Building the Internet of Things

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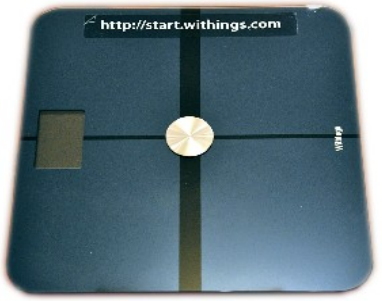
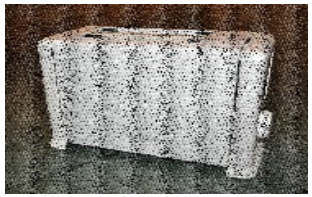
Internet of Things (IOT)

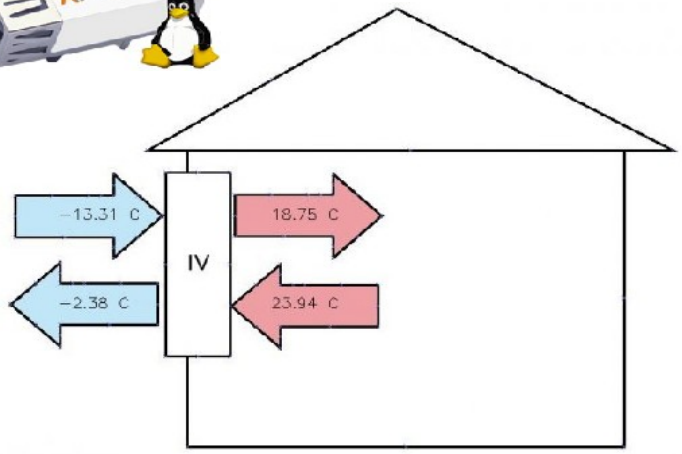
- Everything that benefits from networking will eventually be networked
- As with previous major developments, the Internet will evolve to meet the demand
- There are tremendous cost and other advantages to using IP for all communications
- Not a future thing – we are already there
- We do not always need more research, standards, or new architectures!

IOT is Already Here

- Energy meter with cellular uplink
- Weight scale with Wireless LAN
- IPv6 networking to devices in home
- Home with a SMS, chat, and Facebook user interface







Technology is Already Here

- 2G/3G/4G cellular modules being embedded everywhere – Ericsson 50B prediction
- Ethernet, Wireless LAN, Zigbee – LANs
- IPv6 – crucial for reaching billions of devices
- Web technology, HTTP, XML/JSON, REST, COAP, TLS – easy and universally available

Some Remaining Challenges

Of course, the world is not completely ready:

- We have worked, and will keep on working on remaining challenges
- Examples of recent work in the IETF include routing across multihop sensor networks (ROLL/RPL) and lightweight UDP-based variant of HTTP (CORE/COAP)
- Focusing here on two additional issues: sleeping nodes and interoperability

Sleeping Nodes

- Universal deployment requires wireless technology in many application areas, ruling out PoE and similar solutions
- We desperately need very long battery lifetimes for these devices (months...years...a decade)
- In most cases, this can only be achieved if the device can sleep >99.9% of its time

Why Sleeping is Difficult

Sleeping is difficult for various reasons:

- The communication model requires instant responses (e.g., request – response, web servers)
- Keeping link up in case a message might arrive
- Coming back after sleep implies an expensive network rejoining process (L2, DNA, DAD, DHCP)
- Additional protocol exchanges require staying on for another RTT

Solution Directions

- Changing the communication model (proxies, caches, DTN, store-and-forward)
- Improvements in L2 to avoid staying on unless required by the application
- IPv6 Neighbor Discovery & DAD improvements

Interoperability Challenges

We have remaining work in creating a truly *interoperable* Internet of Things

There are several reasons for this:

- A capability mismatch between different devices
- Need to agree on semantics (e.g., 1 => light on)
- Domain-specific solutions

Capability Differences

- MTU differences
- Simplified vs. full blown web protocol stack (COAP/UDP vs. HTTP/TCP)
- Single stack vs. dual stack
- Sleep schedule
- Processing and communications bandwidth

The key question is whether there are *true capability differences* or just ones we created through incompatible standards?

Semantic Interoperability

- Do we want to build the *Internet of Things Transport Network* based on IP technology?
  - Everything over IP, IP over everything
  - Routers, firewalls, DNS, and basic stack common technology
- That would be tremendously useful, but not by itself an *interoperable Internet of Things*
- For true interoperability, we need to agree on what the messages mean
- Standards vs. code approach (HTML5 vs. Flash)

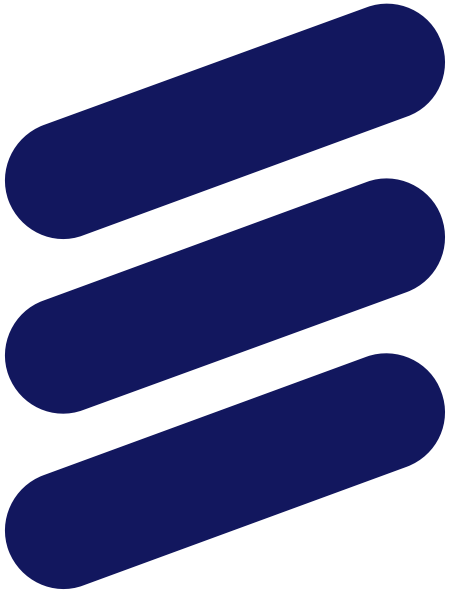
Domain-Specific Solutions

- Some of the problems in this area are hard – really hard
- There is a desire to build optimized solutions that can solve the problem in a particular setting but may not be general enough for all situations
- This leads to point solutions and interoperability problems between them
- Examples: RPL storing vs. non-storing modes, XML vs. JSON vs. binary in transporting data from sensors, ...

Improving Interoperability

- Additional standards for applications, data formats
- Pushing back on domain-specific solutions
- Architectures that employ gateways and middleware

Internet protocol was successful because it was good enough, easy to deploy and scalable, *not* because it was highly optimized to the hardware at the time



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