Recent Protocols for IoT

Type here

		Security	Management
Session	MQTT, SMQTT, CoAP, AMQP , XMPP, CoAP, IEC, IEEE 1888, …	IEEE 1888.3, TCG, Oath 2.0, SMACK, SASL, EDSA, ace, DTLS, Dice, …	IEEE 1905, IEEE 1451, IEEE 1377, IEEE P1828, IEEE P1856
Network	Encapsulation: **6LowPAN**, 6TiSCH, 6Lo, Thread…		
	Routing: **RPL**, CORPL, CARP		
Datalink	Wi-Fi, Bluetooth Low Energy, Z-Wave, ZigBee Smart, DECT/ULE, 3G/LTE, NFC, **802.15.4** Weightless, HomePlug GP, 802.11ah, 802.15.4e, G.9959, WirelessHART, DASH7, ANT+, LTE-A, LoRaWAN, ISA100.11a, DigiMesh, WiMAX, …		

Ref: Tara Salman, Raj Jain, "A Survey of Protocols and Standards for Internet of Things," Advanced Computing and Communications, Vol. 1, No. 1, March 2017, http://www.cse.wustl.edu/~jain/papers/iot_accs.htm
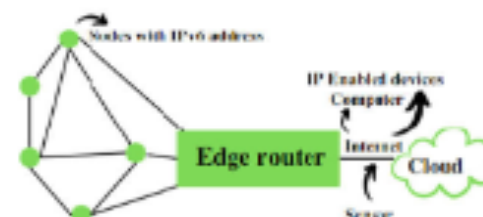
IEEE 802.15.4

- Wireless Personal Area Network (WPAN)
- Allows mesh networking.
  Full function nodes can forward packets to other nodes.
- A PAN coordinator (like Wi-Fi Access Point) allows nodes to join the network.
- Nodes have 64-bit addresses
- Coordinator assigns 16-bit short address for use during the association
- Maximum frame size is 127 bytes

EUI64 Addresses

- **Ethernet addresses**: 48 bit MAC

Unicast Multicast	Universal Local	Organizationally Unique ID (OUI)	Manufacturer Assigned
1b	1b	22b	24b

- **IEEE 802.15.4 Addresses**: 64 bit Extended Unique Id (EUI)

Unicast Multicast	Universal Local	Organizationally Unique ID (OUI)	Manufacturer Assigned
1b	1b	22b	40b

- **Local bit** was incorrectly assigned. L=1 $\Rightarrow$ Local
  but all-broadcast address = all 1's is not local
  IETF RFC4291 changed the meaning so that L=0 $\Rightarrow$ Local
  The 2nd bit is now called Universal bit (U-bit)
   $\Rightarrow$ U-bit formatted EUI64 addresses

- Does the Extended Unique ID function as the MAC address for 802.15.4 devices?
  Yes. They do not use the 48-bit IEEE address.

- If the first bit is one and the second is one does it mean U G?
  No.
  0/1   0/1
  U/M G/L
  0   0 Unicast, globally unique
  0   1 Unicast, Local
  1   0 Multicast, Globally unique
  1   1 Multicast, Local

MAC Frame Format

Frame Control	Seq. #	Dest. PAN Id	Dest. Addr.	Src PAN Id	Src Addr.	Aux. Security Header	Payload	FCS
16b	8b	0/16b	0/16/64b	0/16b	0/16/64b	0/40/48/80/170b		16b

Frame Type	Security enabled	Frame Pending	Ack Reqd	PAN Id Compression	Rsvd	Dest. Addr. Mode	Frame version	Src. Addr. mode
3b	1b	1b	1b	1b	3b	2b	2b	2b

|	
000	Beacon
001	Data
010	Ack
011	MAC Command
Other	Reserved

00	PAN Id and Addr not present
01	Reserved
10	16-bit short address
11	64-bit extended address

6LowPAN

- IPv6 over Low Power Wireless Personal Area Networks
- How to transmit IPv6 datagrams (elephants) over low power IoT devices (mice)?
- **Issues**:
1. **IPv6 address formation**: 128-bit IPv6 from 64-bit EUI64
2. **Maximum Transmission Unit** (MTU): IPv6 at least 1280 bytes vs. IEEE 802.15.4 standard packet size is 127 bytes

802.15.4 Header	Security Option	Payload
25B	21B	81B
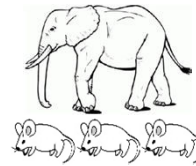
3. **Address Resolution**: 128b or 16B IPv6 addresses. 802.15.4 devices use 64 bit or 16 bit addresses
4. **Optional mesh routing in datalink layer**
   $\Rightarrow$ Need destination and intermediate addresses.

Ref: G. Montenegro, et al., "Transmission of IPv6 Packets over IEEE 802.15.4 Networks," RFC 4944, Sep 2007, http://tools.ietf.org/pdf/rfc4944

- In the review question, what problem does 6LowPan address?

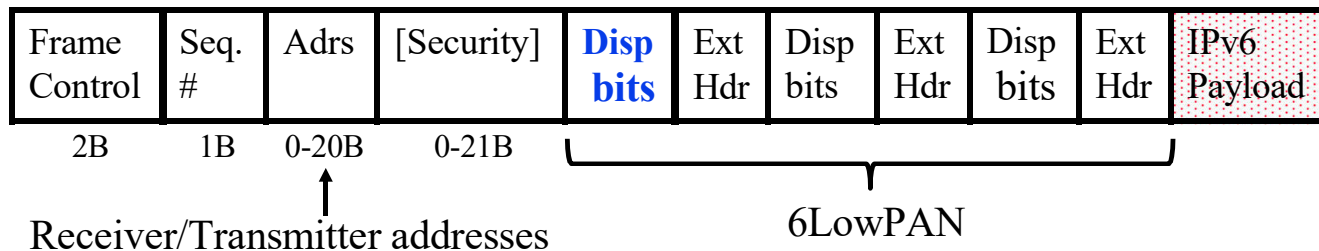*See 7 issues in this slide and next.*

6LowPAN Adaptation Layer

5. **MAC-level retransmissions versus end-to-end**:
   - ➢ Optional hop-by-hop ack feature of 802.15.4 is used but the max number of retransmissions is kept low (to avoid overlapping L2 and L4 retransmissions)
6. **Extension Headers**: 8b $\Rightarrow$ header type

7. **IPv6 and UDP header compression**

Frame Control	Seq. #	Adrs	[Security]	**Disp bits**	Ext Hdr	Disp bits	Ext Hdr	Disp bits	Ext Hdr	IPv6 Payload
2B	1B	0-20B	0-21B							

Receiver/Transmitter addresses

6LowPAN

Ref: O. Hersent, et al., "The Internet of Things: Key Applications and Protocols," Wiley, 2013, 344 pp., ISBN: 9781119994350 (Safari Book)
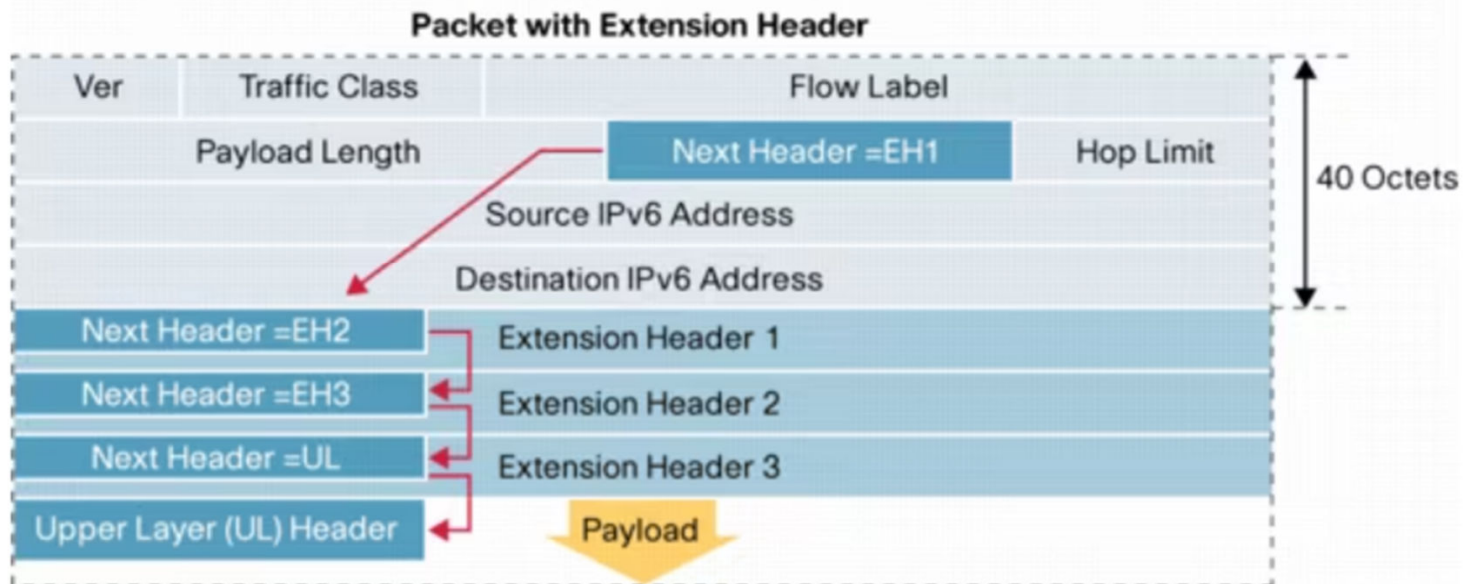
IPv4 Header

Version	IHL	Type of Service	Total Length	
Identification			Flags	Fragment Offset
Time to Live		Protocol	Header Checksum	
Source Address				
Destination Address				
Options			Padding	

IPv6 Header

Version	Traffic Class	Flow Label	
Payload Length		Next Header	Hop Limit
Source Address			
Destination Address			

Legend

- Field's name kept from IPv4 to IPv6
- Field not kept in IPv6
- Name and position changed in IPv6
- New field in IPv6

Ver	Traffic Class	Flow Label		40 Octets
Payload Length		Next Header =UL	Hop Limit	
Source IPv6 Address				
Destination IPv6 Address				
Upper Layer (UL) Header		Payload		

Packet with Extension Header

Ver	Traffic Class	Flow Label		40 Octets
Payload Length		Next Header =EH1	Hop Limit	
Source IPv6 Address				
Destination IPv6 Address				
Next Header =EH2	Extension Header 1			
Next Header =EH3	Extension Header 2			
Next Header =UL	Extension Header 3			
Upper Layer (UL) Header	Payload			

RFC2460 defines the extension headers as shown in the following table along with the Next Header values assigned

Table 1. IPv6 Extension Headers and their Recommended Order in a Packet

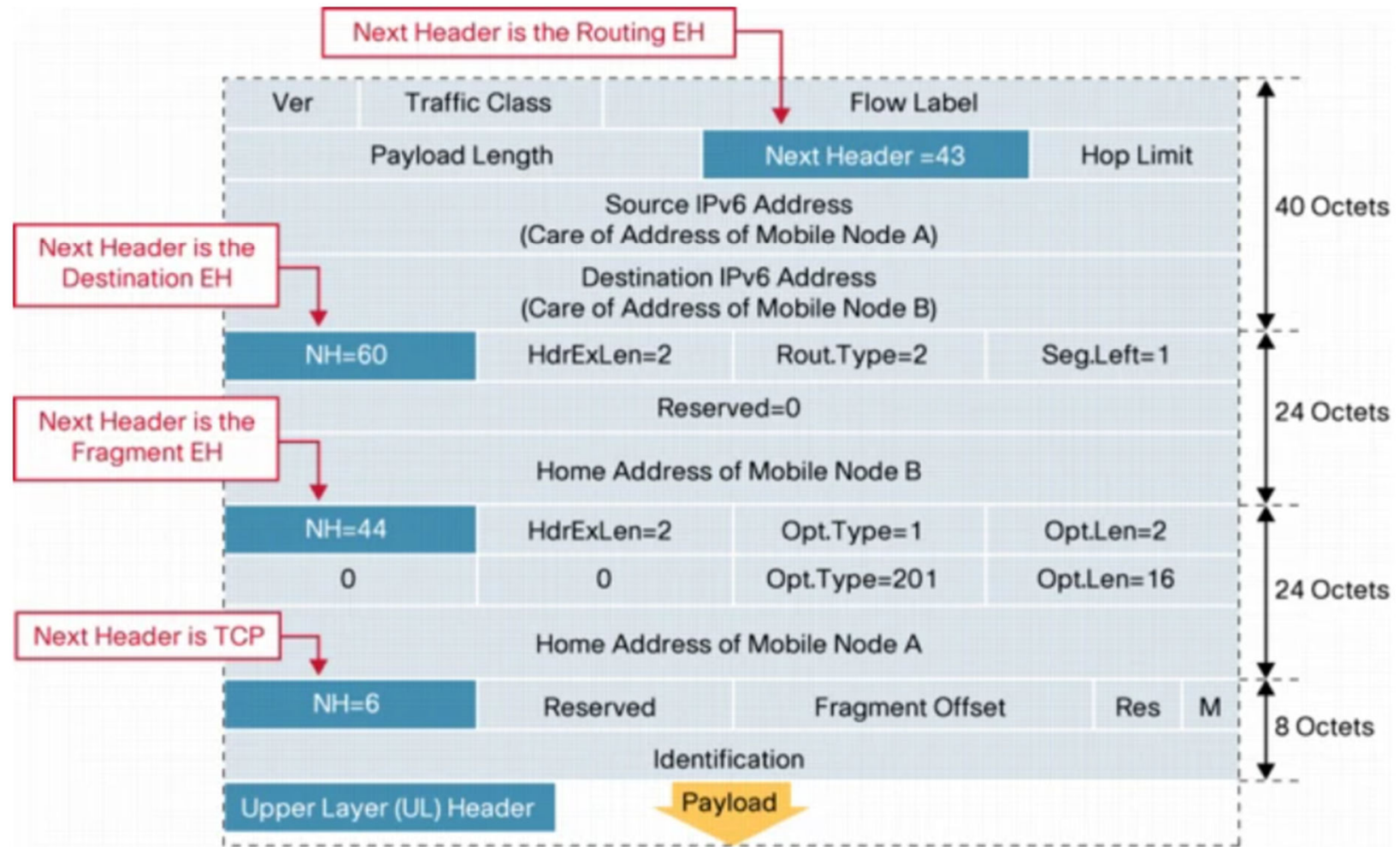| Order	Header Type	Next Header Code
1	Basic IPv6 Header	-
2	Hop-by-Hop Options	0
3	Destination Options (with Routing Options)	60
4	Routing Header	43
5	Fragment Header	44
6	Authentication Header	51
7	Encapsulation Security Payload Header	50
8	Destination Options	60
9	Mobility Header	135
	No next header	59
Upper Layer	TCP	6
Upper Layer	UDP	17
Upper Layer	ICMPv6	58

RFC2460 also recommends the order in which they should be chained in an IPv6 packet:

RFC2460 also recommends the order in which they should be chained in an IPv6 packet:
1. **IPv6 main header**
2. **Hop-by-Hop Options header (if present, it MUST be the first one following the main/regular header)**
3. **Destination Options header**
4. **Routing header**
5. **Fragment header**
6. **Authentication header**
7. **Encapsulating Security Payload header**
8. **Destination Options header**
9. **Upper-layer header**
The only **MUST** requirement is that the Hop-by-Hop EH has to be the first one.

Figure 3. Data Traffic Between Two Mobile Nodes over the Route Optimized Path

Next Header is the Routing EH

Ver	Traffic Class	Flow Label			

Payload Length	Next Header =43	Hop Limit

Source IPv6 Address
(Care of Address of Mobile Node A)

Next Header is the Destination EH

Destination IPv6 Address
(Care of Address of Mobile Node B)

40 Octets

NH=60	HdrExLen=2	Rout.Type=2	Seg.Left=1

Reserved=0

Next Header is the Fragment EH

Home Address of Mobile Node B

24 Octets

NH=44	HdrExLen=2	Opt.Type=1	Opt.Len=2
0	0	Opt.Type=201	Opt.Len=16

Next Header is TCP

Home Address of Mobile Node A

24 Octets

NH=6	Reserved	Fragment Offset	Res	M

Identification

8 Octets

Upper Layer (UL) Header	Payload

Frame Control	Seq. #	Adrs	[Security]	**Disp bits**	Ext Hdr	Disp bits	Ext Hdr	Disp bits	Ext Hdr	IPv6 Payload

Types of Dispatch Bits in 6LoWPAN

(A) IPv6 Header Compression Dispatch (IPHC)
•**Disp Bits:** 01
  Used for **IPv6 Header Compression** (RFC 6282).
  Reduces the **40-byte IPv6 header** to **as small as 2 bytes**.
(B) Mesh Header Dispatch
•**Disp Bits:** 10
  Used for **mesh routing in multi-hop networks**.
  Helps forward packets in **multi-hop topologies**.
(C) Fragmentation Header Dispatch
•**Disp Bits:** 11
  Used when an **IPv6 packet is too large** for a single IEEE 802.15.4 frame.
  The packet is split into **multiple fragments**, each with a **fragmentation header**.
(D) LoWPAN Broadcast Dispatch
  Disp Bits: 00
  Used for **broadcast transmission** to multiple nodes in the network.

Without compression:

IPv6 Header: 40 bytes
UDP Header: 8 bytes
Payload: 10 bytes
Total: 58 bytes

IPv6 Header: 3 bytes
UDP Header: 4 bytes
Payload: 10 bytes
Total: 17 bytes (71% reduction)

The **primary compression algorithm in 6LoWPAN is IPHC (RFC 6282)**, which works alongside **UDP compression** and **fragmentation techniques** to make **IPv6 and UDP headers lightweight**. **ROHC is sometimes used** for further optimization in specific applications like VoIP.

Algorithm	Purpose	Compression Level	Typical Use Case
IPHC	IPv6 Header Compression	High	IoT, Sensor Networks
LOWPAN_UDP	UDP Header Compression	Moderate	CoAP, MQTT, LoRaWAN
LOWPAN_FRAG	Fragmentation	Low	Large IPv6 Packets
ROHC	Full Header Compression	Very High	VoIP, Multimedia

IPv6 Address Formation

- **Link-Local IPv6 address** = FE80::U-bit formatted EUI64
- **Example**:
  - EUI64 Local Address = 40::1 = 0100 0000::0000 0001
  - U-bit formatted EUI64 = 0::1
  - IPv6 Link-local address = FE80::1 = 1111 1110 1000 0000::1
- IEEE 802.15.4 allows nodes to have 16-bit **short addresses** and each PAN has a 16-bit **PAN ID**.
  1st bit of Short address and PAN ID is Unicast/Multicast
  The 2nd bit of Short Address and PAN ID is Local/Universal.
  You can broadcast to all members of a PAN or to all PANs.
- IPv6 Link Local Address = FE80 :: PAN ID : Short Address
  Use 0 if PAN ID is unknown.
  2nd bit of PAN ID should always be zero since it is always local.
  2nd most significant = 6th bit from right)

Homework 14A

- What is the IPv6 Link-Local address for a IEEE 802.15.4 node whose EUI64 address in hex is 0000::0002. Indicate your final answer in hex without using ::

- EUI64 in Binary =

- U-bit EUI64 Binary =

- U-bit EUI64 Hex =

- IPv6 Link Local Address =