Non-Inverse Architecture (NIA)

Stationary Super-Beacon 1
Any frequency

Mobile Super-Beacon
It can be any ultrasonic frequency if Super-Beacon. It must be the same frequency if Beacons HW v4.9

Stationary Super-Beacon N
Any frequency

Stationary beacons:

- Mounted high on walls or ceilings
- Have any ultrasonic frequency, if Super-Beacon. The same ultrasound frequency if Beacons HW v4.9
- Measures distances to neighboring beacons and builds submaps automatically
- Communicate with the router wirelessly in an ISM band

Submaps:

- Advanced feature that allows building independent submaps/clusters/cells of beacons in separate rooms or zones and thus creating maps consisting of multiple submaps and covering large buildings (with an area of thousands of m2) like the cellular network coverage

Distance between beacons-neighbors is up to **30 meters**.

Mobile beacon:

- Installed on robot/drone/forklift and interacts with it via UART or SPI or I2C or USB (virtual UART)
- Receives location updates from the router up to f=40 Hz
- Location update rate per mobile beacon depends on the number of mobile beacons (n) as f/n
- Contains IMU (3D accelerometer+3D gyroscope)

Indoor Positioning System in NIA consists of:

- 2 or more Stationary Beacons (receiving ultrasound)
- 1 or more Mobile Beacons (transmitting ultrasound)
- 1 central Router

Stationary Super-Beacon 2
Any frequency

Stationary Super-Beacon 3
Any frequency

Key requirement for the system to work well: **unobstructed line of sight** by a mobile beacon of 2 (2D) and 3 (3D) or more stationary beacons within 30 meters – very similar to the visibility of GPS satellites

Router/modem:

- Central controller of the system
- Calculates the position of mobile beacons up to **40 Hz**
- Communicates via USB/virtual UART with Dashboard or robot
- Supports up to 250 beacons and up to 250 submaps

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Inverse Architecture (IA)

Stationary
Super-Beacon 1
19kHz

Stationary beacons:

- Mounted on walls or ceilings
- In IA, stationary beacons belonging to the same submap must have different ultrasound frequencies (19 & 25kHz or 25 & 31 kHz, for example)
- Measures distances to neighboring beacons and builds submaps automatically
- Communicate with the router wirelessly in an ISM band

Stationary
Super-Beacon 2
25kHz

Key requirement for the system to work well: **unobstructed line of sight** by a mobile beacon of 2 (2D) and 3 (3D) or more stationary beacons within 30 meters – very similar to visibility of GPS satellites

Mobile
Super-Beacon
Any frequency

Mobile beacon:

- Installed on robot/person/forklift and interacts with them via UART or SPI or I2C or USB (virtual UART)
- Calculates location updates onboard up to 40 Hz
- Location update rate per beacon doesn't directly depend on the number of mobile beacons
- Contains IMU (3D accelerometer+3D gyroscope)

Router/modem:

- Central controller of the system
- Synchronizes the beacons up to 40 Hz
- Communicates via USB/virtual UART with Dashboard or robot
- Supports up to 250 beacons and up to 250 submaps

Submaps:

- Advanced feature that allows building independent submaps/clusters/cells of beacons in separate rooms or zones and thus creating maps consisting of multiple submaps and covering large buildings (with an area of thousands of m2) like the cellular network coverage

Indoor Positioning System in IA consists of:

- 2 or more Stationary Beacons (transmitting ultrasound on different ultrasonic frequencies)
- 1 or more Mobile Beacons (receiving ultrasound on different ultrasonic frequencies at the same time)
- 1 x Router

Stationary
Super-Beacon N
37kHz

Distance between beacons-neighbors is up to **30 meters**.

Stationary
Super-Beacon 3
31kHz

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Multi-Frequency NIA (MF NIA)

Stationary
Super-Beacon 1
Any frequency

Mobile
Super-Beacon
19/22/25/28/31/34/37/45kHz

Stationary
Super-Beacon N
Any frequency

Stationary beacons:

- Mounted on walls or ceilings
- Have any ultrasonic frequency for Super-Beacon. MF NIA is not supported by Beacons HW v4.9
- Measures distances to neighboring beacons and builds submaps automatically
- Communicate with the router wirelessly in an ISM band

Mobile beacon:

- Installed on robot/person/forklift and interacts with them via UART or SPI or I2C or USB (virtual UART)
- Receives location updates from the router up to 40 Hz
- Location update rate per beacon up to 8 mobile beacons is like in IA. Then – like in NIA, but up to 8 times higher update rate
- Contains IMU (3D accelerometer+3D gyroscope)

Submaps:

- Advanced feature that allows building independent submaps/clusters/cells of beacons in separate rooms or zones and thus creating maps consisting of multiple submaps and covering large buildings (with an area of thousands of m2) like the cellular network coverage

Distance between beacons-neighbors is up to **30 meters**.

Indoor Navigation System in MF NIA :

- 2 or more Stationary Beacons (receiving ultrasound)
- 1 or more Mobile Beacons (transmitting ultrasound on the different ultrasonic frequencies)
- 1 central Router

Stationary
Super-Beacon 2
Any frequency

Stationary
Super-Beacon 3
Any frequency

Key requirement for the system to work well: **unobstructed line of sight** by a mobile beacon of 2 (2D) and 3 (3D) or more stationary beacons within 30 meters – very similar to visibility of GPS satellites

Router/modem:

- Central controller of the system
- Calculates position of mobile beacons up to **40 Hz**
- Communicates via USB/virtual UART with Dashboard or robot
- Supports up to 250 beacons and up to 250 submaps

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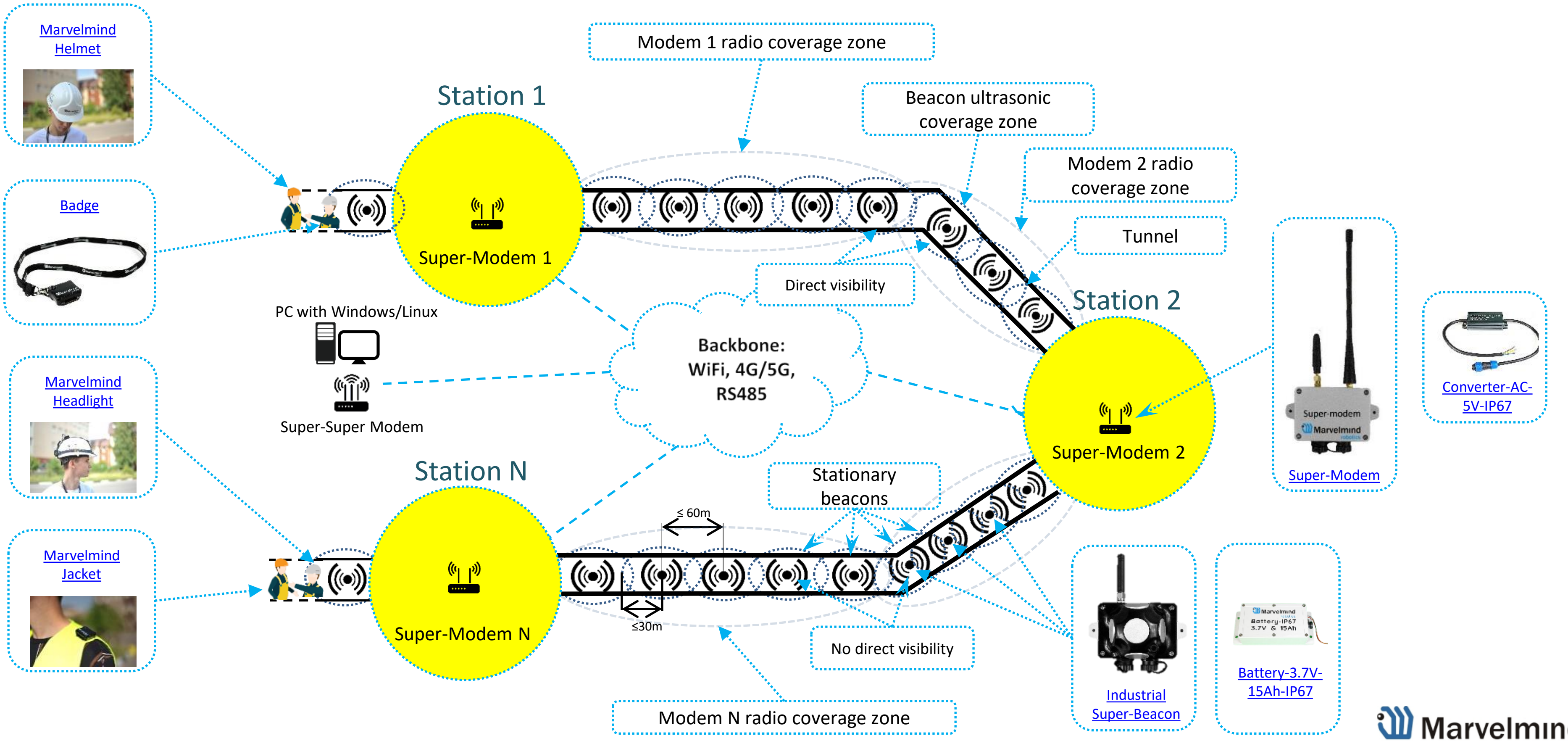
Multi-Modem architecture for very large networks

Tunnel safety example for underground tracking



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Split-Modem architecture for fast-moving objects

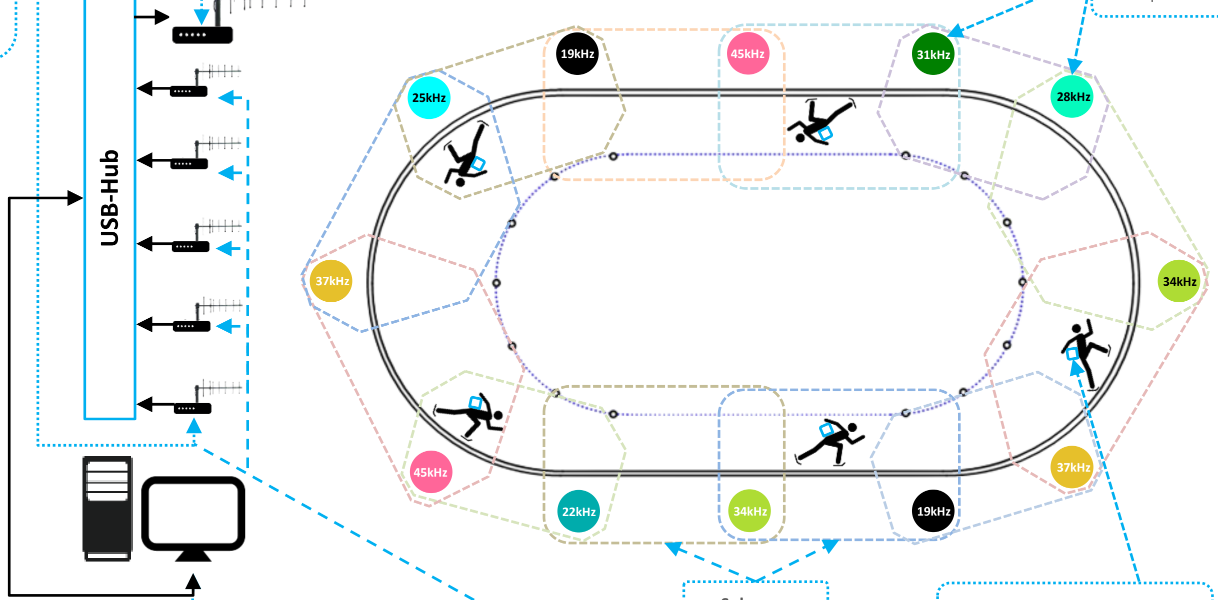
Ice skating example for swift tracking

Modem HW v5.1

Controlling modem:
- Central system controller. Collects data from all beacons and sends them to the central Dashboard.

Stationary beacon:
- Is responsible for tracking mobile beacons.
- There can't be two beacons with the same frequency in one submap or more than one pair of frequencies in the map.

Super-Beacon



Notes:
- Indoor cases: sports, carting, cycling
- Receiving modem is working in pair with one of the mobile beacons.
- Number of receiving modems corresponds to the number of mobile beacons
- Number of supported mobile beacons at a time is limited to 30 for the 915 MHz band
- Dashboard is working with a special modem module
- Coming soon: option of Super-Modem with support of the Split-Modem Architecture

Dashboard with modem module:
- Windows/Linux with running Dashboard with a modem module which takes part of functions of a controlling modem.

Receiving modem:
- Is responsible for receiving data, such as IMU data, from one mobile beacon and sending it to the Dashboard.
- One modem can receive data from one mobile beacon.

Submaps

Mobile beacon:
- Mobile beacon is attached to a target for tracking.
- Mobile beacon is connected to its own receiving data modem.

Beacon Mini-RX, Omni-Mic-IP67

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Architectures comparison

	Non-Inverse (NIA)	Inverse (IA)	Multi-Frequency NIA (MF NIA)
Typical usage	- 1-4 autonomous robots/drones - support up to 250 beacons (stationary+mobile) - When a mobile beacon shall be installed on a noisy drone/vehicle, but stationary beacons are in relatively quieter places	- Many mobile users (people, robots, VR) and when update rate per mobile is important - supports up to 250 beacons (stationary+mobile combined) - When mobile beacons are in quieter places	- 5-16 autonomous robots/drones - supports up to 250 beacons (stationary+mobile combined) - Effectively, MF NIA combines the best from both IA and NIA. But it is still "more NIA than IA" because the mobile beacons are emitting the ultrasound
Not recommended	- In applications, where emitting ultrasound of mobile beacon is undesirable	- For drones – because mobile beacons are receiving ultrasound. The range may be limited to just 2-5m. May be improved with future SW releases	- In applications, where emitting ultrasound of mobile beacon is undesirable
Accuracy	- ±2cm or better with more averaging	- ±2cm or better with more averaging	- ±2cm or better with more averaging
Update rate	- Depends on the number of mobile beacons (n) as f/n –TDMA is used - Slightly depends on the radio profile - Depends on the sizes of submaps - IMU fusion is HW and SW supported	- Does not depend on the number of mobile beacons because they are receiving ultrasound at the same time - Slightly depends on the radio profile - (the same as NIA) - Depends on the sizes of submaps (the same as NIA) - IMU fusion is HW supported. SW support is coming	- Depends on the number of mobile beacons (n) for n>8 –TDMA is used, i.e., it can provide up to 8 times higher update rate than NIA with the same number of mobiles. For up to 8 mobiles, the update rate per mobile is equal to IA - The rest – like NIA
Range	- Can cover as large a territory as you wish using submaps - Up to 30m in real life and up to 50m in lab conditions within a single submap, i.e., stationary beacons shall be placed every 30m or closer (in 1D with horns – up to 120m)		
Map building	- Can build submaps automatically and manually	- Can build submaps automatically and manually	- Can build submaps automatically and manually

Version 2023_07_07

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