MiR Network and Wi-Fi Guide

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Copyright and disclaimer

Original instructions (English)

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Table of contents

1. About this guide

This guide describes necessary and recommended setups of your network infrastructure, both wired and wireless, for your MiR solution to work optimally.

MiR products are highly dependent on the network quality and especially the Wi-Fi, since Wi-Fi is integral to facilitate communication with the robots and the rest of the setup. A poor Wi-Fi setup will result in:

- Latency between user or fleet commands and robot execution
- Unreliable connection to the robot or fleet interface
- Unreliable connection and slow synchronization between robots and MiR Fleet
- Poor resource management with MiR Fleet
- Poor Collision avoidance coordination between robots connected to MiR Fleet

1.1 Version history

This table shows current and previous versions of this document.

Revision	Description
2.10	**Date:** 2024-12-03 • Removed mentions of MiR Log Analytics, as this product has been discontinued and replaced by MiR Insights. Affects sections: Planning your network, Evaluating the network performance, and Where to find more information • Added new subsections for network requirements. New sections: Throughput and Latency • Added information about static IP and DHCP setup. Affects section: IP configuration • Removed WISE modules from description of port 443. WISE modules only support HTTP and not HTTPS. Affects section: Ports

Revision	Description
	• Updated list of ports to include MiR Fleet Enterprise specific ports. Affects section: Ports • Removed LEAP from supported WPA/WPA2 Enterprise protocols. Affects section: Network security • Updated which version of TLS/SSL encryption protocols is unsupported. Added a reference to *How to connect a MiR robot to a Wi-Fi network*. Affects section: Network security
2.9	**Date:** 2024-02-12 • Added guidelines for how to design top modules with good Wi-Fi connection. Added section: Top module design • Updated frequency band compatibility of the internal antennas. Updated section: Robot modifications • Added instructions for disabling the access point on robot with an internal router. Updated section: Robot modifications • Added new SSID feature from software 3.x. Updated section: SSID and roaming considerations
2.8	**Date:** 2023-03-27 • Styling corrections. Affects the whole guide. • Added new front page.
2.7	**Date:** 2023-02-17 • Added Wi-Fi generations to each network standard. Affects the whole guide.

Revision	Description
	• Added section: Wi-Fi watchdog. • General improvements throughout the manual.
2.6	**Date:** 2022-08-11 • Added information that only some robots' internal antennas are only designed for 2.4 GHz. Affects section: Robot modifications. • Updated the styling in the version history table. Affects section: Version history.
2.5	**Date:** 2022-04-28 • Updated port overview. Affects section: Ports. • Updated network performance. Affects section: Evaluating the network performance. • Added section: Network architecture.
2.4	**Date:** 2021-10-28 • Added warnings against modifying robot and violating compliance. Affects section: Improving your Wi-Fi setup. • Updated for robots that no longer have an internal access point.
2.3	**Date:** 2021-04-13 • Improved description of using hidden SSIDs. Affects section: SSID and roaming considerations • Added diagram of required ports.

Revision	Description
2.2	**Date:** 2020-09-15 • Added clarification of data rate and bandwidth requirements. Affects section: Requirements for WLAN. • Added recommendation to not use hidden SSIDs. Affects section: SSID and roaming considerations • Minor corrections throughout the manual.
2.1	**Date:** 2020-05-08 • Added ports required for AI camera and HTTPS communication. Affects section: Ports
2.0	**Date:** 2020-15-05 • Changed title from *MiR network requirements* to *MiR network and Wi-Fi guide*. • Added sections describing how to evaluate and improve your Wi-Fi setup for MiR products.
0.7	**Date:** 2020-12-02 • Protocol requirement note added. Affects section: Network security • Subnet note added. Affects section: IP configuration.
0.6	**Date:** 2019-23-10 • Minor updates and additions to requirements for WLAN. Affects section: Requirements for WLAN.

Revision	Description
0.5	**Date:** 2019-13-02 • MiR500 and MiR Fleet added to scope. • Changes to sections Network security and Ports.
0.4	**Date:** 2018-20-08 • Full rework of manual, including new sections.
0.3	**Date:** 2018-21-02 • Protocol errors corrected. Affects section: Ports
0.2	**Date:** 2017-06-11 • Release review.
0.1	**Date:** 2017-13-09 • First edition.

1.2 Where to find more information

For online courses to strengthen your understanding of MiR products, go to Online training.

If you are looking for more documentation about all MiR products, go to MiR Support Portal where we have the following resources:

1.2.1 Documentation

- **Integrator Manuals** provide all the information you need to set up and prepare MiR robots for the commissioning process. It comes in print in the box with the robots. Integrator Manuals are available in multiple languages. These guides are for PCM (partly completed machinery) robots.

- **Quick starts** describe how you start operating MiR robots quickly. It comes in print in the box with the robots. Quick starts are available in multiple languages. These guides are for CE robots.
- **User guides** provide all the information you need to operate and maintain MiR products and how to set up and use top modules and accessories, such as charging stations, hooks, shelf lifts, and pallet lifts. User guides are available in multiple languages. These guides are for CE robots.
- **Risk assessment guide** describes how to conduct a risk assessment and provides some risk assessed use cases.
- **Commissioning guide** provides examples and guidelines to commission your robot successfully. The Commissioning guide is available in multiple languages.
- **Interface guides** contain descriptions of all the elements of the robot interface and MiR Fleet interface. Interface guides are available in multiple languages.
- **Space requirements** provide helpful information you can use when commissioning or operating your robot.
- **REST API references** for MiR robots, MiR Hooks, and MiR Fleet. HTTP requests can be used to control robots, hooks, and MiR Fleet.
- **MiR Network and Wi-Fi guide** specifies the performance requirements of your network and how you must configure it for MiR robots and MiR Fleet to operate successfully.
- **Migration guides** describe how to upgrade your MiR system from one major software version to the next.
- **Cybersecurity guide** provides important information and instructions to increase the cybersecurity of your MiR product.
- **How-to guides** are short guides providing instruction for maintenance, replacement, commissioning, and other tasks related to MiR products.
- **Troubleshooting guides** can help you determine the cause of an issue you are experiencing with your MiR product and how to resolve it.
- **Release notes** of new products and hardware updates that describe what has been changed and why.
- **Service notes** notify of issues identified in MiR products and changes that are applied.
- **Spare parts and additional products** list all spare parts and accessories you can order for robots.
- **Warranty** describes the MiR standard warranty agreement.

- **Certificates and declarations** for MiR products that prove compliance with standards.
- **Technical guides** provide in-depth information about how MiR products work.

1.2.2 Models and drawings

- **Wiring diagrams** are graphic representations of how the components in MiR robots are wired.
- **CAD files** of the robots that are made to scale can be used to help determine the dimensions of the robot or for illustrative purposes.

1.2.3 Resources

- **MiR Insights** is a tool you can use to analyze how well your robots or fleet are performing. MiR Insights requires a paid license. MiR Insights runs continuously alongside MiR Fleet to give real-time data on several metrics, but can also be used in Logs mode. Logs mode can analyze error logs and provide heatmaps for Wi-Fi signal strength and localization.
- **AprilTag** collection can be used instead of generating your own AprilTags.
- **Space calculator** determines the approximate amount of space your MiR robot will need to operate depending on the size of its footprint.
- **Community** is a forum of MiR users with a collection of questions, recommendations, webinars and other community driven material.
- **Marketing and brand portal** is a collection of our graphical elements where you can download color schemes, rendered images of the robots, and icons.

2. Network requirements

For your MiR application to function optimally, there are certain configurations and requirements that must be fulfilled. The following sections describe how the network must be set up.

2.1 Network architecture

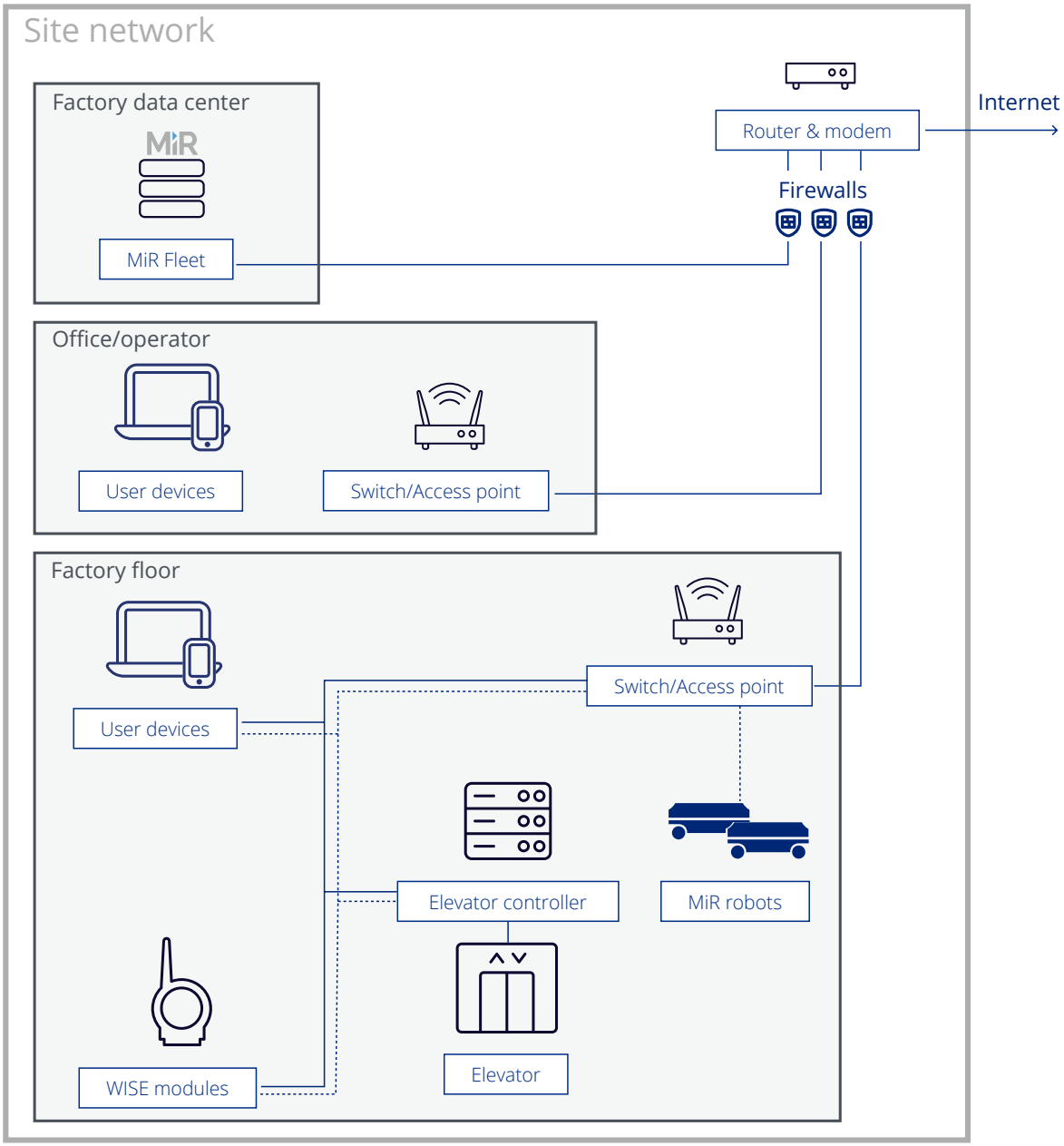
This section describes the basic network architecture you should employ for your MiR system.

2.1.1 Local site network

On the local network level, your setup should be something similar to Figure 2.1. This permits anyone on the site network to communicate with the MiR robots. The key elements are:

- A main router that connects all of the site's sub-networks.
- Each sub-network should have a least one access point or switch to connect devices to. This is used to connect all devices in that network to the main router.
- If you use MiR Fleet, it should connect directly to the main router if possible.
- Robots must be able to connect wirelessly to the access points that cover the area they operate in.
- Additional elevators, WISE modules, and other user devices can use a wired or wireless connection to an access point or switch that connects it to the main router.

Figure 2.1 Diagram of the local network at your site with MiR robots



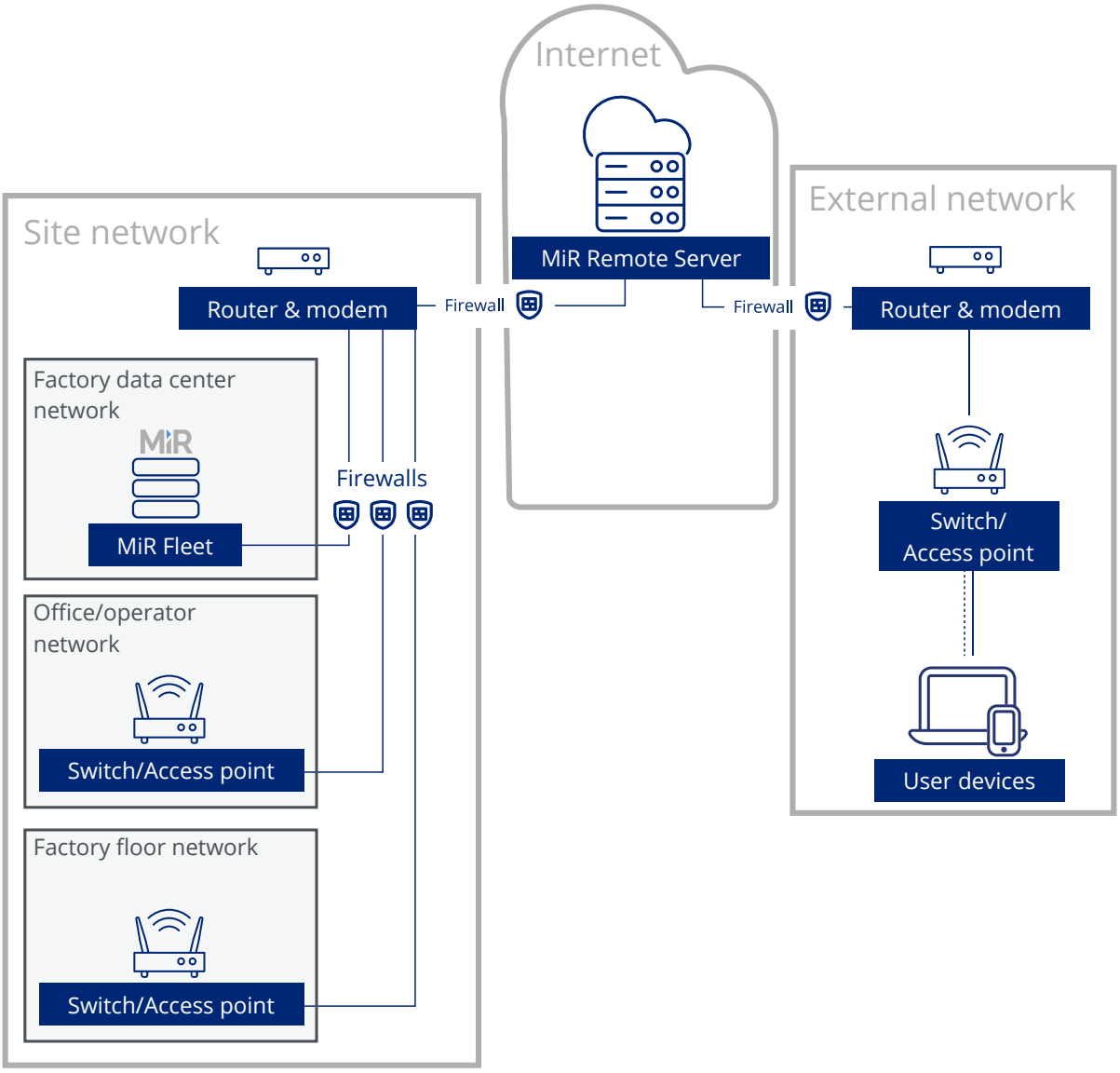
2.1.2 Connection to external network

If you want to be able to control or monitor MiR robots while off-site or use features such as Remote support, your local site network must connect to the internet.

For Remote support to work, your robot must be able to establish an outbound communication to the MiR Remote Server. Once established, MiR Technical Support can access your robot and help troubleshoot the issue.

If you want to access your robots while off-site, you can set up a VPN to connect to your site network.

Figure 2.2 Diagram of how MiR's Remote support or other network can connect to your MiR setup



2.2 Requirements for WLAN

For the robots to operate well, it is important that your network fulfills certain requirements. Depending on your setup, the requirements may differ, but for a Wi-Fi setup used by both MiR robots and other devices, it is often suitable to meet the requirements outlined in Table 2.1 below.

Table 2.1 Guidelines for Wi-Fi requirements

Parameter	Description	Requirement
Signal strength	The signal strength from the robots' perspectives when connected to the best access point.	Min. -70 dBm
Secondary signal strength	The signal strength from the robots' perspectives when connected to the second best access point.	Min. -75 dBm
Signal to noise ratio	Signal to noise ratio from the robots' perspectives.	Min. 20 dBm
Data rate	Rate of data communicated to and from each robot. This is the transfer speed of communications.	Min. 20 Mbps
Channel interference	Number of access points per channel available when signal strength is lowered to -85 dBm	Max. 2 AP/ch at -85 dBm
Latency (round trip time, ping)	Time taken to send and receive messages from robots by, for example, pinging them.	Max. 200 ms

Table 2.2 Guidelines for general network requirements

Parameter	Description	Requirement
Throughput	The maximum potential data that can be transferred over a period of time. Must support 20 Mbps for each robot on the network. The data rate and throughput requirements should be interpreted as that the network must support robots sending and receiving at least 3 Mbps of data with a transfer rate of at least 20 Mbps.	Min. 3 Mbps/robot
Packet loss	Percentage of communication packets that can be lost.	Max. 2%

Additionally, your network must fulfill the following requirements:

- There must be full Wi-Fi coverage throughout the traveling path of all robots. You can evaluate this using heatmaps—"Wi-Fi heatmap" on page 28.
- There must be a WLAN controller to secure that roaming happens at the correct time and without any authentication errors. Make sure that the company network access points are controlled by the same controller.
- The access points must be set up to communicate and share roaming information.
- Make sure that load balancing on the access points is disabled. The robots must be able to roam freely. Load balancing controls the balancing of traffic, for example, between the 2.4 and 5 GHz bands of your network. Note that terminology may vary between manufacturers of routers and access points.
- Airtime balancing must be disabled if possible. This setting changes how much time a device gets on the network depending on the signal strength. Low-signal devices get less time than high-signal devices. This means that a robot that is far away will be allowed less data than a robot that is close by. Note that terminology may vary between manufacturers of routers and access points. Airtime balancing may also be called airtime fairness by some manufacturers.

The robots are able to perform some tasks under worse conditions than mentioned above. However, key features in MiR Fleet such as Collision avoidance, Auto charging and staging, Limit-robots zones, data synchronization between robots, and fleet mission execution will not work optimally or at all.

If more than 60% of the Wi-Fi channel is being used, the MiR system will be affected by latency and packet loss.

2.2.1 Throughput

The following table lists the minimum throughput requirements for each device in a MiR system. For robot flows, the requirements are per robot.

Robot <-> MiR Fleet	**Throughput average (peak): 180 kbit/s (220 kbit/s)**
Uplink	130 kbit/s (160 kbit/s)
Downlink	50 kbit/s (60 kbit/s)
Robot <-> PC	**Throughput average (peak): 520 kbit/s (3 Mbit/s)**
Uplink	500 kbit/s (3 Mbit/s)
Downlink	20 kbit/s (150 kbit/s)
Fleet <-> PC	**Throughput average (peak): 110 kbit/s (2.5 Mbit/s)**
Uplink	100 kbit/s (2.4 Mbit/s)
Downlink	10 kbit/s (75 kbit/s)

2.2.2 Latency

Latency is defined as the time it takes for data to travel from one point to another.

Latency is measured in round-trip time (RTT), which is the time it takes for data to travel from source to the destination and back, thereby accounting for twice the distance.

The following table lists the maximum latency requirements between the different devices in a MiR system.

Device flows	Maximum latency (RTT)
Robot <-> MiR Fleet	500 ms
Robot <-> PC	200 ms
MiR Fleet <-> PC	500 ms

2.3 Requirements for MiR Fleet

- MiR Fleet should be connected to the network through a wired connection.
- MiR Fleet must be in the same physical location as the robot. Geographical distance will cause delay between MiR Fleet and robots.

2.4 Wireless network standards

MiR robots can use the following wireless network standards:

- 802.11a (Wi-Fi 2)
- 802.11b (Wi-Fi 1)
- 802.11g (Wi-Fi 3)
- 802.11n (Wi-Fi 4)
- 802.11ac (Wi-Fi 5)

In software 3.x it is possible to modify which frequencies each robot uses on either 2.4 GHz or 5 GHz bands. If you have not specified any channels, MiR robots connect to the best possible channel it has access to.

In software 2.13.0.2 or higher, you can access these options by enabling **Improved Wi-Fi settings**.

2.5 IP configuration

By default, the robot is set up to use DHCP, but the robot can also be set up with a static IP from the robot interface. If you use this option, you can specify the IP, netmask, DNS, and gateway for the robot's Wi-Fi connection.

When connected to MiR Fleet, each robot must have a unique static IP or a reserved DHCP assigned IP as MiR Fleet uses the IP to identify the robots.

Contact your IT department to determine the best solution for your network structure. To avoid conflicts, make sure unique IP addresses are mapped to specific devices.

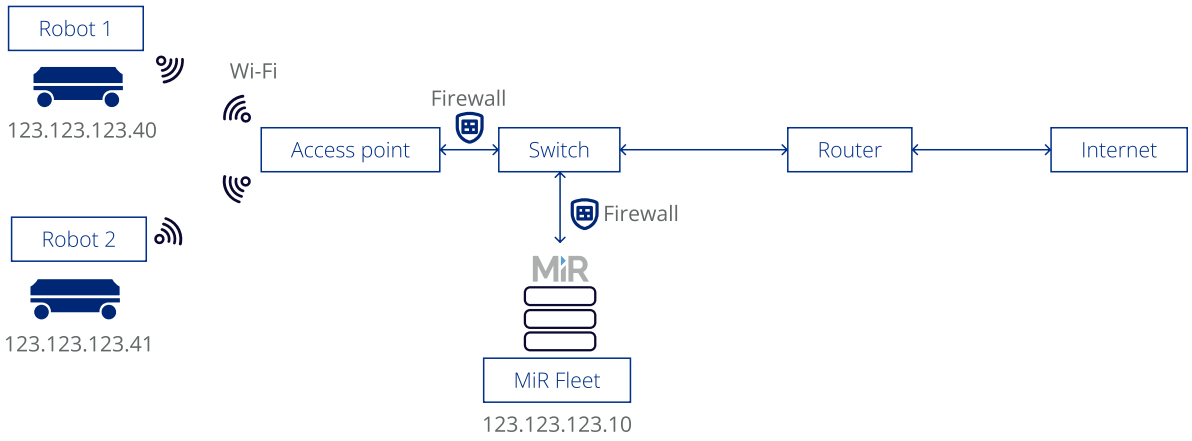
MiR products only work with IPv4. The system is not compatible with IPv6, which is therefore disabled internally.

Due to the robot's internal network configuration, MiR robots are unable to work on an external network with subnet 192.168.12.0/24.

If you are running software 2.13.1.1 or higher, you also have the option to set the robot's default gateway IP address without a Wi-Fi connection being activated. This is useful when you want to utilize an external router or 5G CPE that is connected to the robot via Ethernet to extend the robot's wireless capabilities. For more information, see the guide *How to connect a robot using a 4G or 5G cellular modem*.

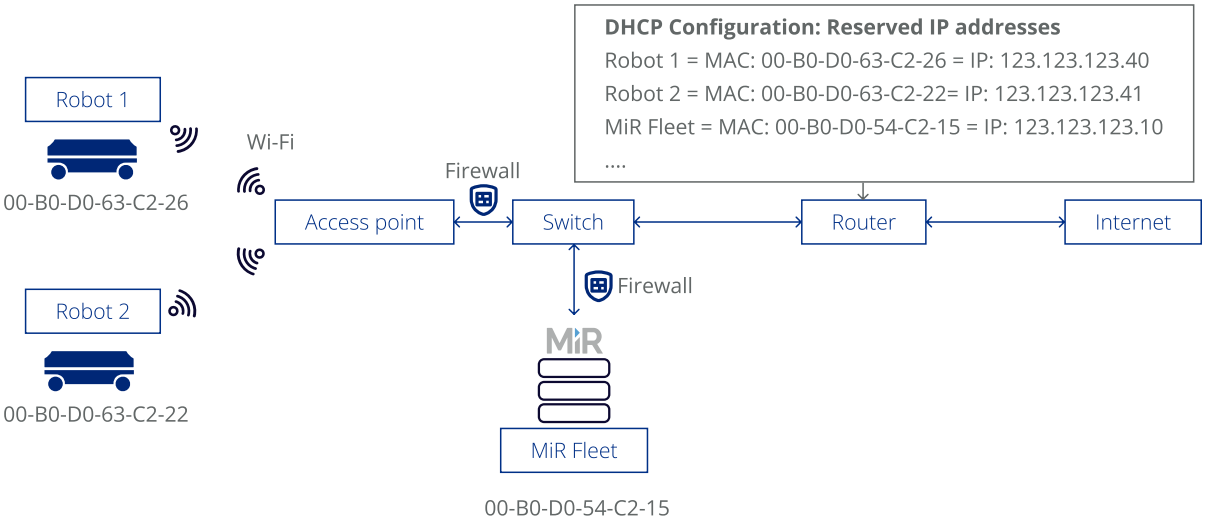
When you use a static IP solution, you set the IP address of the device on the network and configure the system not to change the IP address. You must keep track of which IP addresses have been assigned to avoid assigning the same address to multiple devices.

Figure 2.3 Diagram of a static IP solution



When you use DHCP reservations, in the DHCP server's configuration, you reserve an IP address by binding it to the MAC addresses of robots. The DHCP server automatically assigns the reserved IP addresses to the relevant devices. This protocol reduces the risk of assigning the same address to multiple devices.

Figure 2.4 Diagram of a DHCP reserved IP solution



2.5.1 DNS

MiR robots can work with company-specific DNS servers.

The DNS configuration can be fetched from the DHCP server or assigned manually.

2.6 Ports

All the listed ports are needed for certain functionalities in MiR products. If any of the listed functionalities are to be used on an external network, these ports must be opened and the services allowed by the network firewall.

All ports use the TCP/IP protocol and are all inbound communications except the connection to MiR Remote.

Table 2.3 Ports on MiR Fleet Enterprise

Service	Direction	Port
Robot communication	Robot ↔ MiR Fleet	5060
MiR Fleet web interface	Client → MiR Fleet	80 (HTTP), 44 (HTTPS)
Data	MiR Fleet → SQL database	1443 (if deployed externally)
Robot standalone interface	Client → Robot	5050
Robot web interface	Client → Robot	80 (HTTP), 443 (HTTPS)
REST API	Client → Robot	8080 (HTTP), 443 (HTTPS)
MiR Fleet API	Client → MiR Fleet	80 (HTTP), 443 (HTTPS)
Robot recovery interface	Client → Robot	8888)
ROSbridge communication	Client → Robot	9090
Modbus	Client → Robot	502
MiR Support login (SSH)	Client → Robot	22
MiR Remote	Client ↔ Robot	80

Table 2.4 Ports on software 3.x

Service	Direction	Port
Robot communication	Robot ↔ MiR Fleet	80 (HTTP), 443 (HTTPS)
REST API	MiR Fleet → Client	8080 (HTTPS)
MiR Fleet web interface	Client → MiR Fleet	80 (HTTP), 443 (HTTPS)
ROSbridge communication	Client → MiR Fleet Client → Robot	9090
Robot web interface	Client → Robot	80 (HTTP), 443 (HTTPS)
Robot recovery interface	Client → Robot	8888
Modbus	Client → Robot	502
MiR AI Camera	MiR AI Camera → MiR Fleet	1908 and 80
Elevator (Hitachi driver)	MiR Fleet → Elevator driver	4840
Elevator (OPC UA driver)	MiR Fleet → Elevator driver	4841
MiR Support login (SSH)	Client → Robot	22
MiR Remote	Client ↔ Robot	80

Table 2.5 Ports on software 2.10.0 and higher

Service	Direction	Port
Robot communication	Robot ↔ MiR Fleet	443
ROSbridge communication	Robot ↔ MiR Fleet	9090
Modbus	Client → Robot	502
MiR AI Camera	MiR AI Camera → MiR Fleet	1908 and 80
Elevator (Hitachi driver)	MiR Fleet → Elevator driver	4840
Elevator (OPC UA driver)	MiR Fleet → Elevator driver	4841
MiR Support login (SSH)	Client → Robot	22
MiR Remote	Client ↔ Robot	80

Table 2.6 Ports on software 2.9.0.1 and lower

Source	Destination	Port
Robot web interface	Client → Robot	80
REST API	Client → MiR Fleet	8080
ROSbridge communication	Robot → MiR Fleet	9090

Source	Destination	Port
Modbus	Client → Robot	502
MiR AI Camera	MiR AI Camera → MiR Fleet	1908 and 80
Elevator (Hitachi driver)	MiR Fleet → Elevator driver	4840
Elevator (OPC UA driver)	MiR Fleet → Elevator driver	4841
MiR Support login (SSH)	Client → Robot	22
MiR Remote	Client ↔ Robot	80

2.6.1 Communication examples

The following are simple examples of common communications established with or between MiR products. Depending on how you have segmented your network, it may be necessary to implement network policies to accommodate the MiR product communication traffic patterns to ensure they work as expected.

Connecting to the robot or MiR Fleet interface through HTTPS (SW 2.10.0 or higher)

You initialize this communication by contacting the robot or MiR Fleet web server on port 443/TCP.

When the interface loads, the web browser initializes a WebSocket Secure connection from your device to the robot or MiR Fleet via port 443/TCP. If you are connecting to the MiR Fleet interface, the browser will also initialize the WebSocket Secure connection to each robot connected to MiR Fleet.

MiR Fleet communication to the robot through HTTPS (SW 2.10.0 or higher)

MiR Fleet initializes the communication to MiR robots on port 443/TCP. All communication between MiR Fleet and the connected robots is done via REST.

Connecting to the robot or MiR Fleet interface through HTTP (SW 2.9.0.1 or lower)

You initialize this communication by contacting the robot or MiR Fleet web server on port 80/TCP.

When the interface loads, the web browser initializes a WebSocket connection from your device to the robot via port 9090/TCP. If you are connecting to the MiR Fleet interface, the browser will also initialize the WebSocket connection to each robot connected to MiR Fleet.

MiR Fleet or MiR robots connecting to MiR Remote

You initialize the communication when you select **Connect to MiR Remote** in the user interface. When you select **Connect to MiR Remote**, the robot or MiR Fleet will attempt to establish an outbound communication to the MiR Remote Server hosted at ssh.mir-robots.com via port 80/TCP.

2.7 Network security

MiR robots support different security protocols for wireless networks. All compatible protocols are listed below:

- WPA/WPA2 Personal
- WPA/WPA2 Enterprise:
  - PEAP
  - EAP-TLS: Certificates only accepted in .pem, .pfx or .p12 format.

WPA/WPA2 Enterprise requires the server to support TLS 1.2 or higher. MiR robots will not connect to networks using TLS 1.1 or older TLS/SSL encryption protocols.

See the guide *How to connect a MiR robot to a Wi-Fi network* for more information on compatibility between robot software and encryption protocols. You can find this guide on MiR Support Portal.

MiR robots can also connect to a hidden SSID. However, you should avoid using them.

3. Planning your network

MiR strongly recommends consulting a Wi-Fi specialist to help determine and implement a sufficient wireless network infrastructure for your MiR application.

The following sections provide guidance for how you can plan and determine a suitable Wi-Fi network setup.

3.1 Site map and access point positions

The placement of access points is dependent on multiple factors. The wireless signal can easily be degraded or lost if there are walls, shelves, or other obstacles in the way.

MiR recommends that a network report is drawn up.

The ideal report should document every detail of the network, such as:

- Current access point positions
- Current performance
- Signal coverage
- Interference
- Channel allocation
- Radio frequencies used (2.4 GHz/5 GHz)
- SSID(s) offered

The report should evaluate the network needs and how they can be achieved. For example, if additional or a new generation of network equipment is needed, access points need to be relocated or equipped with different antennas, channel allocation should be altered, or more advanced configuration of the WLAN controller is required.

MiR recommends consulting a map of the entire site and identifying the positions of current access points or determining the ideal location for new access points. To help determine where access points would be best positioned, label the map with information such as:

- Infrastructure that may pose issues to the wireless signals, such as concrete walls and metal structures especially.
- For each access point note down:
  - The SSID (or SSIDs) exposed by the access point
  - The channel used
  - The radio frequency: 2.4 GHz or 5 GHz
- Devices or machinery that generate radio frequencies that may interfere with the access point signals, such as microwave ovens, cordless phones, and Bluetooth-enabled devices.
- The number of physical obstacles that are often within each room or building, and whether there are people there who are likely to have personal devices such as phones or tablets. These devices and the density of people can also affect the wireless performance.

3.2 Network capacity

To meet the requirements, you must ensure that your network has the capacity to handle the number of devices connected to it. Determine the following:

1. The number of devices that are connected to the network.
2. How much data the devices are transferring at the same time on a busy work day.
3. How many access points are required to ensure that all devices are connected and can transfer data without using over 80% of the access points' capacity.

All devices that connect to the same access point share the throughput capability of that access point. Devices take turns to transmit, so only one device is transmitting at a given time. The higher the number of devices connected to an access point, the longer they must wait for their turn to transmit. Therefore, the number of access points should be sized to the number of devices and their airtime consumption. When increasing the density of access points, reduce the transmit power of the access points to limit interference between them.

Airtime consumption depends on the application throughput (how much a device has to transmit) as well as the data rate (how fast a device can transfer that data).

The aggregate throughput can be calculated by multiplying the single device throughput requirement by the number of devices.

Example:

A single robot requires 180 kbit/s. The aggregated throughput for 5 robots is: 180 kbit/s × 5 = 900 kbit/s.

When designing your network, always consider the slowest devices and the areas with the worst coverage. Legacy devices do not support high data rates, so they will have a larger airtime consumption and slow down other devices.

3.3 Wi-Fi heatmap

Consult a Wi-Fi expert to execute a site survey including a heatmap that you can use to identify any area with weak coverage. It is important that there is a strong Wi-Fi signal everywhere across the site where MiR robots operate.

If you have MiR robots that are already operating on your site, you can use MiR Insights to generate a Wi-Fi heatmap based on their connection to the network. For more information about how to evaluate this, see "Evaluating the network performance" on page 42.

If there are areas that are not covered, see "Improving your Wi-Fi setup" on page 29 for suggestions on how you can improve your Wi-Fi setup.

4. Improving your Wi-Fi setup

If you have determined that your Wi-Fi setup is not sufficient, there are multiple methods to improve your Wi-Fi coverage. MiR recommends consulting a Wi-Fi specialist to identify the best way to improve your setup. The following sections outline suggestions that you and the Wi-Fi specialist can consider to improve the Wi-Fi coverage.

If it is only some of your robots that have connection issues in certain areas, consider modifying those robots as described in "Robot modifications" on page 38. Applying any modification to the robot violates the compliance of the robot and it must be re-evaluated to ensure compliance with national requirements.

4.1 Radio frequency interference

If you have identified any access points that are located close to devices that generate radio frequency, you should consider the following:

- Monitor whether MiR robots experience issues around the radio frequency source. If they do, try to move the access point further away from the radio frequency source and see if this improves the performance of the robots in the area.
- Shield the noise source so it does not radiate frequency interference.
- Consider switching radio frequency (from, for example, 2.4 GHz to exclusively using 5 GHz).
- Try to arrange access points so they are within direct line of sight of each other.

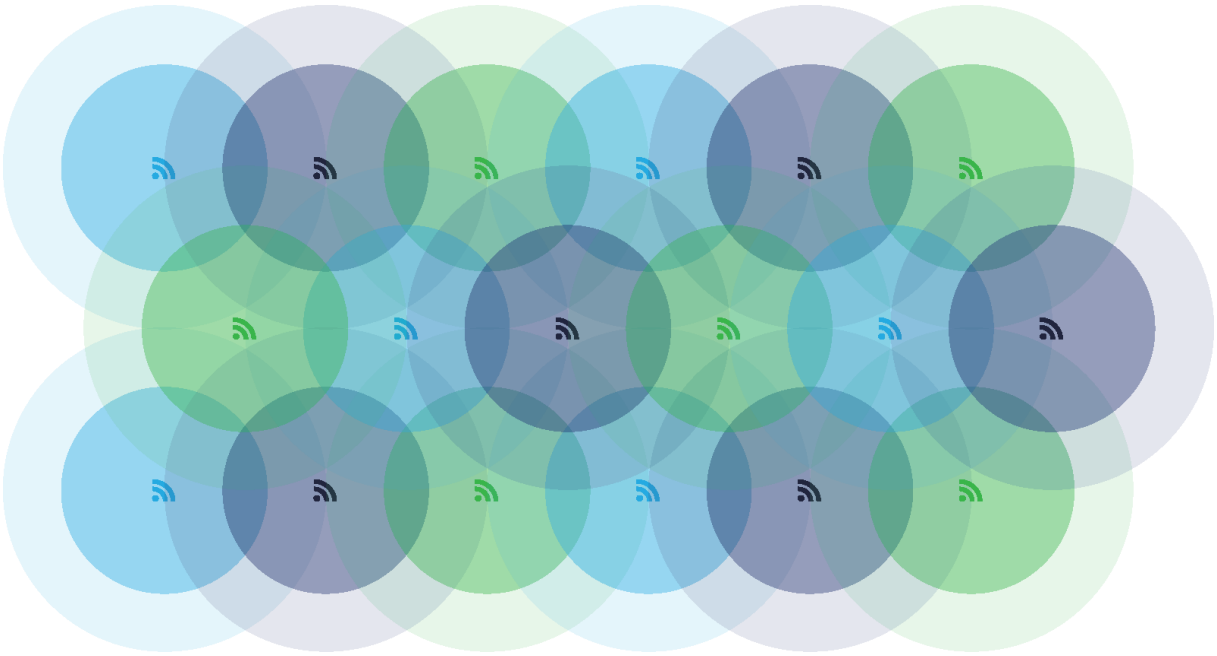
Note that it does not matter whether it is the access point or the robot that is close to the interference source; if either of them are close to the interference, communication can be disrupted.

4.2 Channel planning and overlapping coverage cells

Although radio frequency can interfere with the Wi-Fi signals, the Wi-Fi signals are affected more often by other Wi-Fi signals. To minimize this interference, it is important to arrange and configure your access points as follows:

- Make sure that neighboring access points run on different and non-overlapping channels.
- Ensure there is only enough overlap between access point coverage areas to ensure a safe handover when a robot reassociate from one access point to the other.

Figure 4.1 Illustration of a simplified scenario where access points cover a circular area in a site without any interference from structures or other devices

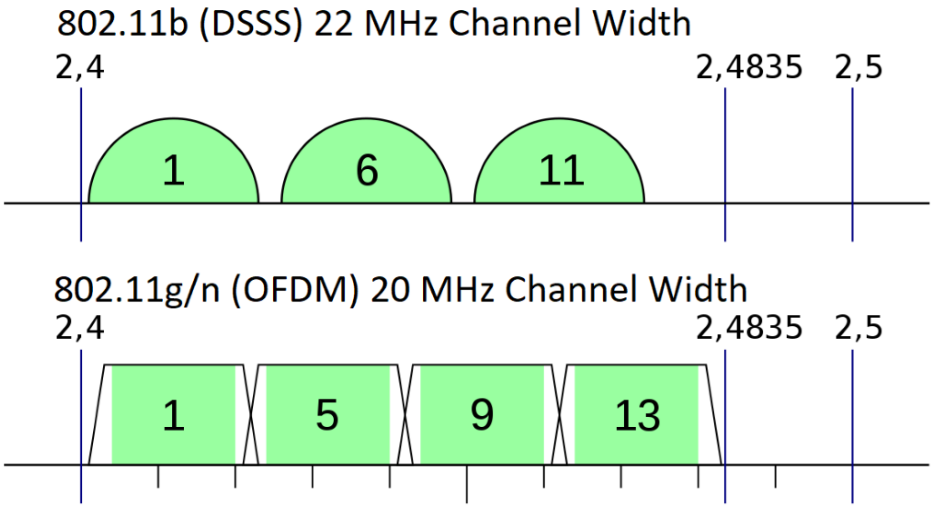


4.2.1 Channel planning 2.4 GHz

When you are using a 2.4 GHz band, always use a channel width of 20 MHz per access point, and avoid using channels where the frequencies overlap. Since channels are divided by only 5 MHz, you should only use channels with four or five channel intervals to avoid channels interfering.

In principle, 802.11n (Wi-Fi 4) allows assigning two channels (40 MHz) per access point, but that interferes with too many channels and is only useful in simple cases with few access points.

Figure 4.2 Channel separations on 802.11b (Wi-Fi 1) and 802.11g (Wi-Fi 3) standards



There are two possible channel selections:

- If you are within the North American region, there are 1-11 channels available. To avoid interference between channels, only use channels 1, 6, and 11.
- If you are using 802.11b (Wi-Fi 1), the channels have a width of 22 MHz. To avoid interference between channels, only use channels 1, 6, and 11.
- If you are outside of North America and are not using 802.11b (Wi-Fi 1), there are often 1-13 channels available. To avoid interference between channels, only use channels 1, 5, 9, and 13.

4.2.2 Channel planning 5 GHz

There are significantly more channels available on a 5 GHz band. The available channels are region dependent. To determine which channels you can use in your region, consult a Wi-Fi specialist or your local governmental body in charge of the regulatory domain for 5 GHz.

All channels on a 5 GHz band have a frequency width of 20 MHz or a multiple of 20 MHz. Channels on a 5 GHz band are also divided by 5 MHz intervals, meaning that only every four channels are defined to ensure there is no overlap between channel frequencies.

If a sufficient number of channels is available to avoid interference, it can be advantageous to use two channels (40 MHz) per access point. When an access point uses two channels, it is able to transfer data twice as fast to and from the connected robots. Keep in mind, if each access point uses two channels, the number of available frequencies is halved. You must ensure that you can keep the coverage area of access points that are using the same channels separated—see Figure 4.1.

For access points where the channel utilization is especially high, you can also use four channels (80 MHz) per access point. This can be efficient if only a few clients with high throughput requirements are connected. This is often not required for MiR products.

4.2.3 Increasing Wi-Fi capacity with channel planning

To improve the Wi-Fi capacity you can adjust your channel configuration as follows:

- If there are a sufficient number of available channels, you can add more access points that are not using interfering channels, or increase the throughput used by each access point.
- If all available channels are in use, you can minimize the area of interference by reducing the transmission power per access point. This will also shrink the coverage area. Make sure these do not drop below the required value.
- To focus the signal strength within the coverage areas without increasing the signal strength in interference areas, you can use directional antennas.
- Both 2.4 GHz and 5 GHz have advantages and disadvantages.
  - **2.4 GHz:** Has longer range and is better at penetrating metal and concrete, but it is limited to three main channels and transmits data at lower speeds. Fewer channels result in signal noise, and most production environments have a very high noise floor on the 2.4 GHz band. Many technologies can create noise on the 2.4 GHz band, such as USB and Bluetooth.
  - **5.0 GHz**: Has shorter range and not as good performance traveling through obstacles as 2.4 GHz, but there are more main channels available, and it transmits data at higher speeds. The exact number of channels depends on the region you are in.

Both adjacent-channel and co-channel interferences should be avoided or minimized. A general recommendation is to use different channels for neighboring access points. Be aware that adjacent channels in the 2.4 GHz band are overlapping, therefore non-overlapping channels should be used in order to avoid adjacent-channel interference.

It is recommended to conduct a proper site survey to make sure that a client always has adequate duplicate coverage from multiple access points. Each Wi-Fi client station needs to connect to an access point with a minimum RSSI of -70 dBm and a backup secondary access point with a minimum RSSI of -75 dBm.

Roaming problems will occur if there is not enough duplicate cell coverage. Too little duplicate coverage will effectively create a roaming dead zone, and connectivity might even be temporarily lost, however, too much duplicate coverage will also cause roaming problems.

Example:

A client station may stay associated with its original access point and not connect to a second access point, even though the station is directly underneath the second access point.

This can also create a situation where the client device is constantly switching back and forth between two or more access points on different channels. Most access point manufacturers recommend 15-30% overlap of -70 dBm coverage cells.

4.3 Minimum data rate

Setting the minimum data rate can improve a robot's ability to roam well between access points and improve the utilization of the Wi-Fi capacity. The default minimum data rate for legacy 802.11b (Wi-Fi 1) is 1 Mbps and for newer standards it is 6 Mbps. The following points describe why you may want to change the minimum data rate:

- Access points transmit beacons at the lowest available data rate per SSID. With a low data rate, a significant percentage of the capacity is wasted on transmitting beacons. With a high data rate, the beacons are transmitted faster and utilize less of the network capacity.
- Increasing the minimum data rate will make robots search for access points where they can transfer data faster. Many Wi-Fi clients stick to an access point for as long as possible before changing, even if they can connect to access points with a stronger signal.
- The Wi-Fi utilization is also improved, since robots do not spend as much time transferring data at low rates through access points where their connection is poor. With better roaming, the robots will spend more time transferring data through access points with a faster data rate.

At sites with good and stable Wi-Fi coverage, it can be an advantage to increase the minimum data rate to 12-24 Mbps. High-density 5 GHz deployments may have an even higher optimal minimum data rate.

On sites where the Wi-Fi coverage often varies, for example in warehouses where the Wi-Fi is affected by changing inventory, it may be necessary to keep the minimum data rate low, to ensure that robots are always able to connect to an access point.

4.4 SSID and roaming considerations

If you are using multiple SSIDs, you should consider the following:

- Access points can transmit multiple SSIDs where each SSID provides a logical separation between different networks. All SSIDs and access points on the same frequency share the same physical channel. Traffic on one SSID will degrade the performance (latency, packet loss, and data rate) on other SSIDs on the same channel. For this reason, critical SSIDs should therefore use their own channel, while secondary SSIDs can use another.
- Robots will always favor the access point with the highest estimated throughput. If you have multiple access points serving the same SSID on different bandwidths simultaneously, robots are more likely to only use the access point the the higher bandwidth.
- Each SSID broadcasts a beacon at the minimum data rate. If the minimum data rate is high, adding additional SSIDs does not impair the capacity significantly, but at low minimum data rates, the number of SSIDs should be limited to the ones you really need.

When configuring roaming (changing to an access point with a better signal), you should consider the following:

- If you are using software 2.x, for roaming to work, the access points must use the same SSID, use the IP addresses of the same network segment, and be in the same VLAN.
- If you are using software 3.x, there is the option to enable roaming between all of the connected SSIDs. Note that at each time the robot jumps between connections, it will always be connected to a single network.
  - This setting is disabled by default and should be used only for specific use cases. For simplicity and for better performance, we recommend connecting robots to one network only, preferably dedicated to the MiR system.
  - If you are using dynamic IP allocation (DHCP), the robot's IP address may change when the robot roams to a different network. Since robots are associated to MiR Fleet using their IP addresses, this may result in MiR Fleet losing connection to robots.
  - To enable roaming between multiple SSIDs, go to **System > Settings > Wi-Fi** and enable **Connect all**. Add all of the SSIDs you want your robot to roam between.
- To ensure the robots transition to other access points smoothly, there must be good secondary coverage. In other words, when a robot moves away from one access point, the signal strength from the next access point must be good before the signal quality from the first degrades—see "Network requirements" on page 12.
- The network should support fast reauthentication to other access points. You can limit the security measures to very basic WPA2-PSK to increase the authentication speed, but there are also other options for caching the keys for authentication, which are just as fast and do not sacrifice security.
- Hidden SSIDs should be avoided when stable and optimal roaming performance is desired. While connected to an access point, a robot listens passively for beacons from other access points and creates a list of options to roam to. Hidden SSIDs don't broadcast their name in beacons, making it impossible for the robot to construct this list in advance. In order to roam in such an environment, the robot has to disconnect from its current access point and perform an active scan by sending probe requests to all the access points. Only after that, can the robot construct the list of options and pick the best candidate to connect to. Since this process requires disconnection and active scanning, it can take several seconds to complete, causing complete loss of communication in the meantime.

4.5 Wi-Fi watchdog

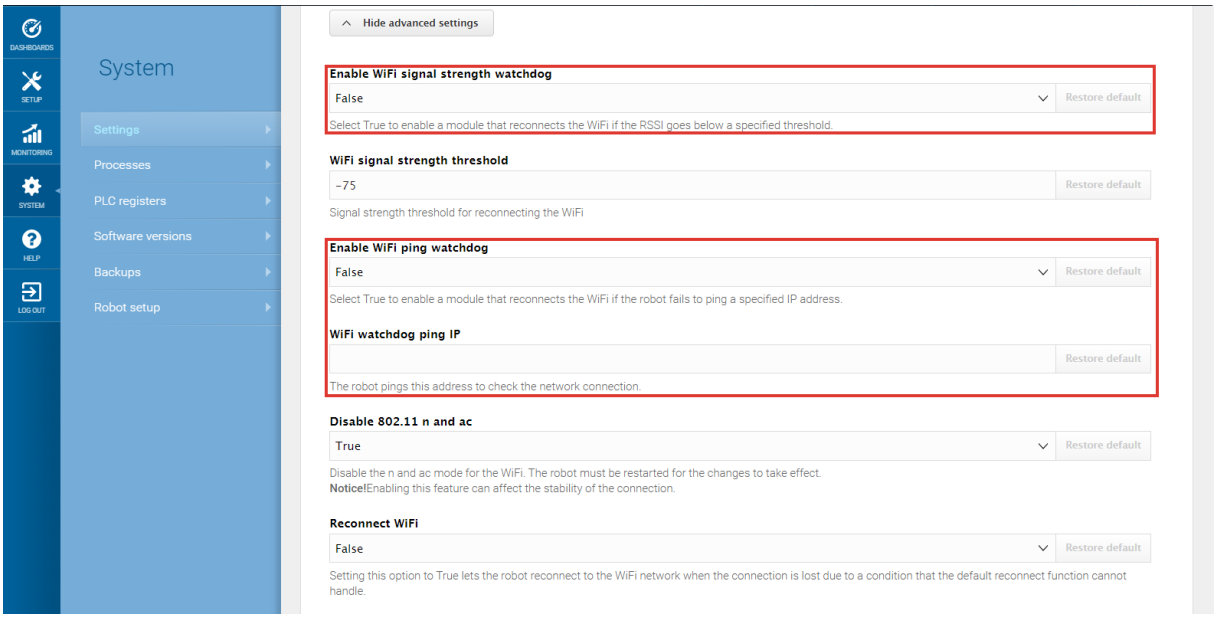
The Wi-Fi watchdogs are only available in software 2.x. In software 3.x, they are no longer needed. Use the **Background scan frequency** setting instead to influence how aggressively the robot should scan for access points with a stronger signal.

In software 2.x, the purpose of the Wi-Fi watchdog functions is to trigger a reassociate (roaming) event because the robot's Wi-Fi daemon is not accomplishing its task satisfactory or in time.

Wi-Fi daemon is a piece of software that manages (connects, roams, disconnects) Wi-Fi connections. The term daemon covers a program that runs continuously and handles periodic service requests that a computer system expects to receive.

MiR robots have two Wi-Fi watchdog functions that can be enabled in the robot interface under **System > Settings > Wi-Fi > Show advanced settings**:

- Enable Wi-Fi signal strength watchdog
- Enable Wi-Fi ping watchdog



Do not enable the signal strength watchdog and the ping watchdog simultaneously as they function better when only one is used.

4.5.1 Enable Wi-Fi signal strength watchdog

The Enable Wi-Fi signal strength watchdog function enables a module that reconnects the Wi-Fi if the RSSI (Received Signal Strength Indicator) goes below a specified threshold. The function monitors the RSSI level and compares it to the default or user configured threshold value. When the value dips below the threshold, a reassociate (roaming) event is triggered.

Be aware that if the threshold has been set to an unobtainable value, it will cause the RSSI watchdog to trigger reassociation events (forced roaming). In that case, the Wi-Fi connection gets temporarily terminated continuously for no reason.

4.5.2 Enable Wi-Fi ping watchdog

The Enable Wi-Fi ping watchdog function enables a module that reconnects the Wi-Fi if the robot fails to ping a specific IP address. The function uses ICMP (Internet Control Message Protocol) packages to determine if the Wi-Fi link is strong enough to carry a minimum size payload.

Be aware that if you configure the ping watchdog to ping against the server hosting the Fleet, you are not only testing if the Wi-Fi link is sound, but also the connection to the rest of the network and the server hosting the fleet.

In many cases where the ping watchdog causes a lot of reassociation events (forced roaming), it is because the ping destination is unreachable for some reason. Most often the Wi-Fi link is healthy, and the issue is somewhere else, for example, the router, switch, or server. In that case, the Wi-Fi connection gets temporarily terminated continuously for no reason.

4.6 Robot modifications

NOTICE

A MiR robot is only approved for use with the antennas it is designed with. Harmful electromagnetic interference with other products is potentially the result of using an antenna with stronger gain.

Ensure compliance with national requirements if you decide to replace or modify an antenna or mount an additional antenna on the robot.

There are a few modifications you can apply to robots to improve their connection to the network:

- Robots are equipped with internal antennas—see the user guide or integrator manual for your robot for the antenna locations. If your robot is carrying a payload that obscures the antenna radiation pattern (often dense and large objects), consider applying the following actions to improve the connection:
  - Reposition the payload to be at least 40 mm away from the antennas.
  - If your top module enables it, mount an external antenna where interference from the payload is minimized. It is the responsibility of the modifier to ensure that the robot still complies to national requirements. See the *Optional features* list for antennas provided by MiR.
- The internal antennas used by MiR100, MiR200, MiR500, and MiR1000 are only designed for 2.4 GHz. If you want to use them with a 5 GHz network, they may not perform well. Contact MiR Technical Support for our recommendations to improve the performance.

  The internal antennas used by MiR250, MiR600, and MiR1350 support both 2.4 GHz and 5 GHz and are suitable for most applications.
- Older robots have an internal wireless access point that broadcasts a hotspot you can use to connect to the robot.

  If your robot does have an internal access point, it can interfere with other access points. Consider applying the following actions to improve the connection:
  - Turn off the access point on the robot to eliminate the interference—see "Disabling the Wi-Fi hotspot" on the next page.
  - Dedicate a frequency or a band to the robot access points that only they can use. Contact MiR Technical Support for assistance to configure the access point settings.

- Software 2.13.0.2 released several changes in the Wi-Fi handling and Wi-Fi settings. To improve the connection, you can consider updating your robot to this software version or higher. After updating, under **System > Settings > Wi-Fi**, you can enable the new Wi-Fi system. When the new system is enabled, you can edit your Wi-Fi connections to scan more often and specify which channels the robot should scan on for better connections. For more information, see the guide *How to connect a MiR robot to a Wi-Fi network*.

  In software 3.x, the robots can only use the improved Wi-Fi system and you do not have to enable it manully.

4.6.1 Disabling the Wi-Fi hotspot

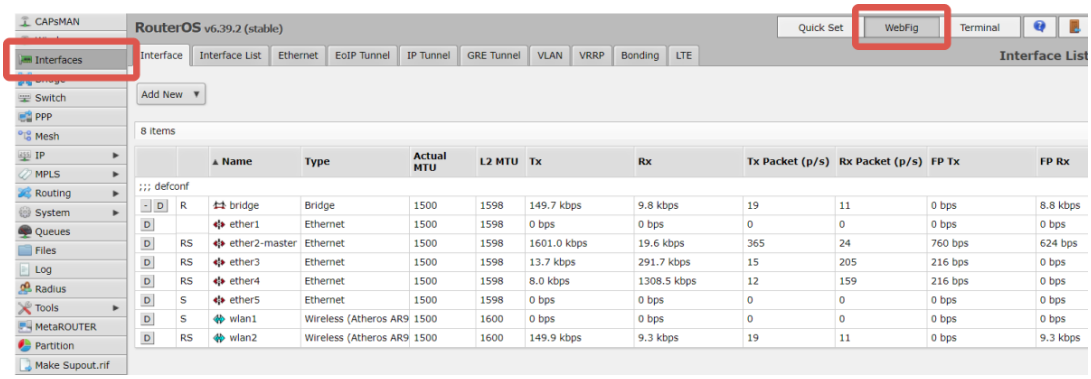
1. Connect to your robot's network using an Ethernet cable. Connect the Ethernet cable from your computer to a port in the robot computer or router.

2. Enter 192.168.12.1 in the browser.

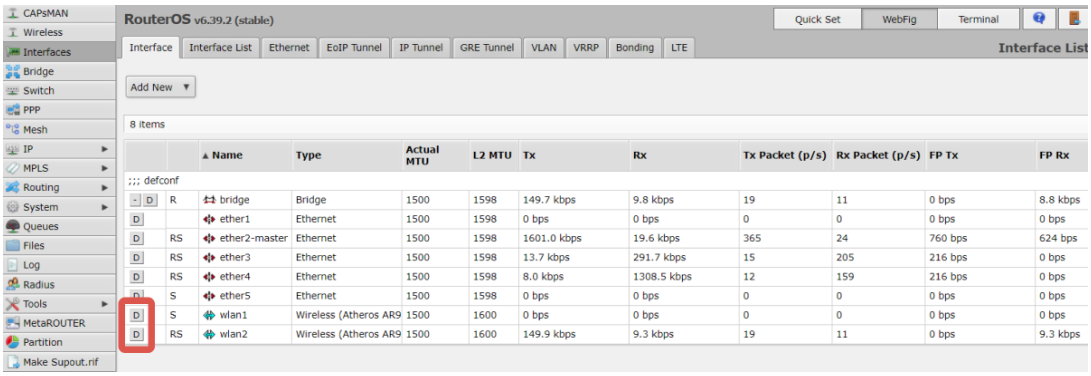
3. Sign in using the following credentials:

   - User: root
   - Password: mirex

4 Go to **Webfig > Interfaces**.



5 Select **D** for wlan1 and wlan2.



4.7 Top module design

The design of the top module mounted to your MiR robot also influences the quality of the Wi-Fi connection. The following list provides some of the minimum requirements you should consider. MiR recommends that you contact a Wi-Fi specialist to help determine the optimal equipment and setup for your site.

- To avoid invalidating compliance with radio emission regulations, such as FCC and CE, use the antennas that are already mounted to the robots.
- Do not surround antennas with conductive, dense, or metallic material. They will have a negative effect on the performance of the antennas.

- You can relocate antennas by extending their connection with cables.

  Keep antenna cables as short as possible and with the fewest connection point. The longer the cable and the greater number of connection points, the more the signal degrades.
- Use 50 Ω coax antenna cables.
- Select equipment that is compliant and suited for the frequency band your site or application uses.
- If your top module manages its own Wi-Fi connection, consider aspects such as:
  - Range
  - Radiation pattern (often you want to use omnidirectional antennas)
  - Frequency band
  - Efficiency
  - Impedence
  - Compliance with standards
  - Interference between the robot and other radio device on the top module
  - Gain
  - Polarization
  - Voltage standing wave ratio (VSWR)

5. Evaluating the network performance

If you meet the network requirements outlined in "Network requirements" on page 12 and are still experiencing issues with the Wi-Fi connection to your MiR robots, you can use MiR Insights to analyze the network from the robots' perspectives. You can use the tool to see a network heatmap that can help you identify problematic areas in your network, and you can review the communication data collected by MiR Fleet and your MiR robots. For more information about how to use MiR Insights, see the guide *MiR Insights User Guide*.

Some of the main things you can look for in the data are:

- If the entire map has a high cycle time for MiR Fleet, but individual robots have a good connection to the network, it is also possible that MiR Fleet is receiving too many requests. In this case, you must review which devices are communicating with MiR Fleet and reduce the requests from devices that are not MiR robots.
- From a MiR Fleet error log, you can also filter the heatmaps to show the performance of individual robots. This is a fast way to determine if there are any robots in particular that have difficulty connecting to the network.
- If you do determine that a certain robot has poor network connection and the suggestions in "Robot modifications" on page 38 do not help, focus on the data from that robot alone.

If you cannot determine why your MiR setup is not performing as expected, contact MiR Technical Support and include an error log from MiR Fleet and any robots that aren't performing as expected. Make sure to generate the error log shortly after you experience any performance issues. Do not turn off your MiR products before generating the error log, otherwise useful troubleshooting data may be lost.

6. Check list

To summarize the content of this guide, when planning or modifying your Wi-Fi network it is recommended to do the following:

1. Ensure your network meets the requirements in "Network requirements" on page 12, or a set of network requirements determined by a Wi-Fi specialist for your setup.

2. If possible, disable load balancing and airtime balancing on your access points.

3. Determine if your network capacity is suitable for the number of devices connected to your network.

4. If you are using MiR Fleet, make sure that:
   - MiR Fleet is connected to the network through a wired connection.
   - MiR Fleet is in the same physical location as the robot. Geographical distance will cause delay between MiR Fleet and robots.

5. Make sure your network uses one of the following network standards:
   - 802.11a (Wi-Fi 2)
   - 802.11b (Wi-Fi 1)
   - 802.11g (Wi-Fi 3)
   - 802.11n (Wi-Fi 4)
   - 802.11ac (Wi-Fi 5)

6. If you are configuring the IP value, make sure to use IPv4.

7. Make sure you are not using subnet 192.168.12.0/24 with MiR robots.

8 Make sure the following ports are open:

- Port 80
- Port 443
- Port 8080
- Port 9090

9 Make sure you are using one of the following security protocols:

- WPA/WPA2 Personal
- WPA/WPA2 Enterprise:
  - PEAP
  - EAP-TLS: Certificates only accepted in .pem, .pfx. or .p12 format

10 If you are using WPA/WPA2 Enterprise, make sure the network server supports TLS 1.2 or higher.

11 Determine if there are areas in your site where there is high interference from the structure, personnel, and other devices.

12 Generate a Wi-Fi heatmap to view the coverage of your access points to determine if there are areas where you need more access points, or the existing ones need to be reconfigured.

13 Check that devices generating radio frequency are not interfering with the signal from nearby access points.

14 Set up your access points so access points using the same channel do not have overlapping coverage areas.

15 Use either a 2.4 GHz or 5 GHz band.

16 Use every four channels to avoid interference.

17 Use directional antennas to focus the signals from the access points.

> **NOTICE**
>
> A MiR robot is only approved for use with the antennas it is designed with. Harmful electromagnetic interference with other products is potentially the result of using an antenna with stronger gain.
>
> Ensure compliance with national requirements if you decide to replace or modify an antenna or mount an additional antenna on the robot.

18 Reduce the power per access point to reduce the coverage area, but make sure the signal strength does not drop below the required value.

19 If your site has a stable and good Wi-Fi coverage, increase the minimum data rate 12-24 Mbps.

20 If you have a low minimum data rate (around 1-6 Mbps), reduce the number of SSIDs.

21 Make sure all access points the robot uses offer the same SSID, use the same VLAN, and use IP addresses within the same network segment.

22 Avoid using hidden SSIDs on your network.

23 Make sure the network supports fast reauthorization to other access points.

24 Make sure the payload of the robot is not interfering with the antenna signal by:

- Mounting an external antenna.

  NOTICE

  A MiR robot is only approved for use with the antennas it is designed with. Harmful electromagnetic interference with other products is potentially the result of using an antenna with stronger gain.

  Ensure compliance with national requirements if you decide to replace or modify an antenna or mount an additional antenna on the robot.

- Repositioning the payload at least 40 mm from the antenna.

25 For robots that can broadcast a Wi-Fi hotspot from their internal access point, you can turn off the access points on the robots to eliminate interference, or dedicate a channel that only the robot access points can use.

26 Re-evaluate all of the above points regularly as Wi-Fi is not a static thing. Performance changes with the usage pattern, the number of clients, the type of clients, and with changes to the physical environment.