Blip: Identifying Boats in a Smart Marina Environment

Trifun Savić, Keoma Brun-Laguna, Thomas Watteyne

Blip: Identifying Boats in a Smart Marina Environment

Trifun Savić
Wattson Elements/Falco
Paris, France
trifun.savic@wefalco.fr

Keoma Brun-Laguna
Wattson Elements/Falco
Paris, France
keoma.laguna@wefalco.fr

Thomas Watteyne
Inria
Paris, France
thomas.watteyne@inria.fr

***Abstract*—In this paper we present Blip, a system for boat identification that uses the existing Internet of Things (IoT) network of sensors deployed inside a smart marina. Blip combines the data from two types of commercial low-power wireless sensors: Falco Presence and Falco Boat. The former is deployed on the pontoons, to detect boats that dock at the slips. The latter is installed inside the boats' cabins to monitor various parameters and trigger an alarm in case of: intrusion, fire, shock and tilt. To identify a boat, we fuse the boat presence events from the Falco Presence devices and the health reports from a Falco Boat. The health reports contain information about nearby Falco Presence devices and their received signal strength (known as Received Signal Strength Indicator or RSSI). When a boat enters the marina, Falco Boat joins the network and starts sending health reports. Initially, Blip estimates the slip location assigning the boat to the slip where a Falco Presence has the strongest RSSI. Then, Blip selects the closest slip to it, which changed to occupied in a given time window. We validate our system using a historical dataset from a marina over a period of 4 months. Every slip in the marina is equipped with a Falco Presence device, and 8 boats are equipped with a Falco Boat device. The results show that the Blip system identifies boats upon entering the marina with 100 % accuracy. The main advantage of the Blip system is that it provides location-aware service to the marina without any additional cost or hardware deployments.**

***Index Terms*—Smart marina, Smart parking, Location-aware services, Identification, Internet of Things (IoT)**

Fig. 1. Presence sensor for boat detection inside a smart marina.

I. Introduction

An Internet of Things (IoT) network consists of electronic devices called "motes", which are connected with each other and with the central gateway. These are battery-powered devices that communicate wirelessely. A mote can be either a sensor device that measures and collects data, or an actuator device that activates/deactivates other devices such as motors. A central gateway connects an IoT network to the Internet, typically with a dedicated cloud-based application [1], [2]. This allows users to have, in near real-time, the data from the sensors or to send command to an actuator. Aside from their main role of being a sensor or an actuator devices, it is important to know the exact location of the motes inside a network [3]. Enabling localization capabilities in an IoT network opens many commercial opportunities, especially if we don't need to install additional hardware.

The boating industry is one of the many use cases that benefits from IoT technology. Today's marinas are quickly evolving, with many boat owners renting their boats through online platforms or living on them inside the marina throughout the year [4]. This leads to an increase in costumer demand, and marina owners need to guaranty the safety of the boats and offer new services. IoT technology enables tremendous opportunities for marinas and boat owners. From the marina's point of view, the systems for automatic boat detection or real-time monitoring of electricity consumption could lower labor and costs. On the other hand, boat owners want to have more visibility on the state of their boats, using devices that can monitor and raise alarms in a case of an undesired event on the boat.

Aside from knowing if the certain slip is occupied, the marina wants to know which boat occupies the slip. This feature allows the marina to maximize slip occupancy and report in real-time where all the boats are inside the marina. Currently, boat identification is done manually in the marina; that is, teams of marina employee walk around the slips to write down which one is occupied, on a piece of paper. While commercial IoT sensors exist for monitoring slip occupancy

(Fig. 1), they do not know which boat is on which slip, i.e. they do not perform boat identification.

In this paper we propose Blip, a system that identifies boats in a smart marina environment. Blip uses the existing infrastructure of wireless sensors, deployed in a marina, to identify boats as they enter a marina and dock at a slip. Blip combines the data collected from the presence sensors (installed on each slip to detect a presence of a boat) and the boat monitoring sensors (installed inside the boats' cabins to detect events such as intrusion, fire, tilt, shock), in order to estimate at which slip a boat is located. Blip combines two main information collected from these devices. First, the information from a presence sensor when a slip changes state from unoccupied to occupied, i.e. when a boat docks inside a marina. Second, from a boat monitoring sensor, a report containing the list of the presence sensors it can sense wirelessly (located close to the boat). Aside from the presence sensors' IDs, this report contains the information about the radio signal strength received from each presence sensor. This is called Receive Signal Strength Indicator (RSSI).

In previous work on boat identification inside a marina, Krpetic et al. [5] propose a berth occupancy and boat identification system using a ZigBee IoT network. The authors use ultrasonic sensors for the boat presence detection and ZigBee nodes installed inside boats as RFID tags. However, authors assume that the boat has docked at the right slip if a slip state changes to occupied and if the boat that should be at that slip appears inside the IoT network. This assumption is wrong when there is already a different boat at the slip, with the correct boat being already inside the marina on another slip and reporting its ID. Moreover, the authors do not report the validation of their system on a historical dataset from a marina. In our system, we use the presence sensors RSSI information collected by the boat monitoring device to determine the area of the marina where the boat is. Blip then combines this information with presence sensors changing state from unoccupied to occupied in order to identify the boat. We also validate our approach on the historical dataset from Sète, a smart marina in the South of France. The results show that Blip is 100 % accurate, successfully identifying 8 boats in a 4 month period.

There are several localization and smart parking systems proposed in the literature, which we could deploy for our use case [6]–[10]. However, we want to avoid introducing more complexity and additional costs to the existing IoT network, already deployed inside a smart marina environment. In addition, we also address the zero infrastructure dependency research challenge in constrained localization systems [11]. Usually, commercial localization and identification systems require heavy mains-powered infrastructure, which in most cases cannot carry any additional information like sensor readings or actuator commands. The proposed system does not require any mains-powered devices to serve as infrastructure, in order to enable boat identification. Blip uses the infrastructure of battery powered devices already deployed, capable of operating several years on batteries. Blip is a software update to an existing commercial IoT system.

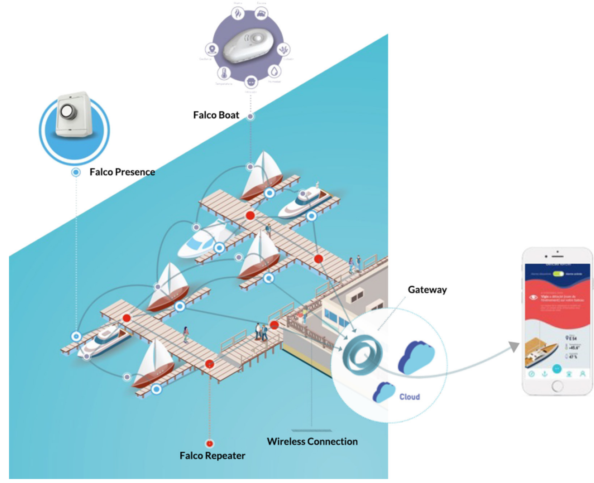

Fig. 2. Internet of Things network (IoT) for the smart marina environment.

The remainder of the paper is organized as follows. Section II describes the smart marina environment and presents a commercial IoT solution for marinas. Section III shows the hardware setup used in Blip. Section IV presents the Blip algorithm for boat identification. Section V describes the dataset used for algorithm validation. Section VI discusses the results. Section VII concludes this paper.

II. Smart Marina Environment

Smart marina provides automated services to marina managers and boat owners using IoT technology combined with cloud-based applications. The IoT technology inside the marina enables real-time services such as boat monitoring, slip occupancy and electricity consumption measurement. We can display the data collected from the IoT sensors on a cloud-based smartphone application, where the boat owner can check, in real-time, the state of their boat. Also, the smartphone application provides other services such as: weather information, live camera, marketplace, contract renewal. The combination of the low-power wireless sensors and the cloud application provides a lot of commercial opportunities for the marina, as well as lowering labor and costs. On the other hand, the boat owner gets more visibility on the state of their boat and has all marina services available on their smartphone.

Falco is a company that creates IoT solutions for smart marinas [12]. Falco creates devices for real-time boat monitoring, boat presence detection and electricity consumption. Specifically, it creates a low-power, time-synchronized, wireless mesh network of sensors, operating at 2.4 GHz. This network includes a central gateway which forwards all the data generated by the IoT devices to the cloud. Also, Falco offers the cloud-based digital solutions for both marina managers and boat owners. Fig. 2 shows the Falco IoT network inside a smart marina environment.

In this paper, we focus on a specific aspect of a smart marina: boat identification. A marina consists of slips, which are similar to "parking spot" for boats. Each slip is uniquely identified and managed by the marina, which manages and rents them. When a boat comes into the marina, it moors at a specific slip. For detecting the presence of a boat, Falco develops low-power wireless sensors, called “Falco Presence”. These devices are small boxes which are riveted on each slip, continuously monitoring whether the slip is occupied, and reporting any change wirelessly. Falco also develops “Falco Boat”, a device installed inside the main cabin of the boat, for monitoring different events such as: fire, shock, intrusion, etc.

With Falco Presence devices, we are able to monitor the split occupancy in real-time. However, we are not able to know exactly which boat occupies which slip. On top of knowing whether a slip is occupied, the marina really wants to know which boat occupies it. This is done today manually: marina employees go around the pontoons and check if the boat is moored on the slip indicated in the boat’s contract.

Therefore, we propose a boat identification algorithm that automatically recognizes which boat is at which slip. This algorithm does not require any additional hardware to be deployed inside the IoT network. Instead, we combine the data received from the Falco Presence and Falco Boat devices, in order to uniquely identify a boat once it enters the marina.

Automatic boat identification is highly beneficial to the marina managers. Having this information, they can know whether the boat is moored on a slip that is not indicated by the contract. Also, they are able to know if a small boat is moored on a big slip, and therefore have the maximum utilization of slips in the marina. Finally, marina managers can have the information about the number of times a boat entered/left the marina.

III. Hardware Setup

As we already mentioned in the Section I, the main advantage of the proposed boat identification algorithm is that it does not require additional hardware as long as the marina is equipped with Falco sensors. Specifically, the two devices that allow the boat identification are shown in Fig. 3. Apart from their primary functions to send, in real-time, the slip occupancy and boat parameters, we use additional data that these devices generate and feed them to our algorithm.

Falco Presence device is a low-power wireless sensor that is capable of detecting, in real-time, whether a slip is occupied. The slips inside the marina are uniquely identified by a Falco Presence device, with one device installed at each slip. The device is powered by a 3.6 V battery. It contains a radio module operating at 2.4 GHz and a boat detection sensor, all mounted inside an IP67 protected enclosure. In its normal operation, the sensor is able to detect a presence of a boat and report this information to the central gateway. However, this sensor is not able to identify exactly which boat is moored at the slip it monitors.

Falco Boat device monitors the state of a boat within the marina. Similar to Falco Presence, this device communicates wirelessly with other sensors inside the IoT network and sends the data to the cloud. Falco Boat is able to detect events such as fire, intrusion, tilt and shock. It also periodically measures the

Fig. 3. Commercial low-power wireless sensors for boat monitoring and boat presence detection: Falco Boat (left) and Falco Presence (right).

temperature and humidity and sends the data to the gateway. This device is powered with 3 V (2x standard AA batteries) and is easily mounted inside the boat’s cabin. It also operates at 2.4 GHz band, forming a mesh network with other Falco devices. Its MAC address can be used as a unique identifier of the boat, in which we install the device. Additionally, the IoT infrastructure inside the marina generates events when the Falco Boat joins or disconnects from the network. We use this information to determine whether the boat enters/leaves the marina network.

IV. Blip Algorithm

Boat identification happens each time a boat enters a marina. For the algorithm to work, the marina needs Falco Presence sensors to be installed on pontoons, and a Falco Boat sensor inside a boat we want to identify upon entering the marina. We process the data from the sensors and as a result, the algorithm outputs a slip where the boat is located. The Falco IoT network is a time-synchronized wireless sensor network, which is essential for the proposed system. Data generated by the Falco devices are timestamped, which allows us to easily combine the data from different sensors.

From the Falco Boat devices Blip uses the following data: health reports (hrs), join and lost events. The Falco Boat generates a health report every 22.5 min, when it is operational inside the marina network. This packet contains the list of neighbor devices from the network, which it can wirelessly sense. For each of the discovered devices, the health report contains the MAC address of the neighbor device and the Received Signal Strength Indicator (RSSI) of the frame received from that device. From this data, we only need the information regarding the Falco Presence devices in the vicinity of a boat. Therefore, Blip filters all the health reports generated from the Falco Boat device, keeping only the health reports that correspond to discovered Falco Presence devices. The join and lost events are generated by the marina network each time a Falco Boat device connects/disconnects from the network. We use this information to determine whether a certain boat enters the marina. If the boat enters the marina, the algorithm runs all the steps to identify the boat upon mooring at its slip.

From Falco Presence devices we collect: the GPS locations of Falco Presence and the presence events. Each slip inside the marina correspond to one Falco Presence device. During the installation of the Falco Presence devices, their GPS coordinates were recorded. The presence events are generated by the Falco Presence device each time it detects a change in the occupied/unoccupied state of the slip. Blip algorithm looks for all Falco Presence devices inside the marina that change state from unoccupied to occupied in a given time window. It uses this information to determine when a boat has entered (or left) some particular slip.

Finally, we select the appropriate presence time window as an input to the algorithm, in which we observe the state of the presence sensor events. In the selected time window, Blip looks for the slips that changed state from unoccupied to occupied. When the boat enters a marina, it needs time until it moors at its slip. As the boat navigates through the marina, its Falco Boat device can join the network before it docks, resulting in a presence event *after* the join event. On the other hand, Falco Boat can also join the network after the boat docks, which causes the presence event changing from unoccupied to occupied *before* the network join event. We therefore center the presence events time window at the Falco Boat's join event time. This means that the algorithm observes presence events half of the time window before and half of the time window after the join event time.

Algorithm 1 shows all the steps for the boat identification. The inputs of the algorithm are: health reports, join and lost events, presence events, slip locations and time window t. From join and lost events, we first check if the boat equipped with a Falco Boat device has entered the marina. If we find that a boat entered the marina, we take all presence events within a time window, centered at the join time of a Falco Boat device that entered marina. If there is only one Falco Presence that changed state to occupied we output the location of that sensor as a result. Otherwise, from the Falco Boat's hrs, we select the discovered Falco Presence devices with the highest RSSI and assign its slip location (latitude and longitude) to the boat. If there are presence sensors that change state from unoccupied to occupied in the given time window, we extract the list and calculate the distance between each presence sensor location and the slip location obtained from hrs. We compute the distance using Haversine or the great circle distance [13]. The distance between the two sensors d is calculated as follows:

$$d = 2r \arcsin \cdot \sqrt{\sin^2\left(\frac{(x1-y1)}{2}\right) + \cos(x1)\cos(y1)\sin^2\left(\frac{(x2-y2)}{2}\right)} \tag{1}$$

where r is the radius of the Earth and $(x1, x2)$ and $(y1, y2)$ are the latitude and the longitude of the two presence sensors, respectively. The result of the Blip algorithm is a slip with smallest d.

Algorithm 1: Blip

Input: hrs, join, lost, presence event, slip, t
Output: slip
1 Look for a **join** event from Falco Boat
2 Upon **join** check,
(I) **if** boat in **lost**, then boat entered marina.
(II) **else**, first **join**, go back to 1.
3 Get **presence events** in ((**join** - $t/2$) + (**join** + $t/2$)).
4 Get every **slip** location from 3.
5 **if** only 1 presence event **then** result $\rightarrow$ **slip** location
6 **else** from **hrs** get **slip** with $max(RSSI)$.
7 Calculate d between **slip** in 6 and each **slip** in 4.
8 Result $\rightarrow$ **slip** location from 4, where $min(d)$

V. Dataset

We implement Blip in Python and validate it on historical dataset from the Sète marina in the South of France. The dataset spans from 10-Aug-2021 to 30-Nov-2021, and contains all the data generated by all devices inside the Falco network. This marina is entirely equipped with Falco Presence sensors, installed on each of the 471 slips. In addition to the presence sensors, there are 8 boats that have a Falco Boat device installed in their cabins. Blip identifies the boats as they arrive in the marina and dock at a certain slip.

In our dataset, we found 34 events for 8 boats entering the marina. For each of these events, our implementation computes the slip it believes the boat just moored at. We obtain the ground truth from the contract that each boat has with the marina. A contract contains the information regarding a slip assigned to a boat, and conformation from the marina crew the boat indeed moors there. The goal of our validation is to ensure our algorithm locates the boat at the slip where we know it has moored.

VI. Results

Fig. 4 shows the number of successful boat identifications, depending on the time window in which we observe the state of Falco Presence sensors. With a narrow time window of 15 min, there are only 20 out of 34 successful boat identifications. This indicates that, in some cases, a boat docks before/after the join network time, outside of the selected time window. Therefore, we have 14 moorings without successful identification. On the other hand, if we select the time window that is too wide, we also have some unsuccessful identifications. In case of 105 and 120 min, there are 1 and 2 unsuccessful boat identifications, respectively. This is due to another presence event that happened on a slip located close to the slip where the boat is.

As our algorithm uses the RSSI readings from the presence sensors and assigns a boat to the slip with the highest RSSI, the algorithm reports an unsuccessful identification when two

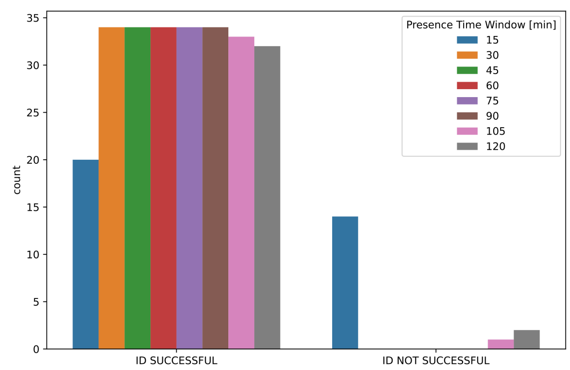

Fig. 4. Number of successful boat identifications depending on different presence event time window.

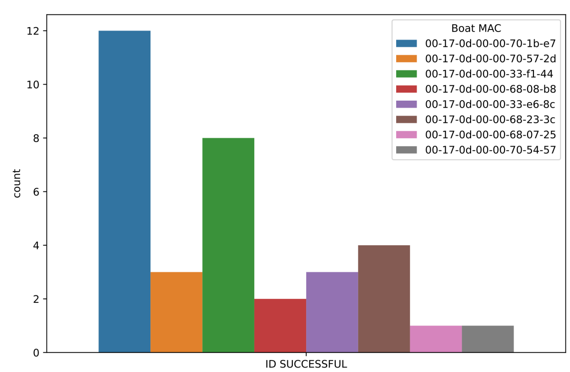

Fig. 5. Boat identification using 60 min presence event time window.

presence sensors are too close to each other. However, Blip ends up with two or more possible slips. Therefore, the algorithm is able to determine that this case occurred, and warn the marina, but it is then up to the marina to go on the pontoons and disambiguate.

As mentioned in Section IV, Falco Boat devices send a health report packet containing the MAC addresses and the RSSI readings of the discovered devices, every 22.5 minutes. Therefore, we select the presence event time window of 60 min. We look for a slip that changed state from unoccupied to occupied 30 min before/after Falco Boat joins the network. Using a 60 min presence event time window, the results show that Blip system is 100 % accurate, correctly identifying which boat is on which slip. Fig. 5 shows the number of successful identifications for 8 boats inside the Séte marina. Moreover, the number of successful boat identifications correspond to the number of times a certain boat left and entered the marina.

VII. Conclusion

In this paper we present Blip, a system for boat identification in a smart marina environment. Blip combines the data from wireless IoT sensors already deployed to determine which boat is located at each slip. We develop the system using the Falco IoT solutions for smart marinas. Our system only uses the existing IoT infrastructure inside the marina, thus introducing no additional costs and hardware complexity. Blip combines data from two types of sensors: Falco Presence deployed on pontoons for detecting a presence of a boat on a slip, and Falco Boat installed inside the boats for detecting events like intrusion, fire, tilt and shock. We validate our system on a historical dataset from 10-Aug-2021 to 30-Nov-2021, from the Séte marina in the South of France. The results show that the Blip system is 100 % accurate, successfully identifying 8 boats, 34 times upon their entry inside the marina.

References

[1] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash, "Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications," *IEEE Communications Surveys & Tutorials*, vol. 17, no. 4, pp. 2347–2376, 2015.

[2] L. Da Xu, W. He, and S. Li, "Internet of Things in Industries: A Survey," *IEEE Transactions on Industrial Informatics*, vol. 10, no. 4, pp. 2233–2243, 2014.

[3] F. Zafari, A. Gkelias, and K. K. Leung, "A Survey of Indoor Localization Systems and Technologies," *IEEE Communications Surveys & Tutorials*, vol. 21, no. 3, pp. 2568–2599, 2019.

[4] L. Mundula, M. Ladu, G. Balletto, and A. Milesi, "Smart Marinas. The Case of Metropolitan City of Cagliari," in *International Conference on Computational Science and Its Applications*. Springer, 2020, pp. 51–66.

[5] R. Krpetic, D. Oletic, and V. Bilas, "Wireless Sensor Network for Berth Supervision in Marinas," in *Sensors Applications Symposium (SAS)*. IEEE, 2012, pp. 1–5.

[6] F. Despaux, A. Van den Bossche, K. Jaffrès-Runser, and T. Val, "N-TWR: An Accurate Time-of-Flight-Based N-ary Ranging Protocol for Ultra-Wide Band," *Ad Hoc Networks*, vol. 79, pp. 1–19, 2018.

[7] E. E. Tsiropoulou, J. S. Baras, S. Papavassiliou, and S. Sinha, "RFID-based Smart Parking Management System," *Cyber-Physical Systems*, vol. 3, no. 1-4, pp. 22–41, 2017.

[8] S. N. Ghorpade, M. Zennaro, and B. S. Chaudhari, "GWO Model for Optimal Localization of IoT-enabled Sensor Nodes in Smart Parking Systems," *IEEE Transactions on Intelligent Transportation Systems*, vol. 22, no. 2, pp. 1217–1224, 2020.

[9] L. Mainetti, L. Palano, L. Patrono, M. L. Stefanizzi, and R. Vergallo, "Integration of RFID and WSN Technologies in a Smart Parking System," in *International Conference on Software, Telecommunications and Computer Networks (SoftCOM)*. IEEE, 2014, pp. 104–110.

[10] T. Lin, H. Rivano, and F. Le Mouël, "A Survey of Smart Parking Solutions," *IEEE Transactions on Intelligent Transportation Systems*, vol. 18, no. 12, pp. 3229–3253, 2017.

[11] T. Savić, X. Vilajosana, and T. Watteyne, "Constrained Localization: A Survey," *IEEE Access*, vol. 10, pp. 49 297–49 321, 2022.

[12] Falco, "Falco - Smart Marina solutions," 2023, (accessed 05 May 2023) https://wefalco.com/.

[13] H. Mahmoud and N. Akkari, "Shortest Path Calculation: a Comparative Study for Location-Based Recommender System," in *World Symposium on Computer Applications & Research (WSCAR)*. IEEE, 2016, pp. 1–5.