Locating Technologies reimagined

Introducing omlox
the open locating standard

omlox

Contents

Foreword from PROFIBUS and PROFINET International – PI

Interoperability –

that is the key theme of our industry association, that is enabling how devices on communicate on the shop floor since more than three decades. But the industrial ecosystem has changed quite a lot since the early days of Industrie 4.0[1]. The level of automation is rising, humans co-work with robots, AI-driven solutions appear and production lines dissolve into flexible matrix productions to cope with volatile demands.

Dr. Matthias Jöst – Committee leader omlox at PROFIBUS and PROFINET – PI

In a dynamic and highly mobile world, Interoperability is nowadays not only about communication anymore but also sharing the location of industrial assets to allow for a more efficient material flow, optimized asset utilization, reduced energy, and space consumption and much more.

The technology group omlox, within our association defines an open locating standard that allows for a seamless, vendor- and technology-independent locating of any industrial asset.

Initiated in 2018, the standard is now supported by members and contributors around the globe, covers all locating technologies and is getting adopted not only in industry and logistics but all other industries as well – from healthcare to smart building, semi-conductor to mining or construction.

This document will give an overview about omlox and guide industry companies on the journey, using location-data to drive their operations and automation to new heights.

[1] Industrie 4.0 refers to the increasing digitalization and automation of production technology. The term was originally introduced in Germany and is also recognized internationally in its German form.

Foreword by Fraunhofer IOSB-INA

"Position yourself for the future."

This statement is to be understood in several ways: In the context of industrial application, this means setting the necessary course for companies towards sustainability and success. Additionally, the term "position" indicates a new means of achieving this goal by utilizing locating technologies.

Besides many exciting data-driven innovations, the success story of Industrie 4.0 has led to the emergence of highly dynamic and flexible production and logistic processes. With their own set of opportunities and challenges, these constantly changing processes can make it increasingly difficult to answer the question of "Where?". Locating technologies can provide an answer to that question as well as laying a foundation for automation and process optimization by creating transparency and eliminating the need to search.

While many non-standardized locating solutions can solve the abovementioned challenges, they are often not very attractive for small and medium-sized enterprises (SMEs) due to their proprietary nature, resulting in little flexibility and potentially high risk. In contrast, standardized technology leads to broader acceptance and easier access. This principle of Industrie 4.0 has been proven many times in the past (e.g. OPC UA). omlox as an open locating standard makes use of this by following a vendor and technology independent approach which allows for interoperability and thus more flexibility. By embracing omlox, companies can effectively future-proof their operations, ensuring they remain competitive in an ever-evolving technological landscape. This forward-thinking approach will not only streamline current processes but also unlock new possibilities for innovation and efficiency gains.

Due to its novelty, companies may not be familiar with omlox. For this reason, this guideline aims to introduce the topic and includes a checklist to assess the state and demand of locating technologies. omlox offers a lot of potential for process optimization and industrial application. I hope that this guideline will encourage companies to position themselves for successful use of locating technologies.

Prof. Dr.-Ing. Jürgen Jasperneite
Director of Fraunhofer IOSB-INA

Management Summary

The integration of real-time locating systems (RTLS) is enabling efficiency in the industrial sector by addressing challenges such as labor shortages and disrupted supply chains. This is achieved by facilitating the automation of asset, resource, and product tracking and management. RTLS is creating significant value by enhancing transparency, optimizing asset utilization, and automating process chains, leading to cost savings and improvements in quality. Locating data is essential for operations automation, maintenance, and material flow, enabling advanced applications such as augmented reality navigation and autonomous vehicle coordination. It serves as a bridge between the digital and physical worlds. The technological landscape of locating solutions is diverse, ranging from global outdoor positioning systems to specialized indoor technologies, offering comprehensive positioning for various environments and applications.

Building on the foundational role of locating technologies, the omlox locating standard is a universal and interoperable platform for RTLS. It represents a significant advancement in location tracking for industrial settings and overcomes the limitations of proprietary systems by enabling cross-vendor interoperability and application versatility. The omlox hub is the central component of the omlox ecosystem. It acts as a middleware that receives location data from various location providers and makes it available to location-driven business applications. This ensures seamless integration and independence from specific manufacturers. Furthermore, omlox specifies the core zone for ultra-wideband (UWB) location providers, enabling high-precision asset locating for many business use cases. Other use cases may be implemented by location providers using other locating technologies like RFID (Radio-frequency identification), Bluetooth, etc.

The purpose of this guideline is to introduce the open locating standard omlox, its capabilities, and benefits. The document presents an omlox locating level model, which provides a scalable framework for locating infrastructure, ranging from basic to sophisticated, enterprise-wide and cross-enterprise applications. This model illustrates the stepwise adoption of omlox and highlights the exchange of data between different entities. Success stories in various industrial sectors demonstrate omlox's ability to deliver significant time savings, minimize errors, and enhance productivity. By implementing omlox technology, one enterprise realized annual savings of over 600 hours in search processes, while another achieved a 27% reduction in error rates and a 22.5% increase in productivity. A third case showed a savings of 200 hours per forklift per year, highlighting omlox's substantial impact on operational efficiency and error reduction.

Effective deployment of omlox technology requires careful planning, consideration of cybersecurity measures, collaboration among stakeholders, adherence to legal standards, an appropriate deployment architecture, and a commitment to ongoing system enhancement. A checklist and an economic analysis are provided to assist small and medium-sized enterprises (SMEs) in assessing their readiness to adopt omlox. The checklist covers operational, technical, legal, and financial dimensions to support well-informed decision-making about implementing the omlox standard.

Overall, this guideline can serve as an entry point into omlox to become qualified to plan installations and applications in cooperation with omlox service providers.

Locating as an enabler

Today, the industry is facing numerous challenges. These include labor shortages, volatile demand, disrupted supply chains, rising resource costs, and additional regulatory requirements.

One of the key challenges for companies today is knowing the location of their enterprise assets, resources, and products. Locating technologies can effectively address this challenge and enable new consumption- or service-based business models.

The following chapters provide an overview of the benefits and opportunities of using such technologies, as well as a detailed discussion of the use of the omlox locating standard.

Why locating technology?

Location is a crucial property of an object, particularly for movable objects involved in a business process. But even in today's highly digitized world, location information is often captured manually and sparsely. In many cases, current locating technology can provide real-time location data and, when used with appropriate software solutions, can replace manual processes. Implementing locating technology can be the first step to automate business processes that rely on location information. Application-specific software solutions can then use the locating infrastructure.

When considering locating technology, the focus of the implementation should be on added value that can directly create transparency, save costs, or improve quality in a specific process. Having locating technology in place can lead to additional solutions in other fields. Over time, the use of locating technology can become a standard practice within an organization, leading to a significant increase in the level of automation.

What opportunities does locating technology offer?

Locating technology can solve multiple business challenges when applied with suitable software solutions. This is the case for a variety of business sectors (e.g. healthcare, logistics, etc.). However, this guideline focuses on industrial and manufacturing use cases for ease of understanding. In this field, location data can generate added value in various ways, such as:

Track and Trace Applications

Automatically locating assets on the shop floor, warehouse, yard, or any other environment can reduce the need for manual search, establish a more efficient usage of assets or maintain an up-to-date inventory and save costs. Assets can be products, tools, humans, or transportation vehicles.

Location-based Automation

A change of location of an object is an indication of a certain step in a process-chain. Therefore, location data can be used to trigger automation and documentation processes. If for example, a product is built in a step-based production process, geo-fences and proximity events can be used as an input for automation. Examples for automations are, presenting relevant information to a worker at a specific station or generating a shipping list based on the goods on a truck.

Operation and Maintenance

Maintenance and operation of mobile assets can be challenging especially in a dynamic environment and when rules for operation need to be applied. Precise locating can assist workers and maintenance staff and give orientation in unknown locations. Especially in combination with modern user interface technologies like

Augmented Reality (AR), users can navigate and find objects hands free.

Material flow

In production and intralogistics, the number of autonomous vehicles and robots is increasing. Organizing the movements of all elements in an optimized and safe way is challenging. Real-time locating can be a key technology to implement specific automations and location data enables a holistic overview.

What locating technologies are available?

Locating technology has been used in numerous areas for years, particularly with Global Navigation Satellite Systems (GNSS). It is a versatile tool that can be applied in various fields. GNSS, such as GPS (Global positioning system) or Galileo, are used to determine position data. Today GNSS receivers are integrated into many consumer products such as smartphones and cars. Professional applications in logistics and numerous other fields around the globe can use the global satellite infrastructure to acquire real-time position data of objects and use it in application-specific software systems.

In addition to these global locating technologies, position data can also be used to solve problems on a local level where objects move within a specific area or building. To determine local position data, underlying technologies require their own infrastructure. Multiple technologies can be used for indoor locating, which creates new opportunities for applications that rely on real-time locating data.

Beyond GNSS, a range of wireless and vision-based technologies enable precise location in a variety of ways. UWB utilizes time-of-flight measurements for high accuracy. Bluetooth Low Energy (BLE) and WIFI can determine proximity based on signal strength. Meanwhile, 5G and Narrowband IoT (NB-IoT) detect devices in cellular networks for broader coverage. Vision-based technologies, such as cameras, can be combined with Simultaneous Localization and Mapping (SLAM) algorithms to locate objects using visual cues. Table 1 provides an overview of the accuracy and coverage of available locating technologies for local use [1].

Multiple technologies enable locating, which can solve the problem of determining the exact position of an object in real-time on a global scale outdoors and locally indoors. When using suitable technologies for a specific use case, position data within the required accuracy boundaries is available. This data can serve as the vital information that connects the digital world with the real world.

Table 1: Different locating technologies in comparison

Technology	UWB	BLE 5	RFID	WIFI	Cellular (NB-IoT)	Vision (e.g. cameras or SLAM)
Accuracy within	decimeters	meters	meters	meters	meters	Not defined
Coverage (up to)	200 m	400 m (indoors)	100 m	100 m (indoors)	8 km (urban areas) 35 km (rural areas)	Line of sight

omlox - the open locating standard

Indoor locating systems are a powerful tool for operating more resource-efficiently and sustainably. However, many current implementations do not fully utilize the potential of location data due to the complexity of indoor environments and the unavailability of satellite-based locating systems in buildings. Therefore, additional locating technologies are required to provide indoor location data for assets.

Many companies have experimented with indoor locating systems, but have not been able to convert those projects from pilot to full deployment. This is because there is no one-size-fits-all solution for indoor locating technology, and different use cases require different technologies. Flexibility and interoperability are key requirements for a future-proof indoor locating system setup.

The lack of compatibility between systems from different vendors creates a dependency known as vendor lock-in. Once an organization has chosen a particular solution, it is tied to that one vendor. This severely limits flexibility in the event of new requirements or enhancements to the system. This induced dependency leads to high risks and is therefore a barrier to the adoption of tracking technologies in the industry.

However, risks are not limited to the user side alone. Lack of standardization requires suppliers to implement the complete locating workflow, including hardware and software, for their individual solutions. This results in high costs and, consequently, high prices for users. Competition in this area is fierce, particularly for new companies and start-ups. Nevertheless, these companies have the potential to innovate for the benefit of the industry.

This is where the omlox standard comes in. It enables the provision of location data in a technology and vendor independent manner. The name "omlox" is composed of the Latin words "omni" meaning "omnipresent" and "locus" meaning "location".

For this purpose, omlox introduces a locating middleware, the omlox hub (see Figure 2). The hub provides standardized interfaces and will be further described in the following section. The omlox hub receives location data from so-called location zones and it available to business applications via standardized interfaces and data formats.

Within omlox, two types of location zones have been considered:

The core zone is an area where an interoperable ultra-wideband (UWB) system is installed, enabling vendor-independent location of UWB-equipped assets. The omlox standard also defines how assets in industrial environments can be located with the required accuracy using UWB technology (see Figure 1). The core zone as a major component of the omlox standard will be described in more detail in a later section.

Complementary zones, in addition to the UWB-based core zone, can enable omlox-conformant indoor or outdoor locating using various other technologies, including wireless technologies (such as WIFI, BLE, RFID, and 5G), vision-based systems, and satellite-based GNSS technologies (such as GPS or Galileo). The omlox standard does not define these technologies but provides access to them as complementary zones.

The separation of location data collection and usage simplifies the system and reduces workload. As a result, Omlox provides users with the following benefits:

- The design of the modular system enables customers to select and combine positioning technologies and vendors that are best suited for their specific applications.

- The system includes standardized interfaces that facilitate initial system integration and future scalability.
- The system provides technology and vendor-independent access to location data through a standardized API.
- Hardware vendors can focus on optimizing their products' performance while potentially expanding their offerings through strategic partnerships.
- System integrators can benefit from a standardized locating architecture, which simplifies the creation of customized solutions using a broad range of compatible products.
- Service providers can streamline training processes and support due to the uniformity of standardized systems across different technologies and vendors.
- A plug-and-play ecosystem that improves system configurations by making them more flexible and scalable.
- Improved interoperability between different RTLS solutions and devices promotes a unified environment for location-based solutions.

To summarize, omlox is not only a new location technology but also a locating standard that offers the industry simple and fast access to real-time location data.

In 2018, an industrial consortium launched this project with the goal of promoting interoperability among real-time location systems and devices from different vendors by harmonizing access to location data. Today, omlox is governed by the PROFIBUS & PROFINET International standardization body, enabling small and

Figure 1: Exemplary integration of an omlox infrastructure (blue flags) with localized omlox tags (green flags) on the shopfloor

medium-sized companies to enhance their competitiveness using locating technologies.

Technology introduction: omlox hub – the locating middleware

The omlox hub is a locating middleware that facilitates interoperability and flexibility across all locating technologies. It decouples industrial applications that use location data from the actual positioning technologies and their vendors.

This architectural principle, based on a locating middleware, simplifies the integration of locating technologies into applications. It enables seamless tracking both indoors and outdoors, across technologies and vendors, and allows for future-proof systems that can scale from small to large [2].

This section provides a summary of the basic features of the omlox hub specification.

Trackable as a moving object

In an omlox hub, moving things (assets, tools, vehicles, people) can be described as trackables. A trackable is characterized by a unique identifier, a spatial extent, additional attribute data and the dynamic combination of different positioning technologies ("location-providers").

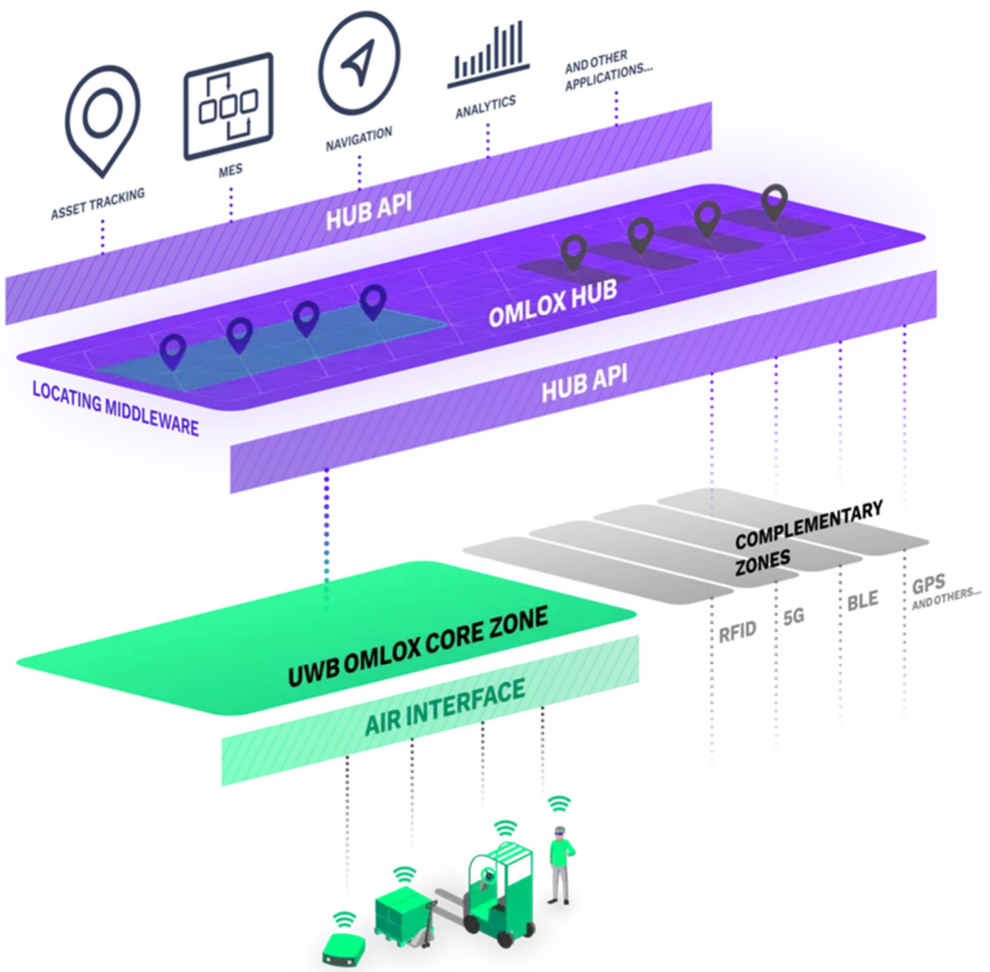

Figure 2: Overview of the omlox ecosystem

Depending on the application, the spatial constellation, or the available positioning technology, locating data can be dynamically assigned to a trackable via application programming interfaces (APIs) (see Figure 3). This allows software applications to query the last known location of a trackable via an API. The actual tracking technology becomes secondary and interchangeable [3].

Georeferencing

An omlox hub translates the location data from the various, typically locally installed zones into a global coordinate reference system (refer to Figure 4). This means that industrial applications always receive consistent data and seamless indoor/outdoor tracking is made possible. Depending on the application, different levels of positioning accuracy are required. The omlox hub uses the EPSG nomenclature[2] to describe different coordinate reference systems. This allows the omlox hub application to be used in different locations around the world.

An omlox hub also supports the reverse, translating position data from a global coordinate back to a locally installed positioning system with its local coordinate system [3].

Location-based functions

The omlox hub supports two major spatial functions in addition to the concept of trackables and georeferencing, which are described in the following paragraphs and illustrated in Figure 5:

Geo-Fencing is useful for determining if an object is inside or outside a fence, which can trigger certain actions such as configuring a machine, notifying a business application, or alerting a user. Fences can be defined using the omlox hub fence API, allowing an omlox hub to compute whether a trackable object enters or leaves a fence. A significant distinction from conventional tracking systems is that fencing operates autonomously from the tracking technology, allowing for the definition of cross-technology fences. To maximize interoperability among different omlox-hub implementations, the omlox standard defines the framework parameters for calculating a fence entry or exit. These parameters include time

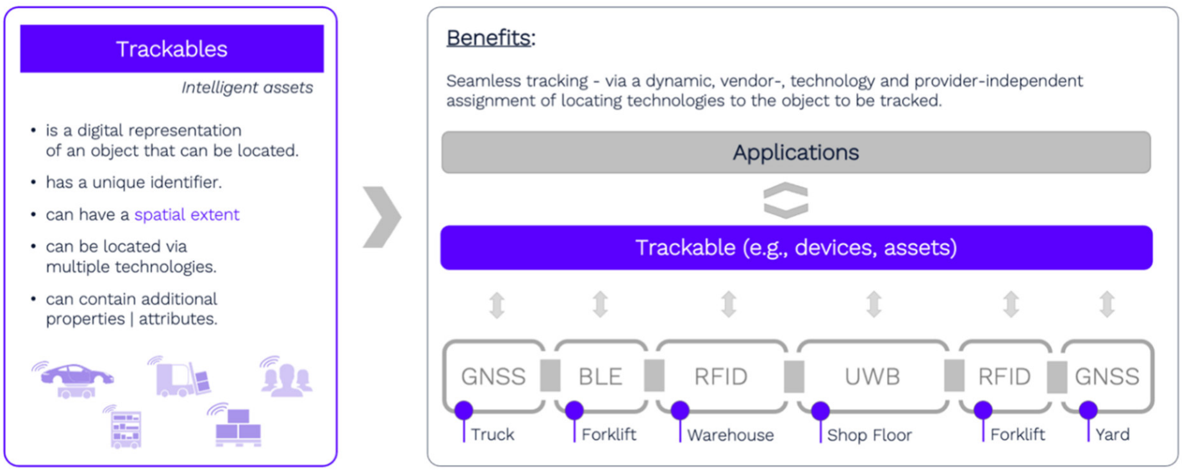

Figure 3: Trackable - assignment of location data

[2] The EPSG nomenclature is a set of unique identifiers that standardize coordinate reference systems for consistent geographic data representation. These identifiers are maintained by the European Petroleum Survey Group.

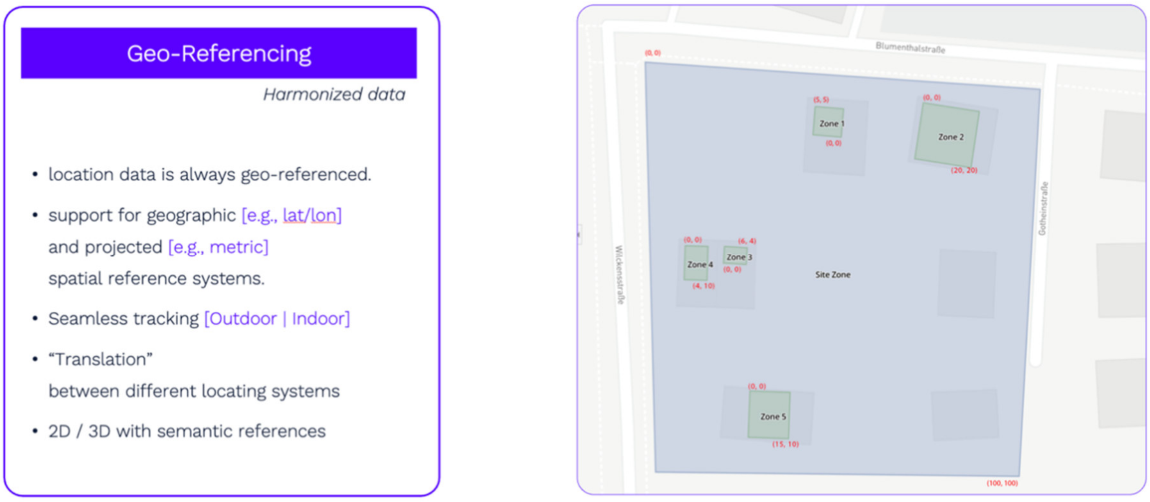

Figure 4: Georeferencing within an omlox hub

intervals to compensate for fluctuations in the tracking data [3].

The ability to detect collisions from omlox trackables can be a valuable feature for many use cases. The collision API of the omlox standard facilitates the calculation of distances between moving objects, enabling the system to send alerts when distances fall below predefined thresholds. The specification outlines the necessary framework parameters for collision detection, ensuring consistency across various omlox hub implementations [3].

Integration and operation

The omlox standard currently supports the following access methods:

- Representational state transfer - REST API
- WebSocket API
- MQ Telemetry Transport - MQTT

These methods are complemented by a lightweight data model that uses JSON for its human readability and adaptability. The flexibility of this model is particularly beneficial when integrating various location technologies.

An omlox hub has a built-in rule engine that allows for the management of multiple location technologies and the use of the most accurate location data available [3].

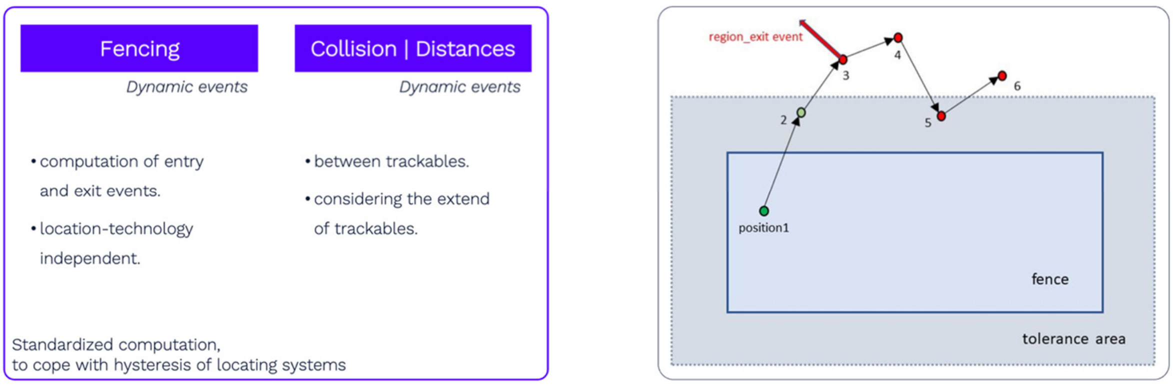

Figure 5: Location-based functions

Technology introduction: omlox core zone – interoperable UWB locating

The omlox core zone defines a locating zone that enables robust, precise, and manufacturer-independent locating of devices equipped with an UWB radio. Therefore, an omlox core-zone comprises fixed infrastructure devices (called satellites) and mobile devices (called tags) to be tracked.

The omlox core zone infrastructure consists of at least three satellites[3] interconnected in a network and connected to a locating engine (includes locating software). The network can be set up both wired and wirelessly e.g. via LTE/5G, WIFI (depending on the options offered by the manufacturer). For locating purposes, the infrastructure communicates with the tags via UWB. This enables either satellites to determine the position of tags (i.e., tracking like shown in Figure 7) or tags to locate themselves (i.e., self-location like shown in Figure 6) [2] [4].

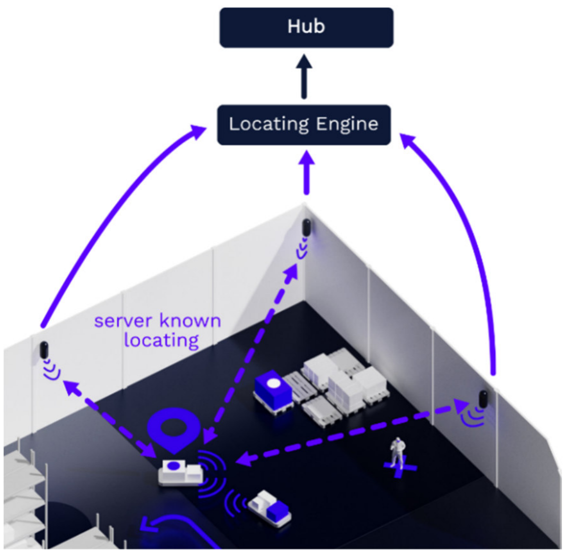

Figure 7: Self-localization of the tag by receiving and evaluating the signals from the infrastructure (GNSS4 below -like)

Omlox provides different location modes for various use-cases:

Self-location (GNSS[4] -like)

The tag only receives the signals from the satellites and can calculate its own position. For this mode the omlox standard specifies accuracy of 60 cm[5].

Precise tracking

Tags and infrastructure transmit and receive signals and thus enable precise locating with an accuracy of 20 cm specified by omlox. Current implementations have shown, that in this mode locating is leading to a higher power consumption compared to the other modes[5] [5].

Energy optimized tracking

The tags only transmit if requested to reduce the power consumption. The accuracy is specified by the omlox standard at 40 cm[5] [5].

The locating involves two steps: Ranging and positioning. During ranging the direct distance

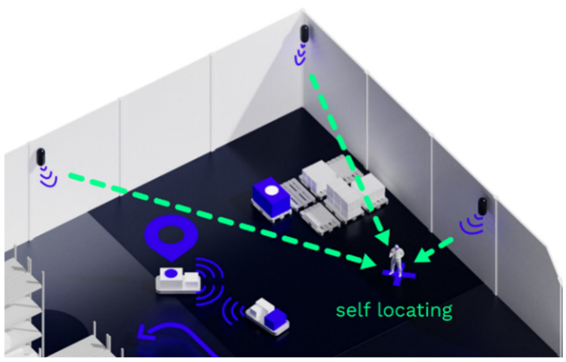

Figure 6: The omlox infrastructure locates the tag by communication between tag and infrastructure

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[3] Minimum number needed for 2D-positioning. 3D-Positioning requires a minimum of four satellites. Depending on the area and the accuracy required, additional satellites may be necessary.

[4] E.g. GPS or Galileo

[5] Under laboratory conditions

between nodes (tags and time-synchronized satellites) is measured. The measurement is based on the time measurement of the propagation times of the UWB signals and is calculated according to two principles: Time of Flight (ToF) or Time Difference of Arrival (TDoA). The subsequent positioning estimates the position. This can be realized via static locating (trilateration and triangulation) tracking strategies [2] [4] [5].

The communication protocol (the omlox air-interface) between tags and satellites is defined by the omlox core zone specification. Since omlox-compliant satellites as well as omlox-compliant tags implement this joint air-interface, tags can easily and quickly discover the presence of an omlox core zone infrastructure and register themselves for tracking. The communication is based on a subset of the mandatory and optional physical layers described in the IEEE 802.15.4 and IEEE 802.15.4z standards. The actual ranging relies on signals within regulated and therefore valuable UWB frequency bands. These are called In-Band signals. All other communication like device management or firmware-updates is offloaded to a separate narrow Out-of-Band (OoB) radio. Depending on the regulatory restrictions in the respective country and the technological capabilities of the devices, the omlox core zone uses at least one of the two UWB channels defined in the omlox standard [4] [5]:

- UWB channel 9 ("8 GHz" high band): World-wide configuration which satisfies global regulation (e.g. Europe, US, China, Japan/Korea)
- UWB channel 3 ("4 GHz" low band): Long-range configuration which is optimized for performance and range (Satisfies regulation in Europe and US)

By integrating omlox with existing UWB radio standards, it ensures that omlox benefits from advantages such as precision and accuracy within a range of up to a few decimeters as well as robustness against highly reflective environments. Additionally, it can also utilize standard-compliant hardware chips, ensuring interoperability, increasing acceptance and market adoption. Furthermore, it ensures compliance with multiple standards from bodies with different focuses, such as the Car Connectivity Consortium (CCC) for the automotive industry and the FiRa Consortium for consumer electronics [2].

Advantages of UWB Locating:

- High accuracy & precision
  (up to a few decimeters)
- Low sensitivity to interference (robustness)
- High data transmission rates
- Low power consumption
- Guaranteed interoperability

Certificates

As an open and collaborative locating standard, omlox is managed by the non-profit organization PROFIBUS & PROFINET International (PI). To ensure the interoperability of devices and software from different manufacturers, PI and its respective committees define and develop standards and monitor their compliance through certification. This requires testing by a test laboratory authorized by PI.

The following certificates are issued to confirm omlox conformity. Hard- and software labeled with the respective certificate/logo were able to demonstrate the required conformity:

(A) (B) (C) (D)

Figure 8: omlox certifications

The omlox air interface certifications (see Figure 8A, logo variation with air 8 only is also possible) guarantee that devices (tags or infrastructure) labeled with this certificate/logo behave as described in the omlox core zone specification and have passed the certification process for the omlox core zone. This means that an omlox infrastructure device marked in this way can locate omlox-certified devices from other manufacturers and devices marked in this way can be located by an omlox-certified infrastructure from other manufacturers (when using the same UWB frequency). In addition, the standardized hub API ensures that location data can be transmitted from the core zone to an omlox hub [2].[6]

The omlox hub API certificate (see Figure 8B) confirms that a hub implements all the specified API in accordance with the hub specification. It also ensures that all specified functions (e.g. fencing, collision events) have been implemented correctly. Therefore, the hub offers the possibility to connect different locating technologies (core zone or complementary zones) according to the specified API and to pass on the position information consolidated to other apps [2].

The omlox connectable app certificate (see Figure 8C) indicates that a software application uses the omlox hub API and can therefore access the position data and other functions provided by an omlox hub [2].

The omlox connectable provider certificate (see Figure 8D) ensures that location providers using other locating technologies than the omlox air interface (e.g. BLE, RFID, proprietary UWB) can function as complementary zones. Products with that logo can provide location data to an omlox hub in compliance to its standardized API [2].

[6] Since only a limited test setup was available in the initial phase of omlox certifications, certification was based on a reduced test scope. In this case, certified devices are marked with a corresponding omlox ready certificate: omlox ready air 8

The locating level model for the industry

In contrast to proprietary locating technology omlox enables the industry to profit from scalable locating and process coverage. Depending on the requirements of the specific business processes locating coverage may scale from small subareas up to cross company, potentially covering the complete manufacturing and sales process of a product. Figure 9 classifies the range of implementation options into four levels. Apart from showing what is possible, this is supposed to serve two purposes: On the one hand, it introduces a common terminology and allows to analyze the status quo of the current locating implementation in accordance with that terminology. On the other hand, it facilitates the determination of goals and process requirements based on the range of possibilities omlox can offer. Each locating level addresses different process challenges that are about to be explained in this chapter.

The omlox locating model illustrates levels of locating technology implementation as well as potential cross company cooperation with the exchange of location data between suppliers and customers on specific levels.

The locating levels are defined as

0. No Locating,
1. Subareas,
2. Larger Areas,
3. Entire Company

The specific features of each of these levels will be addressed in the following.

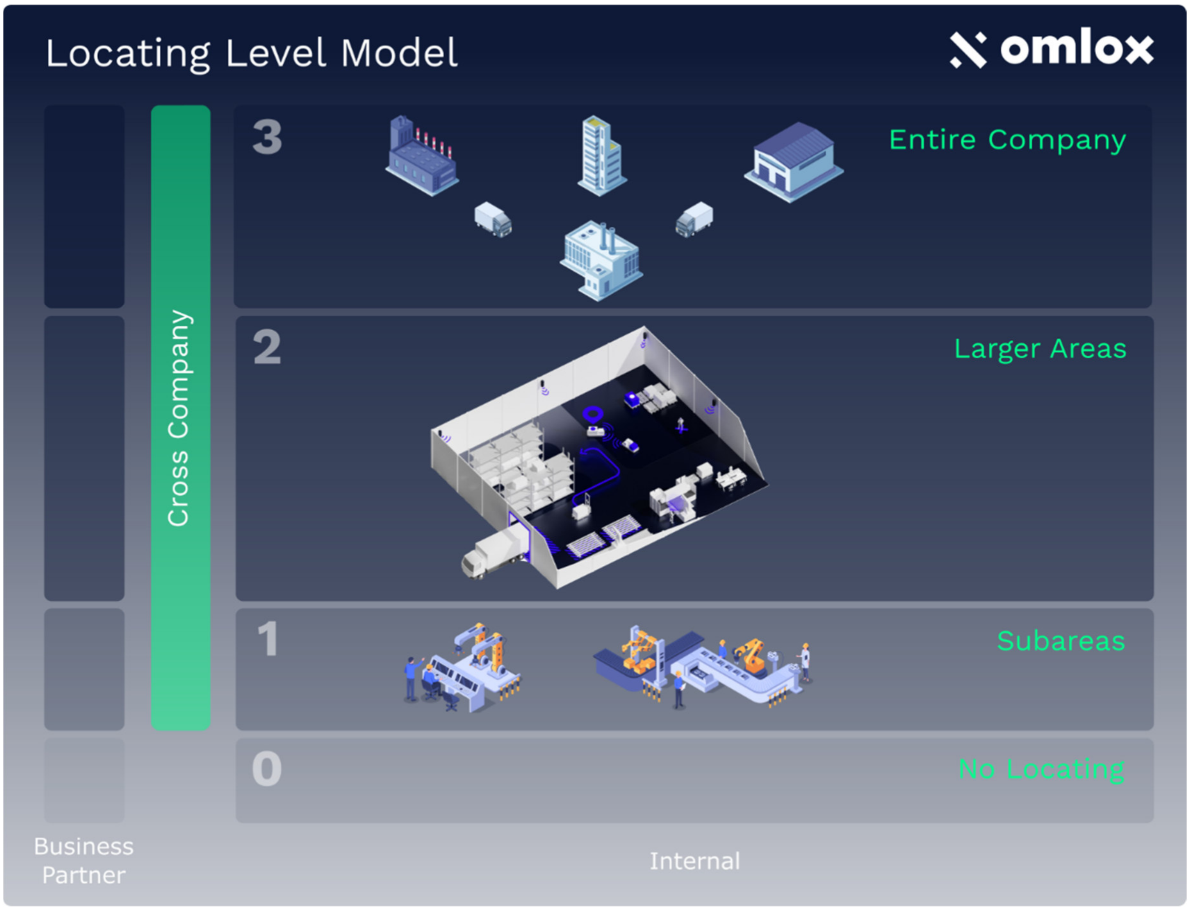

Figure 9: omlox Locating Level Model

Level 0: No locating

This base level describes business processes and areas with no applied locating technology. However, business processes today usually include infrastructure to scan IDs of products, components, tools, or other forms of objects by stationary hardware like barcode scanners or RFID gates. This is required to indicate in the MES (Manufacturing Execution System) or ERP (Enterprise Resource Planning) system that a certain task is complete. Due to the static location of the scanners, this location information may be assigned to objects that are being scanned at these stations. This can be done by enhancing the MES or ERP system with omlox certified software interface components and the introduction of an omlox hub with no hardware swap required. In addition to the business process view in the MES or ERP, this simple link to the omlox hub can significantly improve the management view of production by providing a physical perspective.

Level 1: Locating in subareas

This level is the first actual step towards the usage of locating technology. Locating technology in smaller areas, such as specific production cells or sub-areas of a warehouse, may address very process-specific requirements. Proprietary technologies on the market may fulfill all requirements since the scope of their implementation is limited. However, the use of such proprietary solutions at this level can lead to incompatible siloed solutions, which in turn contradicts the overall management view. This can be avoided by using components that are certified by omlox at this level, which will future proof the process and enable a later integration into the omlox hub.

Alternatively, the implementation of locating technology in subareas may serve as a pilot for later rollout. To date, this has been a necessity due to the large number of proprietary technology offerings and the associated vendor lock-in. The complete locating technology stack including locating hardware and software needs to prove the fulfillment of the process requirements before a rollout may begin. Technology changes after a rollout has begun, may be impossible from economical perspective. Omlox can reduce the risk involved in the process and make it easier to replace technology providers, resulting in faster acceptance and rollout.

Level 2: Locating for larger areas

Larger areas in this context are complete production or logistics environments within a building or limited outdoor areas. These larger areas may contain multiple subareas, each of which may use different locating technologies such as RFID, UWB, etc. This level can serve as an organizational instrument to cover certain business functions (e.g., production line A or warehouse C) or infrastructure (e.g., sales building).

Production assets (e.g., transportation vehicles, tools, etc.) may be operated at different places within these areas and are sometimes hard to find. In this case tracking such assets leads to improved efficiency by eliminating the need to search. This is a typical use case for larger areas.

This scale of locating technology implementation may already cover entire business processes within the company itself. In this case, individual products can be tracked throughout the business process, improving operational transparency within the internal premises. The omlox hub collects location data from all subareas within larger areas and provides access to this harmonized data for potential locating apps that offer dashboards or other forms of analytics or visualization.

Level 3: Locating throughout the entire company

This level is most relevant to companies with multiple locations and trackable items that move between locations. If these items can be tracked both on site, in transit, and at the other location, level 3 is reached. For small or medium-sized companies with only one site, this level is achieved as soon as the main location is fully covered by locating technology.

If assets are being used anywhere on the premises or at different sites of the company, locating throughout the entire company may be necessary. These assets might be tools for machinery or transportation vehicles. Another common use case could be returnable packaging, such as pallets or product trays, that move through multiple company sites during the production process. For product tracking, the same principles apply as for level 2, but on a larger scale.

Key to this is again the omlox hub which acts as a middleware and consolidates all sources from different locations of the company. Depending on the size of the company it may be beneficial to implement multiple omlox hubs on different organizational levels, providing different abstraction layers for visualizations or data analysis.

Cross Company

This aspect of the locating model indicates the potential for systematic and automatic exchange of location data across company borders to streamline processes with business partners. Cooperation in this area requires location data, therefore locating levels 1-3 are necessary. However, cross company interaction is not tied to a specific locating level. Depending on the specific business process location data of small subareas may be sufficient to achieve maximum process efficiency.

Typical use cases for cross company exchange of location data are among others the tracking of raw materials, returnable packaging, pre-processed components, or finished goods. Cross Company can also incorporate external logistics, potentially covering the entire value chain.

Cross company cooperation is implemented via the omlox hub which can interact with other omlox hubs from business partners by automatically exchanging location information. In contrast to proprietary solutions these hubs do not need to have the same implementation. Business partners may have implemented solutions from various providers. The use of a standardized interface ensures smooth interoperability once a business decision has been made regarding the exchange of location data. This simplifies potential collaborations in this area and creates room for process improvements.

Requirements

The omlox hub is the center and starting point of any omlox based locating solution. Even if active locating technology is not available, the hub, in combination with software interfaces to ERP or MES systems, may already collect indirect location data from existing scanning applications such as RFID gates or barcode scanners. Incorporating this existing data might already lead to a quick win by creating a new physical perspective. For subareas air interfaces like the omlox core zone or complementary zones (RFID, BT, WIFI, etc.) can be implemented. This typically requires the installation of reference systems in the infrastructure. The same applies for larger areas and the necessary efforts and costs typically increase proportionally with the area to be covered. For the entire company efforts for organizing and structuring all data needs to be considered. Furthermore, depending on the local infrastructure and the need for reliability, it might be necessary to set up multiple distributed omlox hubs at different business sites.

Use cases

The preceding chapters of this guideline have illustrated how locating technology can provide added value for industrial processes and how standardization can serve as a technology enabler for various levels of locating applications. To provide a detailed insight of how such applications might be implemented, this chapter describes three specific use cases at different companies. These use cases demonstrate how the integration of an omlox system at different localization levels has solved the challenges of the respective company and shows the saving potential that resulted from these measures.

Locating in subareas at MANN+HUMMEL

MANN+HUMMEL utilizes omlox technology at its Speyer production facility in Germany. The company operates globally and manufactures filter systems for industrial and off-road use, typically in small batches. In some cases, end customers hire freight forwarders to collect the filter systems without providing a precise pick-up time, resulting in storage of the filters in a distribution warehouse. At pickup time, the filters need to be collected from the warehouse as quickly as possible. In doing this, MANN+HUMMEL faces challenges in locating these filters, which can be time-consuming and result in missing or incorrectly loaded parts. To address this issue, the company required a solution that would allow them to quickly locate pallets and boxes. Furthermore, they wanted employees to be able to find the location of these items using a mobile device that displays the location on a map.

As a solution, a system using omlox-compatible devices was implemented. The warehouse ceiling was equipped with 15 omlox satellites and individual Power over Ethernet (PoE) wiring was set up. In addition, five omlox tags were integrated into scanners. These scanners (see Figure 10) serve two purposes: the position of the scanner is associated with the stored goods' location during the scan process as the goods remain stationary after being stored. Secondly, the scanner can also be used to locate goods later. The implementation followed the omlox standard and was straightforward. An omlox-compliant hub serves as middleware, connecting barcode information with location tags.

This project was brought to fruition through collaboration among various omlox partners. One system integrator was responsible for coordination and integration, while the core zone infrastructure and hub were provided by respective solution providers. The solution saves 600 hours of search time each year, equivalent to over an hour per day [6].

Figure 10: The scanners used at MANN+HUMMEL (equipped with an omlox tag) to locate stored goods

Locating for larger areas at TRUMPF

TRUMPF is a global leader in machine tools and is internationally recognized for its expertise in laser technology. The production process involves the use of different components, which undergo various manufacturing steps and are sometimes stored temporarily. Due to the complexity of the process and the storage involved, it can be challenging to track specific

Figure 11: The TRUMPF production line at the plant in Austria

sub-orders. Therefore, it is often necessary to locate them within the manufacturing process. Furthermore, there is an issue with parts that have a similar appearance being mistaken for one another, which is problematic because they differ in details and properties.

To streamline the process, TRUMPF has established an omlox-core-zone infrastructure along the production line at its factories in Austria and the USA (see Figure 11). Each order is assigned an omlox-tag, enabling real-time tracking. An omlox hub gathers the position data and provides it for additional processing. This eliminates the need for searching and automatically documents completed manufacturing steps. Programs connected to the hub enable evaluation using visualization software and perform automated bookings in the ERP system. Once complete, a tag can be removed and reused for a new order, saving costs.

Thanks to the omlox system, TRUMPF saves about an hour of search time daily. The error rate has decreased by up to 27%, as mix-ups are prevented, and all processing steps are recorded. Furthermore, buffer storage times are reduced, resulting in a productivity increase of up to 22.5% [6] [7].

Locating throughout the entire company at Liebherr

Liebherr ranks among the world's largest construction machinery manufacturers, with a network of over 130 companies structured into 11 divisions that include earthmoving, mining, mobile cranes, tower cranes, concrete technology, aerospace and transportation systems, machine tools, and automation systems. The company faced challenges in efficiently locating machine parts and components within their distribution centers, as various parts were stored in crates and moved to outdoor storage areas. When orders came in, workers had to manually search for and verify the correct parts for dispatch, a process that was time-consuming and prone to causing delays and additional costs.

To address these operational inefficiencies, a solution based on omlox technology was created by various partners in the omlox ecosystem. The centerpiece of this solution was the hub, which coordinated the entire system. Forklifts were outfitted with special sensors to identify and track assets both inside and outside the facility, ensuring continuous tracking capabilities. GPS antennas were used to track assets across outdoor areas, while omlox core zone tags (UWB) were employed for accurate indoor tracking of forklifts. Additionally, RFID readers were installed to detect the proximity of RFID tags on certain assets, such as crates, linking them to pertinent

Figure 12: Shopfloor at Liebherr equipped with omlox

asset information. The hub consolidated all location data, integrating Auto ID technology (RFID scanners) with RTLS technology (UWB & GPS). An extension for the omlox hub also allowed for mobile localization zones, which meant RFID scanners were not fixed in place but could be moved and updated with real-time location data. When a crate was scanned using RFID, the hub displayed its precise location, both indoors and outdoors, along with the RFID tag data. This system made it easier and more efficient for Liebherr to trace the whereabouts of crates. A mobile application was also developed by a system integrator to help in locating assets, showing their positions on a mobile map.

The integration of various technologies and collaboration with omlox partners (see Figure 12) led to an automated and streamlined solution for real-time asset tracking. This innovation not only improved the flow of traffic and materials, saving 200 hours of operation per forklift per year but also reduced energy use and shipment errors due to the increased asset visibility [8].

Use Cases Conclusion

The use cases highlighted in this chapter illustrate the potential for profitability when implementing locating solutions based on omlox technology. The collaboration among various manufacturers of omlox components is especially beneficial because it enables the creation of customized solutions that meet the specific needs of a company. Moreover, this strategy allows for the solution to be expanded to additional company use cases without the constraints of vendor lock-in.

The potential for scaling up these solutions is vast. In the process of standardizing omlox, more than 300 specific use cases, all emerging from real-world challenges, were considered. The ongoing development of the standard continues to be driven by practical needs.

omlox technology is not confined to industrial and warehousing applications; it can also be adapted for use in other sectors, such as healthcare, which encounter similar issues.

Notes on the use of omlox in industrial applications

To effectively utilize omlox technology in industrial applications, such as those shown in the previous chapter, it is important to consider several requirements and best practices. The following paragraphs describe these requirements and provide guidance on best practices.

Available manufacturers and solution providers

The omlox consortium comprises partner companies that contribute to the open standard and offer products and services to meet various industry needs. Some of these companies manufacture hardware, including trackable devices and omlox core zone infrastructure, as well as software, such as locating engines, omlox hub middleware, and omlox-based applications. Others act as system integrators, providing complete omlox solutions that are tailored to the customer's needs, including extensive support. For a comprehensive list of these vendors and solution providers, refer to the official omlox website[7].

Cyber security aspects

In the context of omlox technology, cyber security aspects such as encrypted data transmission and secure storage are a notable consideration. With the increasing connectivity and data exchange in industrial environments, it is essential to implement robust security measures to protect against cyber threats and unauthorized access. The omlox specification offers security recommendations concerning encryption of all communication to the hub and its API as well as measures for authorization and authentication for software manufacturers to implement [3].

In addition to encryption, restricted and monitored access to the factory premises reduces the risk of locating data from omlox core zones being captured without authorization. Above all, the protection measures for omlox systems must be integrated into the general IT security concept of the company using them.

Operational Setup

The deployment of omlox technology involves consideration of the deployment architecture, whether it is cloud-based, edge-based, or a hybrid approach. Cloud-based setups involve the use of servers and services for data storage, processing, and analysis that can be either remote or hosted locally in an on-premises data center. This provides scalability, centralized management, and access to advanced analytic capabilities. Alternatively, edge-based deployments involve processing data locally on devices or gateways, reducing latency and ensuring real-time responsiveness. A hybrid approach combines the benefits of both, cloud, and edge setups, allowing for flexible and optimized deployment based on specific use cases and requirements. Organizations should evaluate their operational needs, data processing requirements, and connectivity constraints to determine the best operational setup for their omlox implementation.

Identification of relevant stakeholders

Successful implementation of omlox technology requires the involvement and collaboration of various stakeholders. The IT department plays a crucial role in the integration of omlox systems with existing infrastructure, ensuring compatibility and smooth operation. Works councils or

[7] https://omlox.com/solutions

employee representatives should be engaged to address any concerns related to privacy, data collection, and employee rights. Other relevant stakeholders may include operations teams, maintenance personnel, and end-users who will interact with the omlox system daily. By identifying and involving these stakeholders early on, companies can ensure that the implementation of omlox technology meets the specific needs and requirements of all parties involved, leading to a successful roll-out.

Codetermination obligations and GDPR compliance

In certain jurisdictions, the collection of locating data may be subject to codetermination obligations. In the context of an omlox installation this may become relevant, when the locating data can be directly connected to an individual (e.g. a worker that constantly carries a tag). This means that organizations implementing omlox technology may need to consult and involve employee representatives or works councils in the decision-making process related to data collection and usage. This ensures transparency and compliance with legal requirements regarding employee rights and privacy. Organizations operating omlox systems within the European Economic Area (EEA) must comply with the General Data Protection Regulation (GDPR) when handling personal data. They are required to implement appropriate measures to protect personal data, obtain valid consent for data collection, and provide individuals with control over their data [9].

Accuracy of Coordinates

The accuracy of the coordinates in omlox core zones is critical for reliable asset tracking and positioning. It is important to note that excessively high accuracy can be unnecessary and costly, while insufficient accuracy may result in the loss of proper system functionality.

Localization through the omlox core zone can be effectively utilized even in challenging environmental conditions, such as production environments. However, to attain optimal accuracy for the given application, it is recommended to be aware of and to avoid possible interferences: Reflections from large metal surfaces and equipment or machinery with strong electromagnetic properties, such as electric motors, welding cells, and power inverters, can negatively affect signal quality and integrity. Furthermore, the dynamics of an environment, such as frequent changes caused by the movement of people or vehicles, can challenge the system's performance by requiring re-evaluation of position information.

Despite these factors, the use of UWB omlox (core zone) is generally more robust than other radio technologies. This robustness is particularly evident in the presence of other wireless networks, such as WIFI or 5G, and in the event of a restricted line of sight. Deploying additional satellites can help to mitigate environmental factors and achieve high signal quality while ensuring adequate area coverage and redundancy.

Best practices for implementing omlox

When implementing omlox technology in industry applications, it can make sense to follow certain best practices to ensure a successful deployment. Firstly, conduct a thorough analysis of the specific requirements and objectives of the application. This includes understanding the operational environment, asset tracking needs, and integration requirements with existing systems. Secondly, it is recommended to conduct a pilot or proof-of-concept phase that validates the effectiveness of the omlox solution before full-scale implementation. This enables fine-tuning and identification of potential challenges or limitations. Furthermore, investing in employee training and change management programs can facilitate the smooth adoption and acceptance of the omlox system among the workforces. Regular updates and maintenance of the omlox infrastructure, including firmware and software updates, are essential to ensure system reliability and security. Additionally, fostering collaboration and knowledge sharing among stakeholders, such as manufacturers, solution providers, and end-users, can drive innovation and continuous improvement in utilizing omlox technology for industry applications.

Checklist for SMEs

This checklist empowers companies to determine the demand and requirements for omlox-based locating within their company. In addition to finding out a company's status according to the locating level model, this initial self-assessment can be used as a basis for further conversation with experts and system integrators.

Status Assessment

Identifying demand for locating

Does your company often have to deal with time overhead due to searching misplaced or (temporarily) lost objects (e.g. a forklift transports a palette with raw materials to the wrong position)?	Yes ☐ / No ☐
Do you often encounter mix-up of goods/products or delivery of the wrong product to a customer?	Yes ☐ / No ☐
Are you running processes (e.g. for placement) where the ability for precise identification of the relative position of an item is necessary?	Yes ☐ / No ☐
Do you have (redundant) location data existing in several independent systems?	Yes ☐ / No ☐
Would you like to offer your customers the option of locating your products?	Yes ☐ / No ☐
Would you like to provide people (e.g. workers, visitors) or vehicles (e.g. forklifts, AGVs) with individual navigation?	Yes ☐ / No ☐
Are you concerned about functional or factory traffic related safety (e.g. heavy or dangerous machines, AGVs, etc.)?	Yes ☐ / No ☐

Operating Environment

How big is your (production) area? (approximation in m^2) ______________________

Is your operating environment split over multiple sites? If yes, how many? Yes ☐, __________/ No ☐

Please describe the ambient conditions of your environment (including used/stored materials, objects, machines, etc.):

____

Does your working space include indoor areas?	Yes ☐ / No ☐
Does your working space include outdoor areas?	Yes ☐ / No ☐

Does your working space have multiple height levels/ranges? If yes, how many? Yes ☐, __________/ No ☐

Do means of transportation/vehicles (e.g. forklifts, AGVs, etc.) operate in your environment? If yes, how many (approx. quantity)? Yes ☐, __________/ No ☐

Status of locating in your company

Are you already using locating technologies? Yes ☐ / No ☐

Not currently, but in the past ☐

If you are currently or were using them in the past, which locating technologies are/were you using?

- UWB (proprietary) ☐
- UWB (omlox core zone) ☐
- RFID ☐
- BLE ☐
- GNSS (e.g. GPS, Galileo) ☐
- Other: ____

What objects/trackables are/were you locating?

____

In what areas/environments do/did you use locating technologies?

____

What were your experiences with using locating technologies (so far)?

____

To what extent are/were you already sharing location data?

- No sharing beyond the technology/system ☐
- Sharing between multiple location systems and applications within the company ☐
- Sharing between multiple production sites ☐
- Sharing location data outside of the company/with other companies ☐

If yes, what data is/was shared?

____

Requirements for omlox-based locating

What is your aim for introducing omlox-based locating?

- Automation ☐
- Create transparency (What object is where and when? Avoidance of costly searches) ☐
- Quality control in the context of content inspection ☐
- Increase functional safety/access control ☐
- Time reduction (in production, search times) ☐

What (objects) shall be located/tracked?

- Tools ☐
- Vehicles (autonomous or not) ☐
- People (e.g. workers) ☐
- (Raw) materials ☐
- Parts ☐
- Finished products ☐
- High value products ☐
- Lower value products ☐
- Storage and transport containers (e.g. boxes, palettes) ☐

How often does the location of the objects to be localized change?

- Continuously ☐
- Daily ☐
- Weekly ☐
- Monthly ☐
- Other: ______________________________

What scale of precision does the locating require?

- Centimeter ☐
- Meter ☐
- Sub area ☐
- Building ☐
- Other: ______________________________

What mounting options for tags are possible? ____

Are you using ERP or MES systems in your company? If yes, what systems? Yes ☐, __________/ No ☐

To what extent can the ERP/MES systems in use already determine the location of objects?

____

Is there a need for exchange of locating data between ERP/MES systems and the omlox system? Yes ☐ / No ☐

What possibilities for installation/mounting of omlox hardware (e.g. satellites) are already existing in the operation environment?

- Ceiling ☐
- Wall ☐
- Pillar ☐
- Other: ____

What type of energy supply is available near the satellite mounting position?

- None ☐
- Mains voltage (e.g. 230 V) ☐
- Power over Ethernet (PoE) ☐

What network infrastructure is available in the operation environment?

- None ☐
- Ethernet ☐
- WIFI ☐
- 4G/5G cellular radio ☐
- Internet access (for possible cloud connection) ☐
- Other: ____

What form of deployment of additional IT systems (used for omlox locating) is preferred?

- Edge (at the production site, warehouse, etc.) ☐
- Internal or external cloud (e.g. in a data center) ☐
- Hybrid (combined use of edge and cloud deployment) ☐
- Other: ____

Are there any legal or external requirements? Yes ☐ / No ☐

If yes, please describe:

____

Economic analysis

This economic efficiency analysis provides an overview of the possible expenses associated with introducing omlox to the company. The cost items listed below refer to larger or company-wide rollouts and extensions but are not exhaustive. One-off costs can be obtained from quotations provided by potential service providers. If figures are missing, the company must estimate current operating and process costs accordingly. Cost savings may need to be estimated in consultation with a service provider.

One-off costs (cost type)	Costs in EUR
Project management and planning	____________
Evaluation and analysis of the operating environment (e.g. potential interference factors)	____________
Preparing the local building infrastructure for installation (power, network, mounting)	____________
Procurement of omlox related infrastructure components (e.g. satellites, servers, gateways)	____________
Procurement of omlox tags	____________
Procurement of software components (e.g. omlox hub, connectable apps, and providers)	____________
Installation and commissioning of the omlox system	____________
Software Integration of existing systems to omlox hub (e.g. RFID gates)	____________
Interfacing ERP/MES systems and integration into business processes	____________
Configuration and customization of omlox hub (zones, fences, etc.)	____________
IT service costs related to hosting of omlox software components (e.g. hub)	____________
Go-live and roll-out support	____________
Training of employees	____________
Total costs	____________

Operating costs and process costs per year (cost type)	Costs in EUR
License fees for:	
omlox location engine (core zone)	____________
omlox hub	____________
connectable apps and providers	____________
Technical support for omlox systems (e.g. troubleshooting, updates)	____________
IT service costs (e.g. hosting, staff)	____________
Electricity costs	____________
Maintenance (e.g. battery replacement, replacement of defect hardware, firmware updates)	____________
Product associated tracking cost (e.g. RFID tags per product)	____________
Total annual costs	____________

Benefits by of the introduction of omlox (per year)	Savings in EUR
Elimination for the need to search items	____________
Improved material and traffic flow	____________
Higher asset utilization	____________
Elimination of shipping errors	____________
Improving product quality	____________
Higher degree of automation (e.g. location-based booking and documentation)	____________
Total annual savings	____________

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List of Abbreviations

AGV	Automated guided vehicle
API	Application programming interface
AR	Augmented Reality
BLE	Bluetooth low energy (radio technology)
EEA	European Economic Area
EPSG	European petroleum survey group geodesy
ERP	Enterprise resource planning (system)
GDPR	General Data Protection Regulation
GNSS	Global navigation satellite system
GPS	Global positioning system
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of things
MES	Manufacturing execution system
MQTT	Message Queuing Telemetry Transport
NB-IoT	Narrowband internet of things
OoB	Out-of-Band
OPC UA	Open Platform Communications Unified Architecture
PI	PROFIBUS and PROFINET International
PNO	PROFIBUS Nutzerorganisation e.V.
PoE	Power over Ethernet
REST	Representational State Transfer
RFID	Radio-frequency identification
RTLS	Real-time locating system
SME	Small and medium-sized enterprises
SLAM	Simultaneous localization and mapping
ToF	Time of Flight
TDoA	Time Difference of Arrival
UWB	Ultra-wide band (radio technology)
WIFI	Wireless fidelity

Imprint

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