# Non-Inverse Architecture (NIA)

**Stationary Super-Beacon 1 TX=RX=31kHz**

**Stationary beacons:**
- Mounted on walls or ceilings
- Have the same ultrasonic frequency
- Measures distances to neighboring beacons and builds submaps automatically
- Communicate with the router wirelessly in an ISM band

**Stationary Super-Beacon 2 TX=RX=31kHz**

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

**Mobile Super-Beacon TX=RX=31kHz**

**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=25 Hz
- Location update rate per mobile beacon depends on the number of mobile beacons (n) as F/n
- Usually contains IMU (3D accelerometer+3D gyroscope)

**Router/modem:**
- Central controller of the system
- Calculates position of mobile beacons up to **25 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 building maps consisting of multiple submaps and covering large buildings (with area of thousands of m2) like the cellular network coverage

**Indoor Navigation System in NIA consists of:**
- 2 or more Stationary Beacons (receiving ultrasound)
- 1 or more Mobile Beacons (transmitting ultrasound on the same ultrasonic frequency)
- 1 central Router

**Stationary Super-Beacon N TX=RX=31kHz**

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

**Stationary Super-Beacon 3 TX=RX=31kHz**

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# Inverse Architecture (IA)

**Stationary Super-Beacon 1**
**TX=19kHz**
**RX=19+25+31+37+45kHz**

**Mobile Super-Beacon**
**TX=not applicable**
**RX=19+25+31+37+45kHz**

**Stationary Super-Beacon N**
**TX=37kHz**
**RX=19+25+31+37+45kHz**

## 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

## 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 25 Hz
- Location update rate per beacon doesn't directly depend on the number of mobile beacons
- 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 building maps consisting of multiple submaps and covering large buildings (with area of thousands of m2) like the cellular network coverage

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

## Indoor Navigation 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 central Router

**Stationary Super-Beacon 2**
**TX=25kHz**
**RX=19+25+31+37+45kHz**

**Stationary Super-Beacon 3**
**TX=31kHz**
**RX=19+25+31+37+45kHz**

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

## Router/modem:

- Central controller of the system
- Synchronizes the beacons up to **25 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-Frequency NIA (MF NIA)

Stationary
Super-Beacon 1
19kHz

Mobile
Super-Beacon
TX=19 or 25 or 31 or 37 or 45kHz

Stationary
Super-Beacon N
37kHz

**Stationary beacons:**
- Mounted on walls or ceilings
- Stationary beacons belonging to the same submap can have the same or different ultrasound frequencies
- 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 25 Hz
- Location update rate per beacon up to 5 mobile beacons is like in IA. Then – like in NIA, but up to 5 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 building maps consisting of multiple submaps and covering large buildings (with 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 frequency)
- 1 central Router

Stationary
Super-Beacon 2
25kHz

Stationary
Super-Beacon 3
31kHz

**Key requirement** for the system to work well: **unobstructed line of sight** by a mobile beacon of 2 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 **25 Hz**
- Communicates via USB/virtual UART with Dashboard or robot
- Supports up to 250 beacons and up to 250 submaps

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# Architectures comparison

| | Non-Inverse (NIA) | Inverse (IA) | Multi-Frequency NIA (MF NIA) |
|---|---|---|---|
| **Typical usage** | - 1-4 autonomous robots/drones - supports up to 250 beacons (stationary+mobile)<br>- When 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)<br>- When mobile beacons are in quieter places | - 5-10 autonomous robots/drones - supports up to 250 beacons (stationary+mobile combined)<br>- 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. 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<br>- Slightly depends on the radio protocol<br>- Depends on the sizes of submaps<br>- 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<br>- Slightly depends on the radio protocol (the same as NIA)<br>- Depends on the sizes of submaps (the same as NIA)<br>- IMU fusion is HW supported. SW support is coming | - Depends on the number of mobile beacons (n) for n>5 – TDMA is used, i.e. can provide up to 5 times higher update rate than NIA with the same number of mobiles. Up to 5 mobiles the update rate per mobile is equal to IA<br>- The rest – like NIA |
| **Range** | - Can cover as large territory as you wish using submaps<br>- 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, if Super-Beacons or Beacons HW v4.9 or similar dual-use beacons are used. Mini-RX cannot build the map, because they are RX-only | - Can build submaps automatically with Super-Beacons and Industrial Super-Beacons<br>- Manual entry of stationary beacons' location or distances between them is required for Beacons HW v4.9 or Industrial-TX | - Can build submaps automatically with Super-Beacons or Industrial Super-Beacons<br>- Manual entry of stationary beacons' location or distances between them is required for RX-only beacons |



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