Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

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To cite this article: O Postolache *et al* 2019 *J. Phys.: Conf. Ser.* **1379** 012072

Modelling IoT technology for a cargo port

O Postolache[1], Y Yang[2], M Zhong[2], H Yao[2], F Yu[2], X Fu[2] and C Mi[2]

[1]Instituto de Telecomunicações and ISCTE-Instituto Universitário de Lisboa, Portugal
[2]Institute of Logistics Science and Engineering, Shanghai Maritime University, China

E-mail: opostolache@lx.it.pt

Abstract. A work on modelling Internet of Things architecture for cargo ports is described. The main things and their roles in a cargo port, different sensors and instrumentation that was used or might be used for sensing and control in a cargo port, and some examples of IoT technologies that might contribute for improving the safety of processes and the security of the port are presented. By increasing the accessibility and accuracy of relevant information, IoT technologies may increase efficiency and quality of services in cargo ports, the operational safety and security of the ports.

1. Introduction

Internet of Things (IoT) technologies by connecting sensors, devices, and intelligent operations (i.e., intelligent cargo movement) provide clear business benefit in terms of asset tracking and supply-chain management. This is achieved by means of continuous process synchronisation of supply-chain information, and seamless real-time tracking and tracing of objects [1]. Containers port become more and more important and have very fast yearly growth-rate. The goods management and security in the cargo ports are increasingly challenging. The expected increase of trade in the following years, the limited possibility to increase the space and traffic in ports and the need for improved security in the ports (that is high resources and time consuming) require solutions for better management of port asset and processes. Internet of Things technologies already is a solution adopted by some ports to increase the efficiency of management. Most of information systems for cargo ports were implemented for optimization and acceleration of yard stacking. In this paper is presented the work on modelling the IoT framework for cargo ports. What measures and what IoT architecture that might improve the asset and process management in a cargo ports were mainly investigated. In the following sections of the paper we present what are the main objects/things and their roles in a cargo port, what kind of sensors and instrumentation was used or might be used for sensing and control in a cargo port, and some examples of technologies that might contribute for improving the safety of processes and the security of the ports.

2. Port objects/things and their roles

Modelling of an IoT architecture for a domain require a thorough understanding of that domain and conceptualization/generalisation of the domain processes. A reference model can lead to a better understanding of targeted system and a tool for building architecture where design choices are based on best practices, in terms of functionality and information usage, to deal with conflicting requirements regarding functionality, performance, deployment and security. Following we describe a cargo port, listing several objects/things that generally can be found in a cargo port, and their main role.

2.1. Hinterland

Hinterland is defined as port's area that serve both for import and for export of goods, the inland region lying behind port or the area from which products are delivered to a port for shipping elsewhere. Hinterland includes the port authorities (e.g., custom authorities), logistic centre, the hinterland transportation infrastructure, storage yard. Different services are provided in the hinterland - custom clearance, administration of shipping documents, special treatments of goods, special inspection of containers, quarantine, shipping and receiving of containers, maintenance of the containers, loading and unloading of trucks, trains, feeders to/from the hinterland distribution, empty container handling, storage of goods.

2.2. Logistic centre

Logistic centre is a centre in a defined area within which all activities relating to transport, logistics and the distribution of goods (both for national and international transit), are carried out by various operators on a commercial basis. The Logistic Centre must be open to allow access to all companies involved in the activities of the port [2]. It includes offices of shipping companies, freight forwarders, stevedoring firm, waterway authorities, transportation and storage companies. It should comply with international and regional standards and quality performance to provide the framework for commercial and sustainable transport solutions. At the terminal controls tracking of things from ship unloading progress to positioning of containers for shipping, launching and scheduling for taking import containers should be integrated. At the terminal operators the cargo is managed to be sent to distribution centres.

2.3. Carrousel and Carriers

In a cargo port many types of carrousel and carriers can be found: automated guided vehicles (AVG); belt system; chain connected chassis system; overhead grid rail system; semi-trailer truck; trucks; trains; straddle carriers.

2.4. Cranes

Many types of cranes (see ELS classification of crane [3]) can be found in port. These may be classified taking into account the space where is placed (i.e., quay crane and storage yard crane) or the main functionality that a crane have (i.e., goliath gantry crane, transfer crane, block handling crane, floating dock crane, mobile harbour crane, lift trucks – reach stackers, fork lift trucks, container lift truck). In several ports the quay-crane is guided and controlled from central control office with cameras (nobody is on board of the crane, so the crane-crab can be accelerated faster, and the cycle time reduced). Many quay crane picks only one container in a stroke. In a few ports (e.g., Shanghai port) there are quay-cranes that can pick up 2 containers in a stroke and thereby double the capacity. The Chinese company ZPMC has a demonstration system in Shanghai with a fully automated quay-crane system and an automated container yard stacking-system in place.

2.5. Containers

There is a great variety of containers. This variety consists of the most common ones - the dry containers, and those being designed for the special kinds of the goods. The containers can be classified as: dry container; open type containers; open side platform containers; refrigerated containers, platform containers; live animal shipping containers; tank containers.

2.6. Buffer zones

In a cargo port can be found: loading buffer in front of the crane; buffer truck docking station; buffer storage.

2.7. Storage area
The containers are stored at the appropriate temperature required by different goods (i.e., at ambient temperature; fixed temperature; and cold storage/refrigerated). Facilities for different goods storage exists in many cargo ports (e.g., for liquid fuel, grains).

3. Measurements

3.1. The Sea Gauges and Weather Conditions
The weather conditions, particularly wind, ice and high sea waves have great importance during operations of ship berthing and loading. The instrument and equipment used for weather conditions can also be used to estimate the environmental impact of ports (e.g., pollution by noxious gases) and alert on natural disaster. The meteorological station, either on land or the sea, should have instruments for accurate weather data (i.e., barometer, anemometer, thermometer, rain gauge, SODAR - radar or sound waves that determine the wind speed and direction at various elevations above the ground; weather radar that locate precipitation, calculate its trajectory and estimate their types, direction and speed of wind).

In Las Palmas de Gran Canaria’s Port, the main port in Spain, was designed and developed an information system that includes sensors for sea gauges and weather conditions [4]. It might support control tasks, through an alert management that monitors the value of many sensors.

3.2. Position and Displacement Detection
The measurement of position and displacement of physical objects is essential in many port scenarios (e.g., containers management, cranes controls, intrusion detection system, transportation traffic control). Position of the containers that could be managed using a RFID systems or radar devices might serve for intelligent decision for storage (in which multiple handling might be avoided), for monitoring and real time tracking of the containers, for detection of critical events, and also to stop goods’ smuggling and theft. Inductive and magnetic sensors, acoustic or microwave-based sensors have applications for sea tide gauge measurement, liquid level in a tank, elevators displacement. Optical sensors that are insensitive to magnetic fields and electrostatic interferences have also many applications in a port. For example, a system based on optical character recognition for automatic number plate recognition (ANPR) and automatic freight-code recognition (AFCR) was proposed [5]. The system uses this information to tag the photographic evidence of the corresponding vehicles. The system also includes a colour-based indexing scheme, which automatically identify the representative colour of each vehicle captures and better vehicle boundary detection.

Detection of position and displacement of things and people in a port has high importance for safe operations in port and security of port. Issues related to security of a cargo port and safety of processes regard several aspects such as perimeter security, internal security and operative controls, maritime security, decision support systems security, prevention and emergency management, etc. For example, detection of illegal ships and oil slicks as well as protection of the ports from effects of explosives or other weapons of mass destruction are key issues for reducing its economic, environmental and social impact. Synthetic Aperture Radar (SAR) system was proposed for detection of ships and/or oil slicks for maritime surveillance [6]. The system might function well day and night, in stormy weather or rainy days. CetusII AUV and MIRIS high-resolution sonar (i.e., equipped with side-scanning sonar) was proposed for inspection of the ship hull and berthing [7]. A robot equipped with DIDSON for short-range imaging sonar and M900-2250 for long-range imaging sonar was developed and tested by [8]. The robot search and recognize objects by the dual imaging sonar. They suggest that effective underwater exploration might be carried out by using short-range imaging sonar with frequencies of 1MHz or higher (for good quality sonar image) together with long-range imaging sonar with frequencies bellow 1MHz. DoD’s Architecture Framework that employs multisensory approach (i.e., ground surveillance radars and cameras) was proposed to detect, asses and track perimeter incursions [9]. Using these devices, the proposed system can perform the following processes: i) threat analysis - what threats are relevant to the facility, ordering these by their impact, criticality, etc.; ii) operational security -

providing real time situational awareness and incident resolution (i.e., intrusion detection and tracking; intrusion assessment; intrusion response).

Wireless sensors networks have been recognized as feasible means for object tracking. Wireless sensors network based on multi-sensor device Waspmote, developed by Liblium Company, was proposed for optimal management of containers [10]. The authors suggest that by using these devices various information on containers could be obtained: i) position and displacement of container; ii) container doors opening unexpectedly; iii) temperature; iv) air pressure; and v) illegal container content. Currently, different technology for wireless sensors network are commercialized (e.g., Tiny-mesh, Wirepas mesh). However, over the years the major concern related with wireless sensors networks remain the power consumption. Efforts have been made by various researchers to derive ways to extend the lifetime of power storage or to minimize the use of energy in the tracking process. A method for reduction the power consumption in wireless sensors network, that was inspired on Immune Network Theory was proposed by [11]. The algorithm determines the best sleeping policy in order to optimize the power consumption of the entire sensor network. By using artificial immune system when the number of sensors deployed in a sensor field and thus the corresponding density of sensor nodes increases, the average power consumption per sensor decreases.

3.3. Velocity and Acceleration Detection

Sensors for velocity and acceleration detection might have many applications in port (e.g., for traffic control in port). The advances in MEMS technology have produced an increase use of sensor for velocity and acceleration in multi-sensor devices. For example, the Bosh CISS (Connected Industrial Sensor solution) is a multi-sensor device based on MEMS technology that can detect acceleration, vibration, rotation, as well as environmental conditions. This device allows to activate or deactivate sensors and to configure the sampling rates according to specific needs (i.e., data streaming mode, event detection or time aggregation). Detection of the speed and location of illegal ships by using a wireless sensors networks equipped with Global Positioning Systems (GPS) was proposed by [12].

3.4. Chemical, Biological and Radiation Sensors

Multi-sensor technology might be used for real-time and accurate information on cargo (i.e., type of goods, good characteristics transported inside the container). This information might give information for cargo risk evaluation that might be used to plane the container inspection (i.e., chemical screening, biological screening or radiation screening). A system for detection hazardous chemical and biological contents of containers as well as contraband was proposed by [13]. Two screening methods, one external to the container while it is being moved from conveyance to ship or vice versa, and an alternative in-situ method to sample, detect, and report dangerous cargo from inside a sealed container while in transit was described.

3.5. Port Infrastructure and Machinery Health Monitoring

With increasing trade, the usage of port machinery is increasingly continuous, which might enhance the risk of equipment's damage. For safety management of the goods in port, the status of port machinery should be measured by placing on key location of port machinery, sensors for non-destructive detection of materials. Non-destructive evaluation techniques allow detection of the presence of cracks, discontinuities, mechanical fatigue, and other imperfections without material damage. For example, electrical conductivity can be used as an index of mechanical fatigue. The planar meander and mesh-type sensors respond very well to conducting and magnetic materials but no so well to dielectric materials. On the other hand, the interdigital sensor responds very well to dielectric materials [14]. A real-time strain monitoring system based on distributed Fibber Bragg Grating sensors was proposed by [15] for health monitoring of port machinery.

IoT technologies for health maintenance of port infrastructure and port machinery might: i) reduce equipment downtime (i.e., repair service can be performed before the equipment failure); ii) increase productive uptime (i.e., by predictively identifying problems, so repairs can be scheduled during production downtime, rather than peak periods); iii) reduce maintenance costs; iv) increase asset lifespan (i.e., by performing predictive maintenance before costly failures occur); v) improve worker safety.

4. IoT for cargo port

IoT community has developed many architectures, platforms, standards, frameworks, solutions for IoT based information systems.

IoT is a powerful tool for things management in a cargo port by having the capacity to gather insights from the field using sensors technologies as well as by supporting data analytics. In figure 1 a model of IoT technology for cargo port is presented. A function architecture that refer to ITU-T Y.2060 and several required measurements in the cargo port were considered.

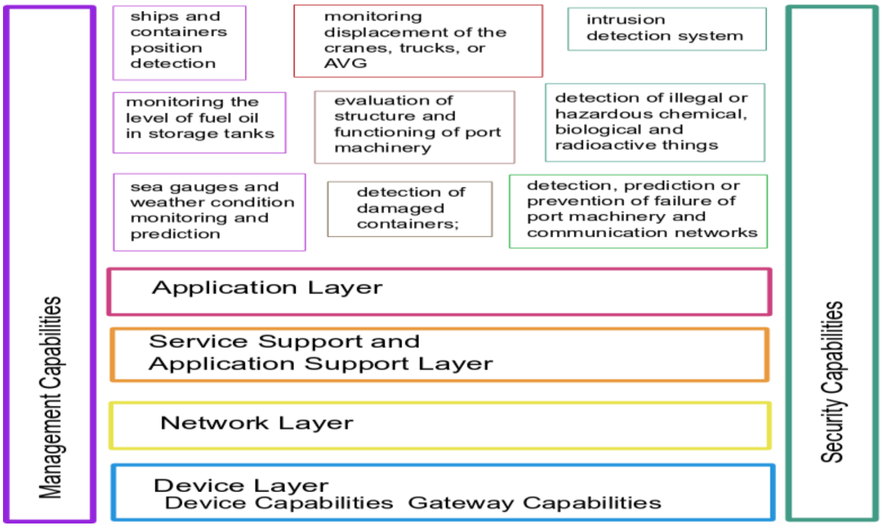

Figure 1. IoT model for cargo port.

The recent development of sensors having low power consumption, low cost, small size, limited radio range, and capacity for long-term working in harsh environments, increase the likelihood of IoT systems development for cargo ports, adapted to the various conditions and features of that port. Multi-model sensing that refers to sensing with different modalities and then exploiting the interdependence of these modalities to extract more useful data, should be considered in IoT system for cargo port. Information from sensors distributed in the port environment might be improved by data fusion and data meaning algorithms.

The communication of data in IoT framework might be supported by different types of wired or wireless technologies such as CAN bus, Zig Bee, Bluetooth, Wi-Fi. There are several hardware platforms available for sensor network deployment such as TelosB, Mica, IRIS, Waspmote, XBee ZB module, LoRa, BTLE, Tiny-mesh, Wirepasmesh, Xelba xOne Hub. Cellular connectivity like LTE is expected to increase in the future, especially with 5G and NB-IoT. The power of communications locations should consider buildings, height restrictions, and other topographic constraints.

Cloud computing, Hybrid Cloud or Microservices might be adopted for IoT architecture for cargo port for computing, storage, analytics and data visualization. Cloud Computing provides functional and also non-functional support (i.e., Service Level Agreements, low latency fault-tolerance, cost-optimization, security). These capabilities are provided as services (Platform-as-Service; Infrastructure as-a Service; Software-as-a-Service; etc.). Hybrid Cloud blends internal information system with cloud powered services. It might integrate private, public and managed cloud with the existing on-premises information system (e.g., Fujitsu MetaArc and Cloud Service K5). This may improve the agility, accessibility and security of the IoT systems for cargo ports. Both ETSI [16] team and Microsoft Azure [17] team recommend the use of Microservices in IoT architecture. Microservices are an architectural approach for developing applications as a set of small services, where each service is running as a separate process, communicating through simple mechanisms [16]. The main advantage of Microservice-based architecture is that one can develop, deploy, upgrade and scale every Microservice independently of the others. Moreover, developing Microservices separately enable the use of different technologies for each Microservice and to have distinctive Microservices for devices that communicate using different protocols. Also, this may support the safety and security of the system. For example, if a Microservice which communicates with a certain group of sensors crashes, the application provided by Microservices which communicate with other sensors will still be up and running.

The amount of data that can be acquired by IoT and the information provided by analytics tool in IoT frameworks are enormous. Nowadays, IoT data and information are susceptible to malicious usage by hackers but also by unauthorized competitors. Therefore, security of IoT system (i.e., protection of the confidentiality, integrity and availability of information asset) should be assured by design at every layer of the system architectures.

5. Conclusions

There are few studies on implemented information and communication technologies for cargo ports. IoT may contribute to increase efficiency and quality of services in cargo ports, the operational safety and security of the ports, by increasing the accessibility and accuracy of relevant information. More researches are needing to find what sensors and instrumentation and what communication and analytics technologies may contribute to design the optimal model and architecture of IoT platforms for better logistic (including security) of a cargo port. IoT for cargo ports should have an adaptive framework, which should allow multi-modalities sensing, modularity (i.e., flexibility to introduce new applications), should ensure adequate and safe connectivity to the existing information systems, and should process enormous quantity of data. As IoT data and information are nowadays susceptible to malicious usage by hackers but also by unauthorized competitors, design for cargo port information systems that support security of information at every layer of the information system architecture is required.

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