WHITE PAPER

Tag tracking

nextome

INDEX

Introduction

This document aims at providing an overview of the Nextome proprietary technology in applications and contexts that aim at localizing people and/or objects.
The localization is done by means of Bluetooth® devices, that are usually referred to as Tags.
The present document clarifies and explains how the technology works.
It will present and analyse all the involved components as well as their functionalities.
Moreover, the technology will be described in terms of main functional specifications, and deployment process/procedures.

The present document will also present the Tag Tracking and the Hybrid Tag Tracking systems. It will focus on the **Tag Tracking Systems**, explaining its value proposition for the customers. Specific reference will be done to the calculation of the position of one (or more) tag(s) and the ability of the system to monitor movements in a reference area. Some of the peculiarities of the Tag Tracking System will also be clarified and compared with Hybrid Tag Tracking solutions.
With the aim of clarifying the advantages of implementing Nextome Tag tracking System, the document will explain the deployment of the system to apply the Tag Tracking technology to the management of gates, such as for example the crossing of doors or corridors that separate rooms with a different destination of use.
This technology can also be applied to all the use cases in which the main aim is to detect proximity condition between the object/person and a specific point of interest.
The document closes with an examination of employment prospects and research and development guidelines.

All details and technical specifications in this document are confidential and subject of international patent applications. Any information contained in this document shall not be disclosed without Nextome prior consent.

The Technology

Reference Architecture

The reference technology aims at **calculating the position of a target tag** (namely, Beacon target), which can be placed on an object or associated with a person. The tags are characterized by ease of use and installation since are now available in the market in the form of wearable tags such as, bracelets, pins, and many more.

The architecture of the technology consists of the following elements:

- **The Target Beacon.**
- **A series of independent Bluetooth® antennas referred to as Gateways and equipped with current wiring and connection to the network.**
- **The Nextome Location Engine.**

The Beacon Target transmits a Bluetooth® signal which is **detected by the Gateways** installed in the monitored area (i.e. buildings, parking lots)
In ***Figure 1***, an overview of the architecture showing how the positioning and tracking procedures require a server to process the signal received and calculate the positions of the Beacon Target.

The signal detection phase consists of the **synchronization of the signals** detected by the set of antennas deployed in the environment, as well as the **reduction of the multipath effects**. Then, the processed detections are converted to distances which are used to calculate the final position of the tag. This procedure is based on the known positions of the Gateways which are considered reference points, namely anchors. Moreover, the antennas must be registered in the system and characterized by their position on the map during the installation phase, which will be discussed later on in the present document.

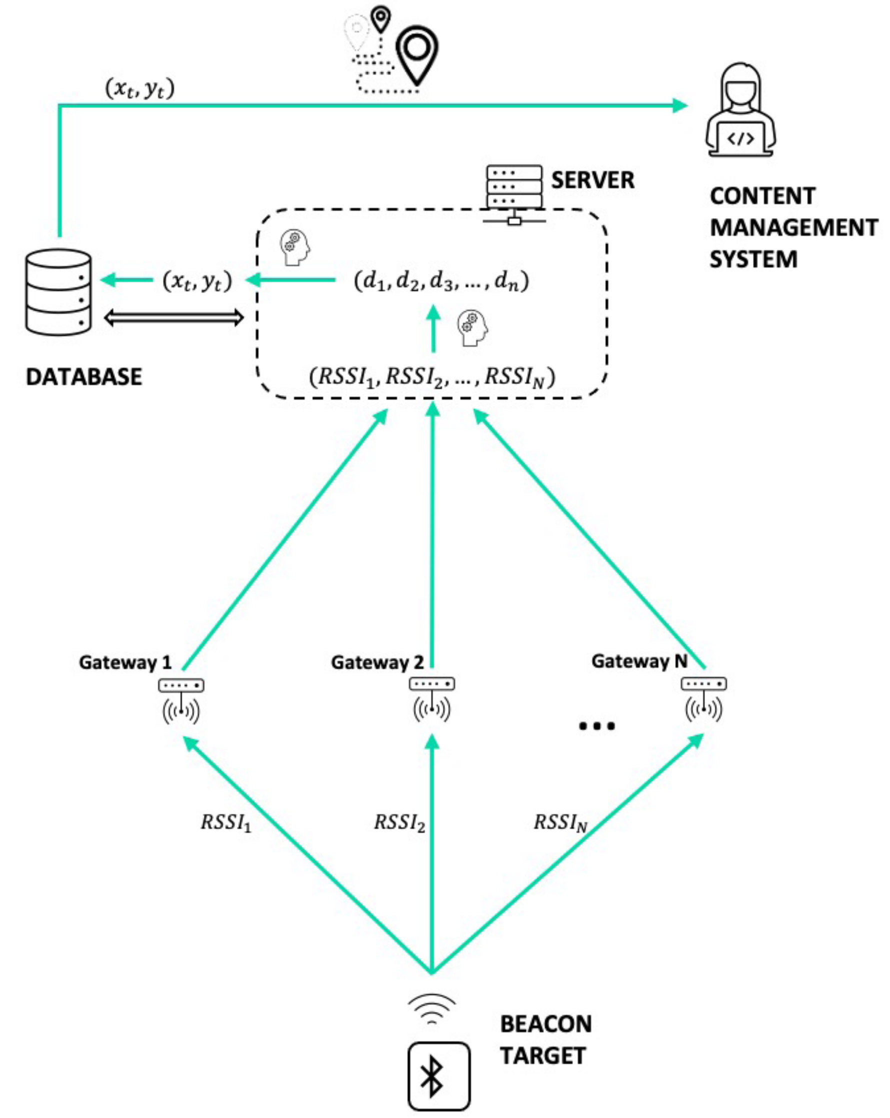

Figure 1: *Overview of the reference architecture.*

The number of Gateways to be installed in the operating environment strongly depends on the operational requirements. In particular, the level of positioning accuracy and the update frequency may vary in a sensibly according to the peculiarities of the deployment. Generally speaking, the more accurate and precise the position, the bigger the infrastructure (in terms of number of Gateways).
This holds true in scenarios where objects are free to move all around the place and are typically not bonded to pre-defined/confined paths.

For all the applications where high positioning accuracy and frequent position updates are not required, only a limited number of gateways are required. This is also true for all the applications where objects/people follow pre-established routes.
The number of installed Gateways can be lowered under the following conditions:

- **Passages approach**, which consists in installing the Gateways only in strategic points to achieve proximity to a gate or tracking position at room level.
- **Hybrid tag tracking**, which consists in exploiting the people present in the structure equipped with the N2M localization app on their smartphone as detector gateways.

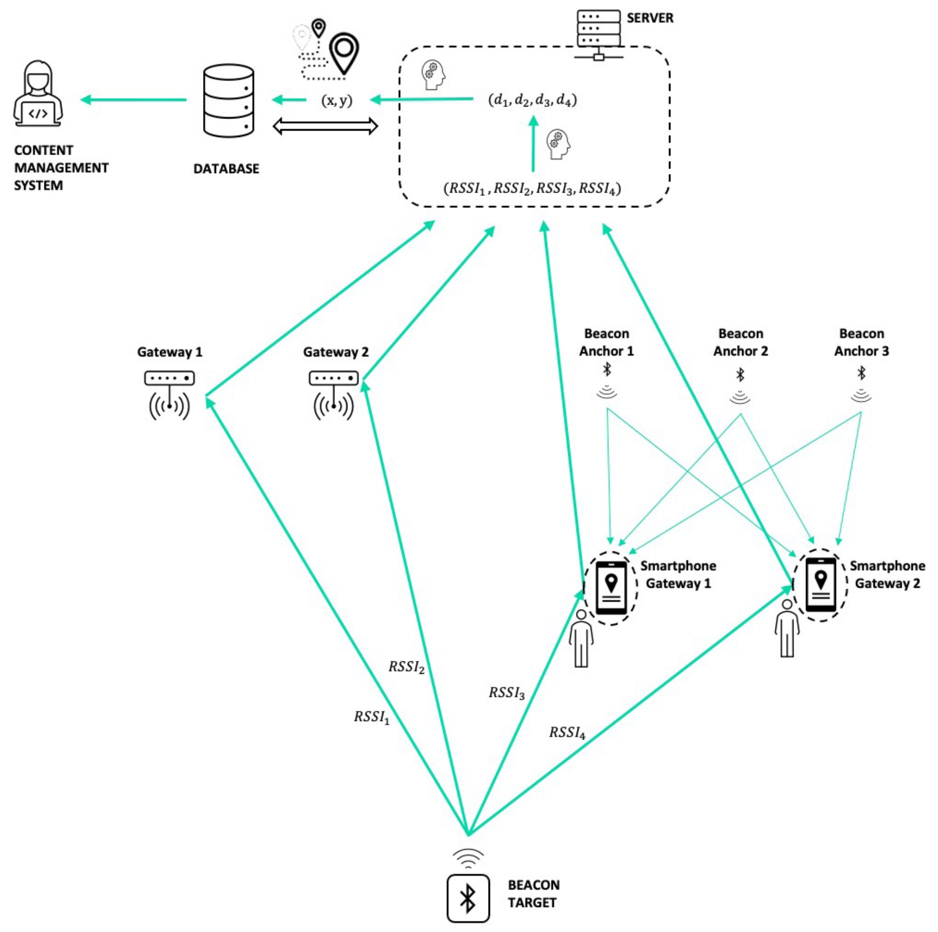

Figure 2: *Overview of the hybrid architecture.*

Hybrid tag tracking is based on the merge of the two technologies 'tag tracking via Gateway' and 'smartphone tracking via mobile application and Beacon anchors'. ***Figure 2*** shows that the localization process can be carried out by the infrastructure in three ways: (i) locating the target Beacon through the smartphones of the people that are in the reference scenario, (ii) using the Gateways, or (iii) relying on both the Gateways and the smartphones. It must be noted that smartphones act as scanners and are enabled to detect the Beacon Target. At the same time, any smartphone that is executing the Nextome application can take part in the localization process when close to a Beacon Target to be located since it:

- **Scan the signals transmitted by the Beacon anchors installed on the ceiling, with the purpose of self-locating the smartphone.**
- **Scan the signals transmitted by the Beacon target to be located.**

Through these two activities, smartphones can act as Gateways.
Now on, smartphones with such tasks/role will be referred to by the term Smartphone Gateway.

A focus on hardware

One of the advantages of Nextome technology is that it is **standard-compliant** and is **not vendor-dependent**. Therefore, the system can be deployed and set up with Bluetooth® devices (namely Beacons) that are compliant with Bluetooth® Low Energy (BLE), from v4.1. According to the reference market, we are currently employing Beacon from Blueup, the BlueBeacon Maxi, or similar.
The choice is motivated by the standard compliance of the devices. They work in the ISM 2.4 GHz band, between 2.402 and 2.480 GHz, and they integrate a Nordic nRF51822 radio transceiver with a System on Chip (SoC) form factor.
One of the most interesting features that motivated the preference, among the competitors, is battery lifetime. Nextome technology aims at creating a long-lasting and reliable deployment for our partners, so enhancing battery lifespan is a goal being continuously refined. The referenced Beacons are supplied by 2xAA LR6 alkaline (2800 mAh capacity @ 25°C) batteries. On these bases, a dedicated fine-tuning of parameters setting (e.g., advertising interval, TX Power) can prologue battery lifetime from a minimum of 9-10 months up to 3 years.

To complete the asset tracking experimental setup, Beacons must be detected and, hence, tracked. This functionality is granted by means of dedicated pieces of equipment that are referred to as Gateways. An Asset tracking **gateway** is a processing unit that continuously scans the reference environment, detects the presence of **Beacons**, and sends them to our servers for any further use, such as elaborating data, filtering outliers, if any, and calculating/storing positions.

According to the required specification, Nextome technology can be used to create a hybrid-tracking setup. In this case, smartphones play a pivotal role in the position calculation procedure. It is, hence, mandatory to use a BLE-compliant smartphone device that must be enhanced with a dedicated app, currently available for both Android and iOS.

The elaborating platform

The elaborating platform that implements the Tag Tracking system is mainly composed of:

- the **Mobile SDK**, which detects the Bluetooth® signals and uses them to calculate smartphones' position. The results can be shown on the screen or stored in the database. It can be integrated into third-party applications. For tag localization purposes, the SDK is only involved in the case of using hybrid localization.
- **CMS Server**, which allows the interaction between smartphones and the database and enables the configuration of environment settings via the web portal.
- **Database**, houses information such as the map table, the reference anchor table, the reference Gateway table, the tag to be located, and the map subsection table (for example, single rooms).
- **Computing service**, which calculates the positions of the Beacons target installed on the objects or people to be located.

A focus on algorithms

The Nextome algorithm inside the computing service is the fusion of different patented and patent-pending technologies created by Nextome research.

The localization algorithm (in the green block in the ***Figure 3***) includes the following proprietary keys of innovation:

1. Data processing is not separate for each gateway, but is managed globally through the **processing of a matrix** that contains all the information relating to each gateway.
2. The innovative **non-linear filtering technique** of the Receive Signal Strength Indicator (RSSI) limits the "multipath fading effect" by removing the non-linear noise caused by Bluetooth® signals bouncing on the walls, floor, furniture, and people moving around. In this way, it is possible to calculate the right location by using an advanced machine-learning approach relying only on the true signals. This algorithm solves the theoretical problem in Non-Line of Sight (NLoS) condition.
   The true signal is extracted by exploding the noisy signal in (theoretically) infinite dimensions and capturing only those dimensions that behave better in capturing the true signal, lowering noise.
3. The calculation of the coordinates of the target point is, hence, reduced to the resolution of a weighted problem of **non-linear least-squares optimization**, which derives from multilateration techniques in place of fingerprinting.
4. **Particle filtering approach** together with map constraints; in this way, the user will never be positioned in an unreachable zone and whatever error will be automatically corrected while the user is walking.

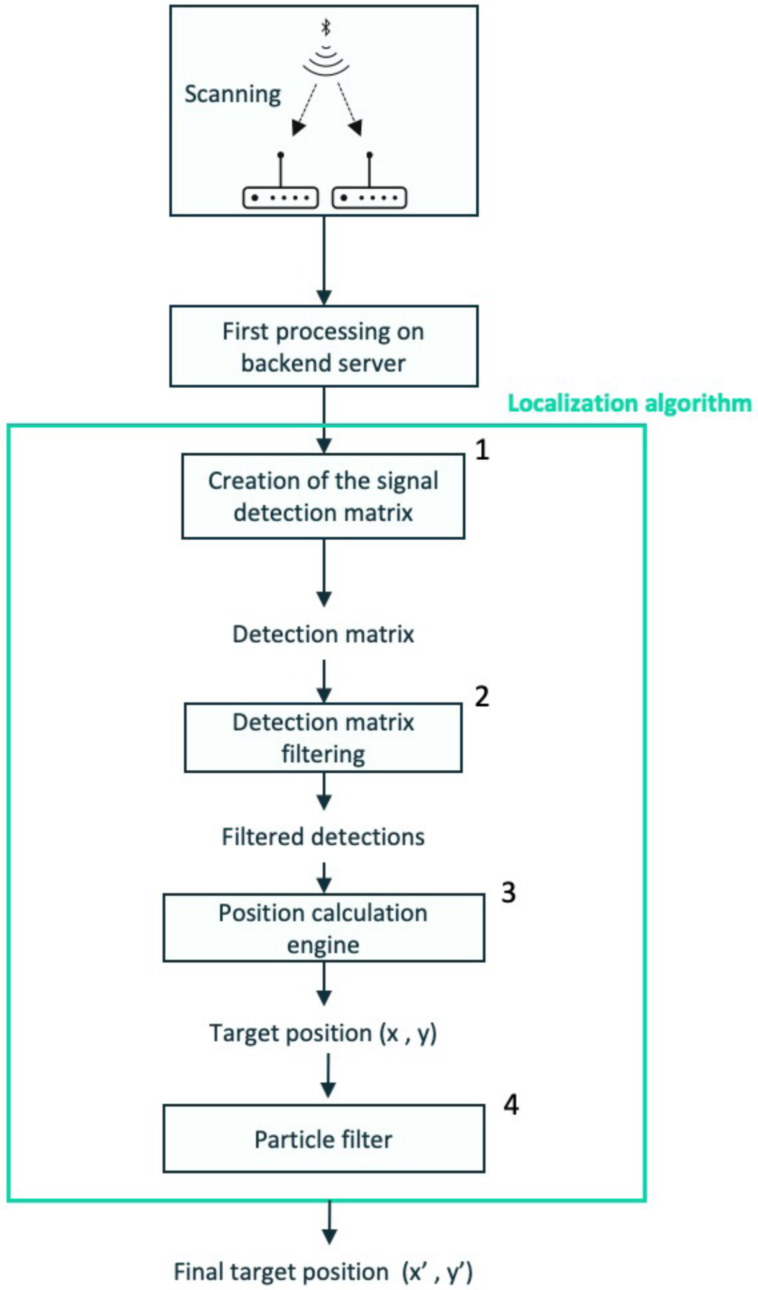

***Figure 3:** Algorithm schema.*

Output

Nextome technology can be used by combining the following 3 modes:

- **Real-time mode, which only allows live positioning data to be viewed or retrieved via API.**
- **Data storage mode, which allows to retrieve the position of the tag for a period of time defined in advance.**
- **Data analytics mode, which activates procedures that process data daily to calculate KPIs and analytics that can be consulted through dedicated dashboards.**

Focus on Real-time mode

In the real-time mode, the following features are allowed:

- **Display the position** on the map (e.g., ***Figure 4***) of the floor of the structure; the floor and the structure are automatically detected by the technology.
- **Coordinates (x, y)** of the position.
- **Association of the calculated position to a specific section of the map**. The sections must be defined in advance and registered in the system. The sections can correspond to physical rooms within the structure or to fictitious areas, functionally defined by the user.
- **Notification when a tag enters/exits in/from certain areas**. The areas must be defined in advance. The entry and exit from controlled areas are called 'event'.

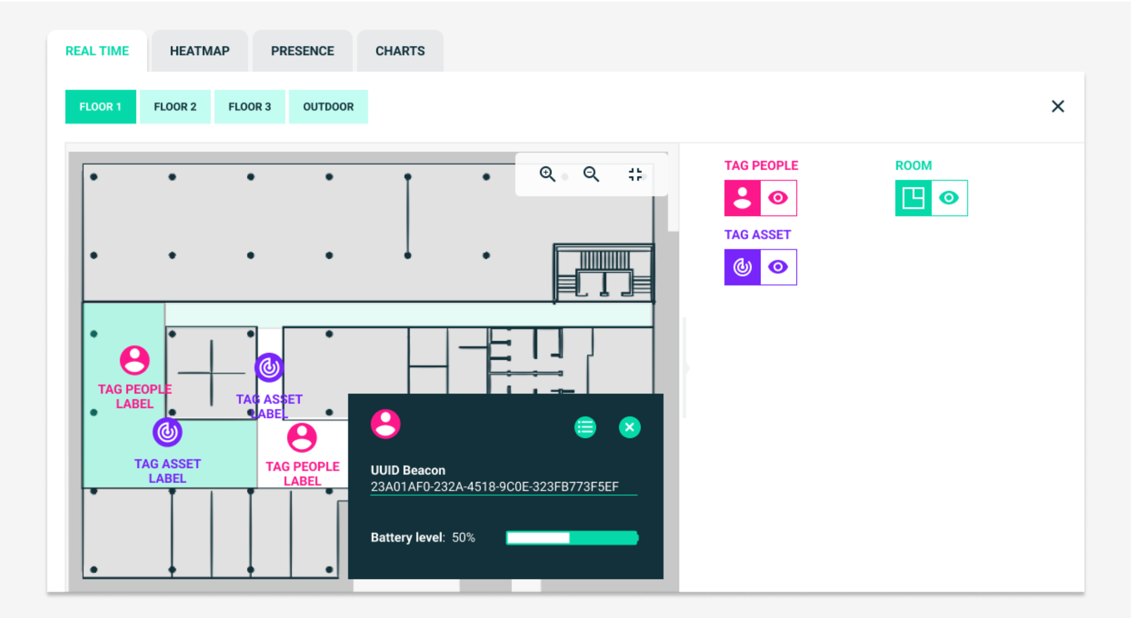

Figure 4: *Real-time mode view.*

Focus on data analytics mode

In case data analytics mode is enabled, it will be possible to take advantage of intelligent business services to obtain useful information, starting from raw data and supported by **Decision Support System** (DSS) services. The platform can be used in the analysis of phenomena that relate to the tracking of tags (tag tracking) and of smartphones. This document focuses on the first one, in which the object of the survey is the beacon target moving within the scenario.

All beacons target in the area transmit data that are collected and elaborated by different systems depending on the case. In the case of standard 'tag tracking' the detections are collected by Gateway, in the case of 'hybrid tag tracking' the detections could be collected by smartphone too, in any case, the data of interest is the position of the tag. As previously clarified, in addition to the position in coordinates (x, y) it is possible to know the room where tags are located.
The detection scanning and calculation of positions are followed by the **storage** of the latter within a dedicated server that communicates with a database to store and historicize information.

The following step is called **ETL**, which stands for Extract, Transform, and Load. These three distinct phases constitute the data processing process that will allow future analyses. In particular, the first operation refers to data extraction from the storage source. In this case, the data source is single and is represented by the database, as shown in ***Figure 5***.

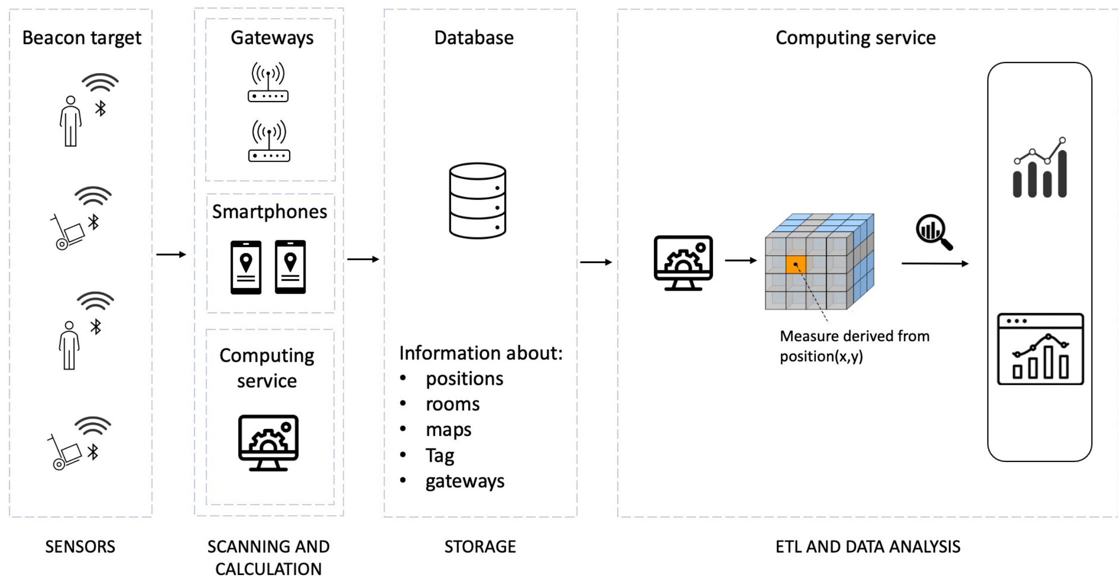

Figure 5: *Business intelligence flow.*

The purpose of the transformation phase is to ensure that data have a homogeneous structure, but also to perform calculations on the starting data to obtain new information. For example, the case in which it is not needed to carry out an analysis on the length of the path taken by a person. In this context, a list of positions may not be sufficient, as it could be useful to subdivide the path and create a list of lengths. After transforming the data and obtaining all the information necessary for future analyses, the following phase is loading the data within structured objects, such as a star diagram or a multidimensional cube in more complex cases.
Once data are structured, complex analysis can be conducted by adopting analytics tools that make it possible to visualize data in various forms, such as, for example, analysis of (**Key Performance Indicators**), historicizations, and **trends**.

To provide a compact representation of the structure of the data, the multidimensional model is reported in ***Figure 6***, where the main analysis dimensions are:

- **Time.**
- **The tag.**
- **The subdivision of space (maps, plans, rooms).**

The measures are derivatives of the position such as:

- **The number of minutes spent in a given area.**
- **Meters traveled.**
- **The number of tag present.**
- **Average residence time.**

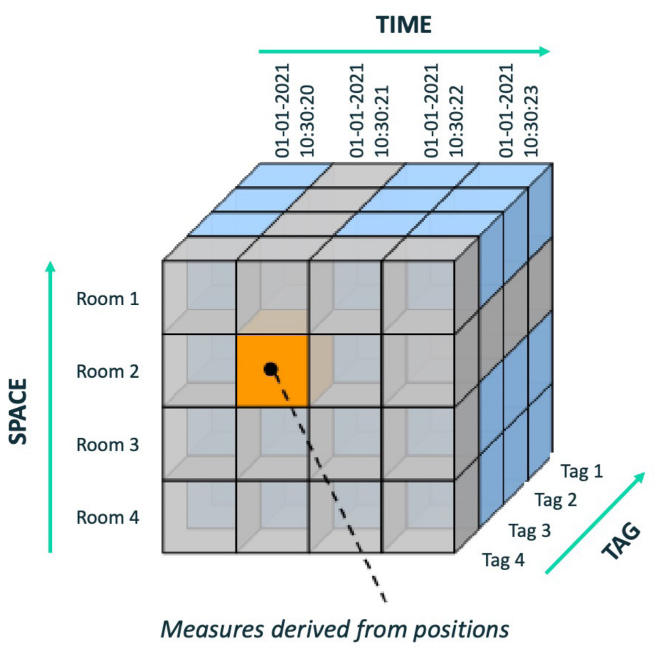

Figure 6: *Multidimensional cube.*

The measures are already available but can be customized according to specific needs and/or application peculiarities.

After choosing the measures of interest and the display methods, as well as the level of interactions with the end user, it is possible to take advantage of dashboards that support the user in strategic decisions or in monitoring situations of interest.

The following figures show some examples of views present in the dashboards.

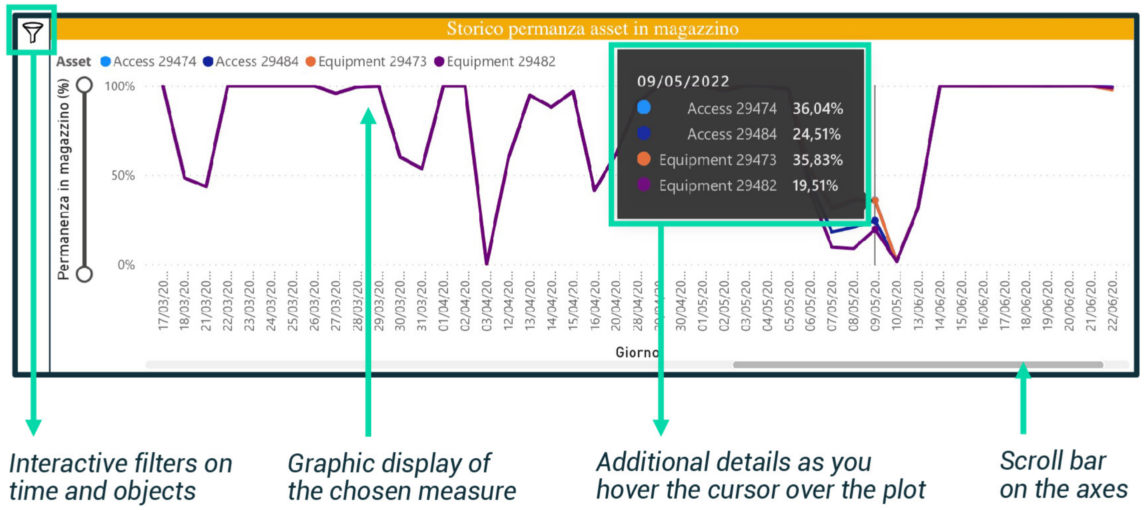

Figure 7: *Graph representing the percentage of time spent in the warehouse by the different assets.*

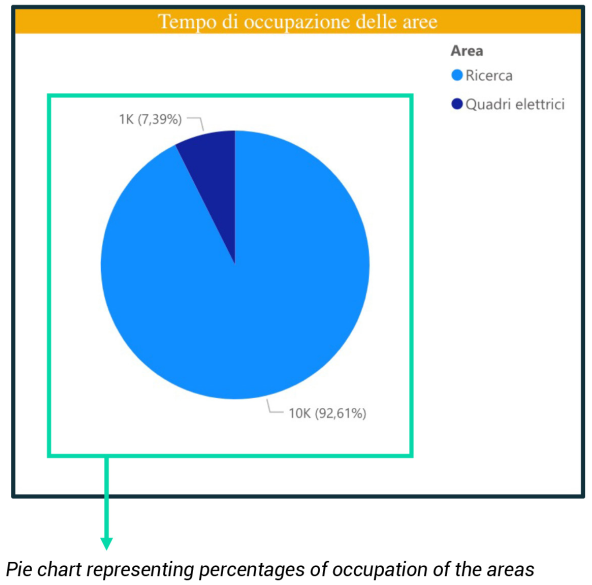

Figure 8: *Pie chart representing percentages of occupation of the areas.*

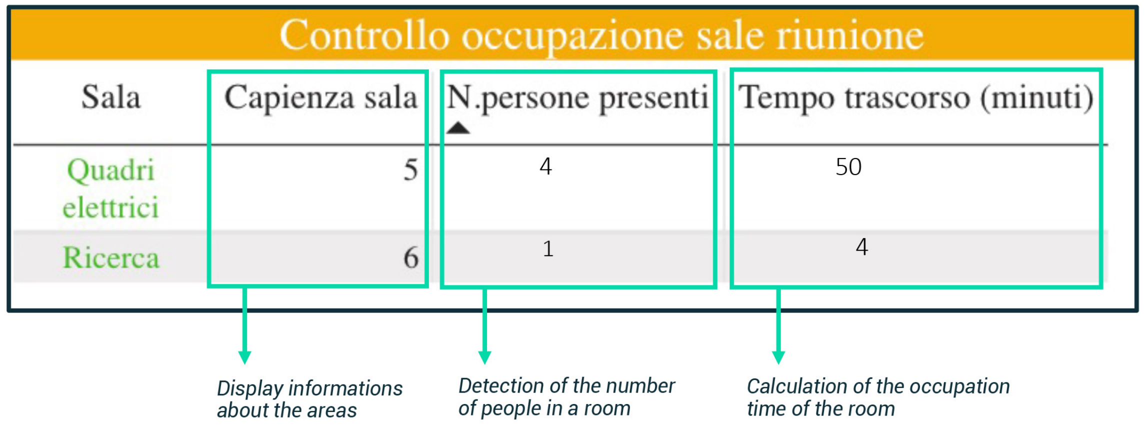

***Figure 9:** Table used to control the occupancy of the meeting rooms.*

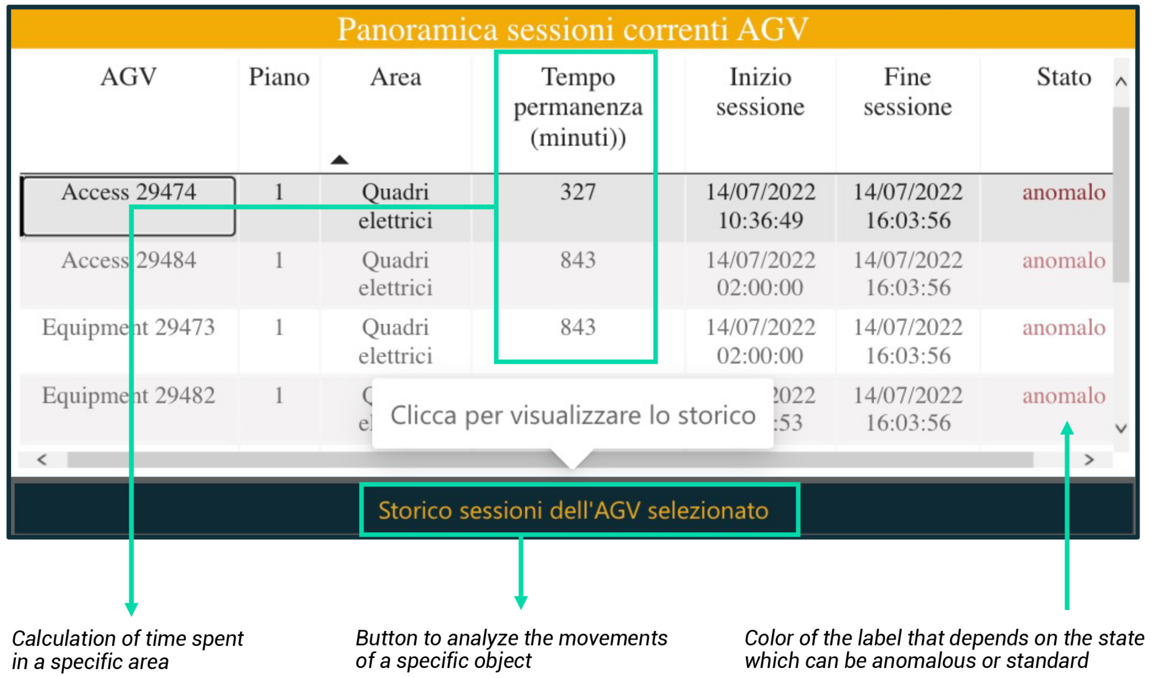

***Figure 10:** Table used to check the status of Automated Guided Vehicle in motion.*

Considerations on installation

The localization algorithm is based on the positions of the gateways. Therefore, a preliminary step for the deployment is the coverage analysis of the reference area. This includes the evaluation of the number of gateways to be deployed in the area, together with the decision on the suitable positions.
Nextome covers this phase by paying attention to the peculiarities of the venue and evaluating radiofrequency signals propagation to grant an effective multilateration, according to the involved algorithms. At the end of this phase, Nextome suggests the **gateways' density and positions**. These parameters **vary according to the geometry of the structure, the division into rooms, the type of walls, and the desired accuracy**, but the average density is about 50 square meters.

It is of utmost importance to register the gateway in the right positions and to make the registration phase as simple as possible to reduce errors and installation time. To this aim, Nextome has developed a dedicated feature within its web app, which is a useful aid for positioning the gateways inside the map. An intermediate result of this procedure is shown in the following ***Figure***. The map used in the web app is standardized, digitized and loaded into the system by Nextome in the preliminary phase of installation.

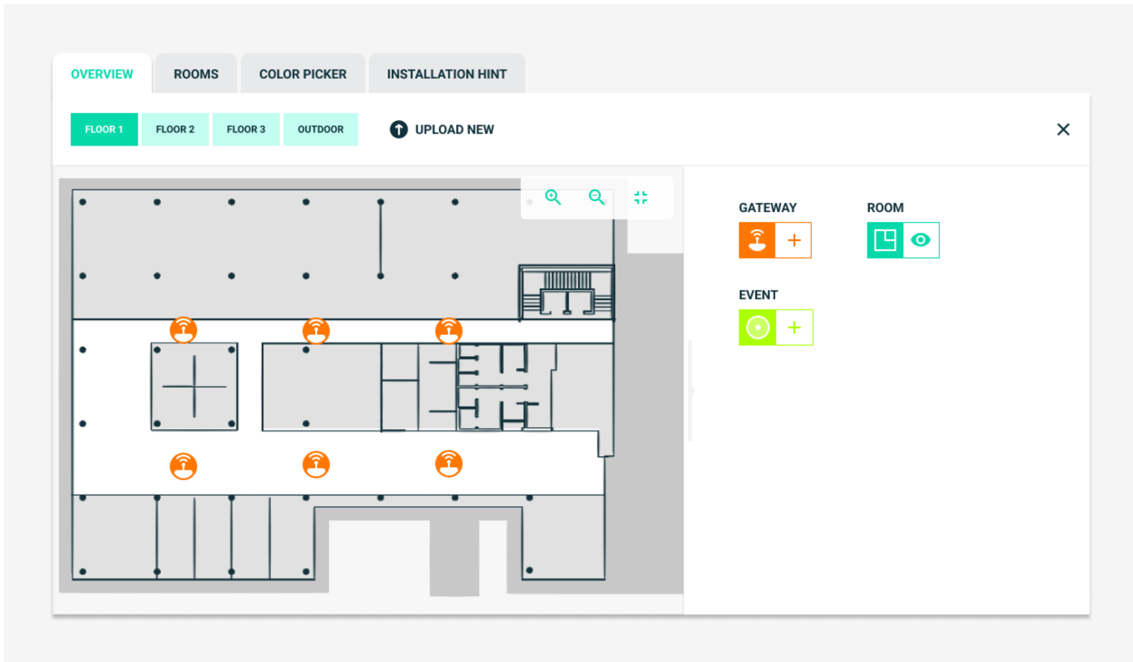

***Figure 11:** Registration of gateway's positions on the web app.*

Once a **Gateway** has been configurated (Wi-Fi interface/ connection), it **must be powered and installed in the right position preferably at a height of 3 m** (if the ceiling is lower, please consider placing it at the highest possible position).

Figure 12 provides an installation examples.

Figure 12: Example of ceiling installation.

When all the Gateways have been installed and set on the map, each Beacon target to be located must be registered as well on the system through the web app to enable tag tracking.
Now, the system is configured and ready to calculate the position of the tags (target beacons).
Dedicated functionalities are available in the web app for each user who wants to add useful information, such as the subdivision of the area into rooms to analyze the data from a particular point of view, or enable notifications or counters at entry/exit from certain areas.
The figure that follows shows an example of how the room can be created. From saving the room onwards, whenever the tag is located in that area it will be associated with that green room.

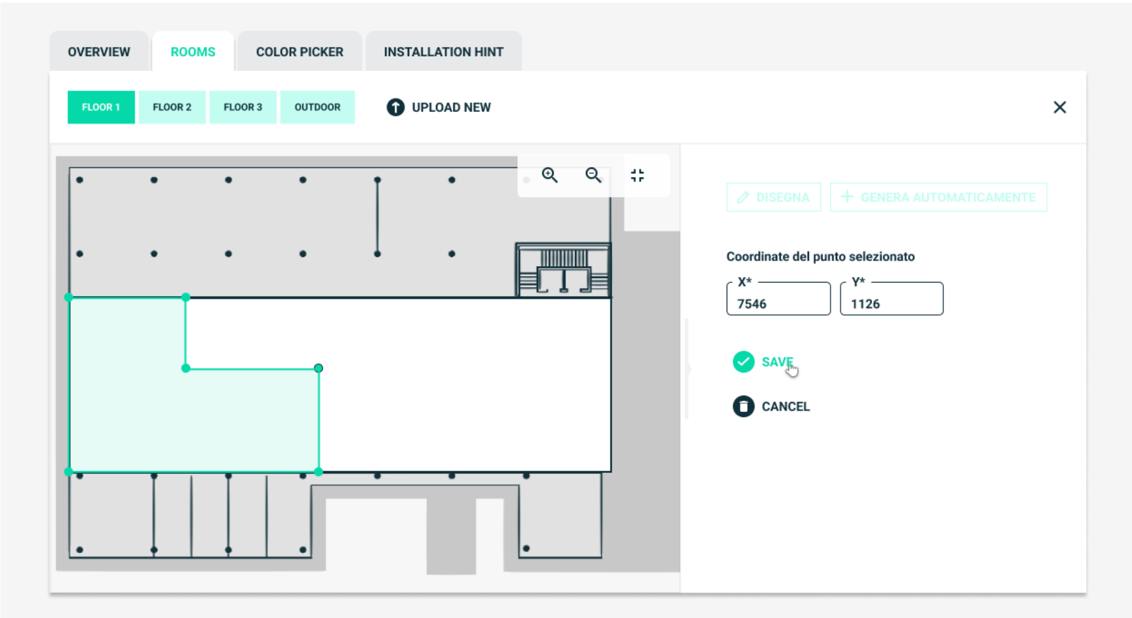

Figure 13: Room creation in the web app.

Future work directions

The tag tracking and the hybrid tag tracking systems are currently considered enabling verticals in the Research and Development sector of the Nextome company.

In the upcoming months, the company **will continue to improve its level of performance both in terms of precision and accuracy of the detected position**. This will make the calculation more efficient and the position more stable and accurate.

From the point of view of data collection, aggregation, and processing, Nextome is working on advanced and sophisticated interconnection systems which will soon see more adaptable and scalable architectural solutions.

Research is currently also highly concentrated on the strategic objective of improving data filtering and analysis systems. Among the most awaited and certainly most promising features, however, there is full support for **Direction Finding** (DF) techniques which involve the use of **Angle of Arrival** (AoA) and Angle of Departure (AoD) to obtain an even more accurate localization and in **3-dimensional space**.

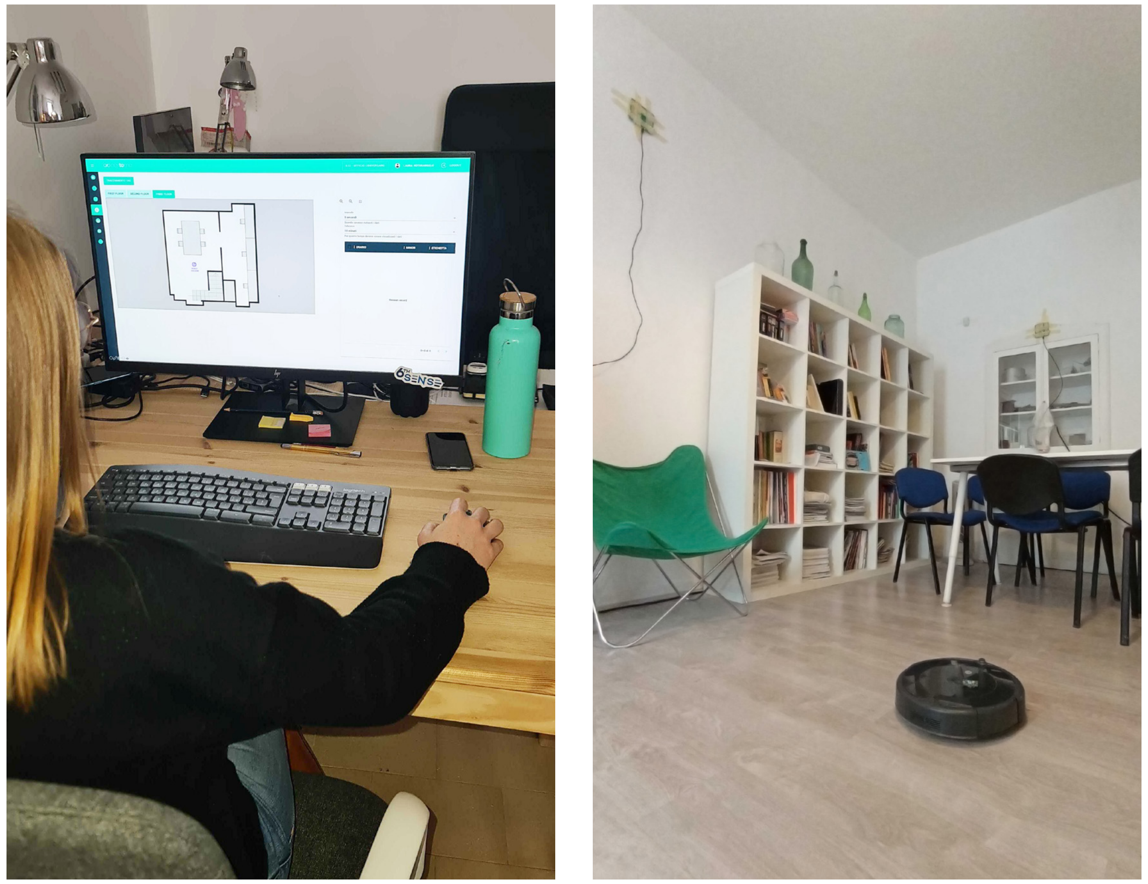

Figure 14-15: Tag tracking based on angle of arrival.

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