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6LoWPAN

IPv6 para WSN

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Outline

- Introduction to 6LoWPAN
- The 6LoWPAN Features and Format
- Neighbor Discovery
- Application Layer
- Implementing 6LoWPAN

Introduction

Internet of Things

- A global network infrastructure, linking physical and virtual objects through the exploitation of data capture and communications capabilities.

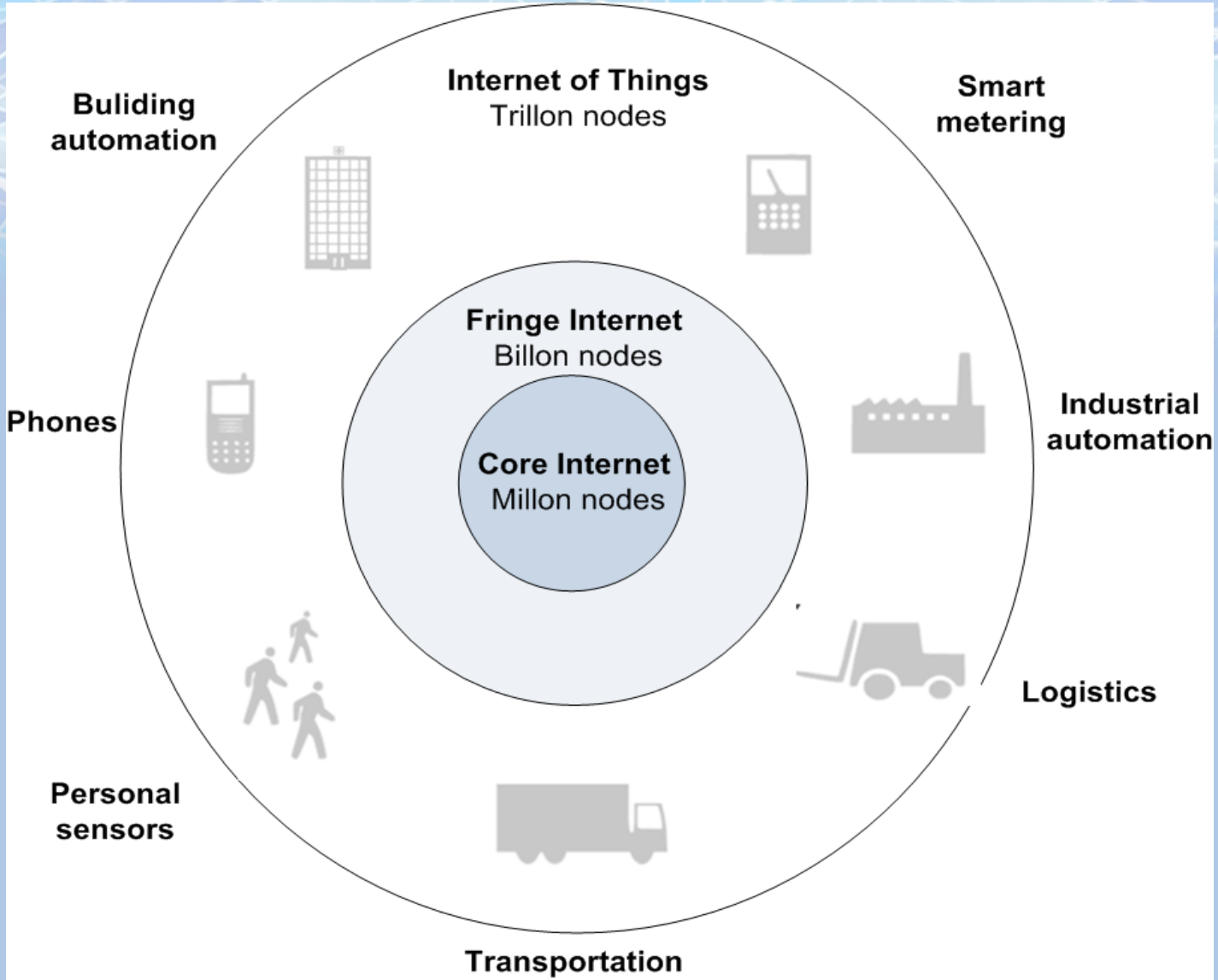
  - This infrastructure includes existing and evolving Internet and new network developments.

  - It will offer specific object-identification, sensor and connection capability as the basis for the development of independent federated services and applications.

  - These will be characterized by a high degree of autonomous data capture, event transfer, network connectivity and interoperability.

Source CASAGRAS 2

Internet of Things
Scope



Internet of Things
Challenge I - Interconnection

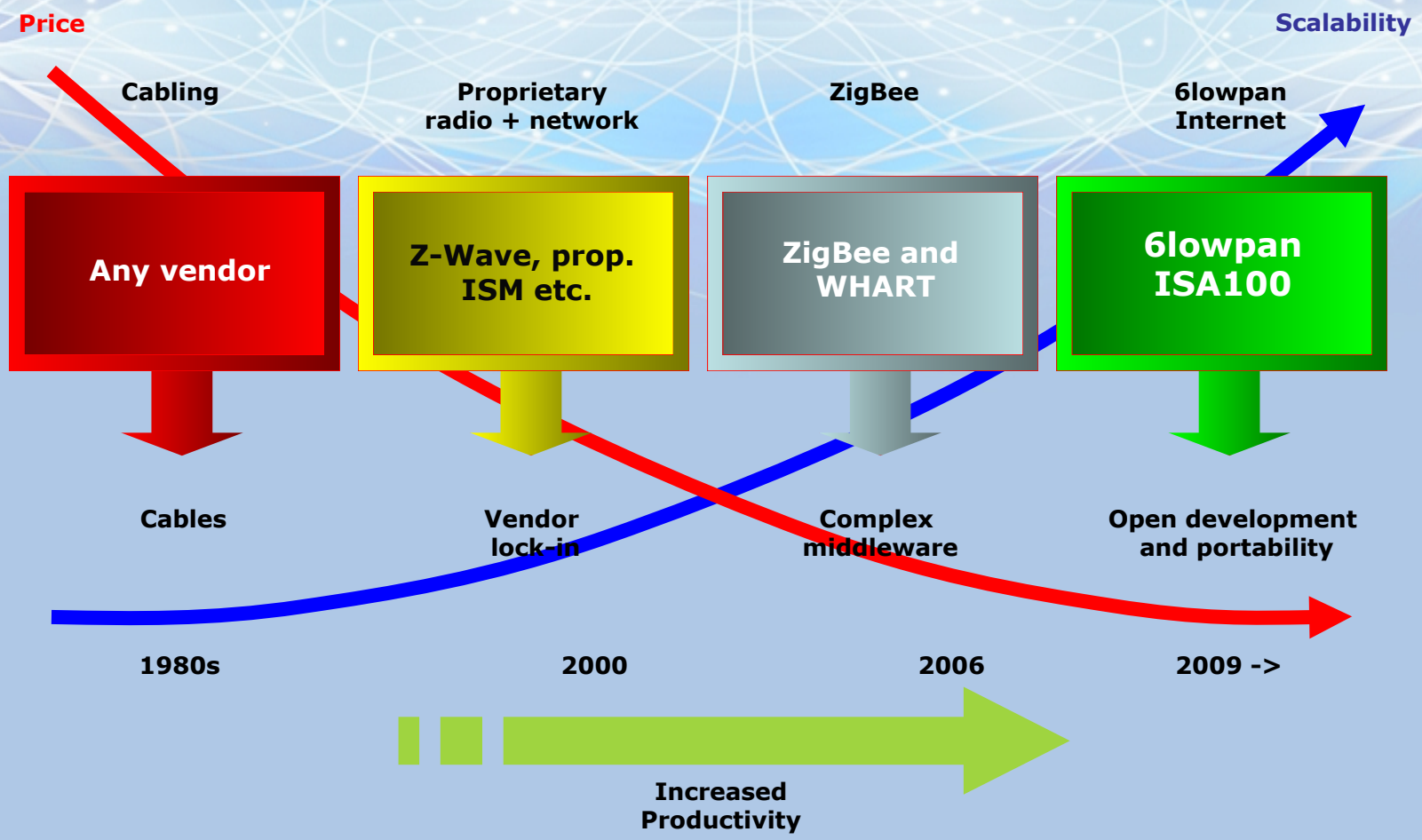
Wires are too expensive

- Electrical wall socket + installation = $50
- Cat5 socket + installation = $150
- 1 Trillon nodes >> 1000 GDP Argentina

Wireless ? …. ->WSN

Technology	Range	Speed	Power Use	Cost
Wifi	100 mts.	10100Mb/s	High	$$$
Bluethoot	10-100 mts.	1-3 Mb/s	Medium	$$
202.15.4	10 – 100 mts.	0,25Mb/s	Low	$

Evolution of Wireless Sensor Networks



Challenge of Iot II

Hard to implement in embedded devices:

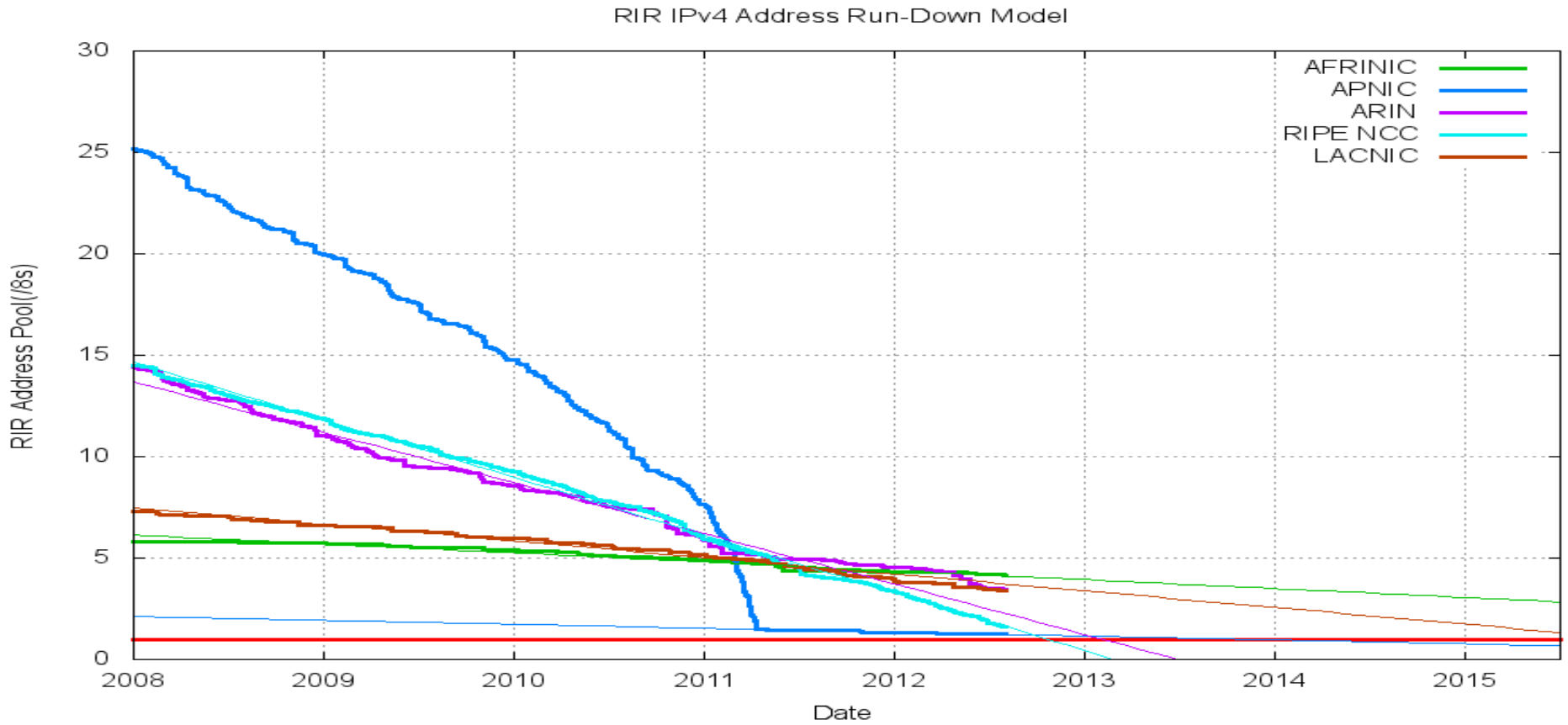
-Power and duty-cycle: Battery-powered wireless devices need to keep low duty cycles.
-Reliability: Standard Internet protocols are not optimized for low-power wireless and lossy networks.
-WebServices: Internet services today rely on webservices, mainly using the transmission control protocol (TCP).
-Management: Management with SNMP or web services.
-Not enough addresses: for assign to all IoTnodes.(2^32)

Internet (v4) Regional Registry Exhaustion

Addresses Challenge

IANA Unallocated Address Pool Exhaustion: 03-Feb-2011

"Exhaustion" when the pool of available addresses in each RIR reaches the last /8 threshold.



IP next generation

IPv6

Some Features:

Address space: 128 bits (2^{128})

- 3.4×10^{38} = 340282366920938463463374607431768211456 addr.
- There are only ~ 10^{25} grains of sand on the earth
- Let's settle for a trillion objects on the net.

Fix size Header

- **No fragmentation** in the path
- Extensibility by adding extension header

Unicast, Multicast y Anycast (**NO Broadcast**)

Stateless and stateful address autoconfiguration

Challenge of Iot III

Hard to implement in embedded devices:

-Frame size: Current Internet protocols require links with sufficient frame length (minimal IPv6 MTU 1280).

-Multicast: Wireless embedded radio technologies, do not typically support multicast (IPv6 ND requires multicast) .

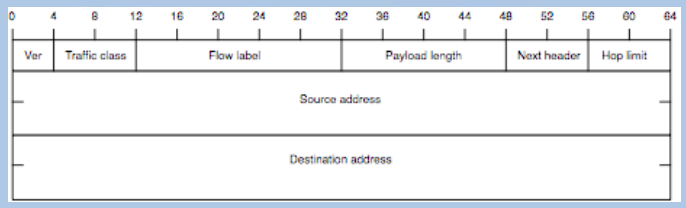
Benefits of 6LoWPAN Technology

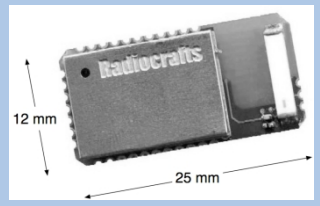
IPv6 over Low-Power Wireless Personal Area Networks

- **Low-power RF + IPv6 = The Wireless Embedded Internet**
  - 6LoWPAN makes this possible
- The benefits of 6LoWPAN include:
  - Open, long-lived, reliable **standards**
  - **Easy** learning-curve
  - Transparent **Internet** integration
  - Standard **socket** api
  - Network **maintainability**
  - Global **scalability**
  - **End-to-end** data flows
  - Use of **existing** Internet infrastructure

What is 6LoWPAN?

- IPv6 over Low-Power wireless Area Networks
- Defined by IETF standards
  - RFC 4919, 4944 (problems,format)
  - RFC 6282, 6775 (compression, nd)
  - RFC 6606 (routing)





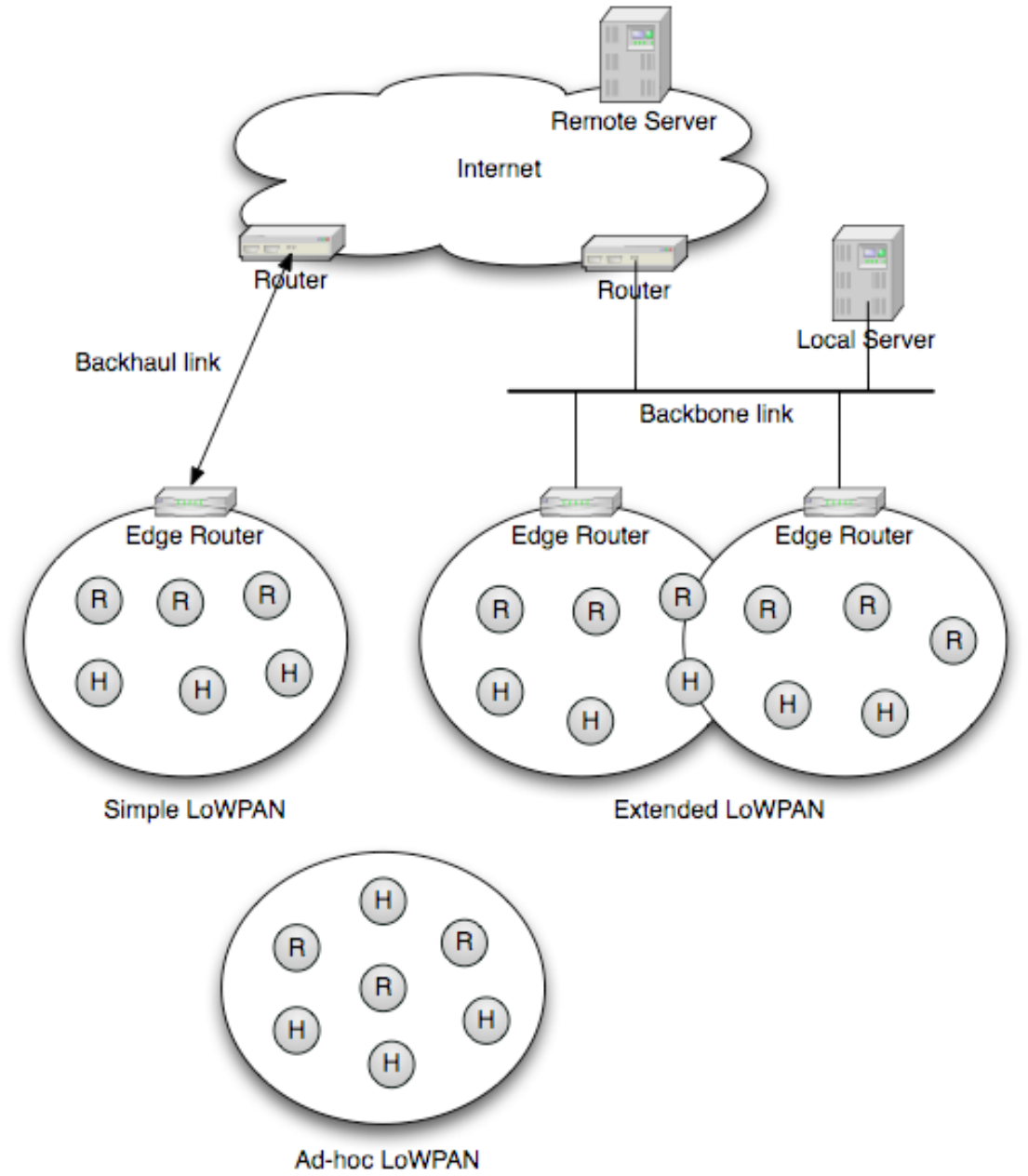
6loWPAN Features

- Useful with low-power link layers such as IEEE 802.15.4, narrowband ISM, power-line comunications and Bluetooth
- Support for e.g. 64-bit and 16-bit 802.15.4 addressing
- Fragmentation

  - 1280 byte IPv6 MTU -> 127 byte 802.15.4 frames
- Efficient header compression
  - IPv6 base and extension headers, UDP header
- Network autoconfiguration using neighbor discovery
- Unicast, multicast and broadcast support
  - Multicast is compressed and mapped to broadcast
- Support for IP routing (e.g. IETF RPL)
- Support for use of link-layer mesh (e.g. 802.15.5)

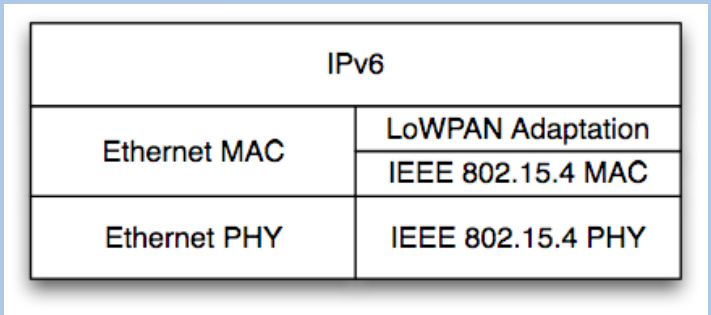
The 6LoWPAN Features and Format

Architecture



Architecture

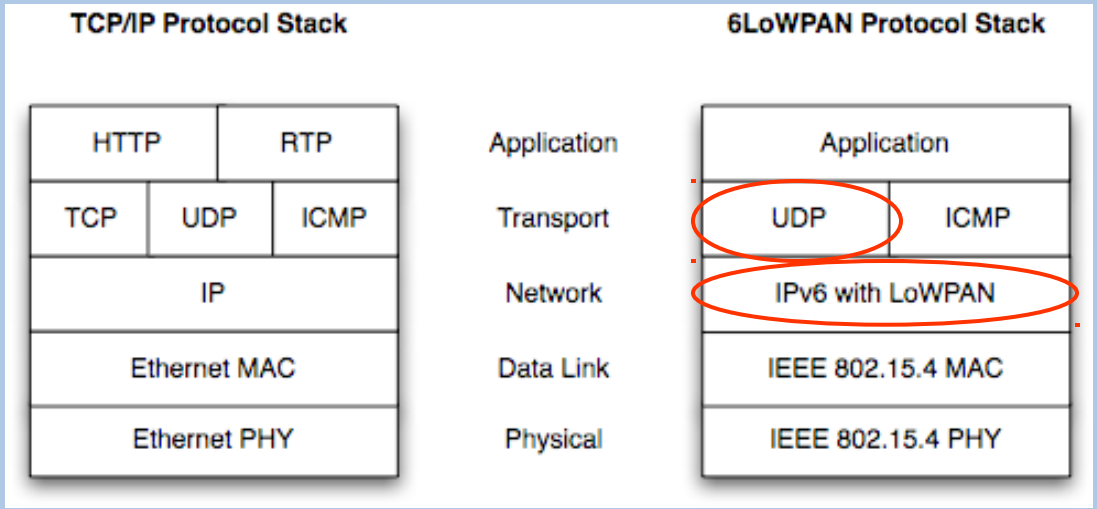
- LoWPANs are stub networks (no transit networks)
- Simple LoWPAN
  - Single Edge Router
- Extended LoWPAN
  - Multiple Edge Routers with common backbone link
- Ad-hoc LoWPAN
  - No route outside the LoWPAN
- Internet Integration issues
  - Maximum transmission unit
  - Application protocols
  - IPv4 interconnectivity (transition)
  - Firewalls and NATs
  - Security



IPv6-LoWPAN Router Edge Stack

The 6LoWPAN Format

- 6LoWPAN is an adaptation header format
  - Enables the use of IPv6 over low-power wireless links
  - IPv6 Fragmentation
  - IPv6 header compression
  - UDP header compression



Dispatch

First byte of the Payload

(http://www.iana.org/assignments/6lowpan-parameters/)

Bit Pattern	Header Type	Reference
00 xxxxxx	NALP - Not a LoWPAN frame	[RFC4944]
01 000000	Reserved as a replacement value for ESC	[RFC6282]
01 000001	IPv6 - uncompressed IPv6 Addresses	[RFC4944]
01 000010	LOWPAN_HC1 - compressed IPv6	[RFC4944]
01 000011 to 01001111	reserved for future use	
01 010000	LOWPAN_BC0 - broadcast	[RFC4944]
01 010001 to 01011111	reserved for future use	
01 1xxxxx	LOWPAN_IPHC	[RFC6282]
10 xxxxxx	MESH - Mesh header	[RFC4944]
11 000xxx	FRAG1 -- Fragmentation Header (first)	[RFC4944]
11 001000 to 11011111	reserved for future use	
11 100xxx	FRAGN -- Fragmentation Header (subseq)	[RFC4944]
11 101000 to 11111111	reserved for future use	

Fragmentation

- IPv6 requires underlying links to support Minimum Transmission Units (MTUs) of at least 1280 bytes.
- IEEE 802.15.4 leaves approximately 80-100 bytes of payload!
- RFC4944 defines fragmentation and reassembly of IPv6
- The performance of large IPv6 packets fragmented over low-power wireless mesh networks is poor!
  - Lost fragments cause whole packet to be retransmitted !
  - Low-bandwidth and delay of the wireless channel
  - 6LoWPAN application protocols **should avoid** fragmentation
  - Compression should be used on existing IP application protocols when used over 6LoWPAN if possible

Fragmentation

```
Initial Fragment

 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|1 1 0 0 0|    datagram_size    |         datagram_tag          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

Following Fragments

 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|1 1 1 0 0|    datagram_size    |         datagram_tag          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|datagram_offset|
+-+-+-+-+-+-+-+-+
```

IP Header Compression (HC1 and HC2)

- No gzip techniques
- No end to end technique – IP addr is needed in every route
- Stateless compression

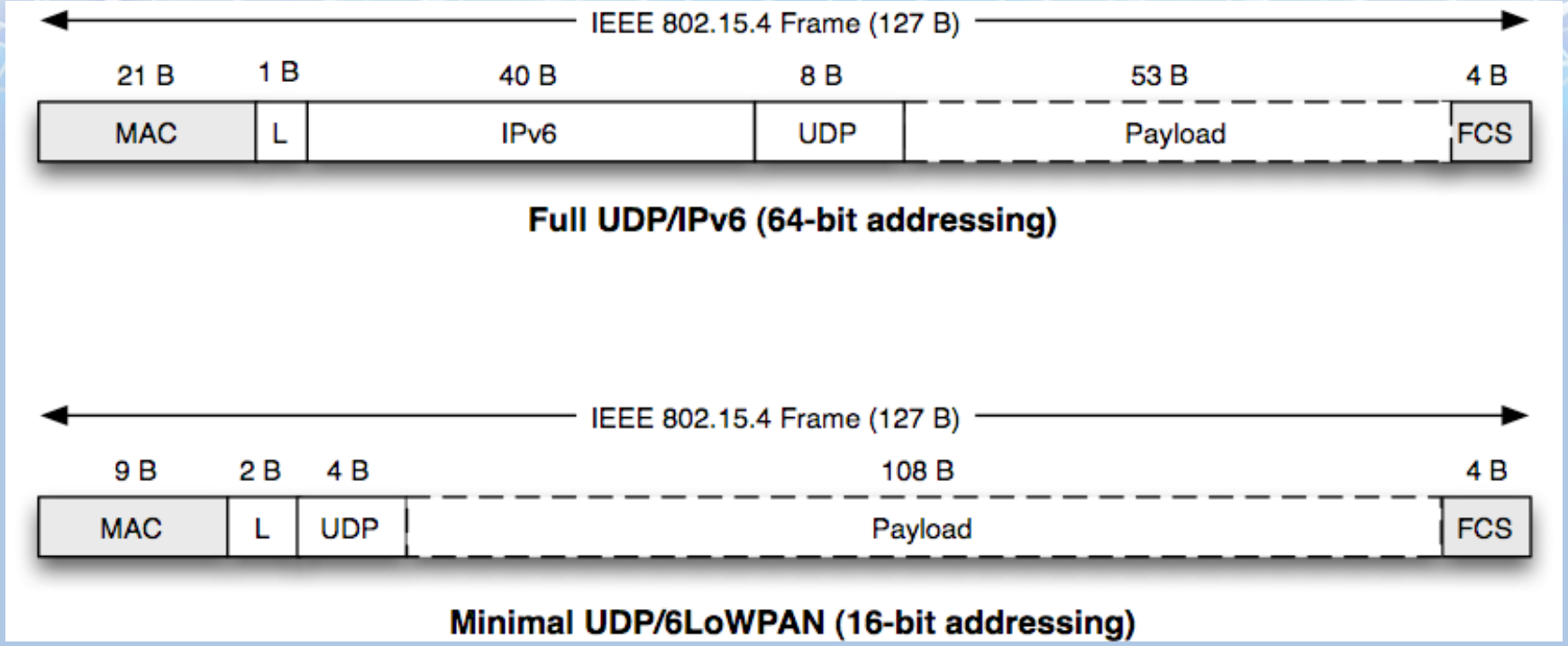
```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| 0 1 0  0 0 0  1 0|SAE|DAE|C|NH  |0 |      Non-Compressed fields...
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  \__dispatch __/  \_ HC1 header_/

 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| 0 1 0  0 0 0  1 0|SAE|DAE|C|NH  |1 |S|D|L|___________| N.-C. fields...
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  \__ dispatch__/ \_ HC1 header_/ \_ HC2 header_/
```

C = Class and Flow Label
SAE/DAE = Source/Destination Address Encoding
NH = Next Header
S/D = Source/Destination Port Compression (61616 + 16)
L= whenever the length es compressed
Never Compressed Hop Limit and UDP Checksum

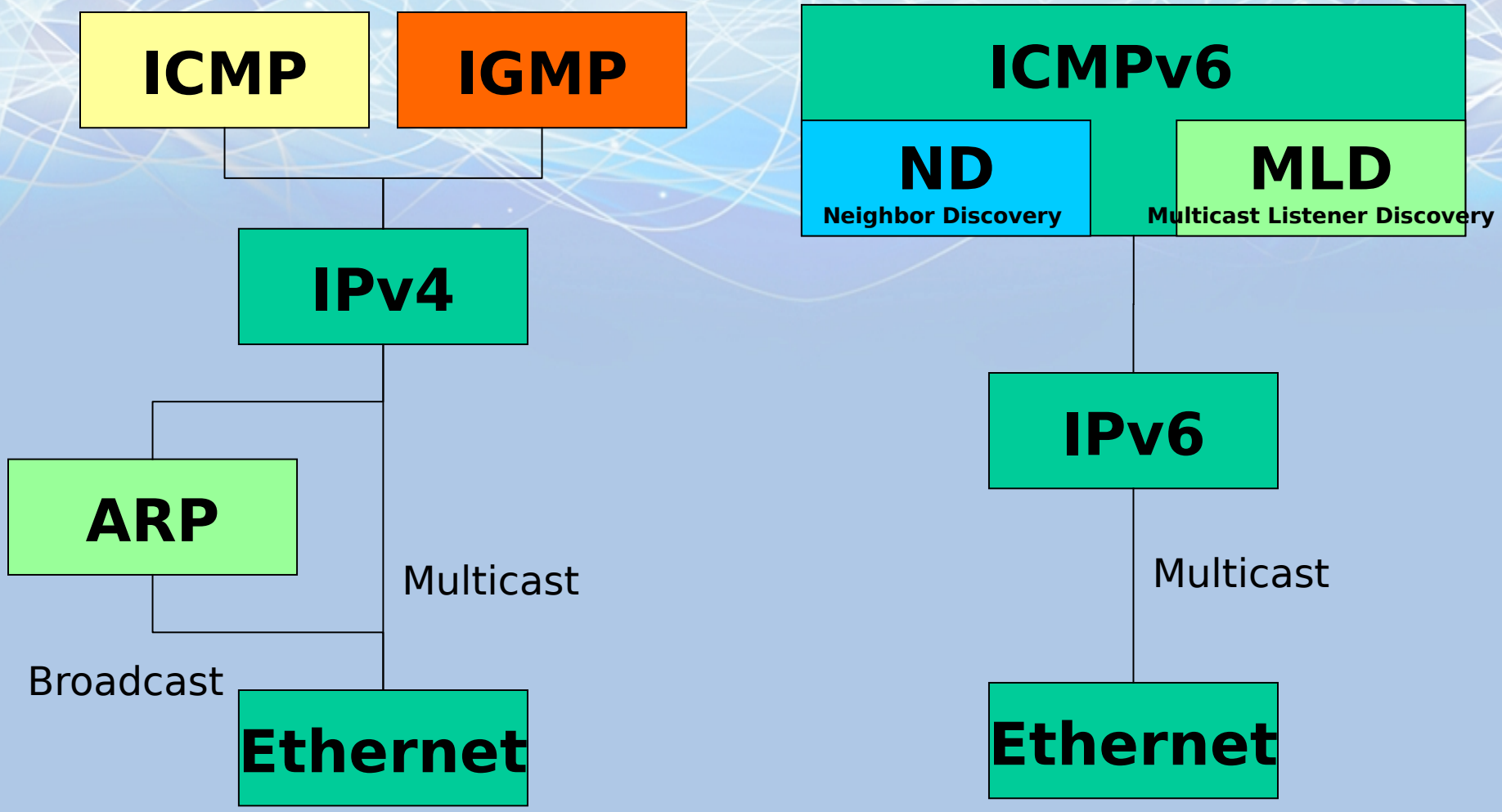
6LoWPAN Headers

- Orthogonal header format for efficiency
- Stateless header compression



Neighbor Discovery

ICMPv6


ICMP
IGMP
IPv4
ARP
Multicast
Broadcast
Ethernet
ICMPv6
ND
Neighbor Discovery
MLD
Multicast Listener Discovery
IPv6
Multicast
Ethernet

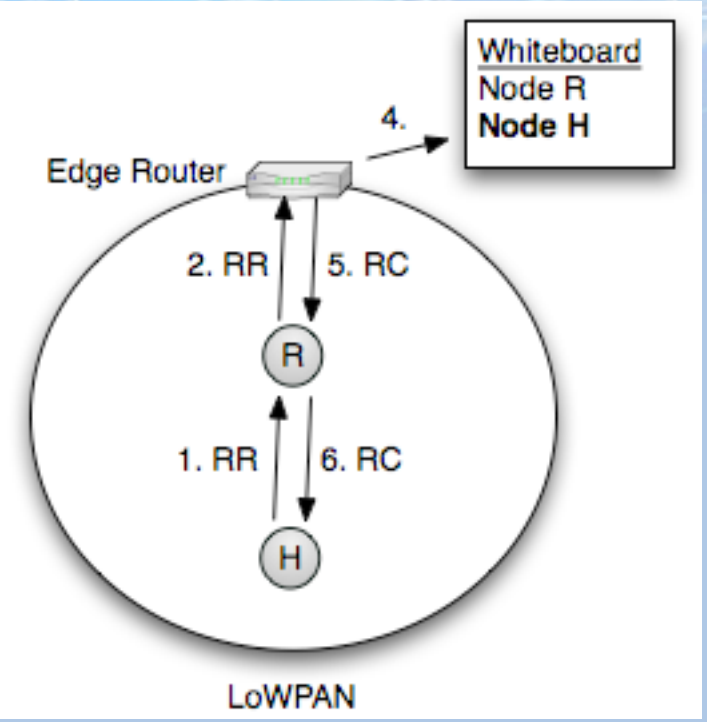
IPv6 Neighbor Discovery

- IPv6 is the format - ND is the brains
  - “One-hop routing protocol” defined in RFC4861
- Finding Neighbors
  - Neighbor Solicitation / Neighbor Advertisement
- Finding Routers
  - Router Solicitation / Router Advertisement
- Stateless Address Autoconfiguration using NS/NA
  - Detecting Addresses Duplication (DAD) using NS/NA
- Neighbor Unreachability Detection (NUD) using NS/NA
- Statefull DHCPv6 may be used in conjunction with ND
- Requirements:
  - Link-layer Multicast
  - Transitive relation between Neighbor

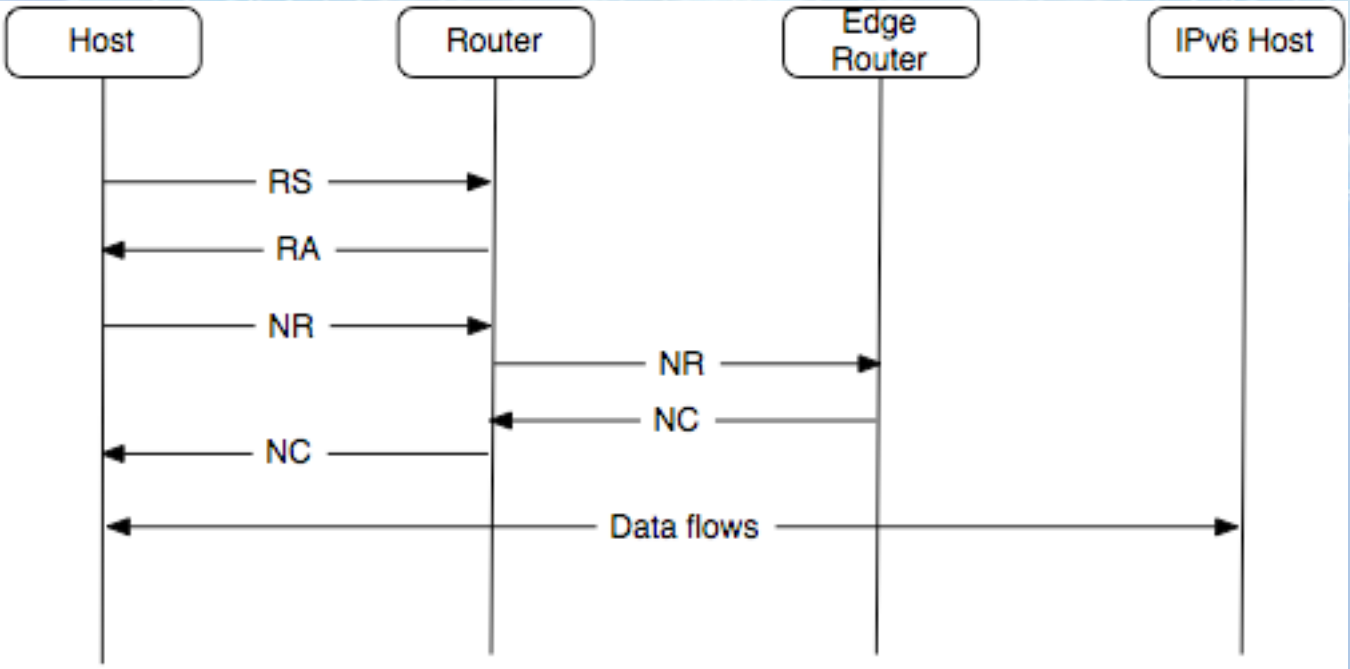
Devices must be awake all the time !!!

The Whiteboard

- The whiteboard is used in the LoWPAN for:
  - Duplicate address detection for the LoWPAN (= prefix)
  - Dealing with mobility (Extended LoWPANs)
  - Locating nodes



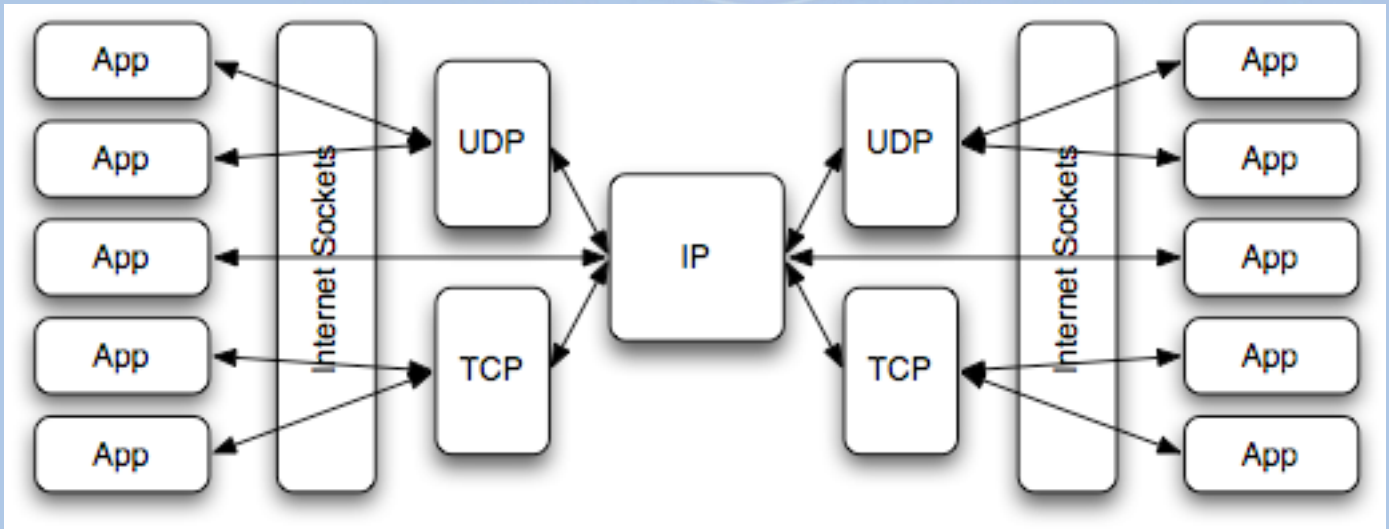
Typical 6LoWPAN-ND Exchange



Application Formats and Protocols

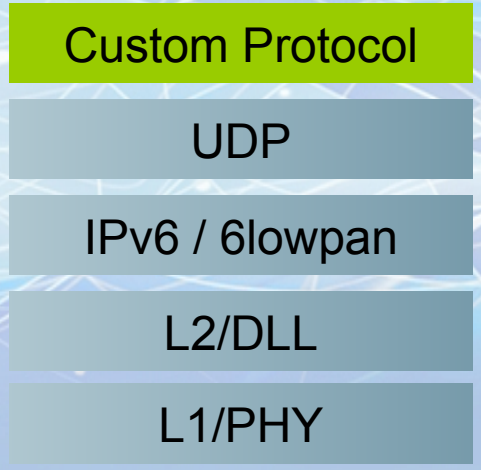
Introduction

- The **processes** of applications communicate over IP using an Internet Socket approach
- 6LoWPAN also uses the same Internet Socket paradigm
- Application protocols used with 6LoWPAN however have special design and performance requirements



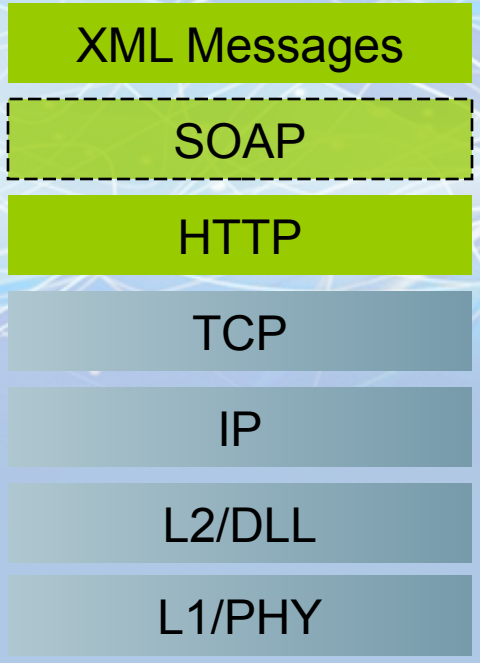
Custom Protocols

- The most common solution today
- Application data typically binary encoded, application specific
- Application protocol uses a specific UDP port, application specific
- As 6LoWPAN is end-to-end IPv6 communications, not a problem
- Advantage:
  - Compact, efficient, security can be integrated, end-to-end
- Disadvantage:
  - Custom server app needed, little re-use, learning curve, interoperability



XML/HTTP

- De-facto for inter-server communications
- Well-known XML schema important
- All Internet servers speak HTTP/XML
- Useable for RPC, pub/sub and events
- SOAP or REST paradigm
- Advantages:
  - Well known XML schema
  - Formal message sequences
  - Internet-wide support
- Disadvantages:
  - Inefficient, complex
- Solution: Embedded web-services
  - Constrained RESTfull Environments (CoRE) RFC6690



Implementation

Protocols Stacks

- **Contiki –** Open Source
  - Low-Power uIPv6/RPL Network and CoAP support
- **Linux** - OpenSource
  - Linux-Zigbee - ¿?
  - Since Kernel 3.8 – Support to RPL and CoAP in progress
- **Tiny OS –** Open Source
  - BLIP, the Berkeley Low-power IP stack IPv6 Ready
- **RIOT –** Open Source
  - 6LoWPAN, IPv6, RPL, TCP, and UDP . Parcial POSIX comp. Real Time
- **Arduino**
  - UIPv6 Stack – contiki ported to support Arduino Mega 2560
  - Pico IPv6 Stack – contiki ported to support Arduino PICO – without RPL
- **Nano Stack 2.0** (Sensinode)
  - Nano Stack, Nano Router, Nano Service
  - Nano Sensor
- **Jennic 6LoWPAN** (Jennic)
  - JN5139 Wireless Microcontroller, Jenie API, SNAP, JenNet

WSNGroup
GridTICs - FRM UTN

SIPIA Net

Wireless Sensor Network for Agronomical Research

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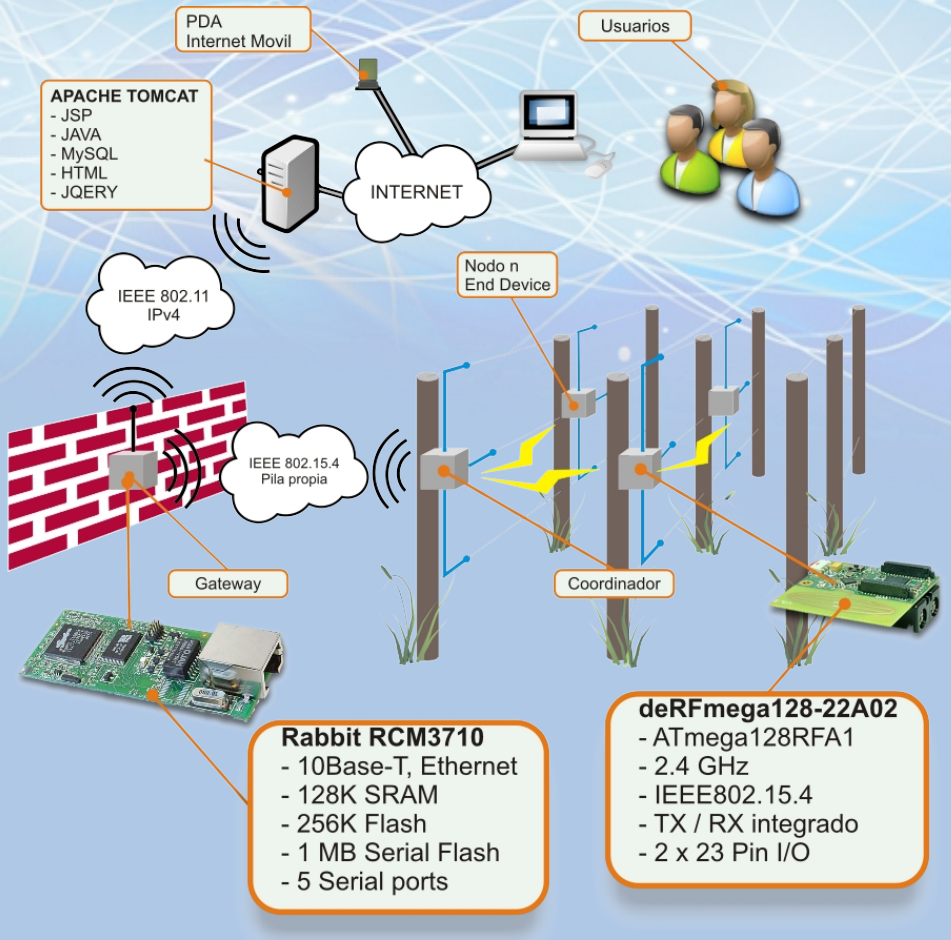

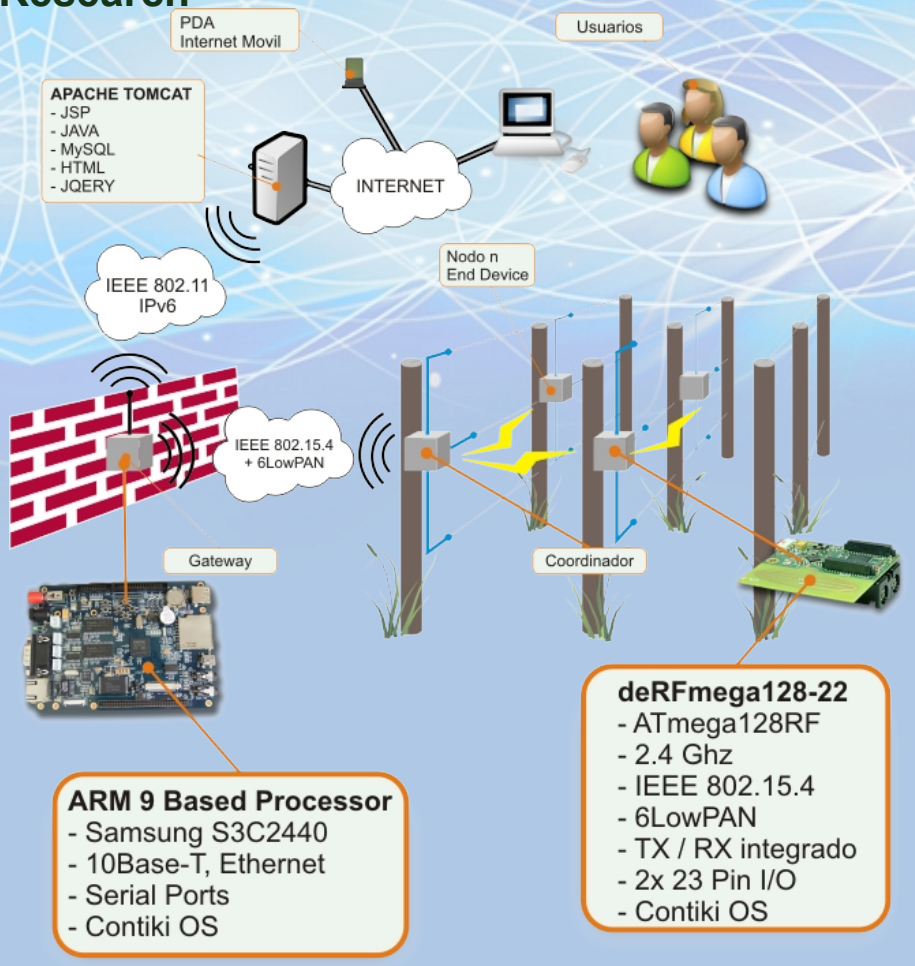

SIPIA Net

Propietary STACK (gridTiCS)

SIPIA6 Net

6loWPAN STACK

References

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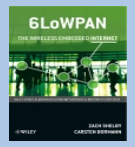

Shelby & Bormann, “The Wireless Embedded Internet” ISBN: 978-0-470-74799-5, (c) 2009 John Wiley & Sons Ltd

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Gracias por su asistencia !!!

PREGUNTAS ?

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