Modernizing Marinas in the Mediterranean Sea using SMartY: Methodologies and Lessons learned

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***Abstract*—Nautical Tourism market is one of the most quickly advancing markets especially in the Mediterranean Sea. At the same time, infrastructures in many marinas and ports still operate using old-school methods for booking, yacht hosting and service offerings. The Smarty solution can help marina administrators all over the world modernize their infrastructures with minimal installation and maintenance cost while it significantly improves the quality of the services offered to their customers. Mooring pillars become connected Internet of Things hubs, with the addition of smart metering devices allowing their users to interact with them through their mobile phones and measure in real time their electricity and water consumption, control their expenses and save on the resources available. It also gives more insights to marina administrators, to better detect losses in water or power, monitor malfunctions or better organize their marina's capacity.**

***Index Terms*—component, formatting, style, styling, insert**

I. Introduction

Nowadays, the nautical tourism market requires the adoption of ICT solutions and systems, transforming the marinas into modern facilities, with enhanced autonomy, safety, environmental friendliness and attractiveness to their customers or visitors. The absence of such systems exacerbates problems such as improper mooring (ie, anchoring on the sides, occupying multiple spaces), unnecessary boat maneuvers or activities that affect the maritime traffic, the operational effort and the optimization of the facilities use. From the sea traveler's point of view, the facilities availability, the traffic conditions in relation to the safety and ambience are the most common concerns. The larger number of yachts inside the marina area leads to higher environmental pollution (air, noise, waste, water) and consequently to an increase in energy consumption (electricity and water), resulting in higher costs for both the marina and the yachter. Therefore, there is a need for a comprehensive overview of activities in the marina which will enable a more efficient operation procedure, with an emphasis on the safety of yachts and marina administrators. Marinas will be able to find the opportunity for higher profit and also lower their costs by finding an appropriate way to manage the increased demand. Also, the satisfaction of yachters is a key indicator of service quality in the marina.

The yachting industry in Europe is a dynamic and competitive sector and a significant contributor to the European economy. With over than 27000 km of inland waterways and more than 70000 km of coastline, Europe offers the perfect environment for the 48 million people who regularly participate in recreational marine activities (36 million boaters), as well as countless numbers of tourists. Over 6 million boats are kept in European waters (more than 25 million boats globally), while 4500 marinas manage 1.75 million berths both in inland and in coastal areas in Europe (more than 25000 marinas and 8 million berths globally) [1]. In Europe there are more than 1 million berth spaces served by already installed pillars with the total capacity expected to rise significantly in following years. The yachting and marinas sector is one of the three pillars of the development of coastal and maritime tourism in Europe and worldwide. According to the EC [2] the size of the sector is estimated at 15 billion euros on an annual basis in the EU and it exceeds 40 billion Euros globally. All in all, the yachting and marina market with an average annual growth rate of 6%, along with the clear advantages technology brings both to yachter and marina ecosystems, indicate a great potential for the acceptance of SMartY, mainly due to the system's multi-dimensional market demand coverage.

II. State of the art

Existing solutions are based on legacy installations with no-restricted capabilities of interconnection/automation/monitoring. Smart pillars enabled with advanced features (utilities consumption monitoring& billing) do exist (ROLEC, GSERTEL, GIGIFIE) but the total cost is very high. These state of the art pillars rely on the presence of existing connectivity with backbone networks to deliver the full range of services, increasing their installation and operation cost. SMartY brings significant added value in the marketable solution of the SaMMY IoT platform as it delivers to Marina administrators the ability to deploy and offer innovative services with significantly lower total costs. These services are delivered with minimum intervention to existing pillars through the integration of low cost, low-energy CPSs (instead of replacing pillars), with increased capabilities that edge data analytics provide in the target market.

Smart metering infrastructures are one of the most highly developed areas in the past years especially in the domain of home and building level solutions [3]–[8]. Most of these systems target the use of electricity in order to provide suggestions and guidelines to users in order to reduce their energy footprint and achieve a more sustainable lifestyle. Others, try to identify potential losses of the network due to unauthorized access, a phenomenon that causes losses to the energy provider as the total amount of energy consumed is not properly billed. Similar techniques are applied to water metering solutions [9], in order to detect leakages and water loss in different parts of the network, including intentional tampering. While such methodologies have been applied at some scale in urban areas, their use in marina or port environments is relatively limited as in some cases the investment has a limited yearly return on investment. On the contrary in some locations, yachting marinas are placed in islands and locations that have limited resources both in electricity and water reserves.

A key factor for the development of smart metering solutions is the recent advances in edge computing solutions and services [10], [11]. Edge computing provides infrastructure administrators and end customers with tools to increase the data security and privacy of their systems, as well as the computing capabilities of their deployments as the data do not need to leave the premises of their owners, with aggregated information and alerts be transmitted on an as needed basis. Edge computing solutions are also designed with energy and connectivity restrictions in mind, making their operational requirements a lot smaller than older solutions (e.g., LoRA vs 4G), reducing operational and maintenance costs.

III. User Interactions

SMartY is envisaged to act as a source-available with real-time resources pool of services and activities for its two main group of stakeholders, namely the Marina Administrators and Yachters (incl. Crew Members, Skippers, Vessel Managers, etc.). A sustainable platform analysis and architecture definition should inarguably take stakeholder perspectives into account, responding to the needs of the relevant actors and entities. Table I presents the services and activities that are available in SMartY versus its stakeholders' categories, as they have been identified. Figure 1 visualizes the high level functional block diagram of SMartY architecture definition.

TABLE I
Services and Activities Matrix

Service & Activities	Stakeholders	
	Marina Administrators	Yachters
Monitoring	✓	
Behavior Notifications	✓	
Historical Readings	✓	
Consolidated Billing	✓	
Per Usage Billing		✓
Electricity Control On/Off	✓	✓
Water Supply On/Off	✓	✓

SMartY Integration Layer is part of a SaMMY-enabled ecosystem that is being developed to provide the necessary abstraction to SaMMY specific semantics. Other integrations involve real-time camera feeds, flexible electronics, underground robotics, and drones, while all integrations are communicating with each other via a broker, currently based on RabbitMQ. The selection has been made so as to allow seamless interaction with hardware components or third-party services and also enable large-scale deployments with the available integrations. SMartY Integration Layer provides a graphical user interface mainly for Marina Administrators, while services for Yachters are encapsulated in relevant service calls with the SaMMY platform.

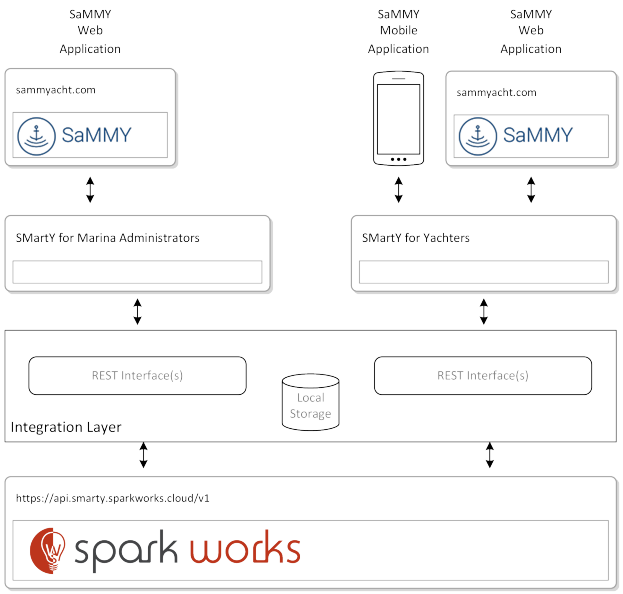

Fig. 1. High level functional block diagram of SMartY

In regards of smart metering services, all stakeholders are offered with the ability to switch On or Off the electricity and water supply per docking station. Yachters have also the ability to monitor the electricity and water supply consumption in their allocated Docking Station of their berth. Marina administrators are empowered with monitoring either current or historical sensors' readings either per docking station or per device, while notifications for excessive electricity and/or water consumption in a specific docking station (or device) are triggered, based on two adjustable boundaries per consumption category: Warning and Critical indicator levels of electricity or water consumption. Finally, Marina Administrators are also capable to collect the aggregated electricity and water consumption data per Docking Station allocated to specific Yachter, by his request to checkout from the Marina moor.

IV. System Architecture

The SMartY architecture is based on the use of Edge enabled IoT devices to improve and modernize legacy metering infrastructures available in marinas and ports, improving the services offered to yachters. The system is designed to

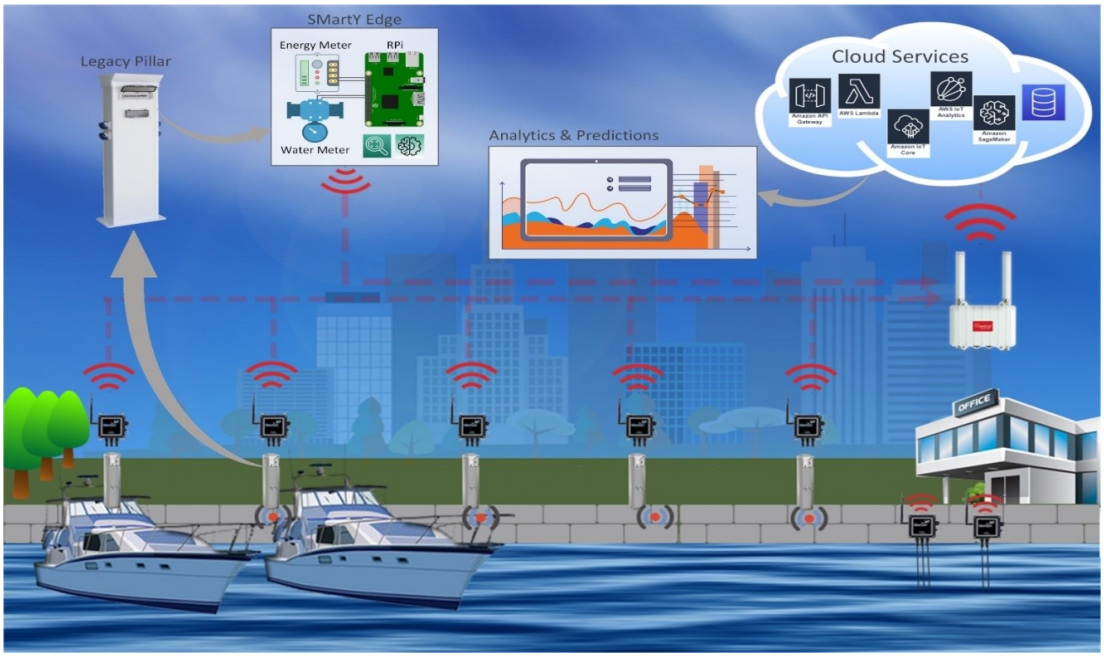

Fig. 2. The high-level architecture of the SMartY platform

work with existing infrastructure as the cost of deploying new state-of-the-art IoT enabled pillars and metering infrastructure requires costly renovations in the marina hardware infrastructures in systems have not yet reached their return of investment dates but have been rendered obsolete. Our system is designed to offer cutting edge solutions with minimal interventions inside the pillars electrical and water supply systems and a small set of devices deployed in the field for data collection and processing on-site, before sending any data needed to Cloud Services as needed. For more detail, our system includes the installation of connected water and power meters in all mooring pillars of the marina, that can wirelessly send metering data to an Edge-enabled gateway device. The SMartY Edge device is based on the Sparks Edge node that will be described later on, and uses the AWS Greengrass IoT runtime to offer cloud-level services on the Edge of the network. Using AWS Greengrass we are capable of offering analytics, forecasting and billing capabilities to the marina users and administrators without the need for network connectivity or always on data communication with the Cloud Services of the system. A graphical representation of the SMartY architecture is available in Figure 2.

A. Core Services

The Core Services of SMartY for data collection, analytics and distributions is deployed on AWS, using a cloud native serverless architecture. Except for the use of AWS Greengrass IoT, we also use for our system the following AWS services:

- AWS IoT Core: A service for registering and managing IoT devices, including the smart meters and the Edge-enabled gateways. It offers features like indexing, data caching, grouping and access management to facilitate the deployment of our infrastructure and secure our operations at all levels.
- AWS Timestream: a fast, scalable, and serverless time series database service for IoT and operational applications that makes it easy to store and analyze trillions of events per day up to 1,000 times faster and at as little as 1/10th the cost of relational databases. All data from the IoT devices are stored in the Timestream database for later processing and analysis from the analytics, forecasting, billing and user interface modules of the system.
- AWS Lambda: a serverless compute service that lets you run code without provisioning or managing servers, creating workload-aware cluster scaling logic, maintaining event integrations, or managing runtimes.
- AWS IoT Analytics: a fully-managed service used to run sophisticated analytics on massive volumes of IoT data without worries about cost and complexity.
- AWS Sagemaker: a service for data scientists and developers to prepare, build, train, and deploy high-quality machine learning (ML) models quickly by bringing together a broad set of capabilities purpose-built for ML.

The serverless architecture helps us develop solutions, services and applications without worrying about scalability or deployment infrastructures. Our software runs in the cloud and at the edges of the network without any change and regardless of the users served while remaining cost effective and responsive.

B. SMartY API

The SMartY API is also deployed on AWS and exposes endpoints for the manipulation of the available IoT things (devices) and groups of things. Things are the IoT devices registered and managed by AWS IoT Core. Thing groups allow

the management of several things at once by categorizing them into groups. Thing groups can also contain other thing groups, and so offer the ability to build a hierarchy of groups. The SMartY API exposes an additional endpoint for the creation of entities during the initial deployment of the system or for the expansion of the installation in a new location.

V. Mooring Pillar Hardware Modifications

Multiple hardware devices and platforms were evaluated in order to identify the most suitable options for deployment in the harsh and demanding environments of ports and marinas. In the rest of this section we present the devices selected for the SMartY deployment, their capabilities as well as their communication and connectivity requirements.

A. Power

For measuring and controlling the power supplies available in the mooring pillars, we selected to use the Shelly 3EM. This device is a professional, ready to use, 3-phase energy meter that can calculate 2-way power consumption: produced and used energy for each of the three phases. The device can be configured to measure three separate points of a mono-phase electrical system and measure each of them separately or a 3-phase power installation with ratings of up to 120A in each phase. It also has an integrated relay output which can be used for a 10A contactor control. This control signal is used, in our installation, as a control signal to switch the 3-phase power supply of the mooring pillar's plug, allowing us to switch the supply on and off as requested by users or system administrators. In order to switch the 3-phase on and off we also use an ABB ESB40-40N contactor to control the 3 phases properly and simultaneously (Figure 3). For each independent power supply available each pillar, a differnt Shelly 3EM device and an ABB ESB40-40N contactor is needed.

Fig. 3. The Shelly 3EM meter used to measure the power consumption in each 3phase Mooring pillar power supply

B. Water

For measuring the water consumption we use the MULTICAL 21 ultrasonic water meter by Kamstrup. Contrary to traditional mechanical meters, MULTICAL 21 is a static meter protected against water ingress with no moving parts. Therefore, it maintains a high and stable accuracy throughout its lifetime of up to 16 years. Its long lifetime is extremely important in order to reduce the cost of the installation and the ROI needed to transform a traditional mooring pillar to a smart one. Multical 21 also has a very low error margin, an industry-leading accuracy and an optimised low start flow which ensures that even the smallest consumption is measured accurately (Figure 4). For controlling the water supply, the mooring pillar was already equipped with a set of solenoid valves controlled by the existing offline installation. In order to control the existing installation we used two Shelly 1 devices that allow us to control the two independent power lines that power the solenoid valves available.

Fig. 4. The Kamstrup MULTICAL 21 ultrasonic water meter use for water consumption monitoring

1) Communication: Shelly 3EM and Shelly 1 devices can be controlled via WiFi. This severely limits their communication range and the locations where they can be deployed (especially when installed inside the mooring pillars' metal enclosures). To overcome this limitation we use a dedicated Sparks 433-Bridge device, that acts as a gateway device inside each mooring pillar, creating a dedicated WiFi network, where each Shelly device is connected. Then the Sparks Bridge is used to continuously poll the Shelly devices and forward their data to the Sparks Edge node through a long distance communication link, using an RFM69HCW radio module at 433MHz and a custom protocol. The communication is bidirectional, as this device is also capable of receiving commands from the Edge node placed in a central location inside the marina so that it can reach as many pillars as possible. The Sparks Edge node is composed of a RaspberryPi device, a Sparks 433-Bridge, and an iM871A-USB receiver that can collect the messages broadcasted periodically from the MULTICAL 21 water meters. The Sparks Edge node can be modified and equipped with more wireless communication adapters and receivers as needed for each specific deployment and can handle hundreds of IoT devices at a single time. The Sparks Edge node can then be connected to the Internet using, based on availability, either a 4G/5G wireless router, wired ethernet connection, WiFi or NB-IoT. It is powered through a typical wall power usb adapter or using Power-over-Ethernet if needed. More details on the software running inside the Sparks Edge node will be provided in the next section.

C. Edge Software

The Sparks Edge node is a device capable of running multiple edge-enabled applications based on the AWS IoT Greengrass open-source edge runtime and cloud service for building, deploying, and managing device software. All software running through the Greengrass runtime have access to all the communication interfaces attached to the node (iM871A-USB receiver and Sparks 433-Bridge) to collect

data and send commands to all IoT devices and controllers deployed in the pilot. The exact set of software running on the device is depicted in Figure 5 and are the following:

- Sparks w-MBus monitor: Receives, decrypts and decodes messages broadcasted periodically from all the MULTICAL-21 meters deployed in the Marina. To perform the decryption process, the application needs to download from the AWS IoT core the decryption keys for each meter. This is done using the Token Exchange Service, in order to get access to the IoT core's apis and the meter's shadows in IoT core where the administrator of the systems should upload the decryption keys. All received data are sent to the AWS Local Messaging to be sent to the cloud as needed.
- Sparks 433-Bridge monitor: The 433-Bridge receives all the messages regarding power consumption and control statuses from the devices deployed inside the mooring pillar. This component is also responsible for sending commands to the devices when needed to switch a power supply on or off. All received data are sent to the AWS Local Messaging to be sent to the cloud as needed.
- Sparks Pi monitor: management component that offers data on the operation of the RaspberryPi deployed in the field, such as cpu, memory and disk usage, temperatures and other debug information as needed. All generated data are sent to the AWS Local Messaging to be sent to the cloud as needed.
- Sparks Buffer: this component receives all data sent to the AWS Local messaging from all deployed monitor components and stores them in a local database. The data stay in the database until they are processed locally or forwarded to the cloud for storage and further analysis.
- Sparks Forwarder: this component picks up the data stored in the local database by the Sparks Buffer and sends them to the cloud if and when a connection to the cloud services is available.
- Sparks Shadow Fetcher: a component that fetches the needed shadows from the IoT Core cloud services in order to get updates on state change requests or decryption keys for newly deployed water meters.

The following core IoT Greengrass Services are also deployed and used in the Edge node:

- AWS Token Exchange Service: a service that provides other components with temporary credentials to use in order to communicate with the AWS IoT Core APIs as needed. Credentials are periodically rotated for security reasons, so only allowed processes can have access to the new ones when needed.
- AWS Local Messaging: An MQTT-like service for publishing data and subscribing to streams of data to facilitate the data exchanges between components running in the same Edge node.

The Sparks Edge node deployed for SMartY uses a 4G router in order to get access to the Internet and communicate with cloud services of AWS for software updates, management

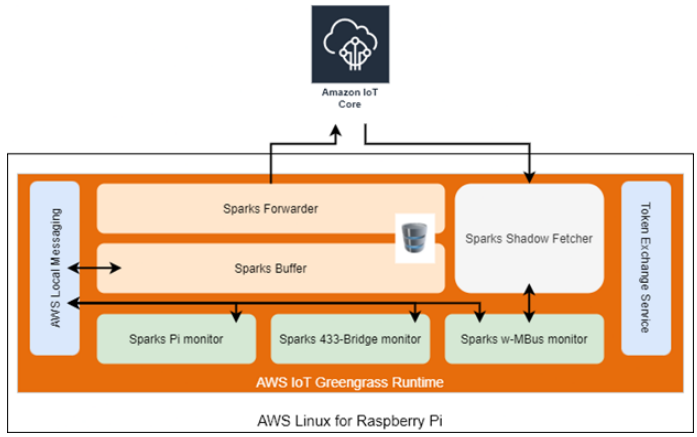

Fig. 5. The software components in the on-site gateway device of the data collection AWS Greengrass deployment

and forwarding data to the cloud. The data consumed for uploading and communicating status updates for all the sensors are part of what we will monitor for the rest of the Pilot deployment, but for previous deployments in other domains they should not exceed a total of 1 GB every month, even in the case of a full deployment for all the mooring pillars available in the Patras Mega Yacht Marina. The software inside the Edge node is developed in order to operate properly even when disconnected from the cloud infrastructure due to the requirements of the deployment. The Sparks Buffer and Forwarder components use the internal database to keep all data collected safe in the devices flash storage until confirmation of successful transmission to the cloud services is available. In case of a communication anomaly, or network anomaly, the system can easily recover, and send the stored data, while restoring the rest of the affected services, and keeping the rest of the user services running.

VI. Real World Deployment

The SMartY hardware has been installed, as mentioned before, in the Patras MegaYacht Marina since July 2021. The installation details are shown in the following images. The Sparks Edge Node is installed in a lighting column in the port where the port administrator has provided us with a power supply. The Sparks 433-Bridge device has been installed in Pillar $no11$ together with Shelly and Multical devices for data collection. The distance between the Edge Node and selected Pillar is around 30 meters away in a direct line. The quality of the signal is adequately good (-80 dB) indicating that we would be able to cover the whole port with the given installation. Photos from the installed devices are available in Figure 6.

A. Pilot Problems Identified

Regarding problems with the performed installation, we faced a setback when the installed Sparks Edge Node malfunctioned due to heavy rain in the Patras area .This caused water to enter the device's enclosure and led to the main

computing unit to stop operating. Water reached the device's SD card and caused an SD card failure. The SD card was replaced along with the main computing unit as a precaucion.

Fig. 6. Sparks Edge device installed on-site and modernized Mooring Pillar with Sparks 433-Bridge device and Shelly 3EM

B. Operational Insights

From the first stages of the project's pilot deployment we were able to evaluate the operation of the system in real time and better understand the communication and operational characteristics of the system. Table II shows how many data points are received from the system every 10 days of operation, giving us an understanding of the volume of data produced in the lower levels of the system, and the communication loads generated. Such data are of great use to better estimate the load of a full fledged installation in the Patras MegaYacht Marina and similar installations as they may be proposed in the future.

As our next steps, we plan to deploy and test more analytics applications and capabilities at the edge of the network, to further test the operation of these calculations in a real world installation. This is a crucial part for our system as we plan to migrate most of the processing and analytics capabilities of our infrastructure to the edges of the network, reducing the load on the cloud services, and increasing the local availability of the system regardless of the status of the communication status.

TABLE II
DATA VOLUMES EXCHANGED BETWEEN EDGE AND MOORING PILLAR

Data Type	Data Points Every day
Power Consumption	3700
Water Consumption	500
Switch Status	380
RespberryPi Status	250

VII. CONCLUSIONS & FUTURE GOALS

In this paper we presented a novel pilot installation for water and electricity metering in marinas and ports. Our system uses edge and cloud computing solutions to provide marina administrators and visitors with easy access on water and electricity outlets with precise and transparent billing capabilities. Our solution is tested in a real world installation that will remain operational and expanded in the next months to allow us gather more insights on its operation and the interaction with end users. The system will also be fully integrated in the SaMMY Marina Berth Booking application to provide users with a more integrated experience during their stay in the marina.

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