

Interfacing Android Things with an Arduino

Real-World Experience and Observations

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Interfacing Android Things

Android Things “Makes embedded development as simple as mobile development has become”

- Dave Smith, Google I/O 2017



Interfacing Android Things

Objectives

- Better understand Android Things' applicability:
 - Does Android Things gracefully support typical embedded tasks?
 - Directly manipulate hardware devices?
 - Handle interrupts and asynchronous events?
 - Do Java Threads easily support full-duplex, interrupt-driven devices?

Interfacing Android Things

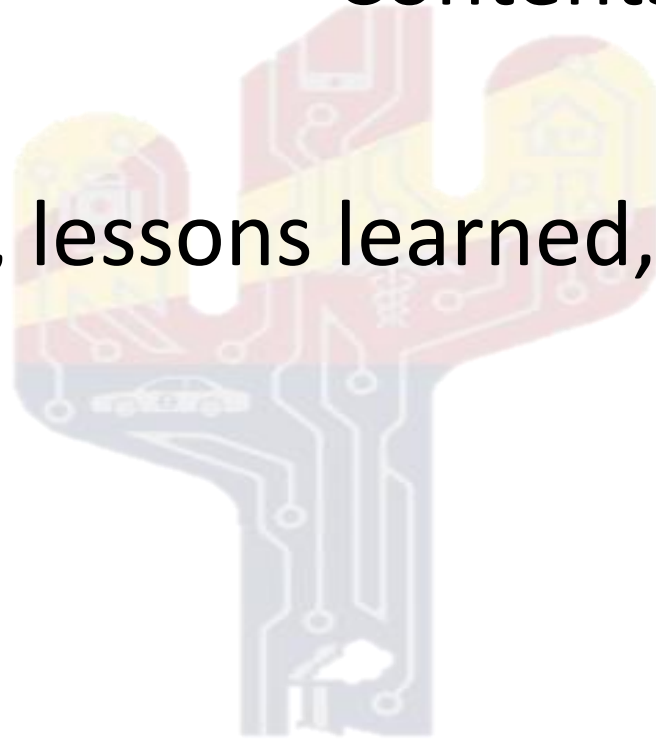
Presentation

- Presentation and Code
<<https://github.com/tjsalo/>>
- Presentation
<<https://www.saloits.com/papers/InterfacingAndroidThingsIoTDevfest2018.pdf>>

Interfacing Android Things

Contents

- The project
- Observations, lessons learned, and opinions



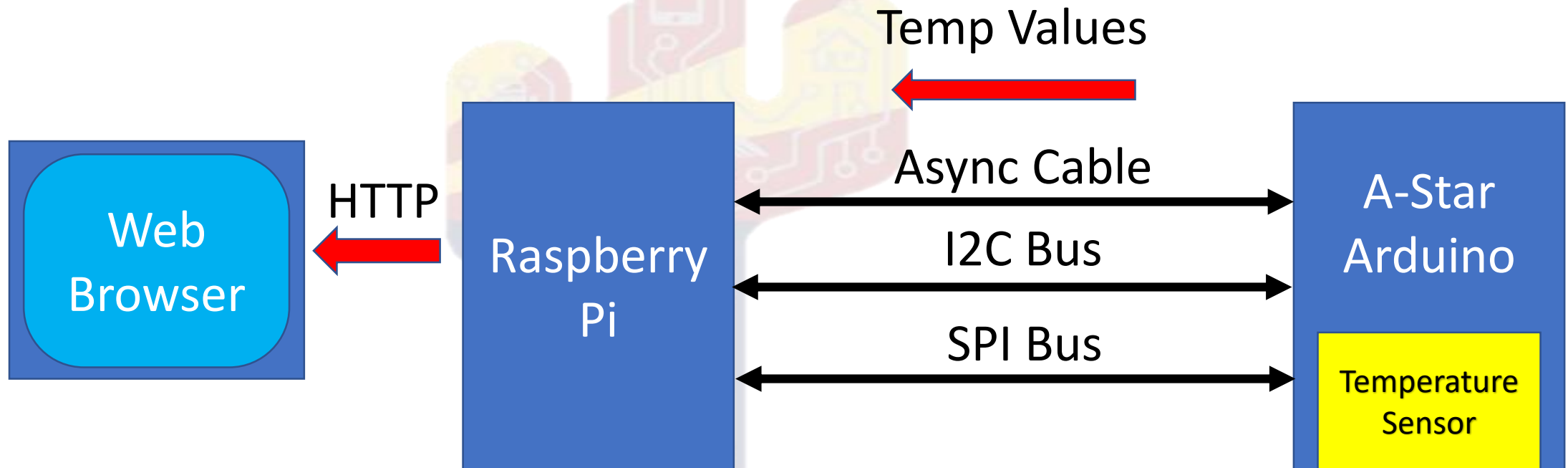
Interfacing Android Things: The Project

The Project

- Interconnect:
 - Raspberry Pi running Android Things and Pololu A-Star
- Transfer:
 - Temperature sensor data from A-Star to RPi
- Display:
 - Temperature sensor data on web page

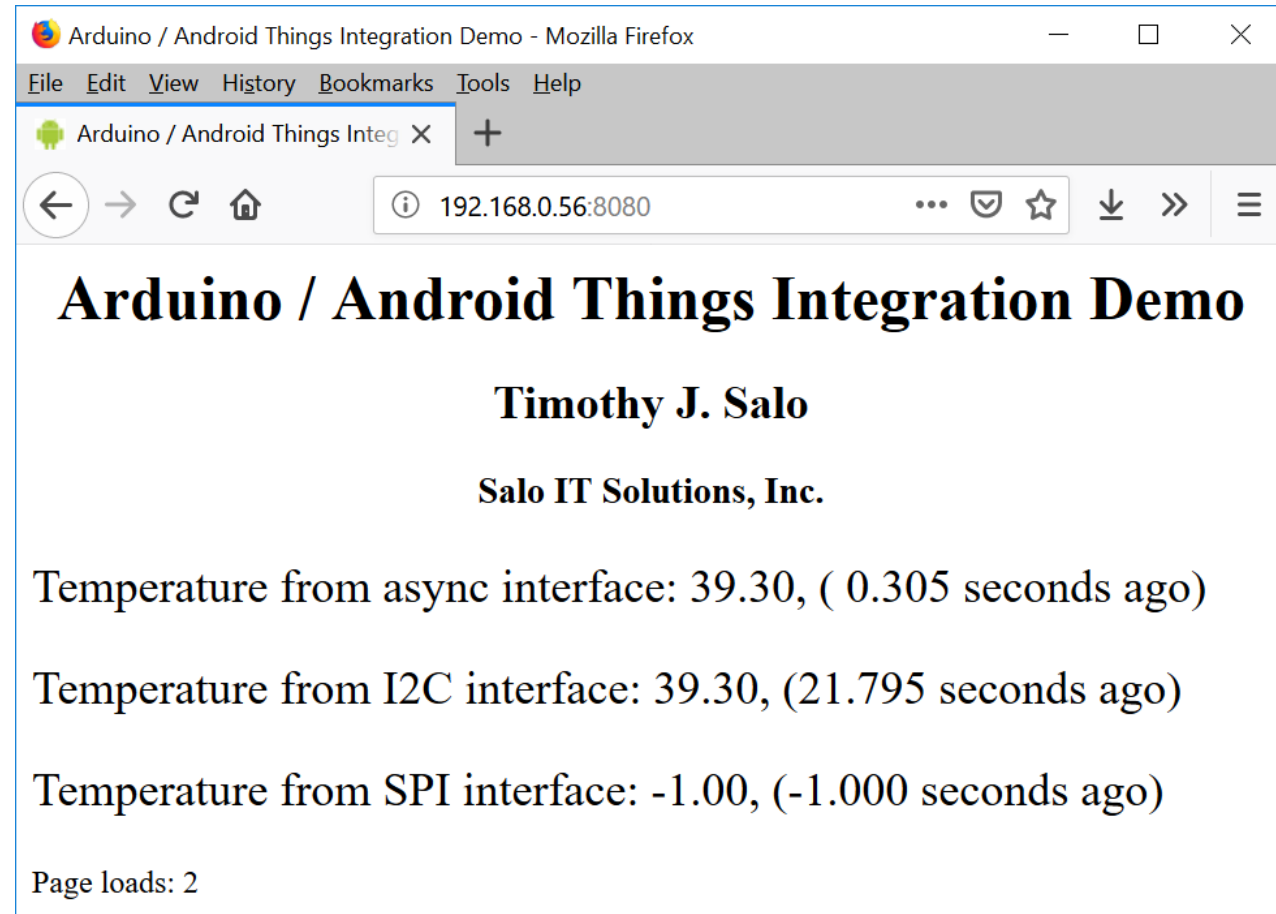
Interfacing Android Things: The Project

Android Things / Arduino Interfacing



Interfacing Android Things: The Project

- SSID: AndroidThings
- <http://192.168.0.56:8080>



Interfacing Android Things: Hardware

Raspberry Pi

- Quad Core Broadcom BCM2837 64-bit CPU
- 1 GB RAM
- 64 GB Flash
- 1.2 GHz
- 3.3 V logic
- Android Things
- NanoHttpd

Pololu A-Star 32U4

- Atmel ATmega32U4 8-bit MCU
- 2.5 KB RAM
- 32 KB flash
- 16 MHz clock
- 5 V logic
- No operating system
- Custom C code

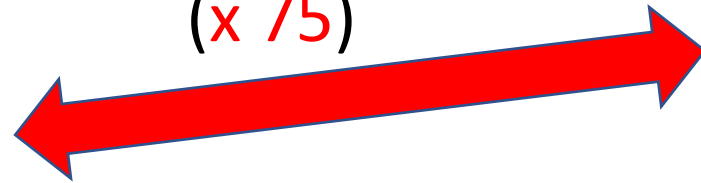
Interfacing Android Things: Hardware

Raspberry Pi

- Quad Core Broadcom BCM2837
64-bit CPU
- 1 GB RAM (x 400,000)
- 64 GB Flash (x 2,000,000)
- 1.2 GHz (x 75)
- 3.3 V logic
- Android Things
- NanoHttpd

Pololu A-Star 32U4

- Atmel ATmega32U4 8-bit MCU
- 2.5 KB RAM
- 32 KB flash
- 16 MHz clock
- 5 V logic
- No operating system
- Custom C code



Interfacing Android Things: Hardware

Connecting Raspberry Pi / A-Star Arduino

- A-Star has Raspberry Pi Bridge
 - 40-pin Raspberry Pi GPIO connector
- **But...**
 - Raspberry Pi uses 3.3 V logic
 - A-Star uses 5 V logic

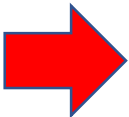
Interfacing Android Things: Hardware

Connecting Raspberry Pi / A-Star Arduino

- **Therefore:**
 - Level converters required on signal pins
- **Furthermore:**
 - Only I2C signals actually connected to 40-pin connector
 - with level converters
 - Rest of signal pins not connected!

Interfacing Android Things: Interfaces

- Communications interfaces



Async	I2C	SPI
Full-Duplex	Half-Duplex	Full-Duplex
Peer-to-Peer	Master/Slave	Master/Slave
Asynchronous (no clock signal)	Synchronous (clock signal)	Synchronous (clock signal)

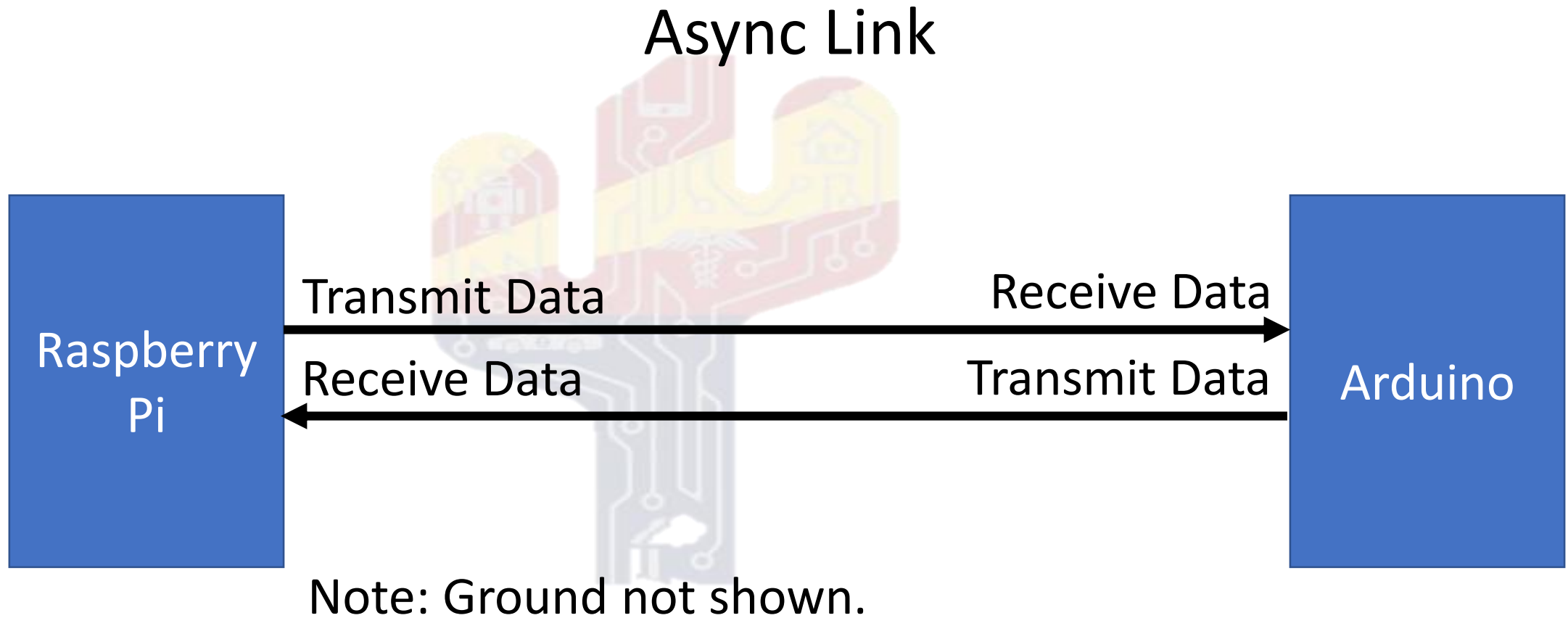
Interfacing Android Things: Interfaces

Async Link

- Serial asynchronous link
- Two data signals
 - Transmit data
 - Receive data



Interfacing Android Things: Interfaces

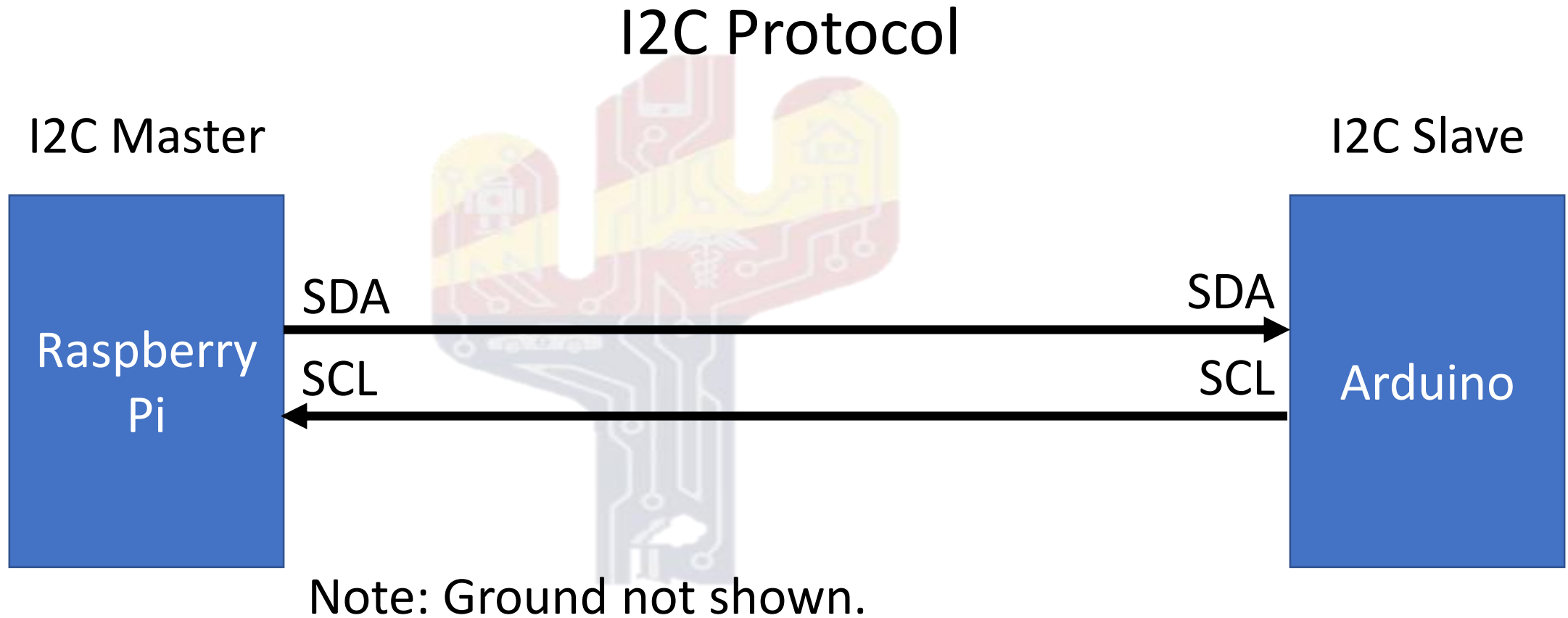


Interfacing Android Things: Interfaces

I2C Protocol

- Inter-integrated Circuit (I2C) Protocol
- Two signals:
 - Serial data (SDA)
 - Serial clock (SCL)

Interfacing Android Things: Interfaces



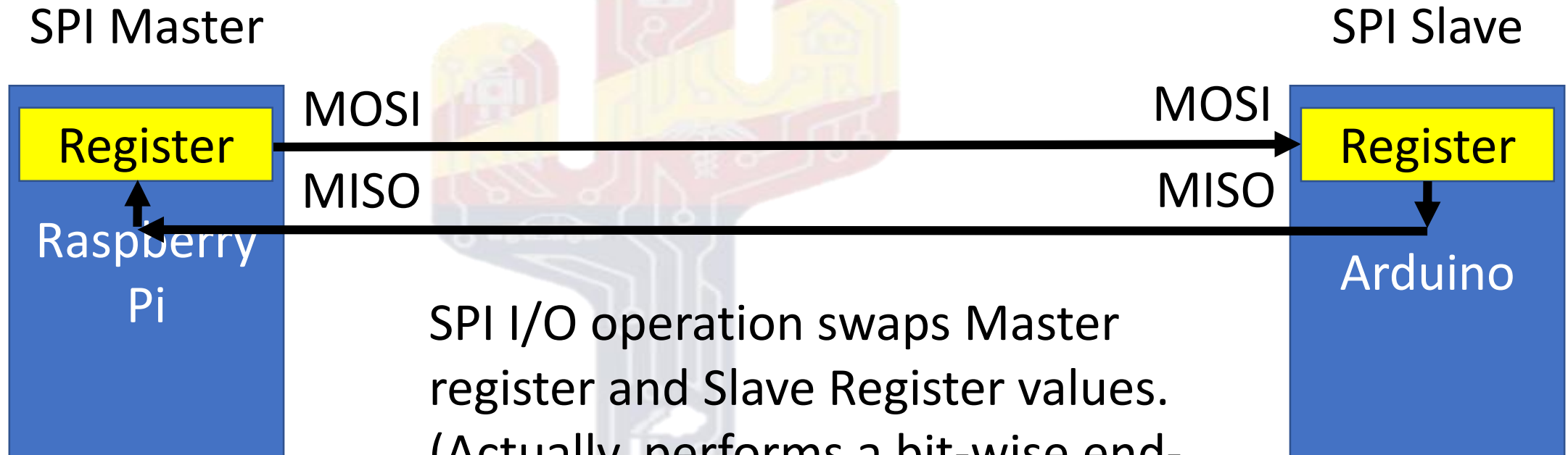
Interfacing Android Things: Interfaces

Serial Peripheral Interface (SPI) bus

- Serial bus used in embedded systems
- Master / Slave operation
- Full duplex (sort of – still Master/Slave)
- I/O operation swaps value of a register in the Master and the value of a register in the Slave
- Can delineate frames

Interfacing Android Things: Interfaces

Serial Peripheral Interface (SPI) bus



SPI I/O operation swaps Master register and Slave Register values. (Actually, performs a bit-wise end-around-shift.)

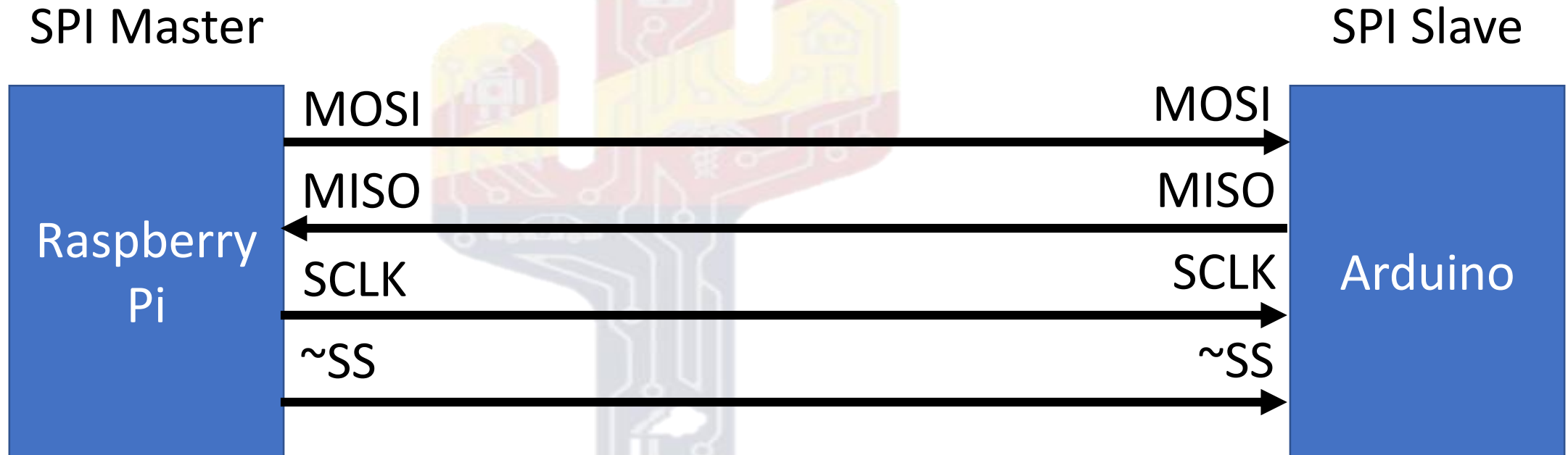
Interfacing Android Things: Interfaces

Serial Peripheral Interface (SPI) bus

- Android Things supports two data transfer modes:
 - Half-duplex data transfer
 - Full-duplex data transfer
- Remember: data transfer controlled by Master

Interfacing Android Things: Interfaces

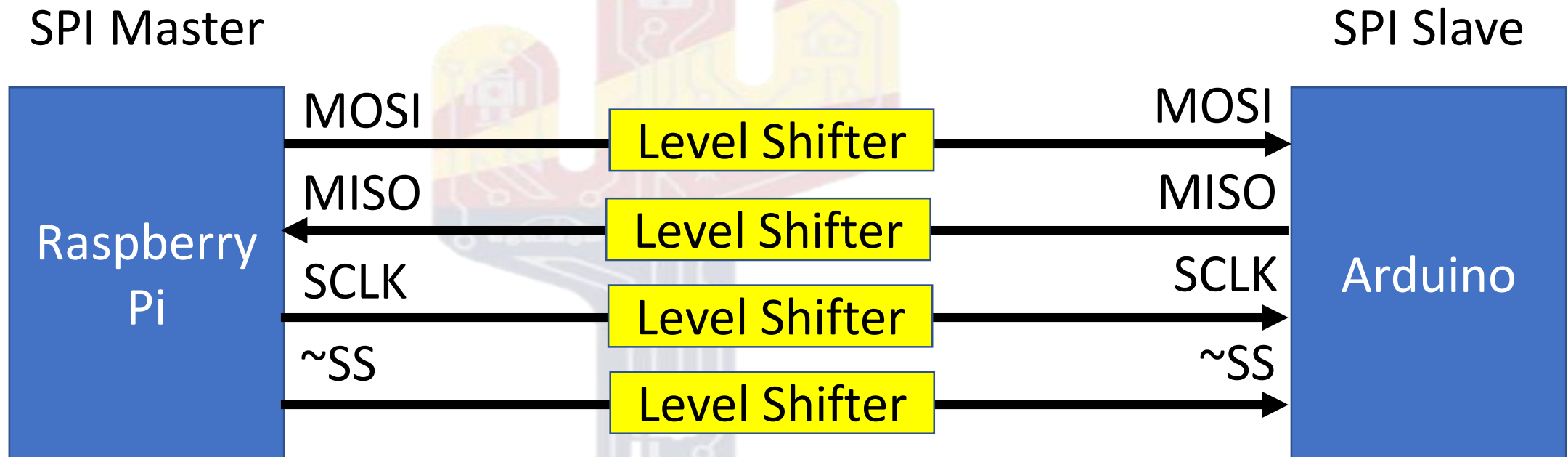
Serial Peripheral Interface (SPI) bus



Note: Ground not shown.

Interfacing Android Things: Interfaces

Serial Peripheral Interface (SPI) bus



Note: Soldering probably required

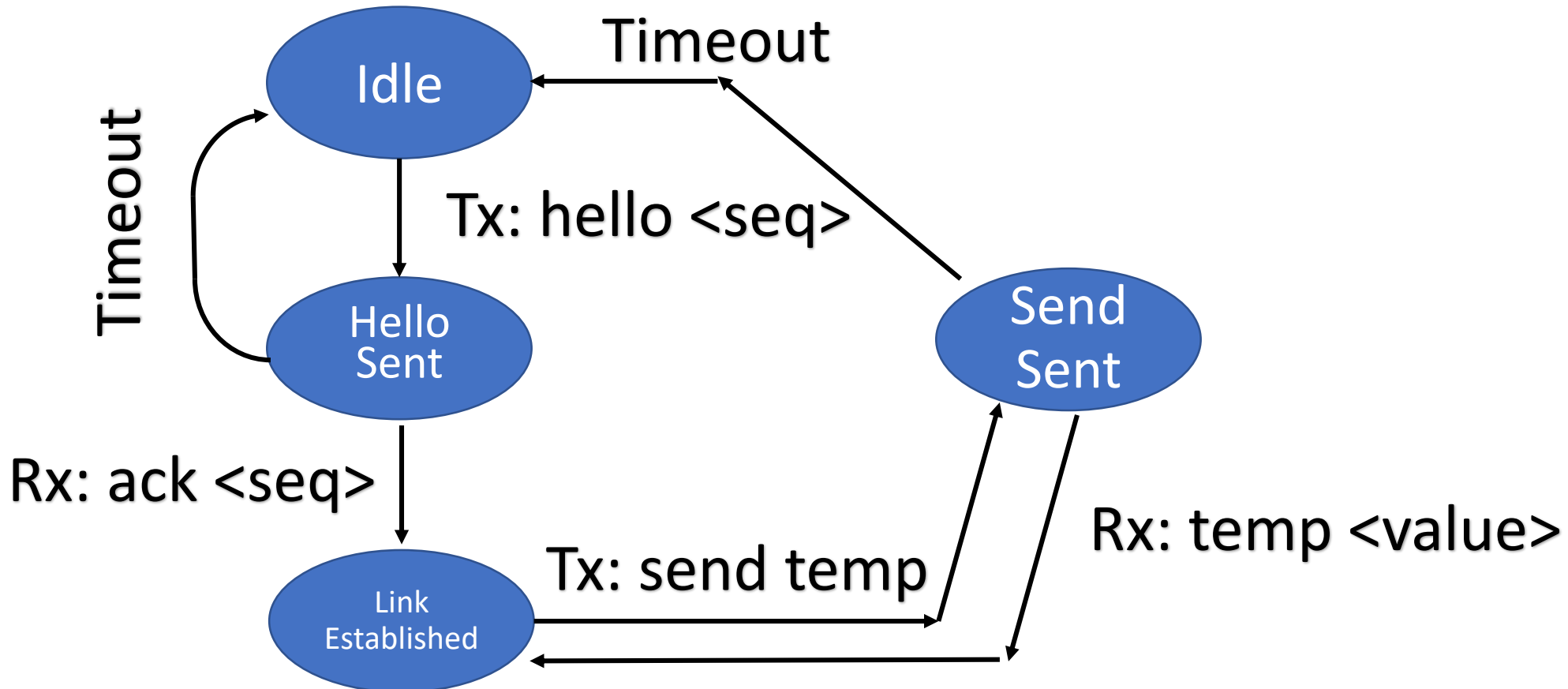
Interfacing Android Things: Communications

Communications “Protocol”

- Messages are ASCII strings, terminated by /n



Interfacing Android Things: Communications



Interfacing Android Things: Software

Typical Embedded Software Architecture

- Update clock (e.g., millisecond clock)
- While (true):
 - Executing pending tasks
 - Process expired timers (execute tasks)
- Handle interrupts
 - Manage peripherals / communications / clock/ ...

Interfacing Android Things: Software

Planned Android Things Software Architecture

- Main Thread:
 - Android stuff
 - Fire up other threads
 - Create web pages
 - A bit of coordination
- One Thread per physical interface
 - Manage link, communications

Interfacing Android Things: Project Results

Project Results

- Implementation results decidedly mixed
- Some stuff worked, some stuff didn't
 - Async Interface works well
 - I2C interface largely works
 - RPi hardware bug (I2C clock stretching)?
 - SPI interface barely works
 - Noisy connections to level shifters?

Interfacing Android Things: Observations

Observations

- Android Things ecosystem
- What is “embedded programming”?
- Java Thread and asynchronous events
- Java String
- Hardware state visibility
- Low-level development
- Mobile developers don't...
- Whither Android Things?

Interfacing Android Things: Observations

Caveats

- I am not an Android developer
- I am not a Java programmer
- I am not an electrical engineer
- Long ago, I was an assembly language systems programmer

Interfacing Android Things: Observations

Android Things Ecosystem

- The Android Things ecosystem has many nice capabilities
 - Android Studio
 - Leverage Android developer expertise / documentation / ...
 - Leverage Android code base / examples / ...
 - Rich IDE
 - adb
 - ...

Interfacing Android Things: Observations

Android Things Ecosystem

- The Android Things ecosystem has many nice capabilities
 - Over-the-air (OTA) software updates
 - Addresses one of the more vexing IoT problems

Interfacing Android Things: Observations

Android Things Ecosystem

- The Android Things ecosystem has many nice capabilities
 - Android Things Console
 - Has potential
 - Feels like a prototype

Interfacing Android Things: Observations

Android Things Ecosystem

- The Android Things ecosystem has many nice capabilities
 - User-level device drivers
 - Capability has potential
 - Doesn't appear to be easily (user) extensible
 - Limited insight into kernel / hardware state
 - May be difficult to debug / repair

Interfacing Android Things: Observations

What is “Embedded Programming”?

- “Embedded programming” covers orders-of-magnitude spectrum
 - Integrated solution (e.g., OS) unlikely to cover full spectrum
 - Android Things applicable to only [very] upper end of spectrum
 - We might need better terminology

Interfacing Android Things: Observations

Java Thread and Asynchronous Events

- I couldn't make Java Thread class adequately handle asynchronous events
 - Async link is full-duplex, peer-to-peer
 - Thread must handle asynchronous events (receive character) plus timers

Interfacing Android Things: Observations

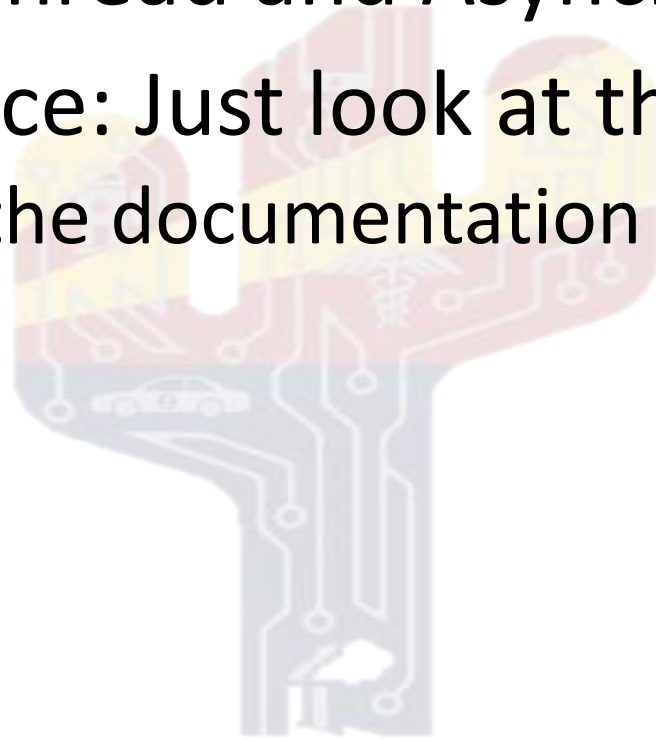
Java Thread and Asynchronous Events

- Android Thread extended with non-preemptive scheduler [sic]
 - Looper
 - Handler
- Limited documentation / examples
 - Documentation terse
 - Some examples, advice appear possibly poor

Interfacing Android Things: Observations

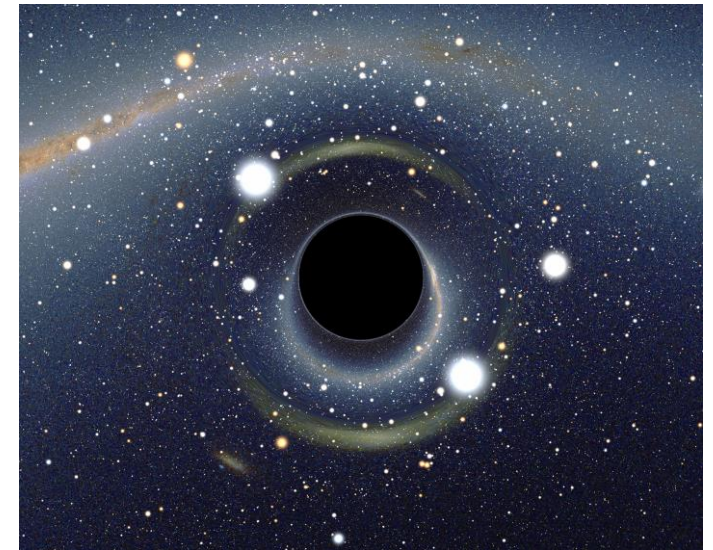
Java Thread and Asynchronous Events

- It's open source: Just look at the source code
 - The code *is* the documentation



Interfacing Android Things: Observations

“Just Look at the Source Code”



Interfacing Android Things: Observations

Java String

- This project passes ASCII strings between devices
 - C handles strings pretty sort of well
 - Single representation for char[] and string
 - No conversion between representations

Interfacing Android Things: Observations

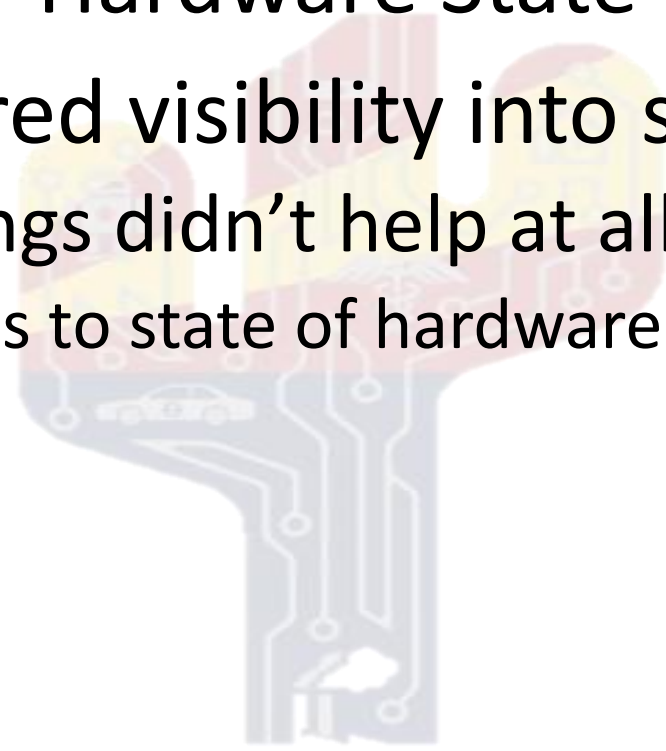
Java String

- This project passes ASCII strings between devices
 - Java String objects are heavy weight in comparison
 - Object creation is expensive
 - String and byte[] representation are different objects
 - No, I don't care about character sets
 - try/catch UnsupportedOperationException???

Interfacing Android Things: Observations

Hardware State Visibility

- Project required visibility into state of hardware
 - Android Things didn't help at all
 - Little access to state of hardware / kernel



Interfacing Android Things: Observations

Hardware State Visibility

- Project required visibility into state of hardware
 - Most hardware debugging done on Arduino
 - printf (although non-trivial)
 - Display individual bytes received
 - Display individual interrupts
 - Displayed system state on three LEDs

Interfacing Android Things: Observations

Hardware State Visibility

- Project required visibility into state of hardware
 - Needed to know low-level state of hardware
 - Occasionally used VOM meter
 - Yearned for oscilloscope

Interfacing Android Things: Observations

Low-Level Development

- Do embedded developers need to modify their own kernel or runtime code? Access to root?
 - Is this consistent with Android Things approach?
 - Is this scalable?
 - I wonder about experience of production Android Things developers

Interfacing Android Things: Observations

Mobile Developers Don't

- Fight with the hardware
 - Celebrate the first successful bit transferred
 - Yearn for an oscilloscope
 - Think about noise / transmission lines / ...
 - Solder
 - Prototype
 - Breadboard / hunt for right jumper / ...

Interfacing Android Things: Observations

Mobile Developers Don't

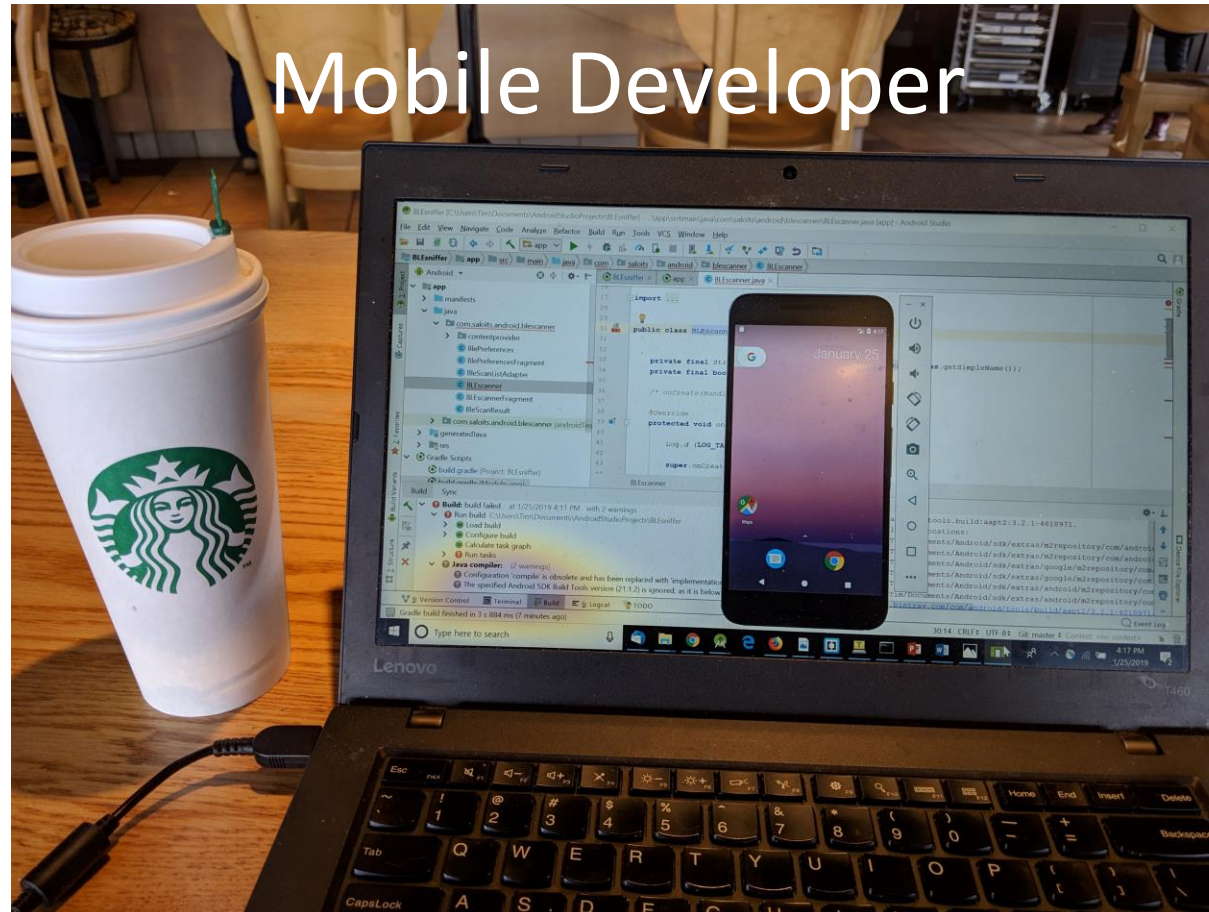
- Examine each interrupt
 - Count instructions in interrupt service routine
 - Examine MCU register state
- Think about memory
 - Reduce buffer sizes to fit memory

Interfacing Android Things: Observations

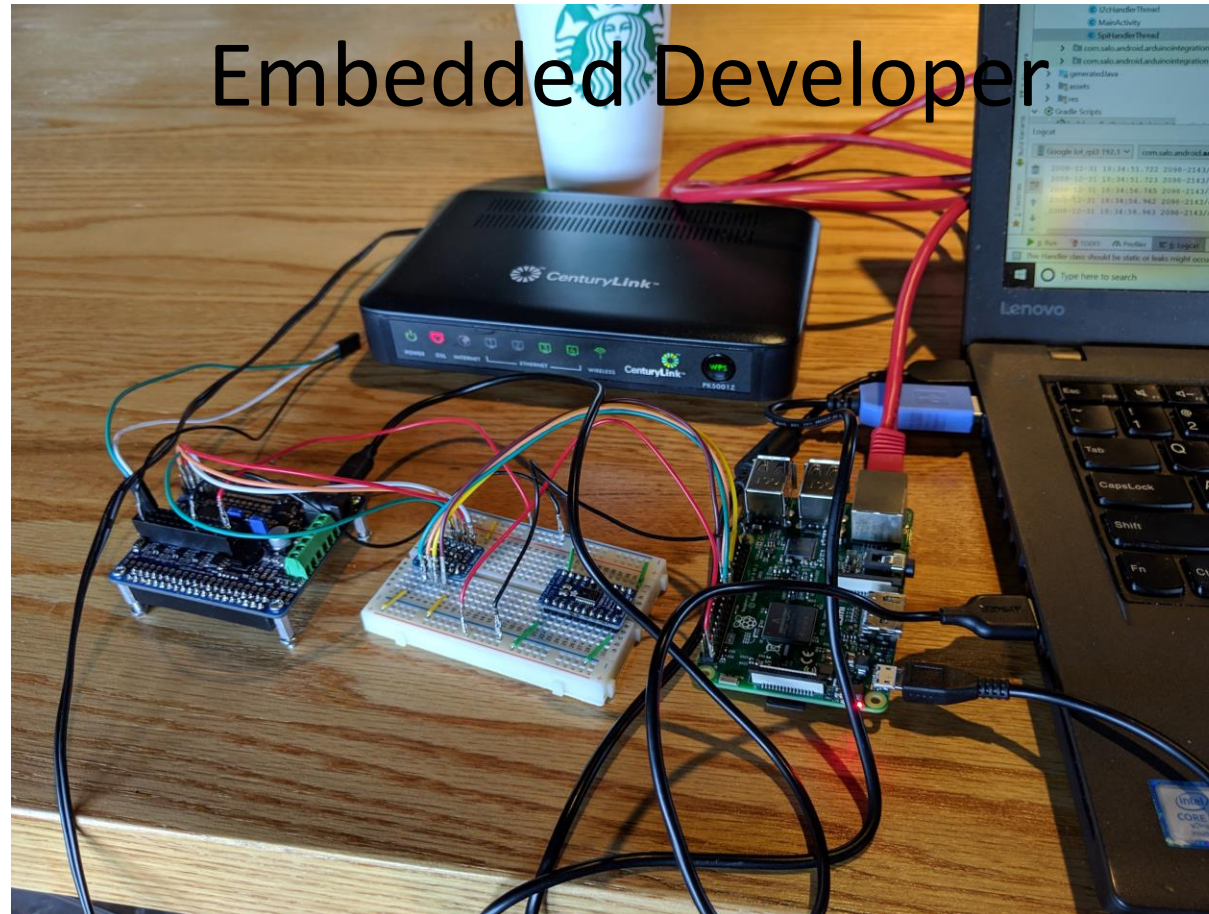
Mobile Developers Don't

- Want to know what lower-level state is
 - Kernel
 - Driver
 - Hardware
- Normally use Looper, Handler

Interfacing Android Things: Observations



Interfacing Android Things: Observations



Interfacing Android Things: Observations

Whither Android Things?

- Will Android Things become a useful tool for embedded programming?
 - I would love to see Android Things become brilliantly successful
 - But...

Interfacing Android Things: Observations

Whither Android Things?

- Will Android Things become a useful tool for embedded programming?
 - Current focus on big iron
 - Multi-core, GHz processors with half-a-gigabyte or more
 - Seems unlikely to ever be useful for MCUs
 - Useful on generic CPUs?
 - Useful outside of Google ecosystem?

Interfacing Android Things: Observations

Whither Android Things?

- Will Android Things become a useful tool for embedded programming?
 - Tied to Google ecosystem
 - Focus appears to be on smart displays (large and small) and home automation hubs

Interfacing Android Things: Observations

Whither Android Things?

- Will Android Things become a useful tool for embedded programming?
 - In my view, Google needs an edge computing solution
 - Important for Google IoT Cloud

Interfacing Android Things: Observations

Whither Android Things?

- Will Android Things become a useful tool for embedded programming?
 - Lots of competition in these spaces
 - Even within Google
 - Chrome
 - Fuchsia
 - Cloud IoT Edge / Linux

Interfacing Android Things

Android Things “Makes embedded development as simple as mobile development has become”

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While the Android Things ecosystem demonstrates some potentially useful capabilities, it is no panacea for the challenges that face embedded developers.

- Tim Salo, IoT Devfest 2019