Industrial Ethernet Designs with MCUs- a Hands on Introduction

Class 4: IE Implementations

12/14/2017

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

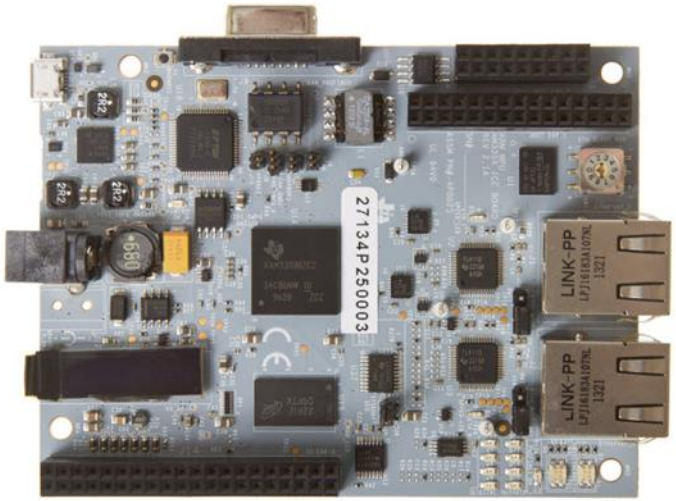
Course Description

- 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

This class will provide descriptions and examples of some Industrial Ethernet implementations and will identify target MCUs and development systems that can be used as hands-on platforms.

- EtherCAT Reminders
- EtherCAT on MCUs
- TI MCU Example
- Multi-Protocol Solution
- Other Target Platforms



EtherCAT Summary

EtherCAT Conformance tested

- Ethernet is the obvious choice for connecting manufacturing nodes to create an Industrial Internet of Things (IIoT).

- However, standard Ethernet falls short of the critical factory-automation requirements for two basic reasons:
  - Its MAC layer does not support real-time, low-latency data transfers.
  - Its star, switch-based topology is very dissimilar from networks found in manufacturing and processing plants.

- To solve these problems, over 2,600 companies have endorsed EtherCAT (Ethernet for Control Automation Technology).

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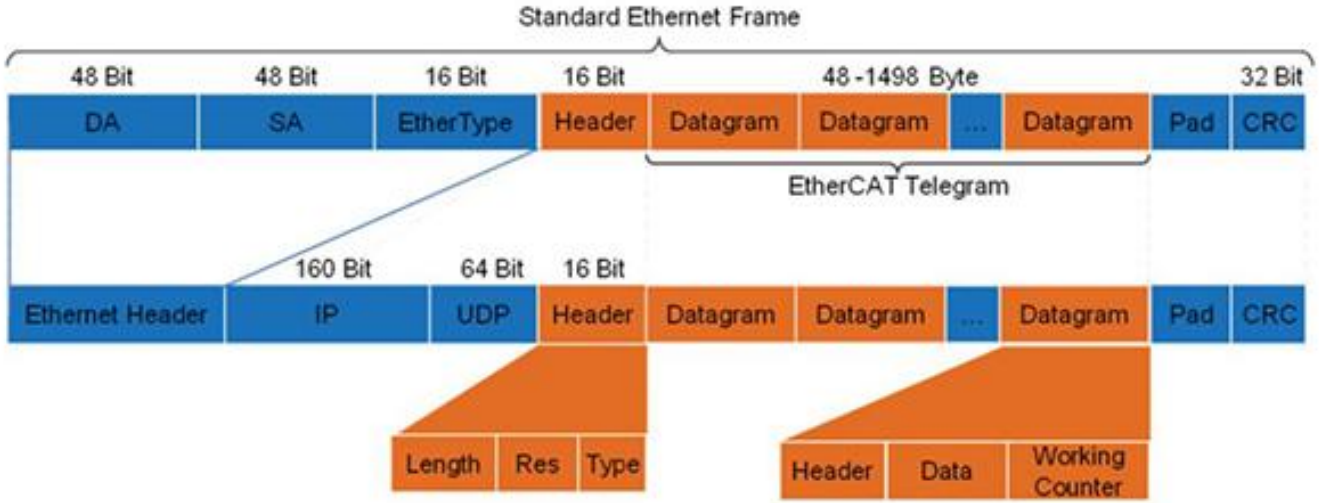
EtherCAT Reminder

- EtherCAT implements a technique called “on-the-fly” processing
- Slaves must have two Ethernet ports for reading from or writing to the frame as it is passing through.
- EtherCAT maintains its compatibility with standard Ethernet by encapsulating an EtherCAT telegram in the Ethernet frame.



EtherCAT on MCUs

- EtherCAT allows any standard PC to be used as an EtherCAT master and communicate with EtherCAT slaves.
- Any viable industrial Ethernet solution must support hard real-time performance, which means EtherCAT requires a dedicated hardware interface at the slave node only.
- There are numerous hardware strategies for designing an EtherCAT slave node- ASIC, FPGA or MCU
- MCUs make it possible for the Industrial IoT roll-out of EtherCAT solutions

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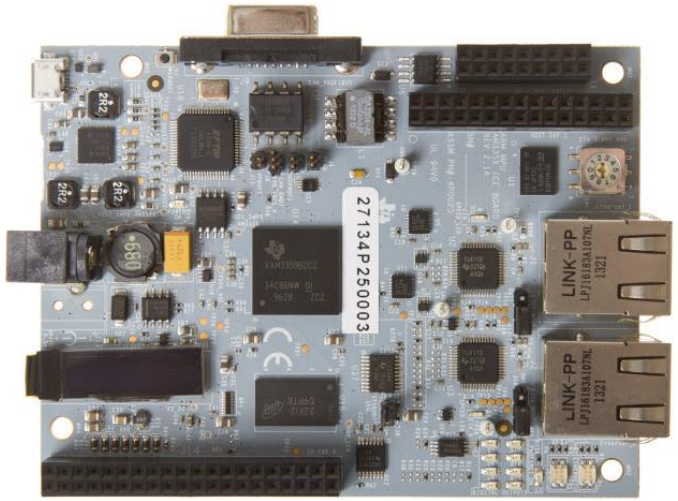
IE Development Platform

TI TIDEP0001

Targeted for EtherCAT slave communications, this development platform allows designers to implement real-time EtherCAT communications standards in a broad range of industrial automation equipment.

- EtherCAT conformance tested
- Free EtherCAT Slave Stack Code
- Free board support package SDK
- Supports other industrial communications- PROFIBUS, Profinet, Ethernet/IP and more)
- Production Ready development platform
- $189.00

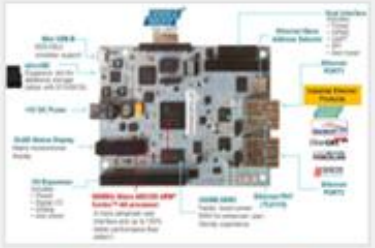


http://www.ti.com/tool/TIDEP0001?jktype=design

IE Reference Designs

Schematic/Block Diagram

Quickly understand overall system functionality.



Download Schematic

Test Data

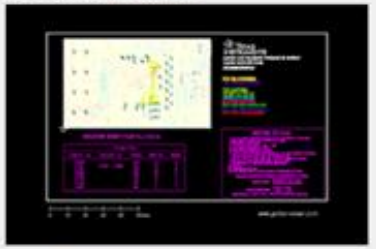
Get results faster with test and simulation data that's been verified.

EtherCAT Conformance tested

Download Test Data

Design Files

Download ready-to-use system files to speed your design process. Get Viewer.



Download Design Files

Reference Designs (5)

Name	Part Number	Tool Type
Ethernet Powerlink Development Platform Reference Design	TIDEP0028	TI Designs
Ethernet/IP Communications Development Platform	TIDEP0003	TI Designs
Multi-Protocol Industrial Ethernet Detection w/PRU-ICSS for Industrial Automation Reference Design	TIDEP0032	TI Designs
PROFIBUS Communications Development Platform	TIDEP0002	TI Designs
Sercos III Communications Development Platform	TIDEP0010	TI Designs

Multi-Protocol Implementation

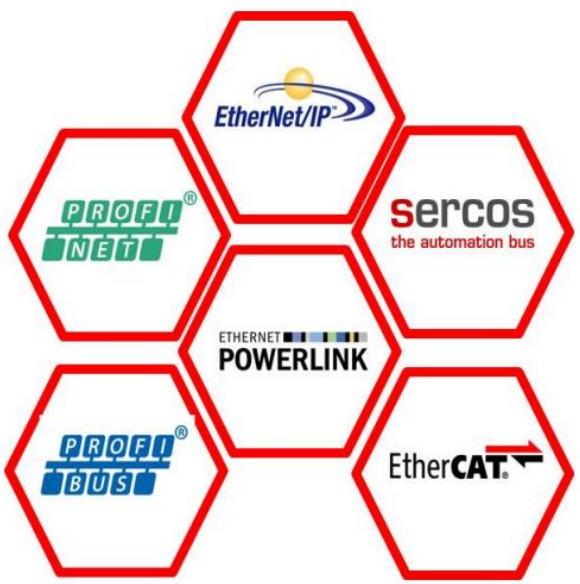
The bootloader is loaded and starts the system.

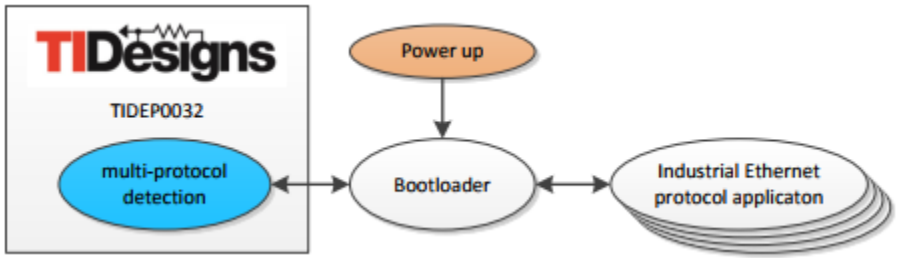
It then loads the multi-protocol industrial Ethernet detection application.

The PRU-ICSS firmware analyzes the incoming Ethernet frames on the real-time Ethernet ports.

Once the industrial Ethernet standard has been determined, the type is stored in non-volatile memory and the bootloader restarts.

The bootloader reads the non-volatile memory and then loads the appropriate industrial automation application





http://www.ti.com/lit/ug/tidua28a/tidua28a.pdf

Programable Real-Time Unit (PRU)

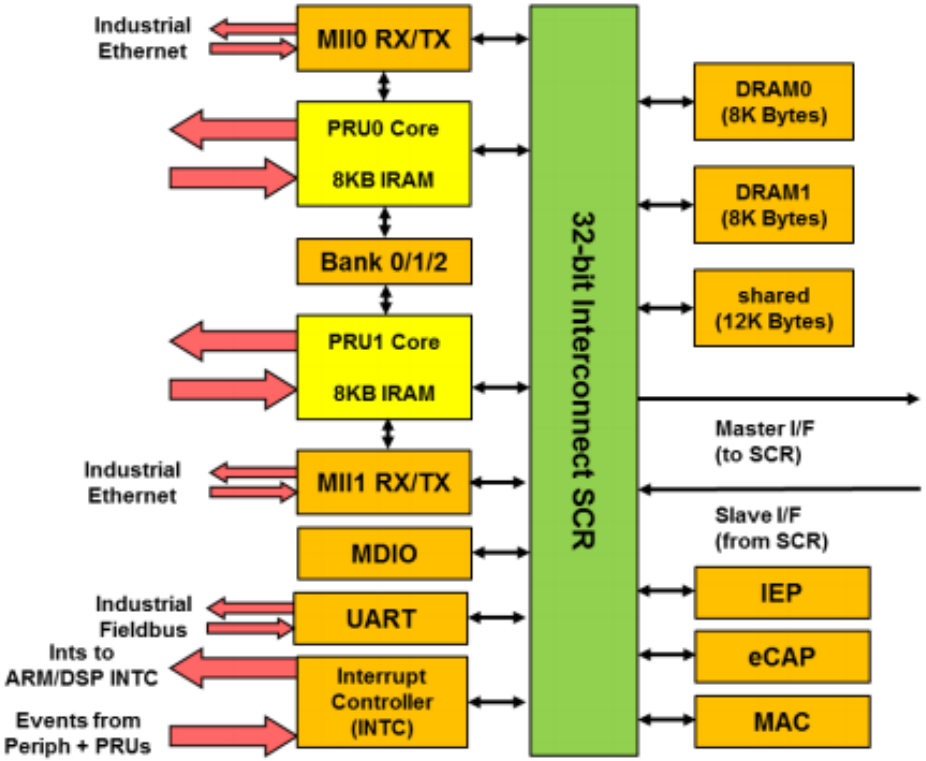
Two dedicated media-independent interfaces (MIIs).

The PRU reads the buffer in chunks of 32-bytes into the circular L2 receive buffer.

The PRU can execute 1024 instructions before the buffer begins to wrap around.

The XIN assembly instruction maps 32 bytes of RX L2 data into register R2 through R9 in a single PRU instruction cycle.

The PRU then stores this 32-byte data into the shared memory to assemble the Ethernet frame fragments.



Ethernet Frame Format

The seven “Preamble” octets (bytes) and the “Start of Frame Delimiter” (SFD) octet are used to synchronize the receive logic to the incoming frame.

The MII block within the PRU-ICSS is configured to remove the 8 bytes of frame header from the incoming frame. Therefore, the MAC destination address is the first information that is stored in the RX L2 ring buffer, followed by the MAC source address.

After the MAC source address, in situations where there is no 802.1Q tag supported by the Ethernet standard, the next two bytes that are received are two octets of the Ethertype field. These two octets are at an offset of 12 bytes from the start of the MAC destination address. The Ethertype information is used to determine the type of the industrial Ethernet standard.

LAYER	PREAMBLE	START OF FRAME DELIMITER	MAC DESTINATION	MAC SOURCE	802.1Q TAG (OPTIONAL)	ETHERTYPE (ETHERNET II) OR LENGTH (IEEE 802.3)	PAYLOAD	FRAME CHECK SEQUENCE (32-BIT CRC)	INTERPACKET GAP
	7 octets	1 octet	6 octets	6 octets	(4 octets)	2 octets	46(42)[1]–1 500 octets	4 octets	12 octets
Layer 2 Ethernet frame			← 64–1518(1522) octets →						
Layer 1 Ethernet frame	← 72–1526(1530) octets →								

(1) From IEEE 802.3-2005 Clause 3.5

Program Flow

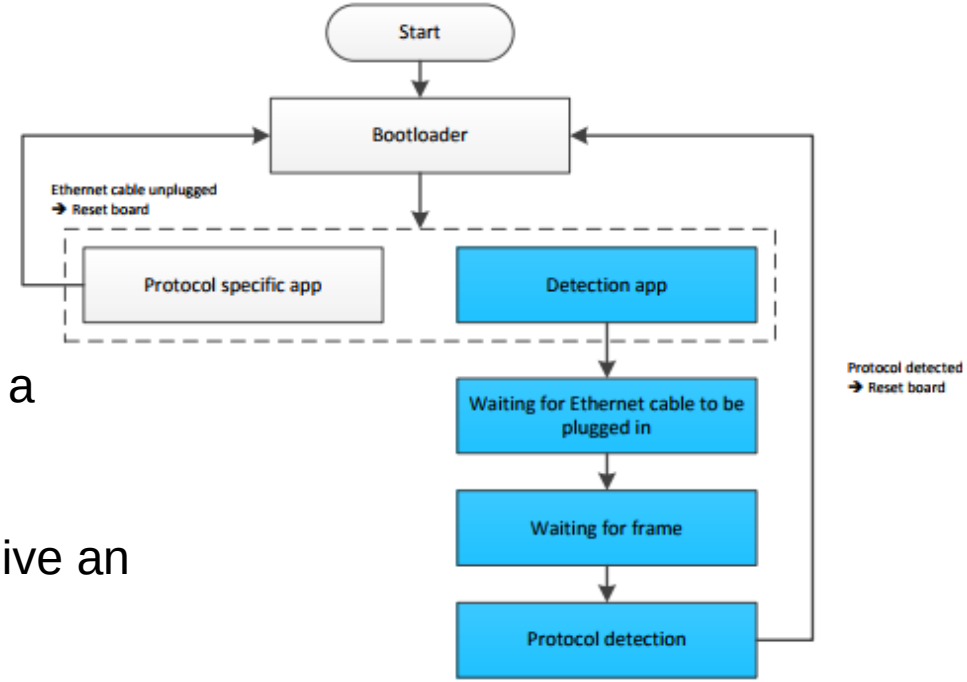
Load the detection application and initializes the system.

Wait for an Ethernet cable to establish a PHY link with the PLC.

The detection application waits to receive an Ethernet frame.

The application analyzes the frame content to determine the industrial Ethernet standard.

The application generates a reset to reload the bootloader.



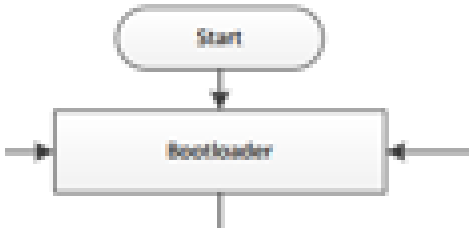
PROTOCOL NAME	ETHERTYPE FIELD VALUE (2 BYTES)	COMMENT
EtherCAT	0x88AE	
PROFINET	0x8892	
Sercos III	0x88CD	
PowerLink	0x88AB	
EtherNet/IP	0x8000	IP protocol

Application Description

The ARM application consists of a main() function, a task, and an interrupt service routine (ISR). The application uses the Texas Instruments SYS/BIOS™ real-time operating system (RTOS).

The main() function performs the following tasks:

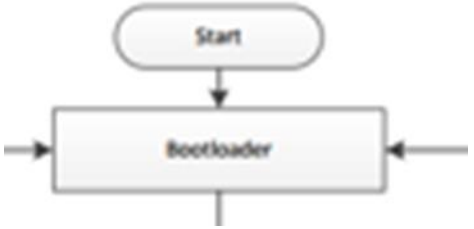
- Initializing SoC device
  - Memory management unit (MMU)
  - Type of board detection based on information stored in the on-board EEPROM
  - Configuration of processor pins
  - SPI, GPIO, LED, and UART peripheral
- Initializing PRU-ICSS, including the RX L2 ring buffer within the MII block
- Registering an interrupt handler that receives events generated by PRU-ICSS
- Registering task reset_task() and Displaying message onto the OLED display
- Starting SYS/BIOS scheduler



Application Description 2

The ISR waits to receive an interrupt generated by the PRU-ICSS firmware.

The interrupt is issued when an Ethernet frame has been received and analyzed. The ISR checks the type of industrial Ethernet standard and writes this information into the RTC_SCRATCH0_REG register.



This register maintains the data integrity if the device performs a cold start (reset), allowing the information stored in this register to be evaluated by the bootloader.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
RTCSCRATCH0
R/W-0h

Application Description 3

The task_reset() waits until the g_reset parameter value equals ”1”; otherwise, the task reset() resumes
sleep mode.

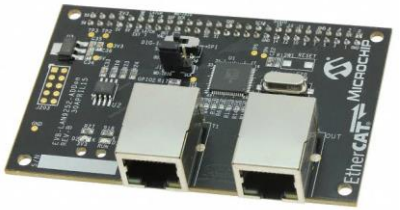
It sets the RST_GLOBAL_COLD_SW bit which triggers a SoC cold-start software reset that causes the bootloader to reload.

The bootloader can determine the kind of industrial Ethernet standard by reading out RTC_SCRATCH0_REG.

Clears the RTC_SCRATCH0_REG register before the bootloader loads the industrial application software with the appropriate industrial Ethernet standard.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8
RESERVED																							
Rreturns0s-0h																							
7					6				5				4			3				2			1
RESERVED																RST_GLO BAL_ SW COLD_				RST_GLOBAL_ WARM_SW			
Rreturns0s/W-0h																Rreturns0s/W-0h				Rreturns0s/W-0h			

Other Target Platforms



https://www.digikey.com/product-detail/en/microchip-technology/EVB-LAN9252-ADD-ON/EVB-LAN9252-ADD-ON-ND/5401238

https://www.digikey.com/products/en/development-boards-kits-programmers/evaluation-boards-embedded-mcu-dsp/786?k=EtherCAT%20Kit

https://www.renesas.com/en-us/products/boards-and-kits/boards-and-kits/device/YDRIVE-IT-RZT1.html

Conclusion

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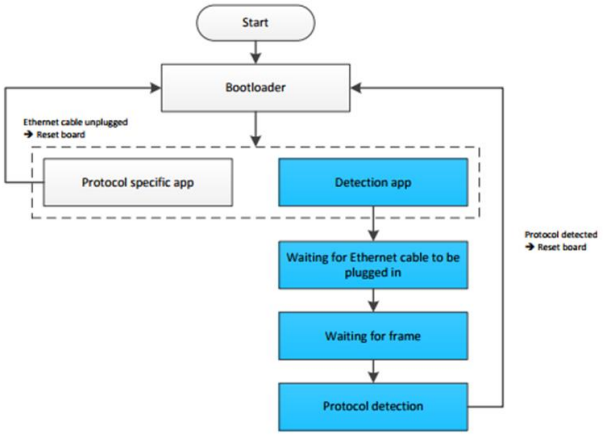

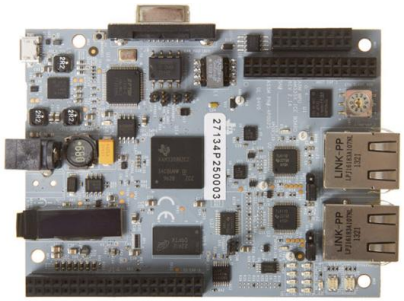

Class Resources

TI Development Platform

- http://www.ti.com/tool/TIDEP0001?jktype=design
- http://www.ti.com/lit/ug/tidua28a/tidua28a.pdf

Motor Control Kit- Renesas

- https://www.renesas.com/en-us/products/boards-and-kits/boards-and-kits/device/YDRIVE-IT-RZT1.html

Microchip EtherCAT Slave Controller

- https://www.digikey.com/product-detail/en/microchip-technology/EVB-LAN9252-ADD-ON/EVB-LAN9252-ADD-ON-ND/5401238

Infineon EtherCAT Kit

- https://www.digikey.com/products/en/development-boards-kits-programmers/evaluation-boards-embedded-mcu-dsp/786?k=EtherCAT%20Kit

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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