Industrial Topology Options

And PROFINET

Introduction

Network topology is a term that describes network connections in homes, cities, offices, factories, etc. Fieldbuses and Industrial Ethernet protocols, such as PROFIBUS and PROFINET, offer a wide variety of topology options. This White Paper will describe the different network topologies available for industrial environments. Then, it will summarize potential benefits and challenges for each topology in a PROFINET network.

Definition

Topology is a generic term to describe device connections in a network. The term is not exclusive to industrial networking. Social networks, for example, have their own topologies between people. Network topology, specifically, is the network layout. In Industrial networking, wired topology options include: line, tree, star, and ring. Further topology options open up with wireless connections.

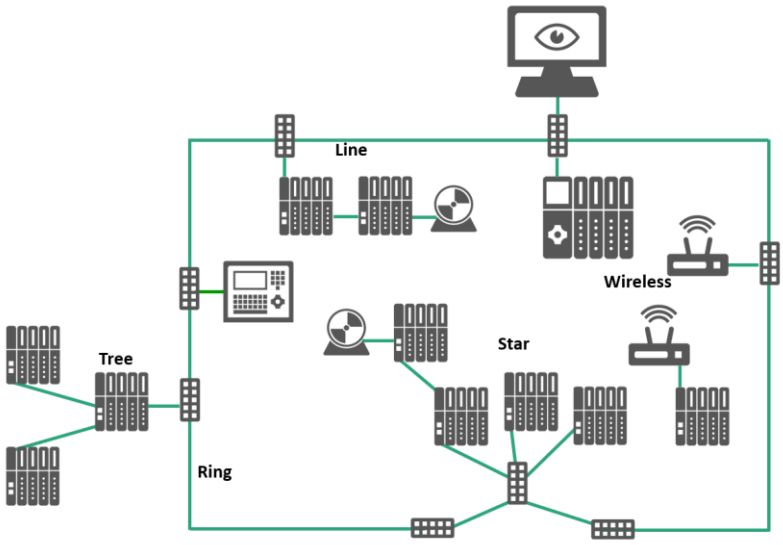

Figure 1 - Plant with multiple topologies

Topologies for Industrial Environments

Topology Options: Fieldbuses

Line topologies are the most common configuration for fieldbuses like PROFIBUS. Users link each device to the next, resulting in a line configuration. Line topologies are typical in fieldbuses based on physical layers such as RS-232 or RS-485 because of their physical layer restrictions. Star or tree topologies are also possible in fieldbus networks, but they are less common.

Topology Options: Industrial Ethernet

In networks based on Ethernet, like PROFINET, there is a variety of topology options: line, star, tree, and ring. Industrial Ethernet devices commonly have multiple ports with an integrated switch. Here, when connecting multiport devices in a line topology, devices receive Ethernet packets through one port and forward them through another as shown in Figure 2.

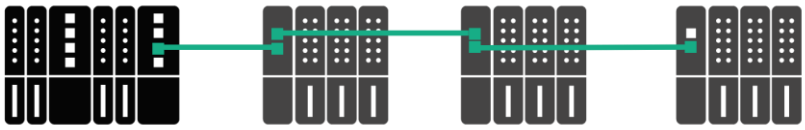

Figure 2 - Line topology

Star or tree topologies are common in hierarchical networks and in-cabinet installations. Inside a cabinet, devices may be in close proximity. It doesn't always make sense to connect them in a line configuration. Instead, star or tree topologies can be more efficient.

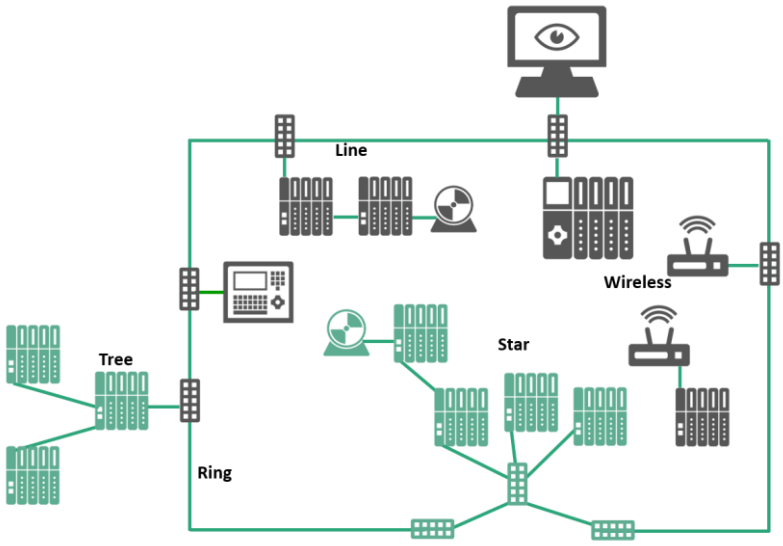

Figure 3 - Highlighted: Star and tree topologies

Ring topologies establish media redundancy. If a wire breaks in one section of the ring, there is a secondary connection to the network. Generally, Ethernet should not be connected in a ring without performing some sort of management. Without managing the ring, Ethernet packets can go in circles forever, using bandwidth. Some Industrial Ethernet protocols, such as PROFINET, provide resources to manage ring topologies. Figure 4 shows an example of a ring topology. All the devices that make up the ring (highlighted in green) must be configured accordingly.

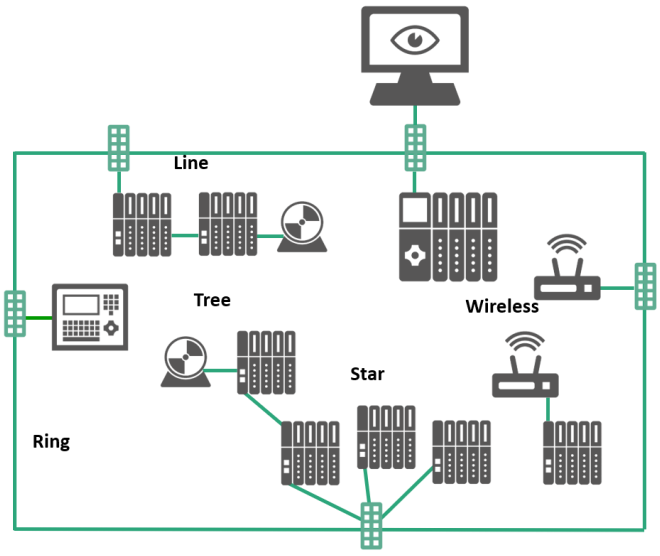

Figure 4 - Highlighted: Ring topology

Industrial Wireless Topologies

Topologies with wireless connections can differ substantially from wired networks. There are many different kinds of wireless topologies. The four main configurations are Point to Point(P2P), Point to Multipoint(P2M), Wireless Distribution System (WDS), and mesh. Wi-Fi (IEEE 802.11) supports all four configurations. Bluetooth (IEEE 802.15) supports P2P, P2M, and mesh.

Point to Point: P2P architectures have a dedicated wireless connection between two devices, between two Access Points (APs), or between a device and an AP. The channel is not shared, and therefore more bandwidth is available on the wireless link.

Figure 5 - Point to Point wireless topology

Point to Multipoint: P2M is the most common wireless configuration. With P2M, users can tie multiple wireless stations(clients) to a controller or other devices through a single AP. For example, having a laptop, an HMI, and a PROFINET network consisting of multiple devices all accessible via wireless. Figure 6 shows a P2M connection to two clients.

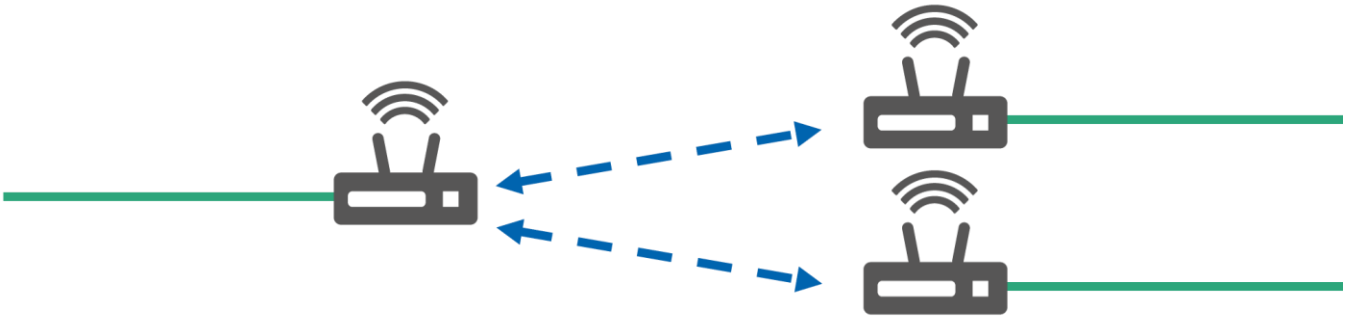

Figure 6 - Point to Multipoint wireless topology

Wireless Distribution System: A WDS extends a wireless backbone with multiple APs. Clients can 'roam' between the AP cells for seamless communication. Figure 7 shows an example of a WDS backbone made up of four cells. The remote AP is the client. It can move between the cells without losing connection to the backbone. Common applications for a WDS include automated guided vehicles (AGVs) or other moving wireless components.

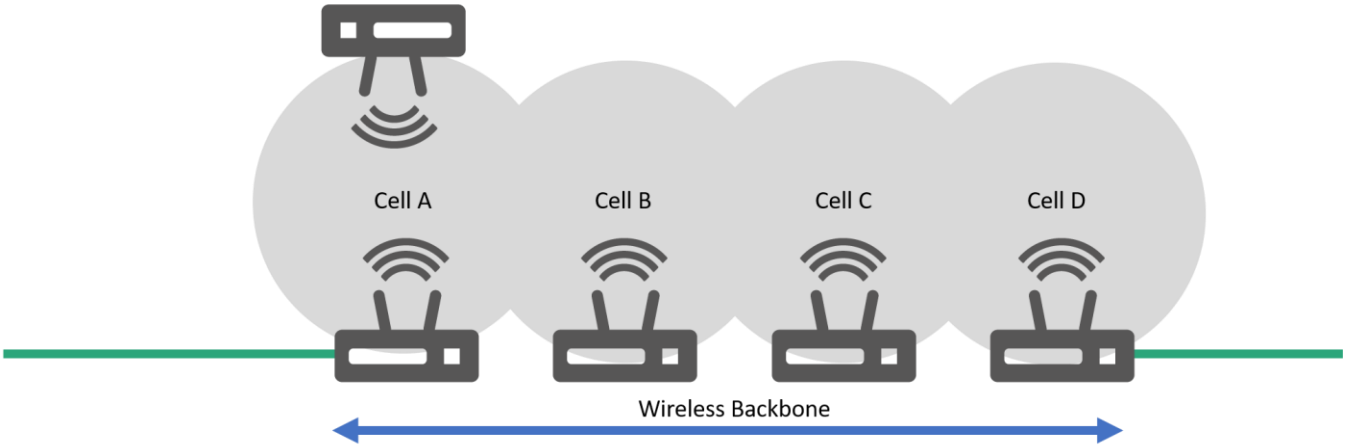

Figure 7 - Wireless Distribution System

Mesh: Wireless devices connect with many redundant interconnections between network nodes in a mesh network. If any node fails in the mesh, there are multiple redundant paths for any two nodes to communicate. In Figure 8, AP1 and AP2 are connected via mesh topology (red connections).

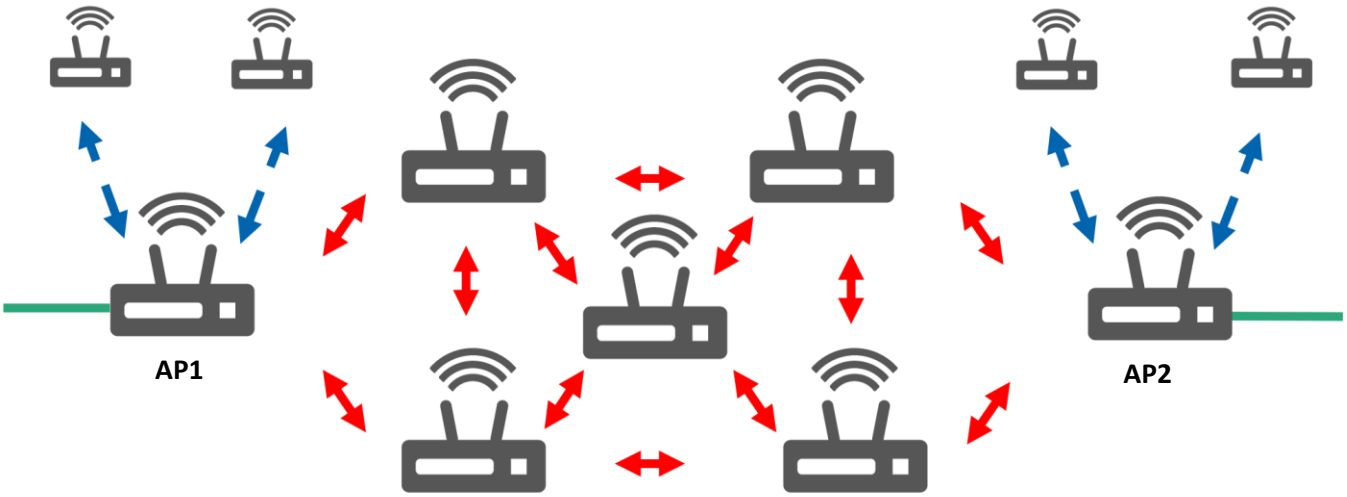

Figure 8 - Wireless mesh topology

In the manufacturing industry, wireless connections are typically used only in specific circumstances: rotating machinery, AGVs, autonomous mobile robots, etc. Their use isn't as prevalent as wired technologies, and therefore wired topologies.

Topology Comparison: PROFINET

Since PROFINET is based on standard unmodified Ethernet, it gives users all topology options. It supports line, tree, ring, and star cabled topologies. Also, it supports wireless connections via Bluetooth or Wi-Fi as part of its specification.

Benefits and Challenges

Topology	Description	Benefits	Challenges
Line	Most PROFINET devices have at least two ports, with such ports being part of a built-in switch in the device. Built-in switches allow users to connect devices in a line topology without external switches.	◆ Built-in switches in PROFINET devices are usually available, external switches are optional. ◆ Less cables needed	◆ If a node in the line fails, downstream nodes lose communication. ◆ User must account for line depth limitations[1].
Star and Tree	Built-in or standalone switches allow for star/tree topologies.	◆ Efficient topology for multiple nodes in close proximity	◆ If a central switch fails, communications to all connected nodes will be affected. ◆ Additional cables and external switches
Ring	PROFINET allows you to implement a ring topology by managing it with two defined media redundancy protocols: Media Redundancy Protocol (MRP)[2] and Media Redundancy for Planned Duplication (MRPD)[3].	◆ Media Redundancy: In case of a failed cable or node within the ring, operations may continue.	◆ Devices in the ring must support PROFINET media redundancy. ◆ Additional cabling ◆ Additional configuration of the devices that make up the ring.
Wireless	Wi-Fi or Bluetooth can become part of a PROFINET network backbone.	◆ No need for cables or additional hardware	◆ Limited speed and determinism ◆ Installation requires in depth analysis of the wireless conditions (interference, signal decay, etc.)

[1] Each switch that is placed between a device and its controller introduces a delay in the data transfer. The number of switches between a controller and a device is called the line depth. A large line depth will introduce delay which must be considered when planning the network topology.

[2,3] MRP and MRPD enable the connection of devices based on ring topologies.

MRP: If the transmission link in the ring is interrupted, the ring manager immediately activates the alternative communication path. The recovery time is in the millisecond range.

MRPD: Each sender in the ring sends two equal frames to the receiver in opposite directions around the ring. In case of a network failure, one frame will still arrive at the receiver. MRPD ensures non-stop connectivity with a recovery time of zero.

Summary

No single topology configuration adapts to all possible applications. Users must assess each particular installation to build an efficient topology configuration. There are several factors to consider when choosing a topology and designing an industrial network (timing requirements, physical environment, special applications, etc.) But it is beneficial to be aware of all topology options together with potential advantages and pitfalls.

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