

## Wireless Topologies

15 minutes

In this course:

- 1 Overview
- 2 Star topologies
- 3 Mesh topologies
- 4 Cluster-tree topologies
- 5 Choosing the right topology
- 6 Self-organizing networks
- 7 Summary
- ? Quiz

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### Overview

The **topology** of a wireless network is simply the way network components are arranged. It describes both the physical layout of devices, routers, and gateways, and the paths that data follows between them.

In this course you will learn about three common wireless topologies for in-plant wireless field network applications – **star**, **mesh**, and **cluster-tree**. Understanding the strengths and weaknesses of each will help you determine which topology is best for your specific application.



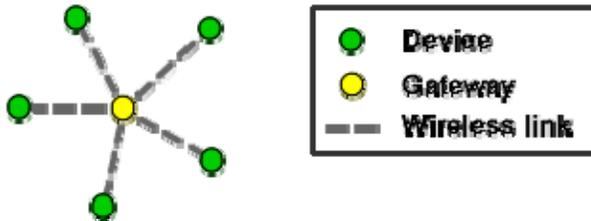
#### Hint:

As you go through the topics in this course, watch for answers to these questions:

- What are the most common wireless topologies?
- Which topology uses the least amount of power? The most?
- How does each topology handle interruptions in transmission paths?
- Which topologies can be used with self organizing networks?

## Star topologies

A star topology is a point-to-point architecture where individual wireless devices, or nodes, communicate directly with a central "hub" or gateway.



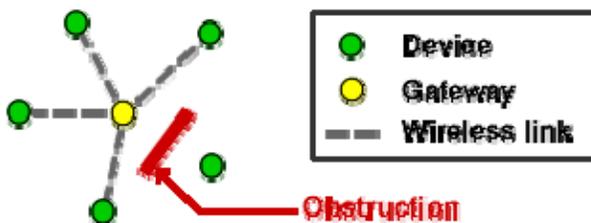
Devices in a star topology communicate only with the gateway – not with each other.

The gateway then transmits the data to a central collection point, such as a control room – either directly, or by connecting to another network. The gateway also receives data from the central point and relays it to the appropriate device.

Because each device communicates directly with the gateway, a star topology is also sometimes described as a "point-to-point" or "line-of-sight" architecture.

These simple, direct wireless connections make star topologies applicable for relatively simple or low-power applications because they can potentially use the least amount of power of all the topologies. However, the distance data can be transmitted (from the wireless device to the gateway) is limited – often 30 to 100 meters if low-power radios are used to extend battery life.

If something disrupts the direct, line-of-sight transmission path between a device and its gateway, there's a good chance communication will be hindered and the data lost. There are plenty of things in a plant to cause such problems, including radio-frequency interference and physical structures such as vessels, piping, and equipment. Even temporary obstructions like trucks, construction equipment, or scaffolding can disrupt communications – as can environmental factors like rain, fog, and humidity.



In a star topology, communication can be interrupted if something disrupts the line-of-sight transmission path between device and gateway.

That's why it's important to conduct a **site survey** as part of the planning for a wireless network based on star topology. The survey identifies where devices can be placed to provide a greater likelihood for line-of-sight transmission (and appropriate range) to the gateway.

Unfortunately, site surveys can be expensive, and they're only a snapshot in time. They can't predict future changes – such as new construction or other environmental changes – that can interrupt that line-of-sight transmission.

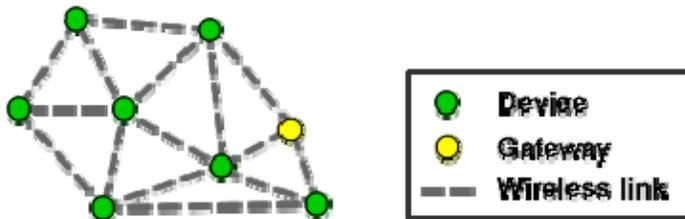
If such changes interfere with communication, you have three options:

- Move the device – which may degrade measurement quality or data reliability
- Move the gateway – which can be difficult if it also has wired connections for communication or power, or if moving it interrupts the transmission path to a different device
- Increase the device signal strength – which decreases battery life, and may still not be sufficient to overcome the interference. (That's why traditional point-to-point wireless devices often have an installed battery life of less than one year.)

Many of these limitations can be overcome by using a topology that allows more than one transmission path between device and gateway.

## Mesh topologies

Unlike in a star topology, where each device talks only to the gateway, the devices in a mesh topology can also communicate with other nodes in the network. A message can "hop" from node to node until it reaches the assigned gateway – a capability called **multi-hopping**.

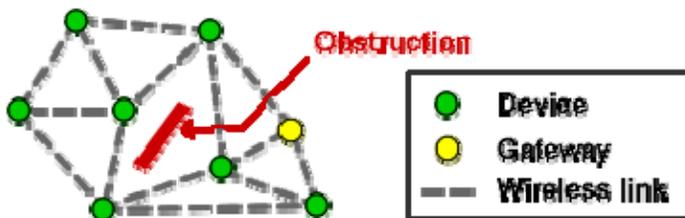


Devices in a mesh topology can communicate with any other network node within range.

This arrangement has both advantages and disadvantages compared to a star topology.

**Easier expansion.** There's no need to add new gateways or relocate existing ones as the network grows. A new device only has to be within range of any existing node to communicate on the network.

**Higher fault tolerance.** Each wireless node has multiple transmission paths back to the gateway and to other nodes. If one path is blocked – or if an intermediate node fails – messages can still get through using other transmission paths. This provides redundancy.



A mesh topology's multiple transmission paths and multi-hop capability enable messages to "go around" blockages or failed nodes.

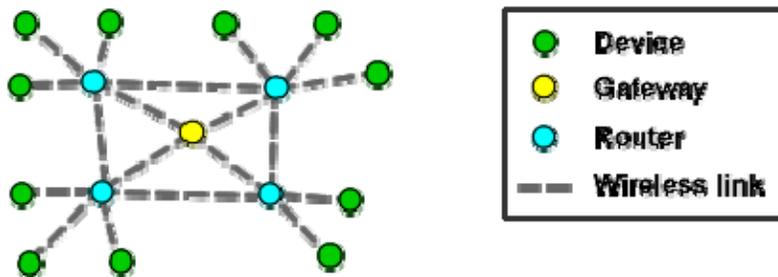
**Potentially higher power consumption.** A traditional mesh topology requires that sensor nodes continuously "listen" for messages from other devices. This "always on" duty cycle reduces battery life.

New network technologies avoid this disadvantage by activating each device only when it needs to send or receive data.

**Network latency.** As the number of hops a device requires to send data to the gateway changes, the latency will also change. Each hop can increase latency, but because measurement updates often occur only once per minute, this latency is typically tolerated by users.

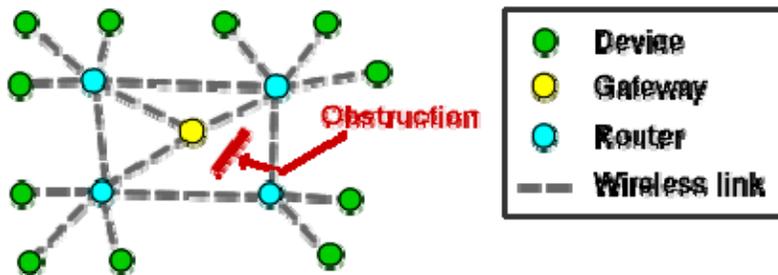
## Cluster-tree topologies

A cluster-tree topology is a hybrid of star and mesh topologies: Wireless devices in a star (point-to-point) topology are clustered around routers or repeaters that communicate with each other and the gateway in a mesh (point-to-multipoint) topology.



A cluster-tree topology combines **point-to-point** communications from device to router with **point-to-multipoint** communications between routers and gateways.

This approach attempts to blend the advantages of both other topologies: potentially low power consumption of the "star" portions of the cluster-tree, and extended range and fault tolerance of the "mesh" portions.



If the direct, single-hop transmission path from between a router and gateway is interrupted, messages can multi-hop through other routers to reach their destination.

However, the disadvantages of a star topology still apply. A site survey is still required to make sure the end devices in each star have a clear line of sight to their assigned router, and there is still no backup path for each device to communicate with its assigned router if there are changes or interference.

## Choosing the right topology

So far you've learned that each topology has its own strengths and challenges. So which is right for you?

The answer is simple: The one whose characteristics best fit the most important requirements of your application.

- A **star** topology may be sometimes acceptable in relatively simple applications where interruptions in communications won't prevent you from achieving desired results.
- If data reliability is crucial, **mesh** topologies will best guard against data loss or signal degradation – with the added benefit of allowing easy network expansion.
- A **cluster tree** may be used if you want to apply different topologies to different parts of the network. For example, battery-powered measurement devices can be linked in a star topology to line-powered routers, which can then be linked in a mesh topology.

But what if you want high data reliability, easy network expansion, and long battery life?

## Self-organizing networks

Because process environments are dynamic, no single topology will always be the best for an application. But **self-organizing networks** have the built-in intelligence and flexibility to automatically use a star, mesh, or cluster-tree topology – or all three – as needed to provide maximum efficiency at any given moment.

In a self-organizing network, every wireless device and gateway has the capability to act as a router for other nearby devices. But instead of having every device talk with every other device all the time, the devices and gateways work together to identify and use the **most efficient communication path** for each message:

- If a device is within range of a gateway, direct point-to-point transmissions allow low power consumption (especially when combined with technology that minimizes the need for communication "re-tries").
- Network expansion is easy. A new device can communicate with the nearest device or gateway – which recognizes the new device as an authorized node on the network, and knows when to receive and transmit its messages.
- If a communication path is disrupted, the network's "self-healing" capabilities automatically re-route messages along the next-most-efficient route.

This capability to dynamically re-configure itself to use the most efficient communication paths – without manual intervention, and without interrupting the flow of data – is what sets a self-organizing network apart from any other wireless solution for process automation. Benefits include lower overall power consumption, reduced message latency, higher data reliability, and robust wireless network performance.

*To learn more about this topic, see the course on **Self-organizing Networks**.*

## Summary

In this course you learned that, while star, mesh, and cluster-tree topologies each have advantages and disadvantages, no single topology works best in every application. You also learned that self-organizing networks offer the flexibility to automatically combine topologies – or use all three – to create a scalable and reliable network. The self-organizing network efficiently manages these decisions to provide the most reliable network possible.

Key points included

- Star topologies have potentially low power consumption, but a site survey will likely be required to identify line-of-site communication paths.
- The multiple transmission paths available in mesh topologies provide high fault tolerance and easy network expansion.
- Cluster-tree topologies still require site surveys to deploy.
- Self-organizing networks can utilize all three topologies, automatically re-configuring themselves to use the most efficient communication paths for optimal data reliability and minimal power consumption.