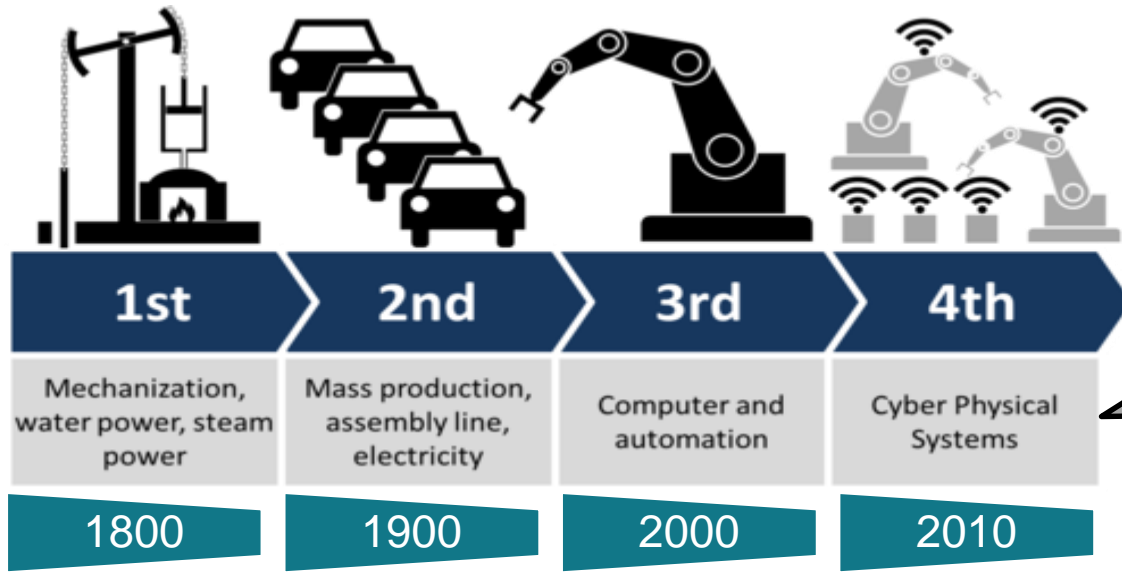# Agenda

- Introduction to Industry 4.0

- Industrial protocols - What and why?

- TI solutions for Industry 4.0

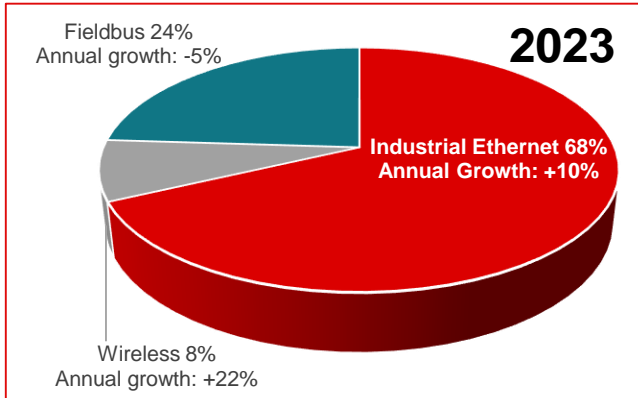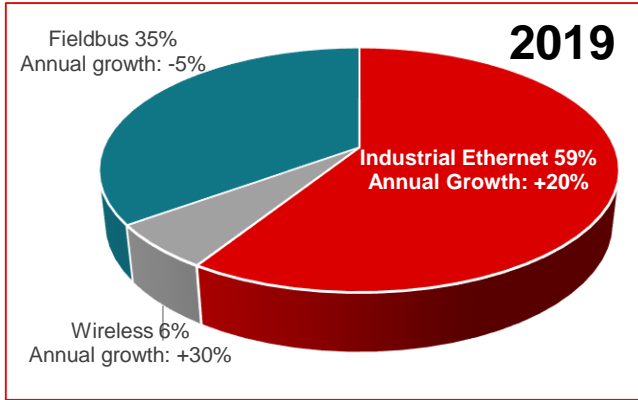- TI partners for industrial networking

- Q&A

Evolution to Industry 4.0

- Industry 4.0 focused on enabling connected smart factories
  - Real-time communication of manufacturing to help optimize productivity and minimize downtime.
  - It consists of intelligent, horizontal and vertical networked systems.
  - Factory adapts dynamically to variations in the supply chain.

1st	2nd	3rd	4th
Mechanization, water power, steam power	Mass production, assembly line, electricity	Computer and automation	Cyber Physical Systems
1800	1900	2000	2010

✓ Interoperability
✓ Better process visibility
✓ Decentralized decisions
✓ Safety & security

* Picture: https://www.kiet.edu/blog/future-of-work-series/understanding-industry-4-0-5-0-better/

TEXAS INSTRUMENTS

Industrial network market share 2019 vs 2023*

2019

Fieldbus 35%
Annual growth: -5%

**Industrial Ethernet 59%
Annual Growth: +20%**

Wireless 6%
Annual growth: +30%

2023

Fieldbus 24%
Annual growth: -5%

**Industrial Ethernet 68%
Annual Growth: +10%**

Wireless 8%
Annual growth: +22%

TEXAS INSTRUMENTS

Industrial network market share 2019 vs 2023*

2019

Fieldbus 35%
Annual growth: -5%

Industrial Ethernet 59%
Annual Growth: +20%

Wireless 6%
Annual growth: +30%

2023

Fieldbus 24%
Annual growth: -5%

Industrial Ethernet 68%
Annual Growth: +10%

Wireless 8%
Annual growth: +22%

Industrial Ethernet protocol breakout 2023

Other Ethernet, 13%
CC-Link IE Field, 4%
POWERLINK, 4%
Modibus-TCP, 7%
PROFINET, 27%
EtherNet/IP, 27%
EtherCAT, 18%

TEXAS INSTRUMENTS

Industrial automation – Today
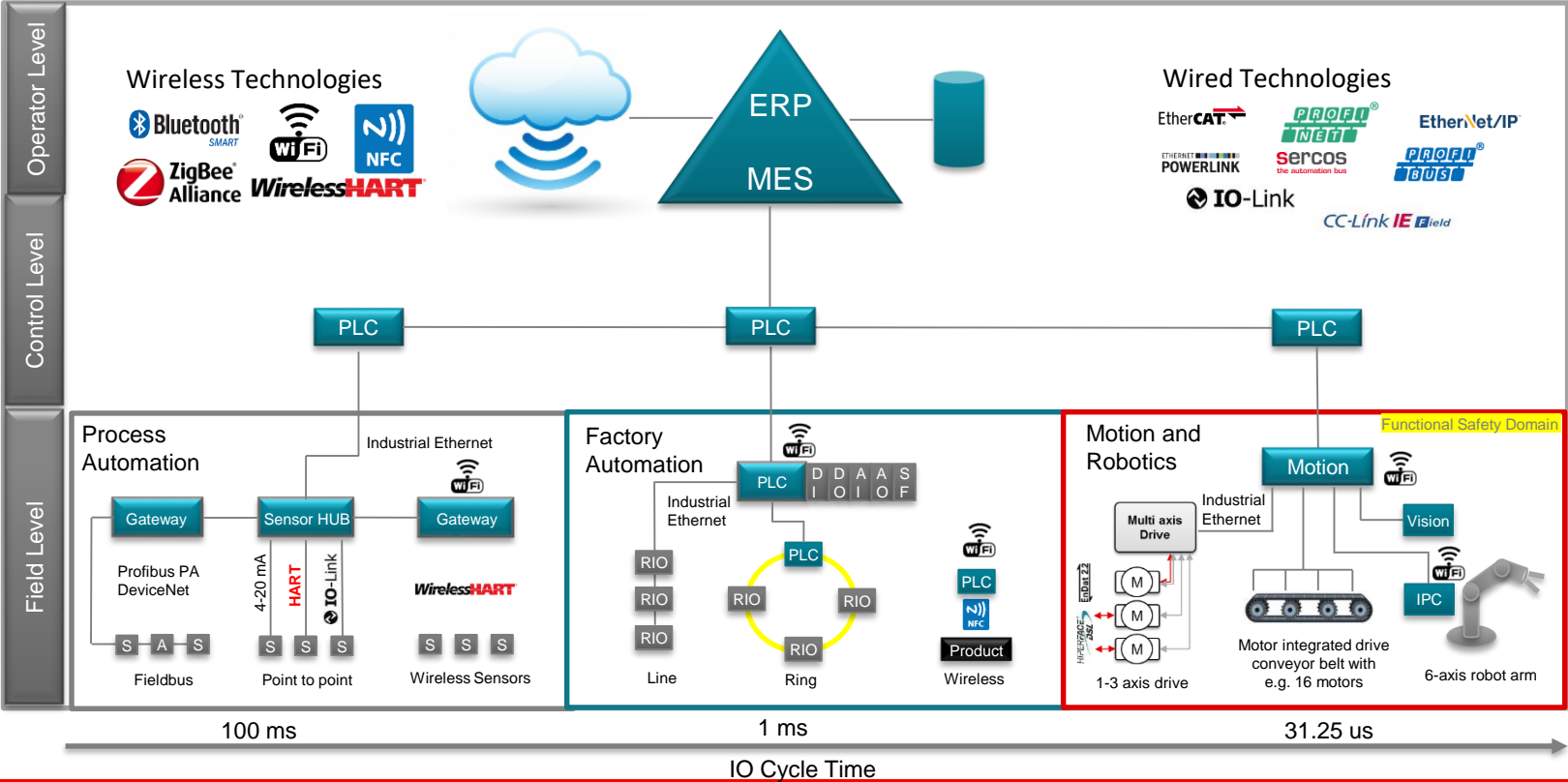
What is industrial networking & industrial Ethernet?

- **Industrial networks connect various field equipment, sensors, and control systems to enable:**
  - Centralized and de-centralized control
  - Real-time monitoring & maintenance
  - Data collection on a "global" scale for advanced analytics / optimizations

- **Industrial networks reduce operational costs by**
  - Improving product quality / minimizing misprocesses
  - Improving throughput / productivity while minimizing equipment downtime
  - Easily scaling to support network expansion or equipment upgrade cycles

Achieved through

- **Industrial Ethernet is standards based Ethernet MAC and Phy layer, often supporting different higher layers - optimized to support real-time, deterministic data.**

- **High speed industrial Ethernet based protocols are rapidly gaining share vs fieldbus protocols (i.e. Modbus, DeviceNet, PROFIBUS) offer a number of advantages – real-time, deterministic data, scalability, flexibility**

7

TEXAS INSTRUMENTS

Challenges with industrial Ethernet today

- **Lack of a unified network**
  - Market consists of multiple non-interoperable protocols
  - Gateways are needed to connect different networks
  - Mixed-networks are more costly to support & manage
  - Equipment costs are more expensive / supplier choices are limited

- **Not all networking equipment is IEEE compliant**
  - Many industrial networking protocols require modified Ethernet MACs at the device & switch, increasing costs and limiting equipment choices.
  - EtherCAT and PROFINET IRT, both of which use non-IEEE standard switch & device hardware, are good examples where the MAC has been modified to improve performance.

TEXAS INSTRUMENTS
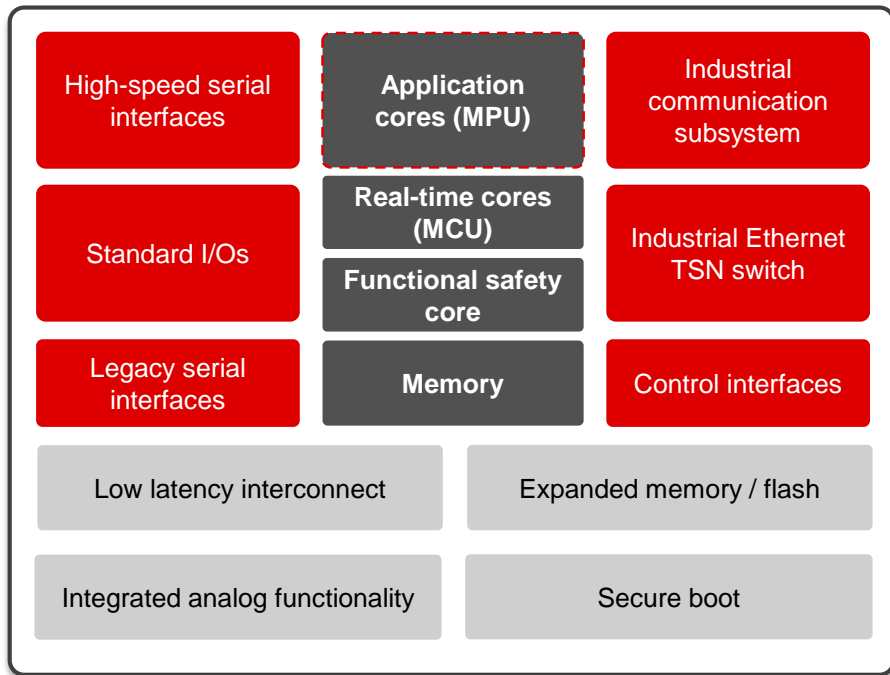
The future of networking: Time-Sensitive Networking

- **Time-Sensitive Networking (TSN) is designed to support the requirements of industrial networks today and tomorrow, as well as automotive, aviation, and audio/video networks.**

- **Individual TSN standards are grouped into four categories:**
    - Time synchronization
    - Low latency, deterministic communication
    - High availability / redundant networking
    - Standardized network management and configuration tools

- **TSN is ensuring interoperability and is predicted to become the dominant industrial networking standard.**
    - Note TSN can coexist/support existing protocols, acting as the "transport" layer. (i.e. PROFINET over TSN, EtherNet/IP over TSN and CC-Link IE TSN)

TEXAS INSTRUMENTS

Industrial networking device architecture

High-speed serial interfaces	Application cores (MPU)	Industrial communication subsystem
Standard I/Os	Real-time cores (MCU)	Industrial Ethernet TSN switch
	Functional safety core	
Legacy serial interfaces	Memory	Control interfaces

Low latency interconnect	Expanded memory / flash
Integrated analog functionality	Secure boot

Performance
- ❑ Real-time cores (and optional application cores)
- ❑ Functional safety & security support

Industrial communication subsystems
- ❑ Multi-protocol industrial networking support
- ❑ Programmable real time peripheral connectivity

PROFI NET   EtherNet/IP   EtherCAT   IO-Link

Industrial Ethernet
- ❑ Multi-port GbE TSN
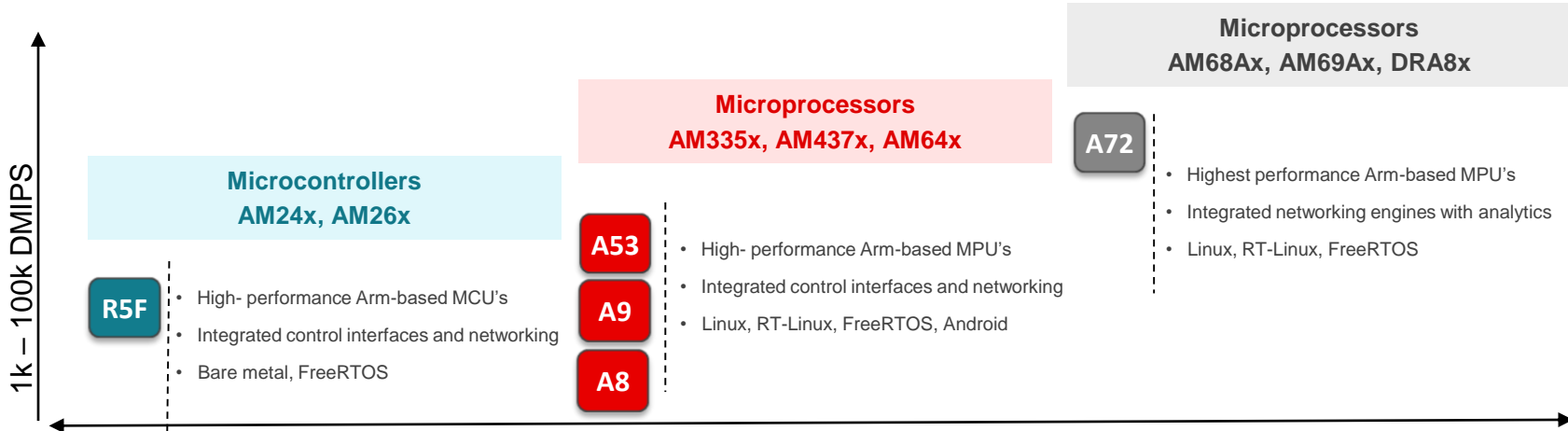- ❑ Independent GbE ports

Motor control
- ❑ Multi-axis motor control (FOC)
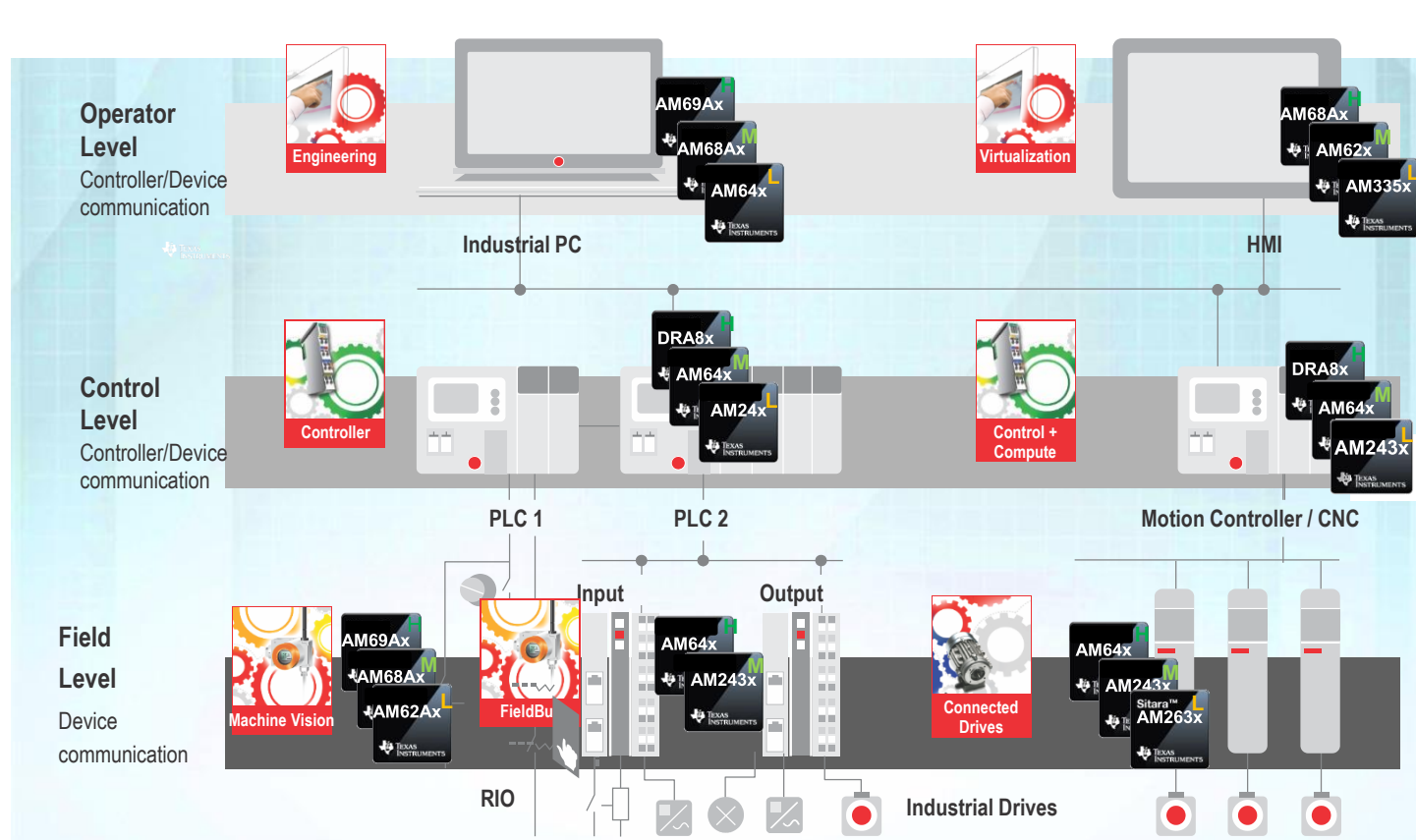- ❑ Multi-protocol position encoder support

Processing scalability
- ❑ P2P options: Scale from real-time cores to integrated application processing without hardware redesign

TEXAS INSTRUMENTS

Scalable portfolio for industrial networking

- Scalable devices for real-time to advanced applications built with industry-standard multi-core options
- Robust, modern I/O and real-time, deterministic communication
- Functional safety and security
- Comprehensive eco-system & expanding third-party network

Microprocessors
AM68Ax, AM69Ax, DRA8x

A72
- Highest performance Arm-based MPU's
- Integrated networking engines with analytics
- Linux, RT-Linux, FreeRTOS

Microprocessors
AM335x, AM437x, AM64x

A53
A9
A8
- High- performance Arm-based MPU's
- Integrated control interfaces and networking
- Linux, RT-Linux, FreeRTOS, Android

Microcontrollers
AM24x, AM26x

R5F
- High- performance Arm-based MCU's
- Integrated control interfaces and networking
- Bare metal, FreeRTOS

1k – 100k DMIPS

TEXAS INSTRUMENTS

TI industrial Ethernet solutions serving Industry 4.0

Operator Level
Controller/Device communication

Engineering

AM69Ax
AM68Ax
AM64x

Industrial PC

Virtualization

AM68Ax
AM62x
AM335x

HMI

Control Level
Controller/Device communication

Controller

DRA8x
AM64x
AM24x

PLC 1

PLC 2

Control + Compute

DRA8x
AM64x
AM243x

Motion Controller / CNC

Field Level
Device communication

Machine Vision

AM69Ax
AM68Ax
AM62Ax

FieldBus

Input

AM64x
AM243x

Output

Connected Drives

AM64x
AM243x
Sitara™ AM263x

RIO

Industrial Drives

Industrial protocols delivered
- Certified market leading multi protocols from TI (device)
- No license required
- TSN & single pair Ethernet ready

Single chip solution
- Secure boot, HSM
- Up to SIL-3 functional safety, IEC 61508

Future proof
- Broad range of performance enabled by pin-to-pin platforms
- Software re-use across platforms

Performance color code

Embedded High end
Embedded Mid end
Embedded Low end

12

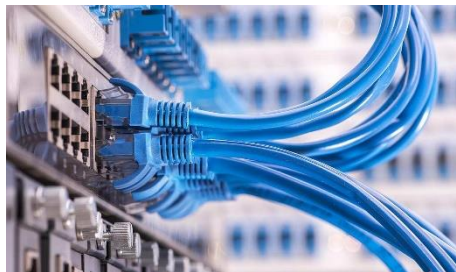# Industrial networking software engagement models

Direct from TI

Certified TI development platforms

SDK includes all TI-offered stacks

Protocol-enabled devices includes stack license

Feature updates & software support directly from TI

TI Microcontrollers & **Microprocessors**

Start with TI industrial toolkit

1. Type "Dev.ti.com/tirex"
2. Training → Select MCU+ Academy for AM243x
3. Documents → Select Industrial Communications Toolkit

TEXAS INSTRUMENTS

Industrial networking software engagement models

From third parties

Stacks licensed from third parties

Separate license per protocol

Licenses available as buyout, per project, and per family

Stack support from third party

Certified solutions

Software partners

Hardware partners

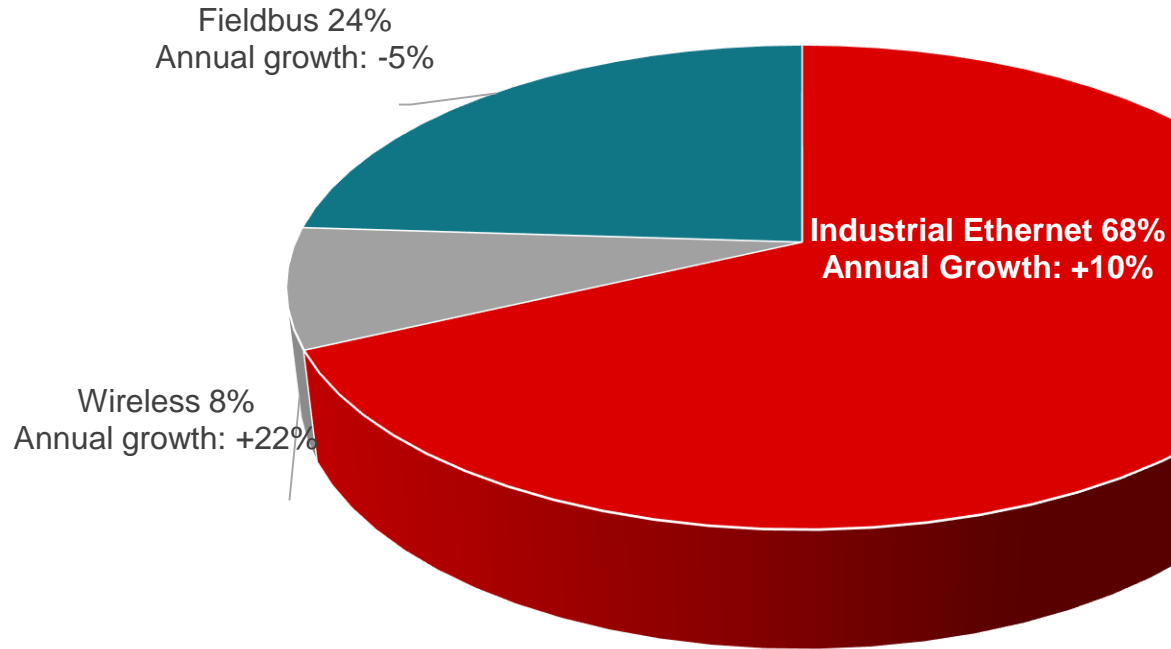TEXAS INSTRUMENTS

Visit www.ti.com/npu

For more information on the New Product Update series, calendar and archived recordings

TEXAS INSTRUMENTS

Industrial network market shares 2023

Fieldbus 24%
Annual growth: -5%

Industrial Ethernet 68%
Annual Growth: +10%

Wireless 8%
Annual growth: +22%

Industrial network market shares 2023

Fieldbus 24%
Annual growth: -5%

Industrial Ethernet 68%
Annual Growth: +10%

Wireless 8%…
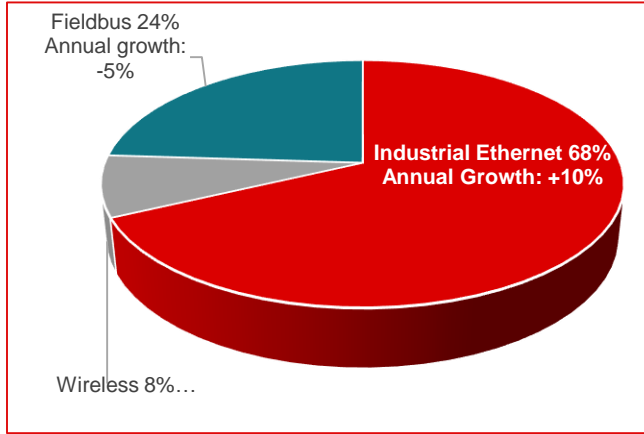
- Datapoint on 2023-5yrs Fieldbus vs Ind Ether

Industrial Ethernet Protocol Breakout

Other Ethernet, 13%

ProfiNET, 27%

CC-Link IE Field, 4%

POWERLINK, 4%

Modibus-TCP, 7%

EtherNet/IP, 27%

EtherCAT, 18%

TEXAS INSTRUMENTS
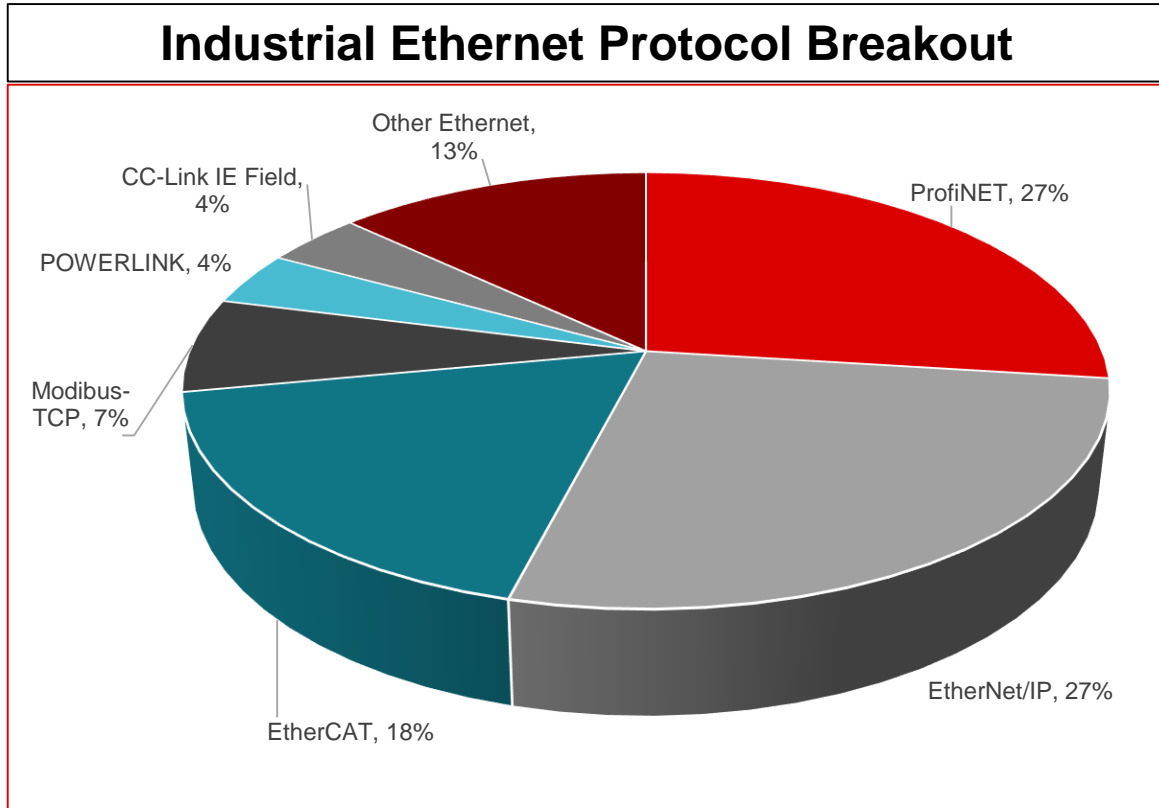
TI Industrial Ethernet Solutions Serving Industrial 4.0

Performance color code
High end
Mid end
Low end

Operator Level
Controller/Device communication

Engineering

Industrial PC

AM69x **H**
AM67x **M**
Sitara™ AM64x **L**

Virtualization

HMI

AM68x **H**
Sitara™ AM62x **M**
Sitara™ AM335x **L**

Control Level
Controller/Device communication

Controller

PLC 1

PLC 2

DRA8x **H**
Sitara™ AM64x **M**
Sitara™ AM24x **L**

Control + Compute

Motion Controller / CNC

DRA8x **H**
Sitara™ AM64x **M**
Sitara™ AM243x **L**

Field Level
Device communication

Machine Vision

AM68A **H**
Sitara™ AM67x **M**
Sitara™ AM62x **L**

FieldBus

Input   Output

Sitara™ AM64x **H**
Sitara™ AM243x **M**

Connected Drives

Sitara™ AM64x **H**
Sitara™ AM243x **M**

RIO

Industrial Drives

Industrial Protocols Delivered
- Certified market leading multi protocols from TI (Device)
- No license required
- TSN & single pair eth ready

Single Chip Solution
- Secure Boot, HSM, sensing
- Up to SIL-3 Functional Safety, IEC 61508

Future Proof
- Broad range of performance enabled by pin-to-pin platforms
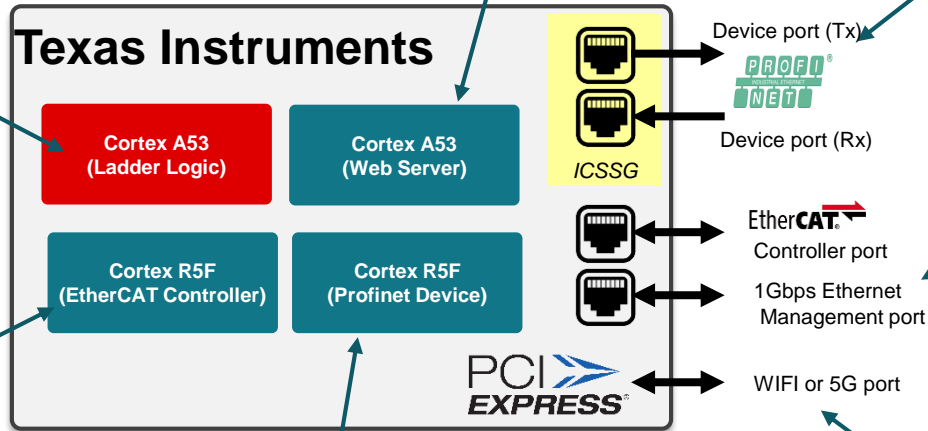- Mainline Linux & FreeRTOS - software re-use across platforms

19

TI Partners for Industrial Networking

PLC with Industrial Comms Example

A core running RT Linux web server, motion control, predictive maintenance, house keeping, and other applications

1Gbps Multi-Protocol Industrial Communications Device support via the AM64x Industrial communication sub system (ICCSG)

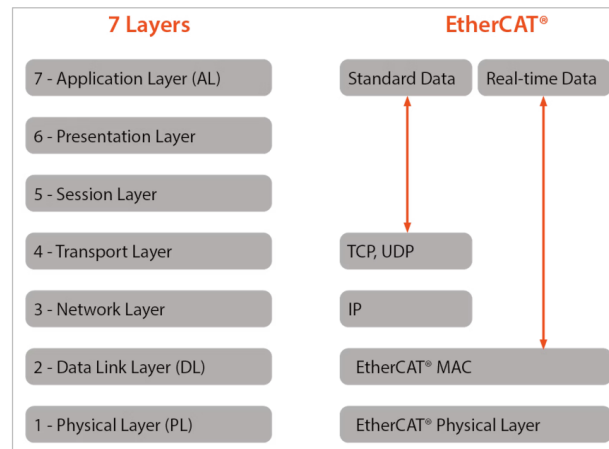PLC Ladder Logic running on "isolated" RT Linux A core

Texas Instruments

Cortex A53 (Ladder Logic)

Cortex A53 (Web Server)

Cortex R5F (EtherCAT Controller)

Cortex R5F (Profinet Device)

ICSSG

PCI EXPRESS

Device port (Tx)

PROFI NET

Device port (Rx)

EtherCAT Controller and management ports

EtherCAT
Controller port

1Gbps Ethernet Management port

WIFI or 5G port

R5F EtherCAT Controller supports as low as 31.25us cycle times

Profinet Device support

PCIe connection to WIFI or 5G wireless modules.

TEXAS INSTRUMENTS

Industrial Ethernet Protocols

- Industrial Ethernet is based on the 802.3 Ethernet MAC and Physical layer, but often has different higher layers than standard Ethernet, optimized to support real-time, deterministic data.

- High speed Ethernet based protocols are rapidly gaining share vs legacy protocols such as Modbus, DeviceNet, and Profibus as they offer a number of advantages including:
  - Higher Speeds (100Mbs & 1Gbs)
  - Single cable for data, control, and clock synchronization
  - Scalability / flexibility / lower cost equipment
  - Real-time, deterministic performance
  - Common network time reference

7 Layers	EtherCAT®	
7 - Application Layer (AL)	Standard Data	Real-time Data
6 - Presentation Layer		
5 - Session Layer		
4 - Transport Layer	TCP, UDP	
3 - Network Layer	IP	
2 - Data Link Layer (DL)	EtherCAT® MAC	
1 - Physical Layer (PL)	EtherCAT® Physical Layer	

PROFINET
INDUSTRIAL ETHERNET

EtherCAT®

EtherNet/IP™

CC-Link IE Field

24

TEXAS INSTRUMENTS

Industrial Communication 3P SW & HW Engagement Models

From Third-party

Stacks licensed from third parties

Separate license per protocol

Licenses available as buyout, per project, and per family

Stack support from third party

Certified solutions

SW Partners

acontis technologies

CODESYS

ibv
Realtime is BLUE

KUNBUS
industrial communication

port

TMG TE

HW Partners

PHYTEC

SolidRun

TQ

Tronlong®

TI provides the total solution for industrial protocols:
Easy engagement starting with Sitara AM243x and AM64x families

Industrial Networking Arm Processor

PCIe 2.0 USB 3.1 / 2.0	1-2x 1GHz Cortex-A53s	2x Industrial Communication Subsystems
I2C,SPI,UART & GPIOs	1-4x 800MHz Cortex-R5Fs	2-port GbE Switch w/ TSN
	1x 400MHz M4F 256KB (FFI)	
2x CAN-FD	2MB SRAM with inline ECC	ePWM, encoder I/Fs, eCAP & eQEP
12-bit ADC @ 4 MSPS	DDR4 / LPDDR4 with inline ECC + OSPI/eMMC/SD I/Fs	
SIL 2/3 Functional Safety (Uses ARM M4F subsystem)	Secure Boot	
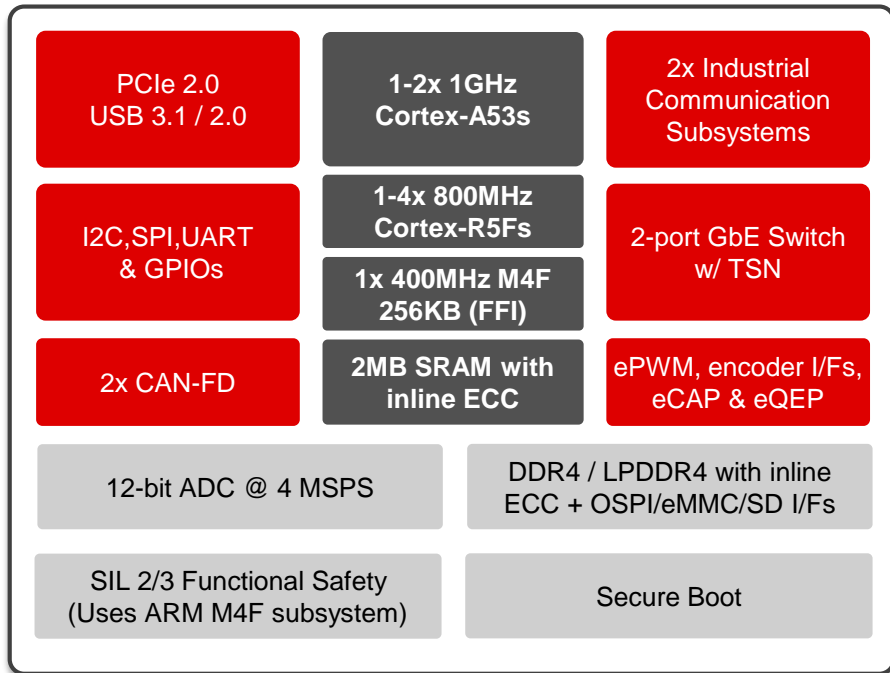
Performance
- ❑ Up to two A53 application cores with up to 6.0 DMIPs
- ❑ Up to four R5F real-time cores with up to 6.7 DMIPs
- ❑ Functional Safety & Security support

Industrial Communication Subsystems
- ❑ Multi-protocol industrial networking support
- ❑ Programable real time peripheral connectivity

PROFINET INDUSTRIAL ETHERNET   EtherNet/IP   EtherCAT   IO-Link

Industrial Ethernet
- ❑ 2-port GbE TSN & cut-through switching (2-ext, 1-int port)
- ❑ Up to 5x independent GbE ports

Motor Control
- ❑ Multi-axis motor control (FOC)
- ❑ Multi-protocol position encoder support

Processing Scalability
- ❑ P2P compatibility with MCU family

TEXAS INSTRUMENTS

Industrial network market shares 2019 vs 2023*

2019

Fieldbus 35%
Annual growth: -5%

**Industrial Ethernet 59%
Annual Growth: +20%**

Wireless 6%
Annual growth: +30%

2023

Fieldbus 24%
Annual growth: -5%

**Industrial Ethernet 68%
Annual Growth: +10%**

Wireless 8%
Annual growth: +22%

Industrial Ethernet Protocol Breakout 2023

Other Ethernet, 13%

CC-Link IE Field, 4%

POWERLINK, 4%

Modibus-TCP, 7%

ProfiNET, 27%

EtherNet/IP, 27%

EtherCAT, 18%
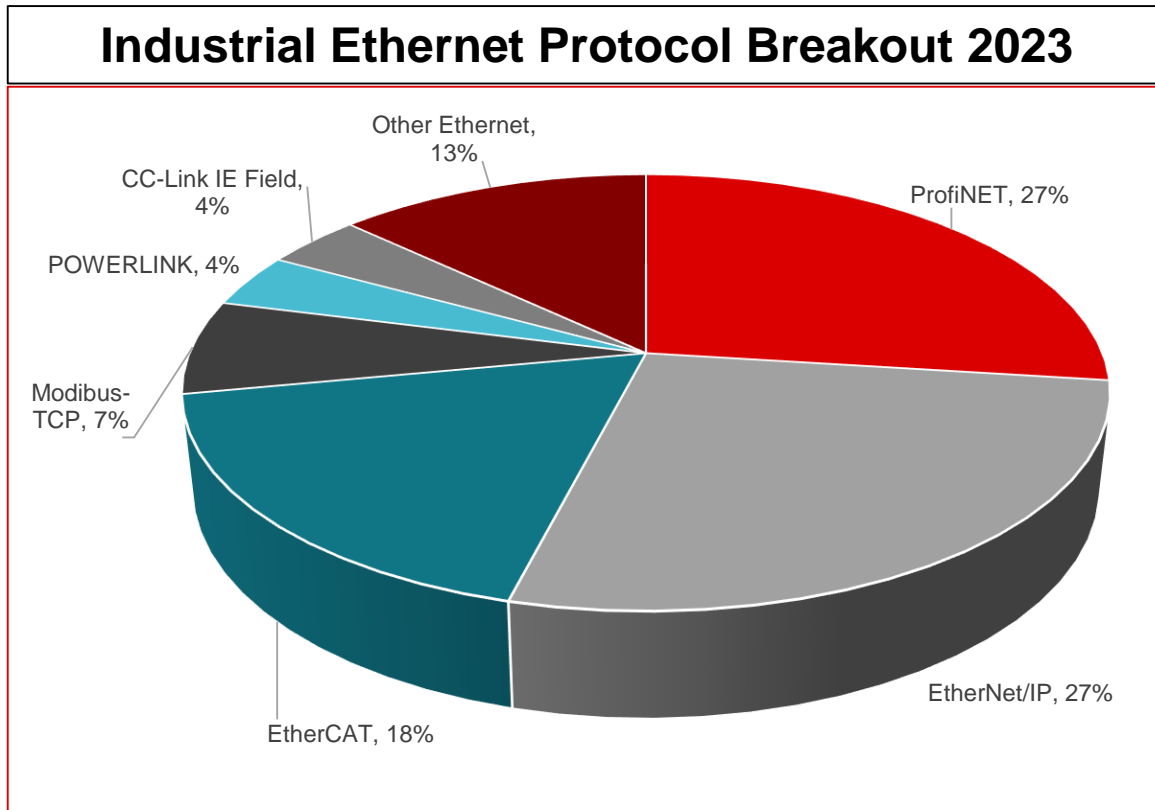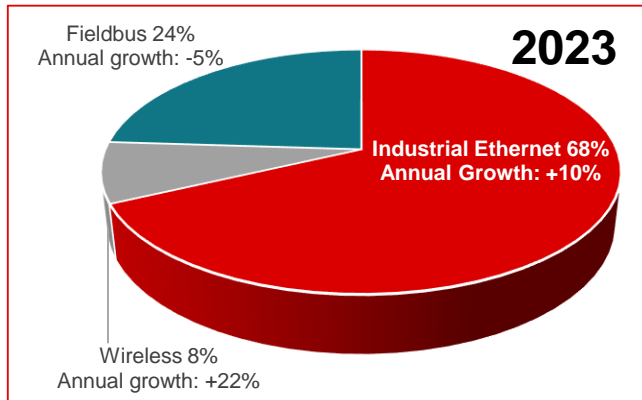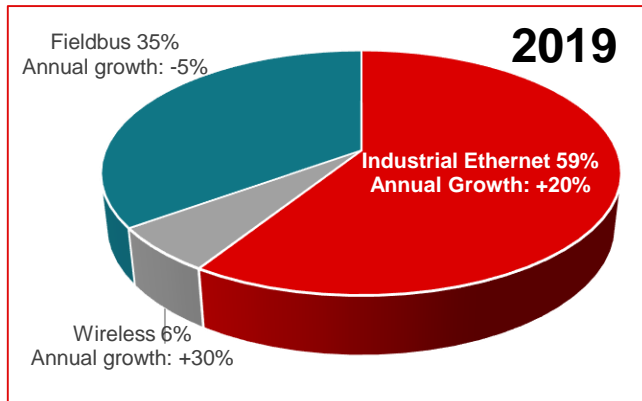
TEXAS INSTRUMENTS

IMPORTANT NOTICE AND DISCLAIMER