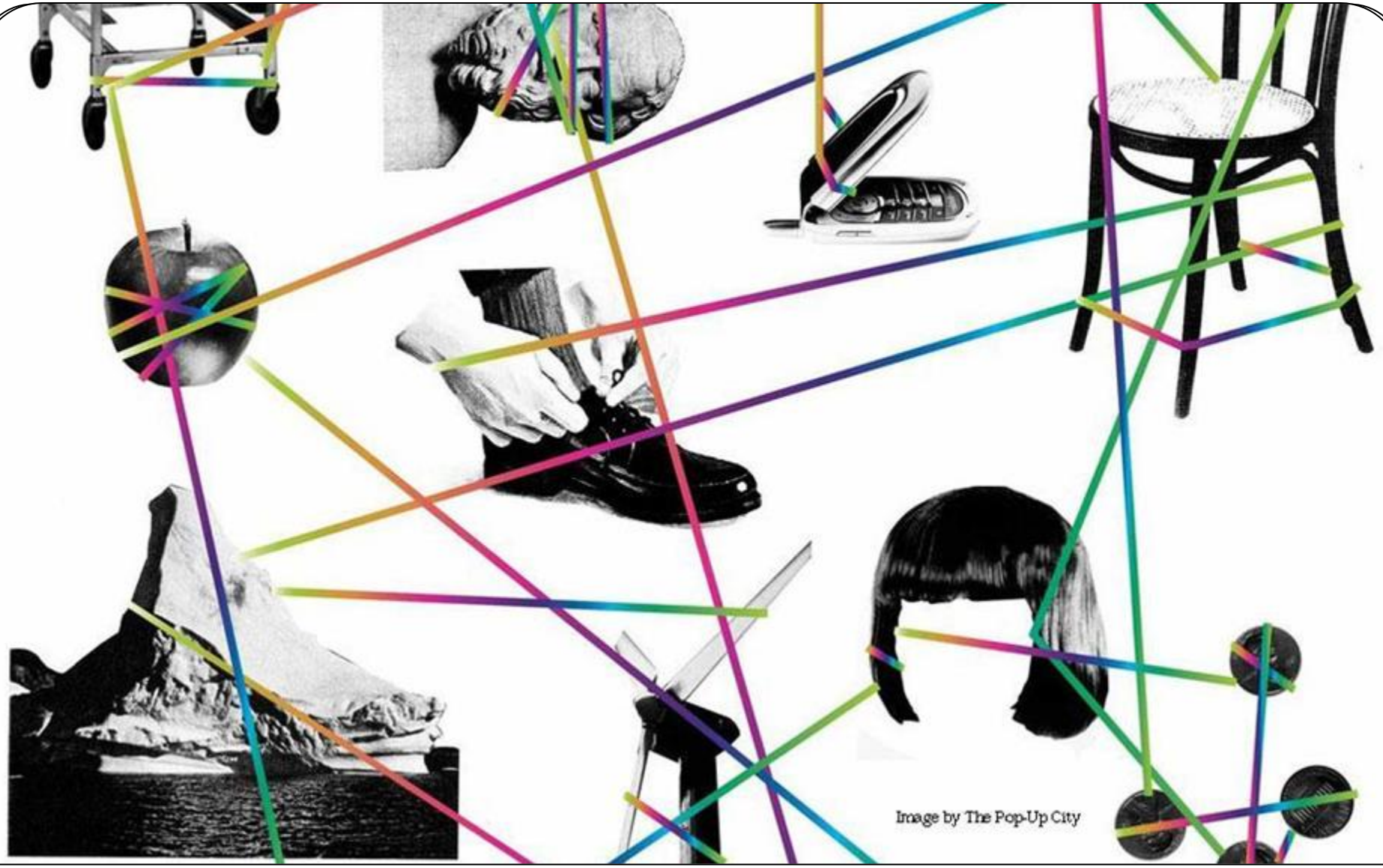


Internet of Things

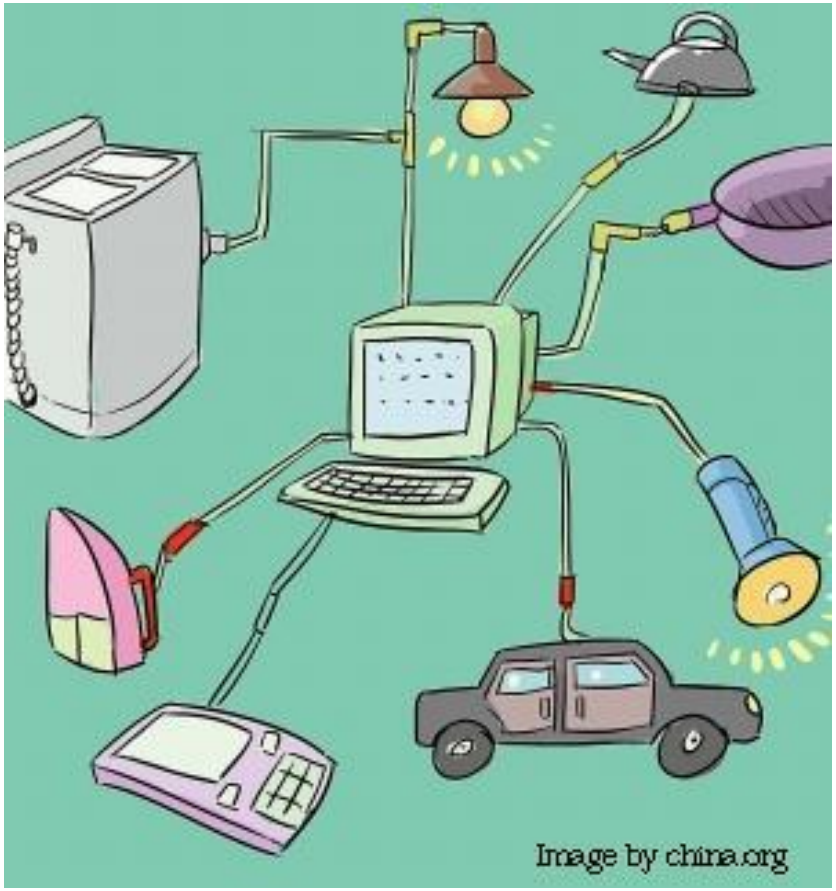
Peng Du

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

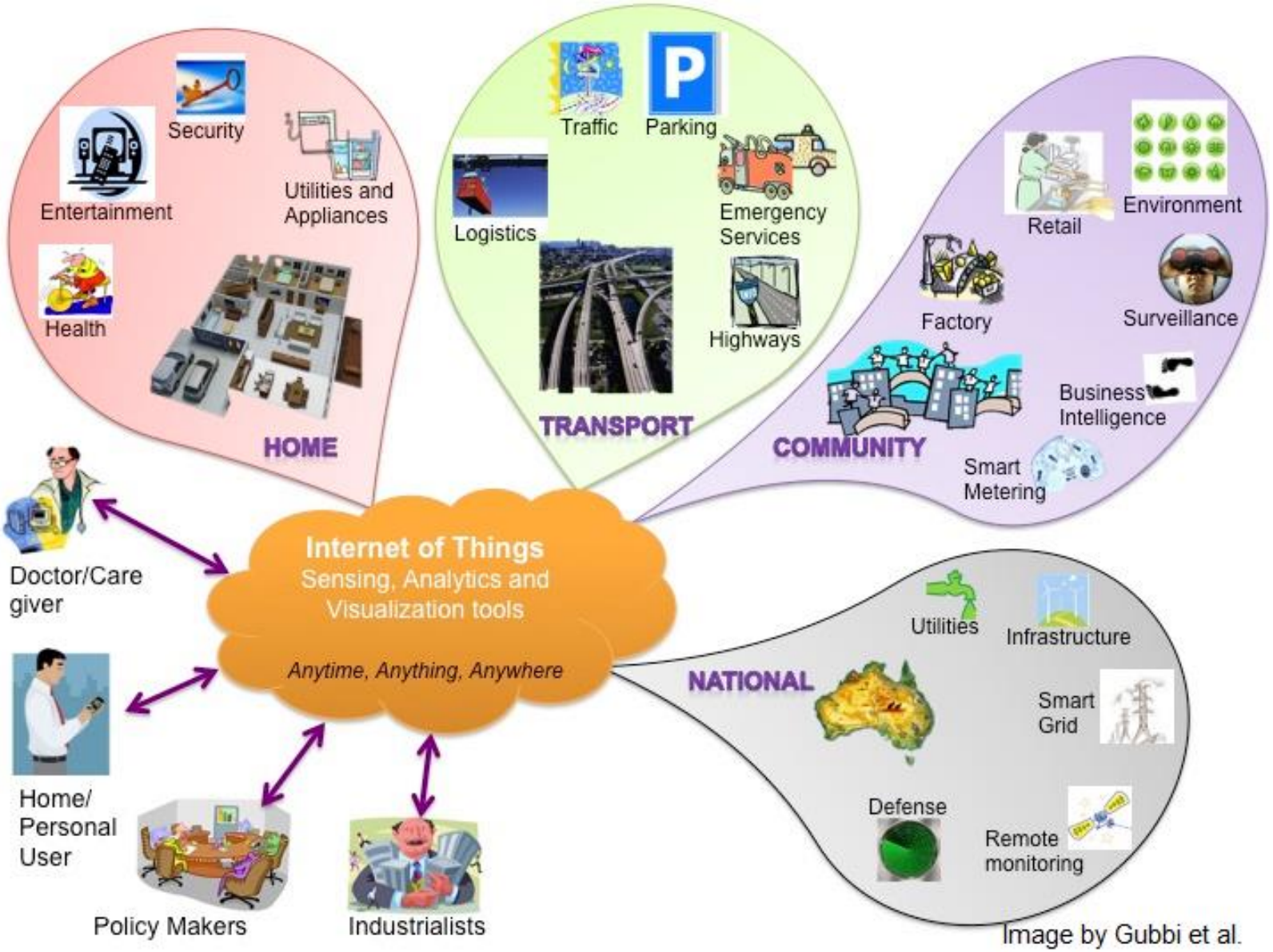


Image by Gubbi et al.

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 !

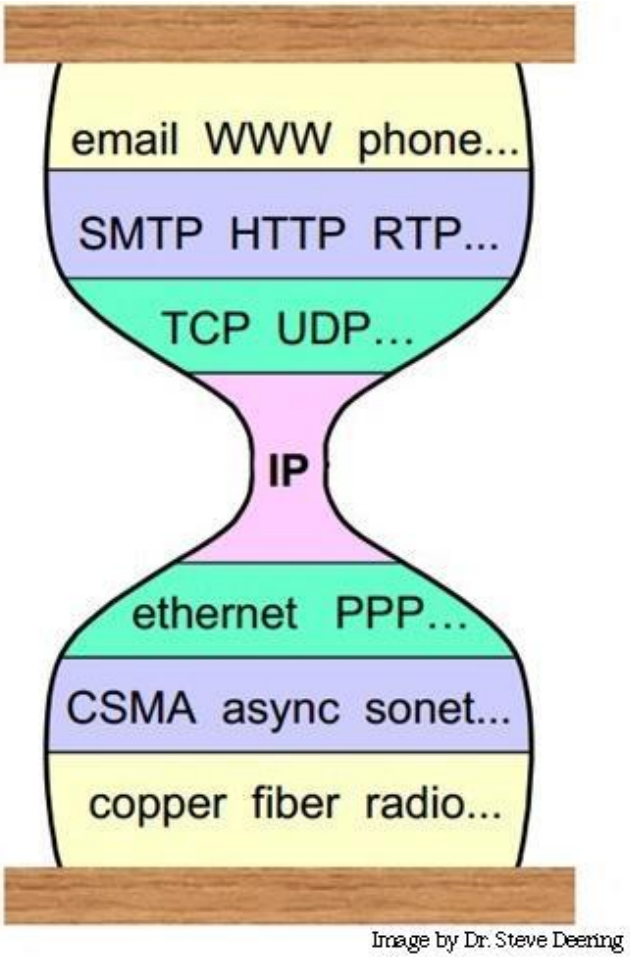


Image by Dr. Steve Deering

- Hourglass shaped TCP/IP protocol suite
- Ideal platform for interoperability

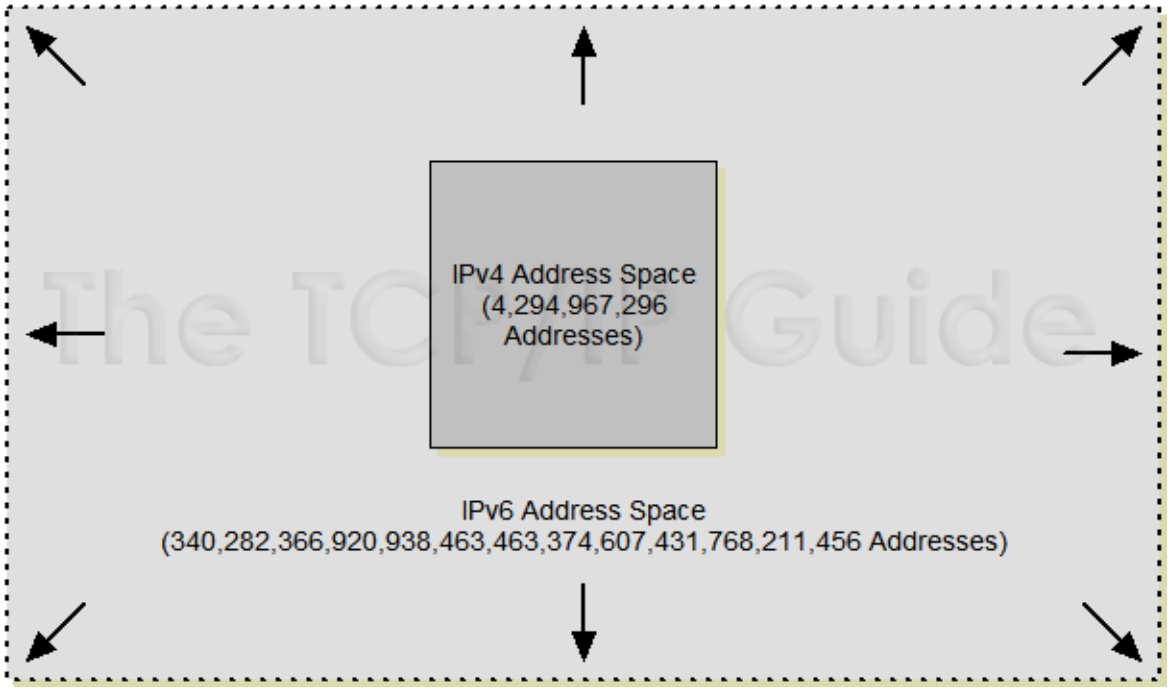
IPv4 is unlikely to cope

- 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

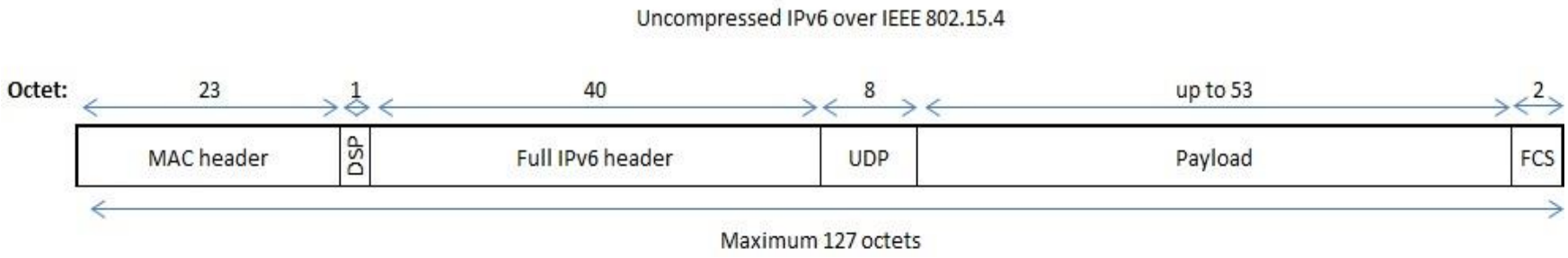
IPv6 - Every bit helps, let alone 128

- 128 bits fields = 2^{128} addresses (340,282,366,920,938,463,463,374,607,431,768,211,456)
- Wiki: approx. 4.8×10^{28} (48000 trillion trillion) addresses for each of the 7 billion people alive on earth (as in 2011)



Might be too heavy for “Things”

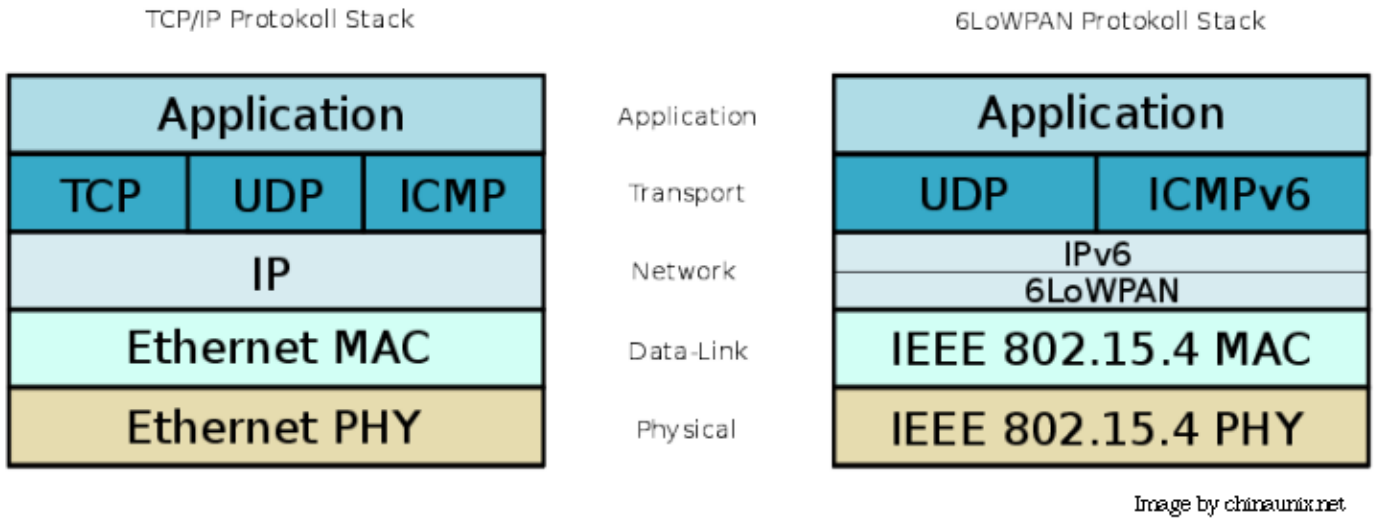
- IPv6 header (40 bytes) is much longer than that of IPv4
- Maximum length of IEEE 802.15.4 data frame is only 127 bytes



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

6LoWPAN

- Adaptation layer

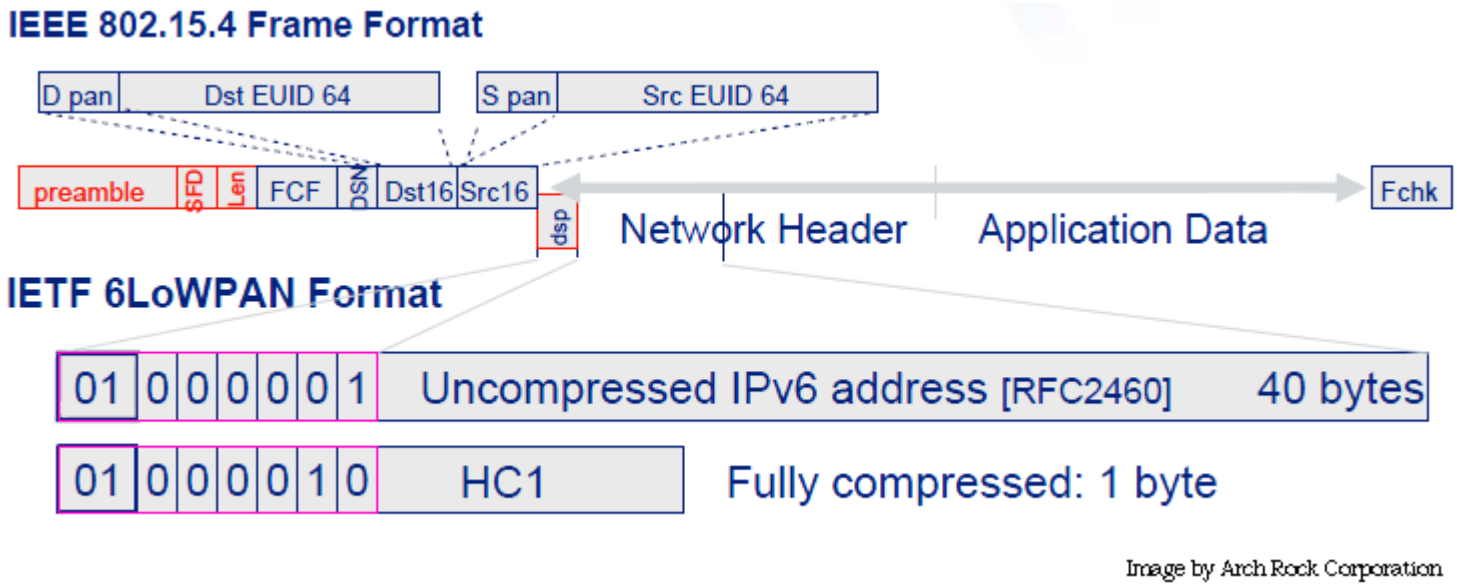


- Fully compatible with IPv6

- Header compression

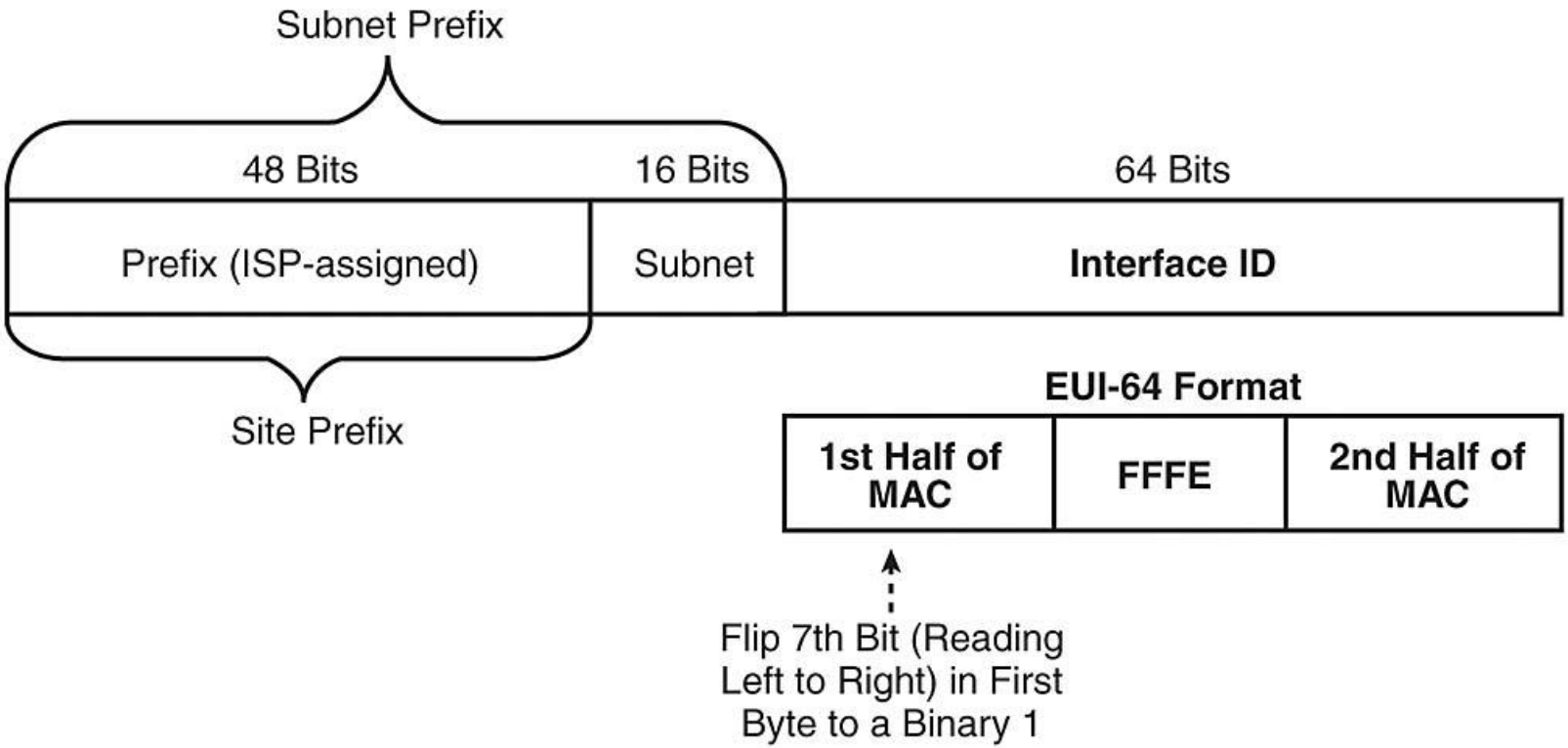
Header compression

- HC1 : For IPv6



- 00 : Not a LoWPAN frame
- 01 : LoWPAN IPv6 addressing

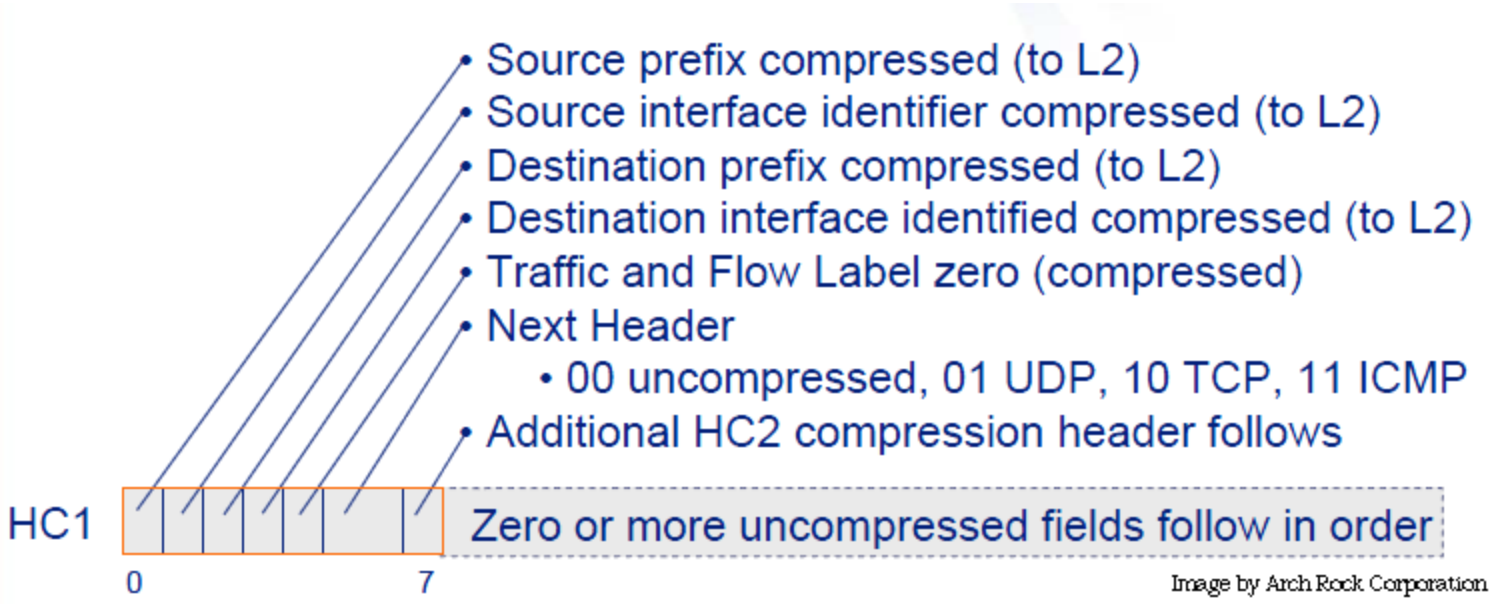
IPv6 address & EUI64 - recap



HC1

Field	Size IPv6	Size 6LowPAN	Description
Version	4 bits	-	IPv6 communication implied
Traffic class	8 bits	1 bit	0= No compression
Flow label	20 bits		1= Compressed. Traffic class and flow label set to 0.
Payload length	16 bits	-	Can be obtained from the MAC frame or the fragmentation header.
Next header	8 bits	2 bits	Only TCP,UDP or ICMPv6 is used.
Hop limit	8 bits	8 bits	This field is never compressed.
Source address	128 bits	2 bits	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 obtaines from the mesh or MAC headers, it compresses to justo one bit always set to 1.
Destination address	128 bits	2 bits	
HC2 encoding	-	1 bit	Informs if next header is also compressed.
Total	40 bytes	2 bytes	

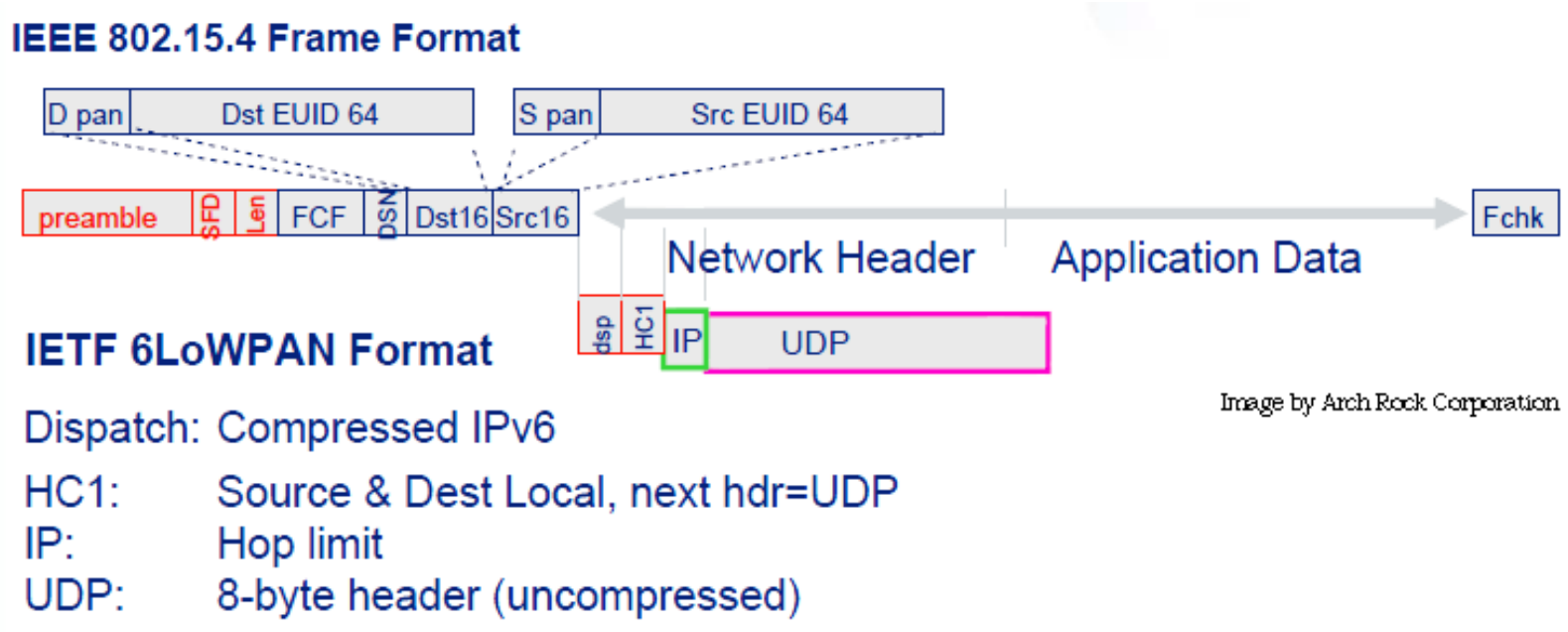
HC1 cont'd



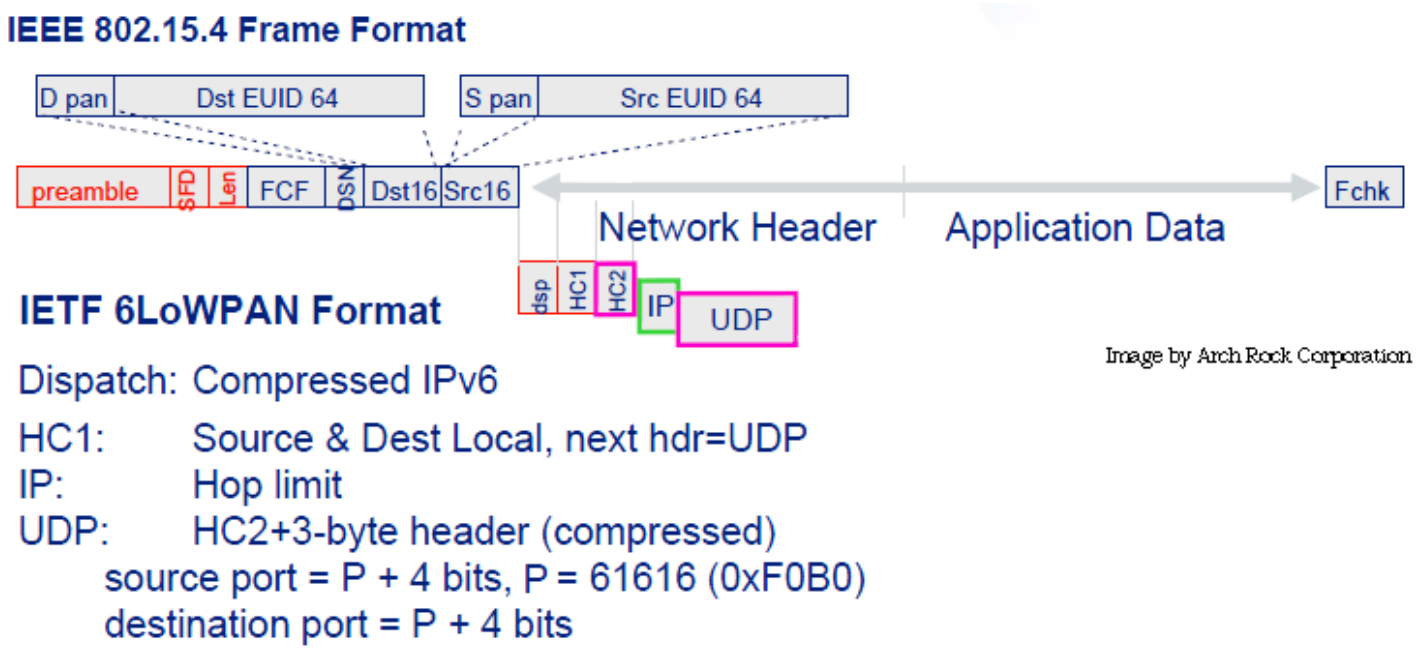
- IPv6 address <prefix64 || interface id> for nodes in 802.15.4 subnet derived from the link address.
  - PAN ID maps to a unique IPv6 prefix
  - Interface identifier generated from EUID64 or Pan ID & short address
- Hop Limit is the only incompressible IPv6 header field

HC2

- Indicated by HC1 header
- For UDP

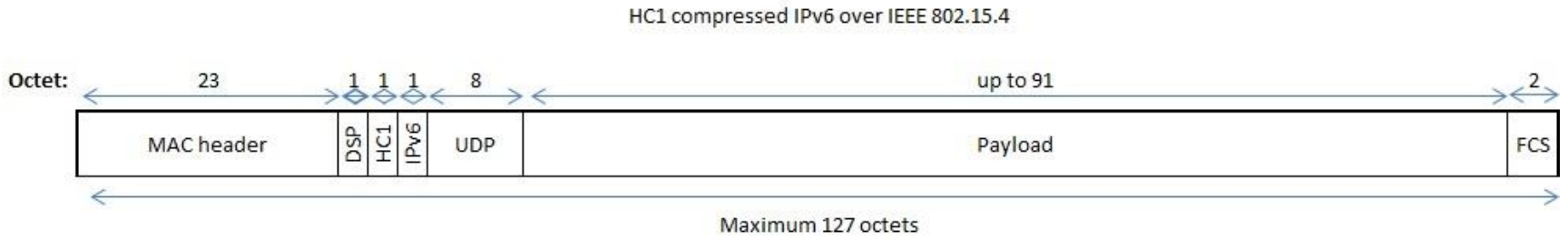


HC2 cont'd

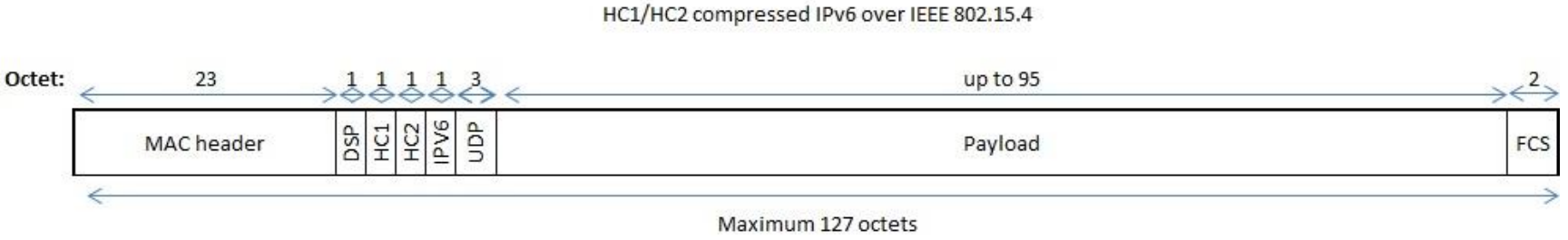


- HC2 : flag bits for source port, destination port and length compression
- Port numbers : 0xF0B*n*

Effect of header compression



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



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

Limitation

- Efficiency drops for non-link-local communication

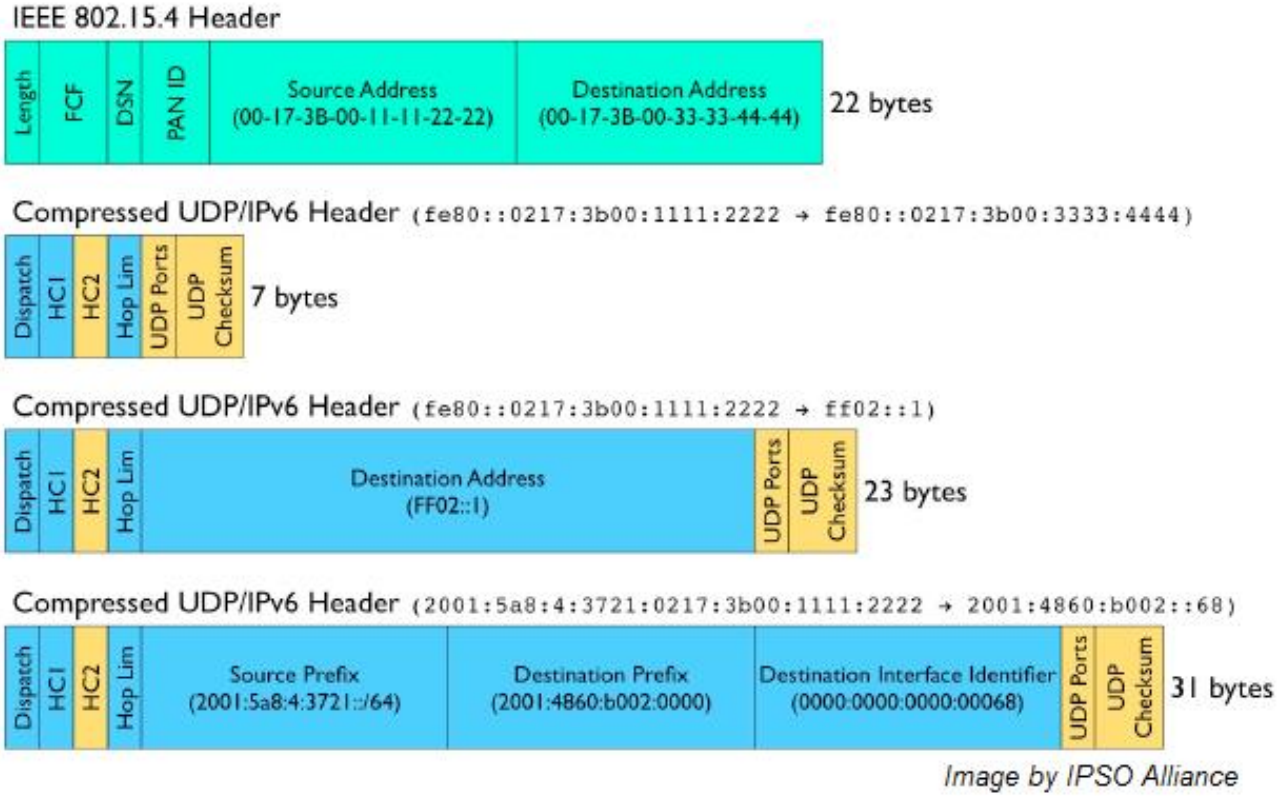


Image by IPSO Alliance

- Context-based compression

Experimental work in lab – setting up

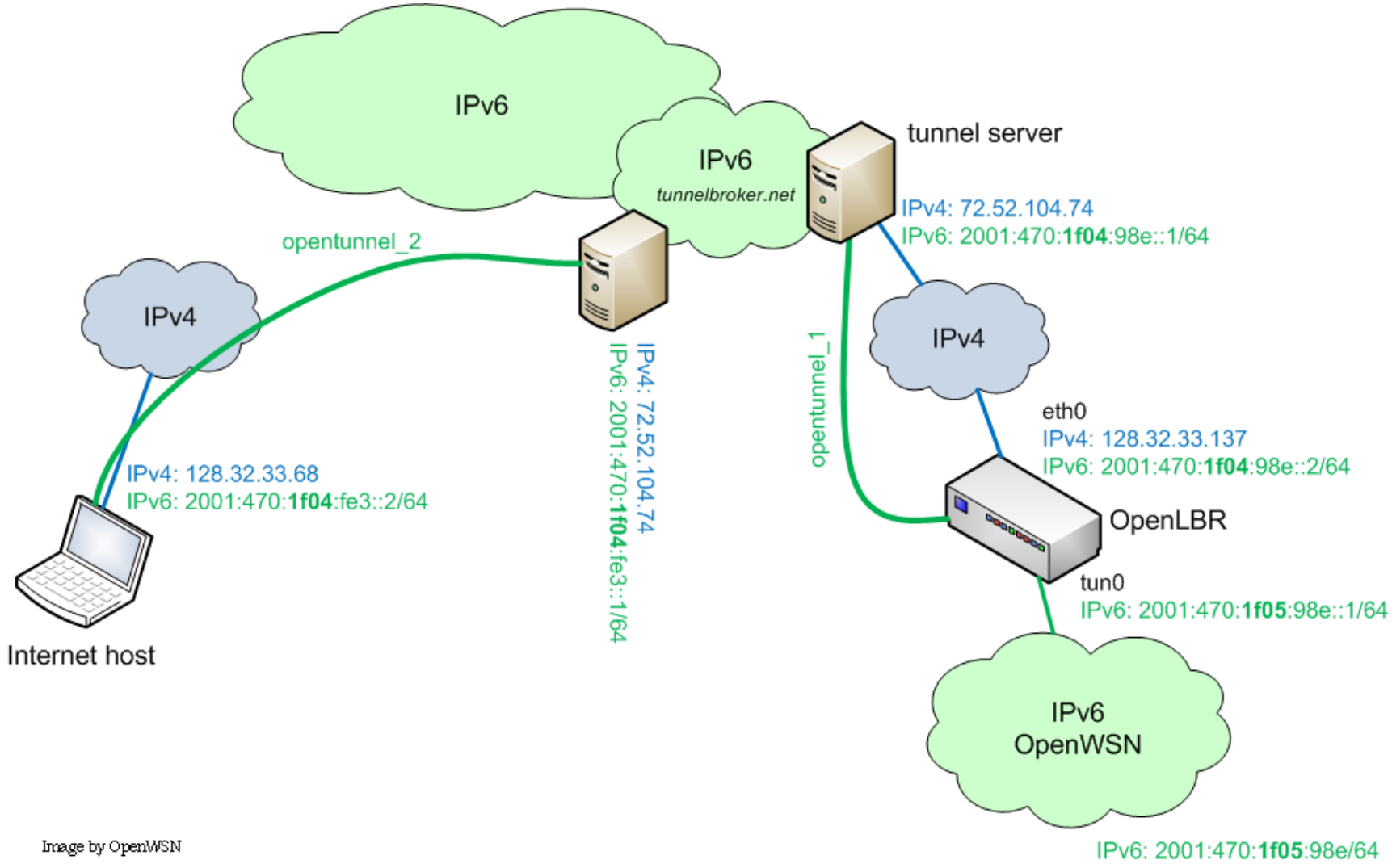
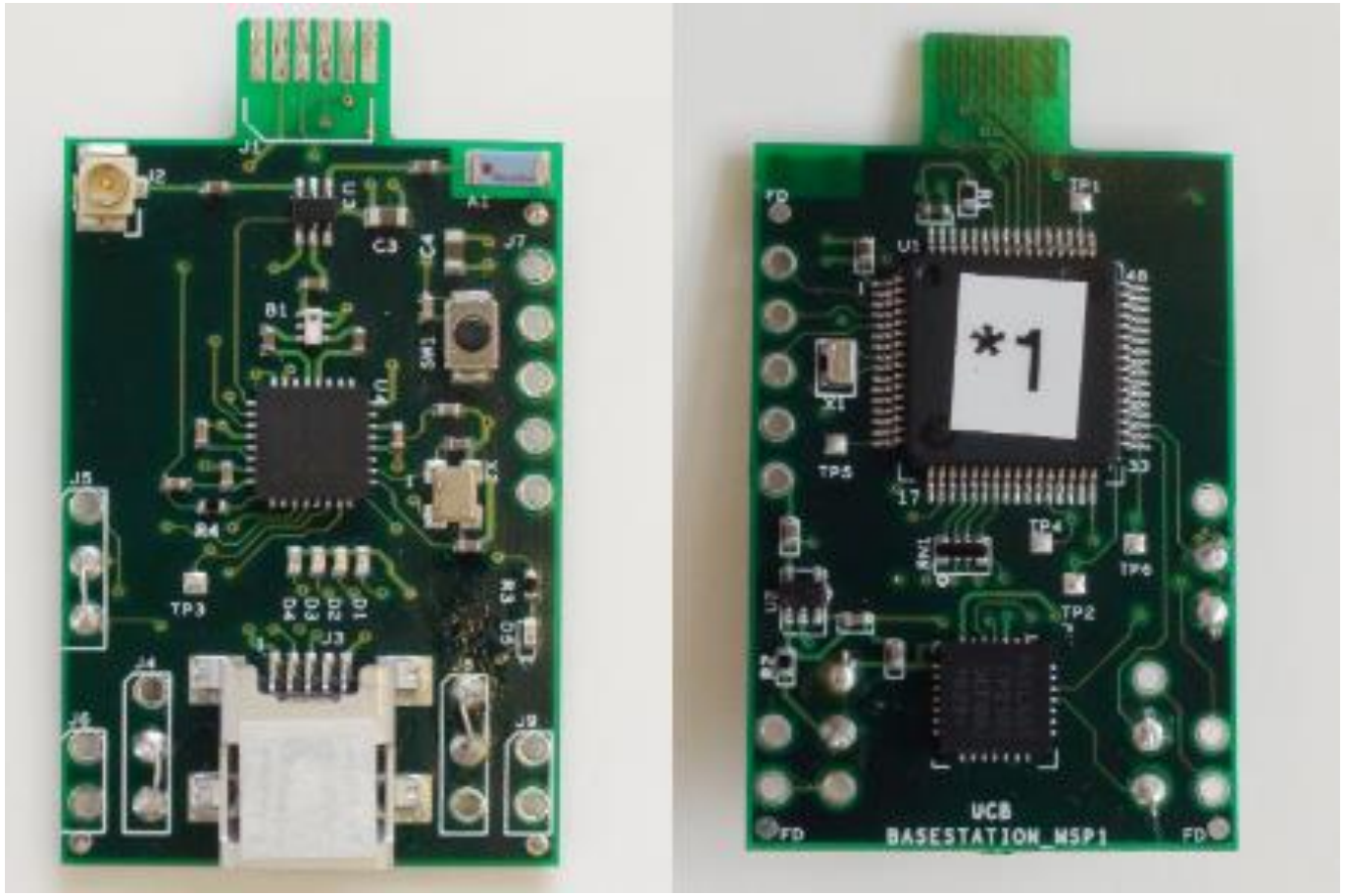


Image by OpenWSN

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 00 14 15 92 09 x..@#E..........
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: 23450000000000000141592090 22cedc5
Dst address: 2001063000c2ff0000000000000000017f
Payload:
009b0a510023690b112a5362626bedc50a00000070f9130300000024ffffffffc9fd99


000000 00 00 86 dd 60 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 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)

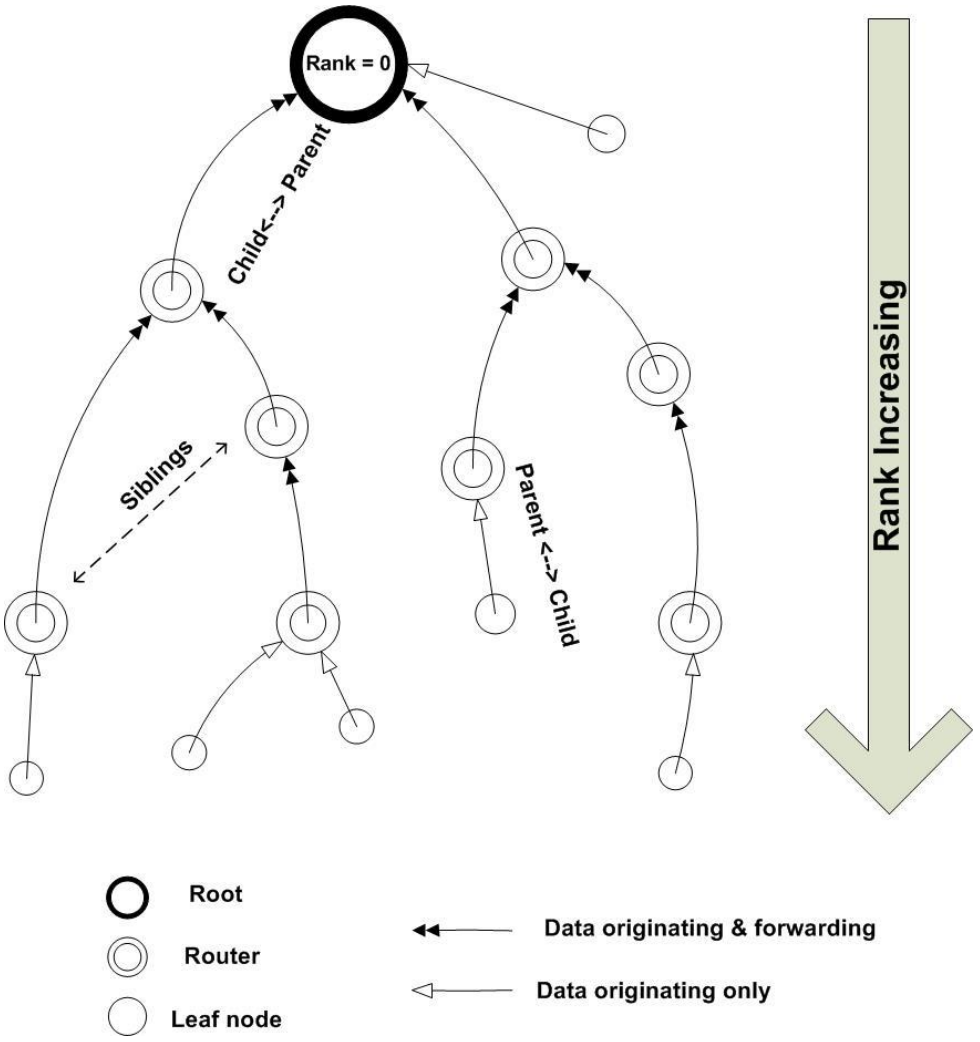
- IETF ROLL working group

- 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