Workshop on Scientific Applications for the Internet of Things (IoT)

March 16-27 2015

IPv6 on WSN

Alvaro Vives - alvaro@nsrc.org

Contents

Objectives

- Know what is a LoWPAN
- Learn why IPv6 is being widely adopted
- Have an overview of 6LoWPAN standards

Introduction (I)

- Use of wireless technologies:
  - Driver of the IoT
  - Implications: more devices with less resources
- LLNs (Low power and Lossy networks):
  - Significantly more devices than current LANs
  - Constrained devices: limited code and ram space, cost, battery life
  - Networks with limited communications distance or range, power and processing resources
  - Elements should work together to optimize energy consumption and bandwidth usage
- Feature widely adopted: IP as network protocol
- Physical and link layers:
  - IETF started with IEEE 802.15.4
  - Others: Low Power WiFi, Bluetooth Low Energy, DECT Ultra Low Energy, ITU-T G.9959 networks, NFC

Introduction (II)

- IETF standardization:
  - **6lowpan**: Standards to have IPv6 communication over the IEEE 802.15.4 wireless communication technology. 6lowpan act as an adaptation layer between the standard IPv6 world and the low power and lossy communications wireless media offered by IEEE 802.15.4. **Only defined for IPv6**, no IPv4
  - **roll**: The LLNs have specific routing requirements that could not be satisfied with existing routing protocols. Routing solutions for subset of application areas of LLNs: industrial, connected home, building and urban sensor networks
  - **6lo**: Work that facilitates IPv6 connectivity over constrained node networks. Extends the work of 6lowpan, defining IPv6-over-foo adaptation layer specifications using 6LoWPAN technologies for link layer technologies of interest

Overview of LoWPANs (I)

- **LoWPAN:** particular instance of an LLN, formed by devices complying with the IEEE 802.15.4 standard.

- The typical **characteristics of devices** in a LoWPAN are:
  - **Limited Processing Capability**: With processors starting at 8-bit, there are different types and clock speeds.
  - **Small Memory Capacity**: From few kilobytes of RAM with a few dozen kilobytes of ROM/flash memory
  - **Low Power**: In the order of tens of milliamperes.
  - **Short Range**: The Personal Operating Space (POS) defined by IEEE 802.15.4 implies a range of 10 meters. For real implementations can reach over 100 meters in line-of-sight situations.
  - **Low Cost**: This drives some of the other characteristics such as low processing, low memory, etc.

Overview of LoWPANs (II)

- Characteristics of LoWPANs:
  - **Small packet size**: Maximum physical layer pkt is 127 bytes, resulting maximum frame size at the media access control layer is 102 octets. Link-layer security imposes further overhead, which in the maximum leaves 81 octets for data pkts
  - Support for both **16-bit short or IEEE 64-bit extended MAC** (media access control) **addresses**
  - **Low bandwidth**: Data rates of 250 kbps, 40 kbps, and 20 kbps for each of the currently defined physical layers (2.4 GHz, 915 MHz, and 868 MHz, respectively)
  - **Topologies include star and mesh** operation
  - **Large number of devices** expected to be deployed during the lifetime of the technology
  - **Location of devices not predefined**, as they tend to be deployed in an ad-hoc fashion
  - **Devices tend to be unreliable**: uncertain radio connectivity, battery drain, device lockups, physical tampering, etc.
  - **Sleeping mode**: Devices may sleep for long periods of time in order to conserve energy. Unable to communicate during sleep periods

Use of IP on LoWPANs

- IP technology and, in particular, IPv6 networking provide the following **benefits** to LoWPANs:
  - Pervasive nature of IP networks allows use of existing infrastructure
  - IP-based technologies already exist, are well-known, proven to be working and widely available. This allows for an easier and cheaper adoption, good interoperability and easier application layer development
  - Open and freely available specifications, easier to be better understood by a wider audience than proprietary solutions
  - Tools for IP networks already exist
  - IP-based devices can be connected readily to other IP-based networks, without the need for intermediate entities like protocol translation gateways or proxies
  - Use of IPv6, specifically, allows for a huge amount of addresses and provides for easy network parameters autoconfiguration (SLAAC)

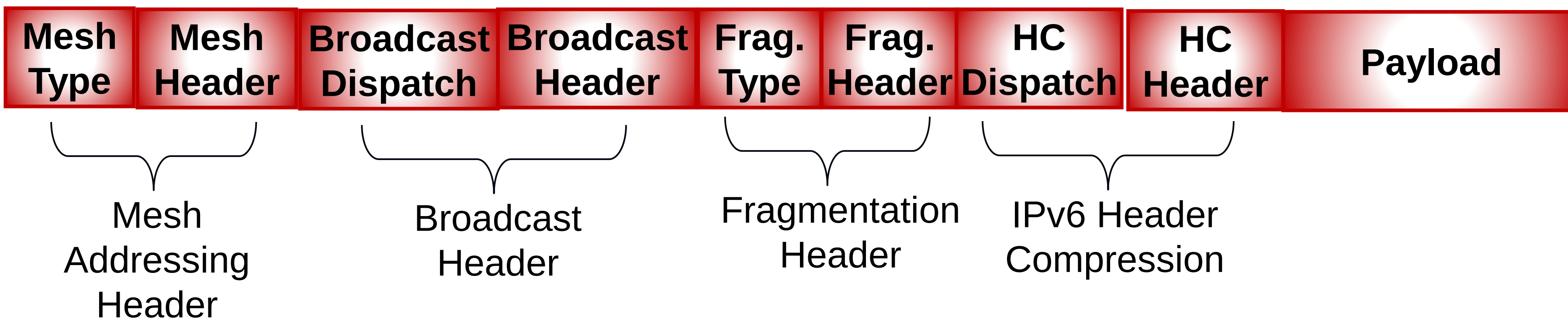
6LoWPAN: Introduction (I)

- There is a need of an adaptation layer between IP and link-layer/physical layers:

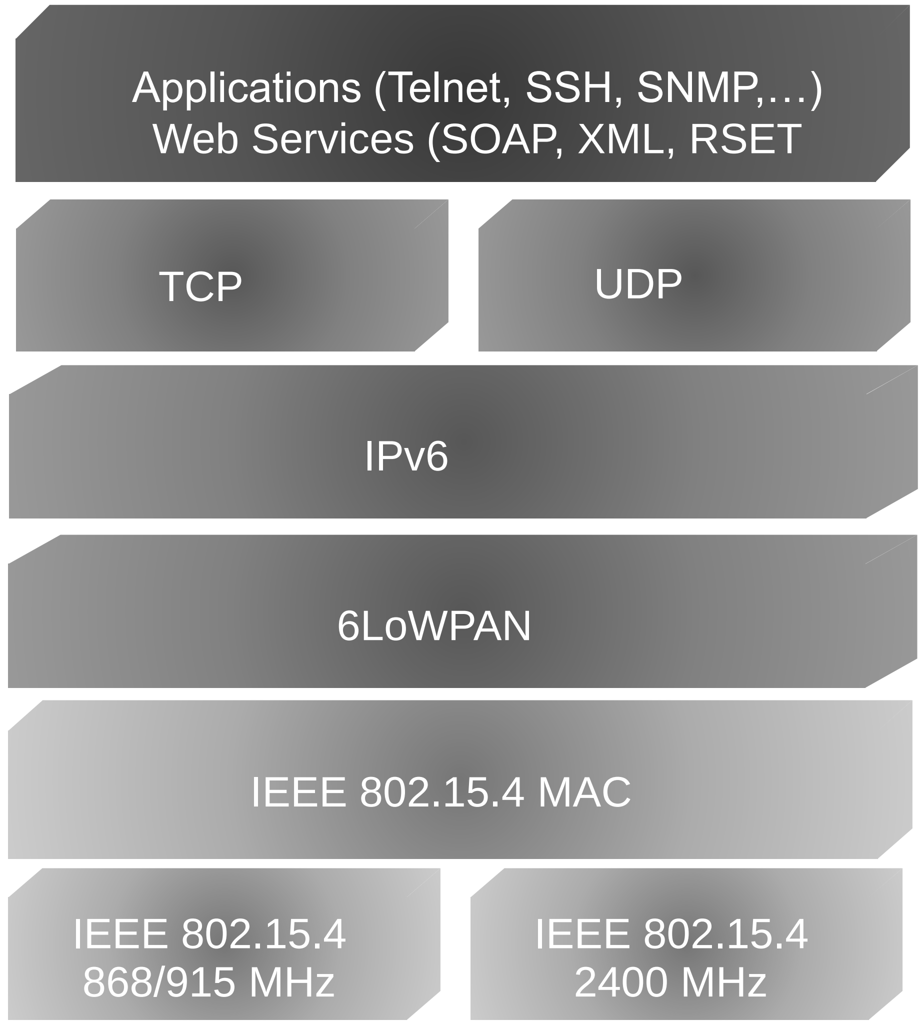
1. Fragmentation and Reassembly layer: IPv6 minimum MTU is 1280 bytes
2. Header Compression: IPv6 header = 40 bytes + EHs
3. Address Autoconfiguration: generate IID
4. Mesh Routing Protocol
5. Broadcast Header: IPv6 Multicast <-> 802.15.4 Broadcast

6LoWPAN: Introduction (II)

- 6LoWPAN encapsulation: header stack



6LoWPAN: Introduction (III)



6LoWPAN: Introduction (IV)

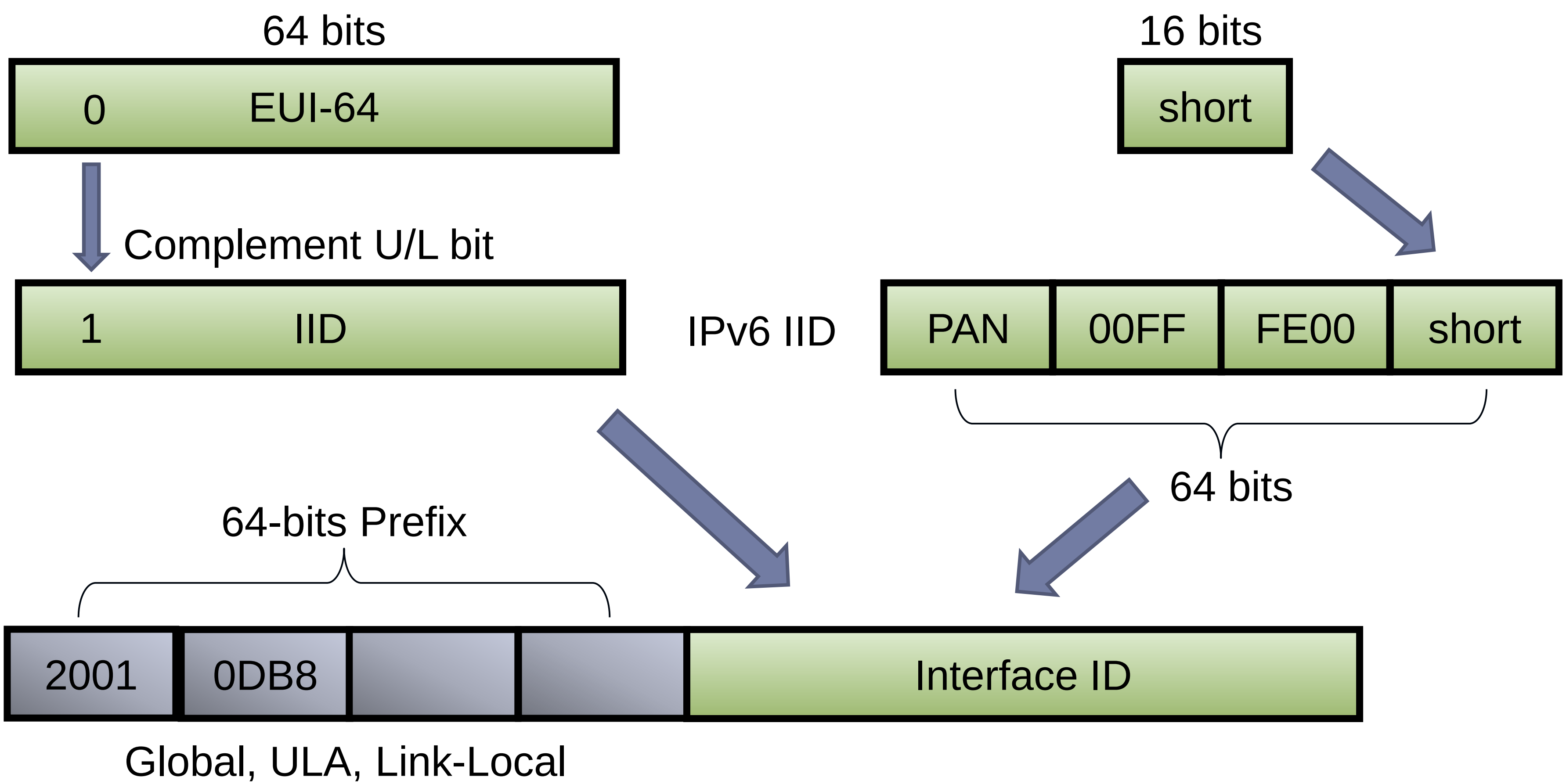
- IEEE 802.15.4 define 4 types of frames: beacon frames, MAC command frames, acknowledgement frames, y data frames.
- IPv6 packets must be sent over data frames

- 6lowpan IETF WG requires:
  - both source and destination addresses be included in the IEEE 802.15.4 frame header
  - source or destination PAN ID fields may also be included

- A PAN ID corresponds to an specific IPv6 link

6LoWPAN (I)

- IPv6 Addresses in 6LoWPAN



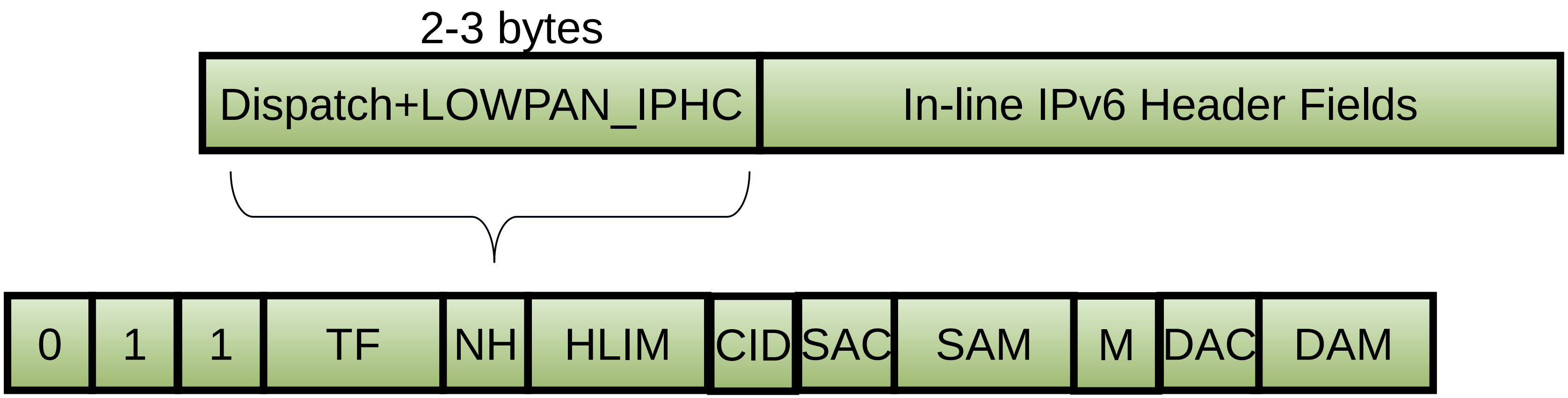
6LoWPAN (II)

- 2 encoding formats defined for compression of IPv6 packets:
  - LOWPAN_IPHC: for IPv6 header
  - LOWPAN_NHC: for arbitrary next headers

- LOWPAN_IPHC assumes the following:
  - Version is 6
  - Traffic Class and Flow Label are both zero
  - Payload Length can be inferred from lower layers from either the 6LoWPAN Fragmentation header or the IEEE 802.15.4 header
  - Hop Limit will be set to a well-known value by the source
  - Addresses will be formed using link-local prefix or a small set of routable prefixes assigned to the entire 6LoWPAN
  - Addresses are formed with an IID derived directly from either the 64-bit extended or the 16-bit short IEEE 802.15.4 addresses

6LoWPAN (III)

- LOWPAN_IPHC Header



TF: Traffic Class, Flow Label (2 bits)
NH: Next Header (1 bit)
HLIM: Hop Limit (2 bits)
CID: Context Identifier Extension (1 bit)
SAC: Source Address Compression (1 bit)
SAM: Source Address Mode (2 bits)
M: Multicast Compression (1 bit)
DAC: Destination Address Compression (1 bit)
DAM: Destination Address Mode (2 bits)

6LoWPAN (IV)

- Two examples of how compression is done:

1. HLIM: Hop Limit

00: Hop Limit field carried in-line
01: Hop Limit field compressed and the hop limit is 1
10: Hop Limit field compressed and the hop limit is 64
11: Hop Limit field compressed and the hop limit is 255

2. SAC/SAM: Source IPv6 Address compression

- SAC=0 (stateless compression)

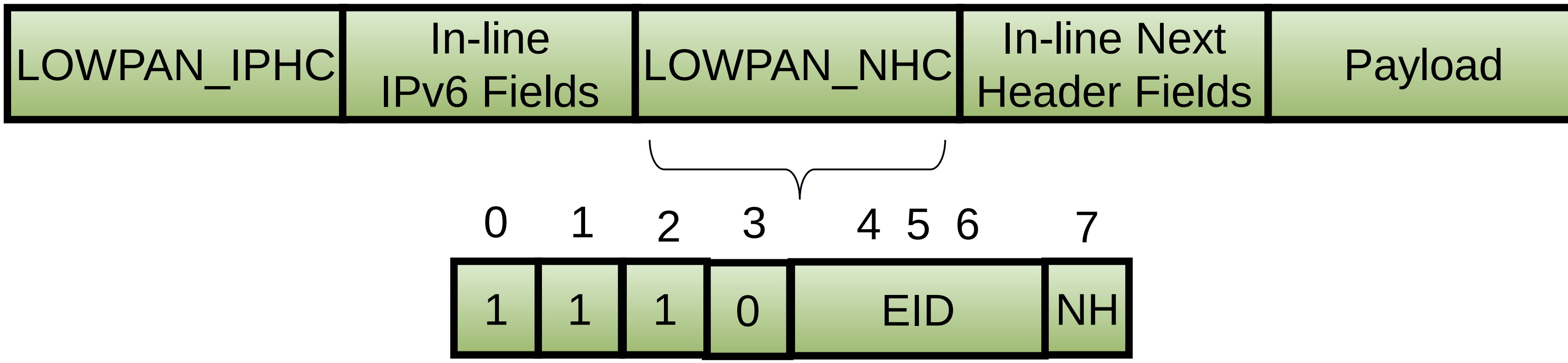
SAM=00: 128 bits. Full address is carried in-line. No compression
SAM=01: 64 bits. First 64-bits elided, link-local prefix. Remaining 64 bits carried in-line
SAM=10: 16 bits. First 112 bits elided. First 64 bits is the link-local prefix. Following 64 bits 0000:00ff:fe00:XXXX, XXXX 16 bits carried in-line
SAM=11: 0 bits. Address fully elided. First 64 bits link-local prefix. Remaining 64 bits computed from encapsulating header

- SAC=1 (stateful compression, context-based)

SAM=00: 0 bits. The unspecified address (::).
SAM=01: 64 bits. Address derived using context info and 64 bits carried in-line
SAM=10: 16 bits. Address is derived using context info and 16 bits carried in-line.
IID bits not covered by context info, taken from 0000:00ff:fe00:XXXX, XXXX 16 bits carried in-line
SAM=11: 0 bits. Address fully elided. Derived from context info and encapsulating header

6LoWPAN (V)

- LOWPAN_NHC -> IPv6 Extension headers



EID: IPv6 Extension Header ID:

0: IPv6 Hop-by-Hop Options Header
1: IPv6 Routing Header
2: IPv6 Fragment Header
3: IPv6 Destination Options Header
4: IPv6 Mobility Header
5: Reserved
6: Reserved
7: IPv6 Header

Changes to ND

- Multicast as used in IPv6 ND is not desirable in LLNs
- LoWPAN links are asymmetric and non-transitive in nature
- Optimizations:
  - Host-initiated interactions to allow for sleeping hosts
  - Elimination of multicast-based address resolution for hosts
  - A host address registration feature using a new option in unicast NS and NA messages
  - A new Neighbor Discovery option to distribute 6LoWPAN header compression context to hosts
  - Multihop distribution of prefix and 6LoWPAN header compression context
  - Multihop DAD, which uses two new ICMPv6 message types

Thanks!

- Questions?

- Alvaro Vives - alvaro@nsrc.org
- http://about.me/alvarovives