Linux Networking for Gateways

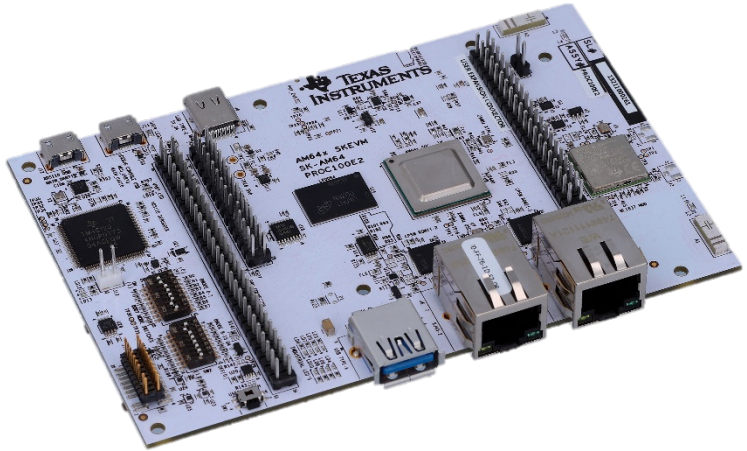
May 2021

Ron Birkett

Welcome and Introductions

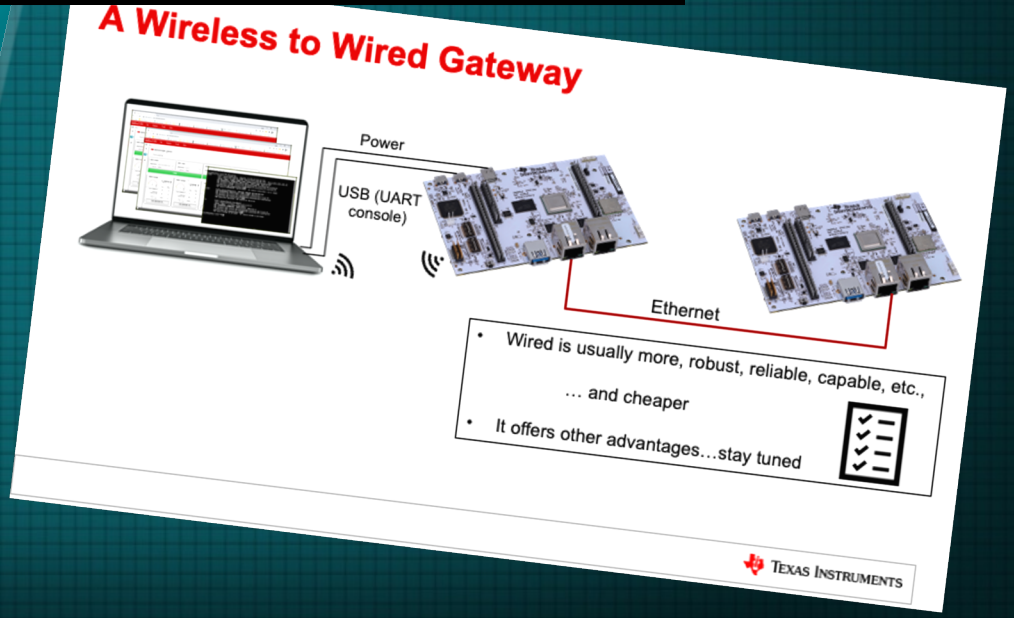
- Presenter – Ron Birkett, Applications for Sitara, 25 years at TI
- Moderators – Schuyler Patton and Pekka Varis
- AM64x Starter Kit Giveaway
  - One name from the list of attendees will be randomly selected after the event
  - We will contact you via registration email to work out details
- Please ask questions via Q&A
- We will be recording and sharing the video…

and start recording…



LINUX WIRED AND WIRELESS NETWORKING

ENABLES A VARIETY OF POWERFUL AND FLEXIBLE TOPOLOGIES



Agenda

- Sitara Overview
- Wireless out of the box on the new AM64x Starter Kit
- Build a Bridge to add Nodes
- Utilize TI CPSW Ethernet for Powerful Wired Networking
- Summary

Sitara overview

Scalable, cost-optimized portfolio with accelerators, analog integration, robust connectivity, security and functional safety designed for industrial markets

Sitara™ Arm® Processors
Texas Instruments

SoCs

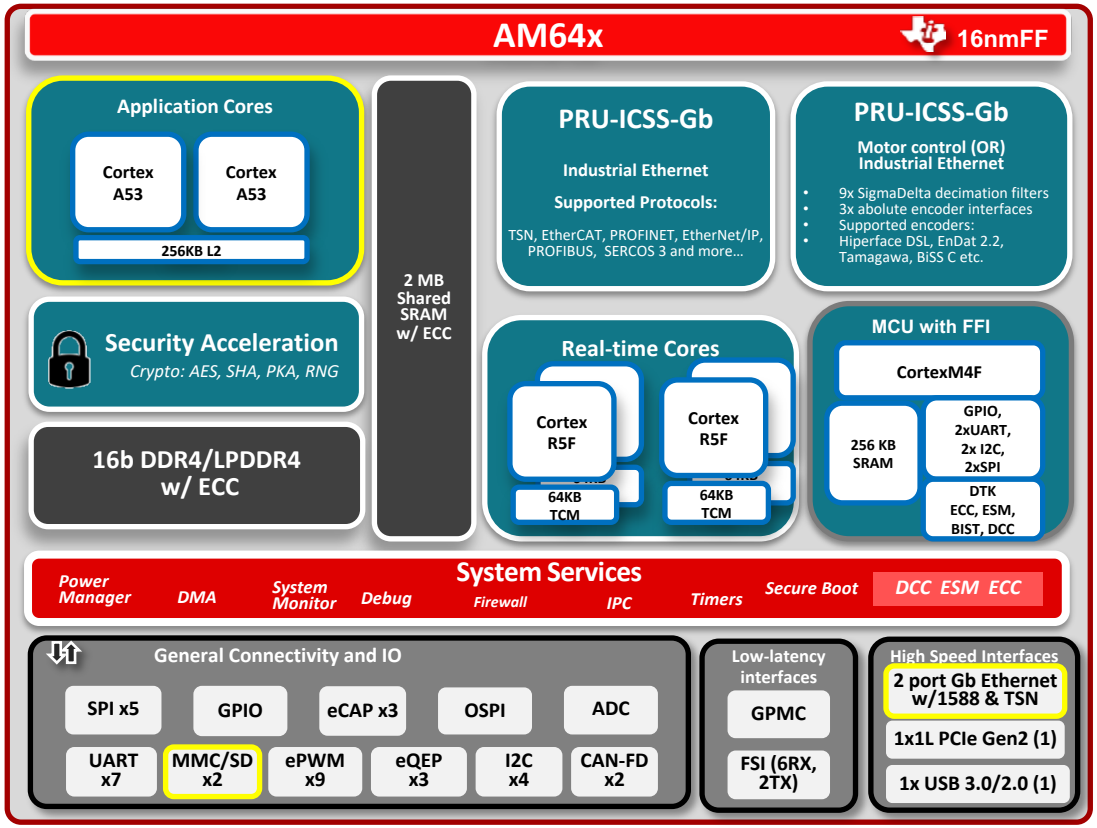
Single-core to quad-core **Arm Cortex-A53, A9 and A8**	**Compute**	**Control**	Single-core to quad-core **Arm Cortex-R5F** with optional Lock-Step support
Secure-boot, run-time security, tamper protection and **high-security modules**	**Functional Safety & Security**	**Analog**	High-level integration of high-performance **ADC, DAC, comparators** and **PWM**
Power-optimized **neural network accelerators, audio DSP,** and **GPU**	**Deep Learning & Accelerators**	**Connect**	**USB, PCIe, Ethernet Switch, Industrial Protocols, CAN-FD,** and more
Open source device enablement for **Mainline Linux, RTOS** and **Bare Metal** 3P software support …	**Unified Software Platform**		Simplified tools (**SysConfig**) and libraries (**DSPLIB**, **TIDL, ...**) to accelerate development and performance entitlement

Power-optimized design | SIL2 functional safety | -40 to 125C temperature range | HiRel DSP

Scalable platform with common software development kit and pin-to-pin compatibility in common packages

AM64x (17mm x 17mm) Cortex®-A53 based processors

- **Cores & Memory**
  - Dual Cortex-A53 up to 1GHz
  - Dual or Quad Cortex-R5F up to 800MHz
  - >2MB on-chip SRAM
  - ECC on all critical memories
  - 16b LPDDR4/DDR4 controller with **inline** ECC
- **Functional safety features**
  - 400MHz Cortex-M4F subsystem has **freedom from interference** to enable usage as a safety monitor
    - Dedicated Peripherals I2C, SPI, UART & GPIO
    - Tightly coupled memory of 256KB
  - Diagnostic tool kit for entire SoC voltage, temp, clock, ECC monitors and Error signaling
- **2xPRU-ICSS-Gb**
  - Enables up to 2x Gb industrial Ethernet protocols
  - 1x industrial Ethernet protocol + motor control current and position feedback
- **Peripheral / IO Highlight**
  - GPMC (32b parallel bus) and FSI (serial connection for use with TI's C2000 MCUs) offer low-latency interfaces to motor control front-end
  - PCIe Gen2, USB3.0/2.0, and 2-port Gb Ethernet Switch CPSW provide high-speed (Gbps) connectivity options
  - RS485 support on UART
  - Octal/Quad-SPI with execution-in-place support
- **Integrated analog**
  - 8-channel, 12-bit ADC with 4 Msps
  - Simplified power solution, Integrated Voltage Monitors
- **Package**
  - 17.2 x 17.2mm, 0.8mm ball pitch



(1) PCIe and USB 3.0 share the same SERDES

Available Now!

AM64x Starter Kit for the Sitara™ AM64x processor

SK-AM64

Features

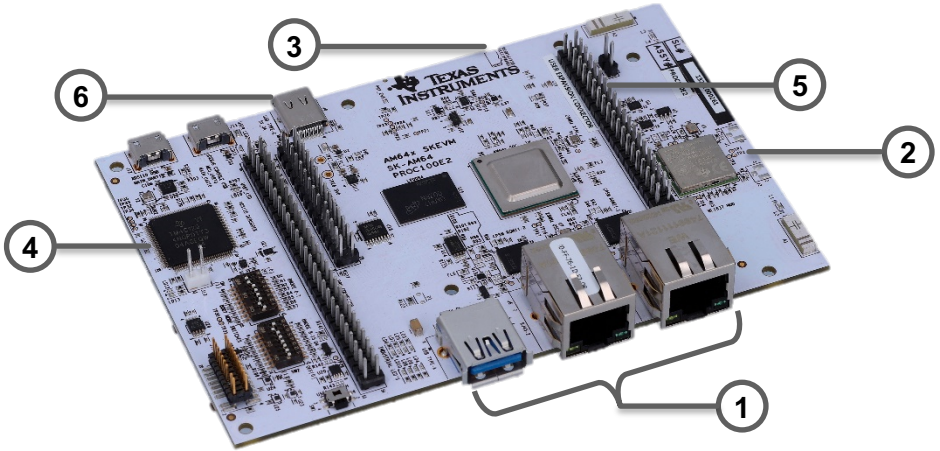
1. 2x Ethernet ports, 1x USB 3.0 Type A device port
2. On-board Wi-Fi + BT (WL1837MOD)
3. Multiple boot options including SD Card
4. On-board emulation with XDS110
5. Expansion headers for PRU, MCU, RPi HATs
6. Powered by USB-C cable (5V, 3A)

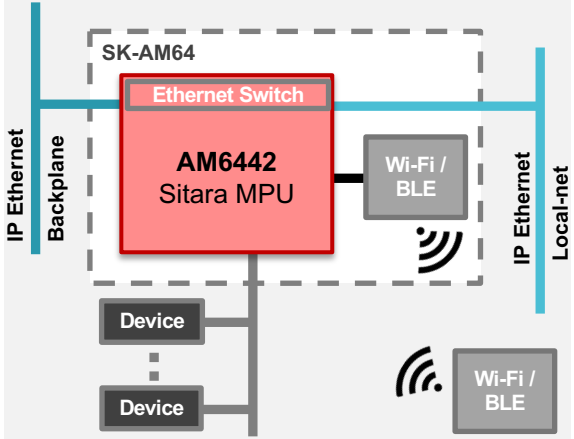
Resources

- SK-AM64 from TI Store **($99 USD)**
- User's Guide
- Quick Start Guide
- Processor SDK

Out-of-Box: Gateway

The AM64x Starter Kit includes on-board Wi-Fi with an SDK created to get Linux and Wi-Fi running as soon as USB-C power is applied

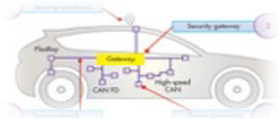




Sitara built around a unified software platform

100% code compatibility

Industrial HMI / Auto Cluster



Telematics and Gateway

FAC / Motor Drives

Network & Control

System Performance

Connections from sensor to cloud

Integration and System Cost

Safety

&

Security

TI supported tools and partner ecosystem

Processor SDK common development experience

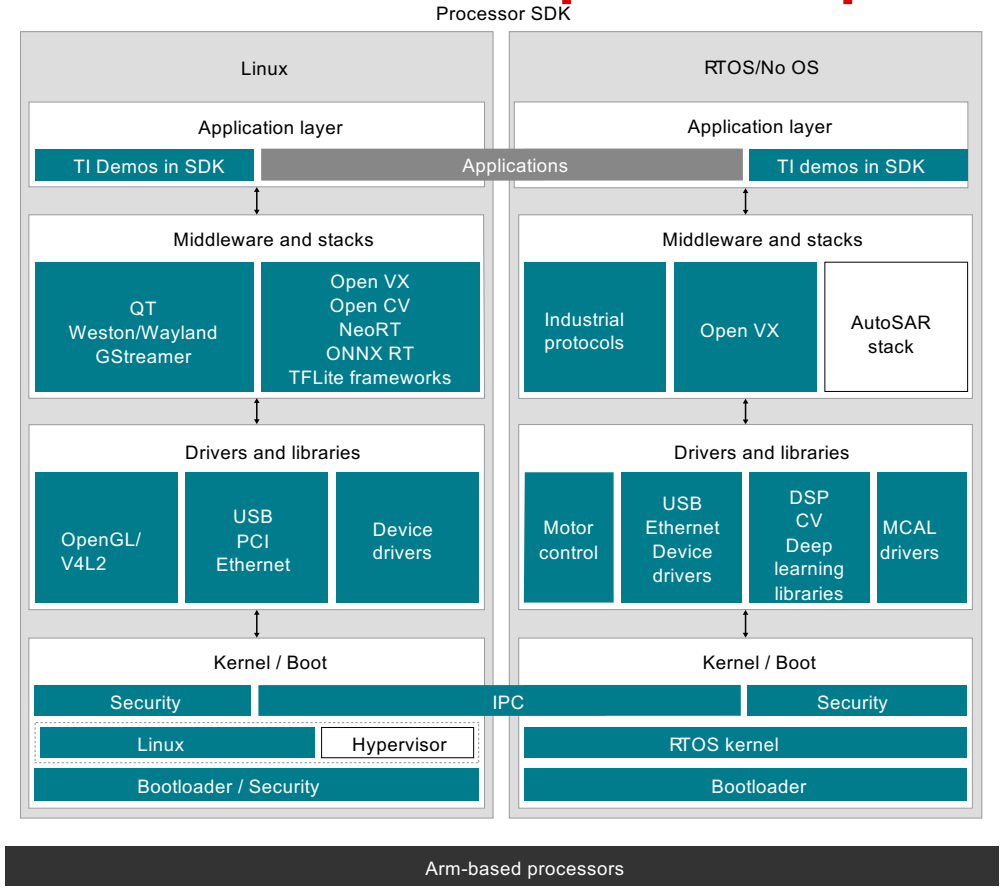
Linux features:

•Updated to the latest Long Term support (LTS) Linux kernel, boot loader and Yocto file system on an annual basis

•Robust, commercial-grade Linaro® GNU compiler collection (GCC) toolchain

•Yocto Project™ OE Core compatible file systems support enables tailored Linux application support

•RT-Linux releases include a fully pre-emptible kernel for real-time applications



RTOS/No OS features:

•Robust real-time RTOS kernel (Free RTOS)

•Includes network communications support, examples, and drivers

•Driver libraries can be used with or without an RTOS kernel

•Free and available as open source

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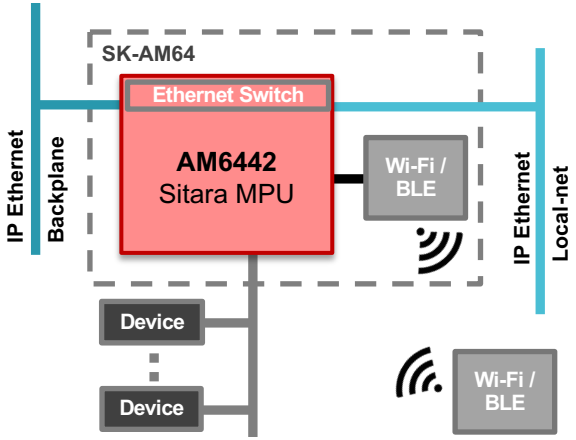
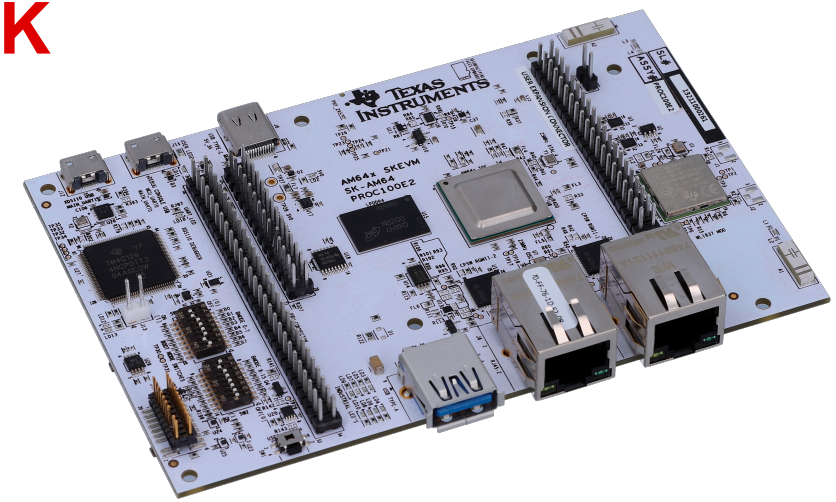
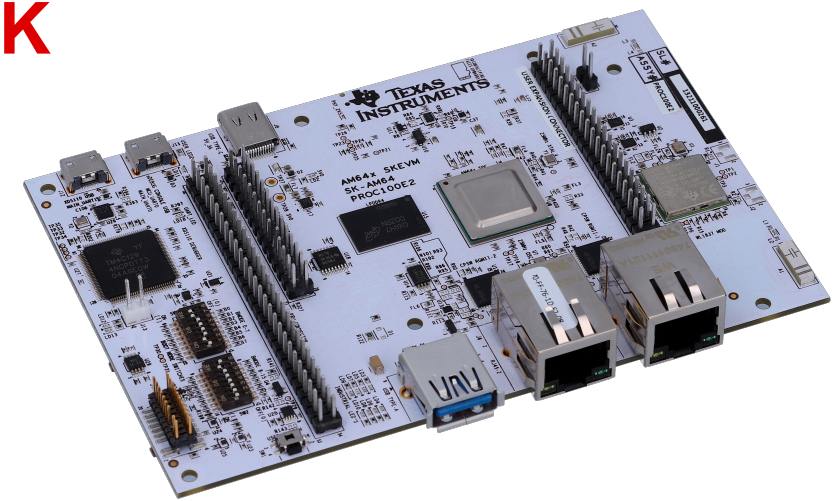


Getting Started with the SDK



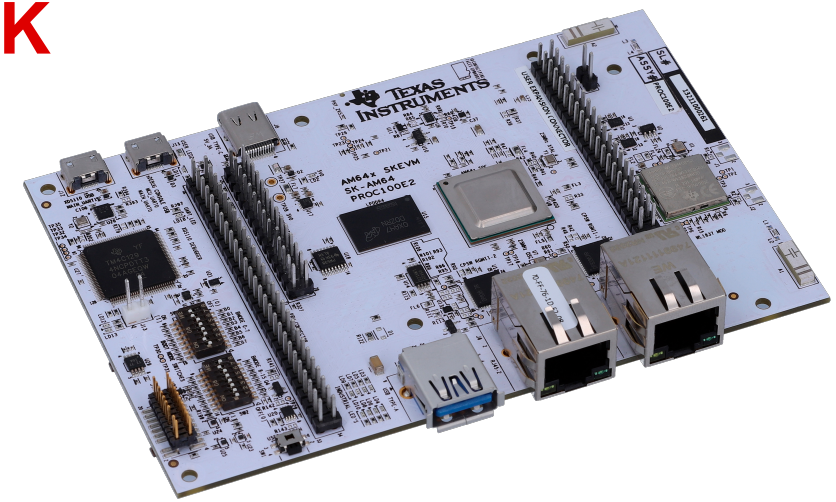
1 Buy AM64x Starter Kit

Getting Started with the SDK



1. Buy AM64x Starter Kit
2. Download the SDK or Linux image

Getting Started with the SDK



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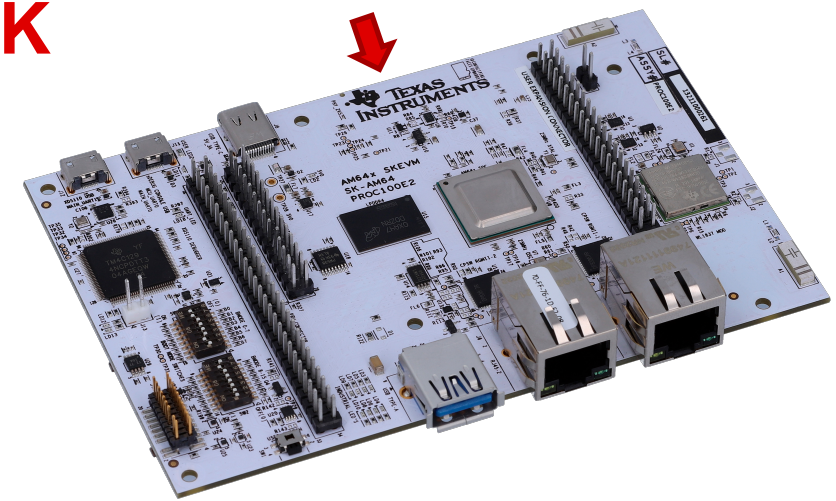
3. Put Linux Image on a SD Card

Getting Started with the SDK

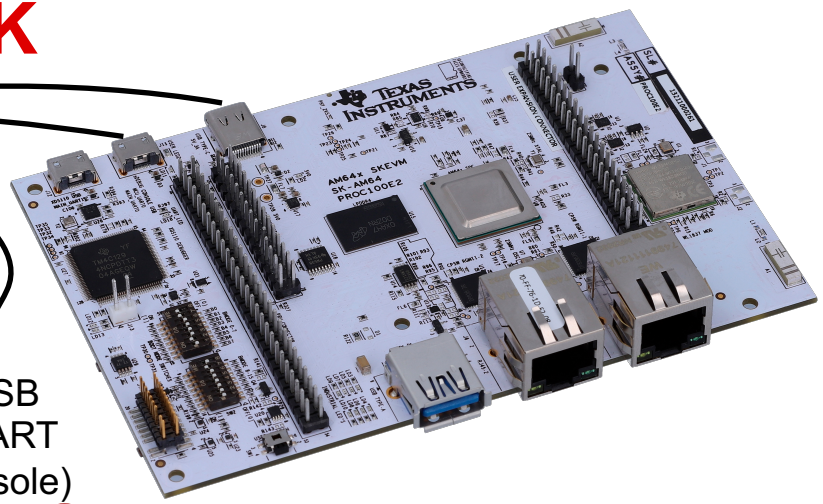


1. Buy AM64x Starter Kit
2. Download the SDK or Linux image
3. Put Linux Image on a SD Card
4. Insert SD Card into SK

Getting Started with the SDK

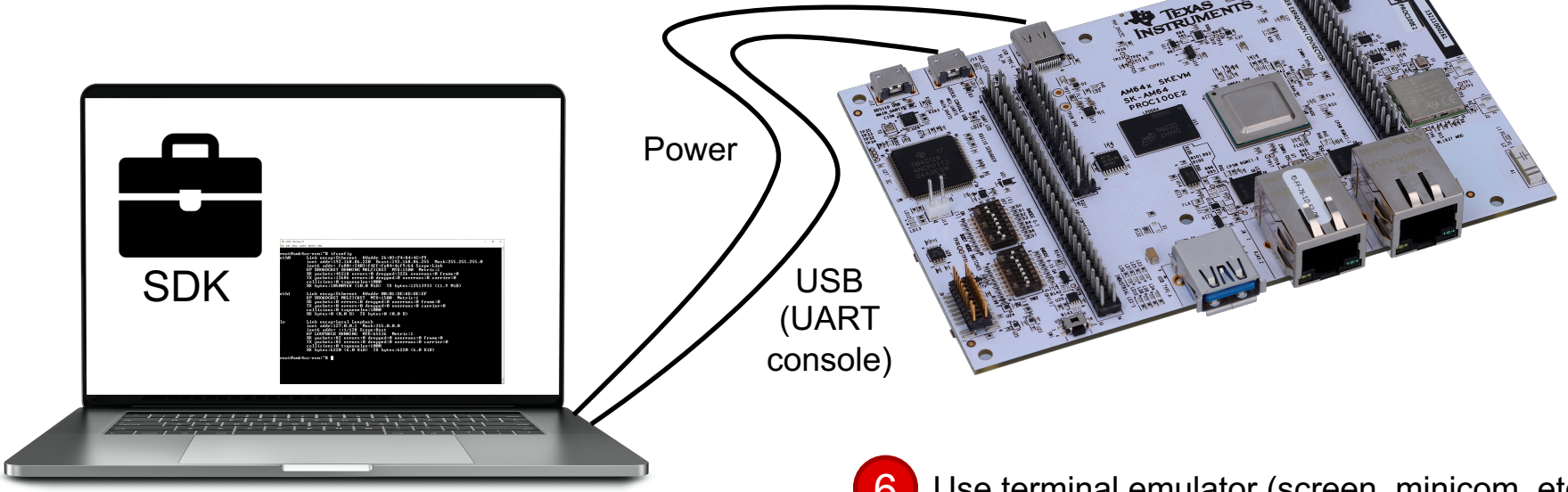
Power

USB
(UART
console)



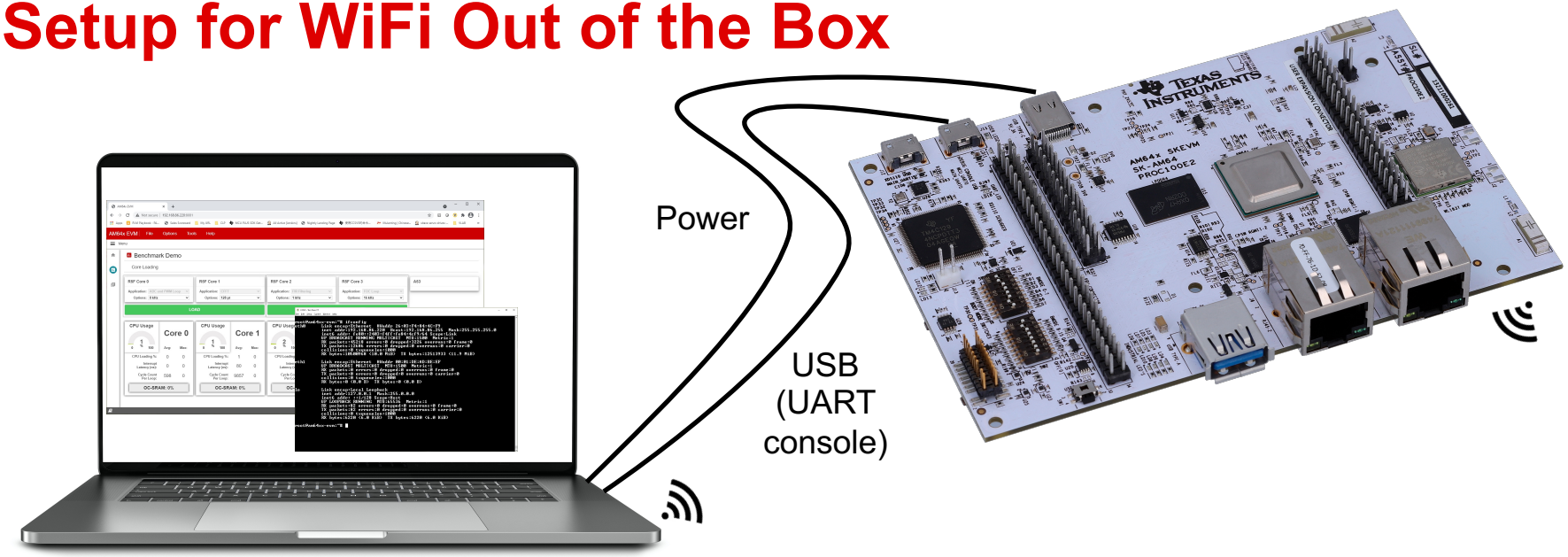
1. Buy AM64x Starter Kit
2. Download the SDK or Linux image
3. Put Linux Image on a SD Card
4. Insert SD Card into SK
5. Connect Micro USB for Linux Console and USB-C power

Getting Started with the SDK



6 Use terminal emulator (screen, minicom, etc.) to connect to console output

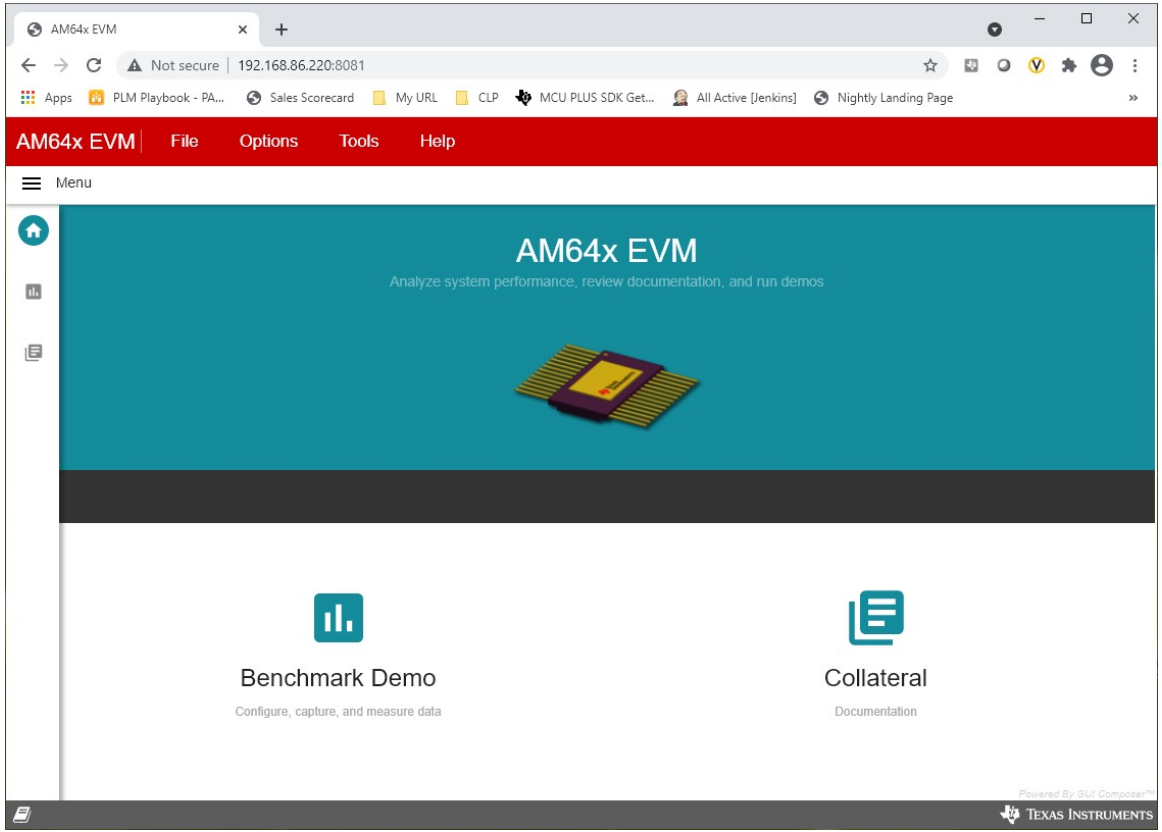
Setup for WiFi Out of the Box



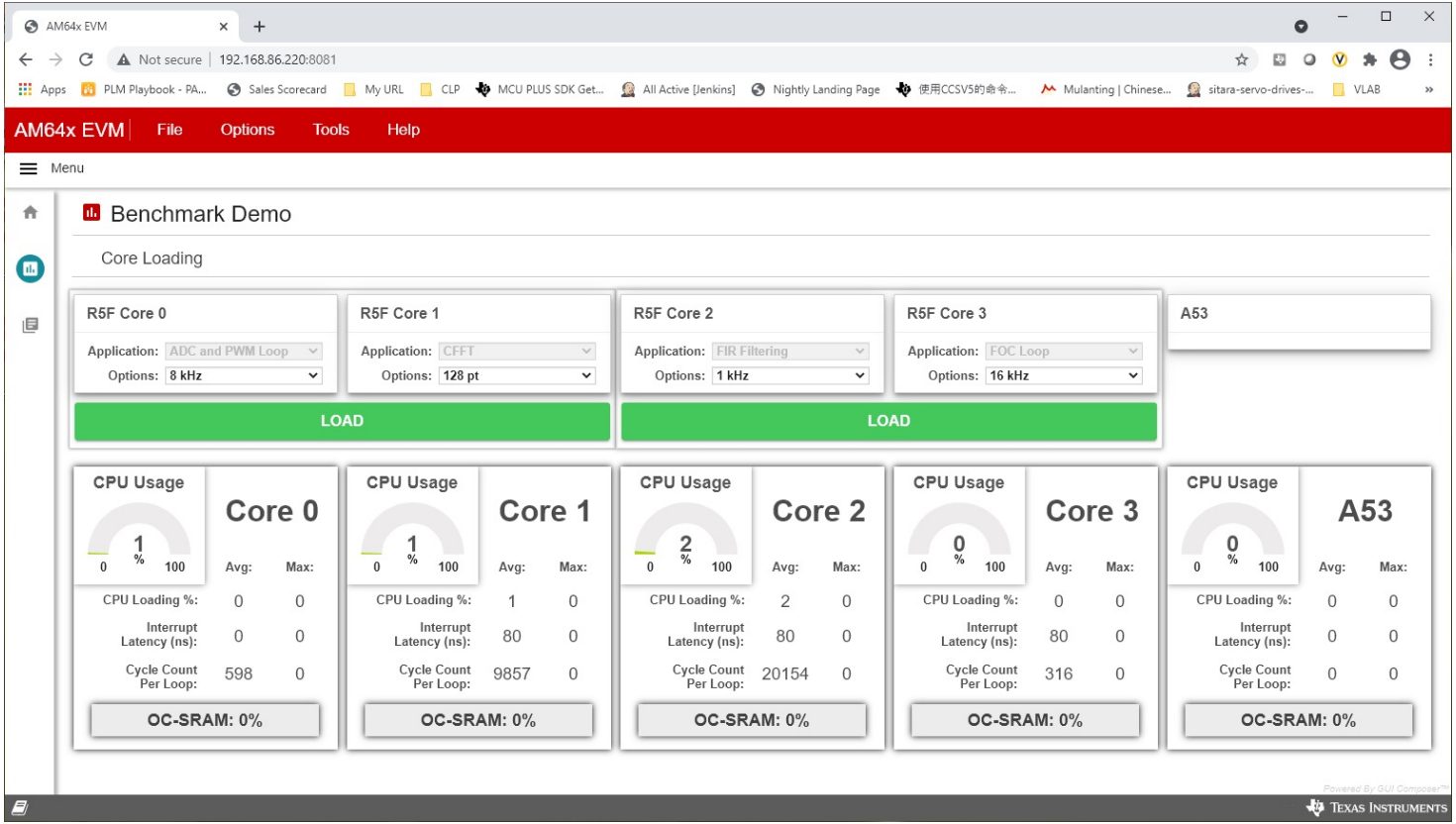
- Computer/phone/tablet
- Web Browser
  - IP addresses on same subnet

- 802.11abgn, 2x2 MIMO, AP, STA, Wi-Fi direct mode, Mesh over Wi-Fi based on 802.11s, Bluetooth, Bluetooth low energy, COEX *onboard*
- DHCP Server running *on Starter Kit in SDK*
- Web servers for demos also running

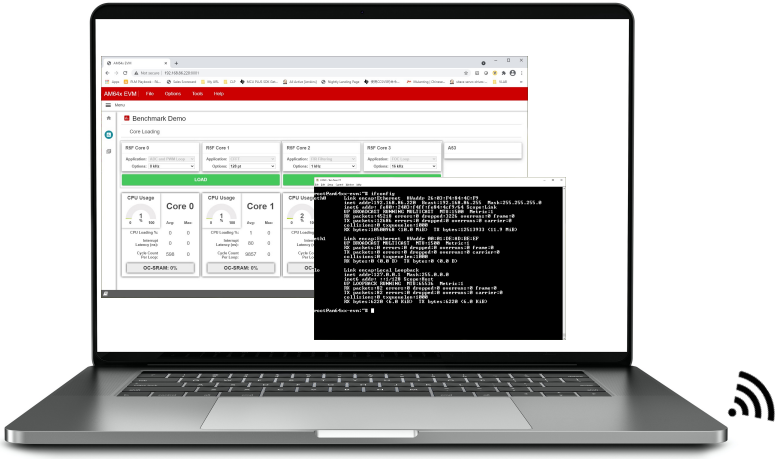
Benchmark Demo – GUI

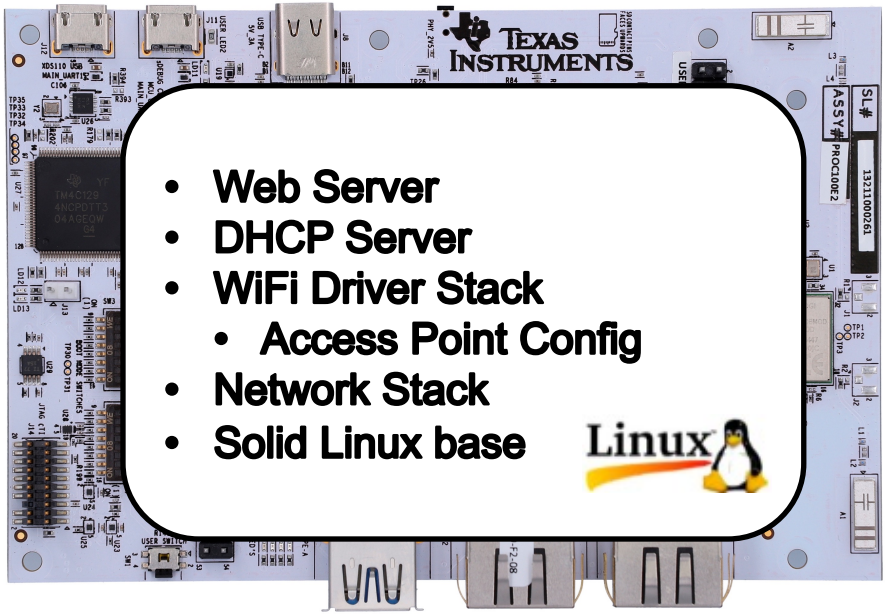


Benchmark Demo – GUI



A Software View

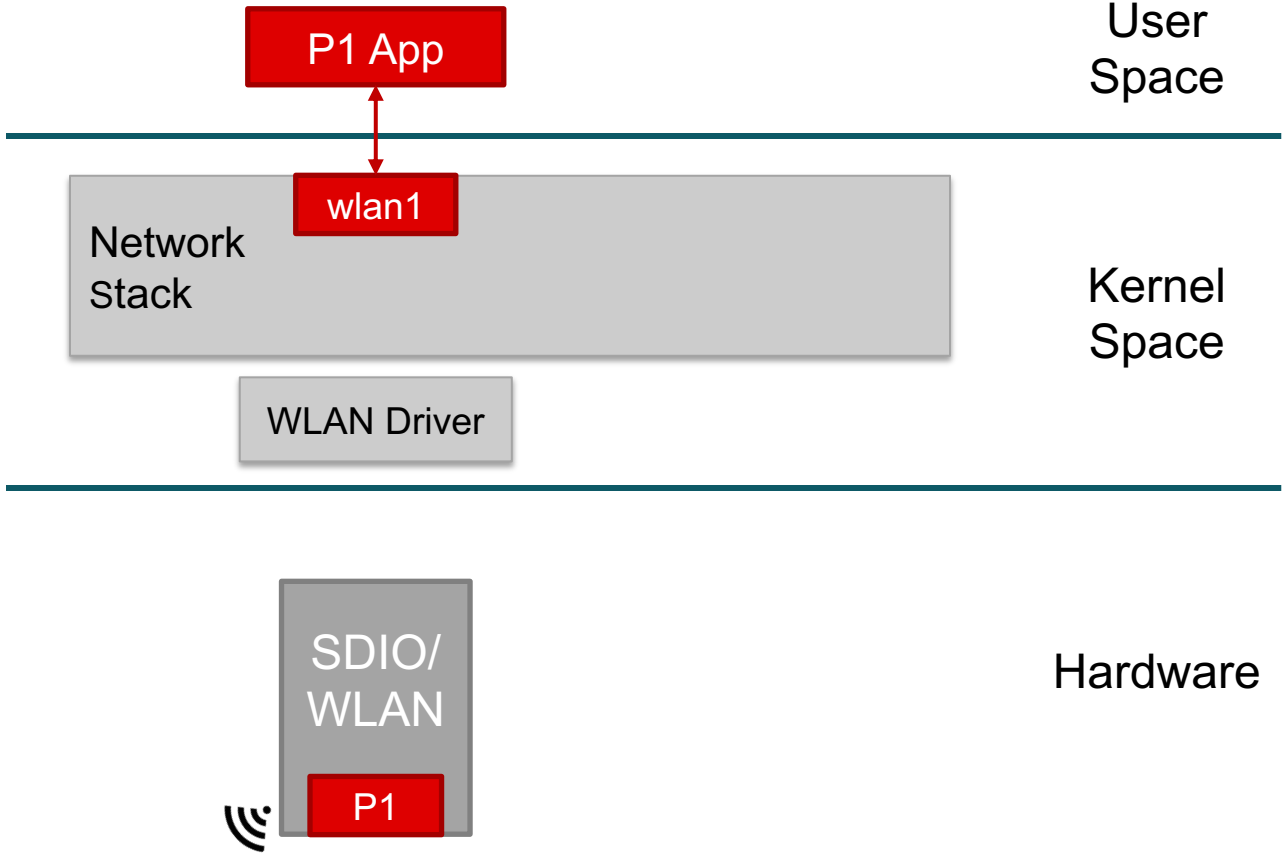




- Linux Networking capability and reliability well established
- TI capabilities utilize common Linux commands
- No need to relearn networking for embedded

Software Stack Overview

- App is web server
- Wireless configured as AP



Questions

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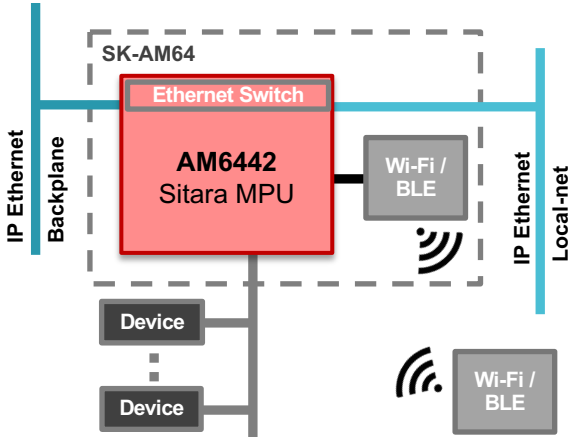
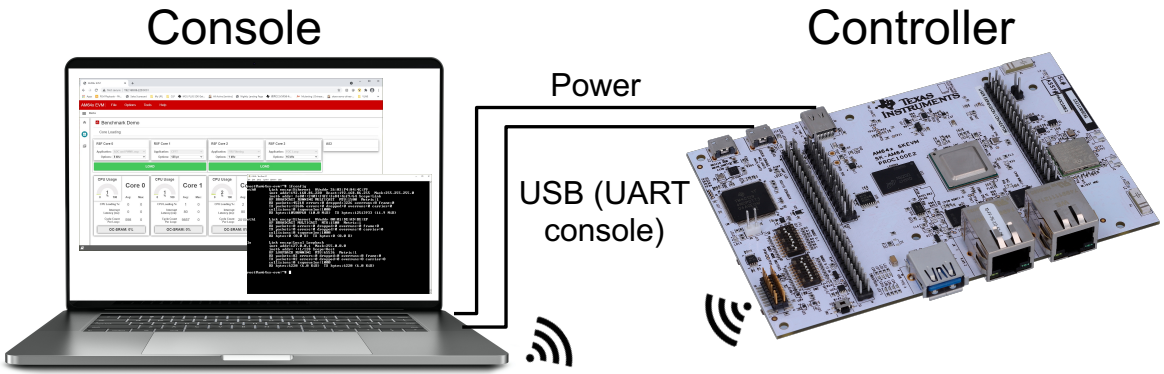


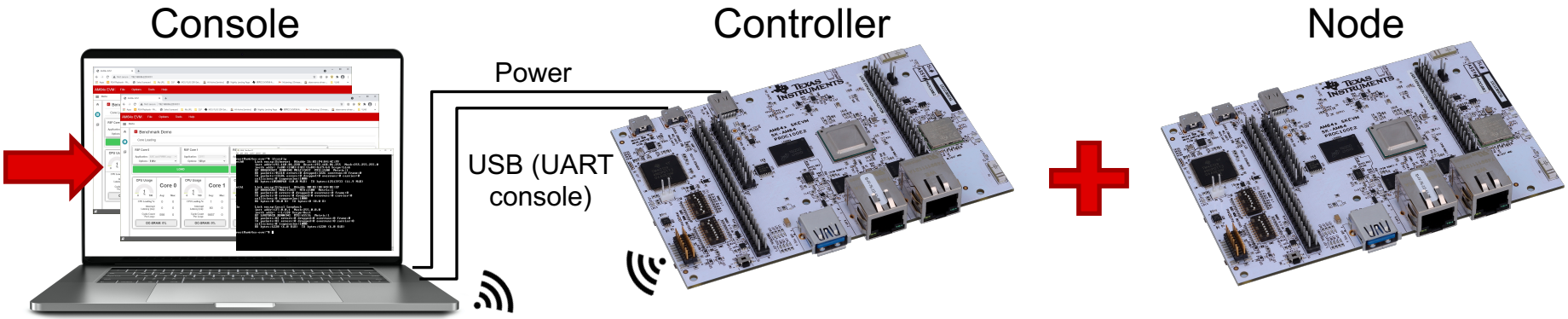
Naming the Topology



- Console provides user access

- Controller implements commands
- Responds to requests

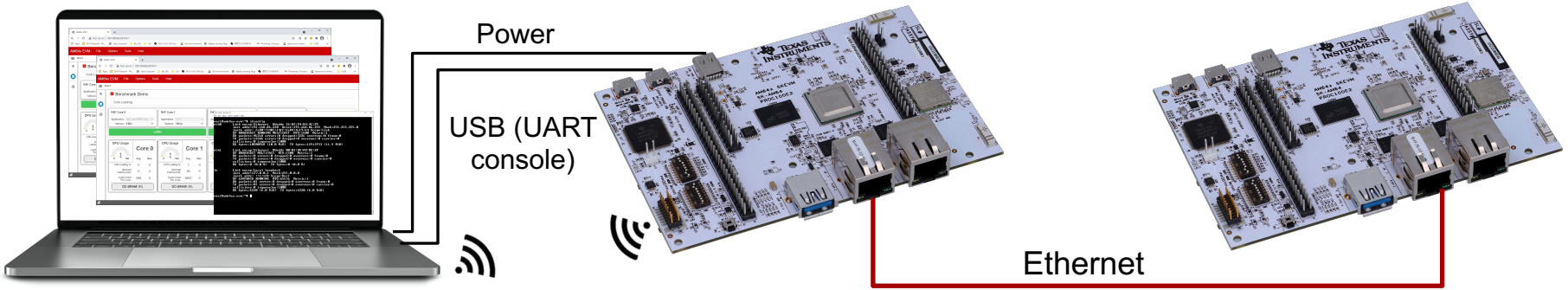
How to add more connections?



Wireless or Wired?

- Nodes are connected to the controller
- End points, sensors, etc.
- Provide data to Controller and Console

A Wireless to Wired Gateway



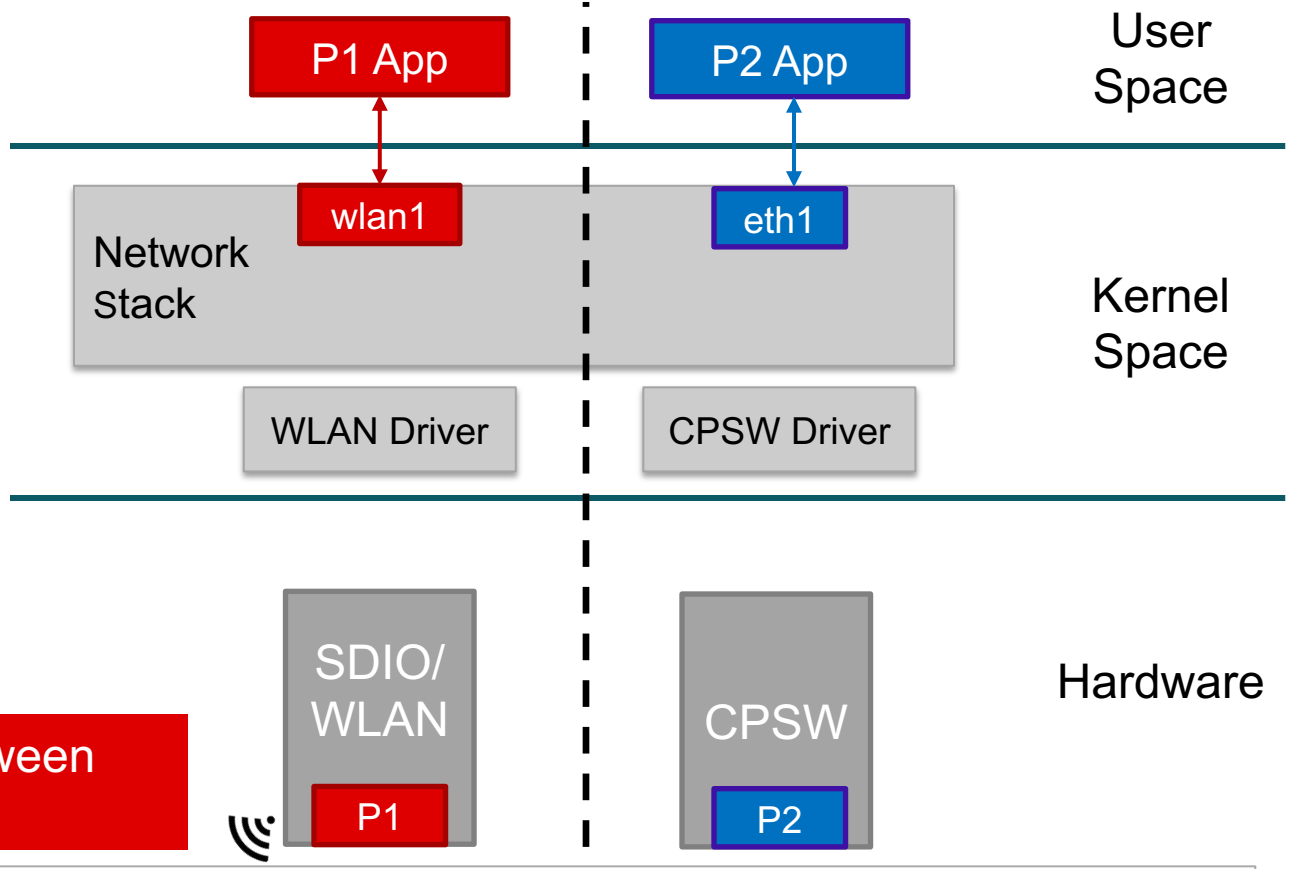
- Wired is usually more, robust, reliable, capable, etc.,

  … and cheaper

- It offers other advantages…stay tuned

Dual Network Connections for Controller

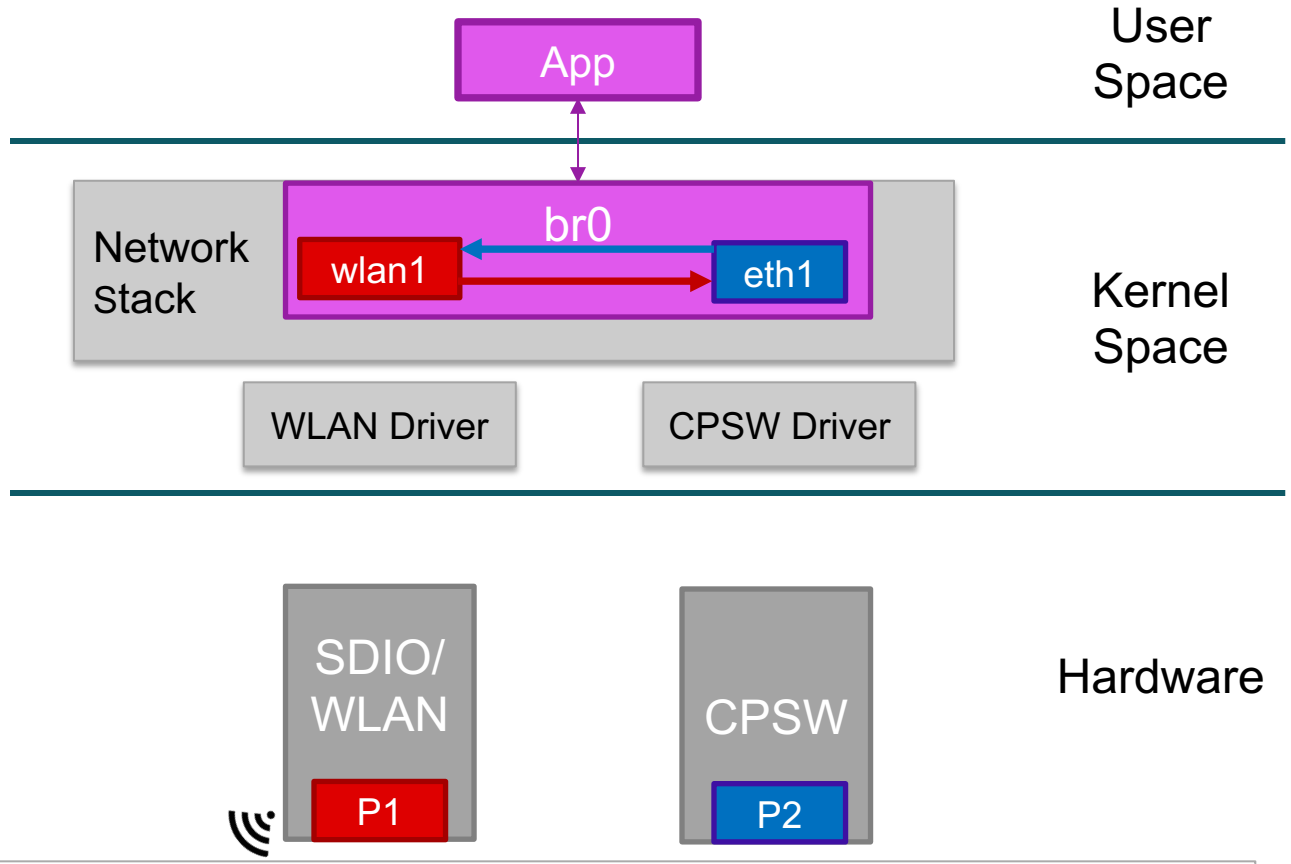
- Two different interfaces (IP Addresses)
- Two different subnets
- CPSW is TI's Ethernet H/W



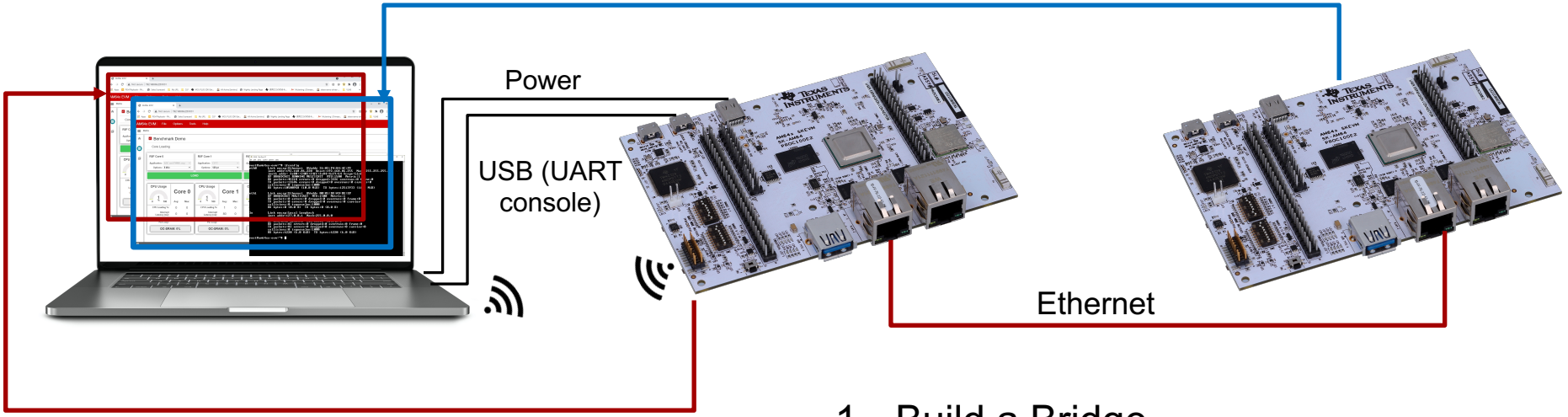
Q: Can packets cross between wlan1 and eth1?

Build a Bridge to Share Traffic

- Use common Linux commands to build a bridge
- TI SDK enables the same commands as common desktop and server distros
- No ”embedded” knowledge needed
- Utilizes ARM resources to do the switching in Kernel space



Wireless to Wired Gateway Demo



1. Build a Bridge
2. Assign IP Addresses
3. Request page from Wireless
   - Same as Wireless demo
4. Request page from Wired

Questions

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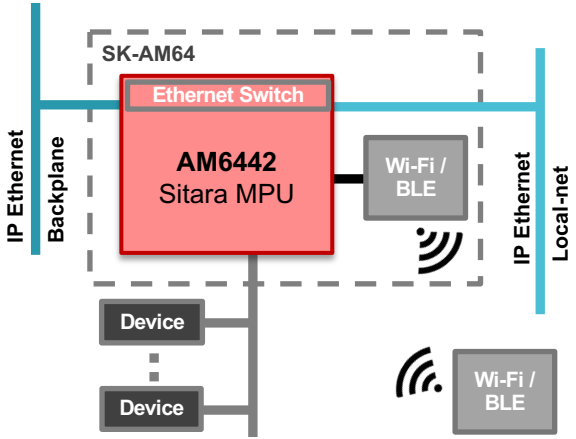
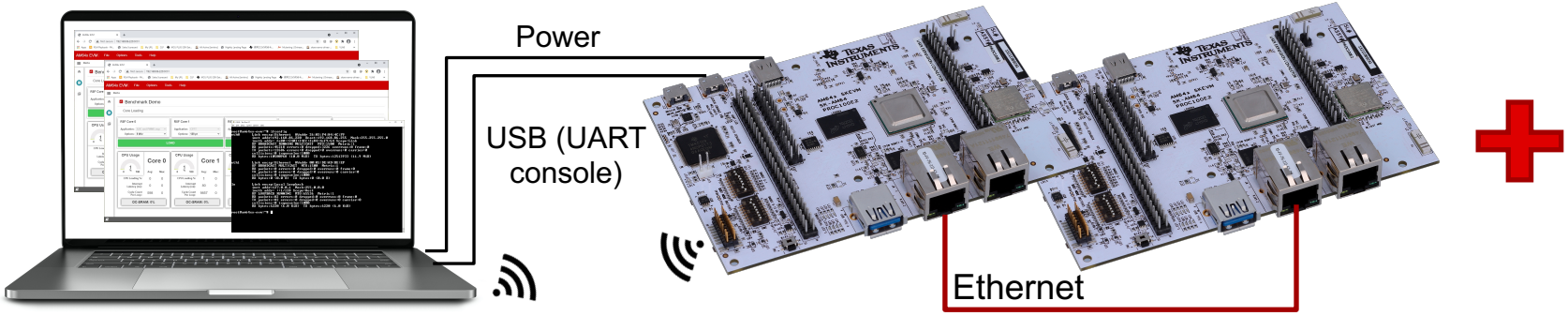
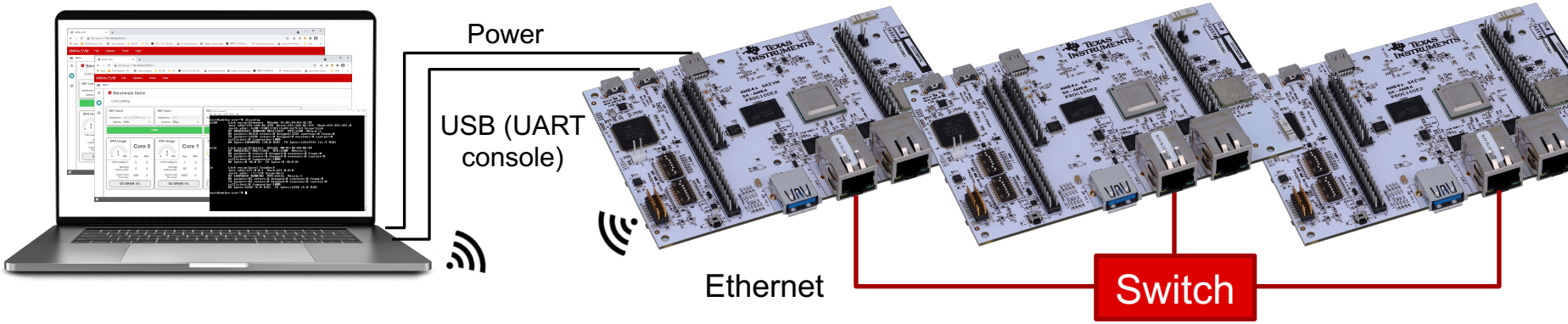


Adding More Nodes



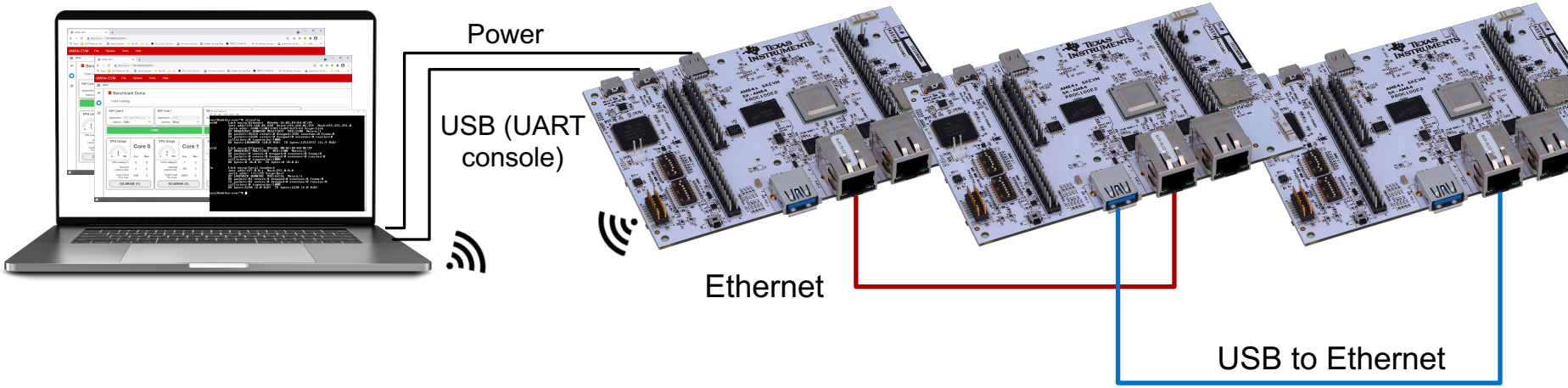
- Wired or Wireless
- Switch
- Daisy Chain
- etc.

Adding More Nodes with a Switch



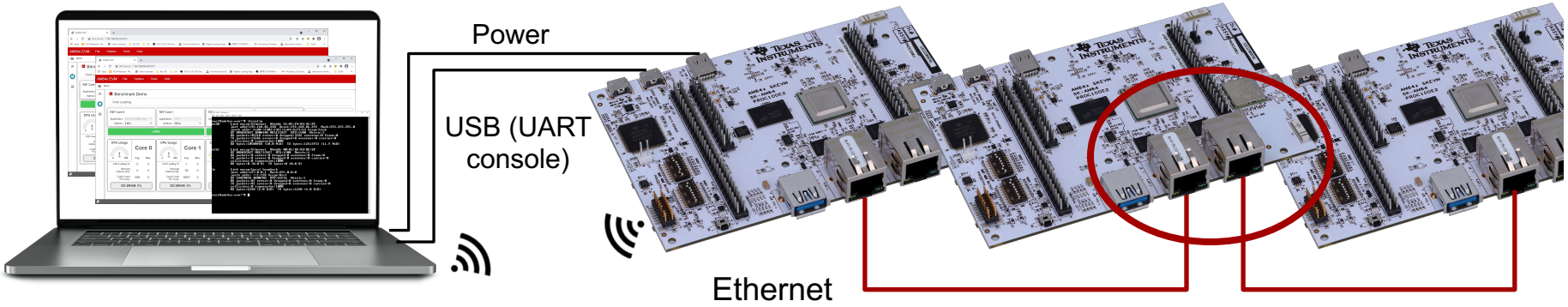
- Easy, validated path to more connections
- Additional cost and complexity
- Could use a lot of cable
- Must decide on number of ports or add more switches

Adding More Nodes by Daisy Chain with USB



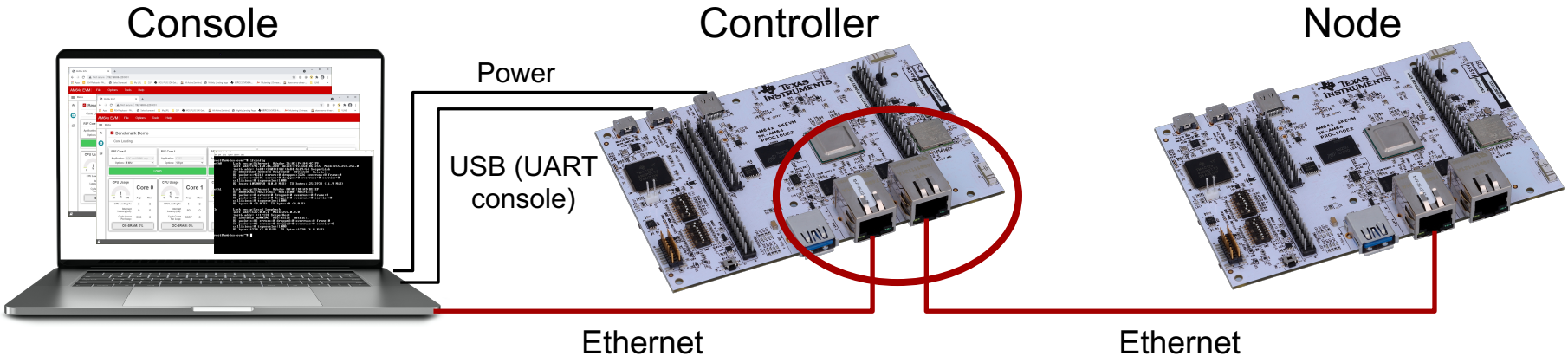
- Daisy Chain is simple and flexible
- Should reduce cabling, especially for long, linear runs
- Great for ring topologies
- *If only one port on device, must use alternatives*
  - USB to Ethernet (for example)

Daisy Chain with Two Connections



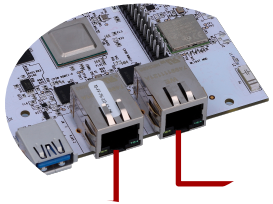
- TI Processors typically include *two* Ethernet interfaces
- Allows simple daisy chained networks that *save cost, cabling and complexity*
- Powerful Linux network stack enables *many topologies*

A Simple Network for Demonstration



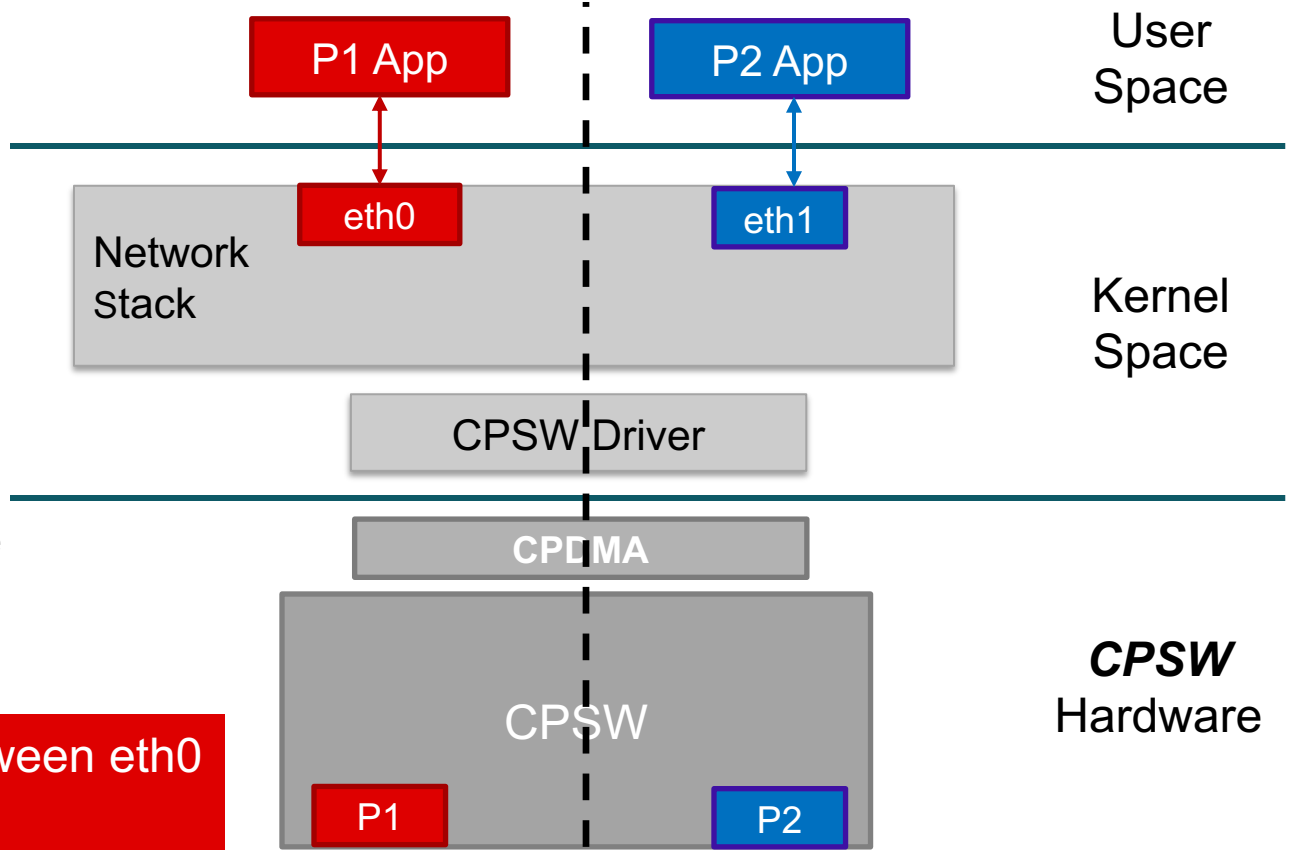
- Let's simplify back to a wired network for closer examination
- One Console, Controller, and Node
- Use statically assigned IP addresses

CPSW Dual MAC Configuration



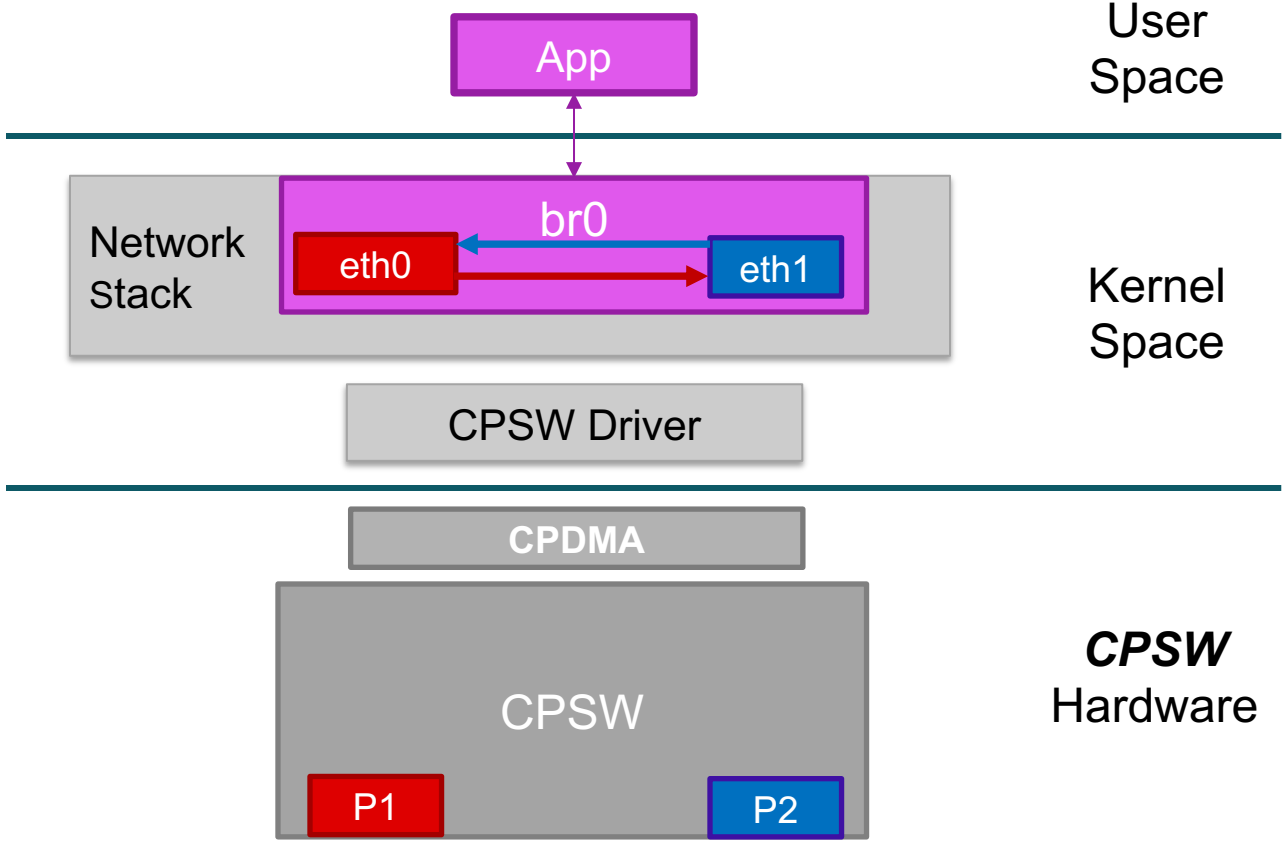
- CPSW is what TI calls our Ethernet Hardware
- This is a *Dual MAC* configuration that provides *two subnets*
- It looks *very similar* to the Wireless to Wired Bridge diagram from earlier

Q: Can packets cross between eth0 and eth1?



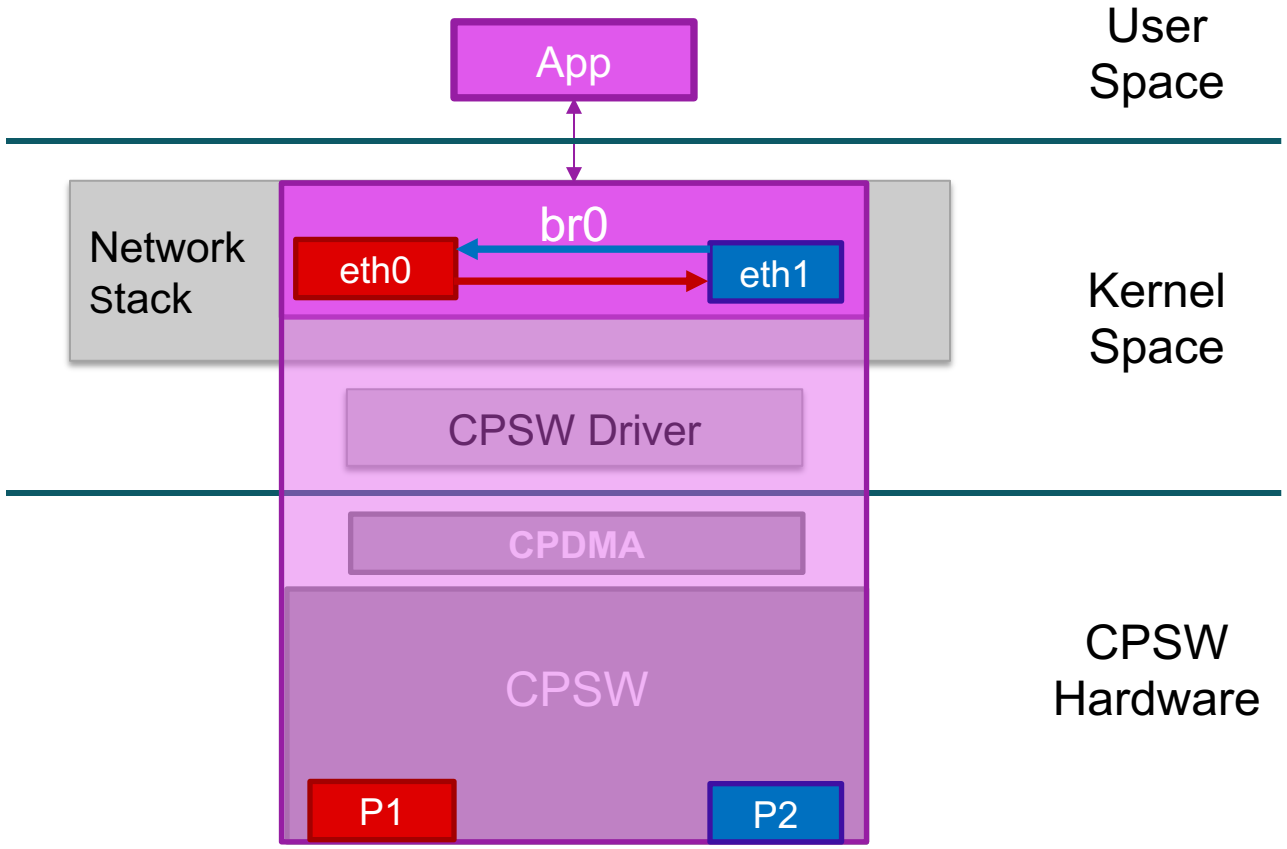
Build a Wired Bridge, or Soft Switch

- Bridge combines two interfaces on same subnet
- Packets can pass between interfaces
- Local port, br0, can have IP address if needed
- ARM resources used to manage packets



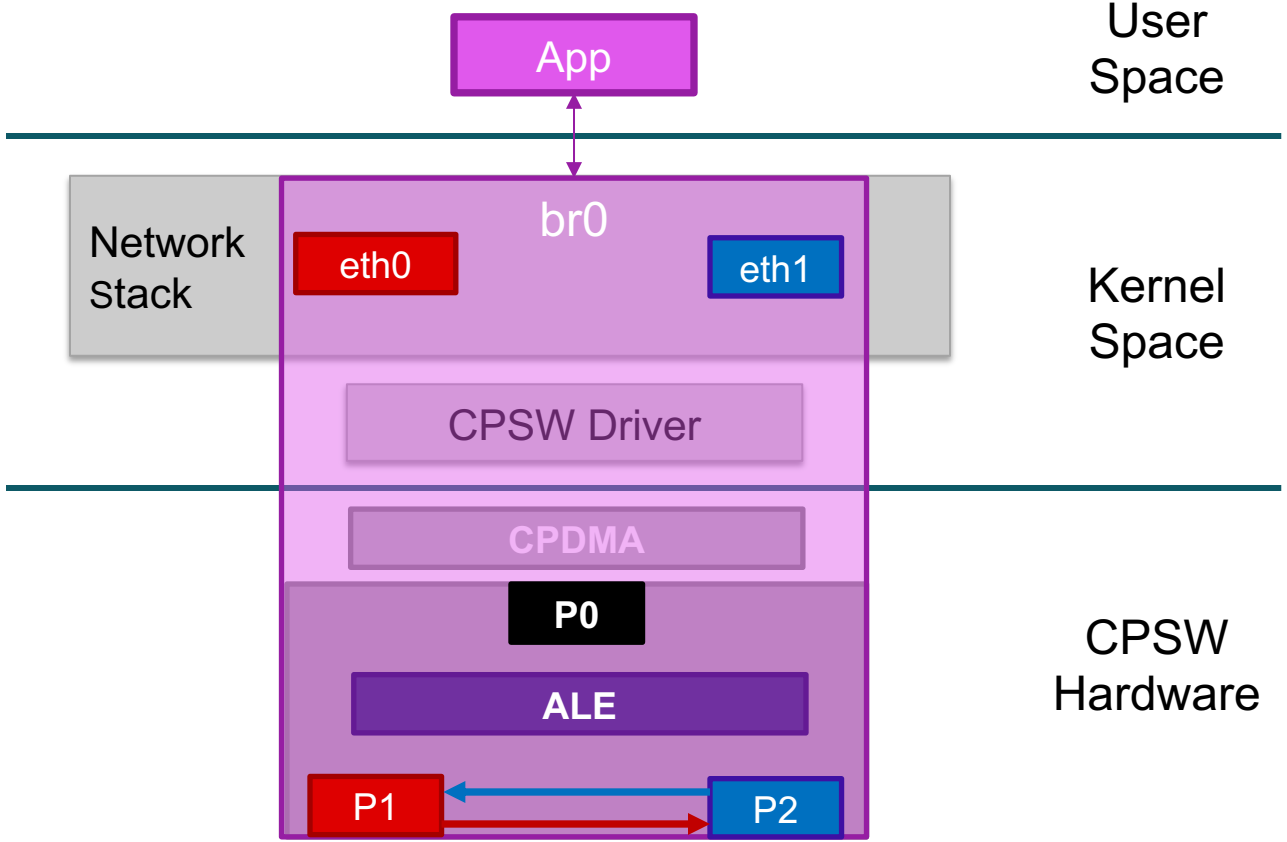
Hard Switch

- Avoid using ARM resources by switching in hardware



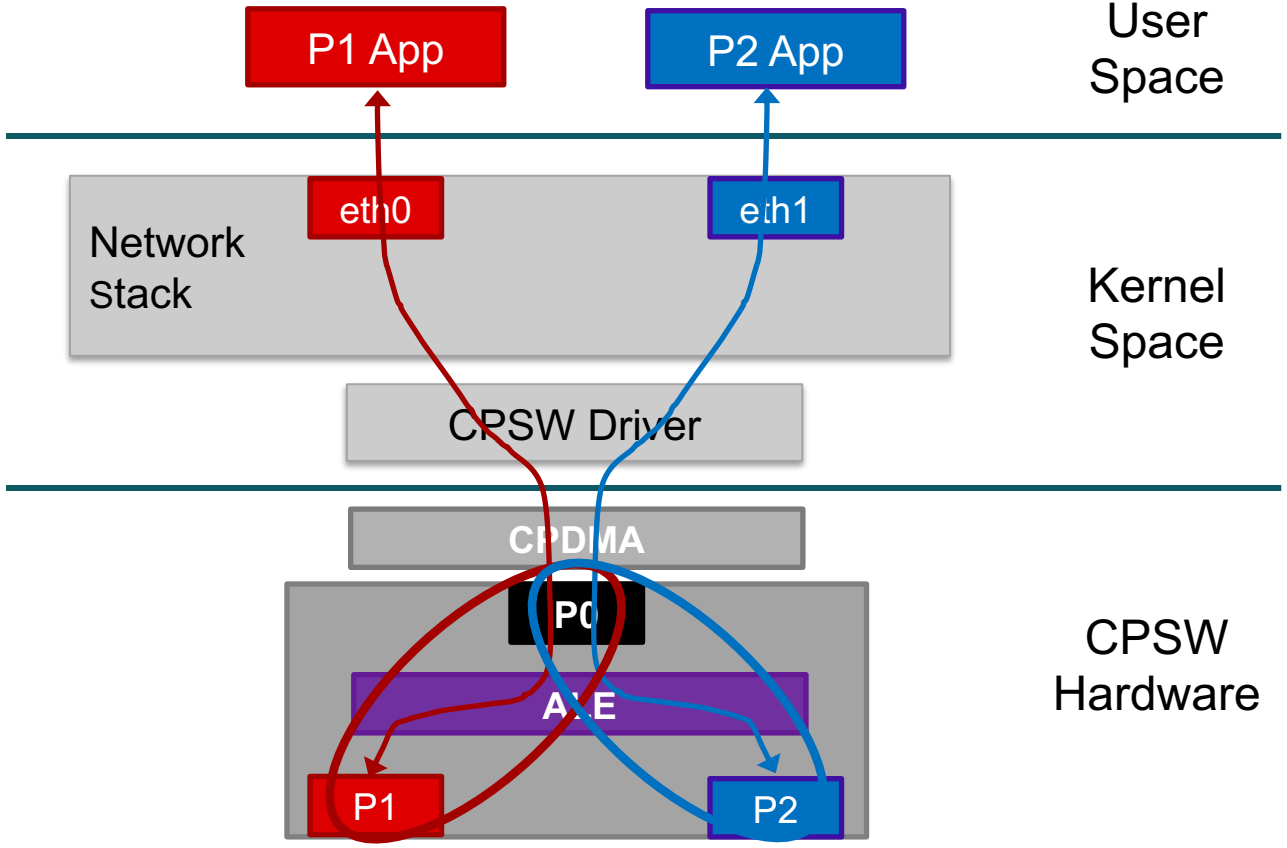
The “SW” of CPSW Stands for Switch

- Hardware switch can be enabled with Linux commands
- Gbit, line rate switching
- Improved throughput and latency
- TSN capabilities as well

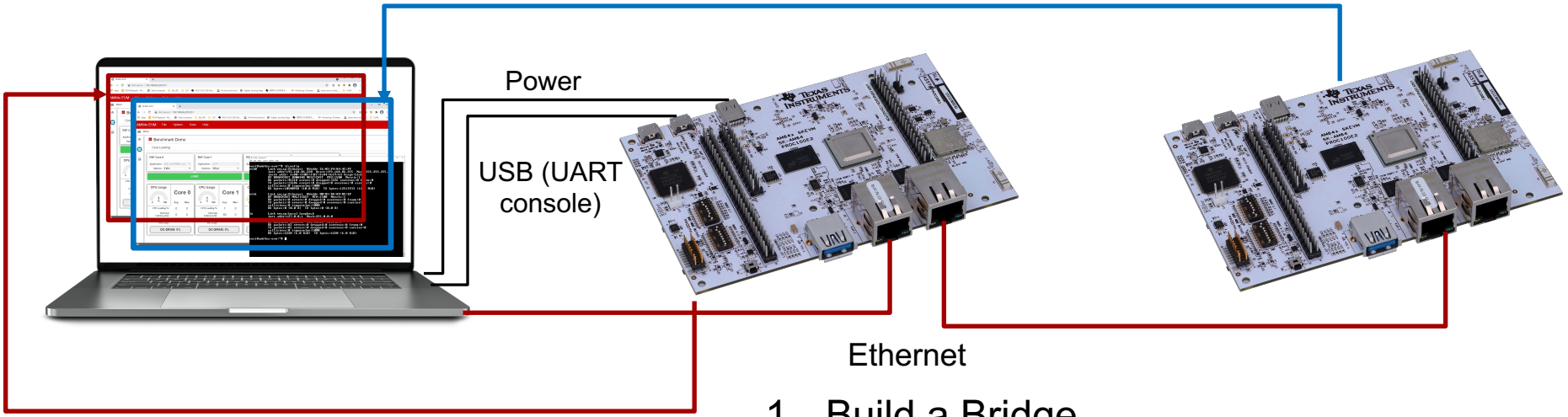


Dual MAC with a Switch

- VLANs used internally to convert switch into two independent ports
- Runtime configurable switch or dual mac
- Software flexibility to change hardware configuration
  - Same box, different use



A Wired Gateway Demo



1. Build a Bridge
2. Assign IP Addresses
3. Request page from Wireless
   - Same as Wireless demo
4. Request page from Wired
5. Turn on Hard Switch and repeat…

Questions

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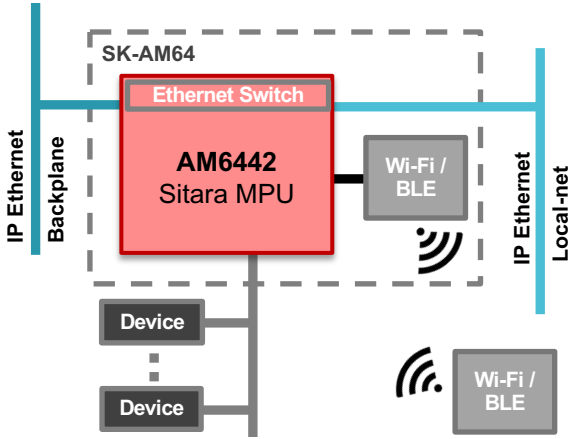


Summary

- TI Processors and Ecosystem enable powerful Linux Networking out of the box
- The new AM64x SK includes WiFi integration and 2 Ethernet Ports
- The CPSW Ethernet supports Dual MAC and Switch configurations
- The Hard Switch can save *approximately 20% ARM loading* at 100mbit
  - Gigabit, line rate switching in hardware
- TI SDK enables standard, well known Linux commands

Resources

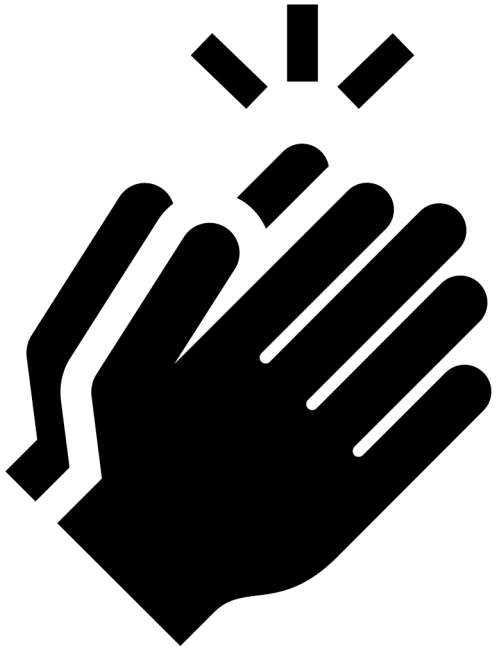
- Slides and videos will be posted here:
  - E2E Post
- AM64x SK EVM
- AM64x Product Page
- Previous Sitara Webinar on Comms and Real-time
  - Includes Presentation and Video
  - Dives further into the Software Architecture of the Web Server Application

Thank You

Thanks for attending!

&

Have a *fantastic* rest of the day



Backup

Controller Commands for WiFi Bridge

add_bridge_wifi_eth1.sh

```
#!/bin/bash

# remove the IP address so it can be given to the bridge
ip addr del 192.168.43.1/255.255.255.0 dev wlan1
ip link add name br0 type bridge
ip link set dev br0 up
sleep 1
# assign IP address to host bridge interface
ip addr add 192.168.43.1/255.255.255.0 dev br0
# add wlan1 interface to bridge
ip link set dev wlan1 master br0
# add eth1 interface to bridge
ip link set dev eth1 master br0
```

Controller Commands for Hardware Bridge

add_bridge_hard_eth0_eth1.sh

```
#!/bin/bash

ip link set eth0 down
ip link set eth1 down
# Command to enable Hardware switching
devlink dev param set platform/8000000.ethernet name switch_mode value true cmode runtime
ip link add name br0 type bridge
ip link set eth0 up
sleep 1
ip link set eth1 up
sleep 1
# Add local host port to the bridge
ip link set dev br0 type bridge stp_state 1
ip link set dev eth0 master br0
ip link set dev eth1 master br0
ip link set br0 up
sleep 1
bridge vlan add dev br0 vid 1 pvid untagged self
ip addr add 192.168.44.1/255.255.255.0 dev br0
sleep 1
```