SureCross™ DX80 Network Basics

A Guide to SureCross Networks

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Printed in USA Dec 2011 P/N 136689

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Networking

Networks exist everywhere around us and are a major contributor to the information age. Some of the most interesting recent developments in factory and process automation have been the networking of machines and controls allowing machine control, data collection, and ultimately informed decisions that can improve productivity, save time, and reduce scrap.

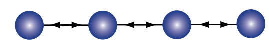
According to Merriam-Webster Online, a network is "a system of computers, peripherals, terminals, and databases connected by [a] communications line." Today's implementations of networks also include wireless networks that use the air as the communications line and range in geographic size from a few meters to spanning continents.

Many of Banner's newest products are part of a network, both wired and wireless. As such, understanding networking basics is important when using or providing technical support to Banner's products.

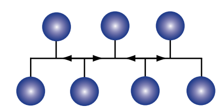
Network Topologies

There are many network topologies, or arrangements, and each topology contributes to the overall network performance. Defined here are a few of the most common topologies for basic networks. In reality, many networks combine elements from multiple topologies.

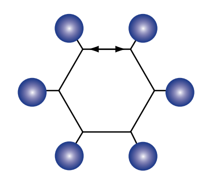
Point to Point: The most basic form of network is called a point-to-point, or line, network. Data typically travels from one node to the next in a specific order. If the communications link between two nodes fails, the network communication halts.



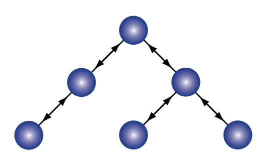
Bus: In a bus network, the nodes are connected through a common communication path, called a bus. Each node on the bus is assigned a unique ID to receive the messages intended for it. All data is transmitted and received by all nodes connected to the bus, though only the intended target responds. Similar to the line network, all communication relies on one common cable connection, so a failure in the bus halts all network operation.



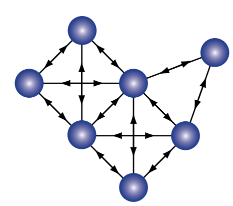
Ring: A ring topology is similar to a bus except that the common cable is looped into a continuous ring. Data is transmitted in one direction and if the link is lost, network communication fails. Because the data travels in a single direction and in a specific order, adding nodes to the ring increases the total network response time.



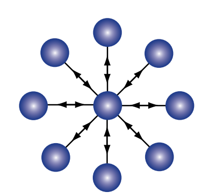
Tree: At the lowest level are nodes, referred to as leaves. Their only function is to transmit information to the next highest level. The mid-level devices are repeaters and at the top is the gateway. While the tree topology handles additional nodes better than the ring or bus topology, if a repeater fails, the connection between the nodes and their gateway is lost.



Mesh: In a mesh network, each node has limited routing capabilities and maintains a network connection with at least two other nodes. Most commonly, nodes within a mesh network maintain a link with all nodes within a specified distance. If one link breaks, information has an alternative path to the gateway. The gateway in this case could be any one node in the network. Mesh networks are reliable because of the greater redundancy in data transmission pathways, but performance slows with each node added to the system.



Star: When many devices are connected to a single point—for example when a number of nodes connect to a single gateway—it's called multi-point to point. Because of its shape, this network is also referred to as a hub and spoke network, or a star network.



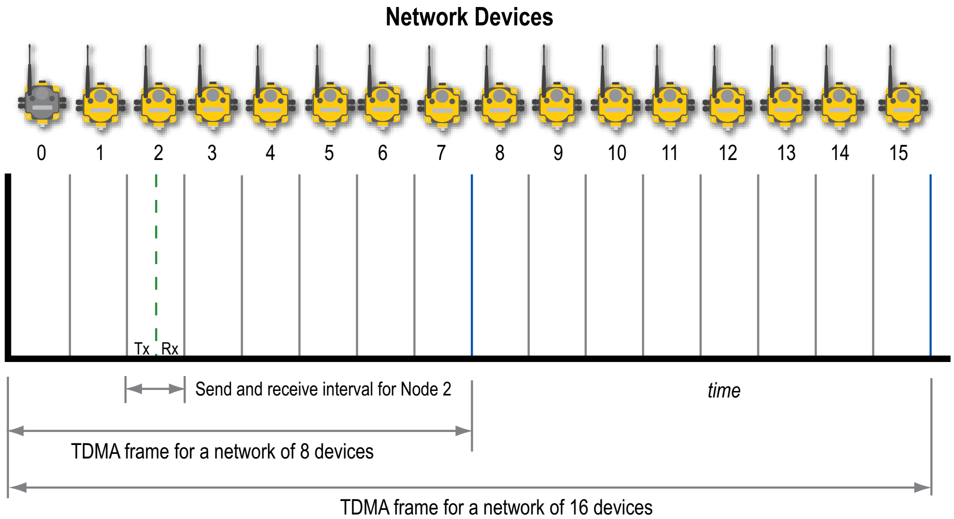
Star topologies also can suffer from some speed decreases with each additional node, but when one node fails, the others remain unaffected. Because the star topology balances performance and speed and allows the use of specific transmit and receive timing, Banner's SureCross wireless network products use the star topology for the wireless networks.

Banner's SureCross™ Wireless Network

To balance reliable communication with efficient power management, the SureCross™ wireless network uses a star network topology. Each node within a network communicates only with the gateway, or master device. To ensure each node can reliably send and receive data to the master device, a TDMA architecture is employed.

TDMA, or Time Division Multiple Access, architecture assigns each node, including the master device, a specific time period in which to send and receive data.

By establishing specific intervals when each node sends and receives data, nodes do not conflict with each other to send and the gateway never has to receive data from more than one node simultaneously.



As the network master device, the Gateway initiates all communications within the network. Each Node may only communicate with the Gateway, and only during that Node's specific transmit and receive timing periods.

Because the Node can send and receive only in specific time intervals, the Node's power usage can be managed efficiently, allowing Nodes to operate from 3.6V lithium batteries when necessary.

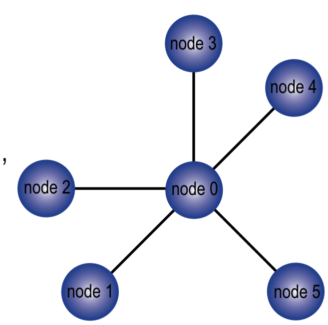
Assigning send and receive times between the Gateway and Nodes involves using unique device identifiers.

Having multiple independent networks networks within range of each other requires unique network identifiers. These unique network identifiers, or network IDs, use different FHSS hop sequences for the networks, preventing the Gateway from one network from accidentally transmitting to a Node on another network.

Network ID

Because the radio network operates over the air, there are limited ways to electrically separate collocated networks. To keep collocated networks separated, Banner uses a network ID number, sometimes abbreviated as NID. Each wireless network operating within radio range is assigned a unique network ID number using the rotary dials on the DX80 devices. Up to 16 unique network identification numbers are available using the rotary dial. Additional Network IDs are possible using advanced features of the DX80 devices.

All devices within a network are assigned the same network identification number, which defines a unique frequency hop table. Because networks 1 and 2 use a different sequence of frequency changes, they are not on the same frequency at the same time. This prevents communication between the networks even when they share the same transmission medium.



Device ID

To route communication between devices, device identification numbers are assigned to each device in a network.

In the SureCross system, device 0 is always the master device, the Gateway. All other nodes are assigned device identification numbers from 1 through 15. Even when all 15 nodes are not installed, the TDMA frame remains established for 15 nodes and the send and receive frames for those nodes are unused. Larger networks may be set up with up to 128 nodes, establishing a much longer TDMA frame.

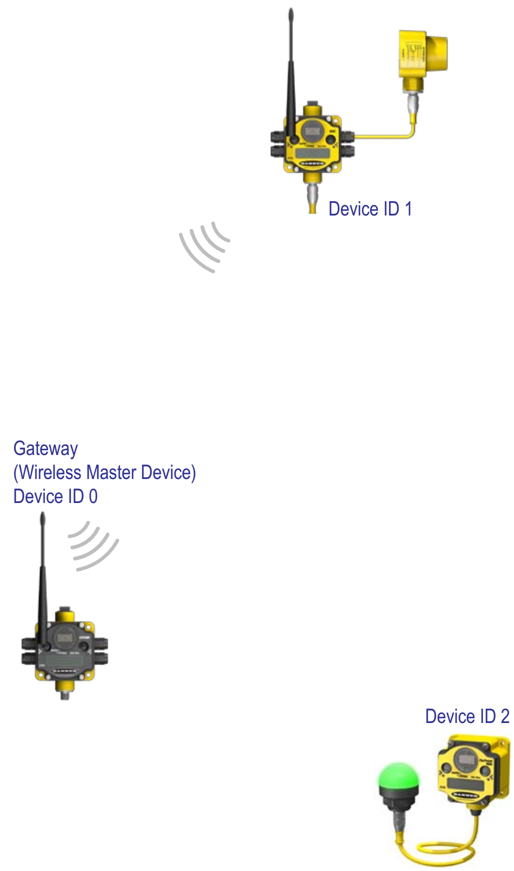
Basic Wireless Network

In the most basic wireless network, input devices are wired to inputs on DX80 devices. The data created by the input device is transmitted to the specified output on another device. A device wired to that output performs a task based on the received data.

The simple wireless network shown illustrates a very basic wireless network containing only two Node devices and a Gateway. More complicated wireless networks might include multiple input and output devices wired to each Node and several Nodes installed in the network.

In our simple example, the sensor wired to device 1 is an input device connected to Node 1's input. Data is transmitted to Node 2 and a device connected to Node 2's output performs a task - in this case the light turns on.

This standard wireless system with I/O is a simple network with no interfaces to the outside world other than the I/O. To bridge the gap between the wireless network and the outside world, the Gateway also functions as a Modbus 485 slave, interfacing between two networks: the wireless network and a Modbus 485 network.



Simple Wireless Network

Modbus RS-485

Modbus Remote Terminal Unit (RTU) running over RS-485 cabling is sometimes abbreviated as Modbus 485 and is a master-slave communications protocol typically used for industrial applications. RS-485 refers to the physical layer of the network.

Modbus 485 is used for the hard-wired interface on Banner's SureCross™ wireless products. The particular variation of RS-485 chosen for Banner's SureCross wired network is 2-wire RS-485 running at 19.2 kilobits per second (kbps).

All connections between a DX83 Ethernet Bridge and a DX80 Gateway are via Modbus 485, as are connections between DX80 devices and the DX85 Expanded Remote I/O modules. A basic DX80 Gateway can be connected to a PLC or other process controller using the Modbus 485 network.

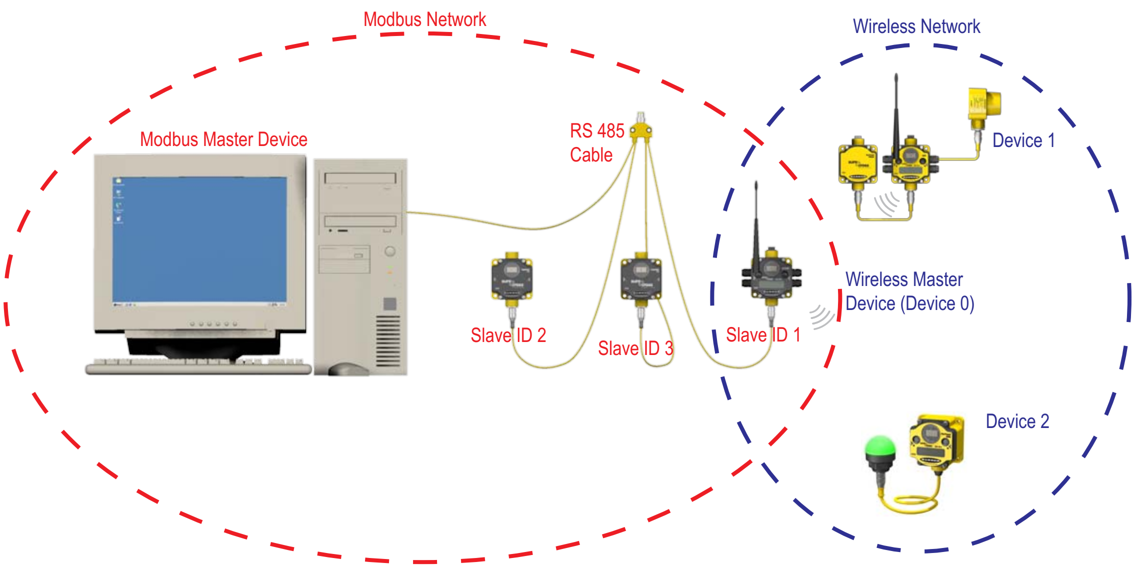
One Modbus master and up to 247 slave nodes may be connected to the bus at any given time, with the slave devices assigned unique slave identification numbers.

Only the Modbus master is allowed to initiate communications on a Modbus network. Messages from the master indicate for which slave device a message is intended and only the slave addressed by the master is allowed to respond. This allows the Modbus protocol to work well with a physical "party line," where everyone "hears" all the network traffic, but only the addressed slave device can respond.

In a traditional Modbus network, the slave devices cannot alert the master when an event occurs. Instead the master must continually poll each slave device to observe changes.

SureCross and Modbus

Specific to Banner's SureCross network, all standard Gateways ship from the factory configured as Modbus slaves with their Modbus slave ID number set to 1. To avoid communications problems, do not connect the SureCross Gateway to a Modbus network already containing a slave ID 1 device.



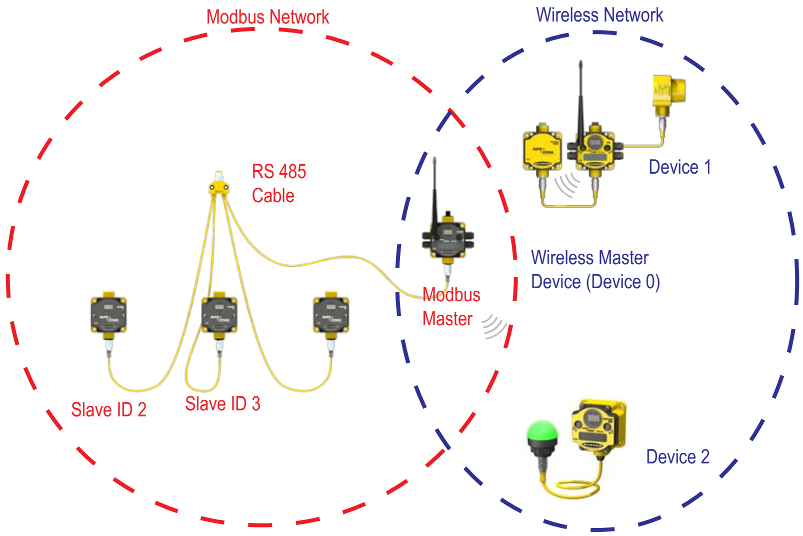
Network 1: Gateway as Modbus Slave

As shown, the DX80 Gateway is a slave device within the Modbus network but remains the master device of the wireless network. In this way, the DX80 Gateway behaves as a true networking gateway by bridging communications between the wireless network and the Modbus RTU network.

The Modbus register map of the Gateway is fixed; there is no setup, programming, or customization needed to use Modbus to access the I/O points on wireless network device.

When a new Node is powered up and added to the wireless network, the Modbus registers are activated at a unique location saved for each wireless network Node device. Refer to Banner's Modbus User's Guide, document part number 132114, for more information about the Modbus register map.

The DX85 Expanded Remote I/O device and many other Modbus slave devices cannot be used on a network without a Modbus master, so the DX80 Gateway includes Modbus master functionality. Because a Modbus network can only have one master, the network cannot include the PLC if the Gateway must have direct control over DX85 devices (see Network 2).



Network 2: Gateway as Modbus Master

The Gateway is configured with a table of external connections that allow the DX85 Expanded I/O devices, as Modbus slaves, to communicate with the wireless Nodes.

For examples of additional Modbus RTU configurations, please refer to Banner document p/n 133601, *DX80 System Layouts*.

Modbus/TCP and EtherNet/IP™ Networks

Attaching host devices to the Modbus network using standard Ethernet hardware requires using one of several Ethernet-based communications protocols.

Modbus/TCP is an open standard protocol developed by the Modbus IDA (www.modbus.org). It is very similar to Modbus RTU except that it uses standard Internet communication protocols, just like Web communications or e-mail. The master is referred to as the client and the slave is the server. Modbus/TCP follows the same structure as Modbus RTU: clients initiate all communications, servers can only respond, etc. However, given the power of TCP/IP, many client/server connections can be open at the same time, with one device functioning both as a client and as a slave.

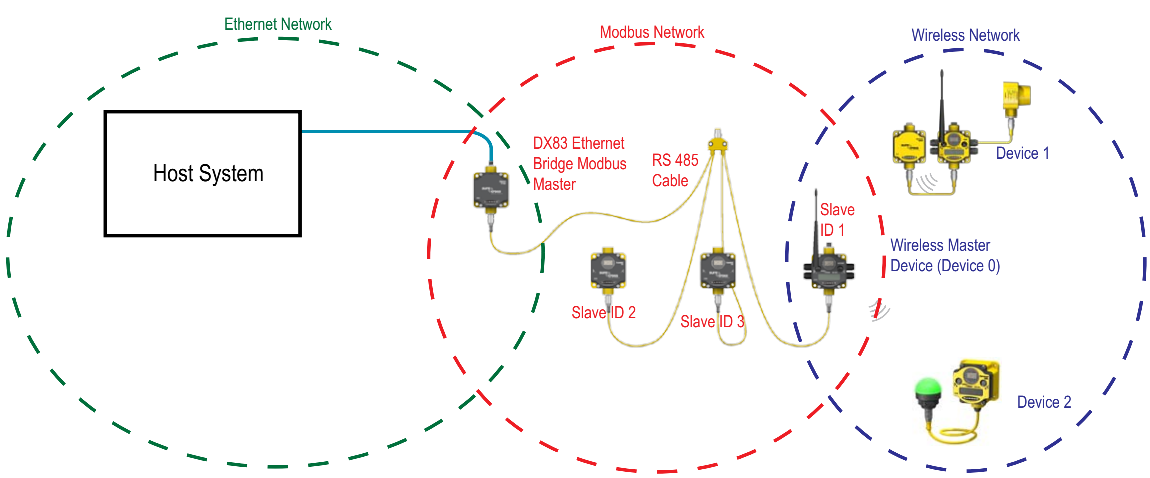
EtherNet/IP™ is an open standard protocol developed by Allen-Bradley, but managed by the ODVA, (www.odva.org). EtherNet/IP is an adaptation of the DeviceNet serial fieldbus protocol using Internet communication protocols. EtherNet/IP stands for Ethernet Industrial Protocol, not Ethernet Internet Protocol. EtherNet/IP is DeviceNet over Ethernet.

Serial and Ethernet Versions of Automation Protocols	
Serial	**Ethernet**
Modbus RTU	Modbus/TCP
DeviceNet	EtherNet/IP

DX83 Ethernet Bridge

Connecting a Modbus RTU network to an Ethernet-based network requires using another type of networking gateway, the SureCross™ DX83 Ethernet Bridge. The Ethernet Bridge device acts as a communications bridge between the Modbus RTU network (Gateway) and Modbus/TCP or EtherNet/IP (host systems).

In the Modbus RTU network, the DX83 Ethernet Bridge is the Modbus 485 master and the Gateway is set to the default Modbus slave setting. The DX85 Expanded Remote I/O device is a slave of the Ethernet Bridge and is not under the control of the Gateway. For other configurations, refer to Banner document p/n 133601, *DX80 System Layouts*.



Network 3: Ethernet Bridge as Modbus Master

For Industrial Ethernet, the Ethernet Bridge functions as a slave device. In the Network 3 image shown, the computer functions as the master industrial Ethernet device. Like the Gateway, the Ethernet Bridge can act as both a master and slave device for the various networks.

The following table lists some of the services provided by the Ethernet Bridge:

Service	Purpose
http, Web server	Setup and configuration of the Gateway, wireless network I/O, and Ethernet Bridge
Ping	Sends a signal to a specific device and waits for a response to determine the communication link status
Modbus/TCP	Provides command and control functions to other industrial devices using Modbus/TCP
EtherNet/IP™	Provices command and control functions to Allen-Bradley deivces (both CIP and PCCC sub-protocols are supported)

The Web page interface accessed using the Ethernet Bridge provides a mechanism for setting parameters on the wireless network. While most wireless parameters are initially configured at Banner, some of the parameters not configured include using the Gateway hardware as a Modbus RTU master, setting up I/O maps for the Modbus master actions, backup and restoring network configurations, changing the IP address of the Gateway, and enabling the EtherNet/IP protocol.

The Ping interface checks to see if a device is present at a particular IP address via the network. This is a troubleshooting tool.

When the DX83 Ethernet Bridge acts as the Modbus/TCP client, the user can set a polling rate and a series of reads and writes on the Ethernet Bridge. This feature allows a network of Ethernet Bridges or GatewayPros over Ethernet with longer cable runs and larger network sizes than would be possible with a network of standard Gateways on a Modbus 485 network.

Register maps for the Modbus TCP/IP server and EtherNet/IP slave connections are fixed, just like the register maps for the Modbus RTU interface on the Gateway. The Modbus TCP/IP and EtherNet/IP protocols require the use of a DX83 Ethernet Bridge or a DX80 GatewayPro.

DX80 GatewayPro

A DX80 GatewayPro combines the wireless capability of the standard Gateway with the protocol converter of a DX83 Ethernet Bridge, resulting in a device that is the master of the wireless network and a slave to an Industrial Ethernet network.

From a customer perspective, the GatewayPro is treated the same as a standard Gateway, with the GatewayPro providing Modbus/TCP or EtherNet/IP slave access to all the information on the wireless network instead of the Modbus 485 slave interface the standard GatewayProvides.

The OSI Seven Layer Model

The Open Systems Interconnection (OSI) seven layer model attempts to describe network communication protocols as a layered series of steps necessary to transmit information between dissimilar devices or networks.

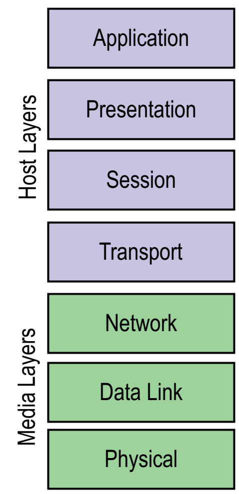
The lowest level of the model is the physical level and pertains to the actual transfer media (air, wires), connector types, voltages, and signaling speeds for a specific type of network. Layers two and three also deal with data transfer at the hardware level.

Layers four through six typically are involved with data addressing - getting the data to the proper end location.

The seventh and highest level of the model is the application layer. The application layer is the interface between the user and the network.

Between each layer are protocols translating the information from one layer to the next. The OSI seven layer model only loosely applies to most communications protocols because several layers may be combined together, especially the layers involved in TCP/IP communications protocols used in the Internet.

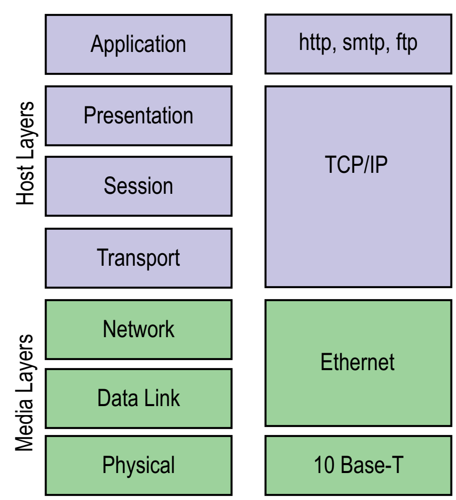
The acronym TCP/IP refers protocols used in the network level (IP) and the transport level (TCP). The TCP/IP layers control how sessions are established, error corrections, and other data transportation issues and encompass multiple layers of the OSI model.



OSI Seven Layer Model

In the Internet example, the application layer includes the protocols for http (Internet website access), smtp (e-mail), and ftp (file transfers) to name just a few.

The networking term “stack” has been used to describe the seven layers. Data must move up and down the same stack to be interpreted correctly.

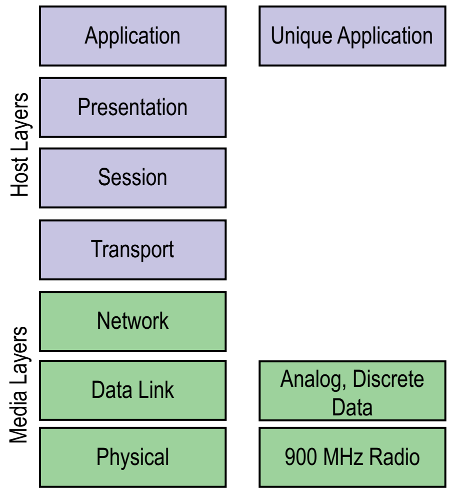


OSI Seven Layer Model - Internet

OSI and Wireless Networks

Though the SureCross wireless product is a proprietary wireless network and the various protocol layers are proprietary, the wireless network can be compared to the standard seven layer model.

Instead of wires creating a connection, the 900 MHz or 2.4 GHz radio signal transmits the binary data, creating a radio signal "link." There are many other technologies and layers, but the most important result is at the application layer where the data exchanged between network nodes is used to monitor and control events.

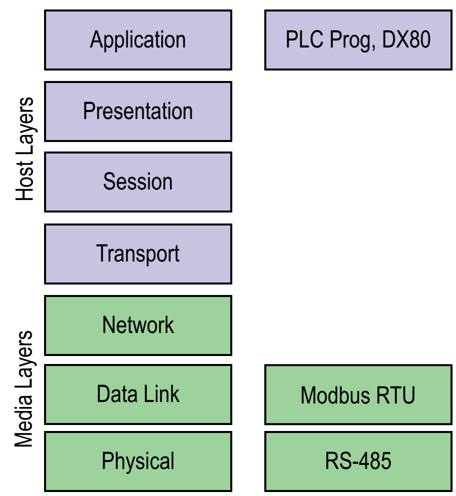


OSI Seven Layer Model - Wireless Radio Network

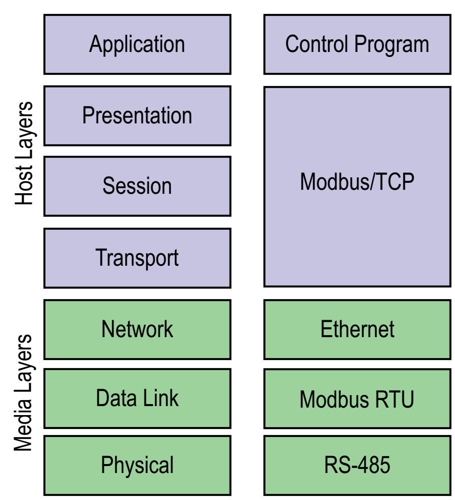
OSI and Modbus RTU, Modbus/TCP

Applying this analogy to Modbus RTU, the lowest layer is defined by RS-485. Modbus RTU functions at the data link layer. The application layer is the PLC program on a PLC or the analogous control program on any host device.

Continuing with the OSI example, Modbus/TCP packages Modbus data packets inside the standard Internet TCP/IP protocols. EtherNet/IP functions the same way. Data moves from the data link layer up to the top of the stack and provides consistently structured data to use with a control program.



OSI Seven Layer Model - Proprietary Modbus RTU Network



OSI Seven Layer Model - Modbus/TCP

Glossary

DX83 Ethernet Bridge	Acts as a communications bridge between the Modbus RTU network (Gateway) and Modbus/TCP or EtherNet/IP host systems and includes the ability to configure the network using a Web browser interface.
DX80 Gateway	SureCross™ DX80 wireless network master communication device used to control and initiate commands to other devices in the system; serves as a “portal” from one network to another and communicates between the wireless network and the central control process.
DX80 GatewayPro	Combines the standard Gateway and the DX83 Ethernet Bridge into one device.
DX80 Node	SureCross DX80 slave device in a wireless network.
Ethernet	An access method for computer network (Local Area Networks) communications, defined by the IEEE as the 802 standard.
EtherNet/IP	Allen-Bradley’s DeviceNet running over Ethernet hardware.
gateway	A general network device that connects two different networks.
master	Maintains the timing clock for all devices within the network and initiates all communications with the slave devices.
Modbus	A master-slave communications protocol typically used for industrial applications.
Modbus/TCP	An open standard protocol very similar to Modbus RTU except that it uses standard Internet communication protocols.
node	Any communications point within a network
slave	Network slave devices communicate to the network master when communications are requested; slave devices do not initiate communications with the master and slave devices do not communicate with each other.
TCP/IP	Transfer Control Protocol / Internet Protocol. Several layers in the OSI model that control the transfer and addressing of information.

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