregated and connected to the (national) wide area networks. For most of the cases in the IoT, wireless solutions are more advantageous. Furthermore, mobility plays an important role here. Therefore, we have greater requirement for mobile broadband communications in this level. This is the mobile backbone of the networking layer in the smart port area. In addition, this level supplies direct connections to end-devices with higher demand of bandwidth, like HD camera, mobile PC/tables/device of the field force, normal Internet services everywhere in the port area, etc. The notion of mobile broadband has appeared in the engineering field related to third generation (3G) of mobile communications, technically known as universal mobile telecommunications system (UMTS). However, this was not able to offer transmission capacity more than 2 Mbps. Therefore, this has been extended to offer higher capacities and its derivation was known as high-speed downlink packet access (HSDPA) that focused on the improvement of downlink connection. This was followed by high-speed uplink packet access (HSUPA) that focused on the improvement of uplink connection. The last two variants have converged in a relative advanced technology called evolved high-speed packet access (eHSPA or HSPA+), which adopted advanced antenna technology as well as advanced modulation and coding schemes to reach up to 40 Mbps. The major (re)evolution in mobile broadband communications was realized by the fourth generation (4G) or long-term evolution (LTE), which can achieve bit rates over 300 Mbps. This milestone was rapidly overruled by the releases of long-term evolution-advanced pro (LTE-A Pro, called also 4.5G) reaching the magic threshold of 1 Gbps. This generation has offered different performance milestones in form of capacity of the bandwidth, shorter transmission delay, and service coverage for massive IoT systems. Nowadays, the fifth generation (5G) is struggling to find field where it can beat the performance of 4.5G. This seems to be a hard task, because different technical aspects as well as economic factors are putting lot of pressure on the deployment roadmaps of 5G. This has resulted in a delay in the widespread deployment of 5G technology.

4.2 Qualitative comparison of broadband technologies for vehicular applications

When we consider the evaluation of communication technologies for vehicular applications in smart port environment, a qualitative comparison is used, according to different criteria, which are throughput, network costs, coverage, adequacy to support massive IoT and the delay/latency. Here, the short-range communications technologies or short-range networks (SRNs) are excluded, because the main challenge of the network communications in port application lies in the set of (**large coverage, short delay, and sometimes broadband**). Furthermore, we have also taken into consideration the costs, which are very important for the network operator, the reliability as main challenge for sensitive application, and finally the IoT adaptability. This latter one is very important because any smart environment has a sensor or IoT layer as basis for any smart thing. Therefore, the communication layer should be adequately chosen for such environment.

Long-term evolution/advanced (LTE/LTE-A) is the first real mobile broadband technology. Having a real success worldwide, this is the backbone for the current mobile network and mobile Internet. Its major strength is its characteristic of “long-term” evolution; thus, it was designed to be able to be extended anytime for any new services. Indeed, the first LTE releases (Release 8 and Release 9) have been quickly evolved to Release 10 and Release 11, etc. Major transitions have realized in a short time, so LTE overrides just usual broadband Internet to support machine-type communication

(MTC), machine-to-machine (M2M), vehicle-to-vehicle (V2V), Internet-of-Things (IoT) communication/services/applications. This lets this technology show higher performance in all criteria compared with other technologies. Of course, it has a unique weakness, which is the coverage compared to the satellite. A very large number of research works have investigated the performance of the LTE in vehicular communications either in the form of V2V, vehicle-to-infrastructure (V2I), vehicle-to-everything (V2X), including Pedestrian, or Internet of Vehicles (IoV) [7–11]. Typical types of utilization of vehicular communications are depicted in (**Figure 9**) for general use as well as for use in the case of maritime port environment by mobile work force.

5G is the newest mobile technology generation. It should bring higher performance than 4G, especially in three dimensions: enhanced broadband throughput, ultrareliable communication, and support of massive IoT devices. The enhanced broadband should support new applications requiring very high capacities, such as virtual reality/augmented reality (VR/AR), which are not expected to be required in smart port environments. A major weakness is relative high cost to be invested. This is because this generation requires the deployment of new infrastructure. In the opposite of the evolved releases of 4G, which the upgrade of the networks is made with less costs. Different works evaluated the use of 5G for vehicular applications, and some of them are even talking about 6G [9, 14–16]. An example of application of 5G for vehicular applications in maritime port environment is given in [17], where higher capacity and lower latency are the objectives of the adopted architecture (**Figure 10**). The competition between 4G/LTE and 5G to build network layer for smart maritime ports will be intensive, because they are on the same level of performance in most of the considered criteria, as illustrated in **Figure 11**. However, 4G has the main advantage of network costs, because 4G network are already massively deployed and proofed in the field, while 5G massive rollout suffer from delay, viability of its business model and other different economic circumstances.

The satellite communication is the excellent solution for the large coverage (everywhere and anytime). This technology did not cease to evolve over the years. However, two major weak points are inevitable: the high costs for broadband communications and the long delay, which is caused by the signal propagation to the sky and back. In spite of this, different mechanisms have been investigated to improve its performance [18–21].

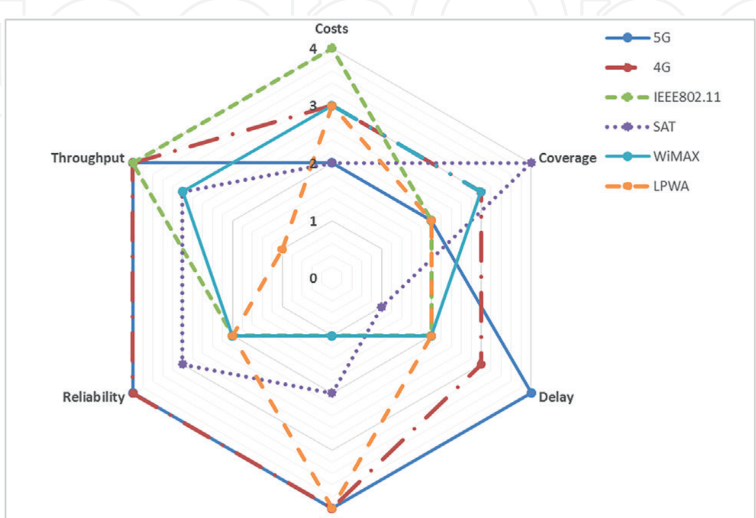

Figure 9.
Types of V2X in LTE standards (left, [12]) and its applications in maritime port environment (right, [13]).

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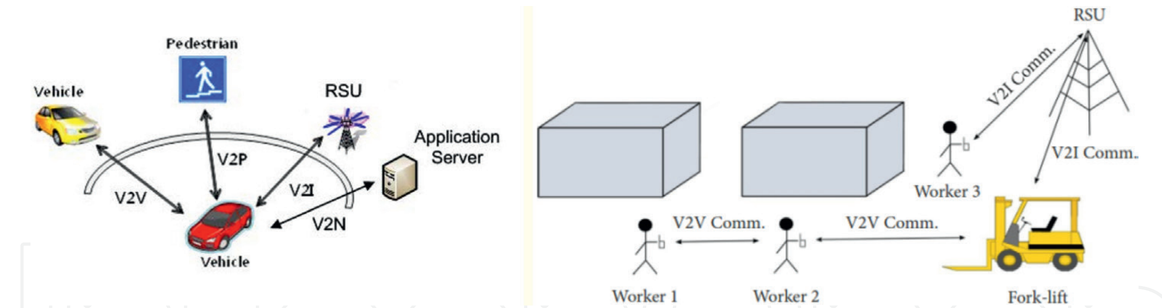

Figure 10.
Example from the practice for the use of 5G in maritime port vehicular applications [17].

To realize the objective of long range or long coverage of IoT applications and devices, without the use of satellite, low-power wide area (LPWA) networks have been developed especially for the narrowband IoT. Thus, high throughput and implicitly the delay are the main drawbacks of this technology. Examples of the utilization of LPWA in vehicular applications can be found in [22–25].

WiMAX technology has been reserved for some industrial applications, after it lose the battle of 4G, and this is the adoption of the usual broadband network for the public mobile network. This worked well for a while, however, with the apparition of massive IoT applications in industrial fields under the name of Industrie 4.0; WiMAX was not able to support the modern services, because its standardization has been frozen more than a decade ago. Therefore, it cannot be a good favorite or alternative for such modern smart environment like smart maritime ports.

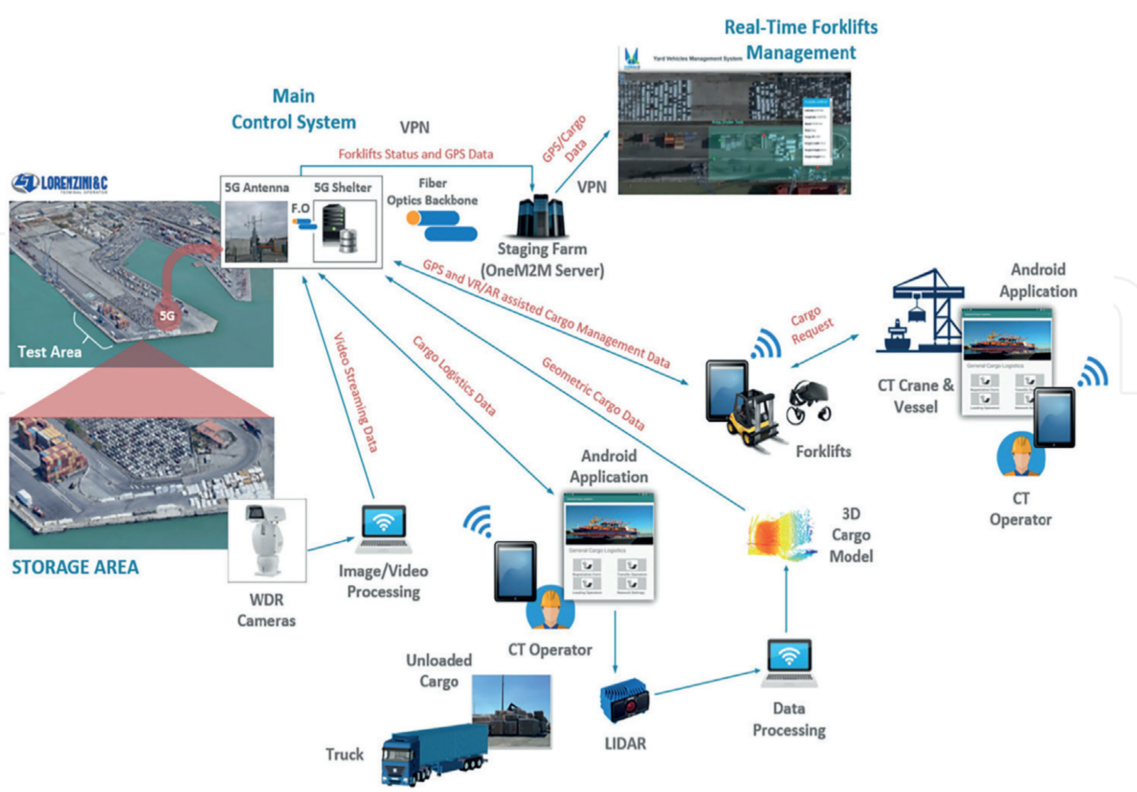

Figure 11.
Qualitative performance of communications technology (relative to each other) for vehicular applications (scores meaning: 4—very good, 3—good, 2—average/acceptable, 1—bad, and 0—very bad).

The success of the WLAN standard (IEEE 802.11) has led to its extension beyond residential and enterprise areas. Special applications have been developed, including for smart cities (IEEE 802.11h) and smart transportation (IEEE 802.11p). While studies have investigated the use of IEEE 802.11p for vehicular applications, such as [26–30], there is a lack of research considering its use in the specific context of a smart maritime port environment.

5. Conclusions

The maritime transport networks are playing a unique and major role in an always more globalized world economy. In such networks, the maritime ports play the role of hubs. Any disturbances in these hubs will negatively influence the worldwide economy Therefore, economy players are transforming the ports through an evolving process to become smart maritime ports. These smart ports are built through an ensemble of smart domains that are adopting sensing, data transmission, and data intelligence to support intelligent decision-making processes. Smart grid/microgrids, smart container management, smart/automated terminal operations, etc. are examples of such smart domains.

In different smart domains, vehicular applications are present. Therefore, the vehicular communications must be taken into consideration while developing the roadmap for smart maritime port. In this chapter, we focused on five communication technologies through the presentation of a qualitative performance evaluation of these technologies. The introduction of autonomous imposes hard requirements for the quality of services to be guaranteed by the communication networks, such as ultra-low latency, ultra-high reliable communication links.

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Conflict of interest

The authors declare no conflict of interest.

Author details

El Idrissi Ayoub[1], Haidine Abdelfatteh[1], Ait-Allal Abdelmoula[2]*, Dahbi Aziz[1] and Aqqal Abdelhak[1]

1 National School of Applied Sciences, University Chouaib Doukkali, El Jadida, Morocco

2 High Institute of Maritime Studies (ISEM), Casablanca, Morocco

*Address all correspondence to: haidine.a@ucd.ac.ma

References

[1] Bodewig K. Shaping the Future Policy of the European Maritime Space Motorways of the Sea Detailed Implementation Plan of the European Coordinator: Report EU Mobility and Transport. Brussels, Belgium: European Commission; 2020

[2] Miller G. Record shattered: 73 container ships stuck waiting off California, FREIGHTS WAVES News on Thursday, September 16, 2021. Available from: https://www.freightwaves.com/news/record-shattered-61-container-ships-stuck-waiting-off-california

[3] Spangler W, Kreulen J, Chen Y, Proctor L, Alba A, Lelescu A, et al. A smarter process for sensing the information space. IBM Journal of Research and Development. 2010;**54**:1-13. DOI: 10.1147/JRD.2010.2050541

[4] Bexiga V. Blue Innovation—Drones in Port Operations, Escola Europa Intermodal Transport. 2021. Available from: https://escolaeuropea.eu/odiseo/issue-30-spring-2019/blue-innovation-drones-in-port-operations [Accessed: June 23, 2021]

[5] Fiedler R, Bosse C, Gehlken D, Brümmerstedt K, Burmeister H-C. Autonomous Vehicles' Impact on Port Infrastructure Requirements. Hamburg: Fraunhofer Center for Maritime Logistics and Services CML; 2019

[6] Haidine A, Ait-Allal A, Aqqal A, Dahbi A. Networking layered for the evolution of maritime ports into a smart environment. In: The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences; Gottingen. Gottingen: Copernicus GmbH; 2021. pp. 251-257. DOI: 10.5194/isprs-archives-XLVI-4-W5-2021-251-2021

[7] Bazzi A, Cecchini G, Zanella A, Masini BM. Study of the impact of PHY and MAC parameters in 3GPP C-V2V mode 4. IEEE Access. 2018;**6**:71685-71698. DOI: 10.1109/ACCESS.2018.2883401

[8] Izydorczyk T, Tavares FML, Berardinelli G, Bucur M, Mogensen P. Performance evaluation of multi-antenna receivers for vehicular communications in live LTE networks. In: 2019 IEEE 89th Vehicular Technology Conference (VTC2019-Spring). Kuala Lumpur, Malaysia. 2019. pp. 1-6. DOI: 10.1109/VTCSpring.2019.8746609

[9] Muhammad M, Safdar GA. Survey on existing authentication issues for cellular-assisted V2X communication. Vehicular Communications. 2018;**12**:50-65. DOI: 10.1016/j.vehcom.2018.01.008. Available from: https://www.sciencedirect.com/science/article/pii/S2214209617302267

[10] Sliwa B, Patchou M, Wietfeld C. Lightweight simulation of hybrid aerial- and ground-based vehicular communication networks. In: 2019 IEEE 90th Vehicular Technology Conference (VTC2019-Fall). Honolulu, Hawaii. 2019. pp. 1-7. DOI: 10.1109/VTCFall.2019.8891340

[11] Gyawali S, Xu S, Qian Y, Hu R. Challenges and solutions for cellular based V2X communications. IEEE Communications Surveys & Tutorials. 2020;**2020**:1-1. DOI: 10.1109/COMST.2020.3029723

[12] European Telecommunications Standardization Institute (ETSI). LTE, Service Requirements for V2X Services. ETSI Technical Specification for (3GPP TS 22.185 version 14.3.0 Release 14).

Available from: http://www.etsi.org/standards-search

[13] Sanja B, Jose Angel L, Schmeink A, Azam S, Mathar R. On deploying vehicular communications at the developing seaport and related innovation success impediment. Journal Transport. 2019;**34**:126-134. DOI: 10.3846/transport.2019.7987

[14] Molina-Masegosa R, Gozalvez J. LTE-V for sidelink 5G V2X vehicular communications: A new 5G technology for short-range vehicle-to-everything communications. IEEE Vehicular Technology Magazine. 2017;**12**(4):30-39. DOI: 10.1109/MVT.2017.2752798

[15] Zeadally S, Javed MA, Hamida EB. Vehicular communications for ITS: Standardization and challenges. IEEE Communications Standards Magazine. 2020;**4**(1):11-17. DOI: 10.1109/MCOMSTD.001.1900044

[16] Cheng X, Huang Z, Chen S. Vehicular communication channel measurement, modelling, and application for beyond 5G and 6G. IET Communications. 2020;**14**:3303-3311. DOI: 10.1049/iet-com.2020.0531/*Fgiure port

[17] Tesei A, Lattuca D, Tardo A, Di Mauro L, Pagano P, Luise M, et al. Securing seaport logistic vehicles using a distributed ledger-based credential management system. IEEE Open Journal of Vehicular Technology. 2021;**2021**:2. DOI: 10.1109/OJVT.2021.3067209

[18] Cui G, Long Y, Xu L, Wang W. Joint offloading and resource allocation for satellite assisted vehicle-to-vehicle communication. IEEE Systems Journal. 2020;**2020**:1-12. DOI: 10.1109/JSYST.2020.3017710

[19] Yin Z, Jia M, Cheng N, Wang W, Lyu F, Guo Q, et al. UAV-assisted physical layer security in multi-beam satellite-enabled vehicle communications. IEEE Transactions on Intelligent Transportation Systems. 2021;**23**(3):2739-2751

[20] Lei A, Ogah C, Asuquo P, Cruickshank H, Sun Z. A secure key management scheme for heterogeneous secure vehicular communication systems. ZTE Communications. 2019;**14**(S0):21-31

[21] Yuhan R, Rui Z, Yongzhao L, et al. Spectral-energy efficiency tradeoff in cognitive satellite-vehicular networks towards beyond 5G. In: 2019 IEEE Wireless Communications and Networking Conference (WCNC). 2019. pp. 1-6

[22] Yuke L, Shuangshuang H, Linyao Y, et al. LoRa on the move: Performance evaluation of LoRa in V2X communications. In: IEEE Intelligent Vehicles Symposium (IV). Suzhou, China. 2018. pp. 1107-1111

[23] Akira S, Yoshitaka S, Toshihiro T. Evaluation of performance on lpwa network realizes for multi-wavelength cognitive v2x wireless system. In: 2019 IEEE 10th International Conference on Awareness Science and Technology (iCAST). Morioka, Japan: IEEE; 2019. pp. 1-6

[24] Jinhyung O, Dong-Woo L, Kyu-Min K. Unmanned aerial vehicle identification success probability with LoRa communication approach. In: IEEE 31st Annual International Symposium on Personal, Indoor and Mobile Radio Communications. London, United Kingdom. 2020. pp. 1-6

[25] Fei G, Jianwei N, Landu J, et al. Survey of the low power wide area network technologies. Journal of Network and Computer Applications. 2020;**149**:102459

[26] Singh A, Singh B. A study of the IEEE802.11p (WAVE) and LTE-V2V technologies for vehicular communication. In: International Conference on Computation, Automation and Knowledge Management (ICCAKM). 2020. pp. 157-160. DOI: 10.1109/ICCAKM46823.2020.9051468

[27] Singh PK, Nandi SK, Nandi S. A tutorial survey on vehicular communication state of the art, and future research directions. Vehicular Communications. 2019;**18**:2214-2096. DOI: 10.1016/j.vehcom.2019.100164

[28] Trujillo-Flores JI, Torrealba-Meléndez R, Muñoz-Pacheco JM, Vásquez-Agustín MA, Tamariz-Flores EI, Colín-Beltrán E, et al. CPW-fed transparent antenna for vehicle communications. Applied Sciences. 2020;**10**:6001. DOI: 10.3390/app10176001

[29] Arena F, Pau G, Severino A. A review on IEEE 802.11p for intelligent transportation systems. Journal of Sensor and Actuator Networks. 2020;**9**:22. DOI: 10.3390/jsan9020022

[30] Klapez M, Grazia CA, Casoni M. Minimization of IEEE 802.11p packet collision interference through transmission time shifting. Journal of Sensor and Actuator Networks. 2020;**9**:17. DOI: 10.3390/jsan9020017