Industrial Ethernet Designs with MCUs- a Hands on Introduction

Class 1: An Overview of Ethernet

12/11/2017

Warren Miller

This Week's Agenda

12/11/17 An Overview of Ethernet

12/12/17 An Introduction to Industrial Ethernet

12/13/17 Industrial Ethernet Applications

12/14/17 Industrial Ethernet Implementations

12/15/17 Industrial Ethernet- an example

Course Description

- Industrial Ethernet is still a key communication technology for factory control.
- It is built on the long legacy of Ethernet, but adds significant capabilities for increasing robustness and reliability.
- This course will provide an overview of the key differences between our familiar Ethernet protocol and the Industrial version.
- A hands on example will use easily available software and development boards to dig into some of the key details of an actual Industrial Ethernet implementation. Students can optionally obtain the hardware and software to follow along with the implementation.

Today's Topics

Ethernet is a pervasive connectivity technology used in many connected devices. This class provides a quick overview and sets the stage for understanding its Industrial cousin.

- What is Ethernet and why is it still around?
- How is data transferred?
- What protocols are used?
- What are common applications for Ethernet?
- What resources are available to learn more?

What is Ethernet?

Much of the content for this section is available here: http://computernetworkingsimplified.in/data-link-layer/overview-ethernet-protocol-types/

Ethernet is one of the oldest LAN technology but still the most popular and the most widely used one in LAN environments. It is used in almost all networks including home, office, universities and enterprise networks.

Ethernet is basically a:

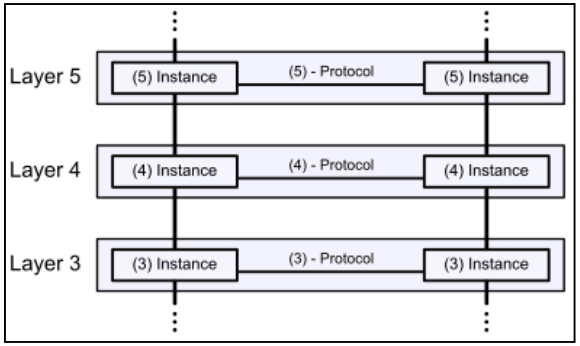
- next hop carrier data link layer protocol for carrying network layer packets between adjacent hops
- a connectionless best effort data link layer protocol. That means it does not have the LLC layer functionality of logical links and applications should rely on the higher layers to provide reliability functionality.
- For shared lines (e.g. bus), Ethernet supports the media access control (MAC) functionality through the use of the standard CSMA/CD protocol.
- It supports error detection through CRC and flow control via PAUSE frames.
- It does not support reliability and error correction
- It supports for a wide variety of physical layer protocols, physical media, line rates and topologies (bus, star, point to point).
- Its wide adaptability comes from its simple nature, backward compatibility between different variants (like FE, GigE etc.) and cheap cost of hardware implementation.

Open Systems Interconnect Model

Characterizes and standardizes the communication functions of a telecommunication or computing system without regard to their underlying internal structure and technology.

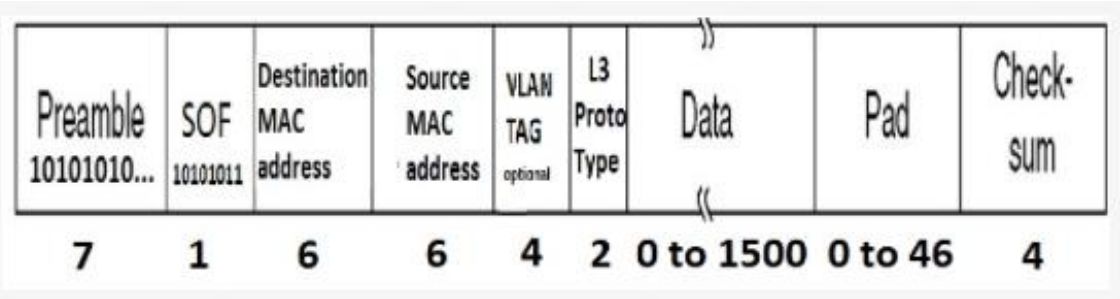
A layer serves the layer above it and is served by the layer below it. For example, a layer that provides error-free communications across a network provides the path needed by applications above it, while it calls the next lower layer to send and receive packets that comprise the contents of that path.

OSI Model			
Layer		Protocol data unit (PDU)	Function[3]
Host layers	7. Application	Data	High-level APIs, including resource sharing, remote file access
	6. Presentation		Translation of data between a networking service and an application; including character encoding, data compression and encryption/decryption
	5. Session		Managing communication sessions, i.e. continuous exchange of information in the form of multiple back-and-forth transmissions between two nodes
	4. Transport	Segment (TCP) / Datagram (UDP)	Reliable transmission of data segments between points on a network, including segmentation, acknowledgement and multiplexing
Media layers	3. Network	Packet	Structuring and managing a multi-node network, including addressing, routing and traffic control
	2. Data link	Frame	Reliable transmission of data frames between two nodes connected by a physical layer
	1. Physical	Bit	Transmission and reception of raw bit streams over a physical medium



Ethernet Frame Structure

- Preamble- 7 byte repeating pattern: 10101010, etc.
- Start of Frame- 1 byte 10101011
- Destination MAC address- 6 byte data link layer destination address
- Source MAC address- 6 byte data link layer source address
- VLAN Header- 4 byte optional VLAN frame header tag
- Protocol type- 2 byte Layer 3 packet type
- Data Field- variable length L3 payload, max 1500 bytes (normal frame)
- Padding field- optional field to maintain a know minimum frame length
- CRC- 4 byte error detection field



Ethernet Variants

- 10Mbps Ethernet,100Mbps (Fast Ethernet -FE),1000Mbps (Gigabit Ethernet -GigE), 10 GigE, 100 GigE etc., mainly based on the data rate.
- Within each variant, there are multiple sub-types like 10Base2, 10BaseT, 1000BaseT etc., based on the type of the underlying physical media, the cable type, the maximum distance supported, etc.

The following hold true for the different variants of Ethernet:

- Framing structure remains the same across all variants, thereby enabling backward compatibility and connectivity between interfaces with different maximum speeds.
- Main differences are at the physical layer based on the following attributes
  - Maximum interface speed (10Mbps, 100 Mbps, 1000 Mbps, 1000Mbps, 10000Mbps etc.)
  - Line Encoding Techniques (e.g. Manchester encoding, 4B/5B encoding, 8B/10B encoding etc.)
  - Media types used (it can either be copper or optical)
  - Cable Types & Connectors (E.g. Cat2, Cat5, Cat 6 etc.)
  - Max Distance Separating nodes in the network (e.g. 10 metres, 20 meters, 100 meters etc.)
- MAC is based on the CSMA/CD protocol

CSMA/CD

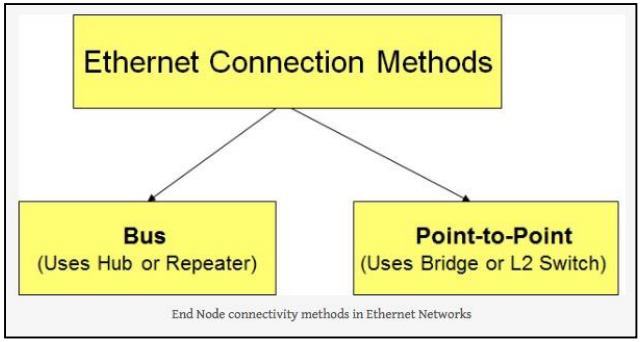
In all the variants of the Ethernet, CSMA/CD is the standard media access control collision resolution protocol used. CSMA/CD is used mainly in bus topologies and in half duplex modes, where multiple nodes share the same bus and thereby contend for a channel. Basically CSMA/CD is based on:

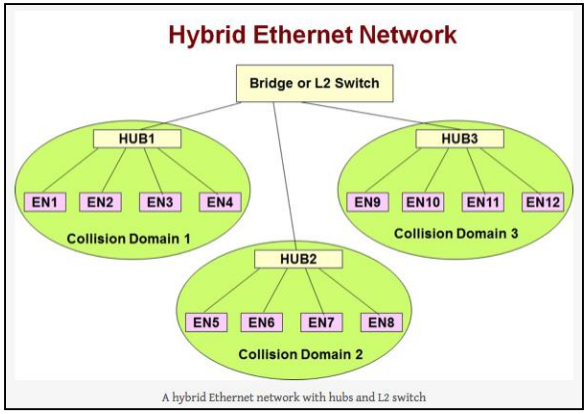
CSMA (Carrier Sense Multiple Access) – Each end node starts transmitting only if the line is not busy already, by looking for the presence of a carrier signal

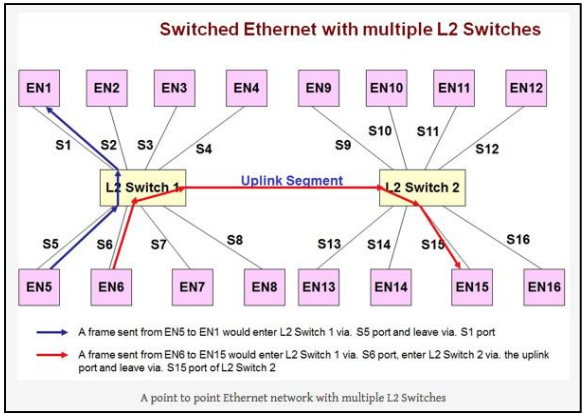
CD (Collision Detection) – If the value of the signal voltage transmitted on the line by a node is different from the line voltage appearing on the line, then the end node detects this as a collision. It immediately sends a special signal called as a JAM signal and stops further transmission of the current frame. Once a collision is detected, an end node uses an exponential backoff algorithm before it attempts retransmission.

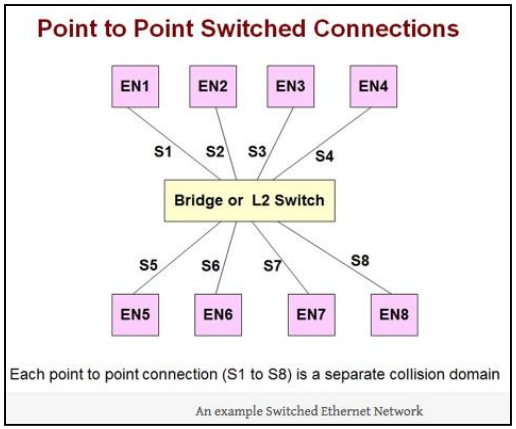
Connection Methods

- Bus- connection to hub or repeater
- Point to Point- switch/bridge
- Hybrid









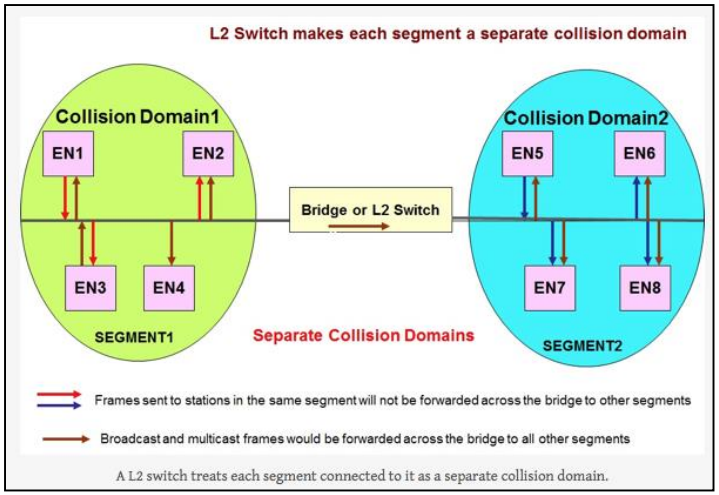
What is Layer 2 Switch?

Different from a repeater, bridge or router?

L2 Switch- data link layer packet switch

Repeater- physical layer extender

Bridge- same as L2 Switch (now)



L3 Router vs. L2 Switch

- Both L2 Switch and L3 Router are basically packet switches and both switch data based on a small header present in the data unit.
- The difference is that an L2 switch is a data link layer packet switch and switches data based on frame headers, whereas a L3 Router is a network layer packet switch and switches data based on the network header.
- The functionality of a L2 Switch is typically known as Switching or Bridging and the functionality of a Router is typically known as Routing.

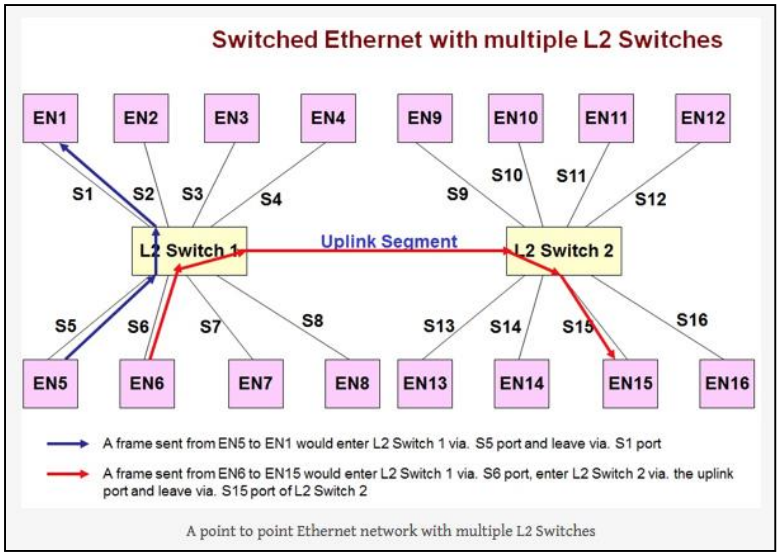
Operation of L2 Switch or Bridge

A L2 Switch or a bridge is a data link layer packet switch and is primarily responsible for forwarding frames within a LAN.
It receives frames via. an input port, determines the exact output port on which the frame is to be sent out based on the destination address in the frame and transmits the frame only on the output port. This way, it makes sure that frames pass only through the required ports and do not cause unnecessary traffic on all other ports, thereby improving overall throughput in the LAN.

Address Learning : Building the Address Resolution Logic (ARL) table dynamically (without any configuration) based on the source MAC address of incoming frames.

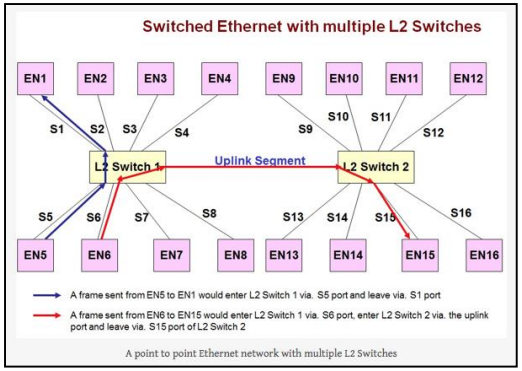
L2 Forwarding : Forwarding incoming frames to the correct output port by referring to the ARL table and the destination MAC address in the incoming frames.

Address Ageing : Timing out outdated/stale entries in the ARL table to facilitate end station movement detection.



A point to point Ethernet network with multiple L2 Switches

Operation of L2 Switch or Bridge- Pt2



Address Learning:
Initially the ARL table is empty and the L2 Switch fills this table dynamically by watching frames passing through it.

When a L2 Switch receives a frame on a port, it looks at the source MAC address field in the frame header. If this MAC address is not present in the ARL table, then it creates a new entry in the table.

Table Entries: The MAC address and port combination show the end station with that specific MAC address is present on that particular port. The time stamp field indicates the time on which the frame was received by the L2 Switch.

If the next frame comes from the same end station, the L2 Switch updates the time stamp field of the already created ARL table entry. This process is repeated for frames received from every end station and the ARL table is built by dynamic learning, without any static configuration.

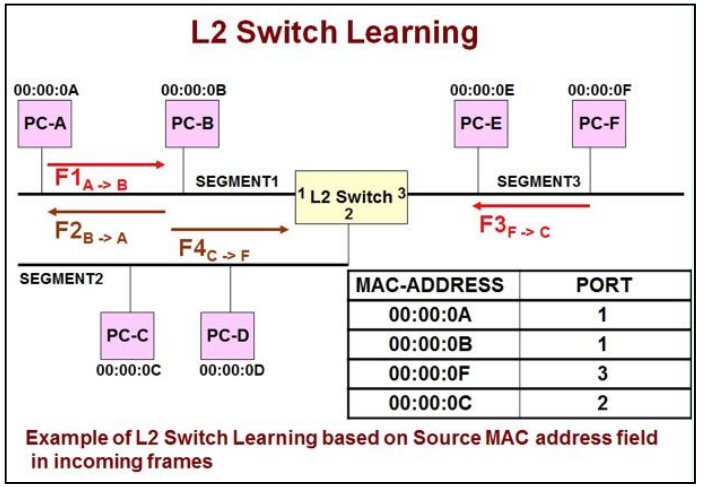
Operation of L2 Switch or Bridge- Pt3

L2 Forwarding:
After updating the ARL table, the next task of the L2 Switch is to forward the frame onto the correct output port.

The L2 Switch does a ARL table lookup to find a matching entry for the destination MAC address of the incoming frame. If a match is found, then the frame is forwarded only to that port, provided that the destination port is different than the one on which the frame arrived.

If the destination port is the same port through which the frame was received, then the L2 Switch does not do anything, as it knows that the destination end node would have already received this frame.

If the ARL table lookup fails, then a copy of the frame is forwarded to all other ports of the L2 Switch, other than the port on which the L2 Switch received the frame. This process is known as flooding.



Operation of L2 Switch or Bridge- Pt4

Address Ageing (Entries Timeout Mechanism):

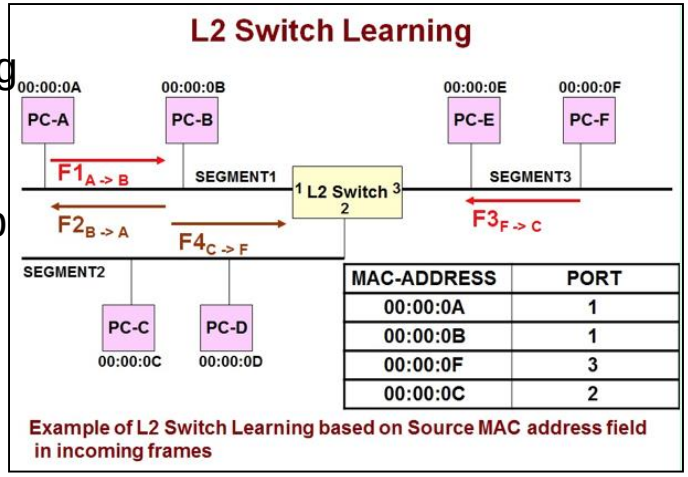
•To facilitate dynamic detection of end station movement and also to remove stale entries from the ARL table, a time stamp field is maintained for each entry in the ARL table.

•As soon as a L2 Switch receives a frame from an end node, it updates the time stamp field of the entry belonging to the end node, with the current time.

•A background process periodically checks the time stamp field of each entry in the ARL table and removes entries that are old.

•The exact value of the time out varies with implementation and is usually configurable as a parameter.

•If an entry times out, then it has to be learned again.



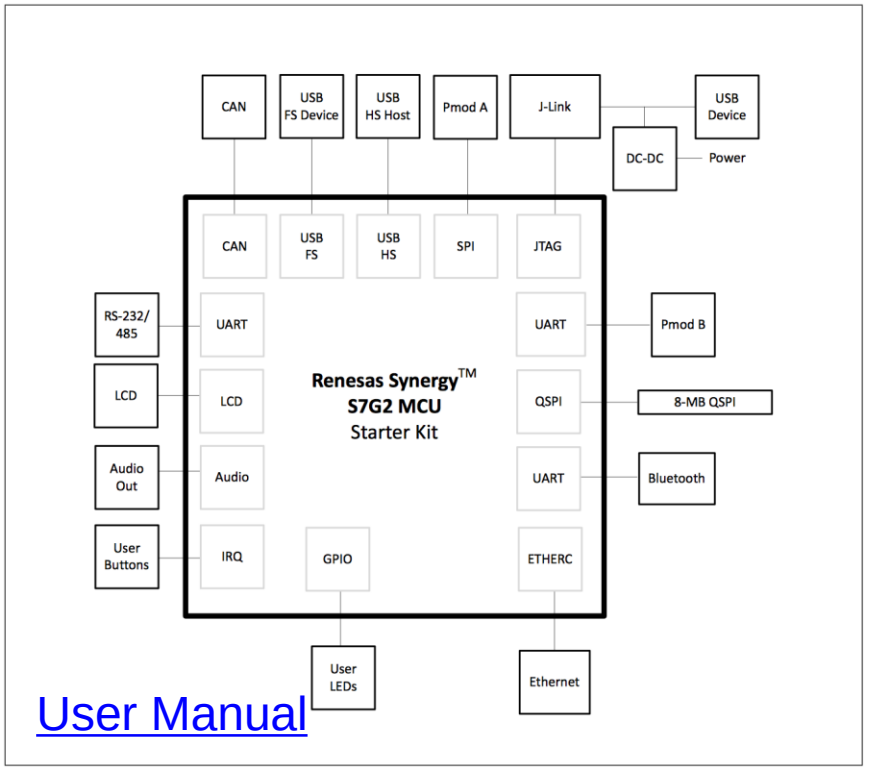
“Regular” Ethernet Kit (Suggested)

Starter Kit for S7G2

Available at Digi-Key:
http://www.digikey.com/product-detail/en/renesas-electronics-america/YSSKS7G2E30/YSSKS7G2E30-ND/5975022

Starter Kit features

- One High-Speed USB Host interface
- One Full-Speed USB Device interface
- One Micro-B USB connector for debug access
- One Ethernet 10/100 RJ45 socket with support for IEEE 1588 Precision Time Protocol (PTP)
- Two 12-pin Type 2A Pmod™ Compatible connector for SPI, IIC, and UART
- Up to 10 standard serial interfaces such as SPI, UART, and IIC
- Multiple LEDs to indicate power and status
- Four user-programmable LEDs
- Two user-configurable push buttons
- QVGA resistive touch (320x240) TFT LCD panel
- Four 40-pin connectors to S7G2 I/O pins
- 8-MB QSPI flash
- Powered through the debug USB interface
- Debug through SEGGER J-Link OB



User Manual

Presented by:

Download and Install

Sign up for the Gallery

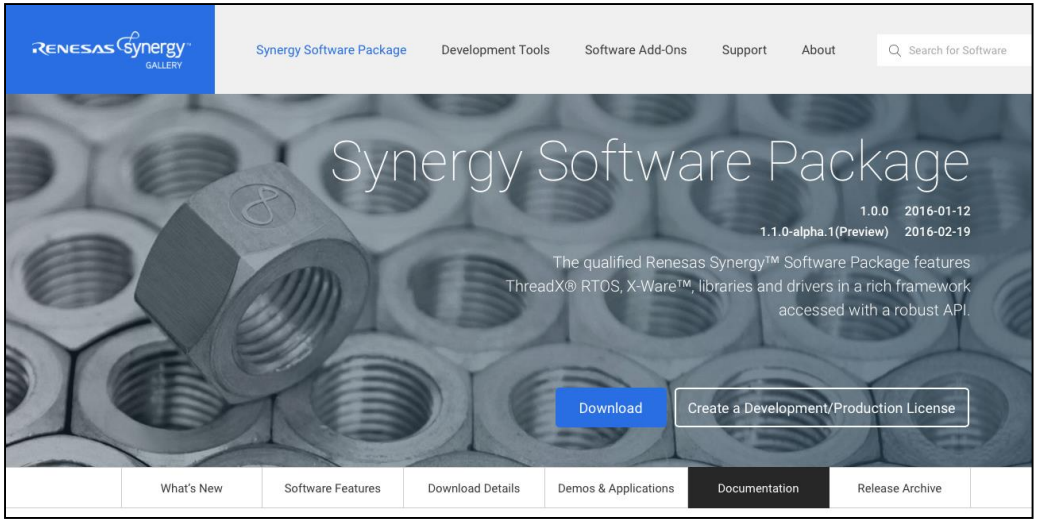
Synergy Software Package Tab

Select Documentation

Follow Instructions Carefully

Once Installed run Threaded Blinky

Located in SSP Users Manual
- Section 3.2
- Shows how to link License file
- If you don't have board you can still compile a project to see how the tools work



Installation Instructions

This package contains SSP v1.1.0 minor release and SSP v1.1.1 patch release; the installer installs SSP v1.1.0 and applies the SSP v1.1.1 patch.

Before installing the SSP, ensure that the following items are installed on the PC:

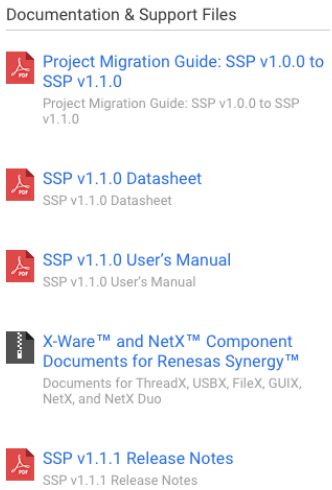
- Renesas e² studio ISDE v5.0.0 (download from Renesas Gallery)
- GNU ARM Compiler (included in Renesas e² studio ISDE v5.0.0 installer)

To install the SSP, follow these steps:

1. Download the following items for the SSP Release from Synergy Gallery:
   - **SSP_Distribution_1.1.1.zip** (SSP Package Installer, including SSP Package, HTML User's Manual and **readme_SSP.txt**); MD5 checksum = 7e91f508a1f7bbcf530adcb9a2664a20
   - **Release_Notes_SSP_ver1.1.1.pdf**
   - Synergy Software Package 1.1.0 User's Manual **r01us0171eu0094_synergy_ssp.pdf**
   - Project **Migration Guide - SSP 1.0.0 to SSP 1.1.0.pdf**
2. Unzip the package and run the **SSP_Distribution_1.1.1.exe** installer.
3. Install the SSP in the root folder of a compatible e² studio installation.
   Note: The default installation folder for the SSP is **C:\Renesas\e2_studio**.

The SSP documentation installs by default to **~Renesas\Synergy\SSP_Documentation**. You can change the default location during the installation. The following documents will be installed:

- **ssp-user-manual-html-v0.94-sspv1.1.0.zip** (HTML version of the SSP User's Manual)
- **readme_SSP.txt** (critical information and last-minute updates)
- Renesas Synergy™ Software Package (SSP) Developer examples **r11an0024eu0100_synergy_ssp.pdf**



Documentation & Support Files

Project Migration Guide: SSP v1.0.0 to SSP v1.1.0
Project Migration Guide: SSP v1.0.0 to SSP v1.1.0

SSP v1.1.0 Datasheet
SSP v1.1.0 Datasheet

SSP v1.1.0 User's Manual
SSP v1.1.0 User's Manual

X-Ware™ and NetX™ Component Documents for Renesas Synergy™
Documents for ThreadX, USBX, FileX, GUIX, NetX, and NetX Duo

SSP v1.1.1 Release Notes
SSP v1.1.1 Release Notes

(https://synergygallery.renesas.com/auth/login)

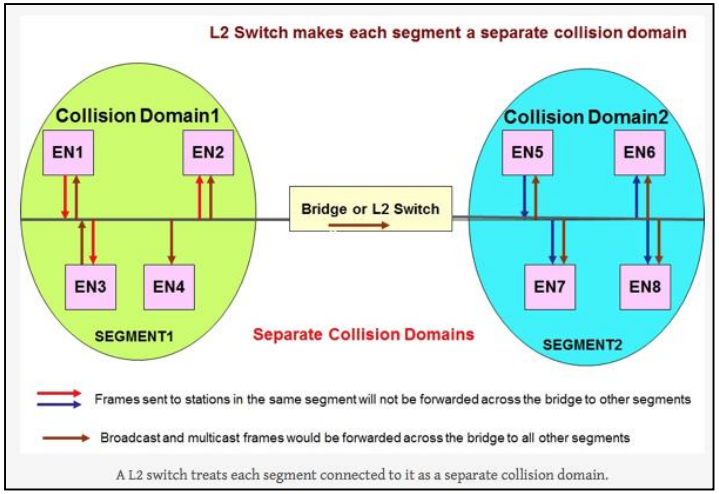
Conclusion

Ethernet

Network Structure

Protocols

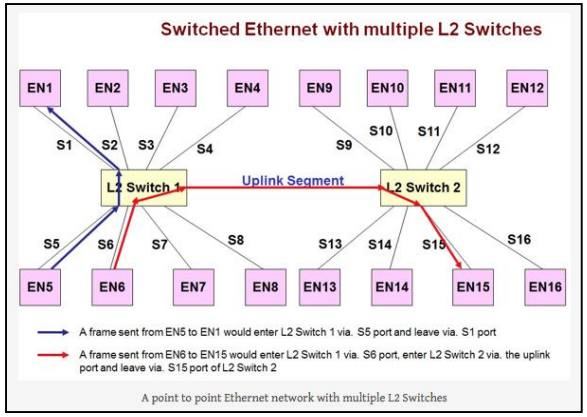
Hands-on Opportunity

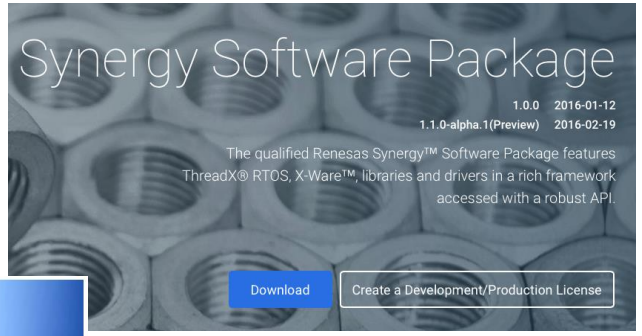


Class Resources

- Content for this class: http://computernetworkingsimplified.in/data-link-layer/overview-ethernet-protocol-types/

- Renesas Synergy Platform Kits at Digi-Key Here
- Kit Resources Here
- Renesas Synergy Platform Here
- Renesas Synergy Gallery Here





Course Resources

Industrial Ethernet Overview- TI

- http://www.ti.com/lit/wp/spry254/spry254.pdf

Industrial Communications Kit

- https://www.digikey.com/en/product-highlight/t/texas-instruments/industrial-communications-engine-using-tis-am3359

EtherCAT Article

- https://www.digikey.com/en/articles/techzone/2015/aug/mcus-and-ethercat-gear-up-for-the-industrial-internet-of-things

Connectivity and Control Systems- TI

- https://dkc1.digikey.com/IE/en/TOD/Texas_Instruments/Connectivity-Control-Systems/Connectivity-Control-Systems.html

Embedded Ethernet- MicroChip

- https://dkc1.digikey.com/IE/en/TOD/microchip/EmbeddedEthernet/EmbeddedEthernet.html
- https://dkc1.digikey.com/IE/en/TOD/Microchip/Ethernet_Controller_Solution/Ethernet_Controller_Solution.html

Introduction to Industrial Ethernet

- http://www.bb-elec.com/Learning-Center/All-White-Papers/Ethernet/Introduction-to-Industrial-Ethernet/AnIntroductionToIndustrialEthernet-WP12B-R1_1112.pdf

Additional Resources

- http://www.ti.com/lit/wp/spry254/spry254.pdf
- https://www.ethercat.org/download/documents/Industrial_Ethernet_Technologies.pdf
- https://www.youtube.com/watch?v=gphJtw0pluo&list=PLgUXqPkOStPum60jqifNt7lDY9_0a0_rX&index=14

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