



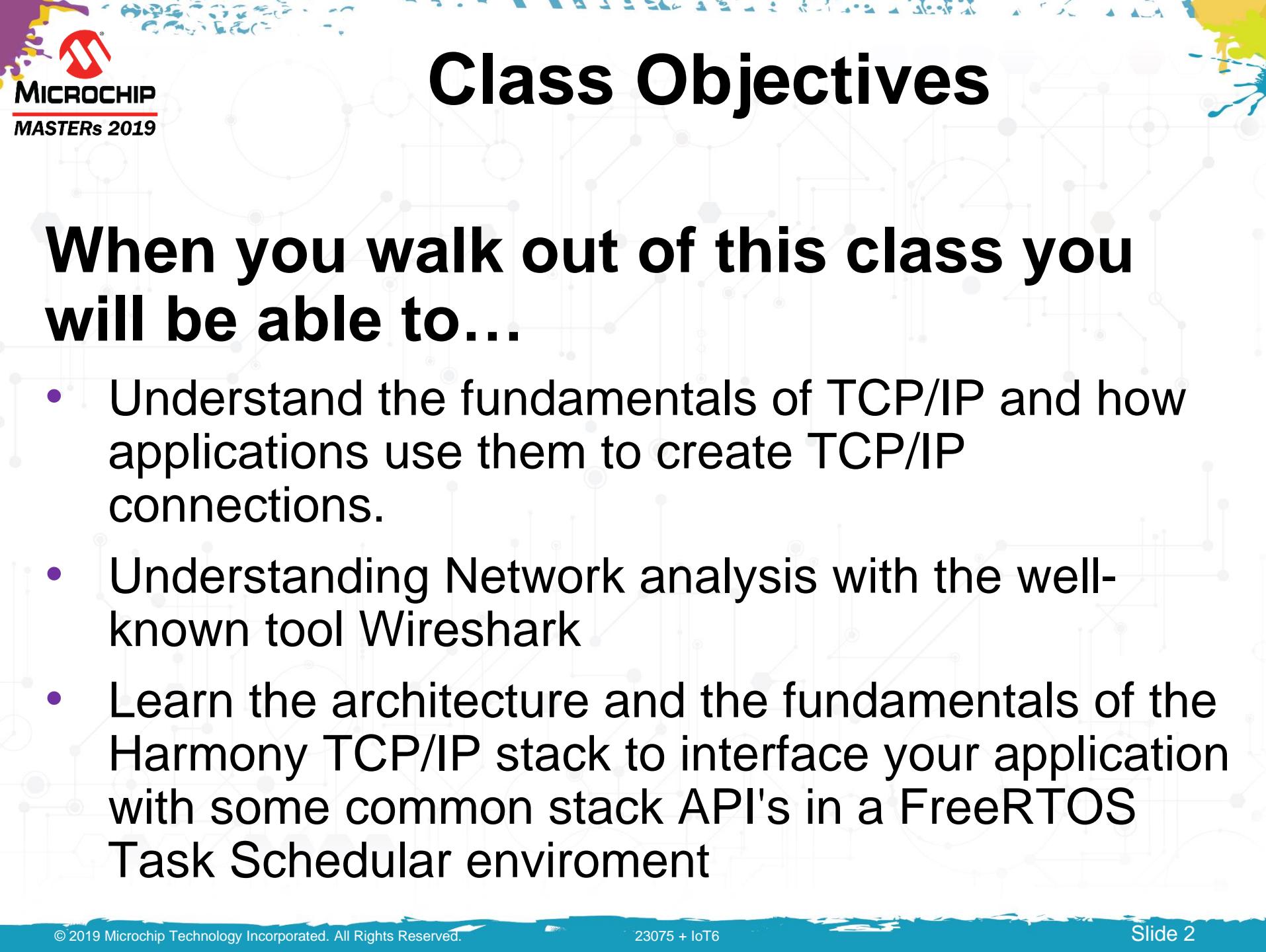
# MICROCHIP MASTERS

2019

## 23075 IoT6

# Simplifying TCP/IP Applications with MPLAB® Harmony





# Class Objectives

**When you walk out of this class you will be able to...**

- Understand the fundamentals of TCP/IP and how applications use them to create TCP/IP connections.
- Understanding Network analysis with the well-known tool Wireshark
- Learn the architecture and the fundamentals of the Harmony TCP/IP stack to interface your application with some common stack API's in a FreeRTOS Task Scheduler environment

# Agenda – Lecture

## Part 1: TCP/IP Fundamentals as a Refresher

## Part 2: MPLAB® Harmony TCP/IP Stack Overview

- TCP/IP Layers and Features
- Network Interface Options
- Processor Requirements

## Part 3: Using the MPLAB® Harmony TCP/IP Stack

- Creating a new project, stack configuration and **connectivity check (Lab 1)**
- MPLAB® Harmony TCP/IP Stack APIs
- Application integration for **local access**, using the example of a Vending machine (**Lab 2**)
- Application integration for **external access** using the example of a Weather Service (**Lab 3**)



# Agenda – Labs

- **Lab 1:** Creating a new project, Stack Configuration and **Connectivity Check**
- **Lab 2:** Application integration for **local access**, using the example of a Vending machine
- **Lab 3:** Application integration for **external access**, using the example of a Weather Service



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## Part 1: TCP/IP Fundamentals as a Refresher

- Five Layer Model and Applications
- TCP vs UDP

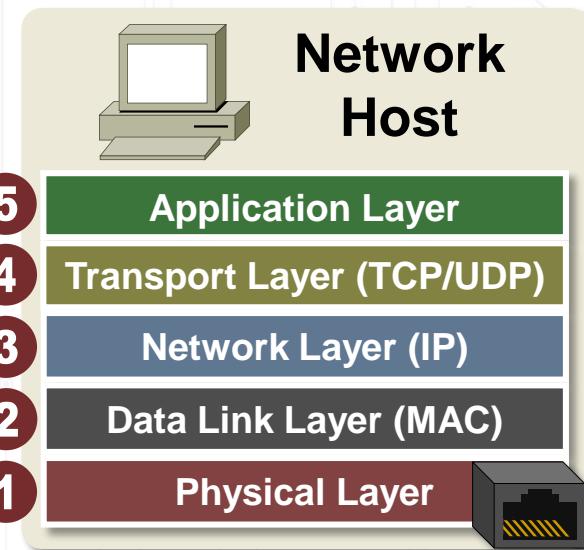


**MICROCHIP**

# Agenda

## Five Layer Model and Applications

- **Five Layer Software Model**
  - Application Layer
  - Transport Layer
  - Network Layer
  - Data Link Layer
  - Physical Layer
- **TCP vs. UDP**
- **TCP/IP Applications**
  - DNS, NBNS, SNTP, DHCP, SNMP, Telnet, SMTP, HTTP





# Basic Needs for TCP/IP Transmissions

- Need to Specify:
  - Most reliable or fastest transmissions
  - Where we want the data delivered



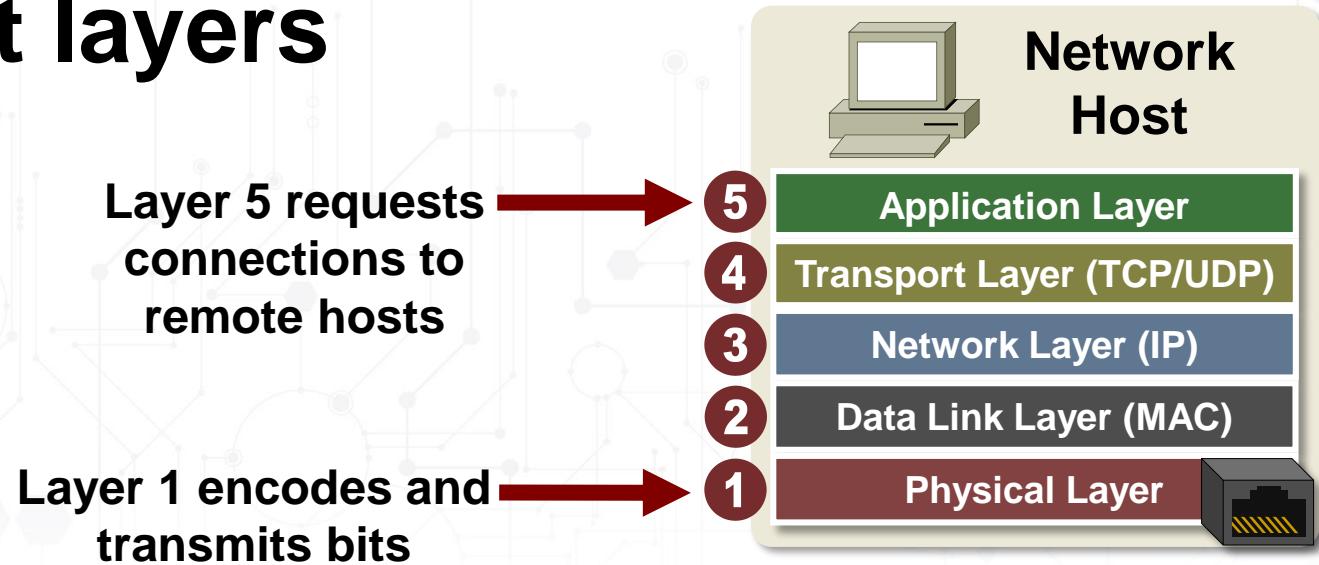
Needs to be sent with all transmitted data.



- Also need to physically transmit the data

# TCP/IP 5 Layer Model

- Each layer performs a specific task needed to move our data across the network
- Each layer only communicates with adjacent layers





# What Does Each Layer Do?

5

## Application Layer

The Application layer is the group of applications requiring network communications.

Host A  
Web Browser

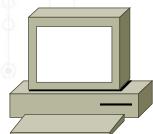
Generates the data and requests connections

Host B  
Web Server

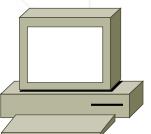
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## Transport Layer (TCP/UDP)

The Transport layer establishes the connection between applications on different hosts.



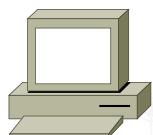
Establishes connections with remote host



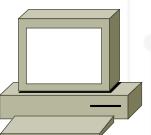
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## Network Layer (IP)

The Network layer is responsible for creating the packets that move across the network.



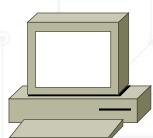
Transfers packets with virtual (IP) addresses



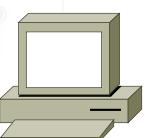
2

## Data Link Layer (MAC)

The Data Link layer is responsible for creating the frames that move across the network.



Transfers frames with physical (MAC) addresses



1

## Physical Layer

The Physical layer is the transceiver that drives the signals on the network.

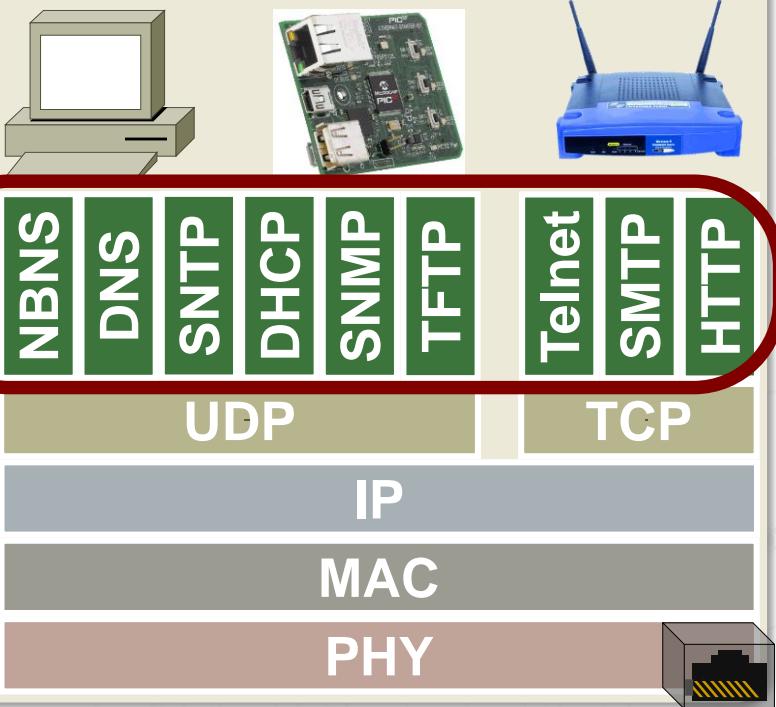


Transmits and receives bits



# Application Layer (Layer 5)

## Network Host



- **Layer 5 is where TCP/IP applications live**
- **Your application typically interacts with these applications**

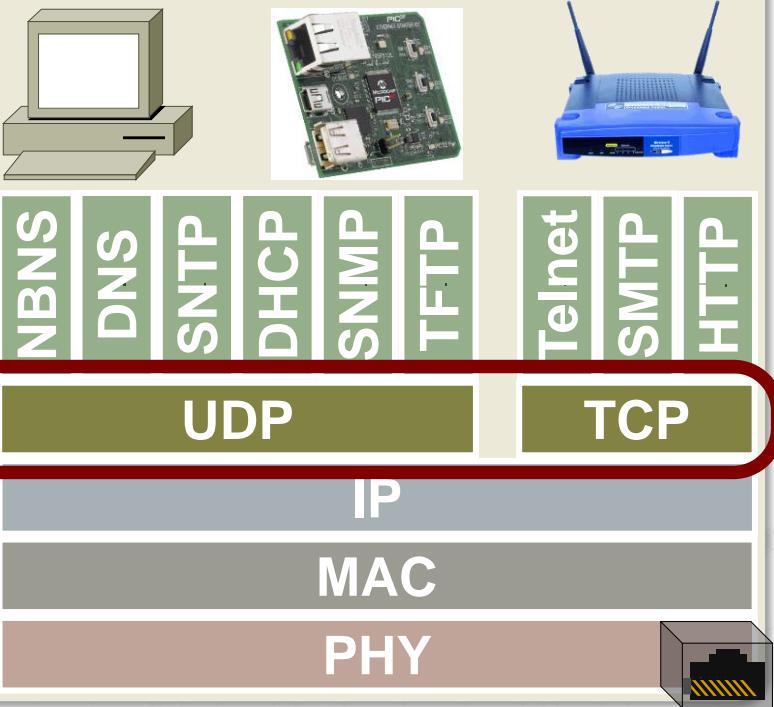


# Transport Layer

## (Layer 4)

- Connects to remote hosts using either:
  - TCP (Transfer Control Protocol)
  - UDP (User Datagram protocol)
- Delivers data to and from applications
- Assigns port numbers to processes running in applications

### Network Host



# TCP vs. UDP



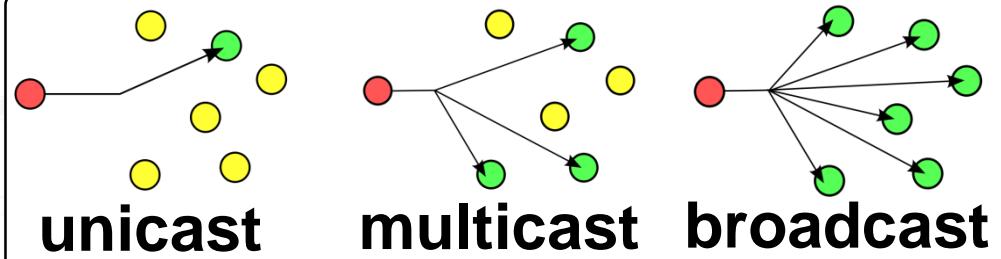
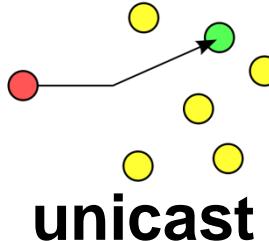
**TCP**

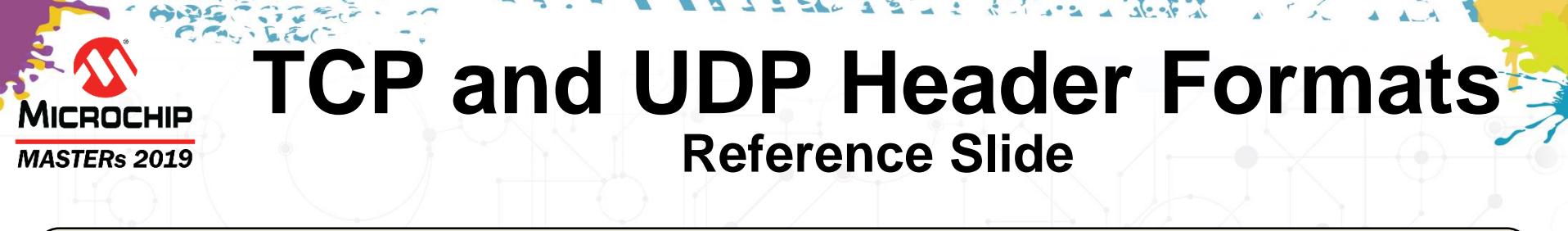


**UDP**

- Slower but reliable transfers
- Typical applications:
  - Email
  - Web browsing

- Fast but non-guaranteed transfers (“best effort”)
- Typical applications:
  - VoIP
  - Internet Radio





# TCP and UDP Header Formats

## Reference Slide

### TCP Segment Header Format

Bit #	0	7	8	15	16	23	24	31
0	Source Port				Destination Port			
32	Sequence Number							
64	Acknowledgment Number							
96	Data Offset	Res	Flags		Window Size			
128	Header and Data Checksum				Urgent Pointer			
160...	Options							

### UDP Datagram Header Format

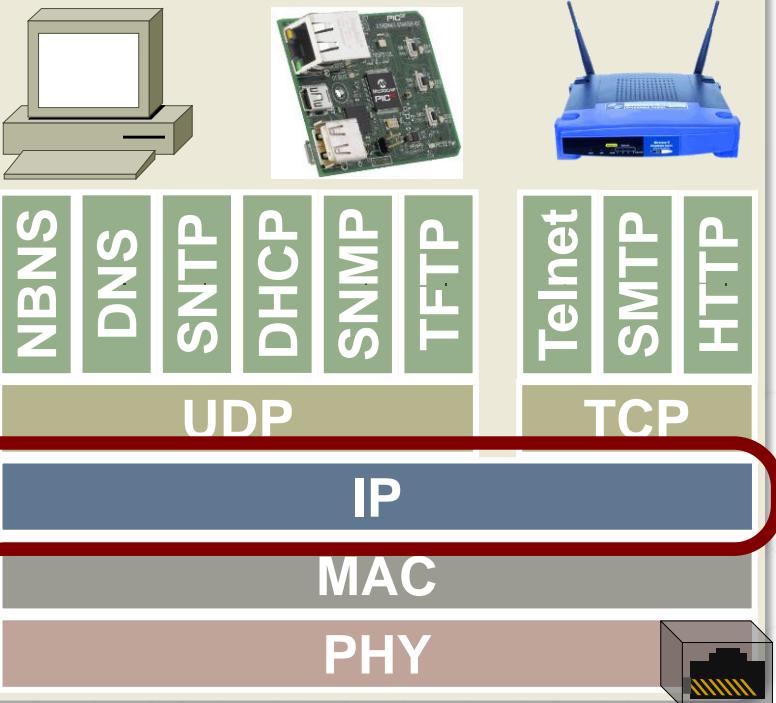
Bit #	0	7	8	15	16	23	24	31
0	Source Port				Destination Port			
32	Length				Header and Data Checksum			

# Network Layer (Layer 3)



An IP address is 32 bits and looks like this:  
192.168.1.101

## Network Host



- **Also known as the Internet layer**
- **Adds a header to the data received from the transport layer**
  - contains the source and destination IP addresses
- **Creates IP Packets**

# IPv4 Packet Header Format (Reference Slide)

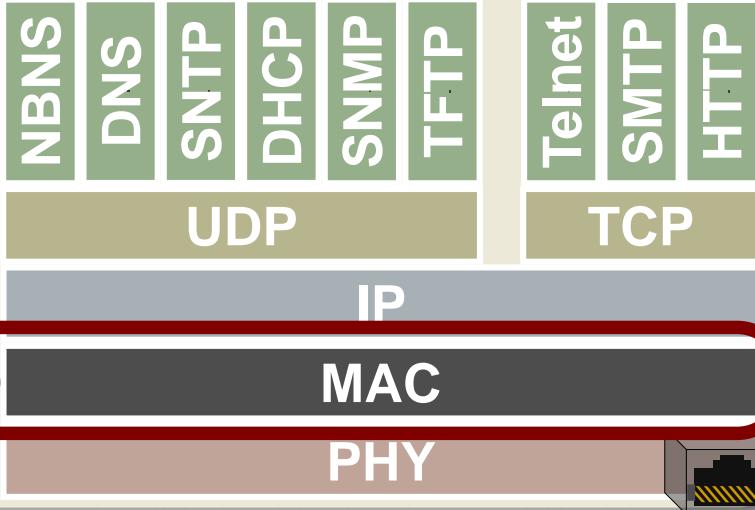
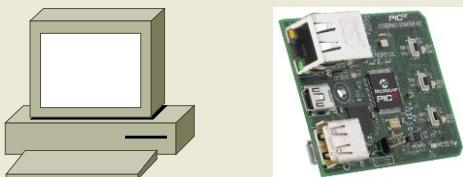
## IPv4 Packet Header Format

Bit #	0	7	8	15	16	23	24	31					
0	Version	IHL	DSCP	ECN	Total Length								
32	Identification				Flags	Fragment Offset							
64	Time to Live		Protocol		Header Checksum								
96	Source IP Address												
128	Destination IP Address												
160	Options (if IHL > 5)												



A MAC address is 48 bits and looks like this:  
F0:DE:F1:1E:E8:93

## Network Host



# Data Link Layer (Layer 2)

- **Uses a Media Access Controller to generate frames**
- **Adds a header to the packet**
  - Source and destination MAC addresses
- **Every host has at least one MAC address**

# Ethernet and Wi-Fi® Frame Formats (Reference Slide)

## Ethernet (802.3) Frame Format

7 bytes	1 byte	6 bytes	6 bytes	2 bytes	42 to 1500 bytes	4 bytes	12 bytes
Preamble	Start of Frame Delimiter	Destination MAC Address	Source MAC Address	Type	Data (payload)	CRC	Inter-frame gap



For TCP/IP communications,  
the payload for a frame is a  
packet



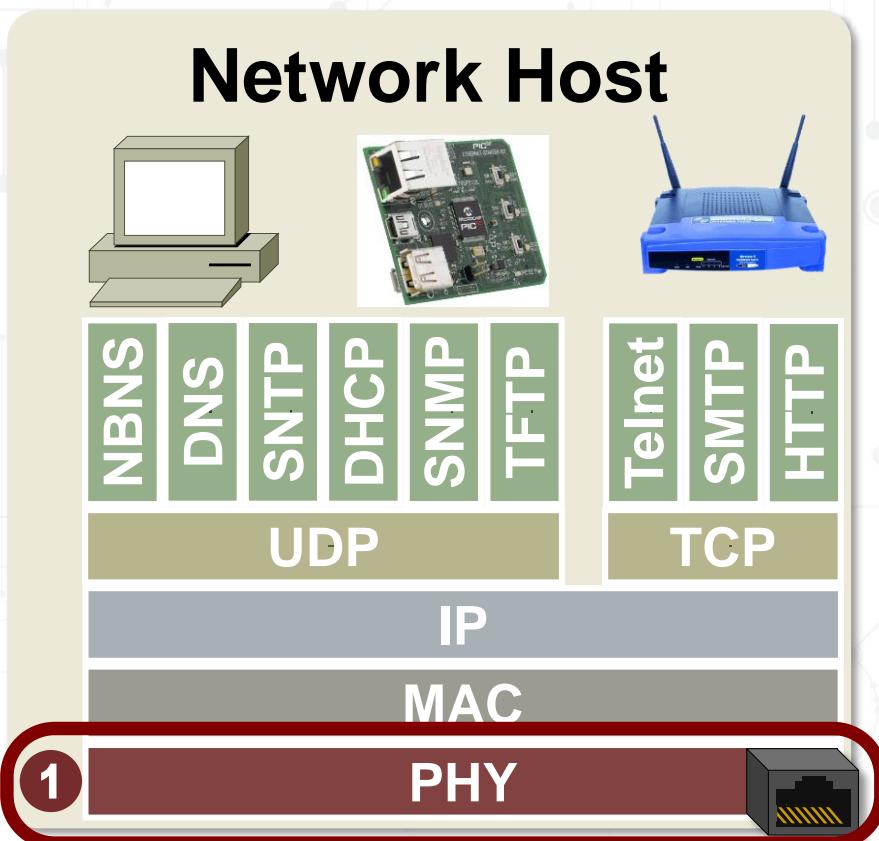
## Wi-Fi (802.11) Frame Format

2 bytes	2 bytes	6 bytes	6 bytes	6 bytes	2 bytes	6 bytes	0 to 2312 bytes	4 bytes
Frame Control	Duration	MAC Address 1 (Destination)	MAC Address 2 (Source)	MAC Address 3 (Router)	Seq Control	MAC Address 4 (AP)	Data (payload)	CRC



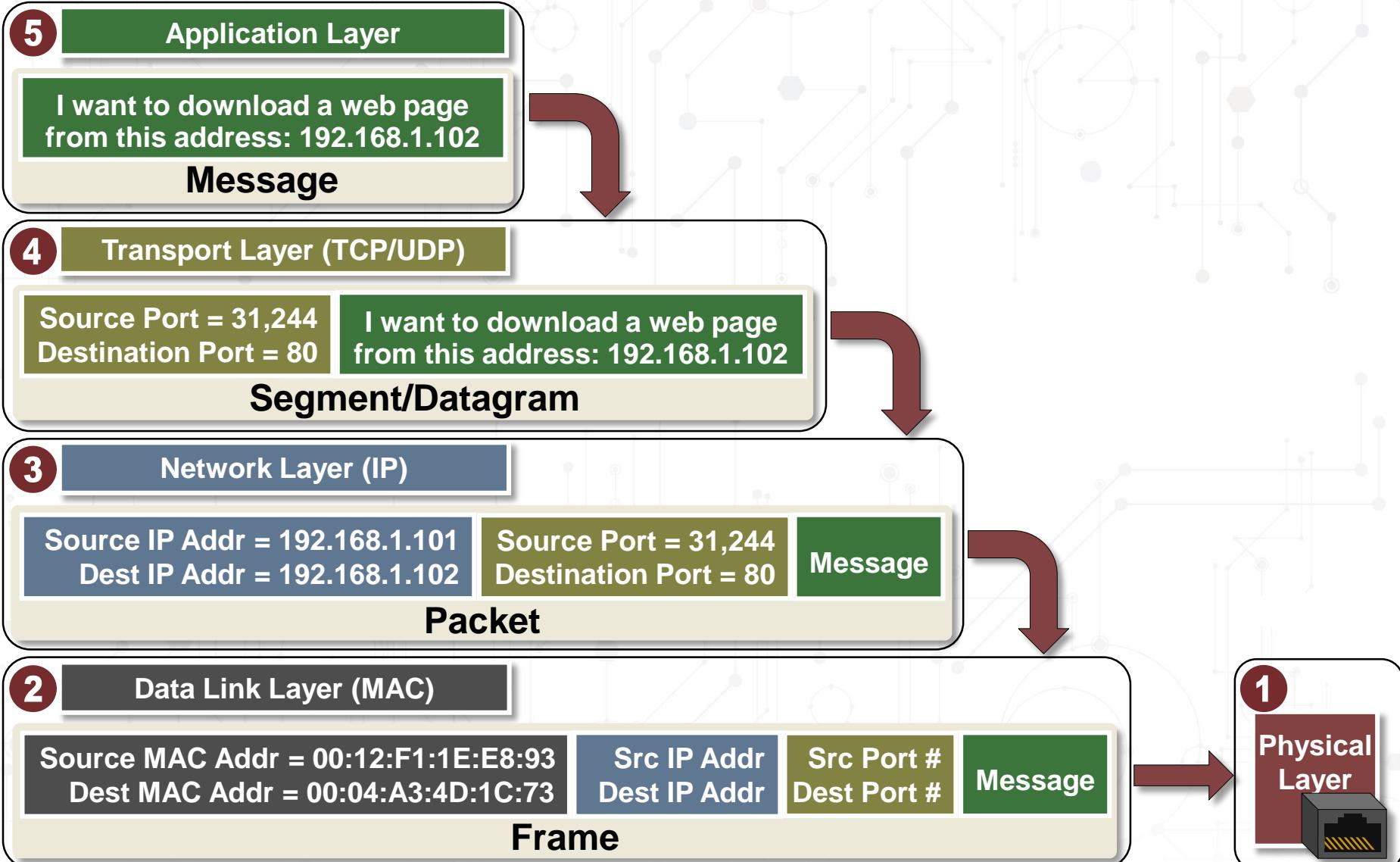
# Physical Layer

## (Layer 1)



- Sends and receives signals on the physical wire or antenna
- Responsible for moving bits
- Found at the end of every network interface

# Transmit Data Using Network Layers





# Receive Data Using Network Layers

5

Application Layer

I want to download a web page  
from this address: 192.168.1.102

Message

4

Transport Layer (TCP/UDP)

Source Port = 31,244  
Destination Port = 80

I want to download a web page  
from this address: 192.168.1.102

Segment/Datagram

3

Network Layer (IP)

Source IP Addr = 192.168.1.101  
Dest IP Addr = 192.168.1.102

Source Port = 31,244  
Destination Port = 80

Message

Packet

2

Data Link Layer (MAC)

Source MAC Addr = 00:12:F1:1E:E8:93  
Dest MAC Addr = 00:04:A3:4D:1C:73

Src IP Addr  
Dest IP Addr

Src Port #  
Dest Port #

Message

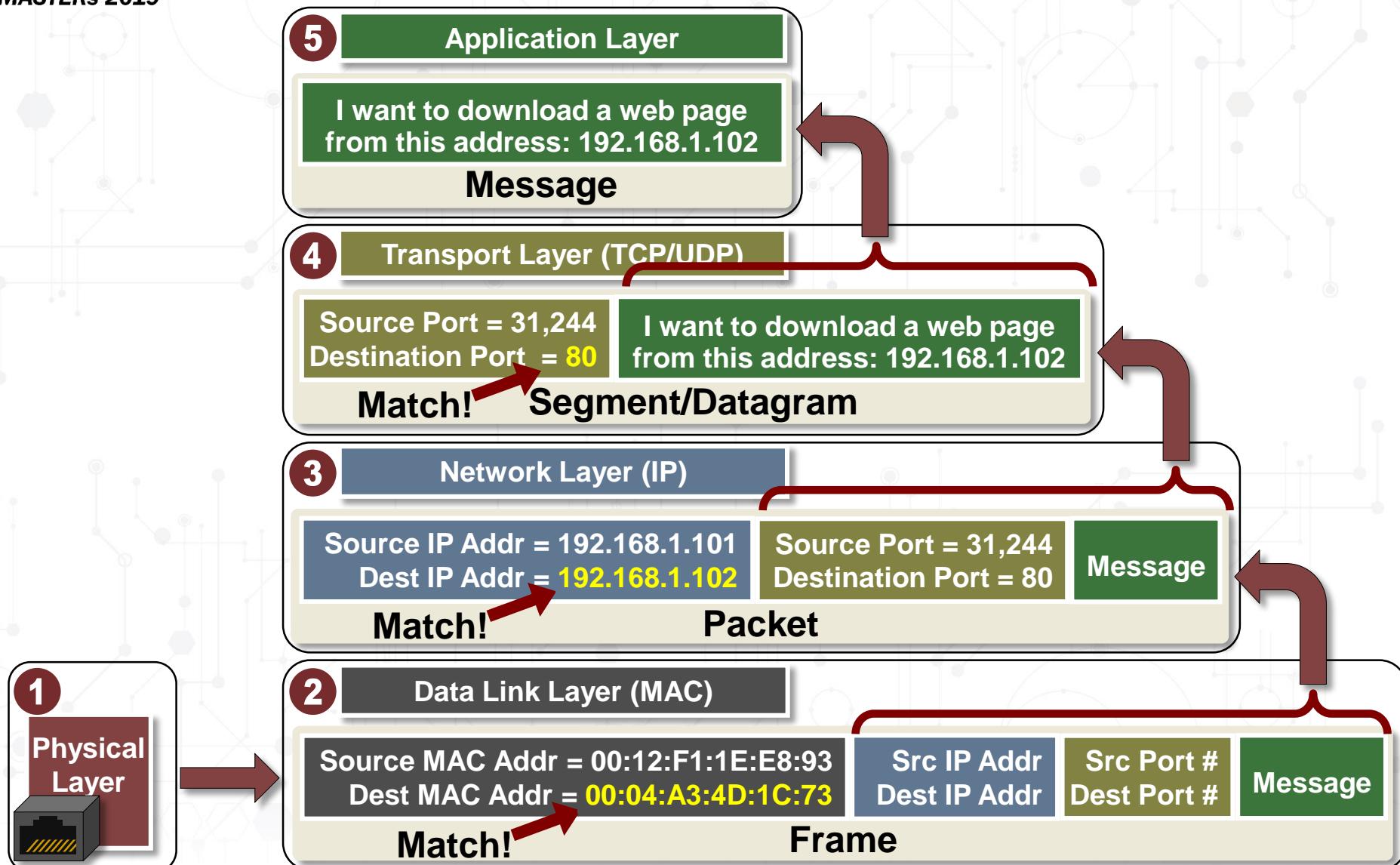
Frame

1

Physical  
Layer



# Receive Data Using Network Layers





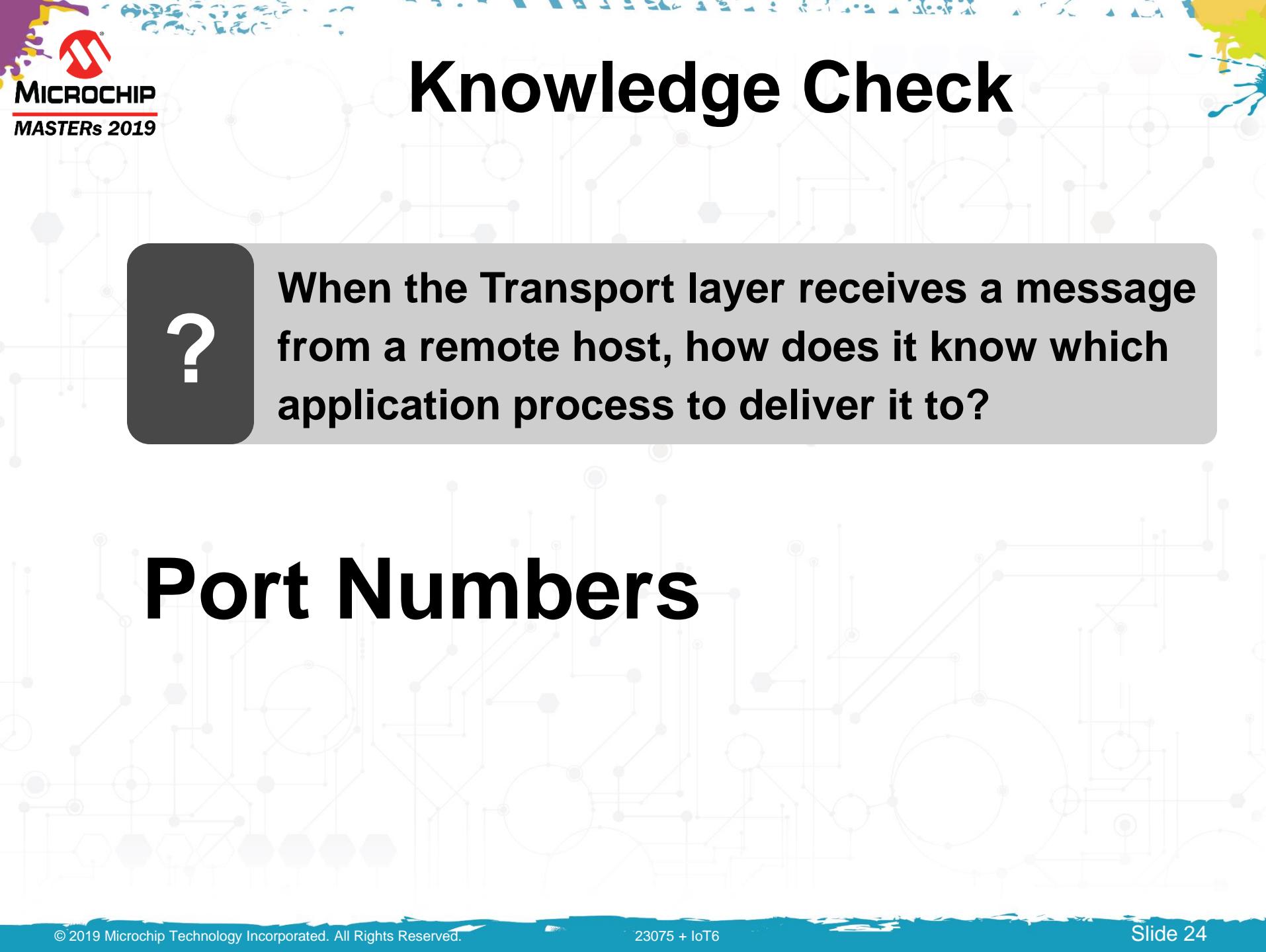
# TCP/IP Protocol Stack

## (Terminology Reference)

Layer #	Layer Name	Protocol	Protocol Data Unit	Addressing
5	Application	HTTP, SMTP, etc...	Messages	n/a
4	Transport	TCP/UDP	Segments/ Datagrams	Port #s
3	Network or Internet	IP	Packets	IP Address
2	Data Link	Ethernet, Wi-Fi	Frames	MAC Address
1	Physical	10 Base T, 802.11	Bits	n/a

# Common TCP/IP Applications

Application	Description
DHCP	Dynamic Host Configuration Protocol assigns IP addresses
DNS	Domain Name System translates website names to IP addresses
HTTP	Hypertext Transfer Protocol used to transfer web pages
NBNS	NetBIOS Name Service translates local host names to IP addresses
SMTP	Simple Mail Transfer Protocol sends email messages
SNMP	Simple Network Management Protocol manages network devices
SNTP	Simple Network Time Protocol provides time of day
Telnet	Bi-directional text communication via a terminal application
TFTP	Trivial File Transfer Protocol used to transfer small amounts of data



# Knowledge Check



**When the Transport layer receives a message from a remote host, how does it know which application process to deliver it to?**

## Port Numbers

# Knowledge Check



**True or false:**  
**The Simple Mail Transport Protocol (SMTP) application uses the UDP transport protocol.**

# False

**SMTP uses TCP to guarantee error free delivery.**



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## Part 2: MPLAB® Harmony TCP/IP Stack Overview

- TCP/IP Layers and Features
- Network Interface Options
- Processor Requirements





# MPLAB® Harmony TCP/IP Stack

- Provides a foundation for embedded network applications by handling most of the interaction required between the physical network interface and your application.
- Fully Implemented and supported by Microchip Engineers.
- Source code is included with the MPLAB® Harmony Distribution.
- Cost: Free\*



\*MPLAB Harmony is only licensed for use on Microchip Microcontrollers

# Architecture

PIC32 Microcontroller running MPLAB Harmony TCP/IP Stack

## PIC32 and SAM Microcontrollers

MII Management  
Interface

MII/RMII  
Interface

SPI  
Interface

**Ethernet Network  
Interface**

External IC

**WiFi Network  
Interface**

External IC/Module

TCP/IP Stack  
Layers

Application,  
Presentation  
& Session

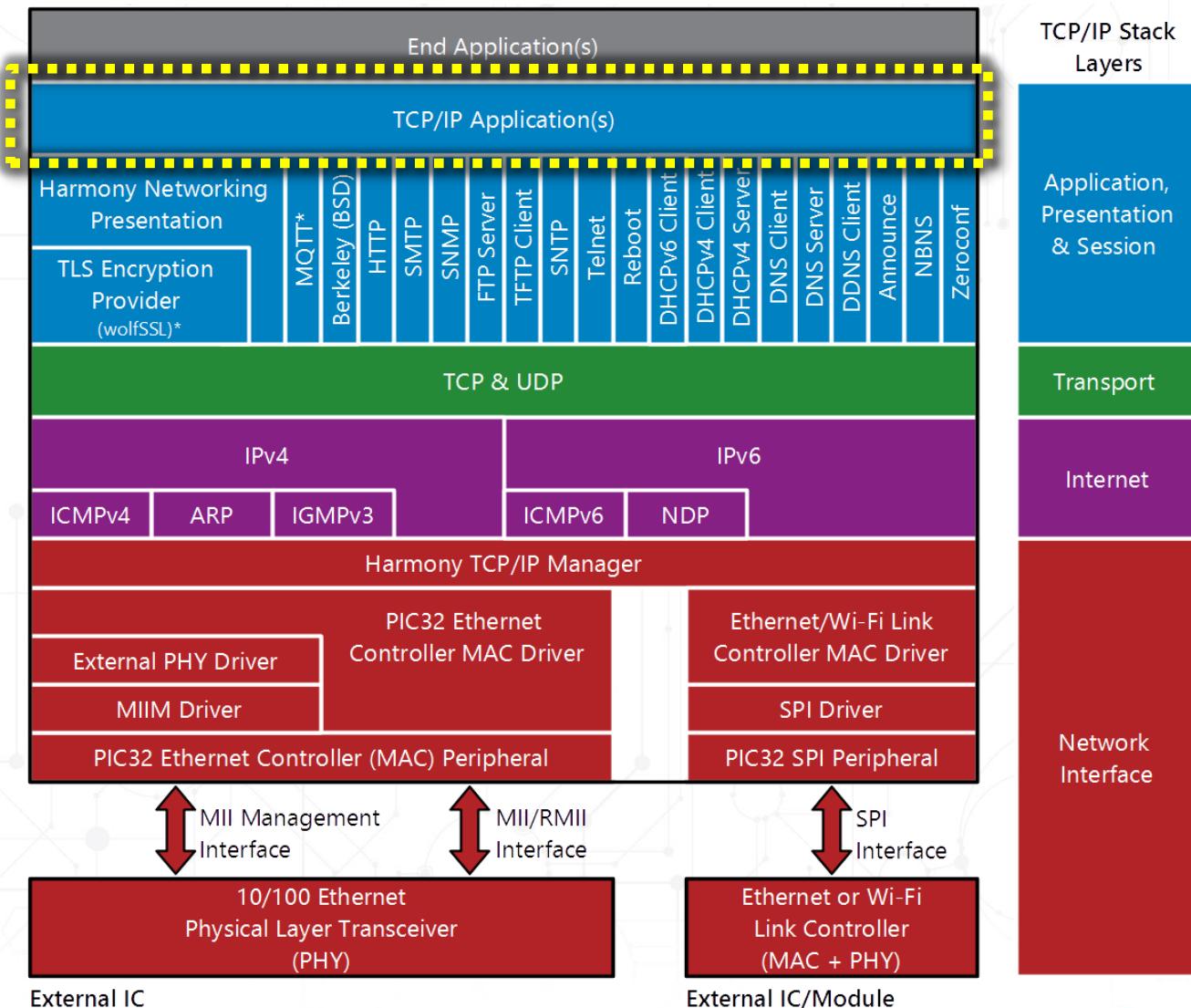
Transport

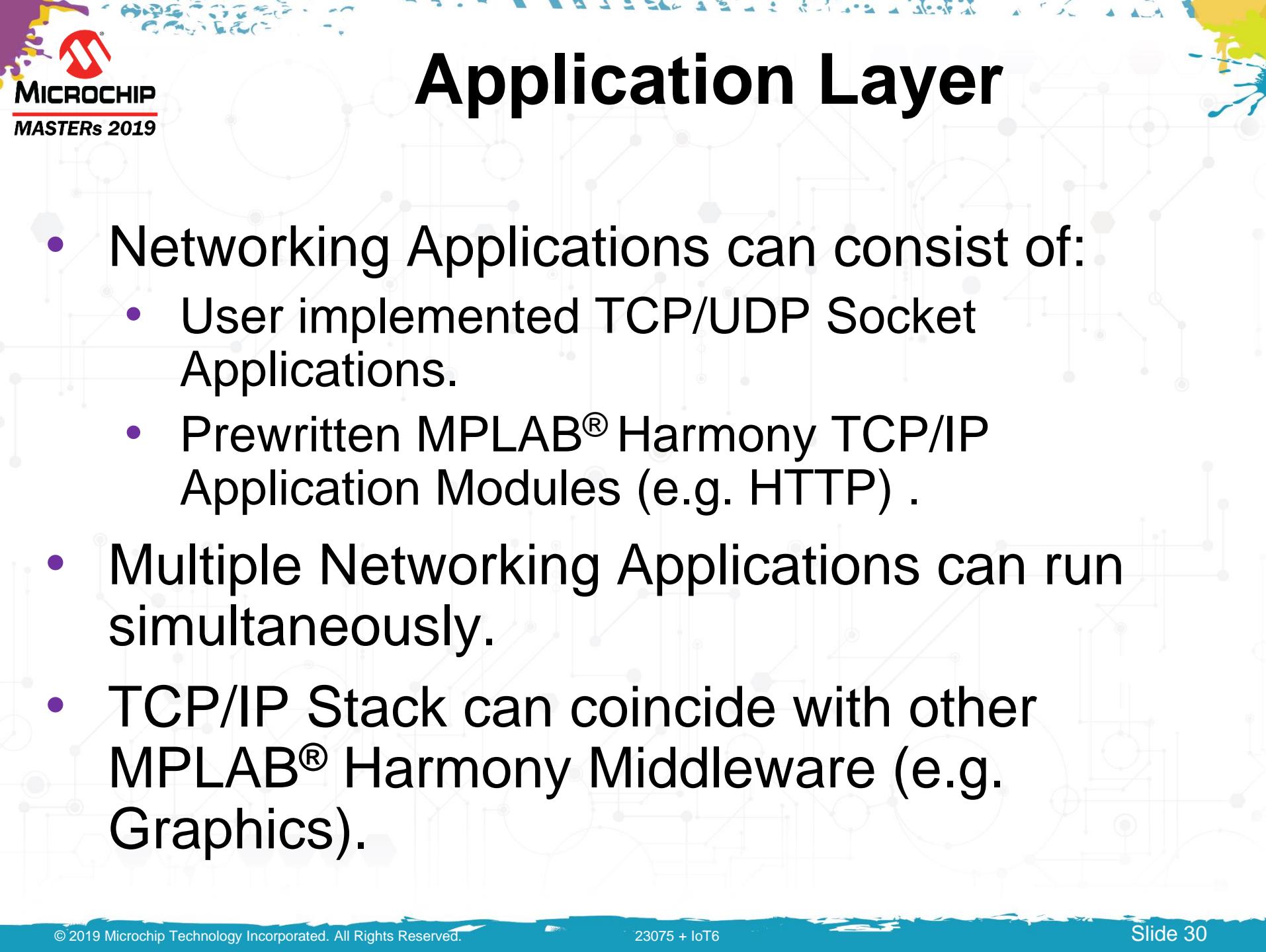
Internet

Network  
Interface

# Application Layer

PIC32/SAM MCU running MPLAB® Harmony TCP/IP Stack



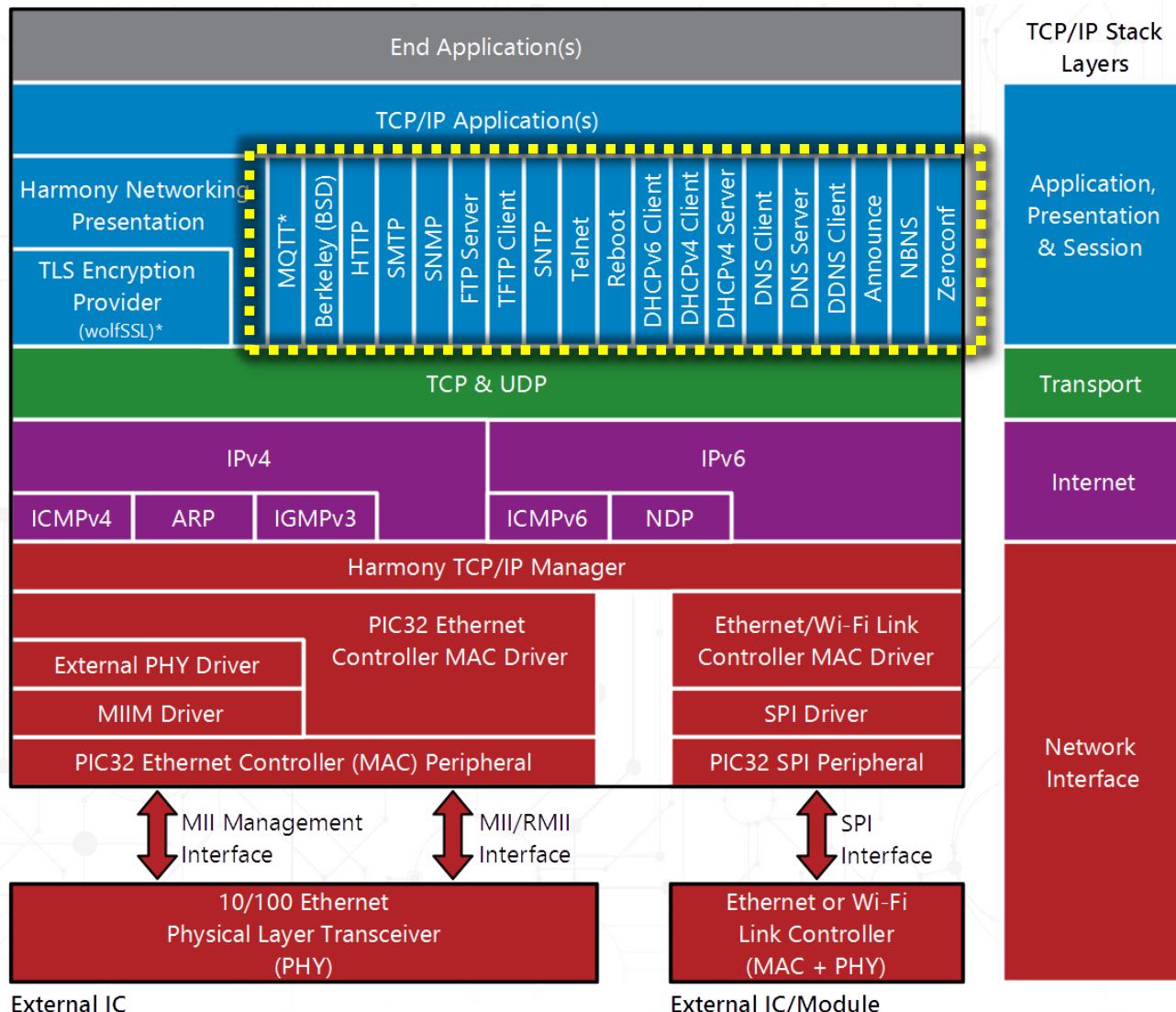


# Application Layer

- Networking Applications can consist of:
  - User implemented TCP/UDP Socket Applications.
  - Prewritten MPLAB® Harmony TCP/IP Application Modules (e.g. HTTP) .
- Multiple Networking Applications can run simultaneously.
- TCP/IP Stack can coincide with other MPLAB® Harmony Middleware (e.g. Graphics).

# Services and Applications

PIC32/SAM MCU running MPLAB® Harmony TCP/IP Stack



# Supported Services

- **DHCP: *Dynamic Host Configuration Protocol***
  - Used for IP Address Assignment
  - Server and Client Support
- **DNS: *Domain Name System***
  - Translates website name to IP Address
  - Server and Client Support
- **DDNS Client**
  - Discovery and registration of public IP address with a DDNS Provider on the internet.

# Supported Services

- **Announce**
  - Microchip TCP/IP Discovery Protocol used for identifying devices on a local network.
- **NBNS: NetBIOS Name Service**
  - Translates local host names to IP Addresses
- **Zeroconf (Bonjour/Avahi)**
  - A set of technologies to automatically create a usable network including IP Address assignment, distribution and resolution of hostnames, location of network services.

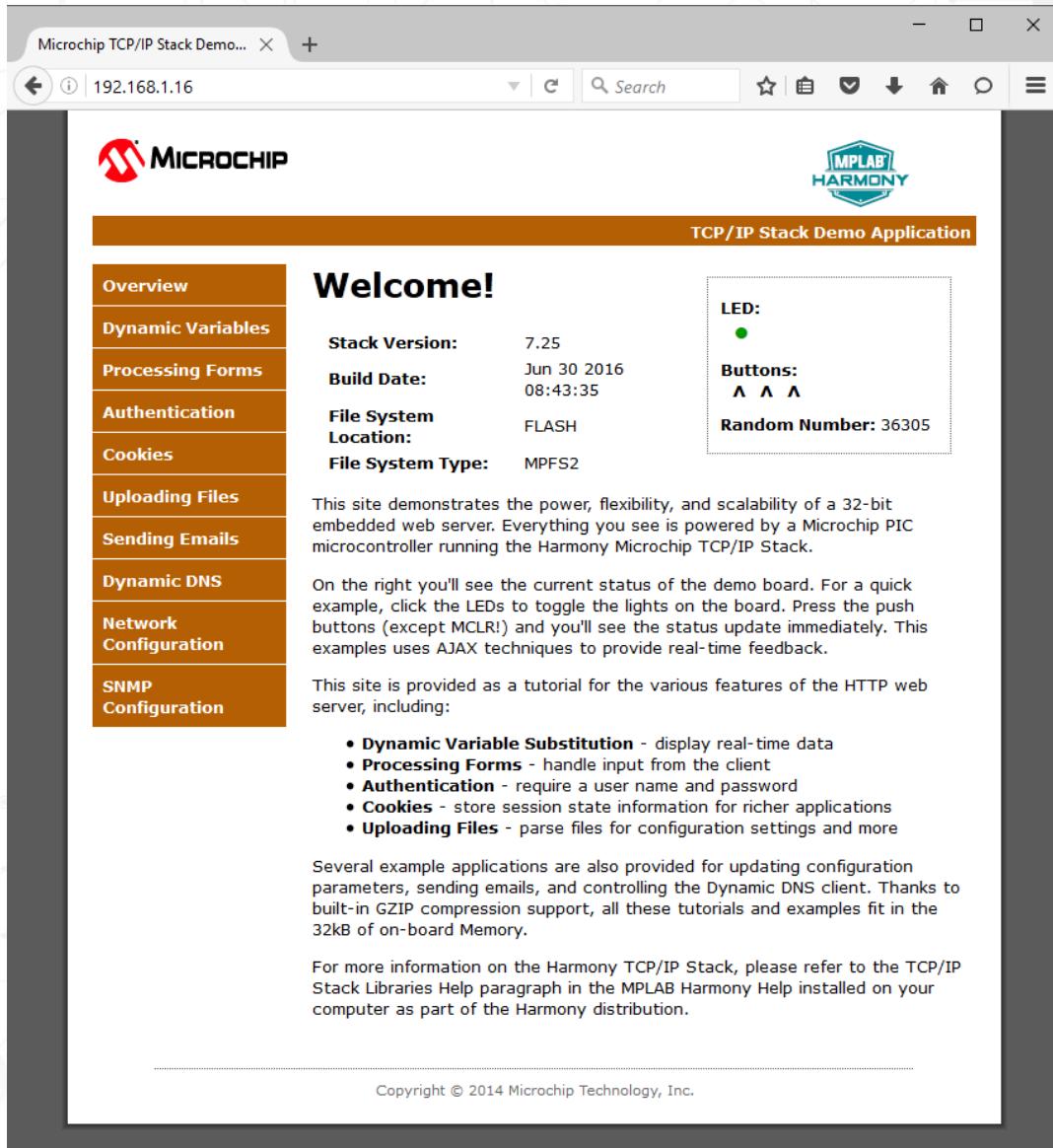
# Supported Services

- **MQTT: Message Queue Telemetry Transport**
  - Machine-to-machine (M2M) or "Internet of Things" connectivity protocol
  - Lightweight publish/subscribe messaging transport
  - Supported with third party **wolfMQTT** which is bundled with MPLAB® Harmony.
    - <https://www.wolfssl.com/wolfSSL/Products-wolfmqtt.html>

# Supported Applications

- **HTTP: Hypertext Transfer Protocol (Web Server)**
  - Allows for serving of Webpages
  - Webpages can be stored in Program Memory, SD Card, or External Flash
  - Supports Forms and Dynamic Variables

# HTTP Web Server



The screenshot shows a web browser window titled "Microchip TCP/IP Stack Demo..." with the URL "192.168.1.16". The page is titled "Welcome!" and displays various system information and controls.

**System Information:**

- Stack Version: 7.25
- Build Date: Jun 30 2016 08:43:35
- File System Location: FLASH
- File System Type: MPFS2

**Status Indicators:**

- LED: (Green dot)
- Buttons: (Three upward arrows)
- Random Number: 36305

**Description:**

This site demonstrates the power, flexibility, and scalability of a 32-bit embedded web server. Everything you see is powered by a Microchip PIC microcontroller running the Harmony Microchip TCP/IP Stack.

**Features:**

On the right you'll see the current status of the demo board. For a quick example, click the LEDs to toggle the lights on the board. Press the push buttons (except MCLR!) and you'll see the status update immediately. This examples uses AJAX techniques to provide real-time feedback.

This site is provided as a tutorial for the various features of the HTTP web server, including:

- **Dynamic Variable Substitution** - display real-time data
- **Processing Forms** - handle input from the client
- **Authentication** - require a user name and password
- **Cookies** - store session state information for richer applications
- **Uploading Files** - parse files for configuration settings and more

Several example applications are also provided for updating configuration parameters, sending emails, and controlling the Dynamic DNS client. Thanks to built-in GZIP compression support, all these tutorials and examples fit in the 32kB of on-board Memory.

For more information on the Harmony TCP/IP Stack, please refer to the TCP/IP Stack Libraries Help paragraph in the MPLAB Harmony Help installed on your computer as part of the Harmony distribution.

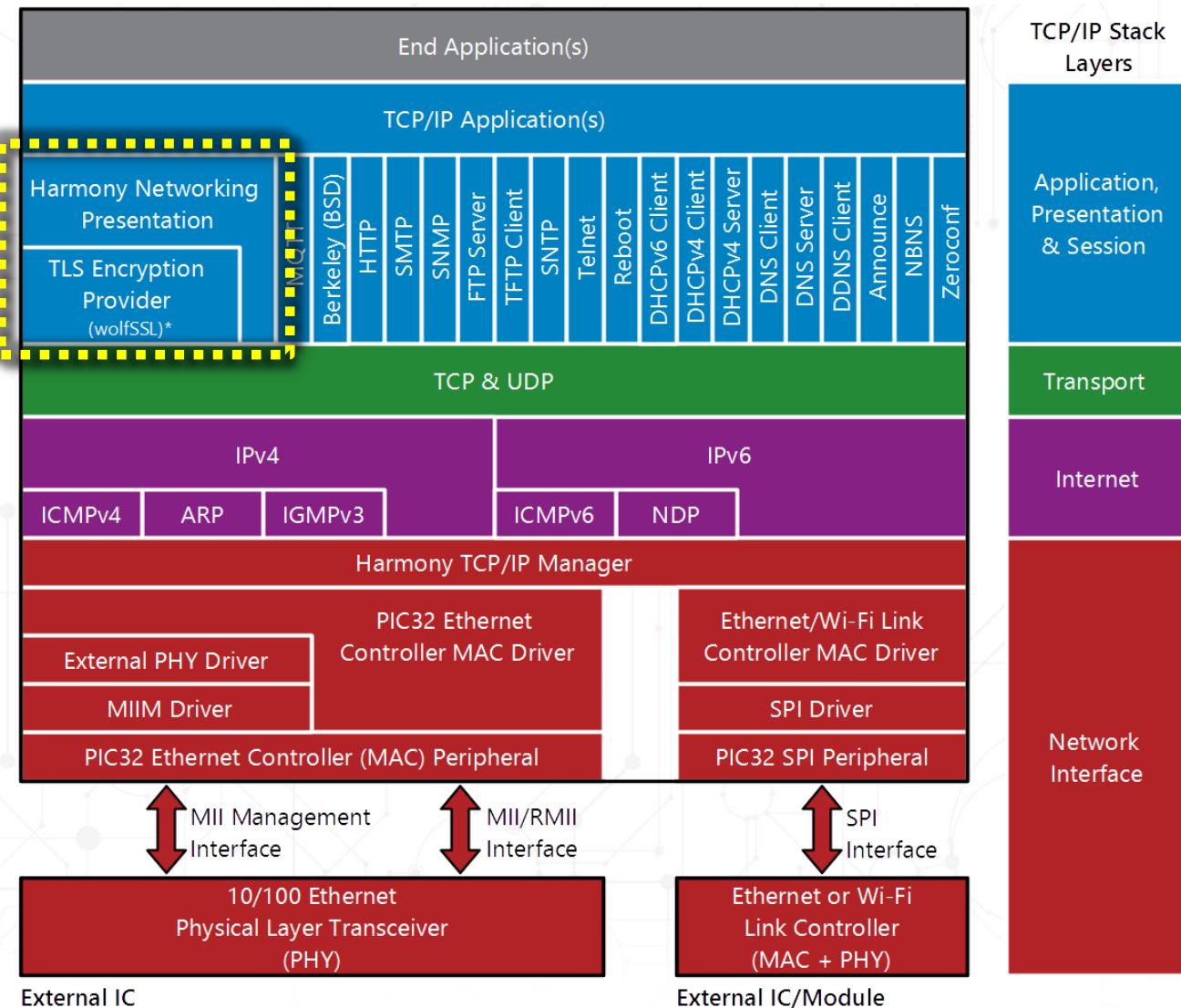
Copyright © 2014 Microchip Technology, Inc.

# Supported Applications

- **SMTP** *Simple Mail Transfer Protocol*
  - Allows E-Mails to be sent.
  - Client Support
- **SNMP** *Simple Network Management Protocol*
  - Allows for management of devices on a network.
- **FTP** *File Transfer Protocol*
  - Allows for transfer of files.
- **NTP** *Network Time Protocol*
  - Allows the time of day to be obtained from a precise timer server on the internet.

# Encryption Provider

PIC32/SAM MCU running MPLAB® Harmony TCP/IP Stack



# Encryption Provider

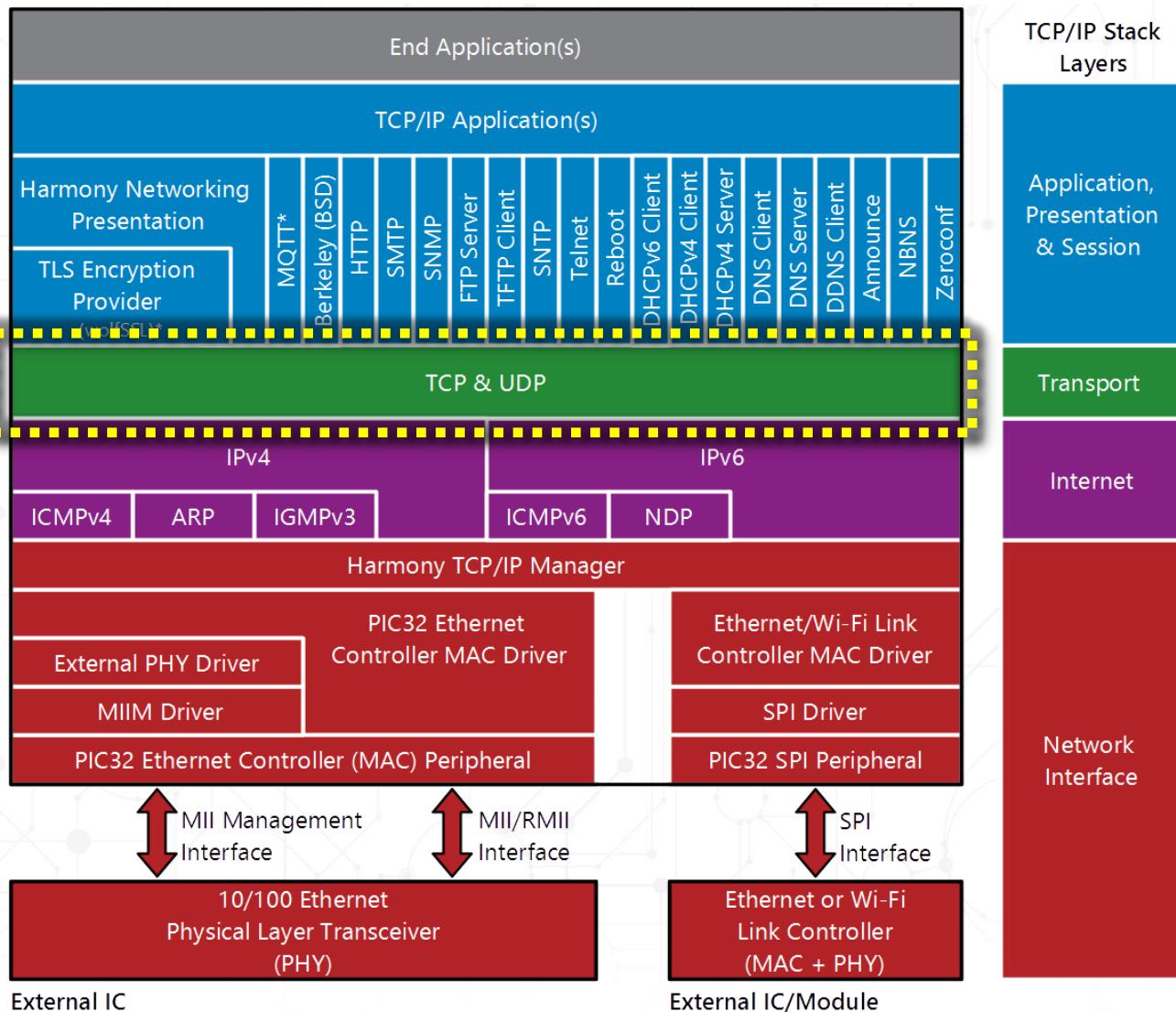
- **TLS from wolfSSL (3rd party provider)**
  - Written in ANSI C
  - Works with or without RTOS
  - TLS 1.2 and DTLS 1.2
  - Integrates directly into MPLAB® Harmony TCP/IP Stack
  - Distributed with MPLAB Harmony
  - Can be evaluated free of charge
  - Requires a commercial license purchase for production



**SSL= Secure Sockets Layer, TLS = Transport Layer Security**

# Transport Layer

PIC32/SAM MCU running MPLAB® Harmony TCP/IP Stack





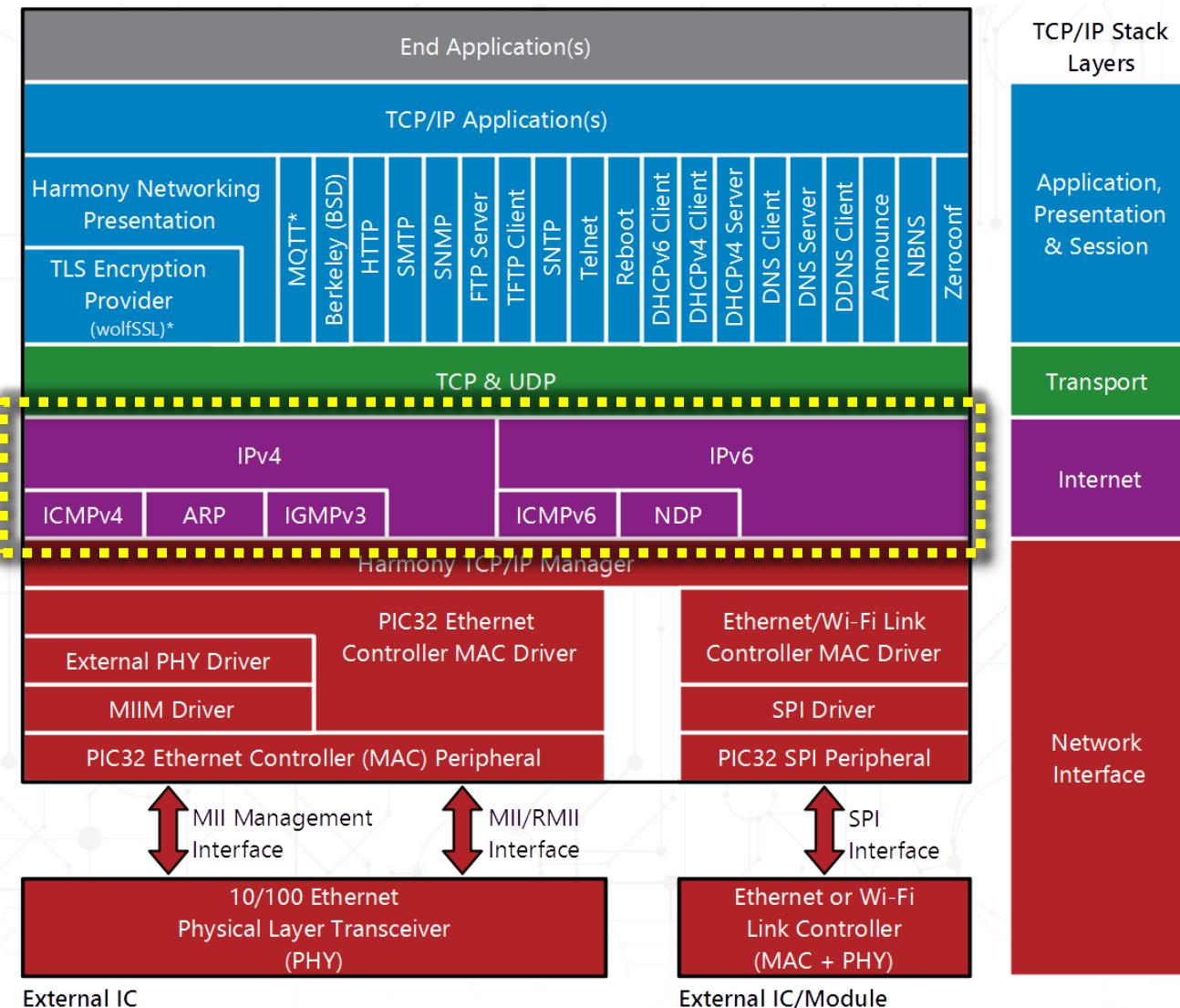
# Transport Layer

- Light-weight and high-performance implementations of the TCP and UDP transport layers.
- Various TCP and UDP configuration options are available at both project generation and run time (eg TX/RX buffer sizes).
- Simultaneous sockets are supported (max number is configurable).
- Simple APIs are used to create socket, check connection status, check TX/RX buffer status, read/write data, and close the socket.



# Internet Layer

PIC32/SAM MCU running MPLAB® Harmony TCP/IP Stack





# Internet Layer

- IPv4 and IPv6 Support
- Both IPv4 and IPv6 can run simultaneously
- The IP Layer is transparent to all applications that use the built in Transport Layer functions.
- IP Datagrams can be sent directly using a special API bypassing higher layer protocols.

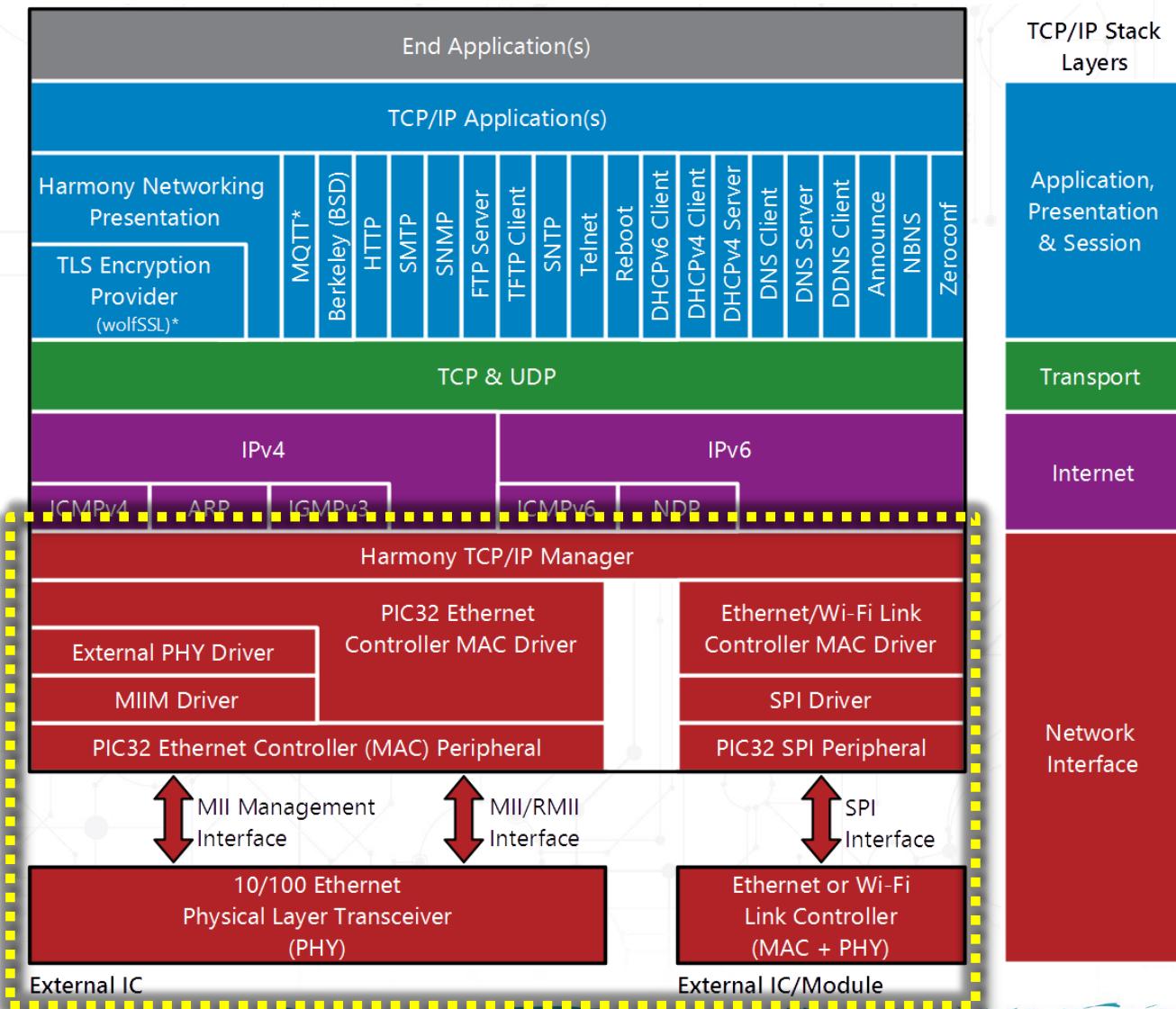
# IPv4 vs IPv6

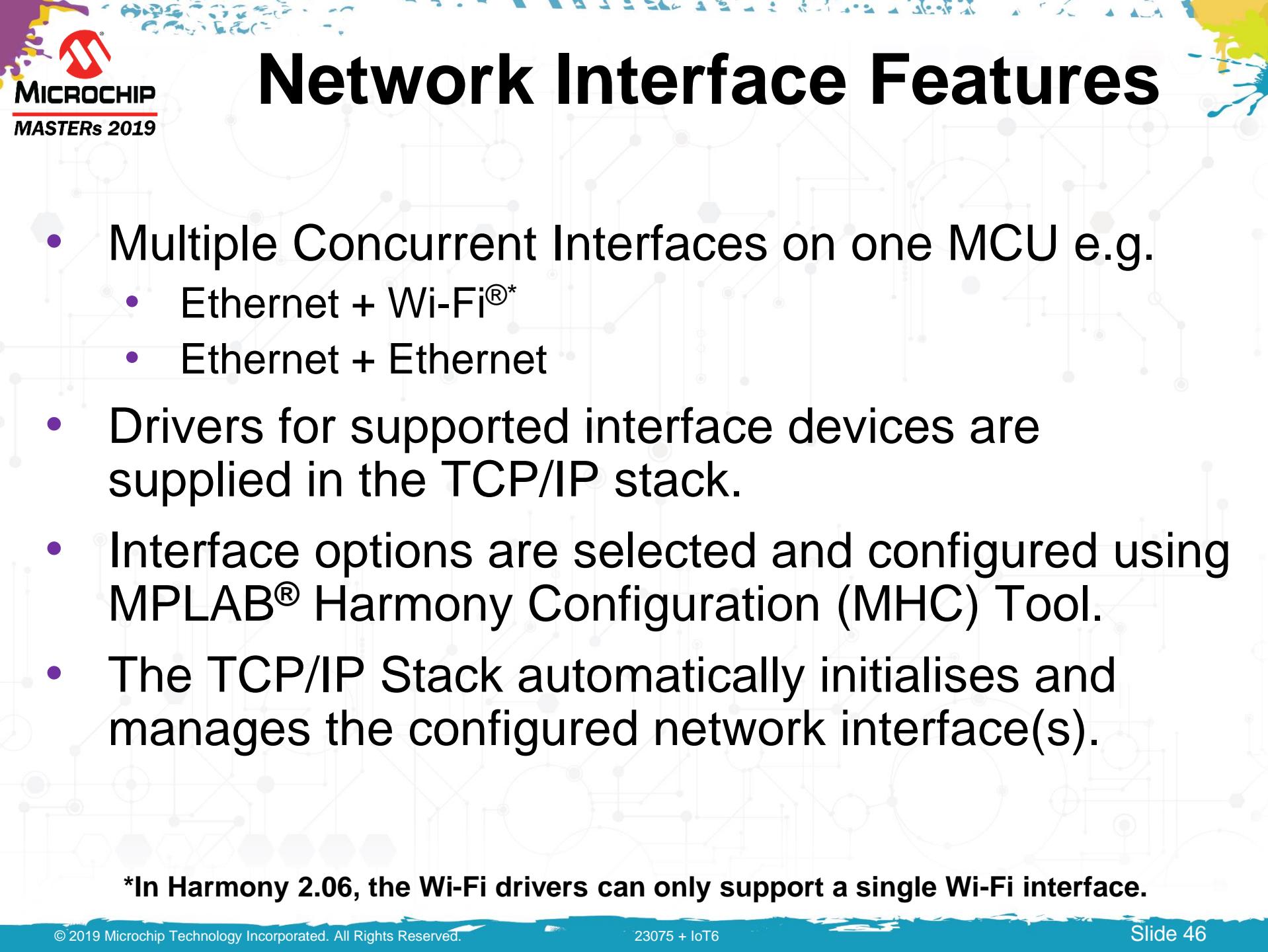
- **IPv4**
  - Four 8-bit segments
  - Decimal numbers 0 to 255
  - Number of addresses: 32 bits = 4.3 billion
- **IPv6** **FE80:0000:0000:0000:75EA:CEFF:FE44:5101**
  - Eight 16-bit segments
  - Hex numbers 0 to FFFF
  - Number of addresses: 128 bits =  $3.4 \times 10^{38}$   
 $= 340,282,366,920,938,463,463,374,607,431,768,211,456$

192.168.1.1

# Network Interface Layer

PIC32/SAM MCU running MPLAB® Harmony TCP/IP Stack





# Network Interface Features

- Multiple Concurrent Interfaces on one MCU e.g.
  - Ethernet + Wi-Fi®\*
  - Ethernet + Ethernet
- Drivers for supported interface devices are supplied in the TCP/IP stack.
- Interface options are selected and configured using MPLAB® Harmony Configuration (MHC) Tool.
- The TCP/IP Stack automatically initialises and manages the configured network interface(s).

\*In Harmony 2.06, the Wi-Fi drivers can only support a single Wi-Fi interface.

# Network Interface Options

## Option 1 Ethernet



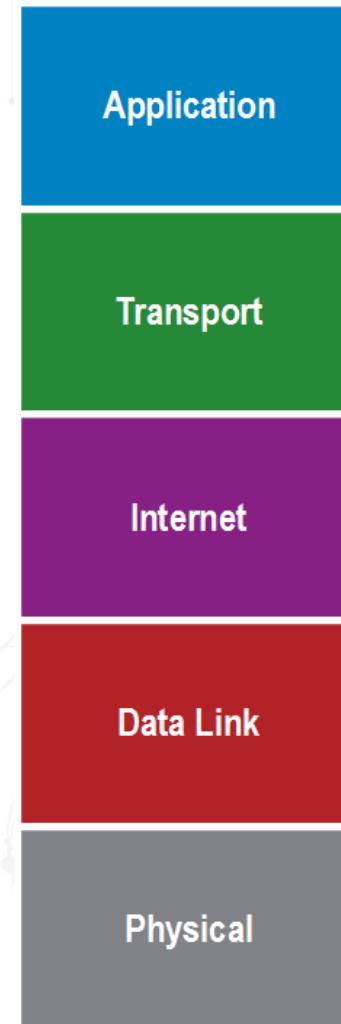
## Option 2 Ethernet



## Option 3 Wi-Fi



## TCP/IP Stack

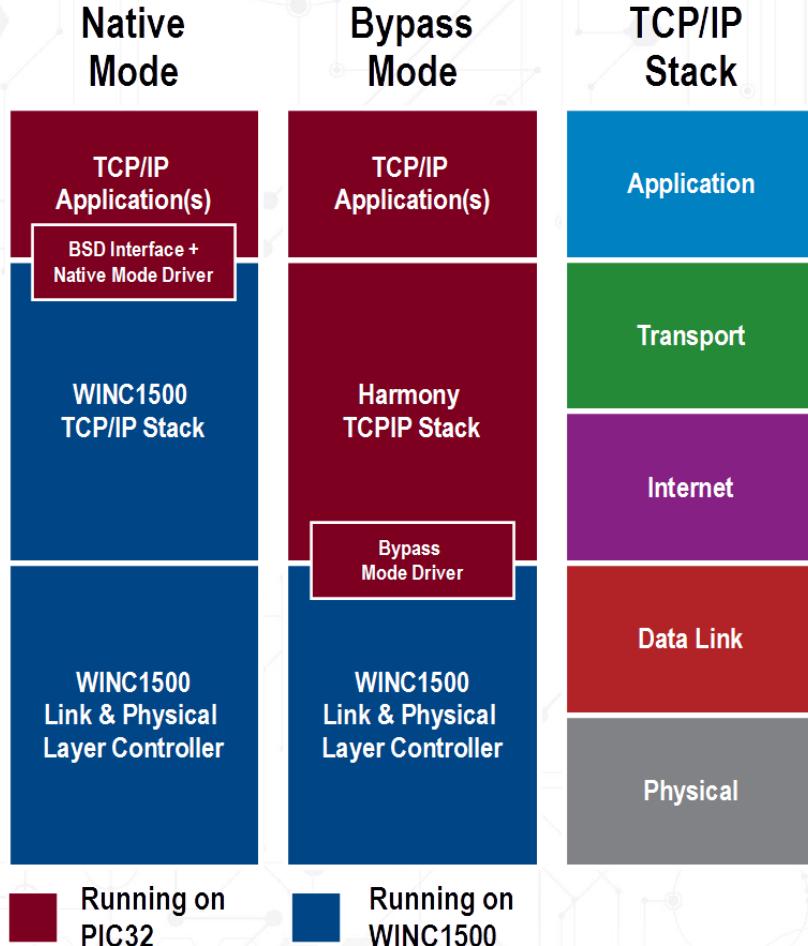


# Supported Interface Devices

- **Ethernet PHYs**
  - Only used with PIC32/SAM devices that have internal Ethernet MAC Peripheral
  - **PHY Only:** LAN8700, LAN8720, LAN8740, KSZ8041 & KSZ8061
  - **PHY + Switch:** LAN9303 & KSZ8863
- **Standalone Ethernet Link Controllers**
  - ENC28J60 (SPI)
  - ENCx24J600 (SPI)
- **Wi-Fi®**
  - ATWINC1500 (SPI)
  - ATWILC1000 (SPI)



# WINC1500 Wi-Fi® Module *Operation Modes with Harmony*



## Two modes of operation:

- **Native Mode:** TCP/IP Stack residing on WINC1500 device is utilised
- **Bypass Mode:** Harmony TCP/IP Stack is utilised

Harmony TCP/IP Stack features are only available when WINC1500 is operated in Bypass mode.





# MAC Address

- All network interface devices must have a globally unique MAC address.
- Some devices are already supplied with a MAC Address, including:
  - PIC32/SAM devices with Internal Ethernet MAC Peripheral
  - All Microchip Wi-Fi® modules
  - Microchip ENCx24J600 Ethernet Controller

# PIC32/SAM MAC Address

- A globally unique MAC Address is programmed into a read only section of Flash Program Memory.
- This feature is only available on PIC32/SAM Devices with an Internal Ethernet MAC Peripheral.
- The address is automatically loaded into the EMAC1Sx registers after reset.
- The address can be manually read using a Harmony API: **PLIB\_ETH\_MACGetAddress**.

# TCP/IP Stack Features

- **Fully dynamic:**
  - Stack initialization/de-initialization
  - Interface up/down
  - Resource management
  - Module configuration
- **Run-time configuration via APIs or Console**
- **Interrupt driven operation**
- **RTOS compatible**

# TCP/IP Console

- **Network specific commands:**
  - Network info
  - Stack and interfaces up/down control
    - Whole stack or one interface at a time
  - IP addresses set/get
  - DHCP, NetBIOS names, etc.
  - Wi-Fi® commands included
  - TCP/IP Heap statistics
  - Socket Debugging



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## Part 3: Using the MPLAB® Harmony TCP/IP Stack

- Open an example project
- Stack (Re)Configuration
- Connectivity Check
- MPLAB® Harmony TCP/IP Stack APIs
- Tools





# Harmony V3

## Device Configuration

### Initialize Device

- Clocks
- Pins
- Memory
- Vectors
- Startup Code
- Essentials...

### Peripheral Libraries

#### Use Peripherals

- Custom Initialization
- Clean & direct
- MCC-Like
- Low overhead
- Custom generated

### Drivers & Services

#### Share Resources & Peripherals

- Built on PLIBs
- Interoperable
- Simple interfaces
- Advanced capabilities

### Powerful Middleware

#### Add MW Stacks

- Graphics
- TCP/IP Networking
- USB Host & Device
- Cryptography
- More...

### Real-Time OS

#### Optimize CPU Usage

- FreeRTOS Included
- OS Abstraction Layer (OSAL)
- Preemptive scheduling

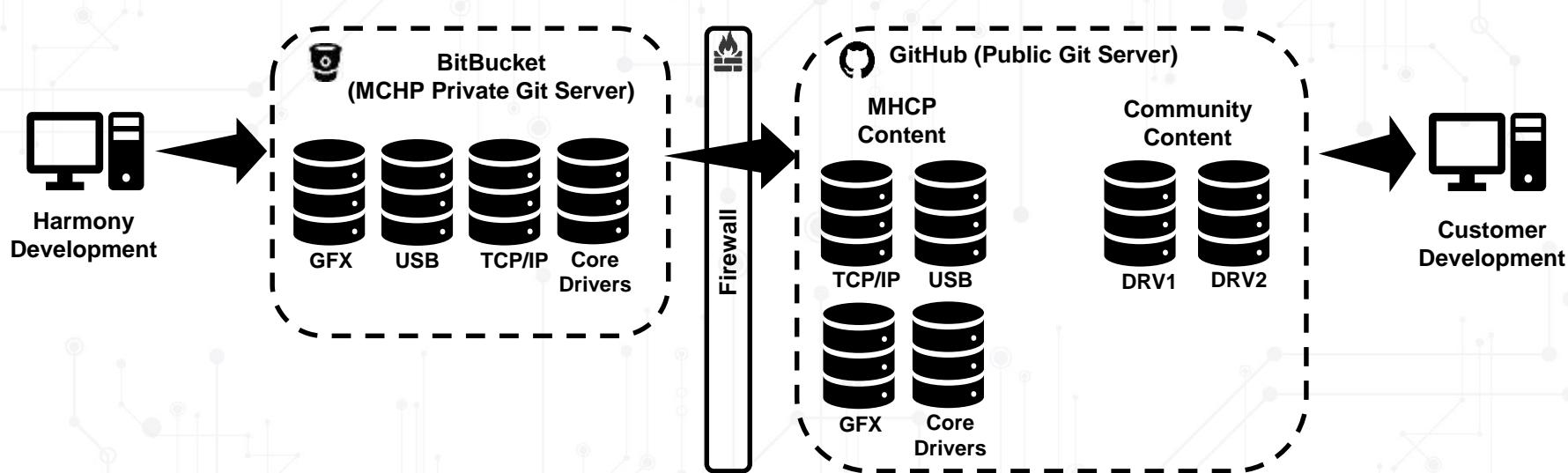
on

Give me a total system solution!

I don't care about libraries. Just get the MCU initialized!

# Harmony V3

## MPLAB Harmony V3 on GitHub



- **Modular:**
  - Individual libraries released when ready. No need to wait for complete Harmony release
  - Customer selects desired modules. No need to download everything.
- **Flexible:**
  - Ability to quickly add/modify project configuration to meet evolving customer needs
- **Open:**
  - Facilitates community content. Customer can select desired content with package manager.



# MHC Git

Configuration Database Setup

Select and configure the packages that will be included in the current project:

Load	Name	Version	Dependencies
<input checked="" type="checkbox"/>	bsp	v3.3.0	csp(3.2.1)
<input checked="" type="checkbox"/>	core	v3.3.0	csp(3.2.1)
<input checked="" type="checkbox"/>	crypto	v3.2.1	core(v3.2.1)
<input checked="" type="checkbox"/>	csp	v3.2.1	
<input checked="" type="checkbox"/>	net	v3.3.0	core(3.2.1), csp(3.2.1), dev_packs(...)

Configure Device Family and CMSIS Pack Paths:

DFP:

CMSIS:

Configuration Database Setup

Select and configure the packages that will be included in the current project:

Load	Name	Version	Dependencies
<input type="checkbox"/>	audio	v3.1.0	core(3.0)
<input type="checkbox"/>	bootloader	v3.0.0	csp(3.0)
<input checked="" type="checkbox"/>	bsp	v3.2.0	core(3.0)
<input type="checkbox"/>	bt	v3.1.0	core(3.0)
<input checked="" type="checkbox"/>	core	v3.3.0	csp(3.2.1)
<input checked="" type="checkbox"/>	crypto	v3.2.0	core(v3.2.0)
<input checked="" type="checkbox"/>	csp	v3.3.0	
<input type="checkbox"/>	gfx	v3.1.0	core(3.0)
<input type="checkbox"/>	micrium_uicos3	v3.0.0	core(3.0)
<input type="checkbox"/>	motor_control	v3.2.0	csp(v3.2.0)
<input checked="" type="checkbox"/>	net	v3.3.0	core(3.2.1), csp(3.2.1), dev_packs(...)
<input type="checkbox"/>	touch	v3.2.0	csp(v3.3.0)
<input type="checkbox"/>	usb	v3.2.0	core(3.0)

Configure Device Family and CMSIS Pack Paths:

DFP:  [...]

CMSIS:  [...]

Launch Cancel



# MPLAB® Harmony V3

## MPLAB Harmony Configurator

The screenshot shows the MPLAB Harmony Configurator interface with three main panels:

- Available Components (Left Panel):** A tree view of available components, including Audio, Bluetooth, Board Support Packages (BSPs), Bootloader, Graphics, Harmony, Input, Libraries (Cryptographic Library, TCPIP, USB), Peripherals, Third Party Libraries, and Tools.
- Project Graph (Center Panel):** A graph-based interface for visualizing project dependencies. It shows nodes for Device Family Pack (DFP), System, and CMSIS Pack. The System node is currently selected.
- Configuration Options (Right Panel):** A hierarchical list of configuration options under the System category, including Device & Project Configuration, Cortex-M7 Configuration, Clock (PMC), Ports (PIO), Interrupts (NVIC), DMA (XDMAC), RSWDT, and WDT.

At the bottom, a Console window displays the following log output:

```
Harmony Database> [Info]: CSP: create component: Peripheral USART4 (ID = 6418)
Harmony Database> [Info]: CSP: create component: Peripheral USART0 (ID = 6089)
Harmony Database> [Info]: CSP: create component: Peripheral USART1 (ID = 6089)
Harmony Database> [Info]: CSP: create component: Peripheral USART2 (ID = 6089)
Harmony Database> [Info]: CSP: Peripheral [USBSHS id=112292] is not supported in MCC
Harmony Database> [Info]: CSP: Peripheral [UTMI id=11300] is not supported in MCC
Harmony Database> [Info]: CSP: System Peripheral [WDT id=6040]
Harmony Database> [Info]: CSP: System Peripheral [XDMAC id=111161]
```

**Available Components  
(Peripherals, Libraries,..)**

**Project Graph**

**Configuration Options**



# MPLAB® Harmony V3

## MPLAB Harmony Configurator

The screenshot shows the MPLAB Harmony Configurator interface. On the left, the "Available Components" pane lists various peripherals: I2C, PWM, QSPI, RSTC, RTC, RTT, SDRAMC, SMC, SPI, SSC, SUPC, TC, TC2, TC3, TRNG, TWIHS, and UUART. Several components are highlighted with red dashed boxes: SUPC, TC, TC2, TC3, and TRNG. A red arrow points from the "Available Components" pane towards the "Project Graph". The "Project Graph" pane displays three peripheral libraries: USART0 Peripheral Library (UART), TCO Peripheral Library (TMR), and TC1 Peripheral Library (TMR). The USART0 library is highlighted with a green box. A green arrow points from the "Project Graph" towards the "Configuration Options" pane. The "Configuration Options" pane is open for the USART0 component, showing configuration settings for Interrupt Mode (checked), Select Clock Source (MOX), Clock Source Value (150,000,000), Baud Rate (9,600), OverSampling (16 Times), Data (8 BIT), Parity (NO), and Stop (1 BIT). The "Console" pane at the bottom shows the following log output:

```
<Harmony Database>[Info]: CSP: create component: Peripheral USART2 (ID = 6089)
<Harmony Database>[Info]: CSP: Peripheral [USBHS id=11292] is not supported in MCC
<Harmony Database>[Info]: CSP: Peripheral [UTMI id=11300] is not supported in MCC
<Harmony Database>[Info]: CSP: System Peripheral [NVT id=6080]
<Harmony Database>[Info]: CSP: System Peripheral [XHAC id=11161]
<Harmony Database>[Info]: CSP: Peripheral [EUSES id=1] is not supported in MCC
```



# MPLAB® Harmony V3

Peripheral  
initialization only. No  
Driver!  
Access completely  
managed from end-

The screenshot shows the MPLAB Harmony Configurator interface. On the left, there is a sidebar with a tree view of available components:

- Audio
- Bluetooth
- Board Support Packages (BSPs)
- Bootloader
- Graphics
- Harmony
- Input
- Libraries
  - Cryptographic (Crypto) Library
  - TCPIP
  - USB
- Peripherals
- Third Party Libraries
- Tools

Below the sidebar are two tabs: "Available Components" and "Active Components".

The main area is titled "Project Graph" and displays the "Device Family Pack (DFP)" view. A yellow arrow points to the "USART0 Peripheral Library" node under the "UART" category. The "System" and "CMSIS Pack" tabs are also visible.

At the bottom of the interface, there is a "Console" window displaying log output:

```
<Harmony Database>[Info]: create component: USB Device HID
<Harmony Database>[Info]: create component: USB Device MSD
<Harmony Database>[Info]: create component: USB Host
<Harmony Database>[Info]: create component: USB Host MSD
<Harmony Database>[Info]: create component: USB Host CDC
<Harmony Database>[Info]: create component: USB Host HID
<Harmony Database>[Info]: create component: USB Host Audio
<Info>: Startup tasks completed
<Configuration Database>[Info]: Loading Interrupt Manager for ATSAME7Q21B
<Configuration Database>[Info]: Loading SYSTICK for ATSAME7Q21B
<Configuration Database>[Info]: Loading DMA Manager for ATSAME7Q21B
<Configuration Database>[Info]: Loading RSWDT for ATSAME7Q21B
<Configuration Database>[Info]: Starting Pin Manager for ATSAME7Q21B
<Configuration Database>[Info]: Running USART0
<Plugin>[Info]: Loading plugin: C:\cm\h3\csp\arch\..\peripheral\clk_sam_e70\plugin\clockmanager.jar
<Plugin>[Info]: Loading plugin: C:\cm\h3\csp\arch\..\peripheral\mpu\plugin\MPUmanager.jar
<Plugin>[Info]: Loading plugin: C:\cm\h3\csp\arch\..\peripheral\xdmac_11161\plugin\xdmananager.jar
<Plugin>[Info]: Loading plugin: C:\cm\h3\csp\arch\..\peripheral\nvic\plugin\NVICmanager.jar
<Plugin>[Info]: Loading plugin: C:\cm\h3\csp\arch\..\peripheral\pio_11004\plugin\SAME70pinmanager.jar
<Harmony Database>[Info]: Loading System Services for ATSAME7Q21B
<Harmony Database>[Info]: Loading Pin Manager for ATSAME7Q21B
```

At the very bottom, a welcome message reads: "Welcome to the MPLAB Harmony Configurator!"

MPLAB Harmony Configurator



# MPLAB® Harmony V3

Peripheral initialization only. No Driver!  
Access completely managed from end-user

user



# MPLAB® Harmony V3

The screenshot shows the MPLAB Harmony V3 IDE interface. The left sidebar displays a file tree for a project named 'est'. The 'peripheral' folder contains sub-folders like 'clk', 'nvic', 'pio', and 'uart', with 'pib\_uart0.c' selected. The main workspace shows a code editor with C code for USART0 initialization. The code includes comments explaining the configuration of USART0 mode, baud rate, and instance objects. A tooltip is visible over the line of code: `USART0_REGS->US_MR = (US_MR_USCLKS_MCK | US_MR_CHRL_8_BIT | US_MR_USART_PAR_NO | US_MR_USART_NBSTOP_1_BIT | (0 << US_MR_USART_OVER_Pos));`. The status bar at the bottom indicates the current assembly address: PC: 0x0.

```
166     (void)dummyData;
167
168     return;
169 }
170
171 void USART0_Initialize( void )
172 {
173     /* Reset USART0 */
174     USART0_REGS->US_CR = (US_CR_RSTRX_Msk | US_CR_RSTTX_Msk | US_CR_RSTSTA_Msk);
175
176     /* Enable USART0 */
177     USART0_REGS->US_CR = (US_CR_TXEN_Msk | US_CR_RXEN_Msk);
178
179     /* Configure USART0 mode */
180     USART0_REGS->US_MR = (US_MR_USCLKS_MCK | US_MR_CHRL_8_BIT | US_MR_USART_PAR_NO | US_MR_USART_NBSTOP_1_BIT | (0 << US_MR_USART_OVER_Pos));
181
182     /* Configure USART0 Baud Rate */
183     USART0_REGS->US_BRGR = US_BRGR_CD(976);
184
185     /* Initialize instance object */
186     usart0Obj.rxBuffer = NULL;
187     usart0Obj.rxSize = 0;
188     usart0Obj.rxProcessedSize = 0;
189     usart0Obj.rxBusyStatus = false;
```

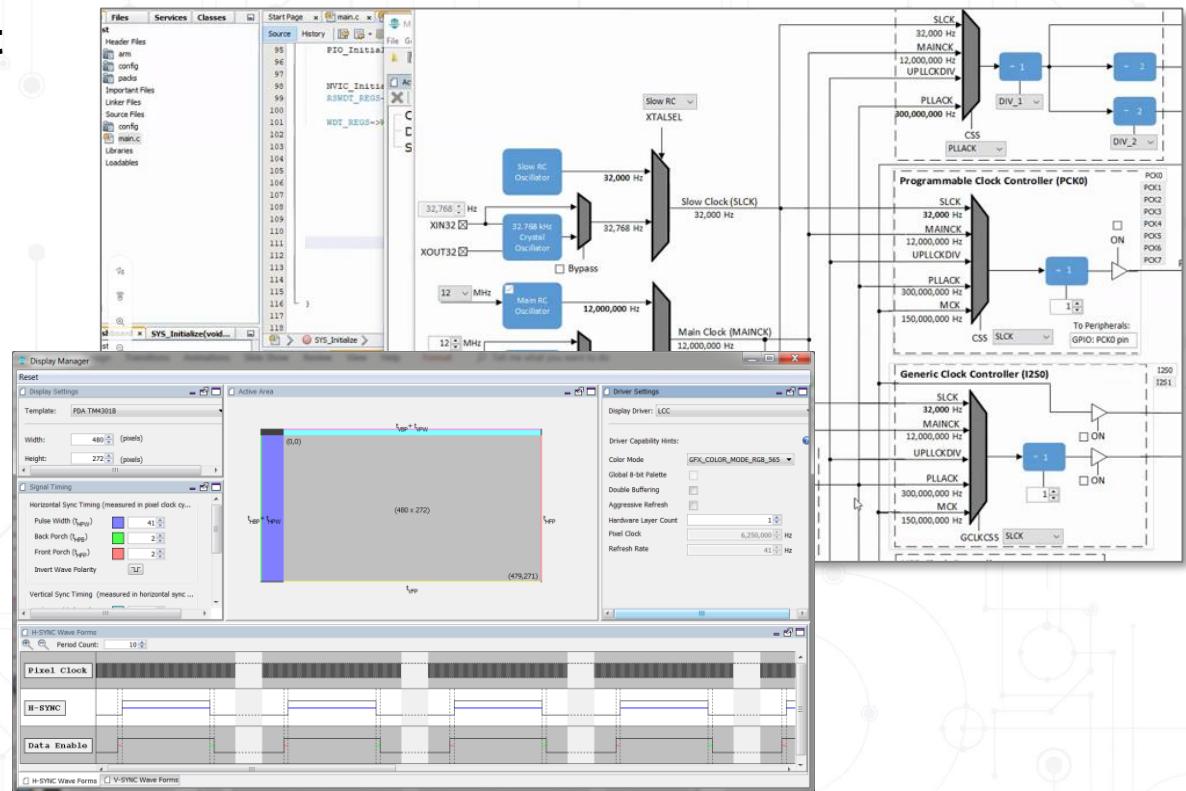
# MPLAB® Harmony V3



## Keep + improve the good things from Harmony V2



- Clock Initialization
- Pinout/I/O Management
  - Graphic
- TCP/IP and SSL1.3
  - Security
  - USB
  - Audio
  - ...





MPLAB Harmony Configurator - sam\_v71\_xult\_freertos

File Generate Tools Utilities Window

Framework: C:\microchip\h3\

Project Graph

View: Root

Active Components

- CMSIS Pack
- CONSOLE
- Core
- Cryptographic (Crypto) Library
- Device Family Pack (DFP)
- EFC
- FILE SYSTEM
- FreeRTOS
- MEMORY
- Presentation Layer
- SAM V71 Xplained Ultra BSP
- System
- TCO
- TCP/IP STACK
  - APPLICATION LAYER
  - BASIC CONFIGURATION
    - NETCONFIG
      - Instance 0
        - TCP/IP Basic Configurator
        - TCPPIP CMD
        - TCPPIP CORE
        - TCPPIP File System Wrapper
    - DRIVER LAYER
    - NETWORK LAYER
    - TRANSPORT LAYER
- TIME
- USART1

Available Components Active Components

Console

Welcome to the MPLAB Harmony Configurator!

Project Graph (Root)

- Device Family Pack (DFP)
  - TC0 Peripheral Library **TMR**
  - TIME System Service **SYS\_TIME**
- CMSIS Pack
  - Core Harmony Core Service
    - RTOS**
    - Core Service**
- SAM V71 Xplained Ultra BSP
  - Cryptographic (Crypto) Library **SYS\_TIME**
  - FreeRTOS Third Party Library **RTOS**
  - LIB\_CRYPTO
  - USART1 Peripheral Library **UART**
  - EFC Peripheral Library **MEMORY**
  - MEMORY Driver **Core Service**
    - Instances
      - Instance 0 **DRV\_MEDIA**
  - FILE SYSTEM System Service **DRV\_MEDIA**
    - SYS\_FS**
  - CONSOLE System Service **Core Service**
    - UART**
    - SYS\_CONSOLE**
    - SYS\_FS**
  - Presentation Layer **net\_pres**
    - Instances
      - Instance 0 **LIB\_CRYPTO**



# Terminal

COM55:115200baud - Tera Term VT

File Edit Setup Control Window Help

TCP/IP Stack: Initialization Started

>TCP/IP Stack: Initialization Ended – success

SYS\_Initialize: The MPFS2 File System is mounted

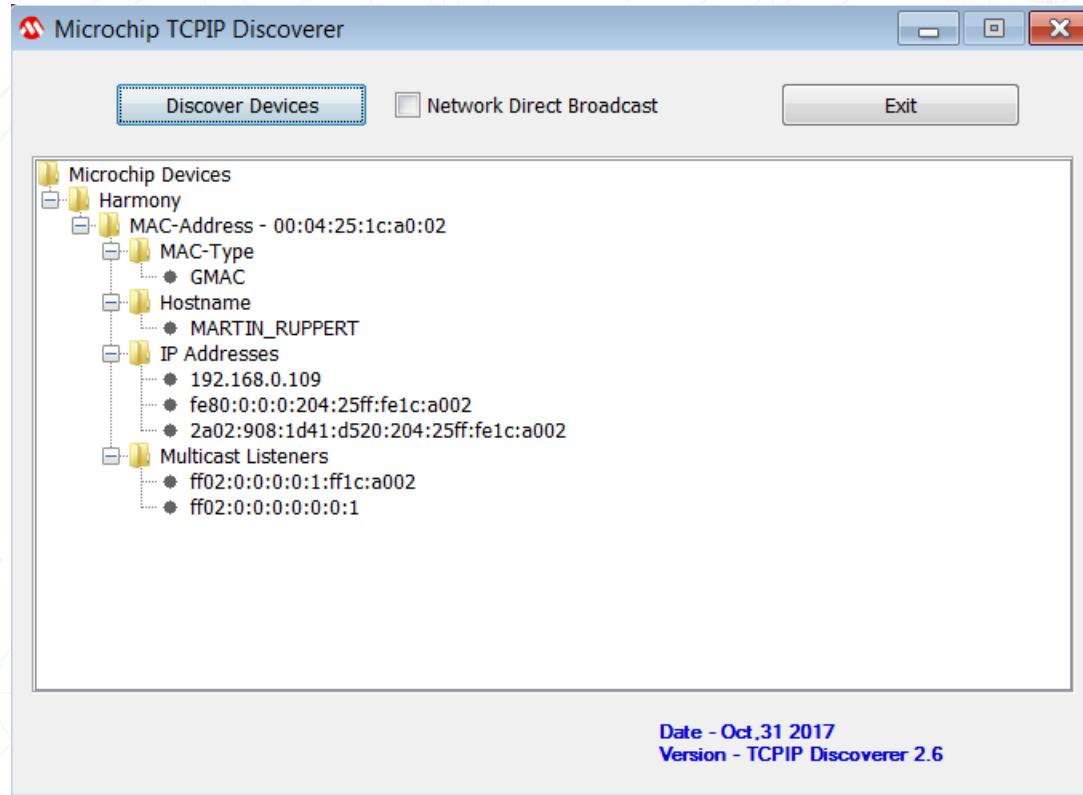
Interface GMAC on host MARTIN\_RUPPERT – NBNS enabled

GMAC IP Address: 0.0.0.0

GMAC IP Address: 192.168.0.109

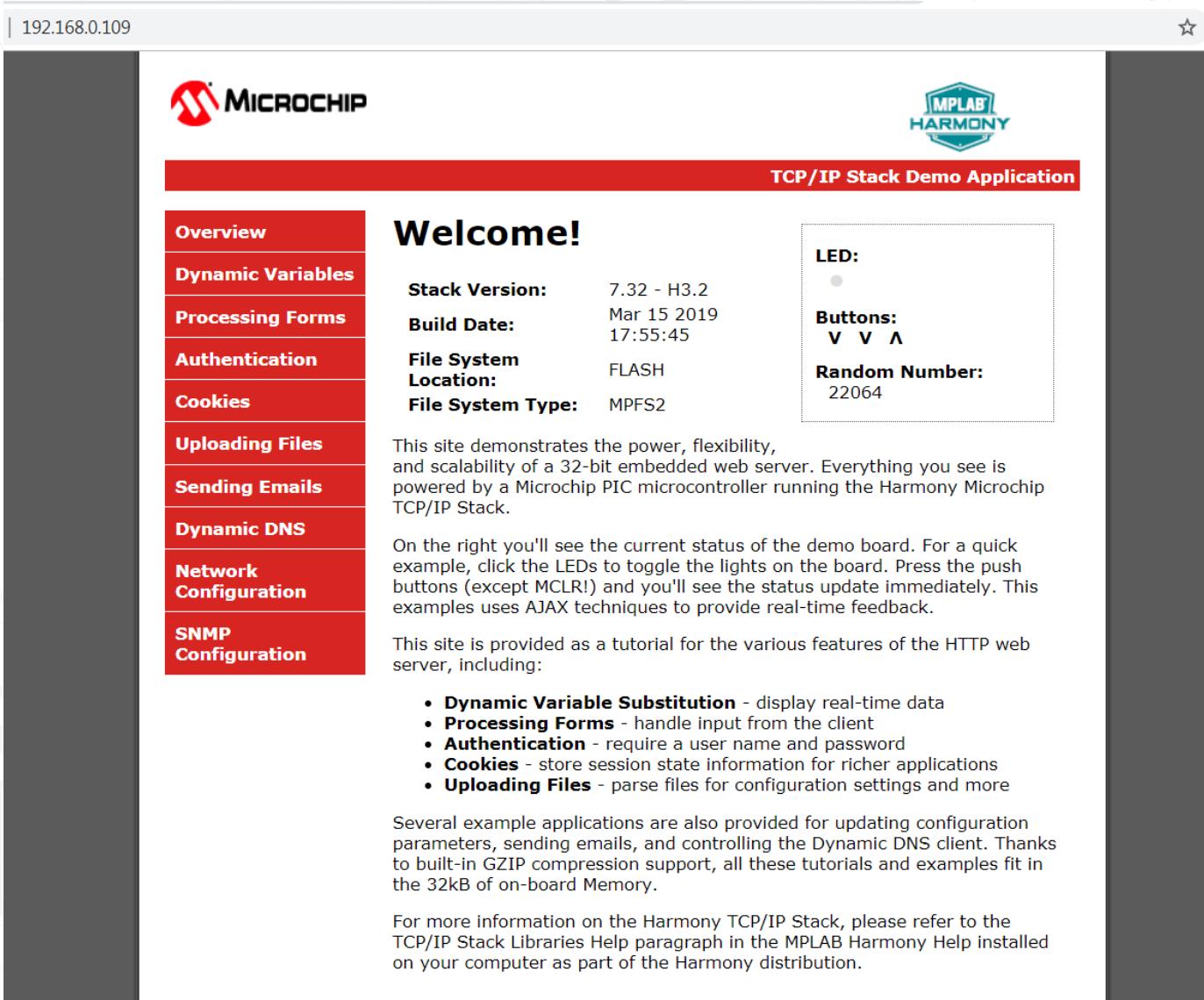


# TCPIP Discoverer



# HTTP2 Webserver

192.168.0.109



**Welcome!**

**Stack Version:** 7.32 - H3.2  
**Build Date:** Mar 15 2019 17:55:45  
**File System Location:** FLASH  
**File System Type:** MPFS2

This site demonstrates the power, flexibility, and scalability of a 32-bit embedded web server. Everything you see is powered by a Microchip PIC microcontroller running the Harmony Microchip TCP/IP Stack.

On the right you'll see the current status of the demo board. For a quick example, click the LEDs to toggle the lights on the board. Press the push buttons (except MCLR!) and you'll see the status update immediately. This examples uses AJAX techniques to provide real-time feedback.

This site is provided as a tutorial for the various features of the HTTP web server, including:

- **Dynamic Variable Substitution** - display real-time data
- **Processing Forms** - handle input from the client
- **Authentication** - require a user name and password
- **Cookies** - store session state information for richer applications
- **Uploading Files** - parse files for configuration settings and more

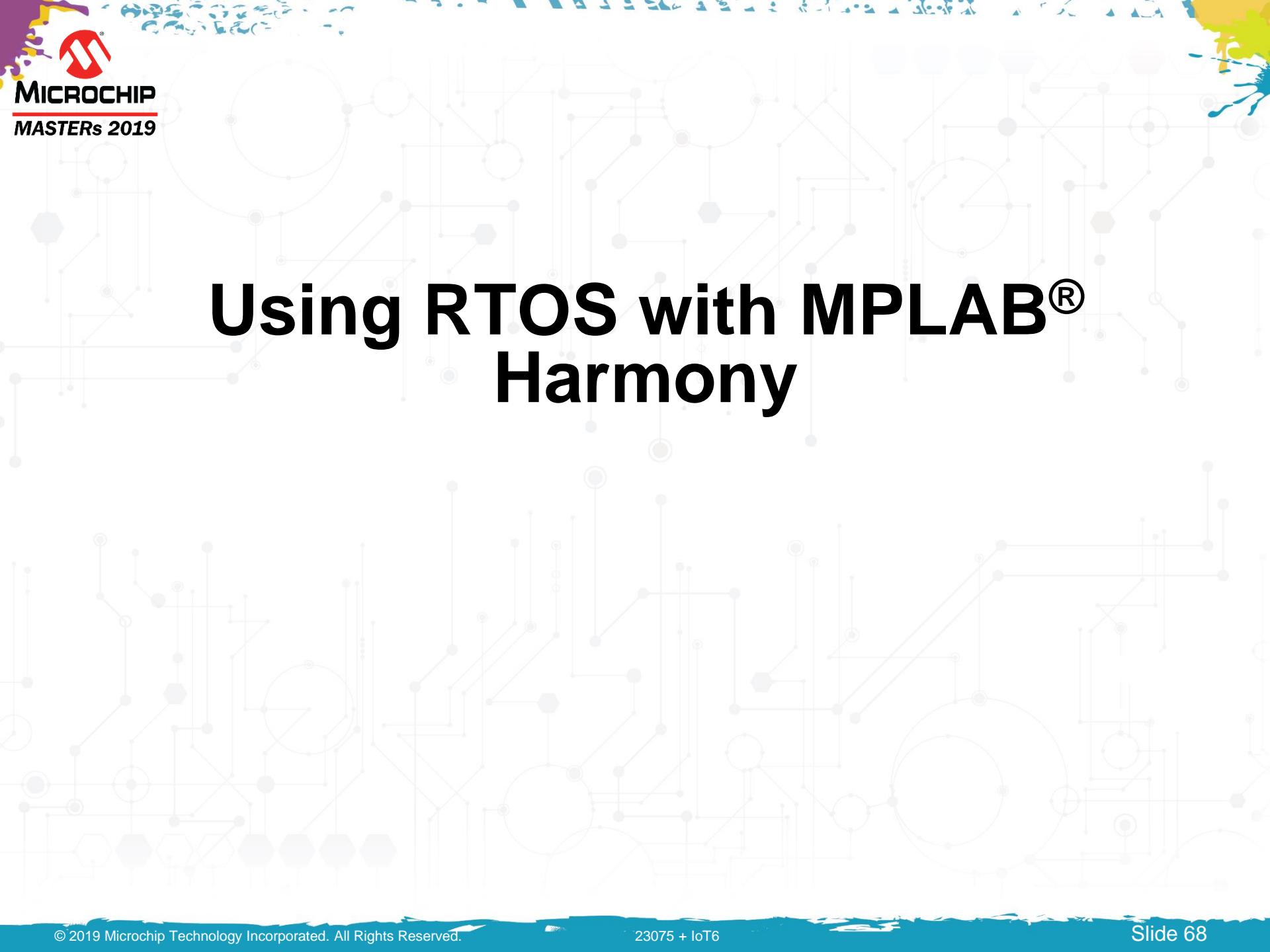
Several example applications are also provided for updating configuration parameters, sending emails, and controlling the Dynamic DNS client. Thanks to built-in GZIP compression support, all these tutorials and examples fit in the 32kB of on-board Memory.

For more information on the Harmony TCP/IP Stack, please refer to the TCP/IP Stack Libraries Help paragraph in the MPLAB Harmony Help installed on your computer as part of the Harmony distribution.

**LED:**  
●

**Buttons:**  
V V A

**Random Number:**  
22064



# Using RTOS with MPLAB® Harmony



# Why use RTOS?

- **Priority based task scheduling**
  - Ensures better responsiveness to events
  - A pre-emptive scheduler always runs the highest priority task that is ready to run, allowing hard real time tasks to meet its deadlines
  - Removes dependency of tasks on the execution time of other functions running in the “super loop”
- **Efficient CPU usage**
  - Does not waste CPU cycles by running tasks waiting on events/resources
  - Idle task is run when there are no application tasks ready to run. This allows putting CPU in low power modes



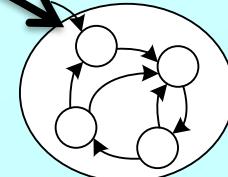
# RTOS Driven

```
static void _SENSORTASK_Tasks(void)
{
    while(1)
    {
        SENSORTASK_Tasks();
        vTaskDelay(10); /*Give time back*/
    }
}
```

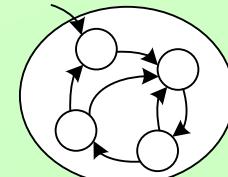
```
void _SYS_Tasks (void *param)
{
    while(1)
    {
        DRV_SPI_Tasks(sysObj.spiObjectIdx0);
        vTaskDelay(10); /*Give time back*/
    }
}
```

```
void SPI_ISR(void)
{
    DRV_SPI_Tasks(sysObj.spiObjectIdx0);
}
```

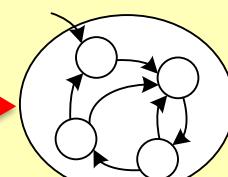
## Application



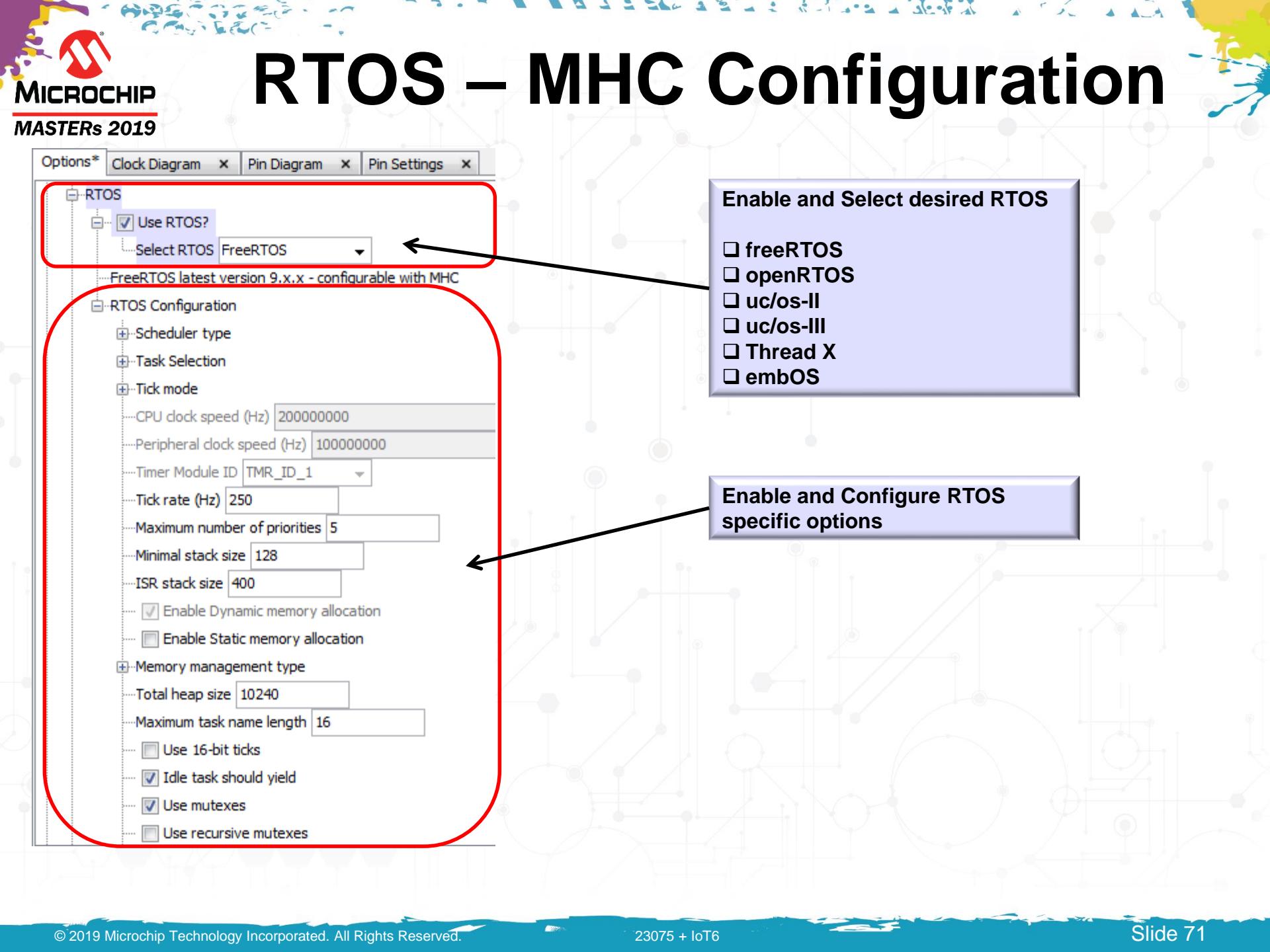
## Middleware

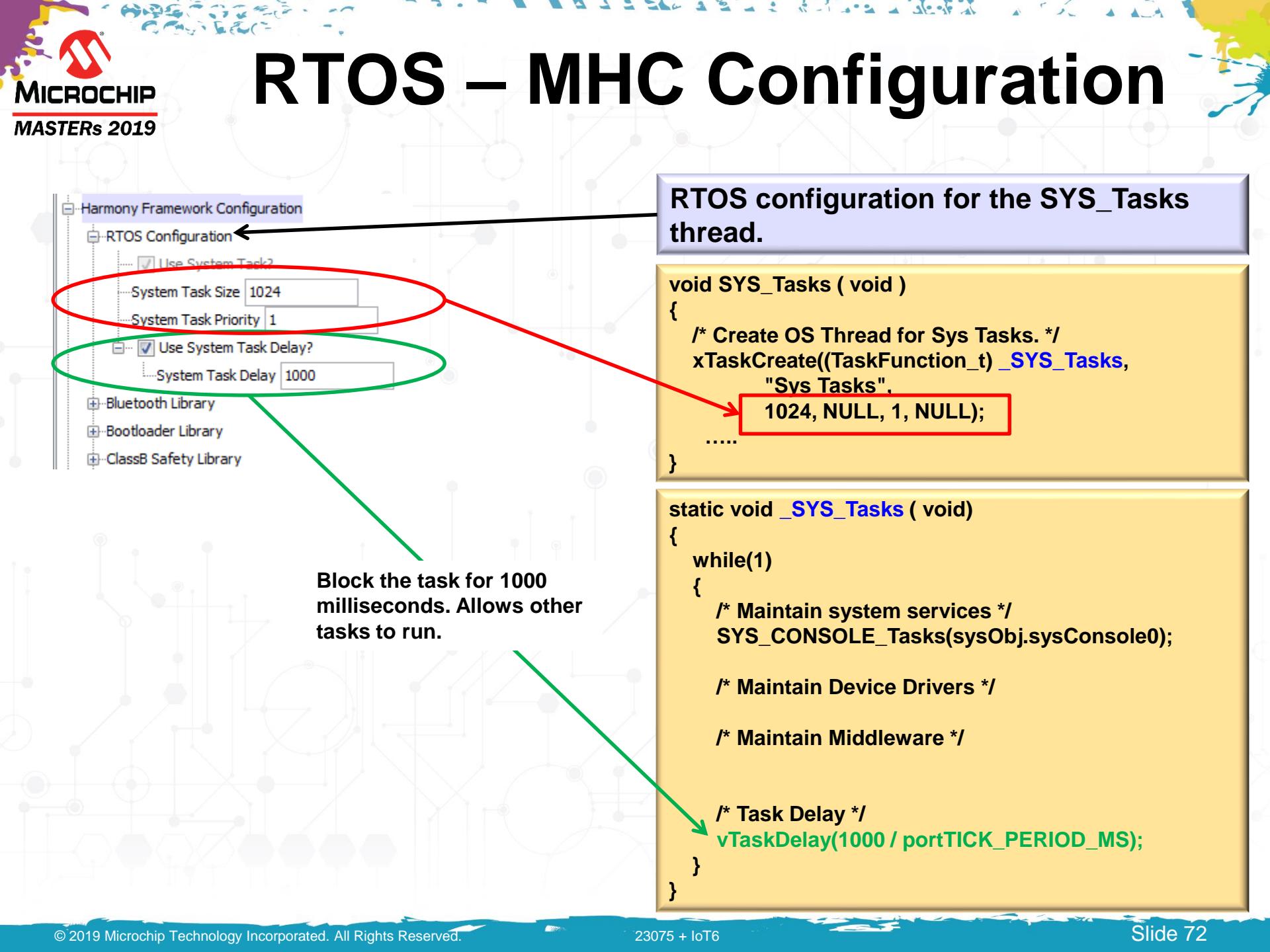


## Driver

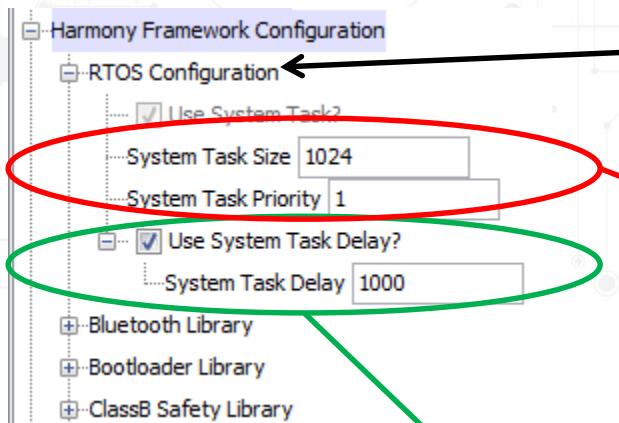


## PLIB





# RTOS – MHC Configuration



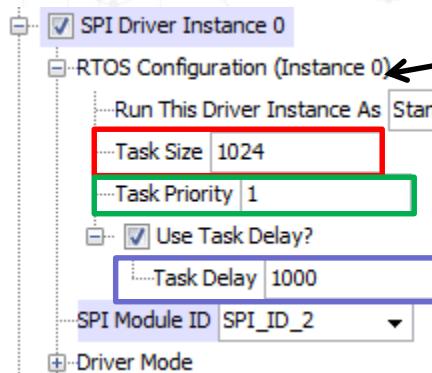
RTOS configuration for the **SYS\_Tasks** thread.

```
void SYS_Tasks ( void )  
{  
    /* Create OS Thread for Sys Tasks. */  
    xTaskCreate(TaskFunction_t) _SYS_Tasks,  
    "Sys Tasks",  
    1024, NULL, 1, NULL);  
    ....  
}
```

```
static void _SYS_Tasks ( void)  
{  
    while(1)  
    {  
        /* Maintain system services */  
        SYS_CONSOLE_Tasks(sysObj.sysConsole0);  
  
        /* Maintain Device Drivers */  
  
        /* Maintain Middleware */  
  
        /* Task Delay */  
        vTaskDelay(1000 / portTICK_PERIOD_MS);  
    }  
}
```

Block the task for 1000 milliseconds. Allows other tasks to run.

# RTOS – MHC Configuration



RTOS configuration for a driver instance which is configured for polled mode operation

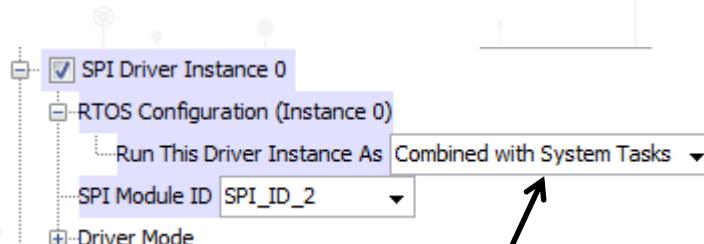
Standalone – Run the driver task as a separate RTOS thread

```
void SYS_Tasks ( void )
{
    /* Create OS Thread for DRV_SPI Instance 0 Tasks. */

    xTaskCreate((TaskFunction_t) _DRV_SPI_IDX0_Tasks,
                "DRV_SPI Instance 0 Tasks",
                1024, NULL, 1, NULL);
    ...
}
```

```
void _DRV_SPI_IDX0_Tasks(void)
{
    while(1)
    {
        DRV_SPI_Tasks(sysObj.spiObjectIdx0);

        vTaskDelay(1000 / portTICK_PERIOD_MS);
    }
}
```



Combined with System Tasks – Run the driver task as part of the **\_SYS\_Tasks** thread

```
static void _SYS_Tasks ( void )
{
    while(1)
    {
        /* Maintain system services */
        SYS_CONSOLE_Tasks(sysObj.sysConsole0);

        /* Maintain Device Drivers */
        DRV_SPI_Tasks(sysObj.spiObjectIdx0);

        /* Maintain Middleware */

        /* Task Delay */
        vTaskDelay(1000 / portTICK_PERIOD_MS);
    }
}
```

# System Initialization & Tasks

```

int main(void)
{
    SYS_Initialize(NULL);

    while(true)
    {
        SYS_Tasks();
    }

    return(EXIT_VALUE);
}

void SYS_Tasks ( void )
{
    /* Create OS Thread for Sys Tasks. */
    xTaskCreate((TaskFunction_t) _SYS_Tasks, "Sys Tasks",1024, NULL, 3, NULL);
    xTaskCreate((TaskFunction_t) _USB_Tasks, "USB Tasks",1024, NULL, 3, NULL);

    /* Create OS Thread for SENORTASK Tasks. */
    xTaskCreate((TaskFunction_t) _SENSORTASK_Tasks, "SENSORTASK Tasks", 1024, NULL, 2,
NULL);

    /* Create OS Thread for EEPROMTASK Tasks. */
    xTaskCreate((TaskFunction_t) _EEPROM_Tasks, "EEPROM Tasks", 1024, NULL, 1, NULL);
    .....

    /*****
     * Start RTOS
     *****/
    vTaskStartScheduler(); /* This function never returns. */
}

```

```

void SYS_Initialize( void* data )
{
    SYS_CLK_Initialize( &clkInit );
    BSP_Initialize();
    sysObj.spiObjectIdx0 = DRV_SPI_Initialize (DRV_SPI_INDEX_0,
&drvSpi0InitData);
    sysObj.drvTmr0      = DRV_TMR_Initialize(DRV_TMR_INDEX_0,
&drvTmr0InitData);
    .....

    /*create Tasks*/
    APP_Initialize();
}

```



# MICROCHIP MASTERS

2019

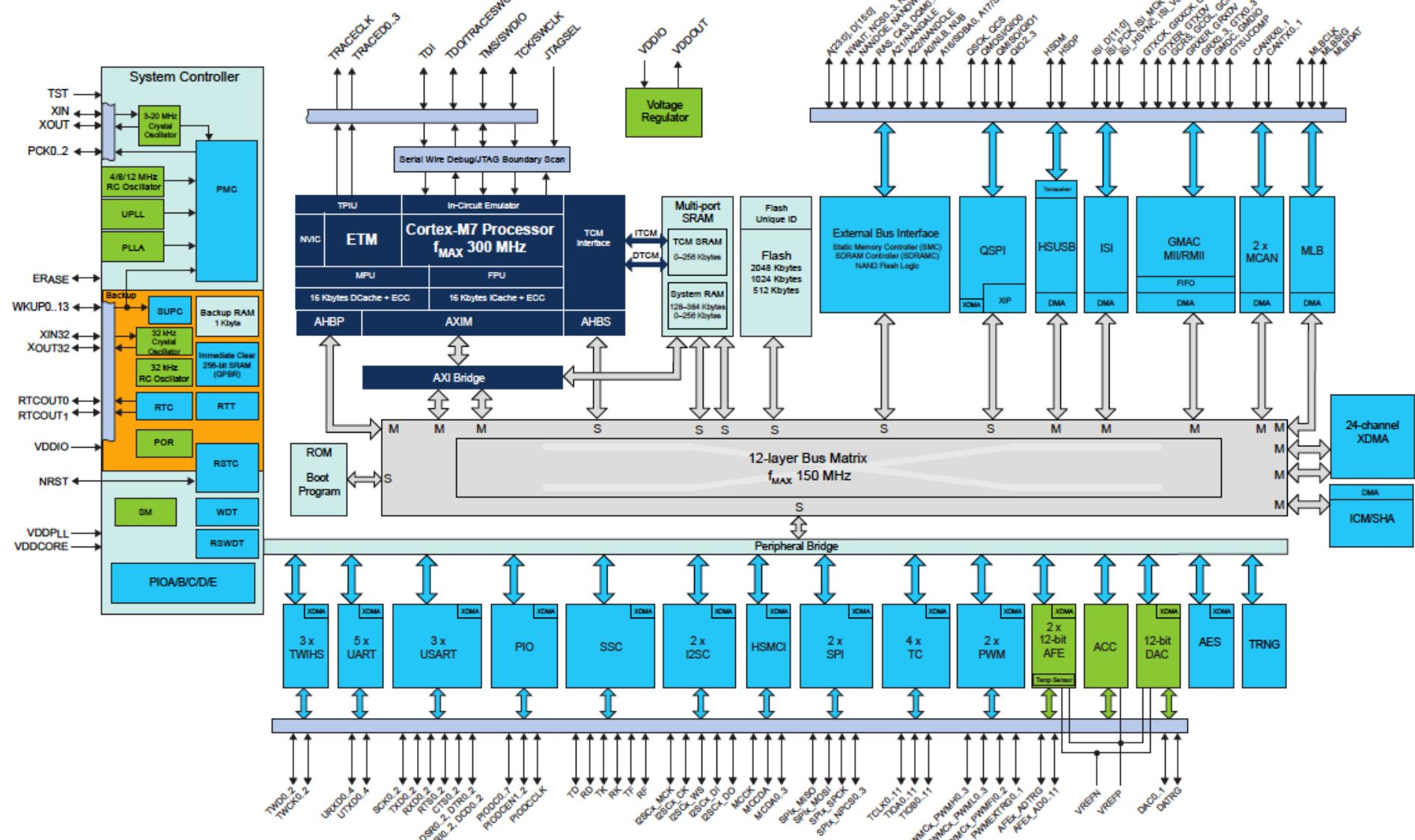
## The Hardware for this Class



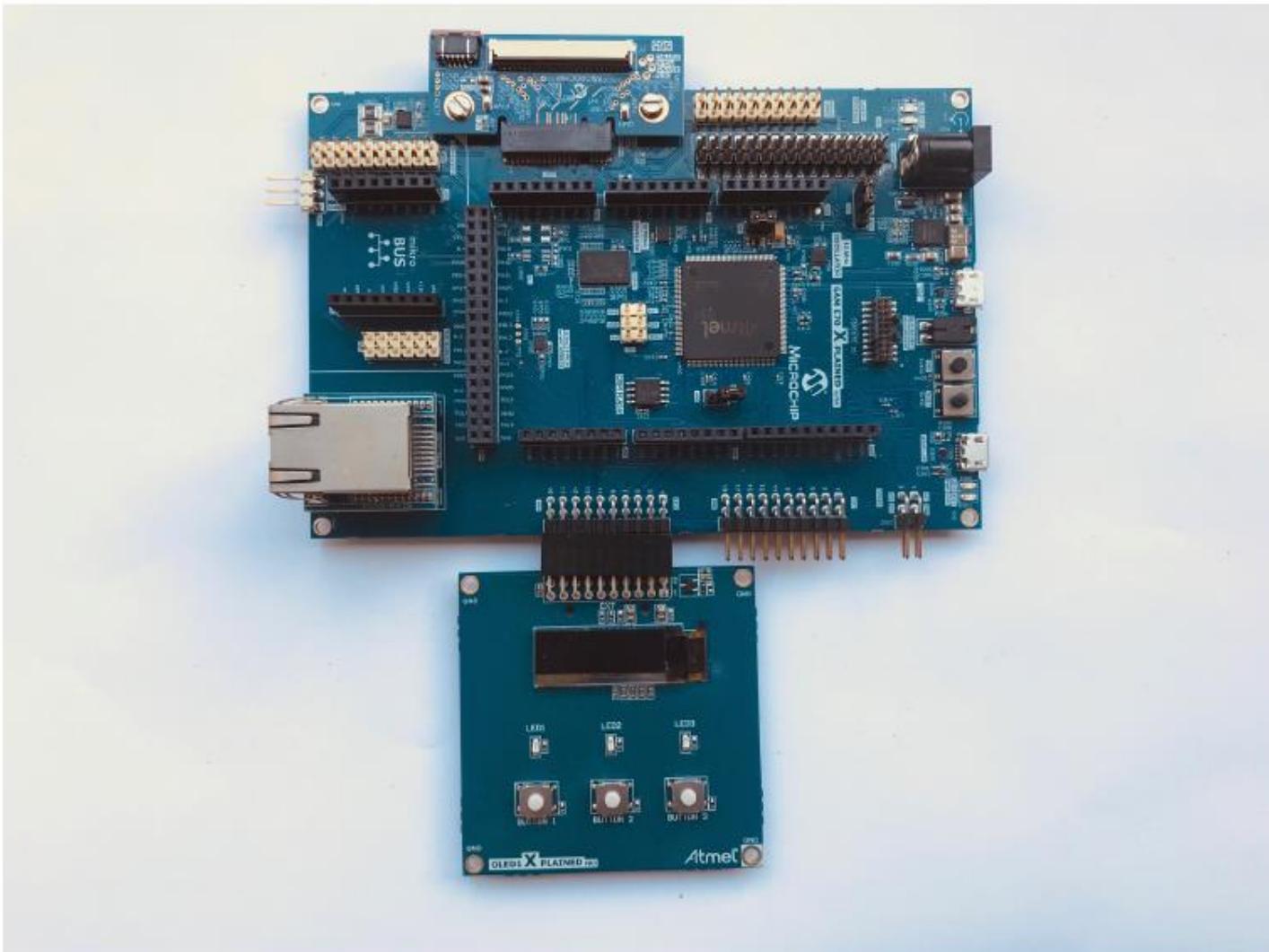


**MICROCHIP**  
**MASTERs 2019**

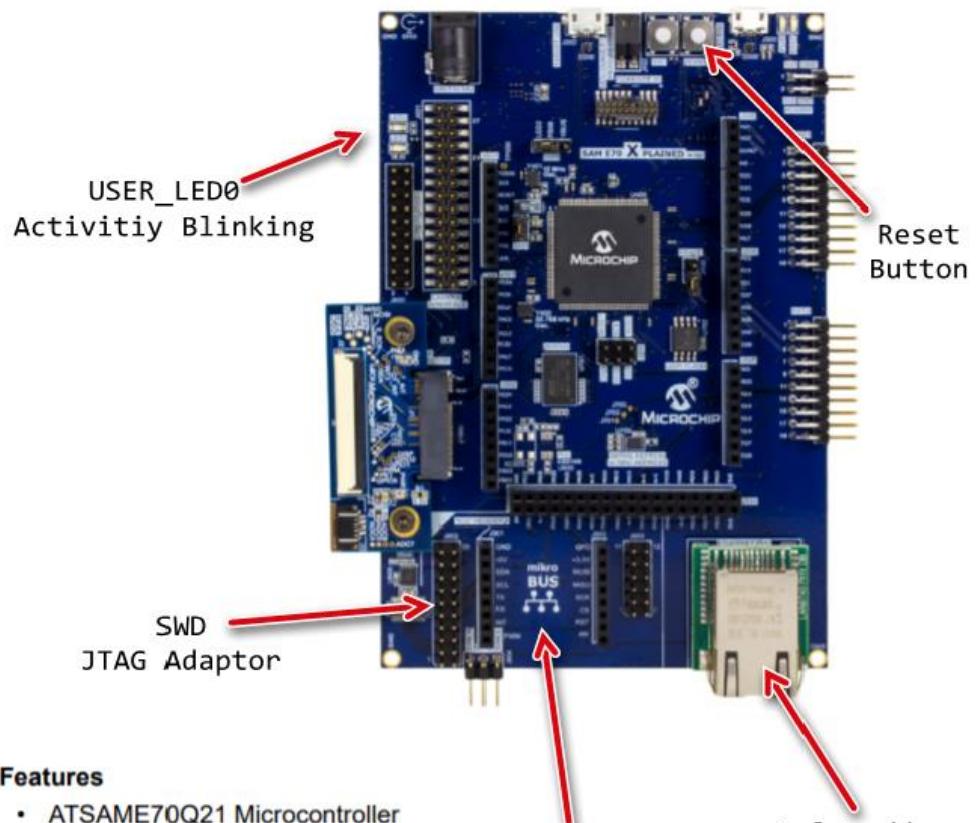
# SAME70



# SAME70 Xplained Ultra

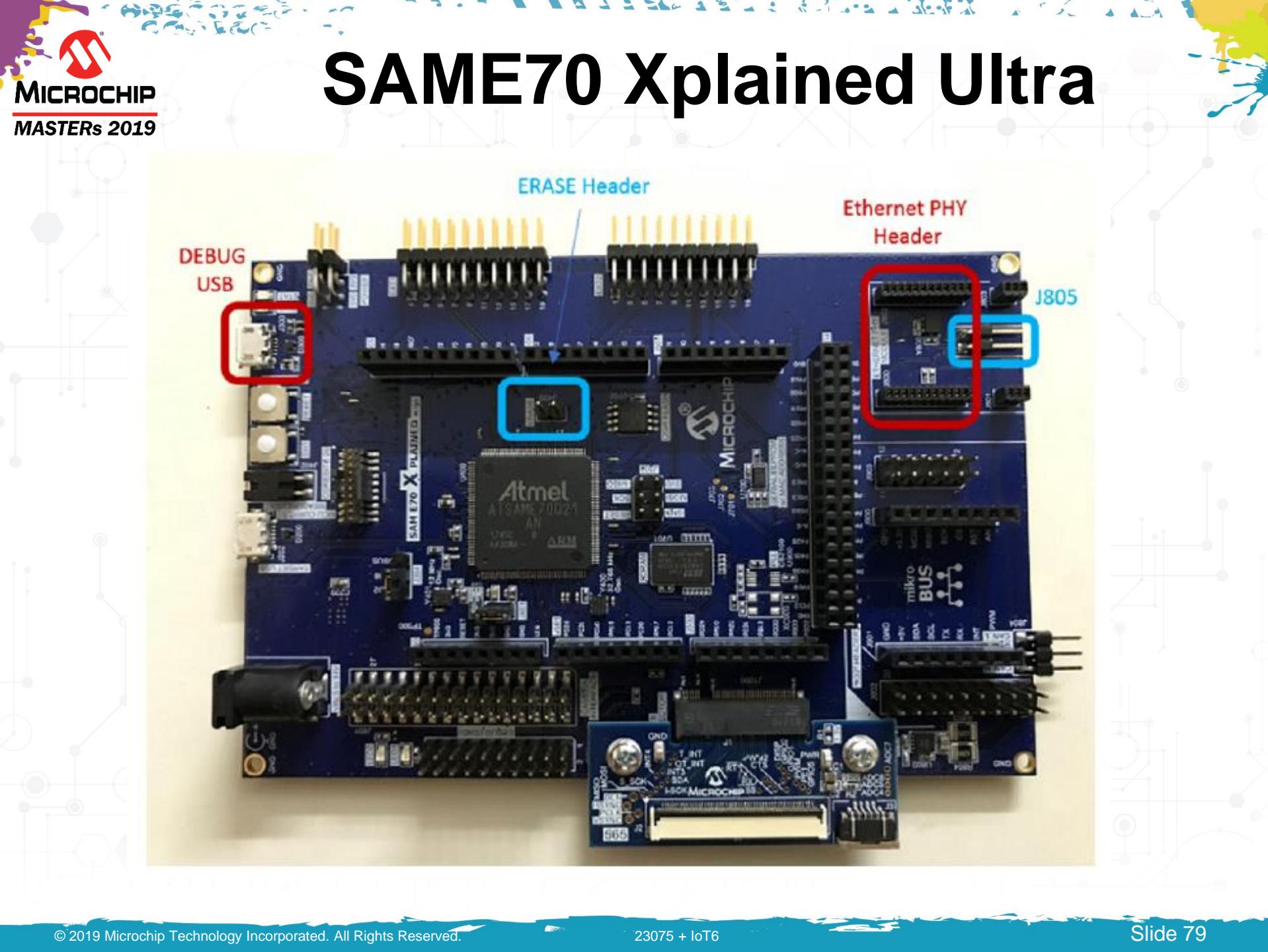


# SAME70 Xplained Ultra

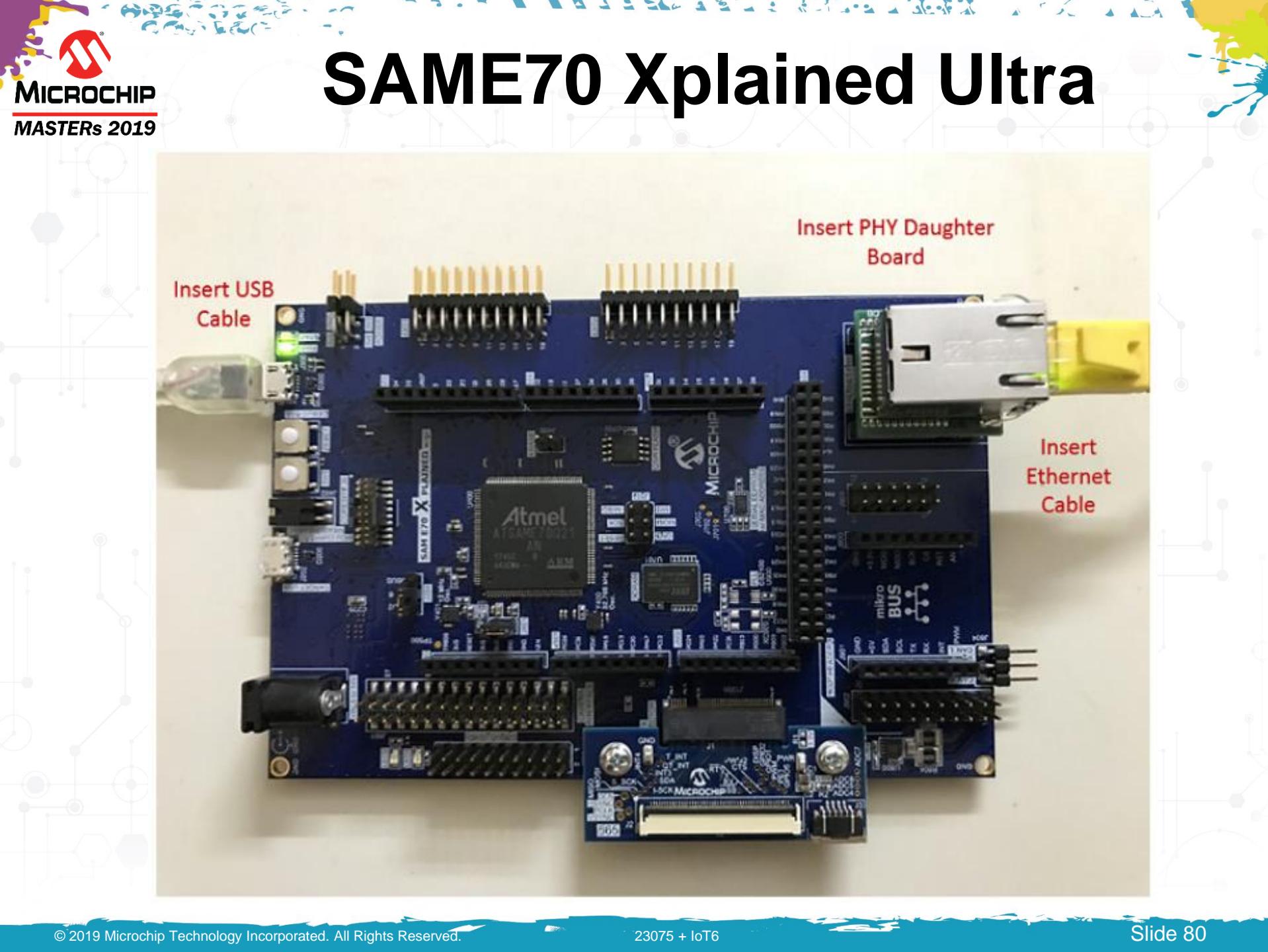


## Features

- ATSAME70Q21 Microcontroller
- One Mechanical Reset Button
- One Mechanical User Push Button
- Two User LEDs
- 12.0 MHz Oscillator (DSC6003)
- 32.768 kHz Oscillator (DSC6083)
- 2-MB SDRAM
- 4-MB QSPI Flash (SST26VF032BA)



# SAME70 Xplained Ultra



# SAME70 Xplained Ultra

# Now it is time for Lab1

A walk through an existing TCP Application,  
adding some changes with  
**MPLAB® Harmony Configurator**  
And playing with the tools

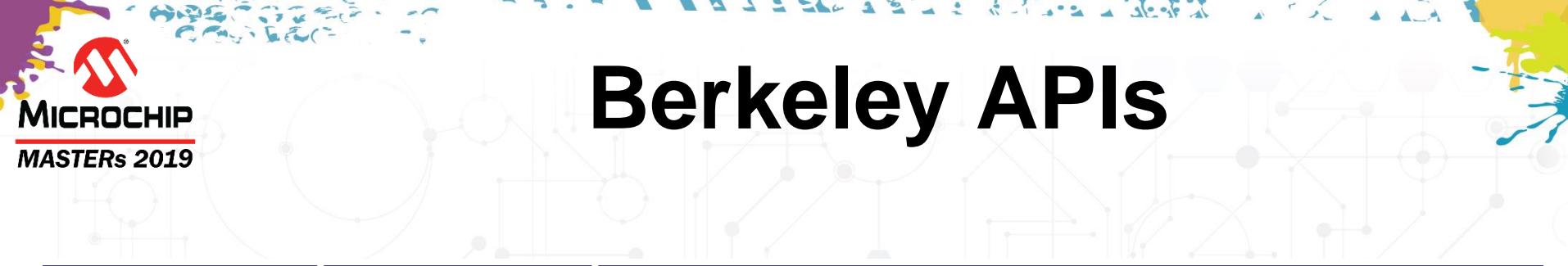


# Using the MPLAB® Harmony TCP/IP Stack **BERKELEY MODULE**



# Berkeley Socket

- Berkeley sockets is an application programming interface (API) for Internet sockets and Unix domain sockets, used for inter-process communication (IPC). It is commonly implemented as a library of linkable modules. It originated with the 4.2BSD Unix operating system, released in 1983.
- A socket is an abstract representation (handle) for the local endpoint of a network communication path. The Berkeley sockets API represents it as a file descriptor (file handle) in the Unix philosophy that provides a common interface for input and output to streams of data.



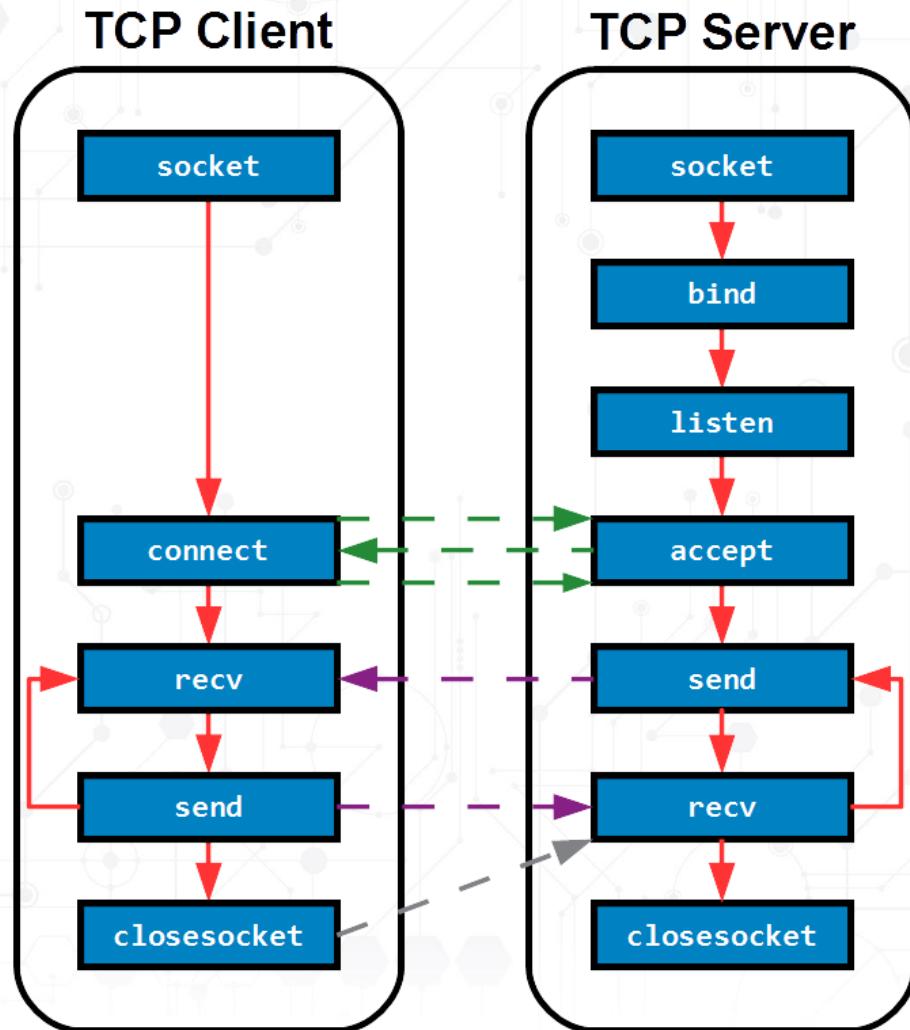
# Berkeley APIs

API Name	Host	Description
<b>socket</b>	Server/Client	Creates a new BSD socket.
<b>bind</b>	Server	Assigns the local address of the communication endpoint.
<b>connect</b>	Client	Assigns the address of the peer communications endpoint, and establishes a connection between the end points.
<b>listen</b>	Server	Sets the specified socket in a listen mode and ready to accept connection requests.
<b>accept</b>	Server	Accept connection requests queued for a listening socket.
<b>send</b>	Server/Client	Send outgoing data on an already connected socket.
<b>recv</b>	Server/Client	Receive incoming data that has been queued for a socket.
<b>closesocket</b>	Server/Client	Closes an existing socket.



**MICROCHIP**  
MASTERs 2019

# BSD Socket Application Flow



Server and Client both create a socket that uses the TCP Protocol.

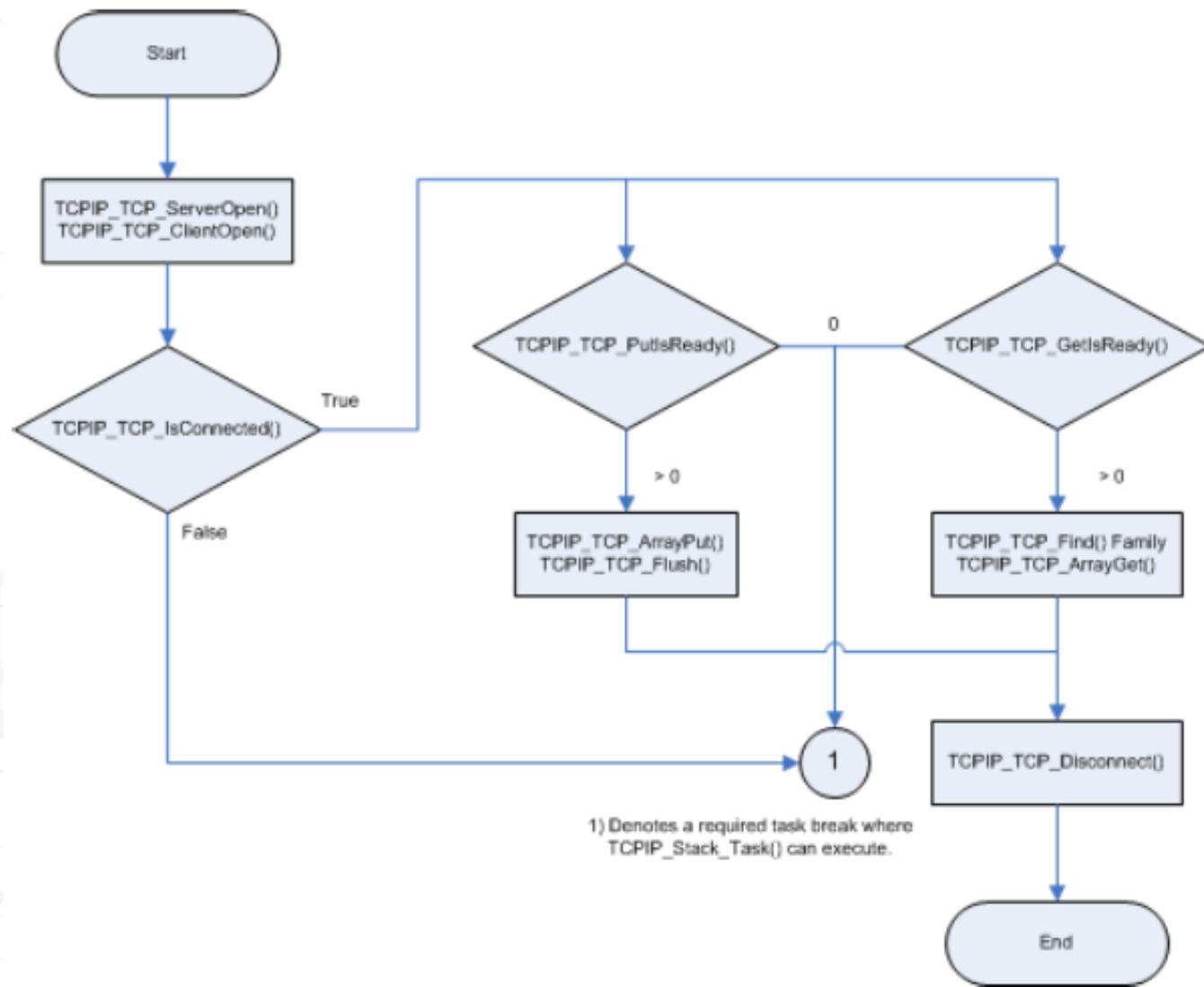
Client attempts to establish a TCP connection with the Server using a 3-Way Handshake.

Server Sends data to Client, recv returns a value > 0.

Client Sends data to Server, recv returns a value > 0.

Client Closes Socket, recv returns a value of 0. Server closes Socket.

# H3 Socket Application Flow



# Tips

- The Berkeley APIs available in the Harmony Framework can only operate in non-blocking mode.
- TCP/IP Applications using Berkeley Module APIs should be implemented using a non-blocking state machine.
- Example application source code can be found in the app.c file in the following Harmony TCP/IP Demonstration Projects:
  - *berkeley\_tcp\_client*
  - *berkeley\_tcp\_server*
  - *berkeley\_udp\_client*
  - *berkeley\_udp\_server*



# Now it is time for Lab2

## A complete Vending Machine Service Application

# LAB 2

- **Vending Machine**
- **Libraries to establish communication between a TCP Client and Server**
- **Dynamic variables and GET request from an HTTP client handled in Harmony HTTP server**

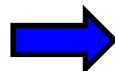
# LAB 2- TASK 1

## Hardware

- SAM E70 Xplained Ultra Evaluation Kit
- OLED1 Xplained Pro Extension Kit



A screenshot of a terminal window titled "COM14 - Tera Term VT". The window displays a command-line interface with the following text:  
>  
=====  
web\_net\_server\_nvmm\_npfs\_freertos\_labi Jun 6 2019 09:01:39  
SYS\_Initialize: The MPFS2 File System is mounted  
MAC TCPPIP\_HOSTS\_CONFIGURATION[0].macAddr: fc:c2:3d:0d:21:d7  
TCP/IP Stack: Initialization Started  
TCP/IP Stack: Initialization Ended - success  
Interface GMAC on host RAJI\_SHAN - NBNS enabled  
(null) - sends message to the server when a Bay is empty  
GMAC IP Address: 0.0.0.0  
GMAC IP Address: 10.13.33.76



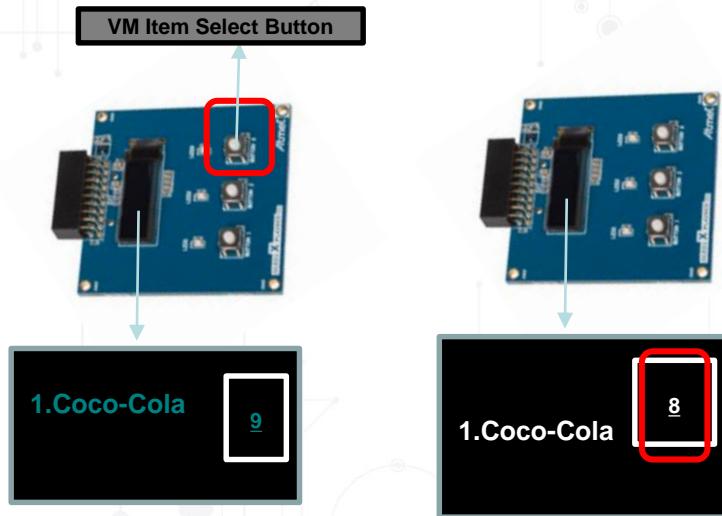
The image shows a web browser displaying the "TCP/IP Stack Demo Application". The page has a red header bar with the Microchip logo and the text "TCP/IP Stack Demo Application". Below the header is a navigation menu on the left with the following items: Overview, Dynamic Variables, SSI Processing, Processing Forms, Authentication, Cookies, Uploading Files, Sending Emails, Dynamic DNS, Network Configuration, SNMP Configuration, and Vending Machine. The "Vending Machine" item is highlighted with a green border. The main content area is titled "Vending Machine Demo". It contains a brief description of how the GET method appends data to URLs, followed by a "VM TRACKER" table. The table has columns for Item and Count, with an "UPDATE" button above it. The data in the table is:

ITEM	COUNT
1	0

Coca-Cola	Coca-Cola Diet	Pepsi	Dr Pepper	Sprite	Fanta	Dasani
9	9	9	9	9	9	9

# LAB2 – TASK1

## Server updates the VM Client



TCP/IP Stack Demo Application

### Vending Machine Demo

The GET method appends the data to the end of the URI. You'll see this data following the question mark (?) in your browser's address bar. Data sent via GET is automatically decoded, and stored in the current HTTP connection data buffer. Your application will handle the data in the TCPIP\_HTTP\_GetExecute callback. TCPIP\_HTTP\_ArgGet function provides an easy method to retrieve submitted values for processing.

As an example, this GET form gets count of the VM items as user input and updates the table

ITEM	1	COUNT	0
UPDATE			

VM TRACKER

Coca-Cola	Coca-Cola Diet	Pepsi	Dr Pepper	Sprite	Fanta	Dasani
8	9	9	9	9	9	9

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### TCP/IP Stack Demo Application

#### Vending Machine Demo

The **GET** method appends the data to the end of the URI. You'll see this data following the question mark (?) in your browser's address bar. Data sent via **GET** is automatically decoded, and stored in the current HTTP connection data buffer. Your application will handle the data in the **TCPPIP\_HTTP\_GetExecute** callback. **TCPPIP\_HTTP\_AArgGet** function provides an easy method to retrieve submitted values for processing.

As an example, this **GET** form gets count of the VM items as user input and updates the table

ITEM	COUNT					
1	0	UPDATE				
2	1					
3	2					
4	3					
TRACKER						
Coca-Cola	Coca-Cola Diet	Pepsi	Sprite	Fanta	Dasani	
8	9	9	9	9	9	9

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### TCP/IP Stack Demo Application

#### Vending Machine Demo

The **GET** method appends the data to the end of the URI. You'll see this data following the question mark (?) in your browser's address bar. Data sent via **GET** is automatically decoded, and stored in the current HTTP connection data buffer. Your application will handle the data in the **TCPPIP\_HTTP\_GetExecute** callback. **TCPPIP\_HTTP\_AArgGet** function provides an easy method to retrieve submitted values for processing.

As an example, this **GET** form gets count of the VM items as user input and updates the table

ITEM	COUNT					
0	0	UPDATE				
1	1					
2	2					
3	3					
4	4					
VM TRACKER						
Coca-Cola	Coca-Cola Diet	Pepsi	Sprite	Dr Pepper	Fanta	Dasani
8	9	9	9	4	9	9

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**4. Dr Pepper**

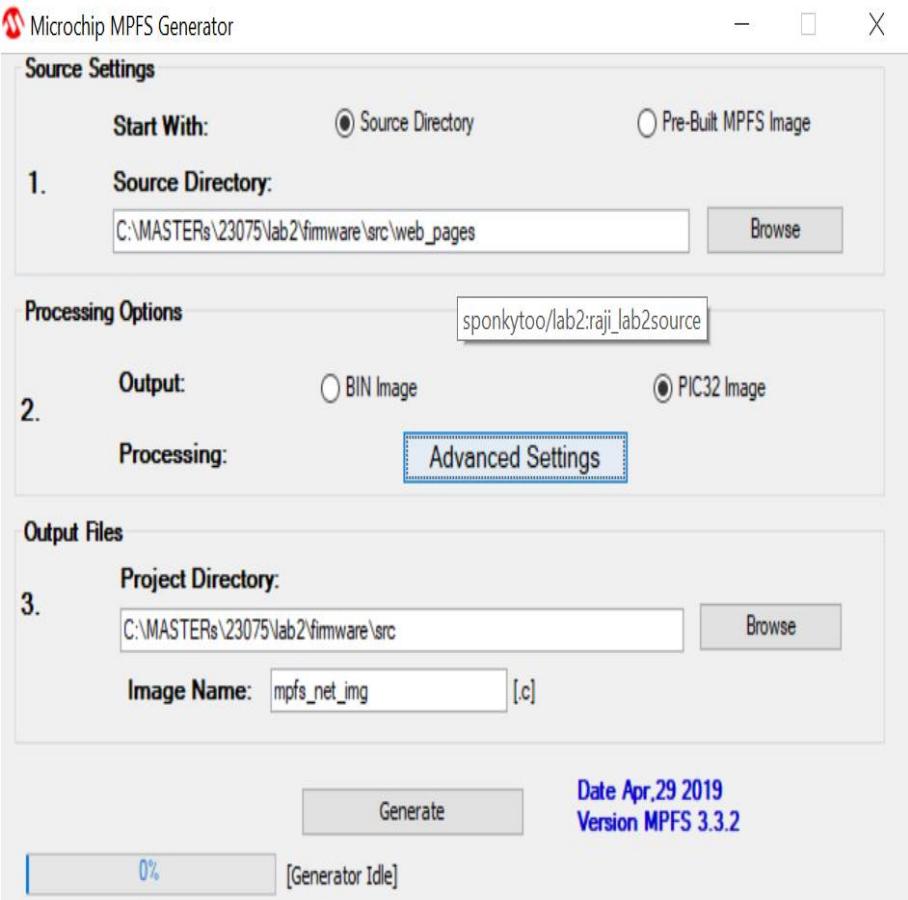
**4**



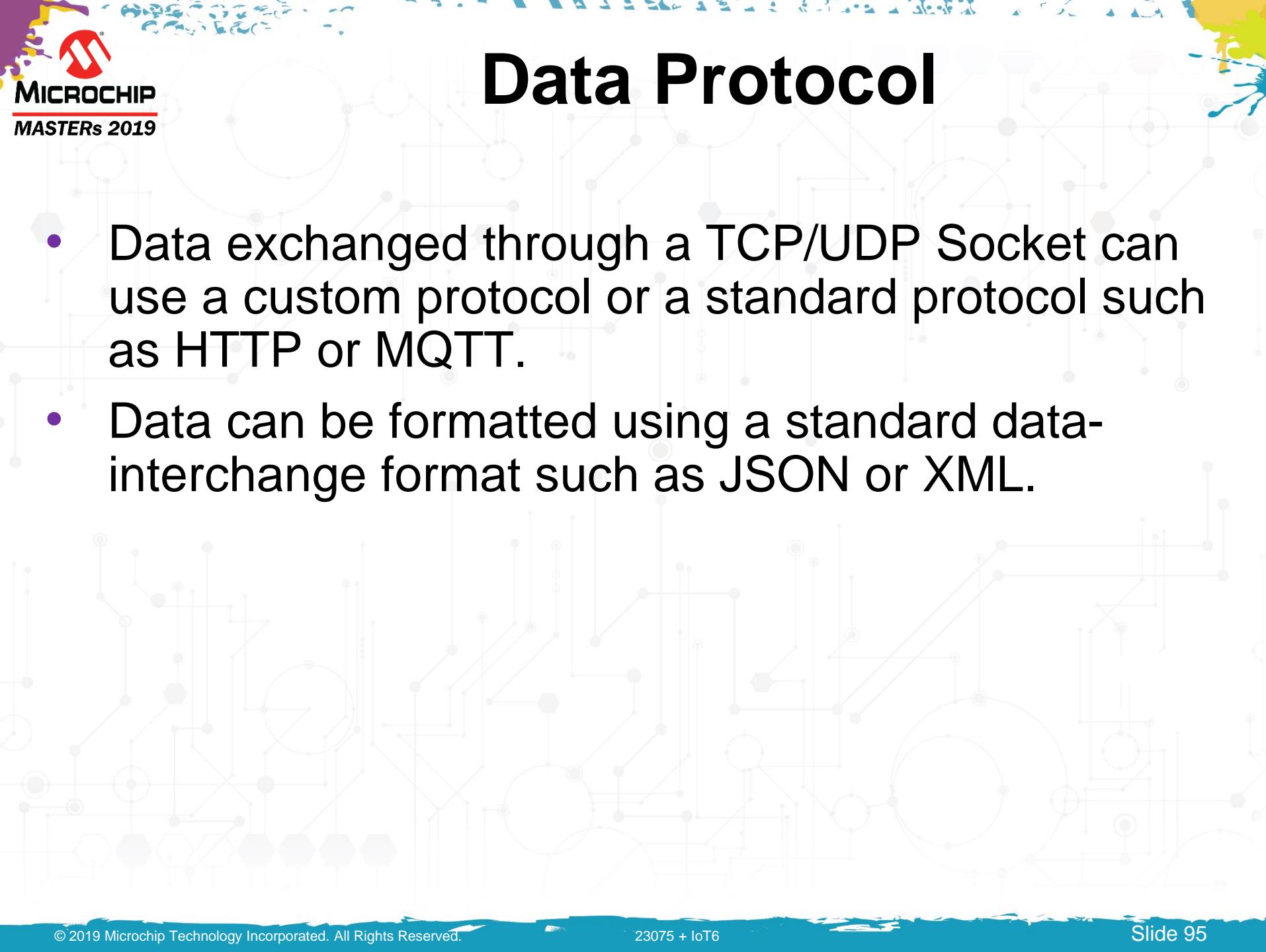
# VM Server

```
martinruppert — minicom - sudo — 80x24
MSG:2727 from fc:c2:3d:0c:20:44 : 1.Coca-Cola is empty
MSG:2728 from fc:c2:3d:0c:20:44 : 2.Diet-Coke is empty
MSG:2729 from fc:c2:3d:0c:20:44 : 3.Pepsi is empty
MSG:2730 from fc:c2:3d:0c:20:44 : 4.Dr Pepper is empty
MSG:2731 from fc:c2:3d:0c:20:44 : 5.Sprite is empty
MSG:2732 from fc:c2:3d:0c:20:44 : 6.Fanta is empty
MSG:2733 from fc:c2:3d:0c:20:44 : 7.Dasani is empty
MSG:2734 from fc:c2:3d:0c:20:44 : 1.Coca-Cola is empty
MSG:2735 from fc:c2:3d:0c:20:44 : 2.Diet-Coke is empty
MSG:2736 from fc:c2:3d:0c:20:44 : 3.Pepsi is empty
MSG:2737 from fc:c2:3d:0c:20:44 : 4.Dr Pepper is empty
MSG:2738 from fc:c2:3d:0c:20:44 : 5.Sprite is empty
MSG:2739 from fc:c2:3d:0c:20:44 : 6.Fanta is empty
MSG:2740 from fc:c2:3d:0c:20:44 : 7.Dasani is empty
MSG:2741 from fc:c2:3d:0c:20:44 : 1.Coca-Cola is empty
MSG:2742 from fc:c2:3d:0c:20:44 : 2.Diet-Coke is empty
MSG:2743 from fc:c2:3d:0c:20:44 : 3.Pepsi is empty
MSG:2744 from fc:c2:3d:0c:20:44 : 4.Dr Pepper is empty
MSG:2745 from fc:c2:3d:0c:20:44 : 5.Sprite is empty
MSG:2746 from fc:c2:3d:0c:20:44 : 6.Fanta is empty
MSG:2747 from fc:c2:3d:0c:20:44 : 7.Dasani is empty
MSG:2748 from fc:c2:3d:0c:20:44 : 1.Coca-Cola is empty
MSG:2749 from fc:c2:3d:0c:20:44 : 2.Diet-Coke is empty
```

# LAB 2 – MPFS Generator



- Packages web pages into efficient storage format
- **Microchip MPFS Utility**
- Can include the utility on the build process



- Data exchanged through a TCP/UDP Socket can use a custom protocol or a standard protocol such as HTTP or MQTT.
- Data can be formatted using a standard data-interchange format such as JSON or XML.

# Data Protocol Examples

Example Sensor Data: "ID: AZ2355, Temperature: 25C, Time: 08:56, Type: K Thermocouple"

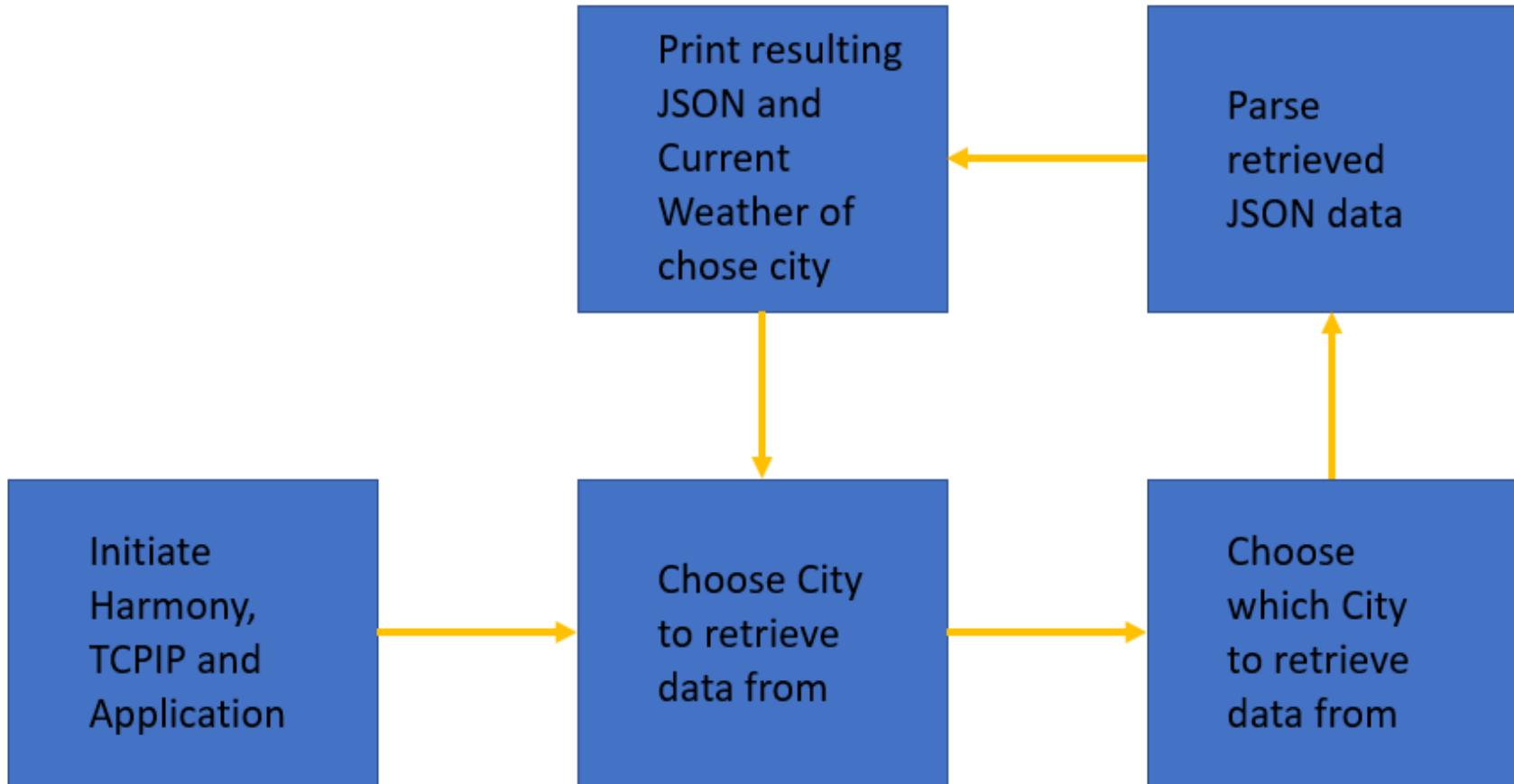
Custom Protocol	Custom over HTTP	JSON	XML
<AZ2355 25C 08:56 KTC>	<pre>POST/sensorData/temperature.html HTTP/1.0 User-Agent: HTTPTool/1.0 Content-Type: application/x-www-form-urlencoded Content-Length: 23</pre> <AZ2355 25C 08:56 KTC>	<pre>{   "sensor": {     "id": "AZ2355",     "type": "kthermocouple"   },   "readings": [     {       "time": "08:56",       "temperature": 25,       "unit": "C"     }   ] }</pre>	<pre>&lt;?xml version="1.0" encoding="UTF-8"?&gt; &lt;root&gt;   &lt;readings&gt;     &lt;element&gt;        &lt;temperature&gt;25&lt;/temperature&gt;        &lt;time&gt;08:56&lt;/time&gt;         &lt;unit&gt;C&lt;/unit&gt;       &lt;/element&gt;     &lt;/readings&gt;     &lt;sensor&gt;       &lt;id&gt;az2355&lt;/id&gt;       &lt;type&gt;kthermocouple&lt;/type&gt;     &lt;/sensor&gt;   &lt;/root&gt;</pre>



# Now it is time for Lab3

## Getting the Weather Report

# Pulling the Weather Data



# Pulling the Weather Data

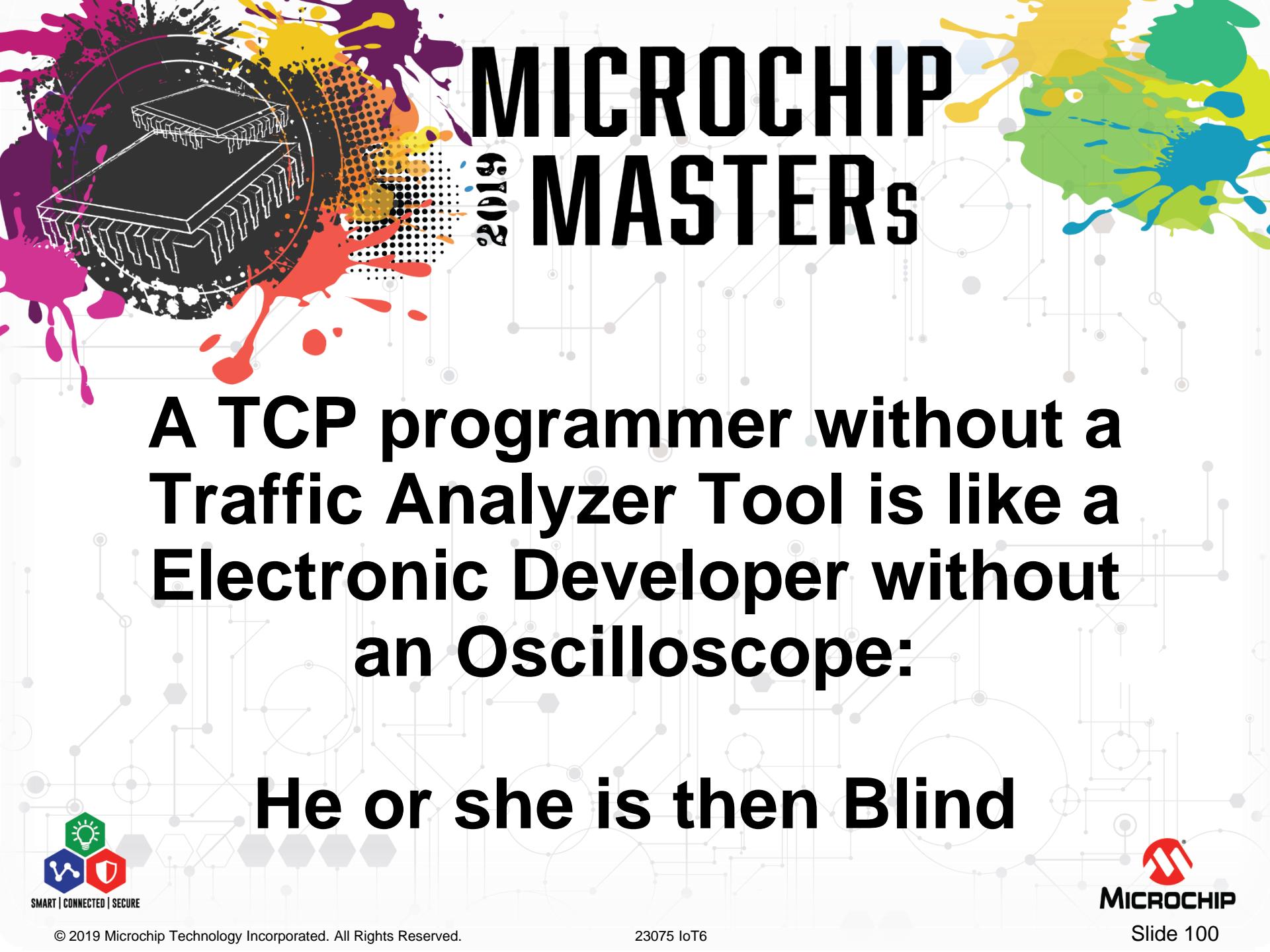
```
martinruppert — minicom - sudo — 80x26
=====
request weather lab3 Jun 10 2019 12:27:31
MAC TCPIP_HOSTS_CONFIGURATION[0].macAddr: fc:c2:3d:0c:20:44
TCP/IP Stack: Initialization Started
TCP/IP Stack: Initialization Ended - success
    Interface GMAC on host MCHPBOARD_C      - NBNS disabled
GMAC IP Address: 192.168.0.19
Waiting for command type: requestWeather <city>

[>rw Phoenix

>cityBuffer: Phoenix
Starting connection

Connection Closed
resultingJson:
  {"coord": {"lon": -112.08, "lat": 33.45}, "weather": [{"id": 801, "main": "Clouds", "des

Current Weather in Phoenix
Humidity: 13
Pressure: 1016
Temperature: 34.22
Main Weather: Clouds
```



# MICROCHIP MASTERS

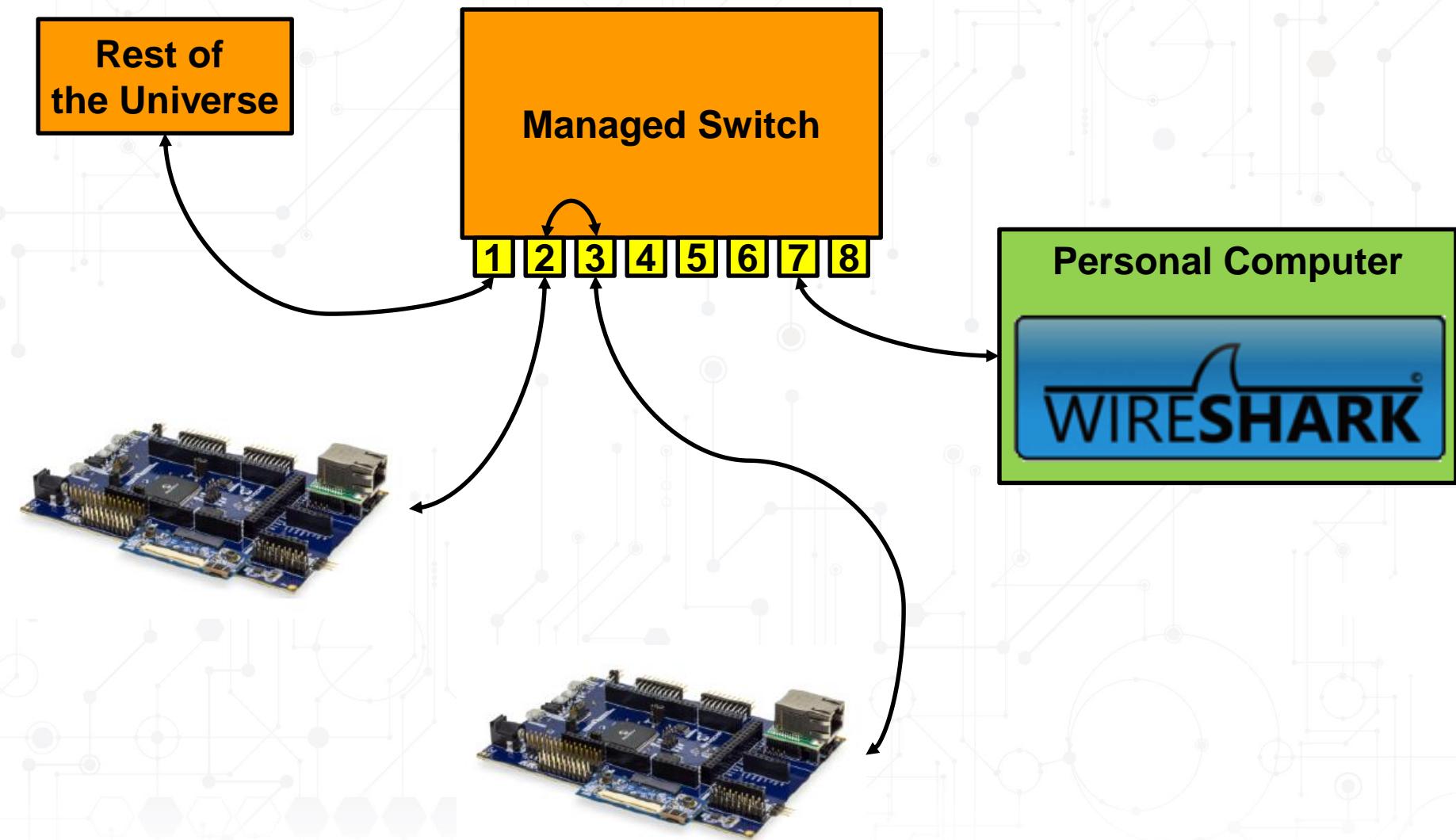
2019

A TCP programmer without a Traffic Analyzer Tool is like a Electronic Developer without an Oscilloscope:

He or she is then Blind



# How to Analyze the Traffic





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# Configuration Software for Managed Switch

ProSAFE Plus Configuration Utility

**NETGEAR®**  
Connected with Innovation™

Network System VLAN QoS Help

Switch Selection

Please select a switch to configure

Discovered Switches

Product	Switch Name	MAC Address	IP Address	Located on IP Network
GS108Ev2	MySwitch	10:0d:7f:bb:ae:91	192.168.0.101	192.168.0.192

Copyright © NETGEAR, Inc.

ProSAFE Plus Configuration Utility-GS108Ev2-MySwitch

**NETGEAR®**  
Connected with Innovation™

Network System VLAN QoS Help

Status | Maintenance | Monitor

Port Statistics Mirroring Cable Tester

**Port Mirroring**

Port Mirroring Configuration

Mirroring **Enable**

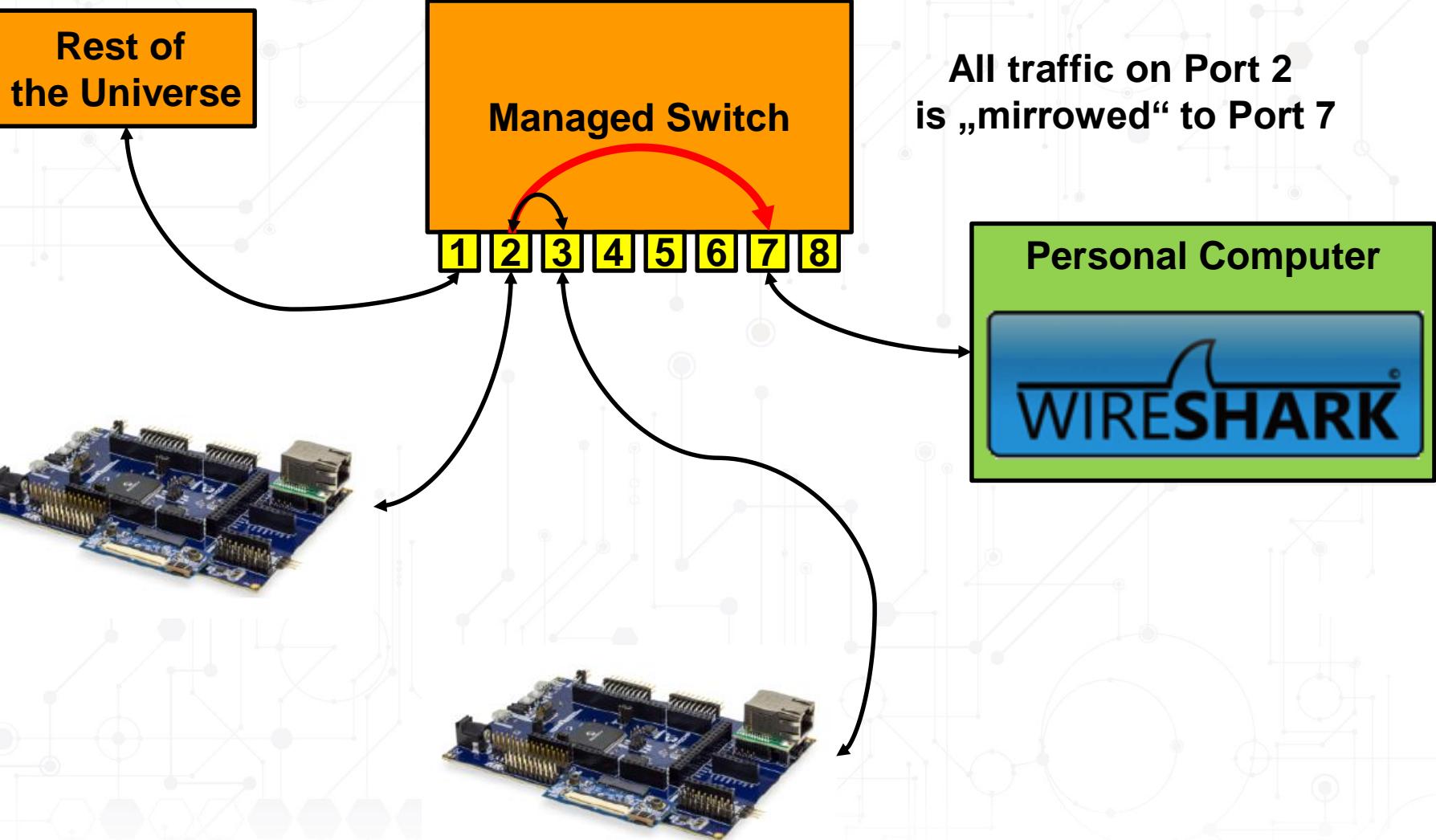
Source Port

Port	01	02	03	04	05	06	07	08
	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>					

Destination Port **07**

The image shows two windows of the ProSAFE Plus Configuration Utility. The main window displays a list of discovered switches, with 'MySwitch' selected. A secondary window provides a detailed view of the 'Port Mirroring' configuration for this specific switch. The 'Mirroring' field is set to 'Enable', and port 02 is designated as the source port, which is currently active. Port 07 is assigned as the destination port. The background features a network diagram with various nodes and connections.

# How to Analyze the Traffic



# Wireshark Filter

Ethernet: en0

eth.addr == fc:c2:3d:0c:20:44

No.	Time	Source	Destination	Protocol	Leng:	Info
11	1.303395	192.168.0.19	192.168.0.108	TCP	60	51094 → 80 [SYN] Seq=0 Win=512 Len=0 MSS=1460
12	1.304437	192.168.0.108	192.168.0.19	TCP	60	80 → 51094 [SYN, ACK] Seq=0 Ack=1 Win=512 Len=0 MSS=1460
13	1.305409	192.168.0.19	192.168.0.108	TCP	60	51094 → 80 [ACK] Seq=1 Ack=1 Win=512 Len=0
14	1.307340	192.168.0.19	192.168.0.108	TCP	107	[TCP segment of a reassembled PDU]
15	1.308279	192.168.0.19	192.168.0.108	TCP	60	51094 → 80 [FIN, ACK] Seq=54 Ack=1 Win=512 Len=0
16	1.308400					en=0
17	1.309324					en=0
18	1.311302					512 Len=0
19	1.312324					en=0
20	3.286390					S=1460

Frame 14: 107 bytes on wire (856 bits), 107 bytes captured (856 bits) on interface en0  
**eth.addr == fc:c2:3d:0c:20:44**

- ▶ Frame 14: 107 bytes on wire (856 bits), 107 bytes captured (856 bits) on interface en0
- ▶ Ethernet II, Src: (00:0c:29:4f:00:00) [00:0c:29:4f:00:00], Dst: (00:00:00:00:00:00) [00:00:00:00:00:00]
- ▶ Internet Protocol Version 4, Src: 192.168.0.19 (192.168.0.19), Dst: 192.168.0.108 (192.168.0.108)
- ▶ Transmission Control Protocol

```

Source Port: 51094
Destination Port: 80
[Stream index: 2]
[TCP Segment Len: 53]
Sequence number: 1      (relative sequence number)
[Next sequence number: 54      (relative sequence number)]
Acknowledgment number: 1      (relative ack number)
Header Length: 20 bytes
▶ Flags: 0x018 (PSH, ACK)
Window size value: 512
[Calculated window size: 512]
[Window size scaling factor: -2 (no window scaling used)]
▶ Checksum: 0x1662 [validation disabled]
Urgent pointer: 0
▶ [SEQ/ACK analysis]
TCP segment data (53 bytes)
0000  00 04 25 1c a0 02 fc c2  3d 0c 20 44 08 00 45 00  ..%..... =. D..E.
0010  00 5d 10 41 00 00 64 06  c4 8a c0 a8 00 13 c0 a8  .].A..d. .......
0020  00 6c c7 96 00 50 bb b3  d3 f3 e0 b0 e1 a6 50 18  .l...P.. ....P.
0030  02 00 16 62 00 00 4d 53  47 3a 38 32 33 20 66 72  ...b..MS G:823 fr
0040  6f 6d 20 66 63 3a 63 32  3a 33 64 3a 30 63 3a 32  om fc:c2 :3d:0c:2
0050  30 3a 34 34 20 3a 20 31  2e 43 6f 63 61 2d 43 6f  0:44 : 1 .Coca-Co
0060  6c 61 20 69 73 20 65 6d  70 74 79  la is em pty

```

Packets: 69 · Displayed: 27 (39.1%) · Dropped: 0 (0.0%) · Profile: Default



# Payload Data



Wireshark · Follow TCP Stream (tcp.stream eq 2) · wireshark\_pcappng\_en0\_201906101710...

MSG:823 from fc:c2:3d:0c:20:44 : 1.Coca-Cola is empty

1 client pkt(s), 0 server pkt(s), 0 turn(s).

Entire conversation (53 bytes) Show data as ASCII Stream 2

Find: Find Next

Help Hide this stream Print Save as... Close

0000	00 04 25 1c a0 02 fc c2 3d 0c 20 44 08 00 45 00	..%..... =. D..E.
0010	00 5d 10 41 00 00 64 06 c4 8a c0 a8 00 13 c0 a8	.].A..d. .......
0020	00 6c c7 96 00 50 bb b3 d3 f3 e0 b0 e1 a6 50 18	.l...P. .....P.
0030	02 00 16 62 00 00 4d 53 47 3a 38 32 33 20 66 72	...b..MS G:823 fr
0040	6f 6d 20 66 63 3a 63 32 3a 33 64 3a 30 63 3a 32	om fc:c2 :3d:0c:2
0050	30 3a 34 34 20 3a 20 31 2e 43 6f 63 61 2d 43 6f	0:44 : 1 .Coca-Co
0060	6c 61 20 69 73 20 65 6d 70 74 79	la is em pty

A data segment used in reassembly of a lower-level protocol (tcp.segment\_data), 53 bytes | Packets: 69 · Displayed: 9 (13.0%) · Dropped: 0 (0.0%) | Profile: Default

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# Class Summary

- Today we covered
  - Basic Knowledge about Ethernet
  - TCP/IP Fundamentals
  - What Socket Programming is
  - Principle Architecture of Harmony
  - Usage of the Harmony Configurator for Software design
  - Why using a Task Scheduler for TCP Apps is a Great Idea
  - Using Wireshark for Traffic Analysis

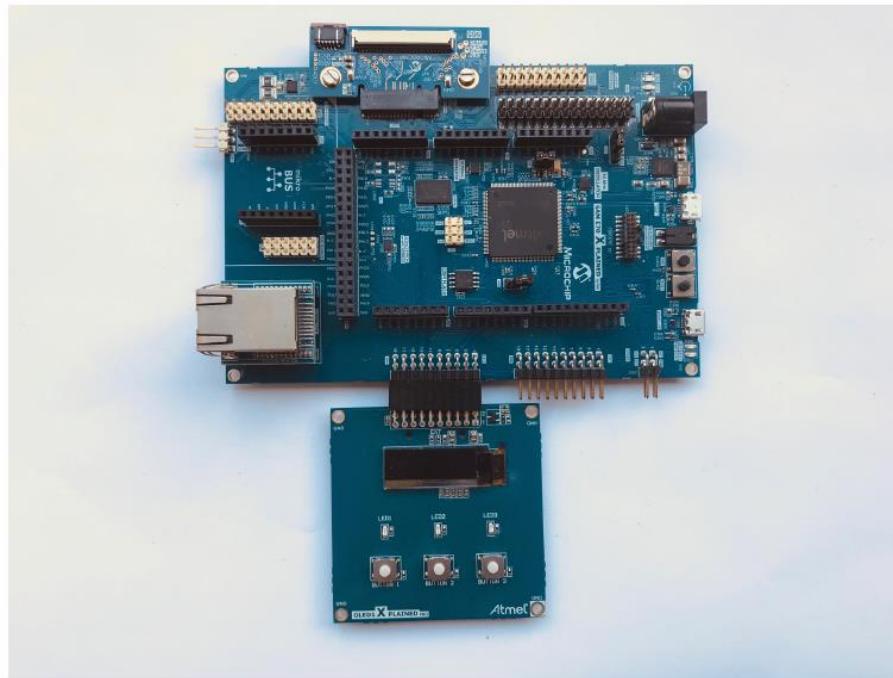
# Additional Resources

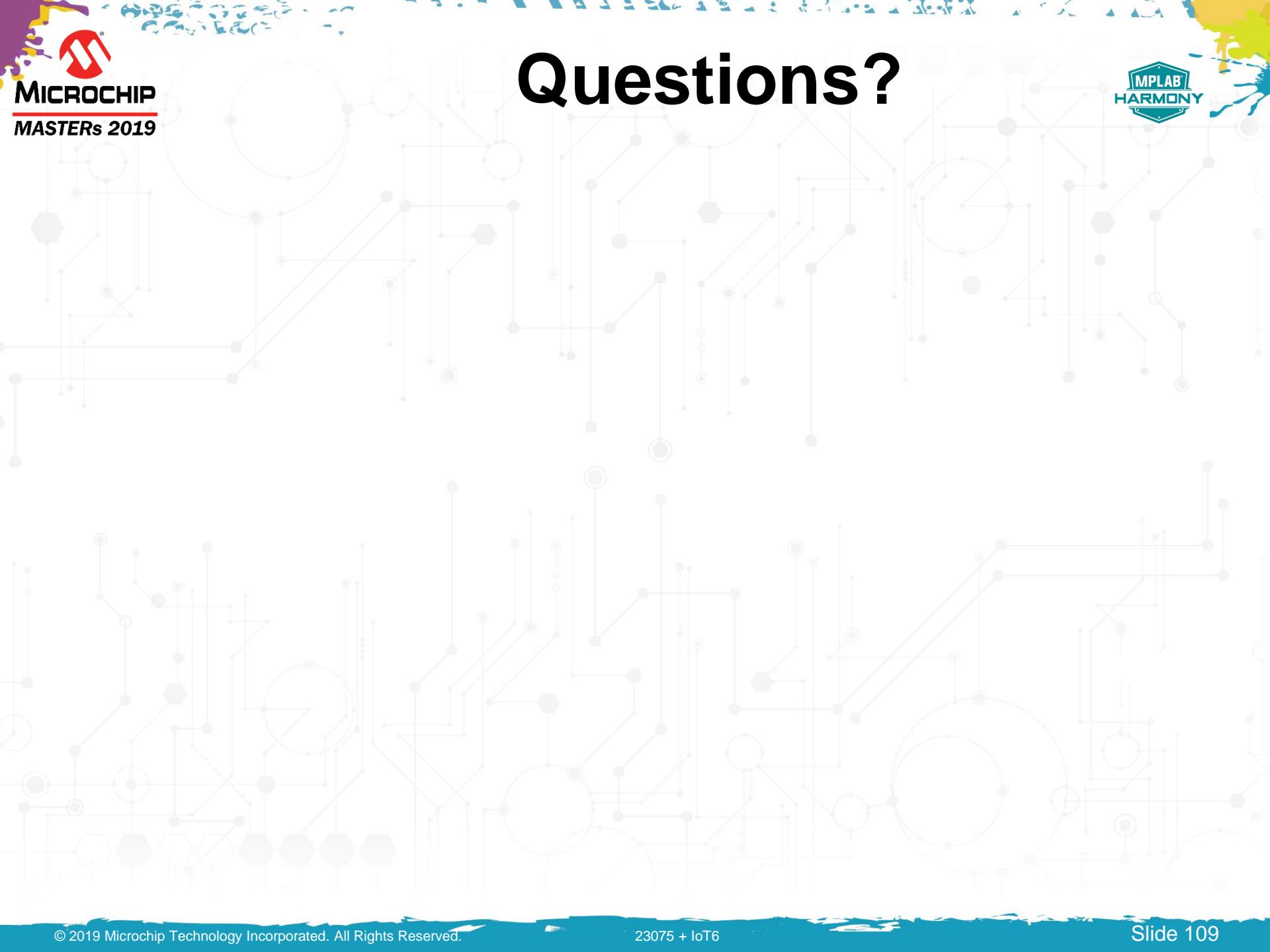


- **Harmony 3 Landing Page**  
<https://www.microchip.com/mplab/mplab-harmony/mplab-harmony-v3>
- **Microchip Harmony 3 on Github**  
<https://github.com/Microchip-MPLAB-Harmony>
- **Wireshark**  
<https://www.wireshark.org/>
- „**The C Programming Language**“  
**Kernighan and Richie**  
<http://alvand.basu.ac.ir/~dezfoulian/files/Programming/Prentice%20Hall%20-%20The%20C%20Programming%20Language-%20Brian%20W.%20Kernighan,%20Dennis%20M.%20Ritchie,%202nd%20ed.,%20ISBN%20.pdf>

# Dev Tools for this Class

- **SAM E70 Xplained Ultra Evaluation Kit for ATSAME70 and ATSAMS70**
  - Part Number: DM320113
  - <https://www.microchip.com/developmenttools/ProductDetails/DM320113>
- **OLED1 Xplained Pro Extension Kit**
  - Part Number: ATOLED1-XPRO
  - <https://www.microchip.com/developmenttools/ProductDetails/ATOLED1-XPRO>





# Questions?



**Many thanks for attending this class**

**And...**

**...let us make this world a better place with  
TCPIP**



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