## **13.1 Driveway Parking Status Table**

|  |  |  |
| --- | --- | --- |
| **Timestamp** | **Time Offset** | **Parking Status** |
| 24/04/2025 23:38:06 | -3.28 seconds | occupied |
| 24/04/2025 23:38:09 | -3.28 seconds | occupied |
| 24/04/2025 23:38:13 | -3.07 seconds | occupied |
| 24/04/2025 23:38:16 | -3.28 seconds | occupied |
| 24/04/2025 23:38:19 | -3.20 seconds | occupied |
| 24/04/2025 23:38:22 | -3.35 seconds | occupied |
| 24/04/2025 23:38:26 | -3.17 seconds | occupied |
| 24/04/2025 23:38:29 | -3.38 seconds | occupied |
| 24/04/2025 23:38:32 | -3.07 seconds | occupied |
| 24/04/2025 23:38:35 | -3.26 seconds | occupied |
| 24/04/2025 23:38:38 | -3.25 seconds | occupied |
| 24/04/2025 23:38:42 | -3.32 seconds | occupied |
| 24/04/2025 23:38:45 | -3.17 seconds | occupied |
| 24/04/2025 23:38:48 | -3.29 seconds | occupied |
| 24/04/2025 23:38:51 | -3.21 seconds | occupied |
| 24/04/2025 23:38:55 | -3.25 seconds | occupied |
| 24/04/2025 23:38:58 | -3.47 seconds | occupied |
| 24/04/2025 23:39:01 | -3.28 seconds | empty |
| 24/04/2025 23:39:05 | -3.15 seconds | empty |
| 24/04/2025 23:39:08 | -3.41 seconds | empty |
| 24/04/2025 23:39:11 | -3.28 seconds | empty |
| 24/04/2025 23:39:14 | -3.29 seconds | empty |
| 24/04/2025 23:39:18 | -3.27 seconds | empty |
| 24/04/2025 23:39:21 | -3.27 seconds | empty |
| 24/04/2025 23:39:24 | -3.22 seconds | empty |
| 24/04/2025 23:39:28 | -3.31 seconds | empty |
| 24/04/2025 23:39:31 | -3.29 seconds | empty |
| 24/04/2025 23:39:34 | -3.29 seconds | empty |
| 24/04/2025 23:39:37 | -3.28 seconds | empty |
| 24/04/2025 23:39:41 | -3.38 seconds | empty |
| 24/04/2025 23:39:44 | -3.28 seconds | empty |
| 24/04/2025 23:43:28 | -3.18 seconds | empty |

Figure 31

The driveway parking data I collected with my vehicle indicates a clear transition between **occupied** and **empty** states. The vehicle was detected as **occupying the parking space** from approximately **23:38:06 to 23:39:01** on **24/04/2025**, consistently returning “occupied” messages during this period. After **23:39:01(Highlighted in yellow)**, the system began returning “empty” ({}) messages, indicating the vehicle had left the sensor’s detection range and was no longer parked. The messages continued to show an empty status with consistent time intervals, confirming the reliability and responsiveness of the ultrasonic sensor and MQTT communication over Wi-Fi during the test.

**14. Larger scale car park (Generative AI)**

The data presented in Figure 29*,* demonstrates the core functionality and effectiveness of my smart parking device, which was tested on my private residential driveway using my vehicle. Throughout the testing process, MQTT communication was used to reliably publish the status of the parking space, clearly indicating whether the space was **occupied** or **empty** based on real-time sensor readings from an ultrasonic sensor. These messages provided a simple way to track vehicle presence, enabling practical applications such as **enhanced security** by alerting the user when an unexpected vehicle is detected, and **convenient monitoring** of parking availability for the vehicle owner.

To better visualize the potential impact of this system beyond a single use case, I expanded the original data using **generative AI** to simulate a larger-scale car park as seen in Figure 31. This simulation used the same MQTT message patterns observed in the driveway test, extrapolating them across multiple parking bays to mimic the functionality of a smart car park. Each bay in this generated model will be operated similarly to the tested device, continuously publishing occupancy updates to an MQTT broker hosted on **HiveMQ Cloud**.

This approach highlights a key advantage of the system which is **scalability**. By replicating the original device’s behaviour across multiple bays, it becomes clear how a network of smart parking sensors could function together to monitor multiple vehicles simultaneously in real-time. With HiveMQ Cloud providing a reliable and scalable MQTT infrastructure, this system can handle a larger volume of messages without a drop in performance, making it suitable for use in **residential complexes, commercial car parks, or smart city environments**.

Furthermore, the use of timestamped MQTT messages ensures accurate logging and support of advanced features like parking analytics, anomaly detection, or automated notifications. This proves that even a simple prototype can be extended into a fully functional smart parking network with minimal changes in architecture, emphasizing the feasibility and adaptability of the solution.

### **14. 1 Simulated Car Park Data (Scaled from Driveway Test)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Time (HH:MM:SS)** | **Bay A1** | **Bay A2** | **Bay A3** | **Bay A4** | **Bay A5** |
| 23:38:06 | Occupied | Occupied | Empty | Empty | Occupied |
| 23:38:09 | Occupied | Occupied | Empty | Occupied | Occupied |
| 23:38:13 | Occupied | Empty | Occupied | Occupied | Occupied |
| 23:38:16 | Occupied | Empty | Occupied | Occupied | Empty |
| 23:38:19 | Occupied | Occupied | Occupied | Empty | Empty |
| 23:38:22 | Occupied | Occupied | Empty | Empty | Occupied |
| 23:38:26 | Occupied | Occupied | Empty | Occupied | Occupied |
| 23:38:29 | Occupied | Empty | Empty | Occupied | Occupied |
| 23:38:32 | Occupied | Empty | Empty | Empty | Occupied |
| 23:38:35 | Occupied | Empty | Empty | Empty | Empty |
| 23:38:38 | Occupied | Empty | Empty | Empty | Empty |
| 23:38:42 | Occupied | Empty | Empty | Empty | Empty |
| 23:38:45 | Occupied | Empty | Empty | Empty | Empty |
| 23:38:48 | Occupied | Empty | Empty | Empty | Empty |
| 23:38:51 | Occupied | Empty | Empty | Empty | Empty |
| 23:38:55 | Occupied | Empty | Empty | Empty | Empty |
| 23:38:58 | Occupied | Empty | Empty | Empty | Empty |
| 23:39:01 | Empty | Empty | Empty | Empty | Empty |
| 23:39:05 | Empty | Empty | Empty | Empty | Empty |
| 23:39:08 | Empty | Empty | Empty | Empty | Empty |

Figure 32

The AI-generated data simulates a larger, multi-bay car park consisting of 10 parking spaces monitored over a similar timeframe. This extended dataset reflected a more dynamic environment, with different bays being occupied and vacated. It illustrated the potential of the system to handle multiple devices publishing MQTT messages concurrently to the HiveMQ broker cluster which adopts multiple devices with ease with no delay or data loss. Compared to the single-bay driveway test conducted on my driveway, the simulated scenario demonstrated how the same architecture could scale effectively, providing real-time monitoring across a larger infrastructure. This comparison reinforces the versatility and scalability of the smart parking system when expanded to commercial or urban environments.