IoT Roadmap in the IETF

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Agenda

IETF and IoT Definitions
IETF IoT WGs
  Internet Area: 6lo, 6tisch, Ipwan, Iwig, ipwave
  Routing Area: roll
  Application and Real Time Area: core
  Security Area: ace

IRTF IoT WG: t2trg
Conclusions
IoT (Internet of Things)
IoT (Internet of Things)

Everything that can be connected will be connected
IoT (Internet of Things)

Everything that can be connected will be connected

Adapt the Internet to different types of networks such as constrained networks/nodes, e.g. send temperature in a 802.15.4 packet
IoT (Internet of Things)

Everything that can be connected will be connected

Adapt the Internet to different types of networks such as constrained networks/nodes, e.g. send temperature in a 802.15.4 packet

Constraints Networks
- low achievable bit rate/throughput
- high packet loss and high variability of packet loss
- highly asymmetric link characteristics,
- limits on reachability over time

Constrained Nodes:
- Limits on power
- Memory
- Processing resources
IoT (Internet of Things)

*Everything* that can be *connected* will be connected

*Adapt* the Internet to different types of networks such as constrained networks/nodes, e.g. send temperature in a 802.15.4 packet

Adapt IPv6
IoT (Internet of Things)

Everything that can be connected will be connected

Adapt the Internet to different types of networks such as constrained networks/nodes, e.g. send temperature in a 802.15.4 packet

Adapt IPv6

Modeling the routing
IoT (Internet of Things)

Everything that can be connected will be connected

Adapt the Internet to different types of networks such as constrained networks/nodes, e.g. send temperature in a 802.15.4 packet

Adapt IPv6  
Modeling the routing  
Modeling the web transfer
IoT (Internet of Things)

Everything that can be connected will be connected

Adapt the Internet to different types of networks such as constrained networks/nodes, e.g. send temperature in a 802.15.4 packet

Adapt IPv6

Modeling the routing

Modeling the web transfer

Security, Mgmt
IoT (Internet of Things)

Everything that can be connected will be connected

Adapt the Internet to different types of networks such as constrained networks/nodes, e.g. send temperature in a 802.15.4 packet
HOW STANDARDS PROLIFERATE:
(SEE: A/C CHARGERS, CHARACTER ENCODINGS, INSTANT MESSAGING, ETC)

SITUATION:
THERE ARE 14 COMPETING STANDARDS.

14?! RIDICULOUS!
WE NEED TO DEVELOP ONE UNIVERSAL STANDARD THAT COVERS EVERYONE'S USE CASES. YEAH!

SOON:

SITUATION:
THERE ARE 15 COMPETING STANDARDS.

**Handbook:** Internet of Things Alliances and Consortia

<table>
<thead>
<tr>
<th>Technology / Architecture Focused</th>
<th>Marketing / Education</th>
</tr>
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<tbody>
<tr>
<td>Link / Comms</td>
<td>Application Developers, Alliance</td>
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<td>Core / Session / Transport / Messaging / Semantic</td>
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<td>MultiLayer</td>
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<td>Vertical Focused</td>
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<table>
<thead>
<tr>
<th>Connected Body</th>
<th>Connected Home</th>
<th>Connected City / Buildings</th>
<th>Transportation</th>
<th>Industrial IoT</th>
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<tr>
<td>Protocol</td>
<td>HealthKit</td>
<td>Wireless Life Sciences Alliance</td>
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<td>Industry</td>
<td>EnOcean Alliance</td>
<td>Open Automotive Alliance</td>
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<td>Continua</td>
<td>Industrial Internet Consortium</td>
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</table>
Internet Engineering Task Force

ORGANIZATION OF VOLUNTARY PARTICIPATION WHOSE GOAL IS....

https://ietf.org/
TO MAKE THE INTERNET WORK BETTER
The goal of the Internet Engineering Task Force (IETF) is to make the Internet work better.
The goal of the The Internet Engineering Task Force (IETF) is to make the Internet work better.

TCP/IP Stack

Physical

Data Link (MAC + LLC)

Internet

Transport

Application

IETF

Applications and Real-Time
General
Internet
Ops & Mgmt
Routing
Security
Transport
IRTF

e.g. IEEE, 3GPP
The goal of the The Internet Engineering Task Force (IETF) is to make the Internet work better.
802.15.4 networks have a MTU of 127 bytes. Very hard to send an IPv6 packet.
LET'S COMPRESS THE IPV6 HEADER
IPv6 over Low Power Wireless Personal Area Networks (6LoWPAN) aims to compress the IPv6 header

IPv6 over Low power WPAN (6lowpan) aims to compress the IPv6 header

- RFC 4944 defines a first version (LOWPAN_HC1) => not efficient

- RFC 6282 defines
  IPv6 Header Compression (LOWPAN_IPHC)
  IPv6 Next Header Compression (LOWPAN_NHC)
  e.g UDP, Extension Headers, etc.
LOWPAN_IPHC Header - Dispatch

Dispatch is a selector, identifies the type of header (e.g. LOWPAN_IPHC, LOWPAN_HC1, etc) immediately following the Dispatch Header.
LOWPAN_IPHC Header

<table>
<thead>
<tr>
<th>Dispatch</th>
<th>LOWPAN_IPHC</th>
<th>In-line IPv6 Header Fields</th>
</tr>
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</table>

| TF | NH | HLIM | CID | SAC | SAM | M | DAC | DAM |

TF: Traffic Class, Flow Label

NH: Next Header

HLIM: Hop Limit

CID: Context Identifier Extension

SAC: Source Address Compression

SAM: Source Address Mode

M: Multicast Compression

DAC: Destination Address Compression

DAM: Destination Address Mode
LOWPAN_NHC

Typical LOWPAN_IPHC/LOWPAN_NHC Header Configuration

e.g.

LOWPAN_NHC: UDP Header Compression

| 1 | 1 | 1 | 1 | 0 | C | P |

Ports

Checksum
AS MORE AND MORE PROTOCOLS NEED TO BE COMPRESSED

6LOWPAN DISPATCH BECOME SATURED
LET'S APPLY PAGING

TO 6LOWPAN DISPATCH
6LoWPAN Paging Dispatch - RFC 8025

Introduce a new context switch mechanism for 6LoWPAN compression,

- Expressed in terms of Pages

- Signaled by a new Paging Dispatch

Paging Dispatch with Page Number Encoding
## Integrating the New Page Column

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<tr>
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<th>Page</th>
<th>Header Type</th>
<th>Reference</th>
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<td>LOWPAN_IPHC</td>
<td>RFC 6282, this document</td>
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[https://www.iana.org/assignments/_6lowpan-parameters/_6lowpan-parameters.xhtml#_6lowpan-parameters-1](https://www.iana.org/assignments/_6lowpan-parameters/_6lowpan-parameters.xhtml#_6lowpan-parameters-1)
IPv6 over Networks of Resource-constrained Nodes (6Lo) WG aims to extend 6LoWPAN to different technologies

- RFC 7428: Transmission of IPv6 Packets over ITU-T G.9959 Networks
- RFC 7668: IPv6 over BLUETOOTH(R) Low Energy
  - IPv6 over Bluetooth Low Energy Mesh Networks
    - draft-ietf-6lo-blemesh-01
- Transmission of IPv6 Packets over Near Field Communication
  - draft-ietf-6lo-nfc-07
- An Update to 6LoWPAN ND
  - draft-ietf-6lo-rfc6775-update-05
Who else is playing with 6LoWPAN?
Who else is playing with 6LoWPAN?

IPv6 over the **TSCH** mode of IEEE 802.15.4e (6tisch)
Who else is playing with 6LoWPAN?

IPv6 over the **TSCH** mode of IEEE 802.15.4e (6tisch)

Industrial Networks

**Time** is divided in **Slots** in **TSCH**

**Channel Hopping** in **TSCH** transmit in different channels

6TiSCH Operation sublayer (6top) provides a set of commands for upper layers to set up specific schedules

---

### Table

<table>
<thead>
<tr>
<th>Protocol Family</th>
<th>(PANA)</th>
<th>6LoWPAN</th>
<th>RPL</th>
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<td>COMI CoAP / DTLS</td>
<td>UDP</td>
<td>ICMP</td>
<td>IPv6</td>
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<tr>
<td>6LoWPAN adaptation and compression (HC)</td>
<td>6top</td>
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<td>IEEE802.15.4 TSCH</td>
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IPv6 over the **TSCH** mode of IEEE 802.15.4e (6tisch)

- **Industrial Networks**
  - Time is divided in **Slots** in **TSCH**
  - **Channel Hopping** in **TSCH** transmit in different channels

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Who else is playing with **6LoWPAN**?

IPv6 over Low Power Wide-Area Networks (lpwan)

---

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<th>(PANA)</th>
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<th>RPL</th>
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<td><strong>ICMP</strong></td>
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<td><strong>IEEE802.15.4</strong></td>
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IPv6 over the **TSCH** mode of IEEE 802.15.4e (6tisch)

**Industrial Networks**

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6TiSCH Operation sublayer (6top) provides a set of commands for upper layers to set up specific schedules

---

Who else is playing with 6LoWPAN?

IPv6 over Low Power Wide-Area Networks (lpwan)

The Working Group will focus on enabling IPv6 connectivity over the following selection of Low-Power Wide-Area technologies: SIGFOX, LoRa, WI-SUN and NB-IOT.

LPWAN Static Context Header Compression (SCHC) and fragmentation for IPv6 and UDP - draft-ietf-lpwan-ipv6-static-context-hc-03
IP Wireless Access in Vehicular Environments (ipwave)

Transmission of IPv6 Packets over IEEE 802.11 Networks in mode Outside the Context of a Basic Service Set (IPv6-over-80211ocb)
-draft-ietf-ipwave-ipv6-over-80211ocb-03

Vehicle to Vehicle

Vehicle to Infrastructure

http://www.sae.org/dlymagazineimages/11029_13957_ART.jpg

http://www.extremetech.com/wp-content/uploads/2014/02/DOT-V2I-program_100349715_m.jpg

IoT (Internet of Things)

Everything that can be connected will be connected

Adapt the Internet to different types of networks
e.g. constrained networks/nodes

Adapt IPv6

Modeling the routing

ROLL (Routing over Low-Power and Lossy Networks)

RPL (IPv6 Routing Protocol for Low-Power and Lossy Networks)

Modeling the web transfer

Security, Mgmt

Adapt IPv6

6LoWPAN
IPv6 over Low power WPAN
ROLL DEVELOPED RPL

WHY COULDN'T WE DO THIS WITH OTHER (IETF) ROUTING PROTOCOLS?
## Results of draft-ietf-roll-protocols-survey

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Routing State</th>
<th>Loss Response</th>
<th>Control Cost</th>
<th>Link Cost</th>
<th>Node Cost</th>
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<tr>
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</table>

**Conclusion...**
LET'S DEVELOP A NEW IOT ROUTING PROTOCOL
ROLL WG
ROLL WG

developed RPL
ROLL WG

Directed Acyclic Graph

DAG

root

6LBR (6LowPAN Border Router)

6LR (6LowPAN Router)

6LN (6LowPAN Node)

ROLL WG

developed

RPL

topology
ROLL WG

RPL
deprecated
topology

Directed DO DAG
Acyclic
Graph

6LN (6LowPAN Node)
6LR (6LowPAN Router)
6LBR (6LowPAN Border Router)
How we form the topology?

Directed DAG

Acyclic

Graph

6LN (6LowPAN Node)

6LR (6LowPAN Router)

6LBR (6LowPAN Border Router)

root

ROLL WG

developed

RPL

topology

6LN (6LowPAN Node)
How we form the topology?

Through Control Messages

ROLL WG

devolved

RPL
topology

 Directed

Acyclic

Graph

Destination-Oriented DAG

root

6LBR (6LowPAN Border Router)

6LR (6LowPAN Router)

6LN (6LowPAN Node)
How we form the topology?

Through Control Messages

How I send the messages?

Directed DAG

Acyclic Graph

6LN (6LowPAN Node)

6LR (6LowPAN Router)

6LBR (6LowPAN Border Router)

Root

ROLL WG

developed

RPL

topology
How we form the topology?

Through Control Messages

How I send the messages?

RPL Control message is a ICMPv6 message
How we form the topology?

Through Control Messages

How I send the messages?

RPL Control message is a ICMPv6 message

What types of messages we need?
How we form the topology?
Through Control Messages

How I send the messages?

RPL Control message is an ICMPv6 message

What types of messages do we need?

To Request information to join the topology - DIS
How we form the topology?

Through Control Messages

How I send the messages?

RPL Control message is a ICMPv6 message

What types of messages we need?

To Request information to join the topology - DIS

To be able to send messages upwards - DIO

Directed Acyclic Graph

6LR (6LowPAN Router)
6LBR (6LowPAN Border Router)
6LN (6LowPAN Node)
How we form the topology?

Through Control Messages

How I send the messages?

RPL Control message is a ICMPv6 message

What types of messages we need?

To Request information to join the topology - DIS
To be able to send messages upwards - DIO
To be able to send messages downwards - DAO
How we form the topology?
Through Control Messages

How I send the messages?

RPL Control message is a ICMPv6 message

What types of messages we need?

To Request information to join the topology - DIS

To be able to send messages upwards - DIO

To be able to send messages downwards - DAO

To send the messages in a secure way

Directed DAG

Acyclic Graph

6LBR (6LowPAN Border Router)

6LR (6LowPAN Router)

6LN (6LowPAN Node)
How we form the topology?

Through Control Messages

How I send the messages?

RPL Control message is a ICMPv6 message

What types of messages we need?

To Request information to join the topology - DIS

To be able to send messages upwards - DIO

To be able to send messages downwards DAO

To send the messages in a secure way

How a node pick up a parent
How we form the topology?

Through Control Messages

What types of messages we need?

- To Request information to join the topology - DIS
- To be able to send messages upwards - DIO
- To be able to send messages downwards - DAO
- To send the messages in a secure way

How I send the messages?

How a node pick up a parent

Objective Function (OF)

Define how RPL nodes select and optimize routes within a RPL Instance.

Define how nodes translate one or more metrics into a rank.

Define how nodes select parents
IoT (Internet of Things)

Everything that can be connected will be connected

Adapt the Internet to different types of networks
e.g. constrained networks/nodes

- Adapt IPv6
- 6LoWPAN (IPv6 over Low power WPAN)
- ROLL (Routing over Low-Power and Lossy Networks)
- RPL (IPv6 Routing Protocol for Low-Power and Lossy Networks)
- Core (Constrained RESTful Environments)

- Modeling the routing
- Modeling the web transfer
- Security, Mgmt
HOW DO I ADAPT A WEB TRANSFER PROTOCOL TO CONSTRAINED NETWORKS?
LET'S USE COAP

A CONstrained APPLICATION PROTOCOL
RESTful protocol:

- Client/server & Request/Response
- GET, POST, PUT, DELETE, PATCH, iPATCH, FETCH methods

URI = host + port + path + query component

The well-know URI: GET coap://[ipv6address]/.well-know/core

Resource Discovery → Resource Directory (RD)

4 bytes Header

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Resource Discovery → Resource Directory (RD)

4 bytes Header

Messages Types: CON, NON, ACK, RESET

Confirmable (CON)  Non-Confirmable (NON)

- Group Communications (RFC 7390)

Pub- Sub Architecture
Observe functionality
IoT (Internet of Things)

Everything that can be connected will be connected

Adapt the Internet to different types of networks

e.g. constrained networks/nodes

Adapt IPv6

Modeling the routing

ROLL (Routing over Low-Power and Lossy Networks)

RPL (IPv6 Routing Protocol for Low-Power and Lossy Networks)

Modeling the web transfer

Core (Constrained RESTful Environments)

CoAP (The Constrained Application Protocol)

Security, Mgmt

6LoWPAN

IPv6 over Low power WPAN

IPv6 over Low power WPAN

DTLS
Comi/CoOL

Authentication and Authorization for Constrained Environments (ACE) – ace WG

Practical Considerations and Implementation Experiences in Securing Smart Object Networks

Object Security of CoAP (OSCOAP)

A Security Threat Analysis for the Routing Protocol for Low-Power and Lossy Networks (RPLs)
Requirements on the Management of Networks with Constrained Devices (RFC7547)

<table>
<thead>
<tr>
<th>Group</th>
<th>Name</th>
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Table 1: Classes of Constrained Devices (KiB = 1024 bytes)

IoT Device Management proposals
Constrained Management Interface (CoMI)

CoMI is a network management interface for constrained devices and networks, called CoAP management Interface (CoMI)

Abstract CoMI architecture
Light-Weight Implementation Guidance (Iwg)

- Energy-Efficient Features of Internet of Things Protocols
- Building Power-Efficient CoAP Devices for Cellular Networks
- CoAP Implementation Guidance
- Practical Considerations and Implementation Experiences in Securing Smart Object Networks
Some Topics:

The Constrained RESTful Application Language (CoRAL)

RESTful Design for Internet of Things Systems

Semantic Interoperability

Guidance Design of Architecture and Data Model for Internet of Things Systems
Other Alliances

OpenThread

What is OpenThread?

OpenThread is...

...an open-source implementation of the Thread networking protocol. Nest has released OpenThread to make the technology used in Nest products more broadly available to developers to accelerate the development of products for the connected home.

...OS and platform agnostic, with a narrow platform abstraction layer and a small memory footprint, making it highly portable.

...a Thread Certified Component, implementing all features defined in the Thread 1.1.1 specification. This specification defines an IPv6-based reliable, secure and low-power wireless device-to-device communication protocol for home applications.

More information about Thread can be found on threadgroup.org.

https://github.com/openthread/openthread

Zigbee

Zigbee is the complete and interoperable IoT solution, from our open mesh network to the universal language that allows many smart objects to work together. Find out more here.

http://www.zigbee.org/

WHAT IS OCF?

The Open Connectivity Foundation is dedicated to ensuring secure interoperability for consumers, businesses and industries by delivering a standard communications platform, a Bridging Specification, an open source implementation and a certification program allowing devices to communicate regardless of form factor, operating system, service provider, transport technology or ecosystem.

The industry leading companies involved in OCF believe that secure and reliable device discovery and connectivity is a foundational component to enable IoT. The good news is that it is underway.

https://openconnectivity.org/
Takeaways

- 6lo WG works to bring IPv6 into different types of Networks through 6LoWPAN protocol
- ROLL WG works on routing aspects, it developed a main protocol called RPL
- core WG works on web transfer aspects through CoAP
- ace works on security aspects
- lwig provides guidelines for implementers
- T2TRG works on open items for IoT
## References

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Thank you very much!