Designing an Enphase Zigbee network tech brief

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Supporting documents

This technical brief should be read along with the following supporting documents:

- Zigbee Range Test user manual
- Zigbee range extension FAQ
- Zigbee Wireless Range Extender data sheet
- Zigbee Wireless Range Extender installation guide
- Zigbee Wired USB Extender installation guide

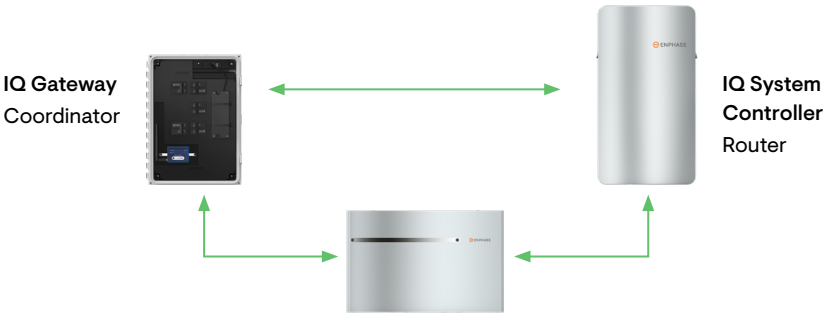
The North American version of Zigbee Wireless Range Extender can be purchased here.

Enphase Zigbee Network

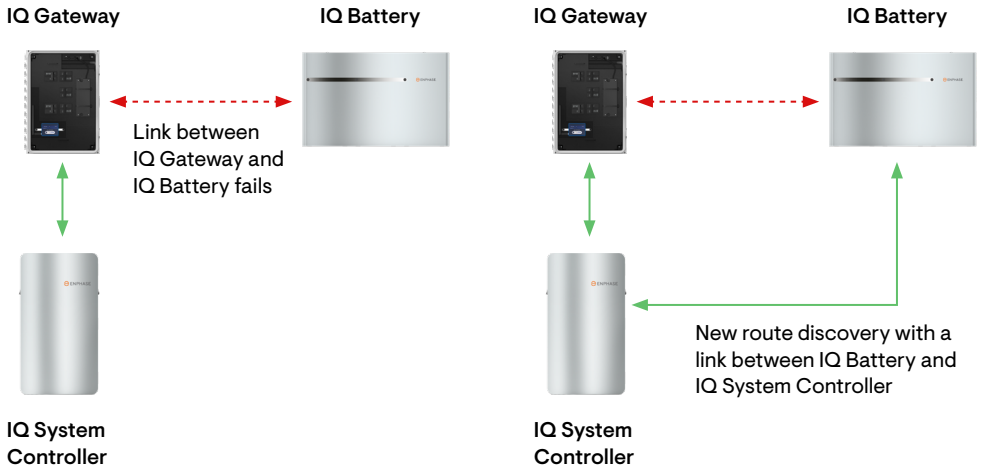
This technical brief contains a detailed explanation of steps outlined in Range Test User Guide to design a robust Enphase Zigbee Network with a high RF link quality.

Zigbee is a wireless mesh network based on the IEEE 802.15.4 standard. Zigbee devices have access to 16 separate 5MHz channels (11-26) in the 2.4 GHz band. Zigbee channels 15, 20, 25, or 26 avoid the most common WiFi channels (1, 6, 11). The Enphase Zigbee Network chooses one of channels 15, 20, 25, or 26 based on minimizing interference from other Zigbee and WiFi networks operating at a site.

The Enphase Zigbee Network consists of equipment in the Enphase Energy System, an IQ Gateway, an IQ System Controller in case of grid agnostic systems, and one or more IQ Batteries as shown in the figure below. The IQ Gateway is an edge device between the Enphase Zigbee Network and the Enphase App. It sends periodic messages to the IQ System Controller and the IQ Battery and receives telemetry data from them. It operates as a Zigbee coordinator and is the only device that can start a Zigbee network. It is responsible for selecting the Zigbee channel, personal area network identifier (PAN ID), security policy, and stack profile for a network. The IQ System Controller and IQ Batteries operate as Zigbee routers. They can relay messages to and from other devices and are key to extending the range of the network by enabling distant devices to communicate with the coordinator using the wireless mesh.

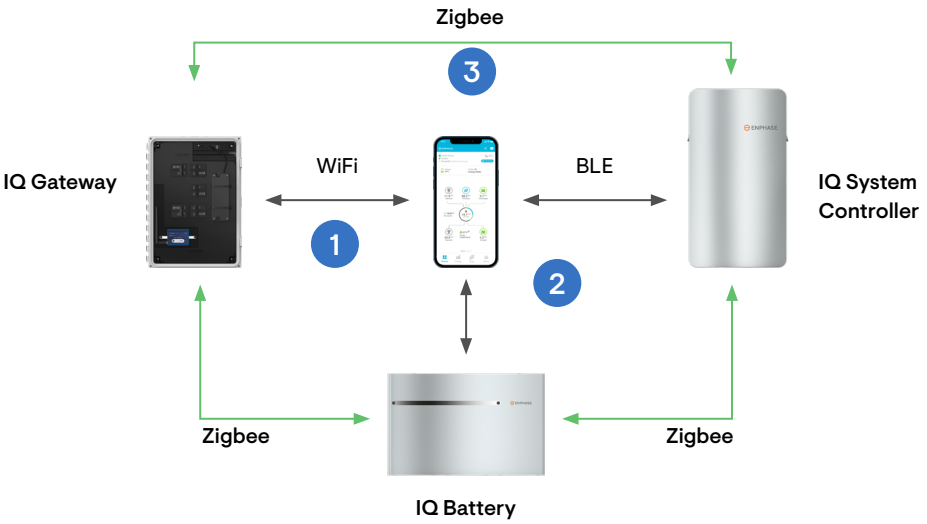


The mesh capabilities of the Zigbee network provide numerous alternate paths for Zigbee messages to reach a destination in case of broken links or wireless interference. Optimal routes are selected by the network layer and may involve hops through other Zigbee equipment as shown in the below figure.



Provisioning and forming Enphase Zigbee Network

Provisioning the Enphase Energy System requires a combination of WiFi, Zigbee, and Bluetooth technologies as illustrated in the below figure.



1. **Establish WiFi link between the Phone and the IQ Gateway:** The Enphase Installer App in the Phone communicates with the IQ Gateway through WiFi AP mode to initiate and control the provisioning process.

2. **Establish BLE link between the Phone and the IQ Batteries & IQ System Controller:** Through a discovery process via mobile BLE, the Installer App connects to each IQ Battery and the IQ System Controller that has been scanned and sends temporary network information to them.

3. **Establish Zigbee link between the IQ Gateway and IQ Batteries/IQ System Controller:** The IQ Gateway in its capacity as a Zigbee coordinator forms a secure Zigbee mesh network with the IQ Batteries and IQ System Controller.

RF link quality

Zigbee RF link quality can be defined as a ratio of RF signal power and sum of powers from all sources of RF noise.

Signal strength is the usable power of the radio waves.

Received signal strength indicator (RSSI) is the measured power of the signal in the RF band of operation, expressed in dBm or decibels relative to a milliwatt. Smaller negative numbers represent a cleaner/stronger signal.

Noise (dBm) is the combined power of all unwanted interfering signal sources, such as crosstalk, radio frequency interference, distortion, etc in the RF channel of operation. This value is measured in decibels. The closer this value is to receiver sensitivity, the better, because that means there is little to no interference.

Signal-to-noise ratio (SNR) is a measure of amount by which the signal power exceeds the noise power.

SNR = RSSI (dBm) – Noise power (dBm)

For example, if RSSI = -60dBm, and Noise power = -90dBm, then:

SNR = (-60dBm) - (-90dBm) = 30dBm

Packet error rate (PER) is the number of incorrectly received data packets divided by the total number of received packets and is expressed as a percentage.

Both PER and RSSI are indirect measures of SNR. If PER is low, and RSSI is high, it implies the RF link has a good SNR. On the other hand, if PER is high and RSSI is low, then a poor SNR is implied. For this reason in Range Test, both RSSI and PER are used to determine RF link quality.

The Zigbee radios in the Enphase Storage System are designed to achieve effective communication under difficult environmental conditions. Each radio has a transmit (TX) power of +19dBm (79mW) in North America and +8dBm (6.3mW) in EMEA. The receive (RX) sensitivity is -102dBm irrespective of region. While the Enphase Zigbee radios have a high transmit power and excellent receive sensitivity, the actual field performance of the network depends on many factors.

In free space, RF signal power reduces by 6dBm with every doubling of distance. However often RF signals have to travel through multiple physical obstructions like walls or furniture. Depending on the nature of the obstruction there can be significant attenuation of the signal.

Other wireless technologies such as WiFi also use RF signals at 2.4GHz. The presence of other signals in the same frequency band causes interference. Weather conditions can have a large impact on RF link quality. Lightning, for example, can cause electrical interference, and fog can weaken signals. Daily human activity can also have an impact on RF link quality. People walking by the equipment or parked cars in case the IQ Batteries are located in a garage can also impact the RF signal strength. Often at sites, a daily variation in RSSI values of up to 30dBm can occur.

General equipment installation guidelines

The following guidelines can be useful while installing the Enphase Energy System.

- Install all equipment in Enphase Energy System within line of sight. This is the best configuration and ensures highest RF link quality.
- In case the equipment cannot be co-located, limit RF signal transmission to penetrating not more than 3 walls. Walls and other common household objects cause absorption and reflection.
- Stucco, concrete, and brick walls significantly attenuate the RF signal and installing equipment on both side of these high attenuation walls is not recommended.
- Avoid locations where there is a lot of human activity such as near entry foyers, doors, and garage walls where RF signal is obstructed by parked cars.
- Maintain an adequate distance between WiFi and Zigbee devices.
  - > 3 m (10 ft) between WiFi and Zigbee devices.
  - > 6 m (20 ft) between WiFi (high gain) and Zigbee devices.
- Do not install wireless devices near machinery such as pumps, motors, fans, or various actuator devices. The resulting EMI (Electro Magnetic Interference) can interfere with Zigbee operation.

The table below qualitatively shows RF attenuation caused by different types of materials.

IMPACT	MATERIAL
Low	Wood
	Plaster
	Plastic
	Fabrics
Medium	Window/clear glass
	Brick/cinder block
	Water
High	Concrete
	Ferrous and non-ferrous material
	Heavy corrugated boxes
	Metal door in brick wall
	Stucco

Zigbee Range Test

The Range Test is a point–to-point test between any two locations at a site. The Zigbee Range Test nodes can be is attached on the wall at any two locations. The Enphase Installer App communicates with the Zigbee nodes over Bluetooth. Zigbee packets are looped around between the two nodes. Both the Received Signal Strength (RSSI) and Packet Error Rate (PER) are measured. Detailed step-by-step guidelines for assembling the Range Test and performing Range Test are provided in Zigbee Range Test user manual.

It is recommended that the Range Test is conducted during Planning and Design phase at a site. This will help installers in eliminating site configurations which lead to a weak or poor RF link quality.

The IQ System Controller and the IQ Batteries can sometimes be successfully provisioned even when the distance between devices is high and RSSI values are very low. However, Enphase does not recommend operating the equipment at very low signal strengths for two reasons:

1. Often large amount of noise or interference is present at sites. Even if network is formed and communication established at low signal strengths, the quality of RF link may be poor, leading to frequent short-term loss of communication and low channel bandwidth.

2. Signal fading due to environmental conditions, movement of humans, rearrangement and moving of furniture and other obstruction, and vehicular movement can cause significant loss of signal strength.

To make sure that sites can meet the above challenges of presence of RF noise and signal strength variation, a threshold of RSSI = -60dBm and PER = 3% is required to be met to pass Range Test. If the test fails, either use of range extension or equipment relocation is recommended.

The table below shows the underlying PER and RSSI threshold values that form the basis of the Range Test results.

ITK DISPLAY	RSSI THRESHOLD	PER THRESHOLD	RANGE TEST PASS/FAIL
Excellent	**-50dBm**	**1%**	**Pass**
Strong	**-55dBm**	**2%**	**Pass**
Average	**-60dBm**	**3%**	**Pass**
Weak	**-65dBm**	**4%**	**Fail**
Unacceptable	**< -65dBM**	**> 4%**	**Fail**

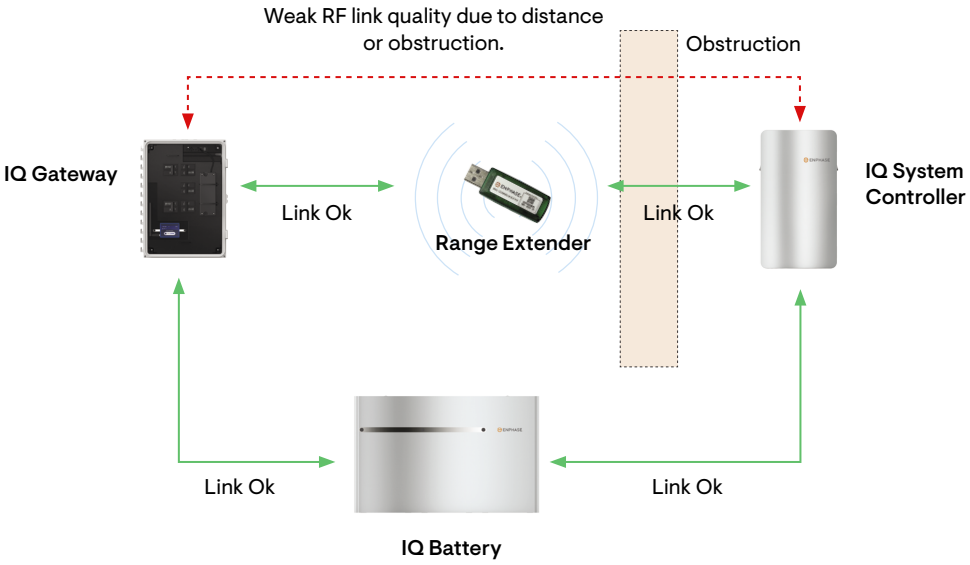
Zigbee range extension

Range extension is recommended whenever the Range Test fails.Enphase recommends two types of range extenders:

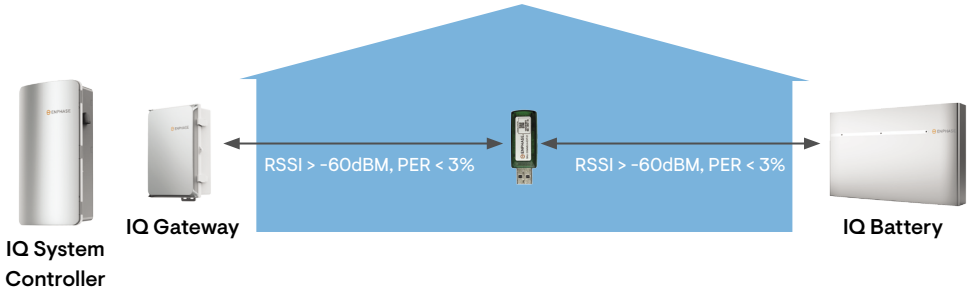
1. Zigbee Wireless Range Extender (ZWRE)

2. Wired USB Extender (WUE)

The ZWRE works as a repeater and provides a path for a “hop” between the equipment. Since the “hop” reduces the effective distance between Zigbee nodes by a factor of 2, packets received by the ZWRE can be expected to have a theoretical RSSI improvement of ~6dBm. It can be deployed at sites where Range Test result is “Weak”. More than one ZWREs is not recommended as there is diminishing return in tradeoff between RSSI improvement and increase in latency.



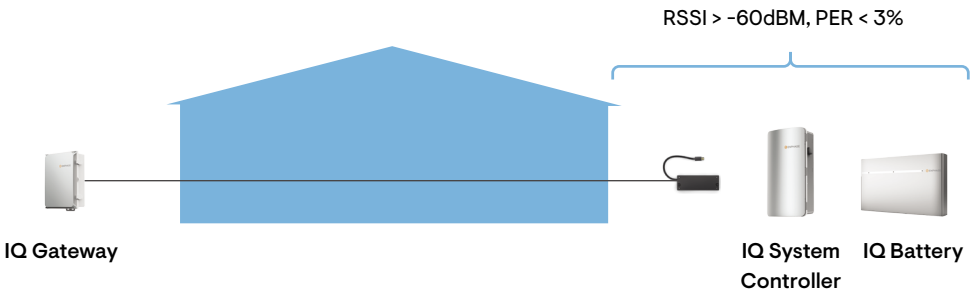
A common use case for installing the ZWRE is shown below. In this site, the IQ Gateway and the IQ System Controller are collocated near the service entrance and the IQ Batteries are installed at a different location often due to harsh weather conditions.



The ZWRE can also be very effective if the direct path between equipment has obstructions such as walls, but the ZWRE provides an alternative path without these obstructions. One example could be sites where the equipment is located on perpendicular walls and do not have line of sight. In these cases, if an appropriate location of ZWRE can be found, then the ZWRE can have a direct line of sight with all the equipment, thereby providing a “hop” with a significantly better RF link quality.

Antenna location is important for optimal performance. ZWRE antennas radiate and receive the best signal perpendicular to the direction they point. Select either a vertical or horizontal position of the ZWRE depending on location of Enphase Energy System equipment.

In sites where the IQ Gateway is located far from the IQ Batteries and IQ System Controller, the WUE can be an effective way to improve RF link quality. In WUE, a USB to ethernet receiver and transmitter pair is used to re-locate Communications-kit close to the location of IQ System Controller and IQ Batteries.



The following steps are recommended for choosing a range extender:

Step 1: Perform Range Test during planning/design phase or before installation. If all the equipment is co-located and within line of sight, range extension may not be needed.

Step 2: If Step 1 fails, continue Range Test to check suitability of ZWRE.

Step 3: If Step 2 fails, repeat Range Test to check suitability of WUE. Use of WUE is recommended if the IQ System Controller and the IQ Batteries are co-located and the IQ Gateway is far from them.

Step 4: If Steps 1-3 fail, consider a different equipment location and repeat Range Test.