An Introduction to the Operating Systems of the IoT

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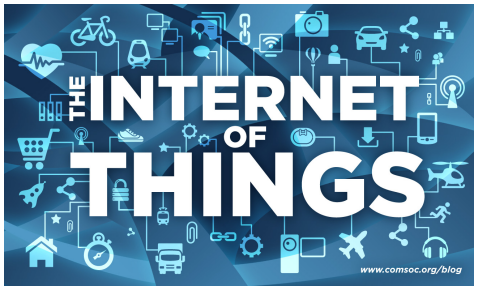
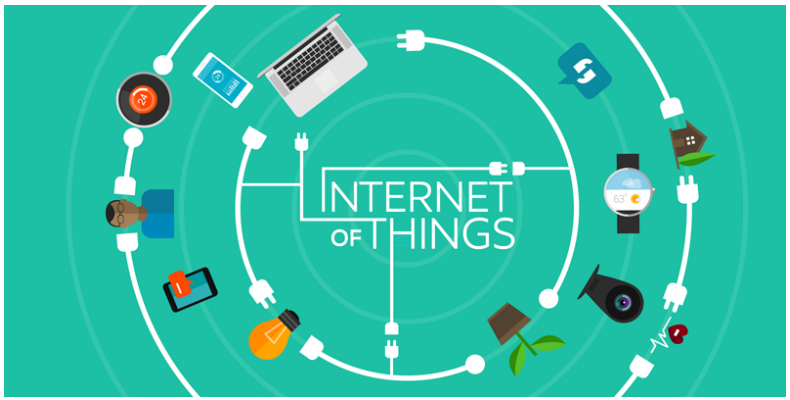
What is IoT...

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

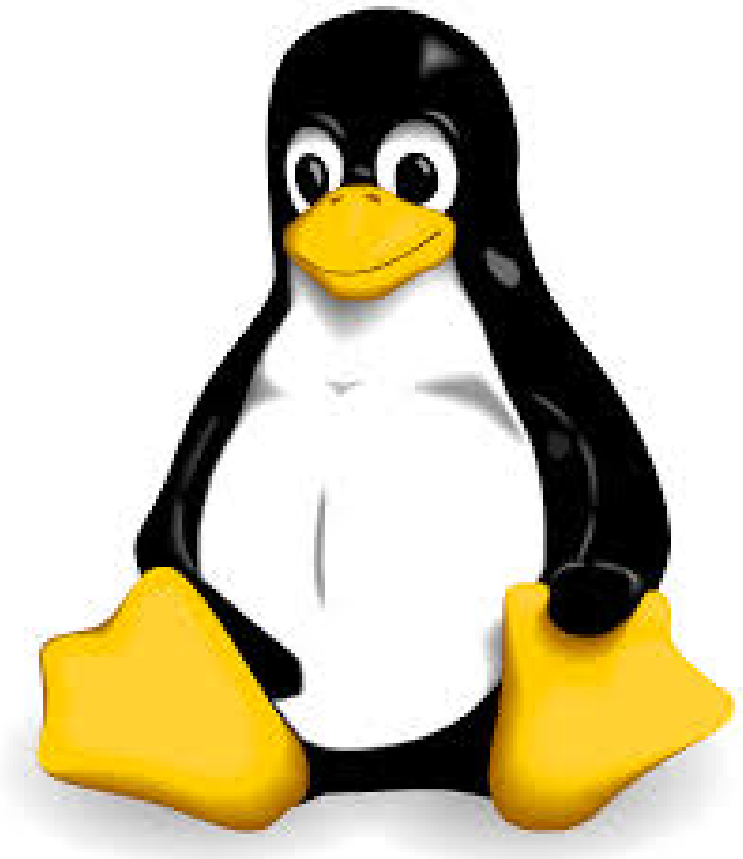
- Contiki is an open source operating system for networked, memory-constrained systems
- Contiki provides three network mechanisms:
  - The uIP stack, which provides IPv4 networking,
  - The uIPv6 stack, which provides IPv6 networking,
  - The Rime stack, which is a set of custom lightweight networking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

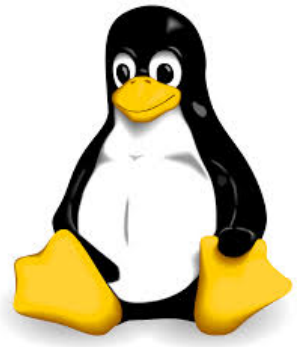


OpenWSN

- 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.

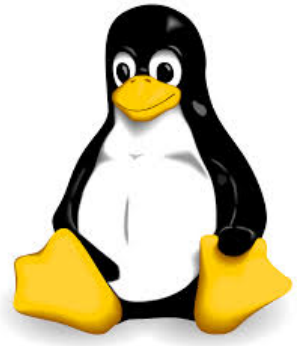
Comparison

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.

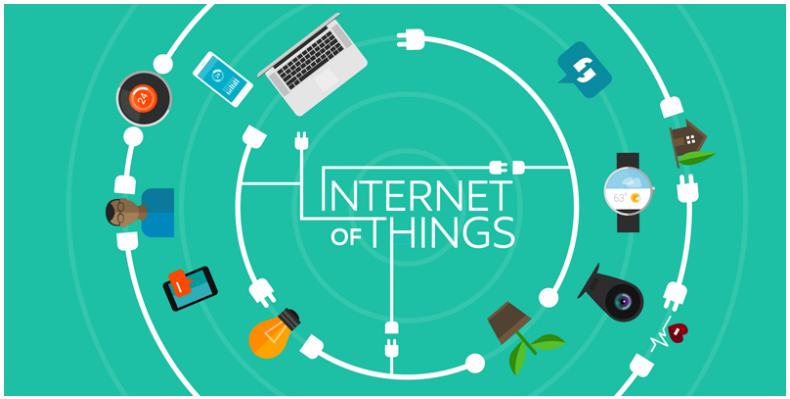
- Linus Torvalds

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
- Linux will certainly have many uses in embedded devices, particularly ones that provide graphically rich user interfaces.
- There are thousands of applications for which Linux is ill suited.

Close Source Operating Systems for the IoT

- ARM mbed
- Huawei LiteOS
- Google Brillo

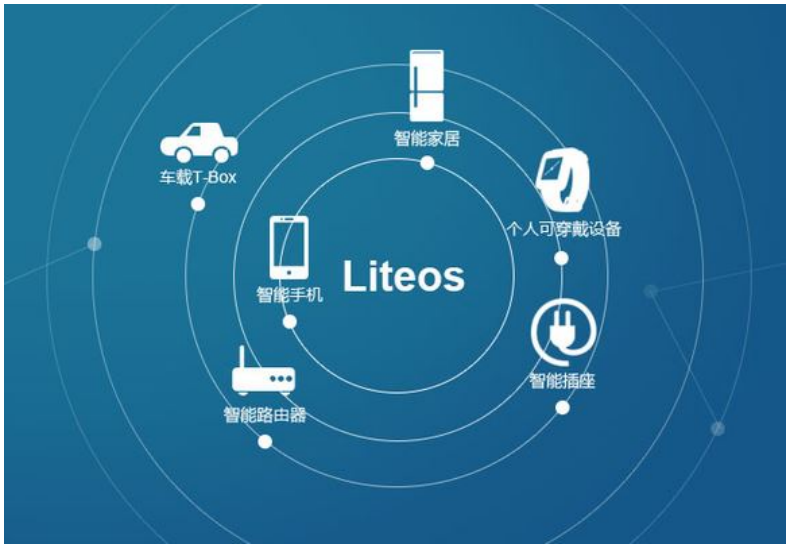


ARM mbed

- Automation of power management
- Software asset protection and secure firmware updates for device security & management
- Connectivity protocol stack support for Bluetooth low energy, Cellular, Ethernet, Wi-fi, Zigbee IP, Zigbee NAN, 6LoWPAN

Huawei LiteOS

- The company says that its LiteOS is the lightest software of its kind and can be used to power a range of smart devices

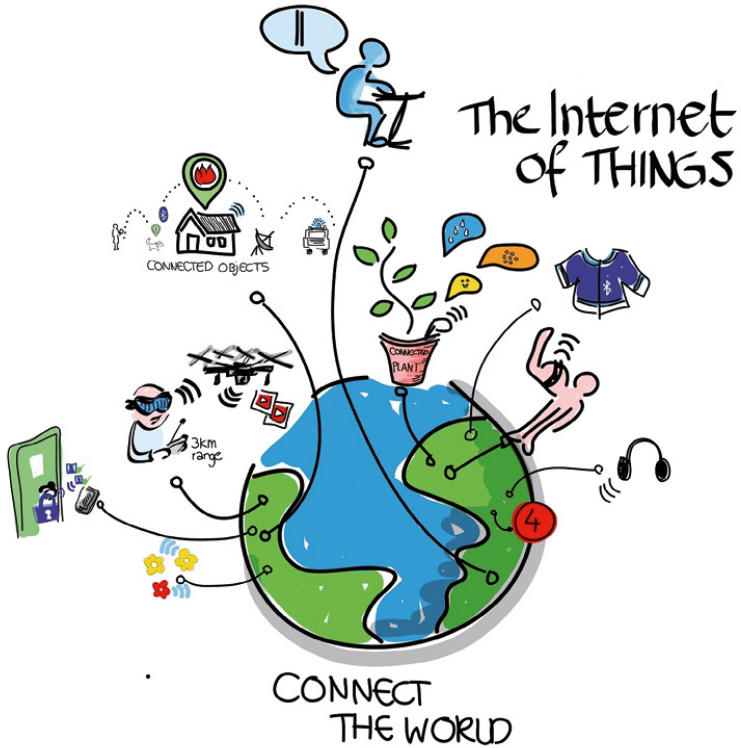


Google Brillo

- Brillo is derived from Android but polished to just the lower levels.
- It supports Wi-Fi, Bluetooth Low Energy, and other Android things.

Requirements for IoT

- Scalability
- Modularity
- Connectivity
- Reliability



Internet Usage and Protocols for the IoT

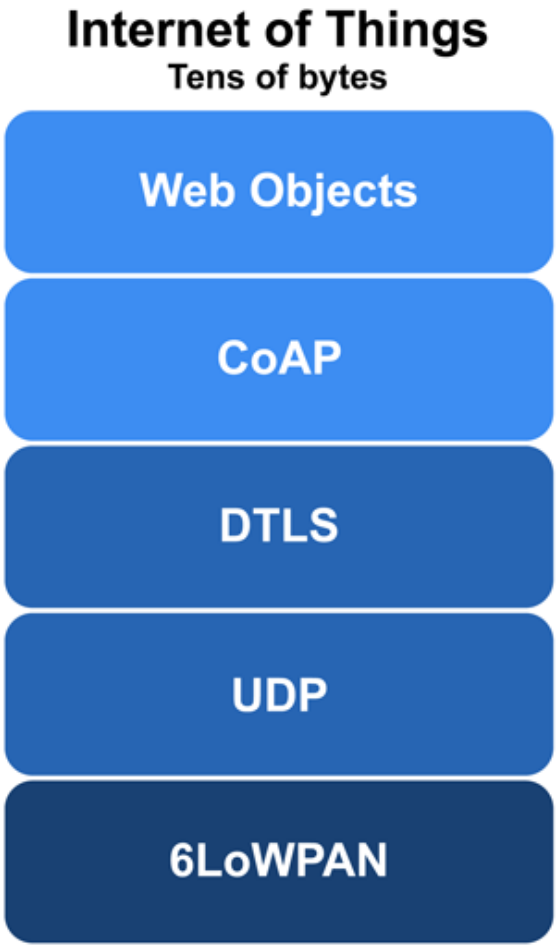
- Can you build an IoT system with familiar Web technologies?

Internet Usage and Protocols for the IoT

- 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.

Internet Usage and Protocols for the IoT

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



- Efficient objects
- Efficient Web
- Optimized IP access

Internet Usage and Protocols for the IoT

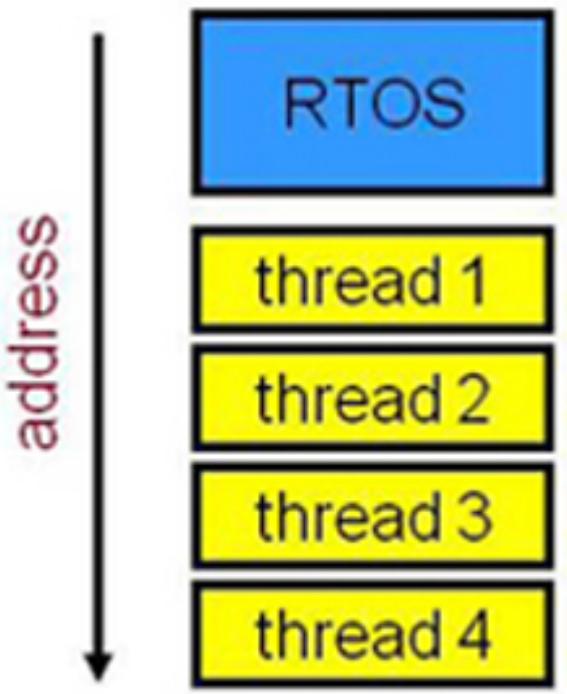
Protocol	*Transport*	*Messaging*	*2G,3G,4G (1000's)*	*LowPower and Lossy (1000's)*	*Compute Resources*	*Security*	*Success Stories*	*Arch*
CoAP	UDP	Rqst/Rspnse	Excellent	Excellent	10Ks/RAM Flash	Medium - Optional	Utility field area ntwks	Tree
Continua HDP	UDP	Pub/Subsrb Rqst/Rspnse	Fair	Fair	10Ks/RAM Flash	None	Medical	Star
DDS	UDP	Pub/Subsrb Rqst/Rspnse	Fair	Poor	100Ks/RAM Flash +++	High- Optional	Military	Bus
DPWS	TCP		Good	Fair	100Ks/RAM Flash ++	High- Optional	Web Servers	Client Server
HTTP/ REST	TCP	Rqst/Rspnse	Excellent	Fair	10Ks/RAM Flash	Low- Optional	Smart Energy Phase 2	Client Server
MQTT	TCP	Pub/Subsrb Rqst/Rspnse	Excellent	Good	10Ks/RAM Flash	Medium - Optional	IoT Msging	Tree
SNMP	UDP	Rqst/Response	Excellent	Fair	10Ks/RAM Flash	High- Optional	Network Monitoring	Client-Server
UPnP		Pub/Subscrb Rqst/Rspnse	Excellent	Good	10Ks/RAM Flash	None	Consumer	P2P Client Server
XMPP	TCP	Pub/Subsrb Rqst/Rspnse	Excellent	Fair	10Ks/RAM Flash	High- Manditory	Rmt Mgmt White Gds	Client Server
ZeroMQ	UDP	Pub/Subscrb Rqst/Rspnse	Fair	Fair	10Ks/RAM Flash	High- Optional	CERN	P2P

Modularity

- IoT device will require a modular operating system that separates the core kernel from middleware, protocols, and applications.

Multi-Tasking, Thread Model

- Most RTOS products on the market are thread model.
- Tasks are now called threads.
- All the tasks code and data occupy the same address space, along with that of the RTOS itself.



Event-Driven, Non-Blocking I/O Model

- Networking Event-Driven
- Non-Blocking I/O

Questions?