Management of the Internet of Things

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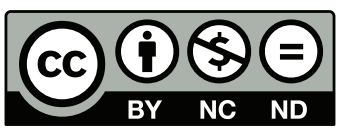

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http://cnds.eecs.jacobs-university.de/

Traveling to NOMS in the IoT Age...

To reach an early morning flight to Krakow, I had to wake up at 5am. The heating system in my house runs on a relatively static schedule. If I have to get up early, there is a good chance that the water is not yet warm or the pumps circulating the hot water are still off. With the IoT, it should be simple to make my heating system read my agenda (that is the agenda of all family members and my guests) so that it knows how to adapt its schedule.

Traveling to NOMS in the IoT Age...

Why is this complicated?

1. heating systems do not expose an API
2. vendors prefer to ship yet another smart-phone app (instead of an API)
3. the apps do not help with automation
4. *family members* is easy to define, *guests* is much harder

IoT - Internet of Light Bulbs?

Year	Company	Product	Radio
2012	Philips	Hue	802.15.4
2013	Lümen by Tabü	Lumen Smart Bulb	Bluetooth
2014	LIFIX Labs	LIFX	WiFi / 802.15.4
2014	Samsung	LED Smart Bulbs	Bluetooth
2014	LG Electronics	?	Bluetooth

1. Most products come with proprietary smart phone apps
2. Some provide APIs to enable new applications
3. These bulbs are initially pretty expensive, but...
4. In the long run, they will compete based on price
5. What about firmware updates in the light bulbs?
6. What about accidental bugs? Or not so accidental bugs?

IoT is much more than Home Automation!

1. Environmental Monitoring
2. Infrastructure Monitoring
3. Industrial Applications
4. Energy Management
5. Medical Applications
6. Building Automation
7. Home Automation
8. Transport Applications
9. Vehicular Networks
10. Community Network Applications

...

⇒ draft-ietf-opsawg-coman-use-cases-01

⇒ Huge differences concerning management tasks, time scales, people involved in management processes, ...

IoT Protocol Stack (IETF centric view)

Layer(s)	Protocol(s)
7	**CoAP + extensions**
5	DTLS + **extensions**
4	UDP
3	IPv6/ICMPv6/**RPL**
2.5	**6LoWPAN**
1-2	IEEE 802.15.4, DECT-ULE, BT-LE, ...

⇒ There are lots of other protocols (and players) in this space: `http://postscapes.com/internet-of-things-protocols`

⇒ Link layers come and go and it matters what smart phones (the universal remote controls) support

IoT Related IETF Working Groups

Time-frame	Working Group	Documents (2014-05-07)
2006-2014	6lowpan	6 RFCs
2008-	roll	12 RFCs
2010-	core	1 RFC (1 RFC Ed Queue)
2011-	lwig	(1 RFC Ed Queue)
2013-	6lo	none yet
2013-	dice	none yet

- $\Rightarrow$ Close to 10 years of IoT related work in the IETF
- $\Rightarrow$ Like with research papers, some RFCs are more important than others (# of documents is not a useful metric)
- $\Rightarrow$ Some RFCs are built on implementation experience, others are implemented after publication (and some never)

Network Management Protocols (IETF centric)

Traditional network management protocols:

1. SNMP (primarily monitoring, event notification)
2. NETCONF (primarily configuration)
3. SYSLOG (event notification)
4. IPFIX (primarily measurement)

Other protocols addressing network management problems:

5. RADIUS/DIAMETER (authentication / authorization / accounting)
6. DHCP (bootstrapping, auto-configuration)
7. MDNS (discovery)

...

IoT Management Protocols?

1: Use what we have?

Make traditional network management protocols work in the IoT context.

2: Adapt what we have?

Keep existing data models but adapt the protocols to work within the IoT protocol stack.

3: Restart from scratch?

Rethink network management, which management protocol functionality is needed and how it can be provided.

$\Rightarrow$ How to choose between these alternatives?

$\Rightarrow$ To what extend does constraintness impact the decision?

IoT Embedded Device Classes

Constrained devices

Class	RAM	Flash
C0	$<<$ 10 KiB	$<<$ 100 KiB
C1	$\approx$ 10 KiB	$\approx$ 100 KiB
C2	$\approx$ 50 KiB	$\approx$ 250 KiB

$\Rightarrow$ Running specialized operating systems (Contiki, ...)

Not-so-constrained devices

Class	RAM	Flash
CS	$\approx$ 1 MiB	8 MiB
CM	$\approx$ 8/16 MiB	16 MiB

$\Rightarrow$ Capable to run embedded Linux / BSD systems

IoT Deployment Options

- DO0 Network of constrained devices, which communicate with each other (but nothing else)
- DO1 Constrained devices directly connected to the Internet or an IP network
- DO2 A network of constrained devices which communicate with a proxy acting as a representative of the device to entities on the Internet
- DO3 Constrained devices connected to the Internet or an IP network via a proxy (e.g., protocol translation)
- DO4 A hierarchy of constrained devices, e.g., C0 devices connected to C1 devices connected to C2 devices connected to gateways
- DO5 Device grouping (possibly in a dynamic manner) where the grouped devices act as one logical device at the edge of the network

IoT Monitoring Functionality Levels

- ML0 Devices push pre-defined monitoring data.
- ML1 Devices allow management systems to pull pre-defined monitoring data.
- ML2 Devices allow management systems to pull user-defined filtered subsets of monitoring data.
- ML3 Devices are able to locally process monitoring data in order to detect threshold crossings or to aggregate data.

IoT Configuration Functionality Levels

- CL0 Devices are pre-configured and allow no runtime configuration changes.
- CL1 Devices have explicit configuration objects. However, changes require a restart of the device to take effect.
- CL2 Devices allow management systems to replace the entire configuration in bulk; changes take effect by soft-restarts.
- CL3 Devices allow management systems to modify individual configuration objects and changes take effect immediately.
- CL4 Devices support multiple configuration datastores and may distinguish between the running and startup config.
- CL5 Devices support configuration datastore locking and device-local configuration change transactions.
- CL6 Devices support configuration change transactions across devices.

Your Help is Needed!

- ⇒ The many possible combinations of the various options (e.g., C2-DO3-ML1-CL2) makes it very hard to find (agreement on) proper solutions
- ⇒ Help reviewing the constrained management use cases and problem statement / requirements Internet-Drafts (What have we missed? What did we get wrong?)
- ⇒ If you have ideas on self-management, try to apply them to IoT scenarios and show that they work
- ⇒ If you have ideas how to translate data models or protocols to make things more IoT friendly, implement them and share the results with the community
- ⇒ If you have ideas on radically different approaches for network management protocols, try to apply them to IoT scenarios and show that they work

Reading Material

M. Ersue, D. Romascanu, J. Schoenwaelder, and A. Sehgal.

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Internet-Draft (work in progress) <draft-ietf-opsawg-coman-use-cases-01>, Nokia Siemens Networks, Avaya, Jacobs University Bremen, February 2014.

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An Overview of the IETF Network Management Standards.
RFC 6632, Nokia Siemens Networks, Cisco Systems, June 2012.