PlantWeb University – Wireless 203

Self-organizing Networks

15 minutes

In this course:

Overview

Of the many wireless technologies available today, self-organizing networks are the most promising wireless solution for wireless field networks in process applications.

As the name suggests, *self-organizing* networks dynamically manage their own configuration and communications, automatically making changes as needed to ensure messages reach their destinations efficiently and reliably. They're also easy to install, and it's easy to add more devices to existing networks.

This course provides an overview of wireless self-organizing networks – from the basics of how they work to their advantages over other technologies. (If you haven't already taken the courses on **Topologies** and **Network Components**, doing so will help you get more from the material covered here.)

Hint

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

- How does information travel through a self-organizing network?
- What determines the path a message follows through the network?
- Which message-synchronization method is better, and why?
- What are the key advantages of self-organizing networks?

The basics

Self-organizing networks combine the high reliability of wired networks with the flexibility and low cost of wireless networks.

Two basic concepts make this possible: multiple communication paths and automatic path configuration.

Multiple communication paths. Each wireless device in a self-organizing network can act as a router for other nearby devices, passing messages along until they reach their destination. This capability provides redundant communication paths – and therefore better reliability than solutions that require direct, line-of-sight communication between each device and its gateway.

Automatic path configuration. Whenever there's a change in the network or in conditions that affect communications, the devices and gateways in a self-organizing network work together to find and use the **most efficient path** for each message – a path that optimizes data reliability while minimizing power consumption.

This path can change if needed. For example, if a truck or scaffold blocks the hop between two routers, then the routers will find alternative paths to get around the obstruction.

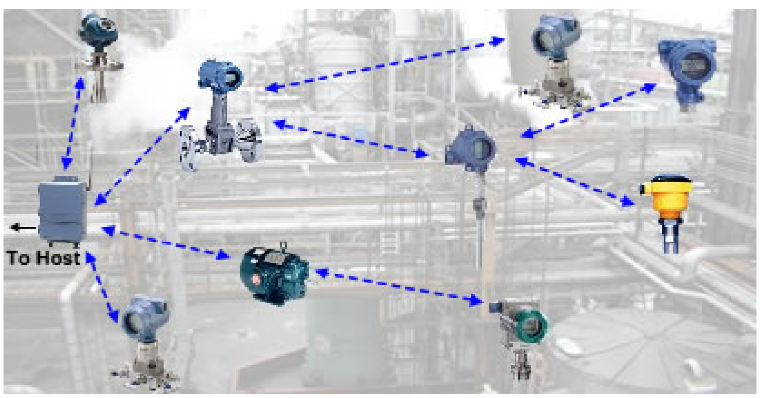
The beauty of the technology is that this reconfiguration happens **automatically**, without manual intervention – whether it's to incorporate a new device in the network, or to re-route messages when necessary to avoid an obstruction or other communication problem.

This animation shows how a self-organizing network works in a typical plant environment.

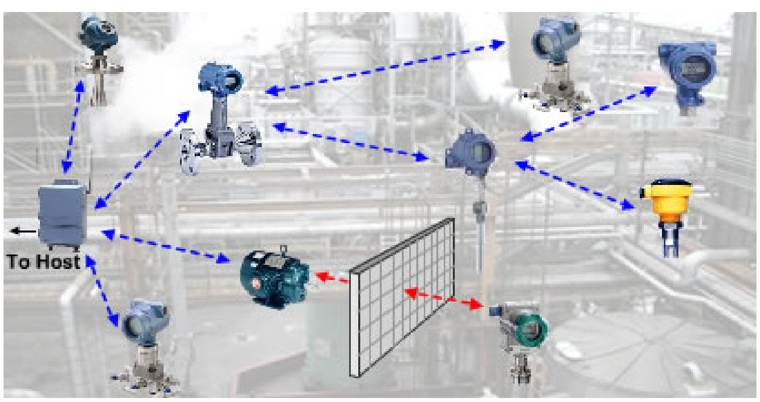
In the simplest configuration of a self-organizing network, wireless devices communicate directly with the gateway.

As you expand the network of devices, the new devices connect automatically.

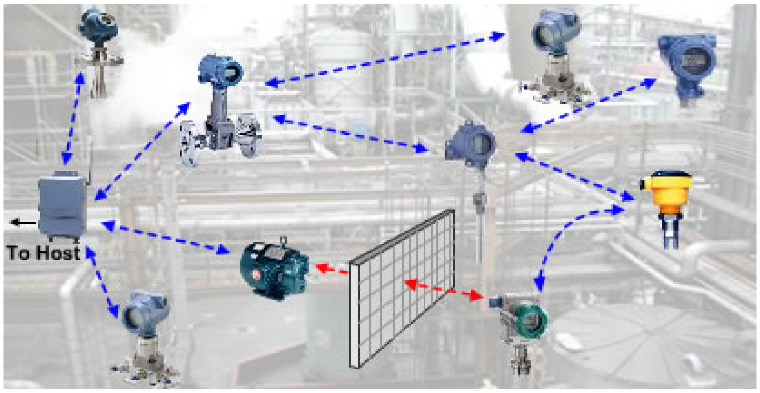
If new devices are not within range of a gateway...



...their messages are passed through other devices until they reach the host.



If something disrupts communication between devices,,...



...the self-organizing network recognizes the problem and, without manual intervention, automatically re-routes communications along the next best path.

You may have noticed in the illustration above that some of the communication paths appear to go around or through obstacles. That's because under some conditions radio waves reflecting off nearby surfaces can reach the next device even when there's not a clear line-of-sight path. Signals can also pass through some low-density materials, but that's less common with all the steel and concrete in a typical plant. Signal strength is reduced in either case, but with all the available devices in a typical self-organizing network, there's often another device close enough to pick up the weaker signal.

Now that we've discovered how messages reach their destination, let's look at the network components that make it happen.

Network components

A self-organized network has three basic components:

- **Wireless devices.** Wireless devices include both a **sensor** to obtain the measurement and a **radio** to communicate the information. Besides being end-points on the network, wireless devices also serve as routers for other devices. They identify a network, join it, and self-organize into communication paths.
- **Gateways.** A wireless gateway is a computer networking device that provides an interface between the devices in a self-organizing network and the host information system. It should provide seamless integration of information from the wireless network into existing host systems.
- **Host Information System.** The host information system is where most users will access the information from their wireless devices. It could be a control system, a PLC, a web interface, or a data historian.

To learn more about these self-organizing network components, see the course on ***Network Components****.*

Synchronizing messages

With all the messages traveling between wireless devices on the network, there's a risk of "collisions" as multiple messages arrive at a device or gateway at the same time. And when that happens, messages can be delayed or lost.

To avoid this problem, self-organizing networks **synchronize** communications. Carefully controlling message timing prevents potential collisions *before* they happen.

There are two ways to synchronize information: **CSMA** (Carrier Sense Multiple Access) and **TDMA** (Time Division Multiple Access).

With CSMA, all devices in the network try to communicate at the same time. If two messages "collide," each device tries to resend the message along a different path and/or at a different time.

The key disadvantage of CSMA is that the bigger the network, the more message traffic and ultimately, the more collisions. At some point, virtually all network traffic consists of message retries.

More collisions mean that more power is required to resend the collision messages. A technology analysis has shown that CSMA-based networks of battery-powered devices would not be able to scale past 50 units.

With TDMA, on the other hand, each device knows exactly when and how often it will communicate within the network. Any messages that are to be sent to other devices or to a gateway are stored until the scheduled time for communicating with that node.

Because each message has a specific time slot to travel through the network, there are no collisions – and no resulting retries.

TDMA networks can also increase network reliability by operating on many different frequencies. If one frequency is busy, a message can hop to a clear frequency to avoid interference or “jamming.” *(To learn more about avoiding problems with jamming, see the course on Security.)*

Because it provides higher reliability, lower message latency, and lower power consumption than CSMA – plus the ability to automatically detect new devices – TDMA is the right choice for self-organizing networks.

Advantages

There are several reasons many users prefer self-organizing networks including

- High reliability
- No site surveys
- Energy efficiency
- Self-reorganizing
- Easy installation
- Diagnostics

Let’s take a closer look at each of these advantages.

Advantages
High reliability

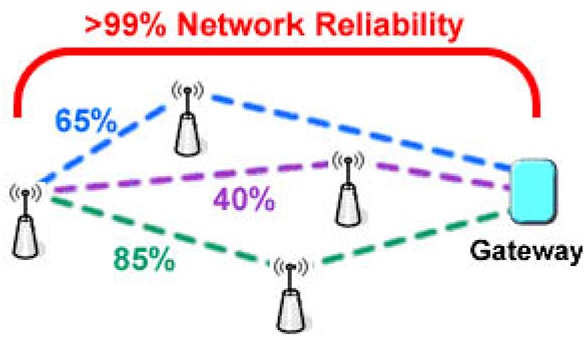
Network reliability is the percentage of messages sent between devices and gateways that actually reach their destination. It's a way of measuring your ability to receive the data you need from your wireless devices.

Self-organizing networks typically have **over 99% reliability**. Compare that to as little as 40% in networks that can't provide the redundant communication paths offered by a self-organizing network.

In a point-to-point wireless network, for example, any disruption in the communication path between a device and its gateway can cause loss of data. Potential disruptions are common in plant environments – from temporary obstacles like construction equipment to radio-frequency interference.

When a self-organizing network encounters such a disruption, however, it simply reorganizes itself to send communications along a different path or on a different frequency.

Even when no single available communication hop consistently provides 99% reliability, a self-organizing network can reach that level of performance by constantly choosing the path that offers the best reliability at the time.



A self-organizing network – even with path reliabilities of less than 99% – can still create reliable paths for communication.

Best of all, reliability increases as you expand your network. That's because more devices mean more potential communication paths, and therefore greater assurance that messages can reach their destinations.

Advantages
No site surveys

A site survey is a physical check of your plant to identify clear, line-of-sight paths for communication links between gateways and wireless devices. The survey may also analyze the potential bandwidth and speed of those links, and possible sources of interference.

Site surveys can take hundreds of hours, especially when plant structures, equipment, and other obstacles limit available communication paths. That's a lot of time – and money. They also can't predict conditions that might disrupt communications in the future.

With self-organizing networks, however, you don't need expensive site surveys. In fact, all you really need to know is the maximum number of wireless devices the network can support, and the wireless signal range of the gateway and routers.

If the logical position for a device (such as close to its measurement point) is too far from its gateway for direct communications, or if something interferes with the signal, other devices within range can relay messages to ensure connectivity.

Advantages
Energy efficiency

A self-organizing network is more energy efficient than traditional point-to-point wireless networks.

As an example, let's say one 1-watt radio used in a point-to-point network has a coverage range of 1500 meters. In a self-organizing network, ten .001-watt (1 mW) devices can cover the same area with 150-meter hops.

Why the 100-to-1 difference in power? Instead of a single device having to “scream” all the way to the gateway, self-organizing networks can “whisper” from device to device until the message reaches its destination.

Some self-organizing networks also use advanced power management to conserve energy. In this approach, wireless devices are not powered continuously. When not transmitting messages, they go into a “sleep” mode that minimizes power usage by turning off all electronics, except for mechanisms that “wake” the device at scheduled communication times. And because of the use of efficient TDMA communications, the "wake" time is short and efficient.

Being more energy efficient means that the battery lasts much longer. This is important because battery life has a large impact on maintenance costs.

*To learn more about power management with wireless networks, see the course on **Power Management**.*

Advantages
Self-reorganizing

You don’t have to tell a self-organizing network how to get a message to its destination, or how to communicate with new devices as they're added to the network.

Instead, each time a new device joins the network, the network automatically adjusts – or self-reorganizes – to bring the new device into the network. If one device or communication path fails, the message is automatically redirected to another device in the network.

Also, if a path with better quality is created by adding a new device, the network will reorganize to take advantage of it.

In effect, the network automatically "heals" itself so any changes to the environment won’t stop a message from reaching its destination.

Advantages
Easy installation

A self-organizing network is easy to install and manage – no sophisticated planning or costly site survey is necessary. All you need to know is the maximum number of wireless devices the network can support, and the wireless signal range of the devices and gateway. As long as each device or gateway is within range of at least one other, you’ll have a reliable, efficient network.

Self-organizing networks also automatically adjust to changes. Even after the initial installation, you can easily add, remove, replace, or relocate devices and gateways.

Once the devices are installed, they will automatically join the network, self-organize, and transmit data.

*For more on this topic, see the course on **Planning and installation of self-organizing networks***.

Advantages
Diagnostics

Imagine if you could not only receive measurement data through your wireless network, but also troubleshoot device problems and upload a software revision – all at the same time?

You can! These capabilities are expected to be available in self-organizing networks based on an emerging standard for wireless access to HART information. The standard is being developed by the Wireless HART working group of the HART Communication Foundation (HCF).

HART devices that use wireless technology can wirelessly communicate important diagnostic data, such as the health of a device or a process. Diagnostic data can also be routed dynamically to other wireless devices so neighboring devices can respond to a “warning” from a failing device.

The value of this diagnostic data is significant. For example, the ability to diagnose instrument alarms from the safety of a control room or maintenance shop can eliminate over 60% of typical "check instrument" trips to the field.

Target applications

The first generation of self-organizing network solutions will target applications with update rates from once every few seconds to once per minute. This is different from wired solutions, where update rates are more commonly in tenths of a second.

Secure, self-organizing networks are well-suited for typical monitoring applications. For example, most plants have hundreds – if not thousands – of points that are manually monitored. In comparison to manual data collection schedules of once per shift, day, week, month, or never, once every few seconds looks almost like real-time data.

Automated wireless monitoring also eliminates many of the problems of manual data collection, including clipboard notation errors, inaccuracies from dial gage indication, and poor repeatability of handheld measurement equipment.

These networks can also support open-loop control and some forms of latency-tolerant control. Potential open-loop control applications include those where it might take an operator an hour or more to obtain the appropriate work permit or go out to the site to perform the appropriate control action, such as turning on a pump or closing a manual block valve. In these cases, one-minute updates provide plenty of response time.

Summary

In this course you learned that self-organizing networks are reliable, affordable, flexible, and scalable – which is why they're emerging as the leading technology for in-plant wireless solutions.

Key points covered in the course include...

- Self-organizing networks use the most efficient communication path for each message – and automatically change that path if needed.
- Their device-to-device communication and self-organizing capabilities also make self-organizing networks easy to plan, install, and expand.
- As more devices are added to a self-organizing network, the additional communication paths make it even more reliable. Network reliability of over 99% isn't unusual.
- Shorter transmission distances – and the advanced power management techniques used in some self-organizing networks – help extend device battery life and thus lower maintenance costs.
- TDMA is the preferred method for synchronizing messages to avoid collisions.
- Networks of devices using the emerging Wireless HART standard can also communicate diagnostic information.

The Emerson Advantage

Emerson's Smart Wireless solutions include full support for self-organizing networks. We offer a full suite of network components, including wireless devices and gateways using channel hopping, TDMA and other standards-based communication technologies – plus our SmartPower™ advanced power management to help minimize energy usage and extend battery life. In addition, our AMS™ Suite: Intelligent Device Manager software can help you make the most of wireless HART diagnostic information. This broad offering enables us to offer complete network solutions, including installation and support by personnel experienced with self-organizing networks.