Internet of Things

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Content

• Introduction to Internet of Things (IoT)

• Challenges

• IPv6 / 6LoWPAN

• ROLL
What is Internet of Things (IoT)

- Internet
  - TCP/IP
- Things
  - Criteria
Elements of IoT

- Enablers
  - Radio frequency identification (RFID)
  - Wireless sensor networks (WSN)
- Data analysis
- Visualisation
Applications

Internet of Things
Sensing, Analytics and Visualization tools

Anytime, Anything, Anywhere

Home
- Security
- Health
- Entertainment

Utilities and Appliances

Transport
- Traffic
- Parking
- Emergency Services
- Highways

Community
- Retail
- Environment
- Surveillance
- Business Intelligence

National
- Utilities
- Infrastructure
- Smart Grid
- Defense
- Remote Monitoring

Image by Gubbi et al.
IoT is interesting

- Huge potential
- Opportunities
- Improved quality of life
- Minimal requirement for users
But there are challenges to handle

- Address crisis

- Interoperability
  - IEEE 802.15.4 at MAC layer
  - A heterogeneous collection of existing or emerging technologies atop

- Others
Look at the waist!

- Hourglass shaped TCP/IP protocol suite
- Ideal platform for interoperability
IPv4 is unlikely to cope

• An IPv4 address is 32 bits long
  • $2^{32}$, over 4.2 billion addresses
  • Managed by Internet Assigned Numbers Authority (IANA) and regional Internet registry (RIR)
  • Thought to be enough at the time of invention (1977)

• Reality proves otherwise
  • The last 5 blocks of main IPv4 addresses maintained by IANA were allocated to RIRs on 3 February 2011
  • Demand is still growing drastically
  • We need IPv6
IPv6 - Every bit helps, let alone 128

• 128 bits fields = $2^{128}$ addresses
  $(340,282,366,920,938,463,463,374,607,431,768,211,456)$

• Wiki: approx. $4.8 \times 10^{28}$ (48000 trillion trillion) addresses for each of the 7 billion people alive on earth (as in 2011)
Might be too heavy for “Things”

- IPv6 header (40 bytes) is much longer than that of IPv4
- Maximum length of IEEE 802.15.4 data frame is only 127 bytes

![Diagram of Uncompressed IPv6 over IEEE 802.15.4]

- Proportion of upper layer data: 53/127.
- IPv6 over Low power Wireless Personal Area Networks (6LoWPAN)
6LoWPAN

- Adaptation layer

- Fully compatible with IPv6

- Header compression
Header compression

- HC1: For IPv6

IEEE 802.15.4 Frame Format
- D pan
- Dst EUID 64
- $\text{preamble}$
- $\text{FCF}$
- $\text{FCF}$
- $\text{Src16}$
- $\text{Dst16}$
- $\text{Fchk}$

IETF 6LoWPAN Format
- Uncompressed IPv6 address [RFC2460]: 40 bytes
- Fully compressed: 1 byte

- 00: Not a LoWPAN frame
- 01: LoWPAN IPv6 addressing
IPv6 address & EUI64 - recap

Subnet Prefix

48 Bits
Prefix (ISP-assigned)

16 Bits
Subnet

64 Bits
Interface ID

EUI-64 Format

1st Half of MAC

FFFE

2nd Half of MAC

Flip 7th Bit (Reading Left to Right) in First Byte to a Binary 1
<table>
<thead>
<tr>
<th>Field</th>
<th>Size IPv6</th>
<th>Size 6LoWPAN</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version</td>
<td>4 bits</td>
<td>-</td>
<td>IPv6 communication implied</td>
</tr>
<tr>
<td>Traffic class</td>
<td>8 bits</td>
<td>1 bit</td>
<td>0= No compression</td>
</tr>
<tr>
<td>Flow label</td>
<td>20 bits</td>
<td>1 bit</td>
<td>1= Compressed. Traffic class and flow label set to 0.</td>
</tr>
<tr>
<td>Payload length</td>
<td>16 bits</td>
<td>-</td>
<td>Can be obtained from the MAC frame or the fragmentation header.</td>
</tr>
<tr>
<td>Next header</td>
<td>8 bits</td>
<td>2 bits</td>
<td>Only TCP,UDP or ICMPv6 is used.</td>
</tr>
<tr>
<td>Hop limit</td>
<td>8 bits</td>
<td>8 bits</td>
<td>This field is never compressed.</td>
</tr>
<tr>
<td>Source address</td>
<td>128 bits</td>
<td>2 bits</td>
<td>If both addresses share the local network, the 64 bit network prefix compresses to just one bit, always set to 1. If the interface address can be obtained from the mesh or MAC headers, it compresses to justo one bit always set to 1.</td>
</tr>
<tr>
<td>Destination address</td>
<td>128 bits</td>
<td>2 bits</td>
<td></td>
</tr>
<tr>
<td>HC2 encoding</td>
<td>-</td>
<td>1 bit</td>
<td>Informs if next header is also compressed.</td>
</tr>
<tr>
<td>Total</td>
<td>40 bytes</td>
<td>2 bytes</td>
<td></td>
</tr>
</tbody>
</table>
HC1 cont’d

- Source prefix compressed (to L2)
- Source interface identifier compressed (to L2)
- Destination prefix compressed (to L2)
- Destination interface identified compressed (to L2)
- Traffic and Flow Label zero (compressed)
- Next Header
  - 00 uncompressed, 01 UDP, 10 TCP, 11 ICMP
- Additional HC2 compression header follows

Zero or more uncompressed fields follow in order

- IPv6 address <prefix64 || interface id> for nodes in 802.15.4 subnet derived from the link address.
  - PAN ID maps to a unique IPv6 prefix
  - Interface identifier generated from EUID64 or Pan ID & short address
- Hop Limit is the only incompressible IPv6 header field
HC2

- Indicated by HC1 header
- For UDP

**IEEE 802.15.4 Frame Format**
- D pan, Dst EUID 64
- S pan, Src EUID 64

**IETF 6LoWPAN Format**
- Dispatch: Compressed IPv6
- HC1: Source & Dest Local, next hdr=UDP
- IP: Hop limit
- UDP: 8-byte header (uncompressed)
HC2 cont’d

- HC2 : flag bits for source port, destination port and length compression
- Port numbers : 0xF0Bn
Effect of header compression

**HC1 compressed IPv6 over IEEE 802.15.4**

- Best case proportion of upper layer data: 91/127

**HC1/HC2 compressed IPv6 over IEEE 802.15.4**

- Best case proportion of upper layer data: 95/127
Limitation

- Efficiency drops for non-link-local communication

- Context-based compression
Experimental work in lab
– setting up

Internet host
IPv4: 128.32.33.68
IPv6: 2001:470:1f04:fe3::2/64

IPv4
IPv4: 72.52.104.74
IPv6: 2001:470:1f04:98e::1/64

tunnel server
IPv4: 72.52.104.74
IPv6: 2001:470:1f04:98e::1/64

tunnelbroker.net
IPv6: tunnelbroker.net

IPv4
IPv4: 72.52.104.74
IPv6: 2001:470:1f04:98e::1/64

IPv4
IPv4: 72.52.104.74
IPv6: 2001:470:1f04:98e::1/64

IPv4
IPv4: 128.32.33.137
IPv6: 2001:470:1f05:98e::2/64

OpenLBR
eth0
IPv4: 128.32.33.137
IPv6: 2001:470:1f04:98e::2/64

tun0
IPv6: 2001:470:1f05:98e::1/64

IPv6
IPv6: 2001:470:1f05:98e::1/64

IPv6
IPv6: 2001:470:1f05:98e::1/64

IPv6
OpenWSN
IPv6: 2001:470:1f05:98e::1/64

Image by OpenWSN
Experimental work in lab
- GINA

- Guidance and Inertial Navigation Assistant (GINA) motes
Experimental work in lab - eBox

- Gateway / edge router between IPv4-based Internet and IPv6-based WSN
Sample packet

--6LowPAN packet--
000000 78 00 11 40 23 45 00 00 00 00 00 14 15 92 09 x..@............
000010 02 2c ed c5 20 01 06 30 00 c2 ff 00 00 00 00 00 ........0........
000020 00 00 01 7f 00 9b 0a 51 00 23 69 0b 11 2a 53 62 ........Q.#i..*Sb
000030 62 6b ed c5 0a 00 00 00 70 f9 13 03 00 00 00 24 bk....p......$
000040 ff ff ff ff c9 fd 99

--IPv6 packet--
Version: 6
Traffic class: 0
Flow label: 0
Payload length: 35
Next_header: 17
Hop limit: 64
Src address: 234500000000000014159209022c6d5c5
Dst address: 2001063000c2ff00000000000000017f
Payload:
009b0a510023690b112a5362626bedc50a00000070f9130300000024fffffffc9fd99

000000 00 00 86 dd 60 00 00 00 00 00 23 11 40 00 00 00 00 ........#.@....
000010 00 00 00 00 14 15 92 09 02 2c ed c5 20 01 06 30 ..............0
000020 00 c2 ff 00 00 00 00 00 00 00 00 01 7f 00 9b 0a 51 ..............Q
000030 00 23 69 0b 11 2a 53 62 62 6b ed c5 0a 00 00 00 .#i..*Sbbk....
000040 70 f9 13 03 00 00 00 24 ff ff ff ff c9 fd 99 p......$.......
Routing Over Low power and Lossy networks (ROLL)

- IETF ROLL working group

- Properties
  - Limited memory of devices
  - Constraint energy
  - Heterogeneous routing metrics

- IPv6 Routing Protocol for LLNs (RPL)
RPL

- Destination Oriented Directed Acyclic Graph (DODAG)
  - Grounded at root/gateway
  - Individual rank for each node (0 for the root)
  - Next hop chosen based on neighbours’ ranks

- Ranking information exchanged via DAG Information Object (DIO)
  - Sent in RPL Control Message (ICMPv6)
RPL cont’d

• ROLL identifies a number of routing metrics
  • Node-related:
    • Memory, CPU, energy, workload
  • Link-related:
    • throughput, latency, reliability, colouring

• Multiple metrics can be used as tie-breakers

• Impractical to define a metric that satisfies all use cases
I hope you have

• A brief idea what Internet of Things is and why it is interesting to us

• Appreciated IPv6 is one of the enabling techniques for future development

• A basic understanding of 6LoWPAN and ROLL