# An Introduction to the Operating Systems of the IoT

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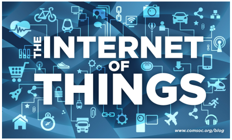
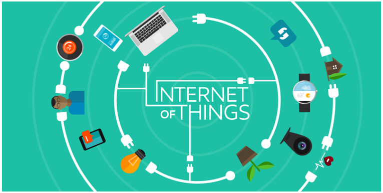
### What is IoT...

The Internet of Things (IoT) is a scenario in which objects, animals or people are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.



# Open Source Operating Systems for the IoT

- FreeRTOS
- RIOT
- Contiki
- TinyOS
- Embedded Linux
- OpenWSN



# FreeRTOS

- FreeRTOS is designed to be small and simple.
- The kernel itself consists of only three or four C files.
- It provides methods for multiple threads or tasks, mutexes, semaphores and software timers.
- Key features are very small memory footprint, low overhead, and very fast execution.

# RIOT

- RIOT is a real-time multi-threading operating system.
- RIOT is based on design objectives including:
  - Energy-Efficiency
  - Reliability
  - Real-Time Capabilities
  - Small Memory Footprint
  - Modularity
  - Uniform API Access
    independent of the underlying hardware
    (this API offers partial POSIX compliance)

# Contiki

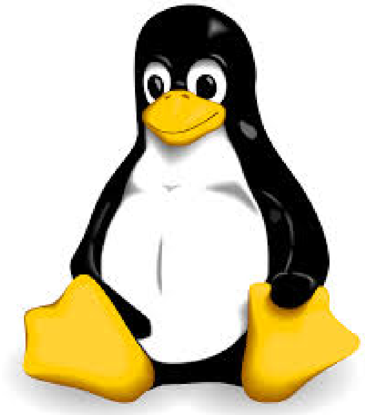
- Contiki is an open source operating system for networked, memory-constrained systems
- Contiki provides three network mechanisms:
  - The uIP stack, which provides IPv4 networking,
  - The uIPv6 stack, which provides IPv6 networking,
  - The Rime stack, which is a set of custom lightweight networking protocols designed specifically for low-power wireless networks.

# TinyOS

- TinyOS is a component-based operating system and platform targeting wireless sensor networks.
- TinyOS is an embedded operating system written in the nesC programming language as a set of cooperating tasks and processes.

# Embedded Linux

- Embedded Linux is created using OpenEmbedded, the build framework for embedded Linux.
- OpenEmbedded offers a best-in-class cross-compile environment.



# OpenWSN

- The goal of the OpenWSN project is to provide open-source implementations of a complete protocol stack based on Internet of Things standards, on a variety of software and hardware platforms.

# Comparison

| OS | Min RAW | Min ROM | C Support | C++ Support |
|---|---|---|---|---|
| Contiki | $< 2kB$ | $< 30kB$ | Partial support | No support |
| Tiny OS | $< 1kB$ | $< 4kB$ | No support | No support |
| Linux | $\sim 1MB$ | $\sim 1MB$ | Full support | Full support |
| RIOT | $\sim 1.5kB$ | $\sim 5kB$ | Full support | Full support |

# Comparison

| OS | Multi-Threading | Modularity | Real-Time |
|---|---|---|---|
| Contiki | Partial support | Partial support | Partial support |
| Tiny OS | Partial support | No support | No support |
| Linux | Full support | Partial support | Partial support |
| RIOT | Full support | Full support | Full support |

# Why Not Linux?

### Real-Time Linux

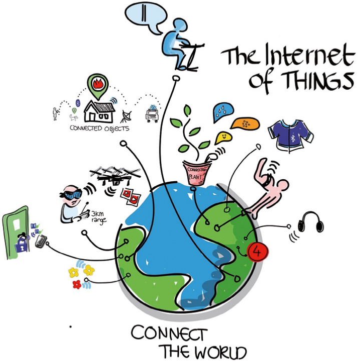
> Controlling a laser with Linux is crazy, but everyone in this room is crazy in his own way. So if you want to use Linux to control an industrial welding laser, I have no problem with your using PREEMPT_RT.
>
> \- Linus Torvalds

# Why Not Linux?

- Linux certainly is a robust, developer-friendly OS
- Linux has a disadvantage when compared to a real-time operating system:
  - Memory footprint
  - It simply will not run on 8 or 16-bit MCUs

# Requirements for IoT

- Scalability
- Modularity
- Connectivity
- Reliability



# Internet Usage and Protocols for the IoT

- Can you build an IoT system with familiar Web technologies?

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- Can you build an IoT system with familiar Web technologies?
- Yes you can, although the result would not be as efficient as with the newer protocols.

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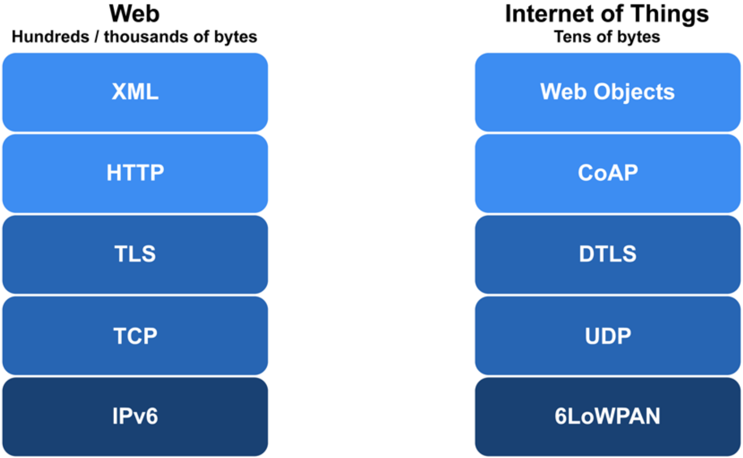

**Web**

Hundreds / thousands of bytes

XML

HTTP

TLS

TCP

IPv6

**Internet of Things**

Tens of bytes

Web Objects

CoAP

DTLS

UDP

6LoWPAN

- Inefficient content encoding
- Huge overhead, difficult parsing
- Requires full Internet devices

- Efficient objects
- Efficient Web
- Optimized IP access

Questions?