The challenges of networking in Wireless Sensor Networks

Winter school on Wireless Sensor Systems

Centre de Développement des Technologies Avancées

Algiers, Algeria, December 14th

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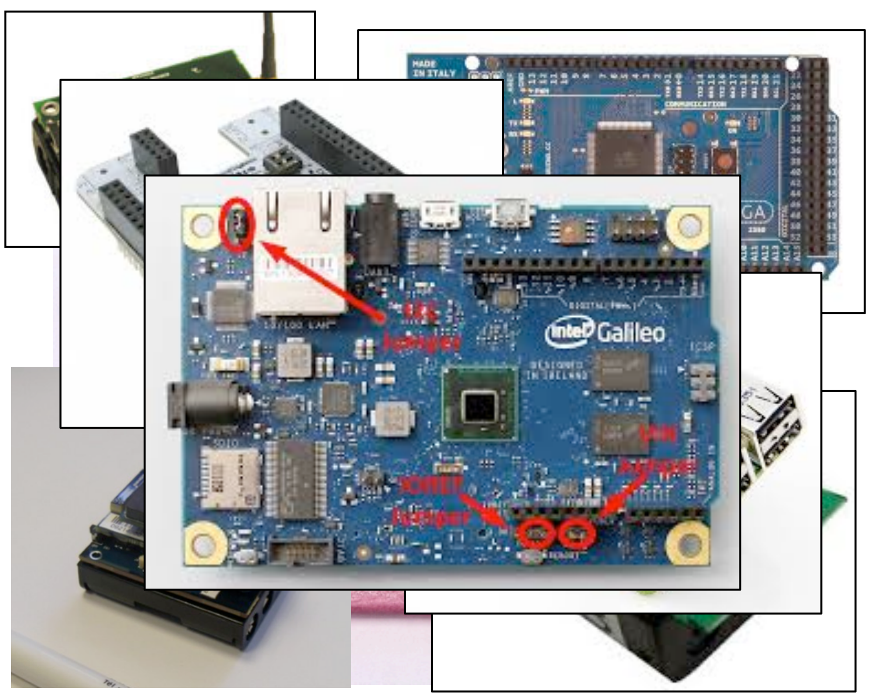
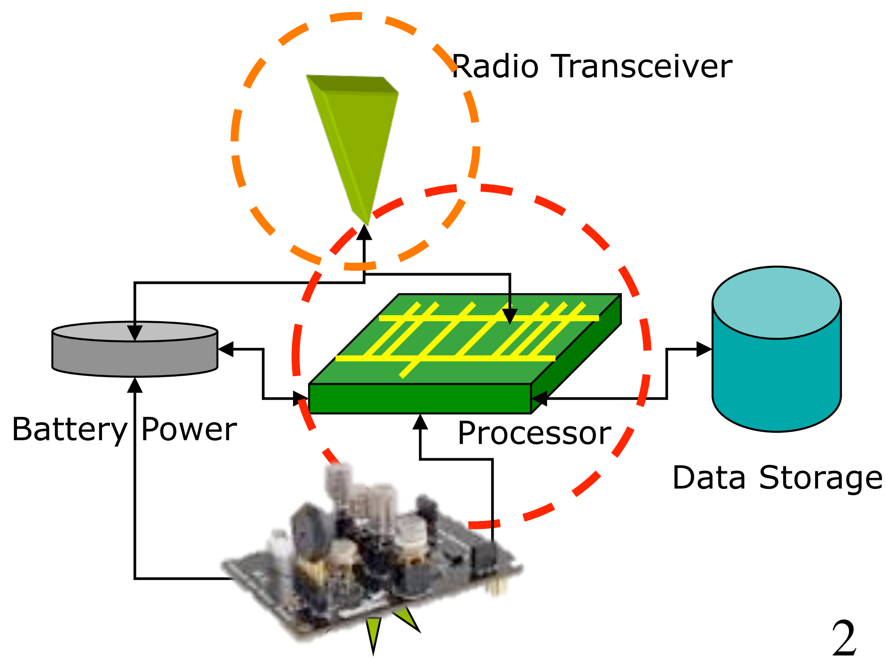
Université de Pau, France

Wireless autonomous sensor

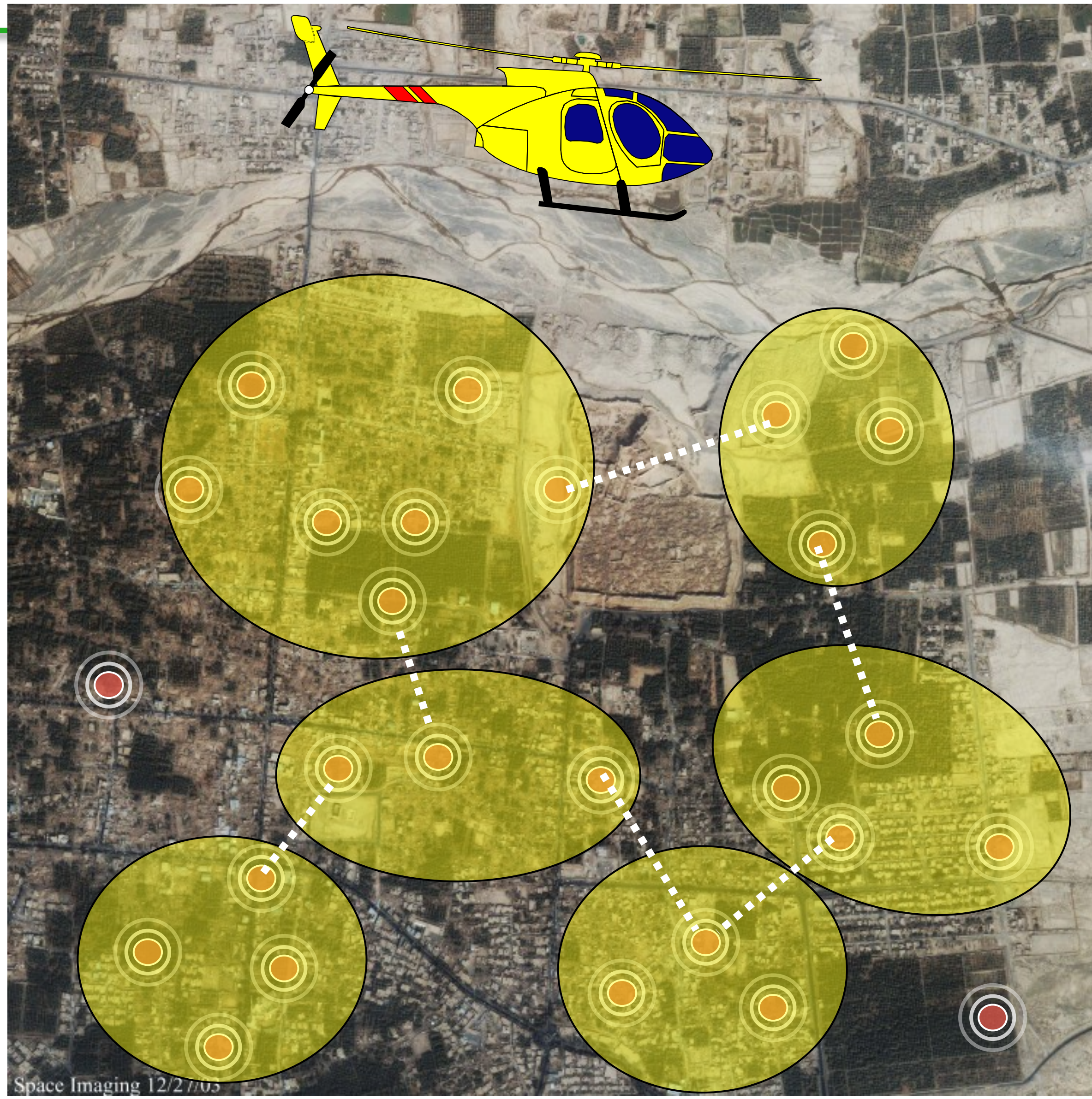
- Wireless Sensor Nodes or embedded Linux still remain the main IoT development platform
- In general: low cost, low power (the battery may not be replaceable), small size, prone to failure, possibly disposable





Sensor networks

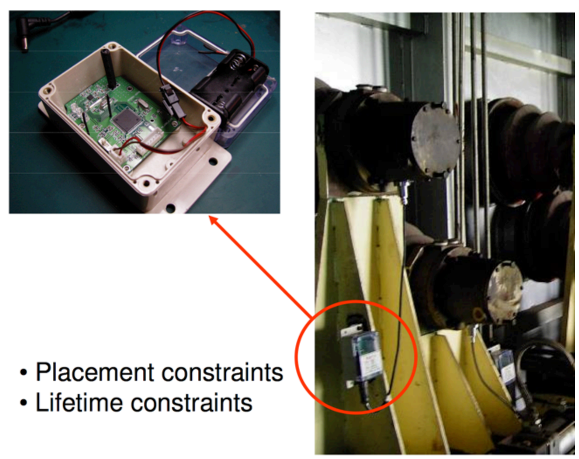
18720 Joules



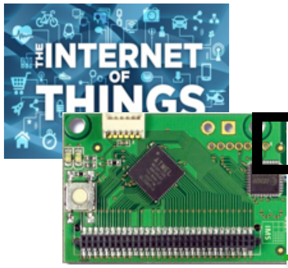
Academics vs Industries

Millions of sensors, self-organizing, self-configuring, with QoS-based multi-path routing, mobility, and …

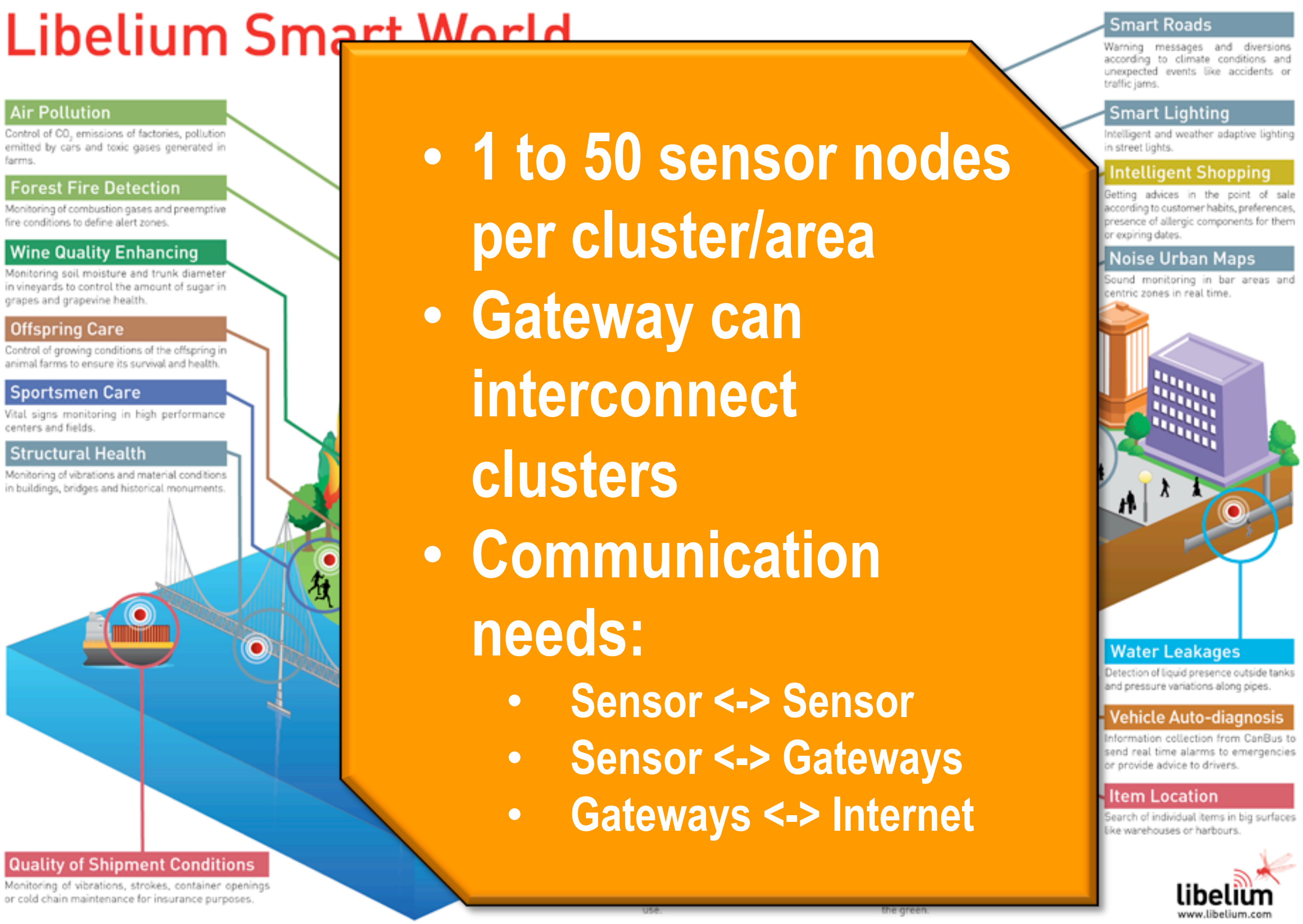
50 sensors, STATIC deployment, but need to have RELIABILITY, GUARANTEED LATENCY for monitoring and alerting. MUST run for 3 YEARS. No fancy stuff! CAN I HAVE IT?



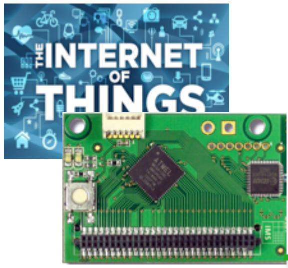
From Peng Zeng & Qin Wang



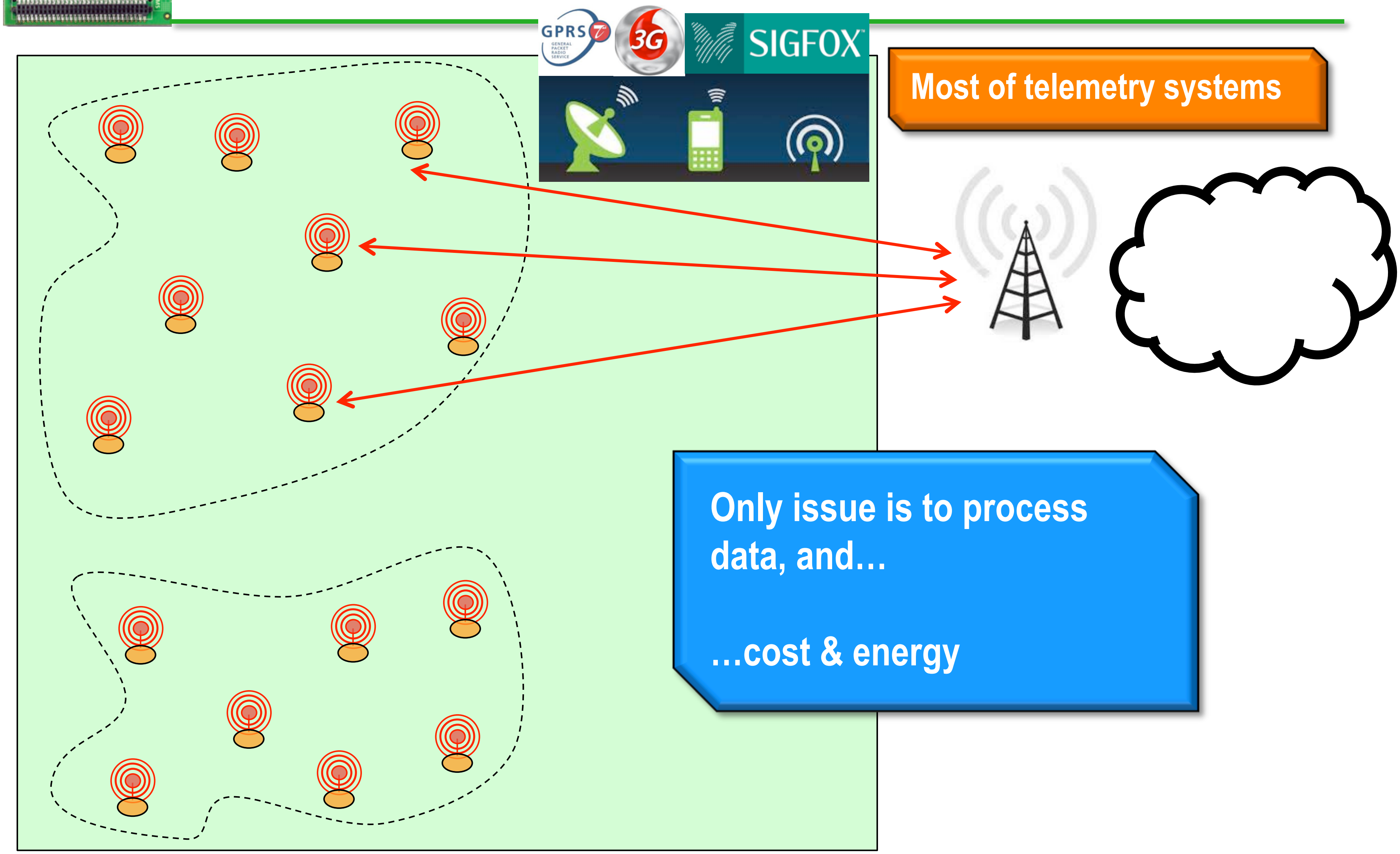
Deployment in Practice



- 1 to 50 sensor nodes per cluster/area
- Gateway can interconnect clusters
- Communication needs:
  - Sensor <-> Sensor
  - Sensor <-> Gateways
  - Gateways <-> Internet



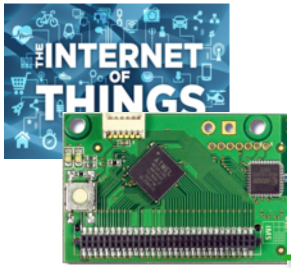
1-HOP COMMUNICATION



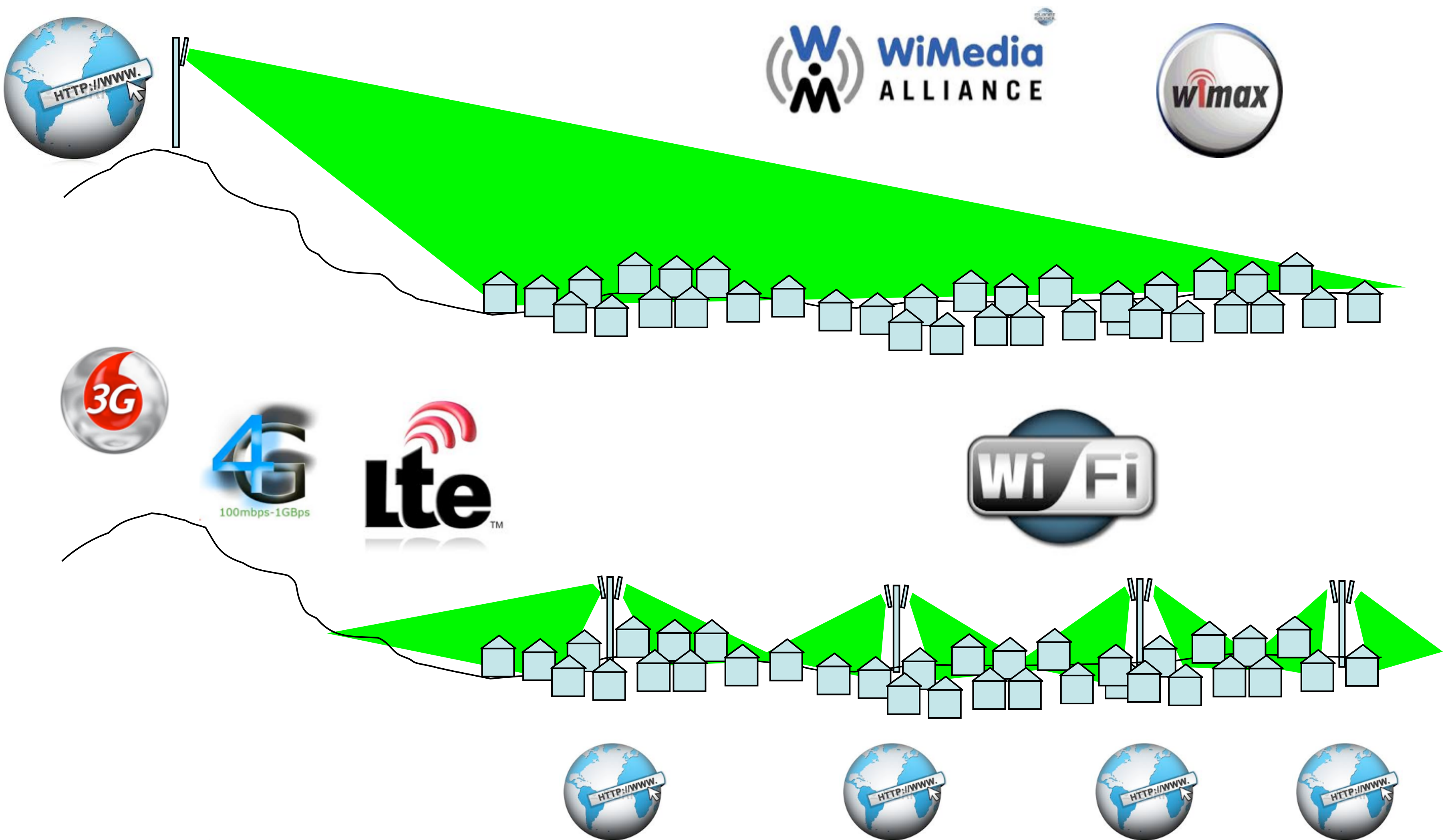
Most of telemetry systems

Only issue is to process data, and...

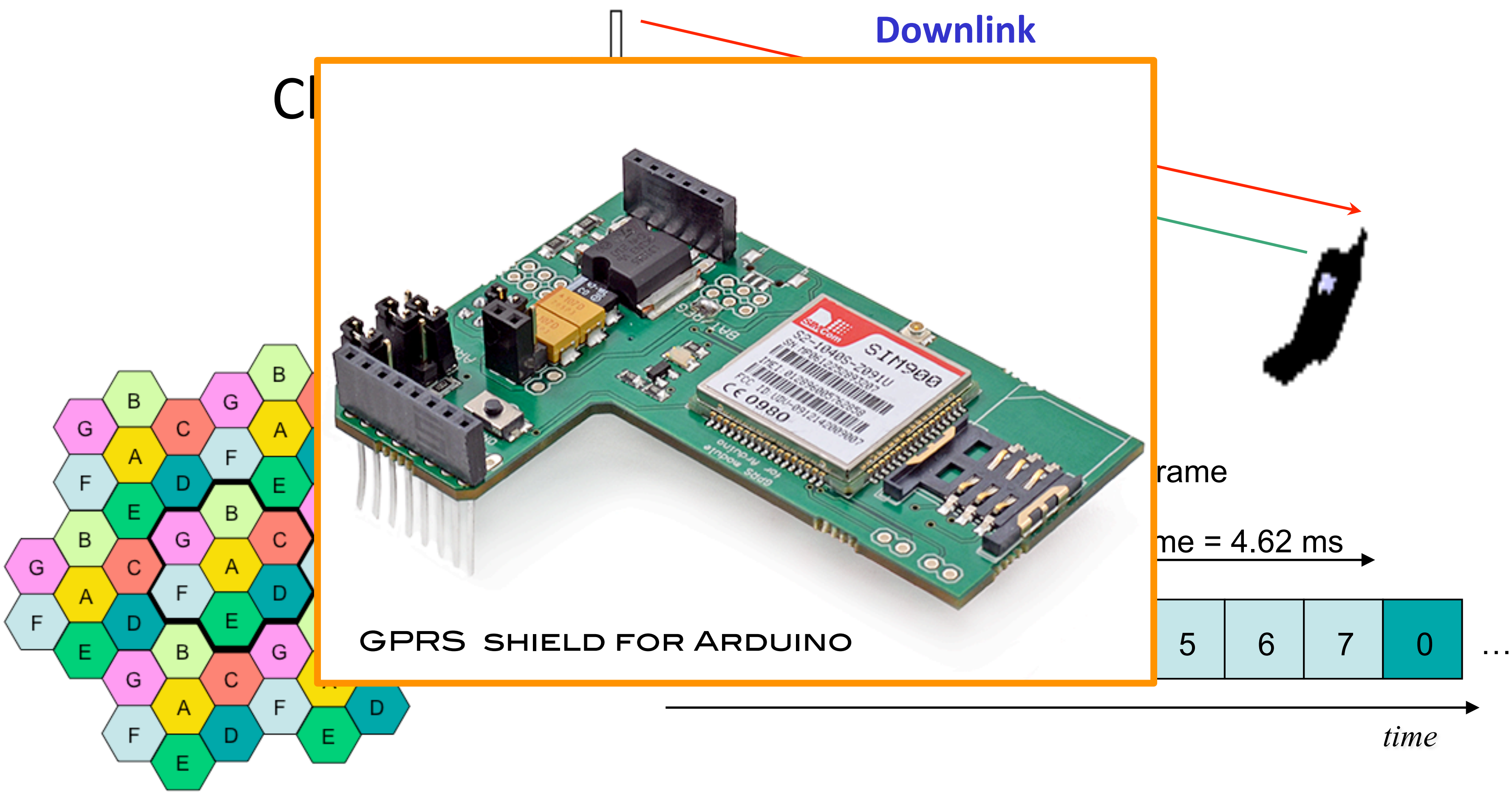
...cost & energy



Cellular model



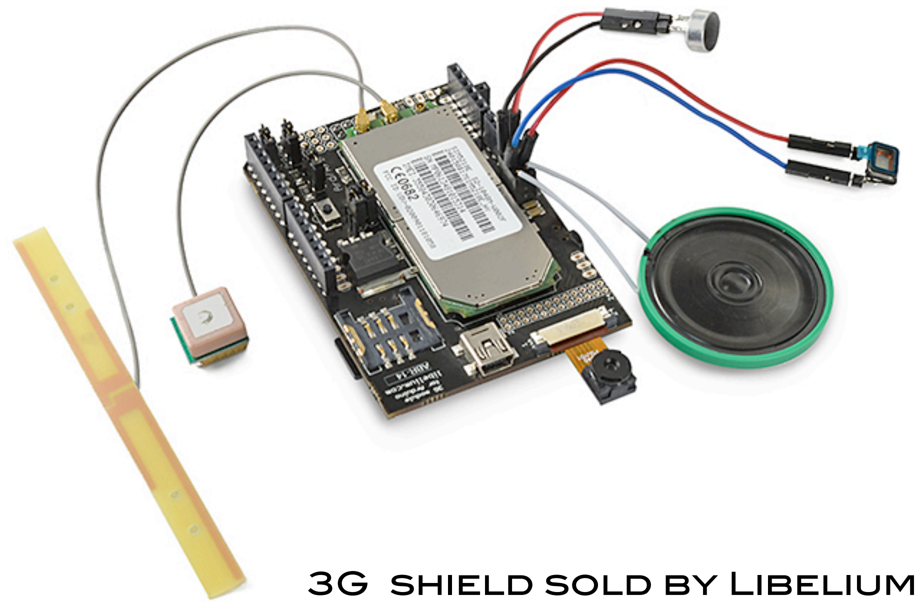
GSM (2G)/GPRS



GPRS shield for Arduino

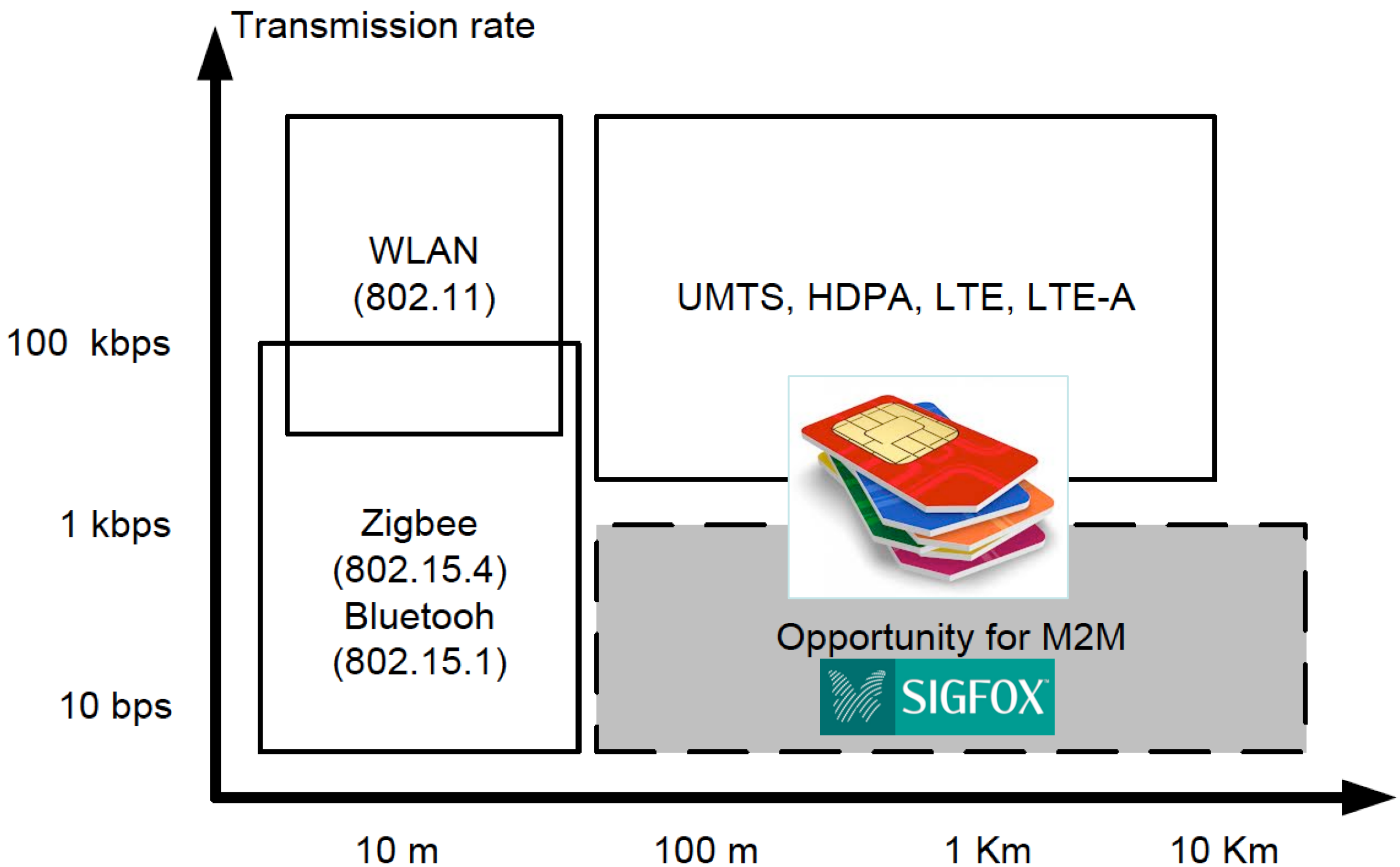
3G and Beyond

- 3G and beyond use CDMA techniques



3G shield sold by Libelium

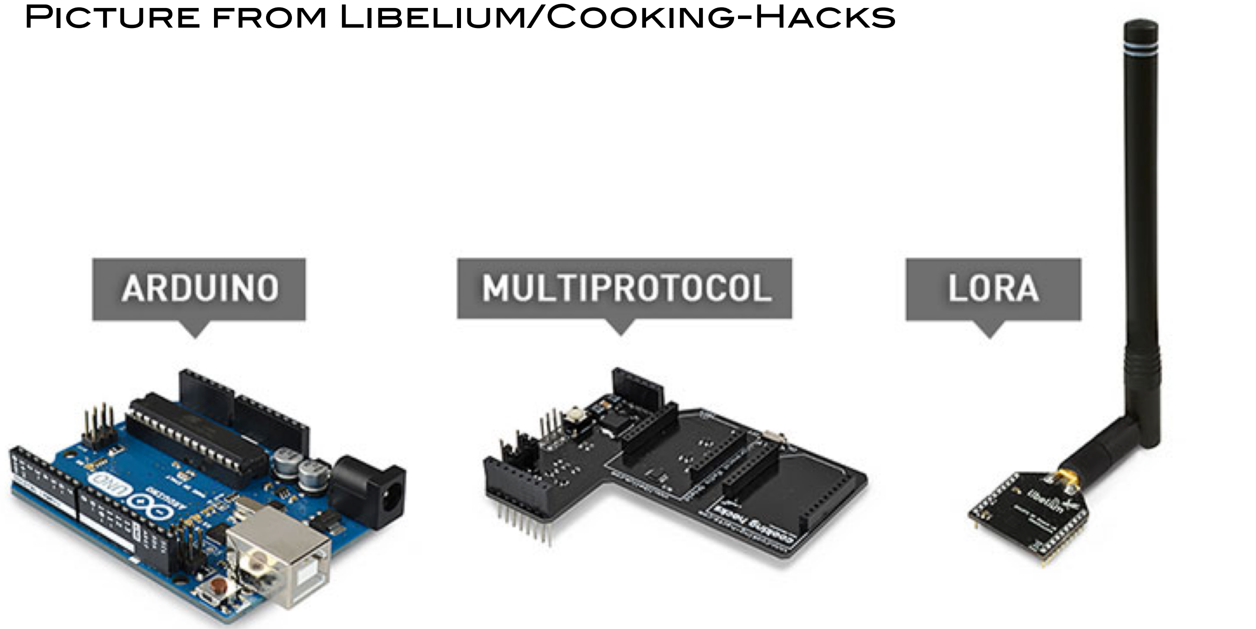
Opportunities for Telco operators & more...



Enhanced from M. Dohler "M2M in SmartCities"

Private long distance communications

Picture from Libelium/Cooking-Hacks

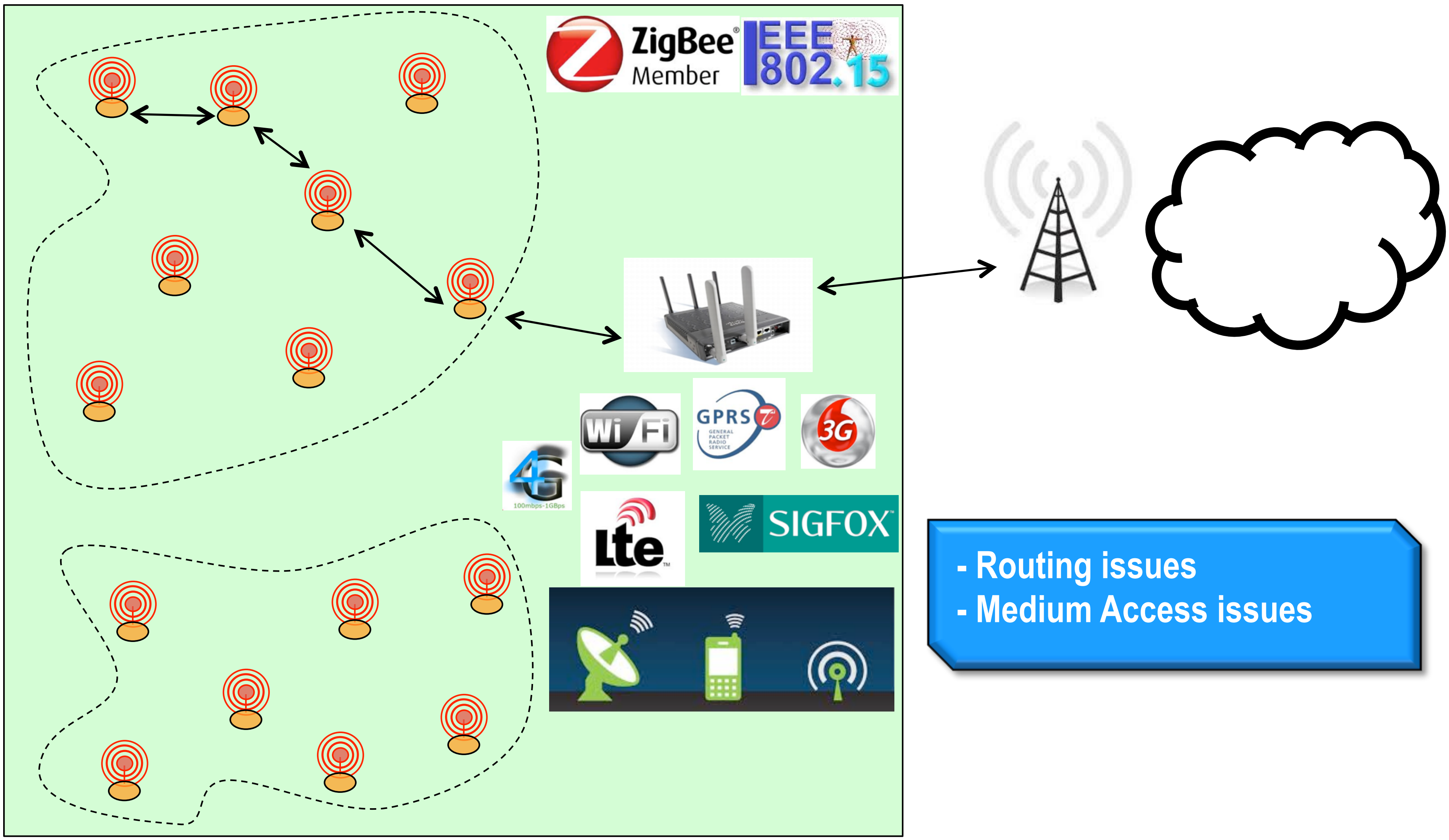


XBEE—
868 MHz
device G3 band for Europe
Outdoor RF line-of-sight
range up to 40 km
Data rate of 24 Kbps

on
863-870 MHz for Europe
Outdoor RF line-of-sight
range up to 22 km in LOS
and 2km in NLOS
Data rate?

Tests from Libelium

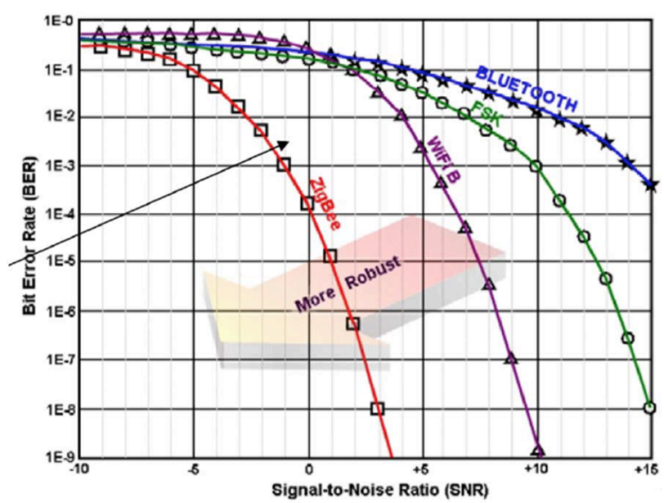
Multi-hop to gateways

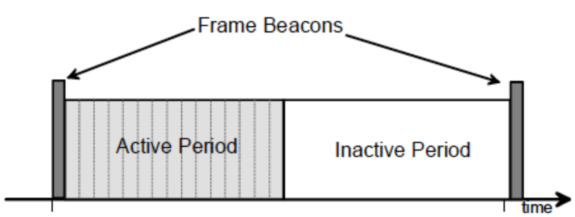


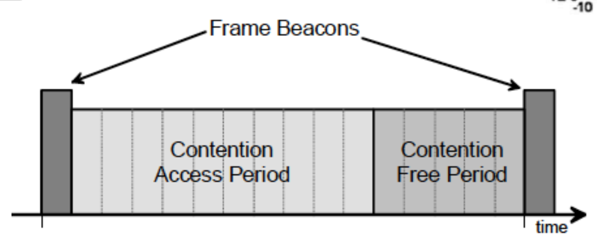
- Routing issues
- Medium Access issues

IEEE 802.15.4

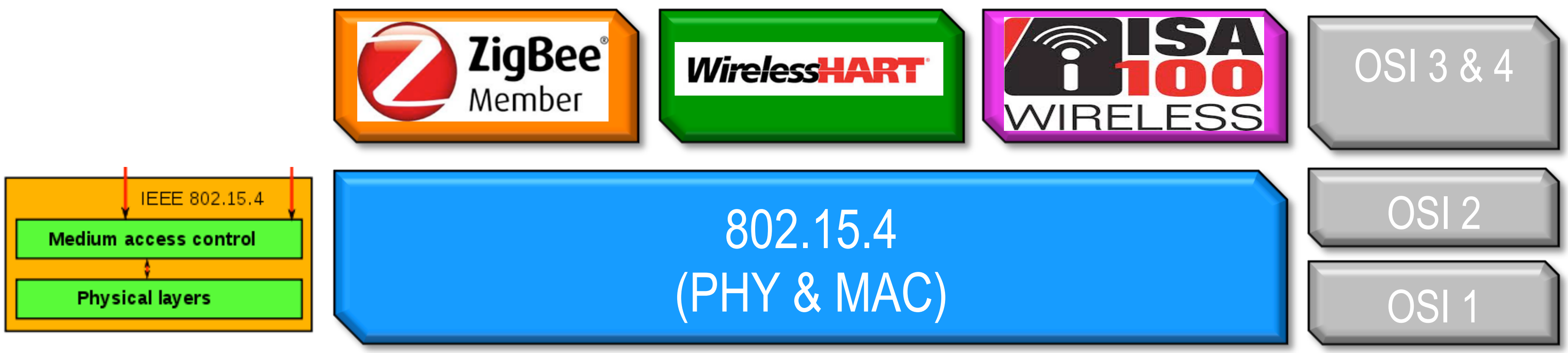
- Low-power radio offering up to 250kbps throughput at physical layer (2.4GHz, O-QPSK)
- Power transmission from 1mW to 100mW for range from 100m to about 1km is LOS
- CSMA/CA (beacon & non beacon)
- Used as physical layer in many stacks
- 64-bit or 16-bit address
- 16-bit PAN ID



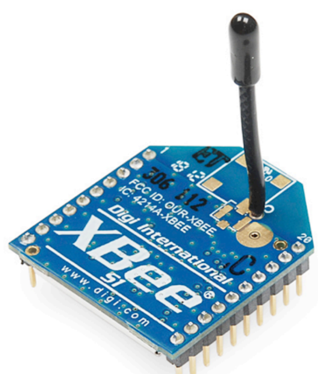




IEEE 802.15.4



CC2420 (TI)

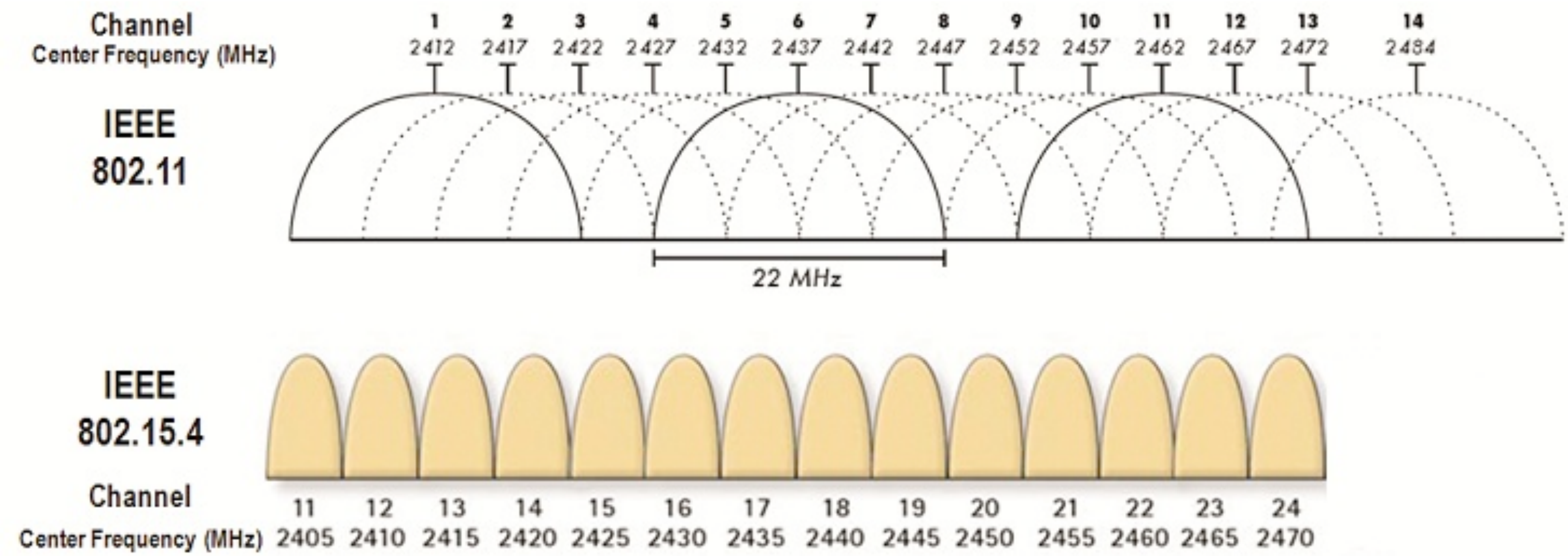


XBee (Digi)

MRF24J40MA (Microchip)

ZigBit AT86RF230 (Atmel)

Spectrum band



MAC FRAME FORMAT

Max size = 127 bytes

Max=102 bytes

Octets: 2	1	0/2	0/2/8	0/2	0/2/8	0/5/6/10/14	variable	2
Frame Control CC61	Sequence Number 58	Destination PAN 3332 r	Destination Address 0013A200 40922078	Source PAN 3332 r	Source Address 0013A200 4086D834	Auxiliary Security Header	Frame Payload HELLO	FCS 2B32
		Addressing fields						
MHR							MAC Payload	MFR

HELLO

64-bit 0x0013A2004086D834
16-bit 0x0010
CHANNEL 0x0C
PANID 0x3332

64-bit 0x0013A20040922078
16-bit 0x0020
CHANNEL 0x0C
PANID 0x3332

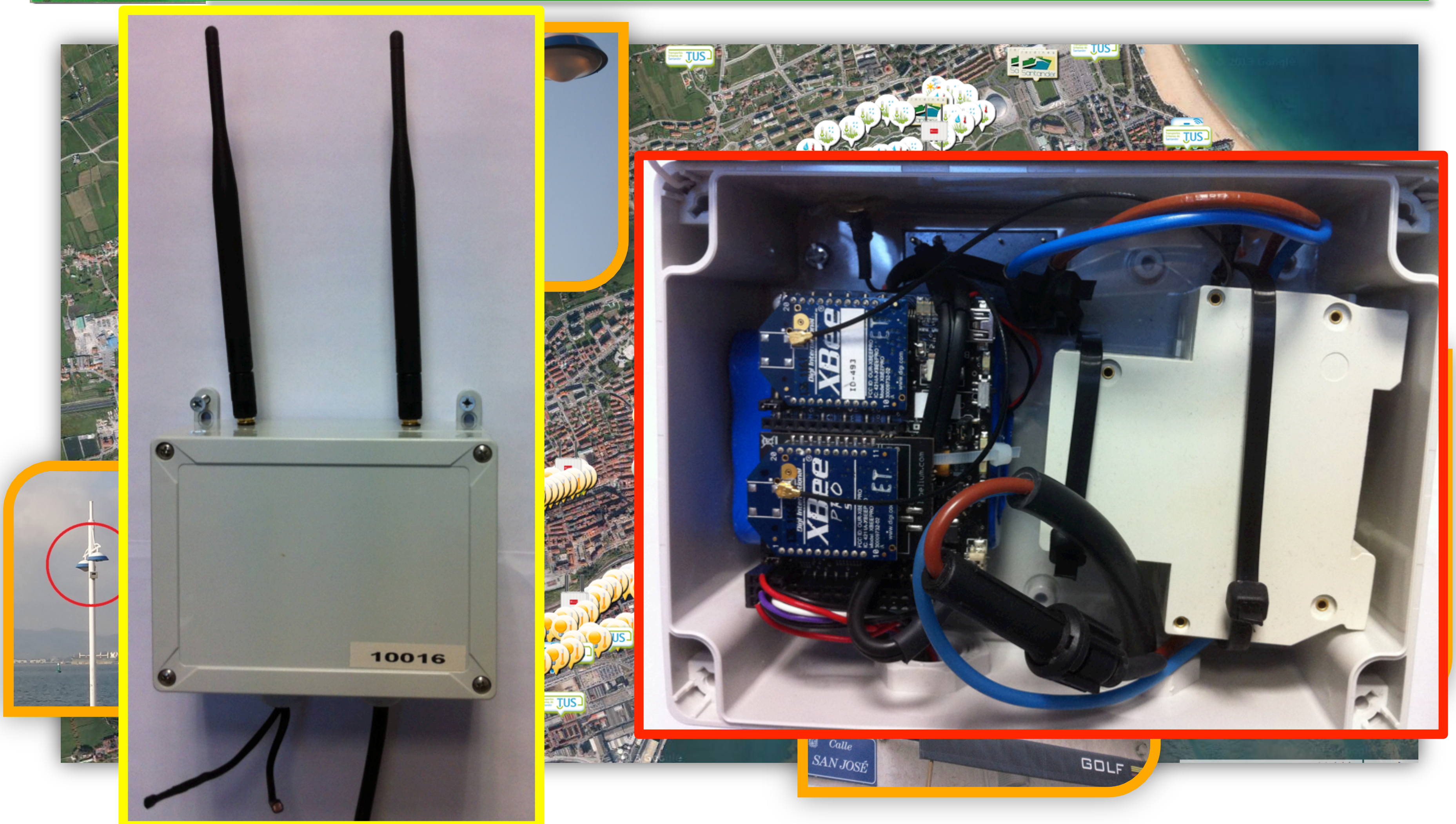
Can broadcast if sent to 0x000000000000FFFF

SmartSantander

www.smartsantander.eu

SmartSantander test-bed

Sensor motes / IoT node



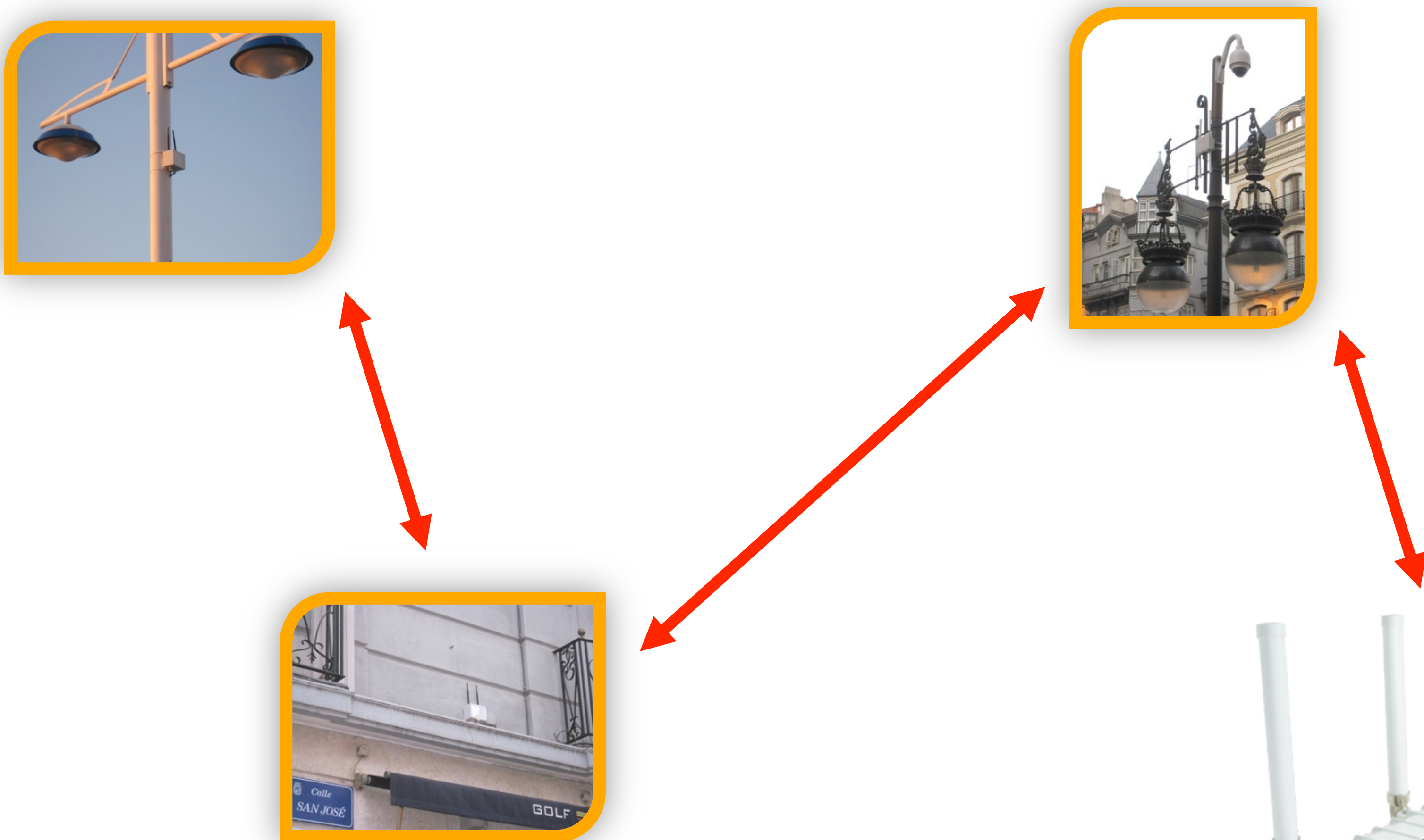
Pictures are taken in the context of the EAR-IT project

SmartSantander test-bed

Gateways

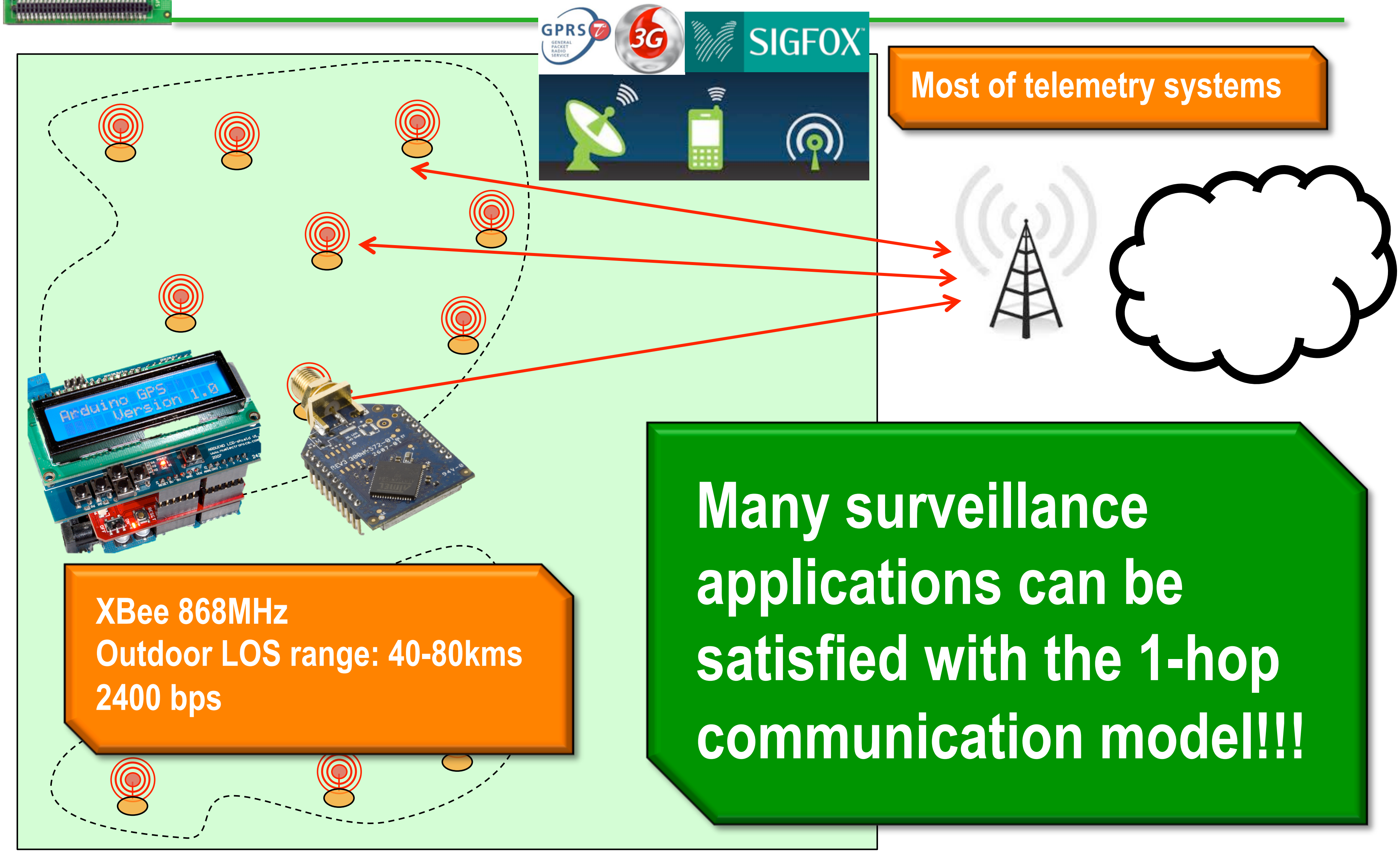
Pictures are taken in the context of the EAR-IT project

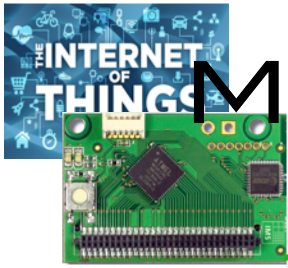
Limit the number of hops to gateways



3 to 5 hops maximum

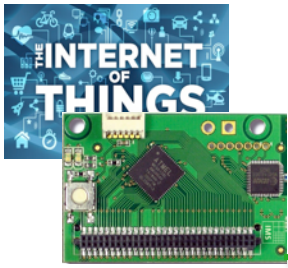
Do I need multi-hop for my app?





Multi-hop routing is still interesting!

- 1-hop model is not economically tractable in large scale deployment
- 1-hop model is usually not energy-efficient
- 1-hop model is hard to optimize in terms of radio access methods
- Routing in WSN is **fundamentally different** from routing in other type of networks, even other wireless networks



Why is it so different?

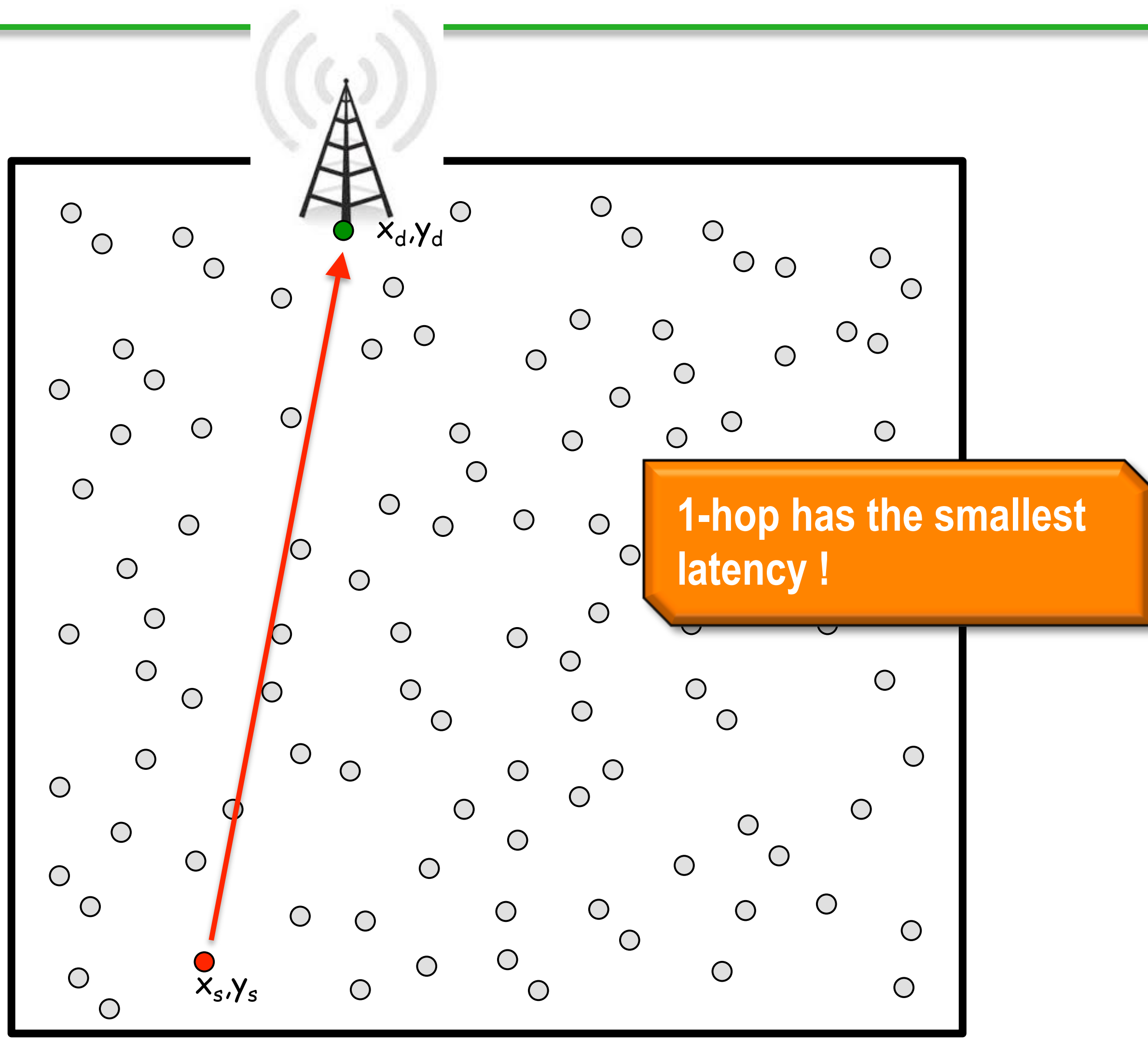
1. WSN are deployed for surveillance → coverage & Latency is important

2. WSN are deployed to get data from remote areas or to react to events → mainly data-centric

3. WSN run on battery → energy saving is important, if not managed correcty, see item 1

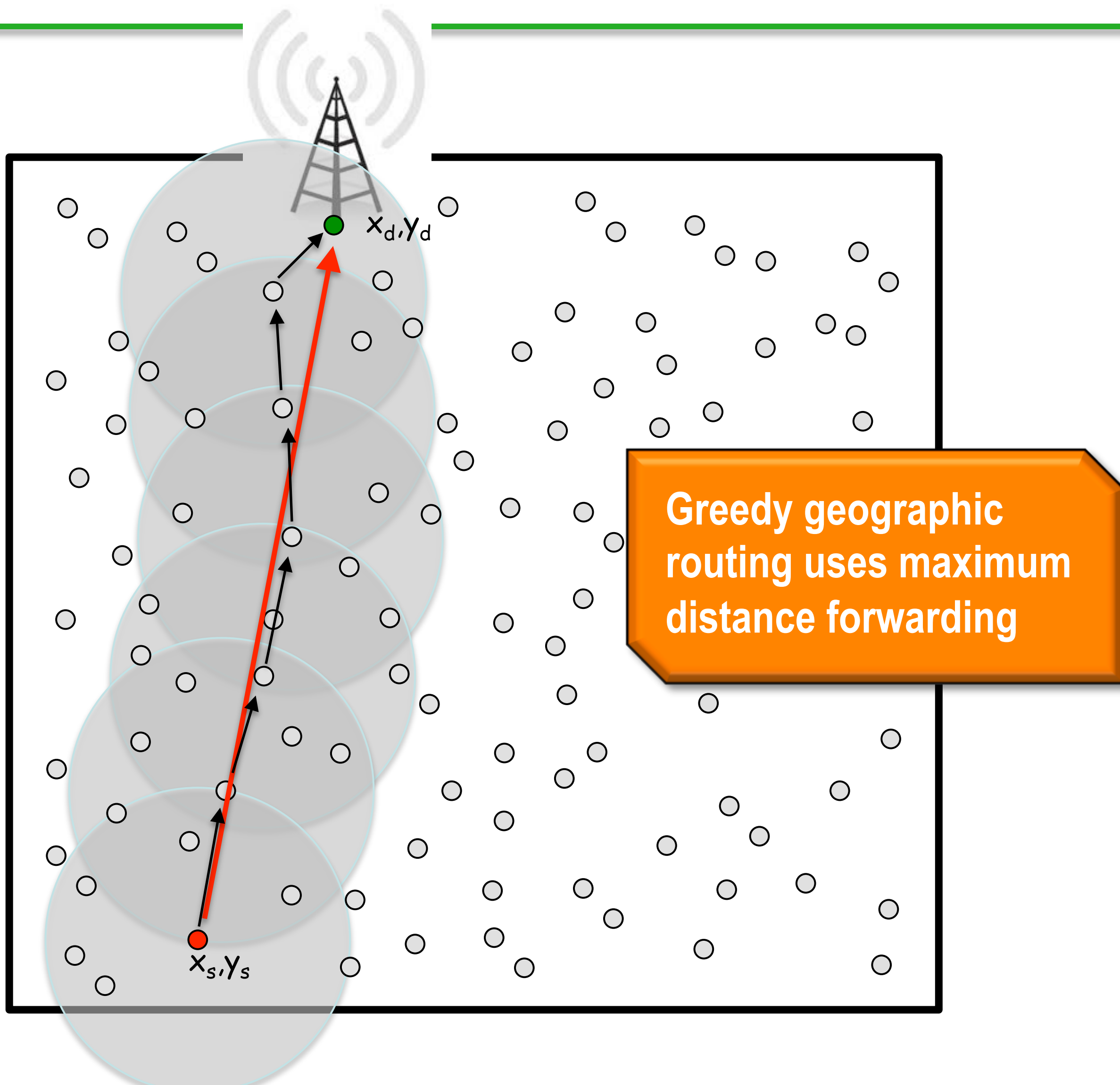
Energy vs Latency

1-hop

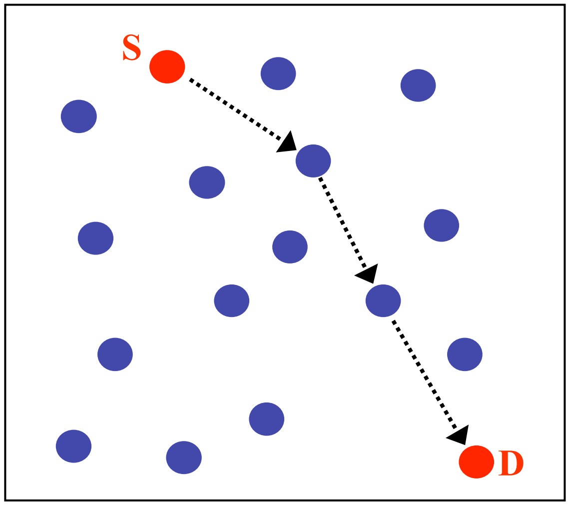


Energy vs Latency

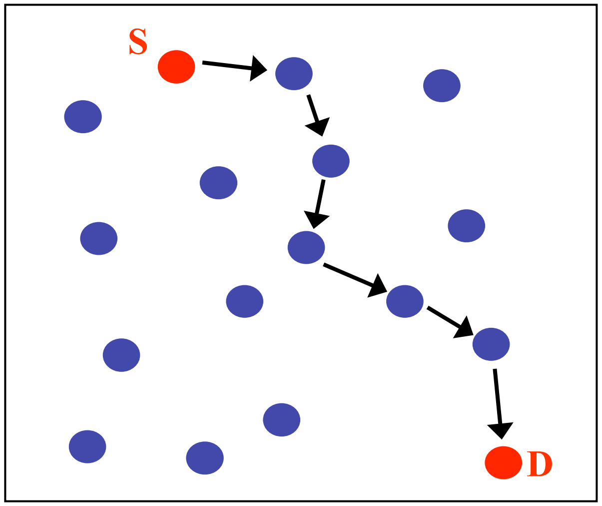
Multi-hop - greedy



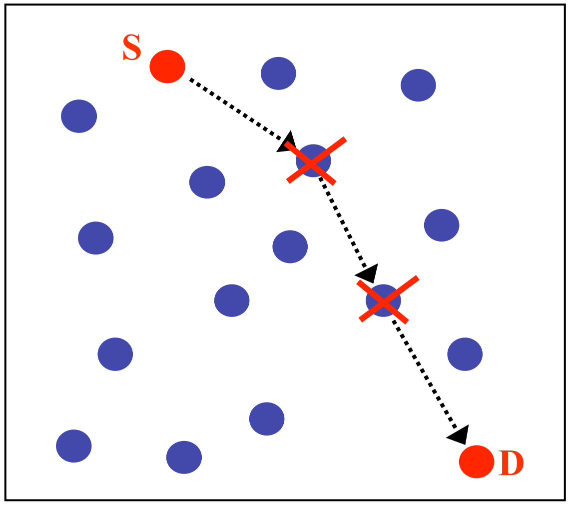
Is maximum distance always good?



Few long links with low quality



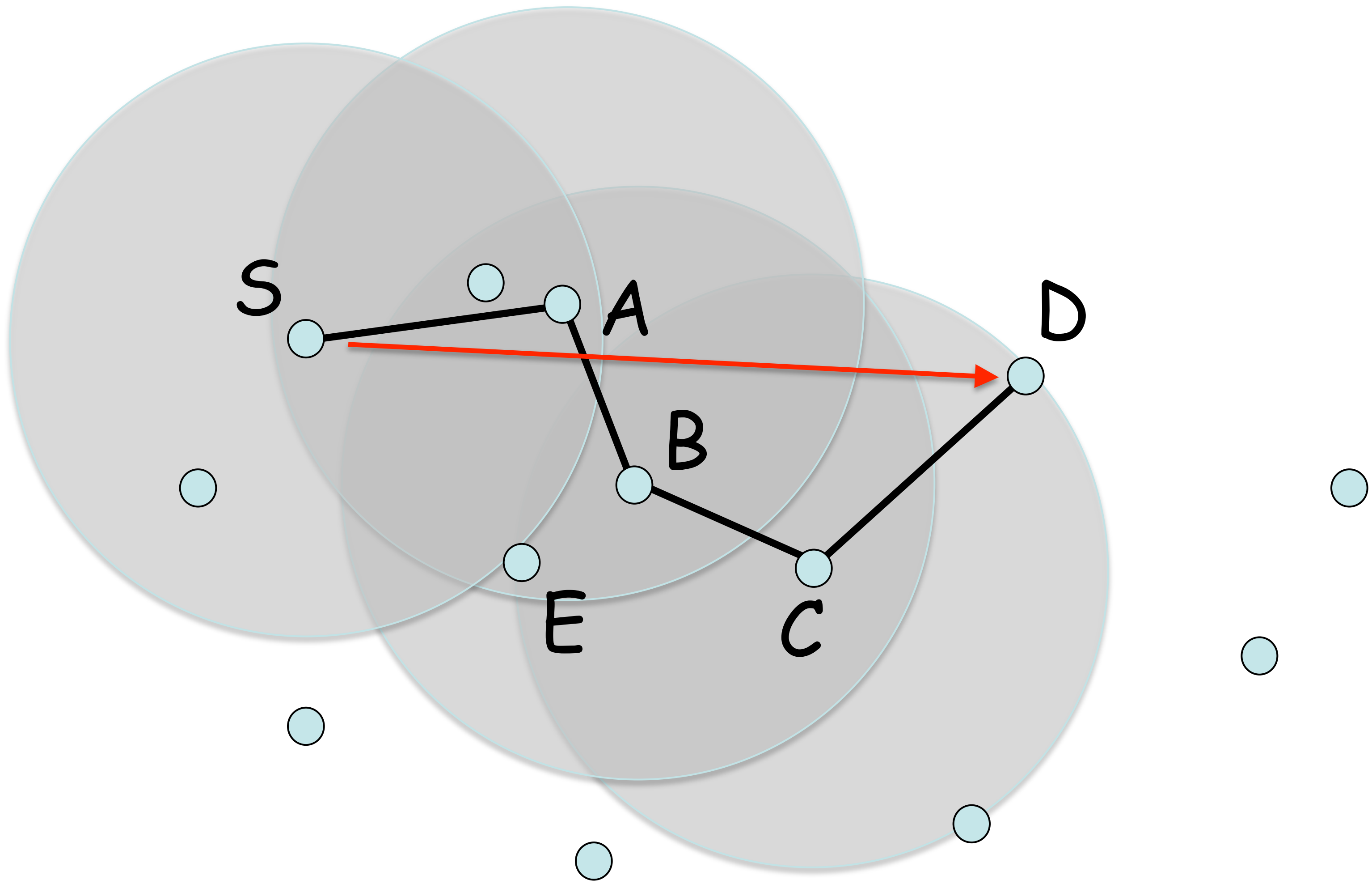
Many short links with high quality



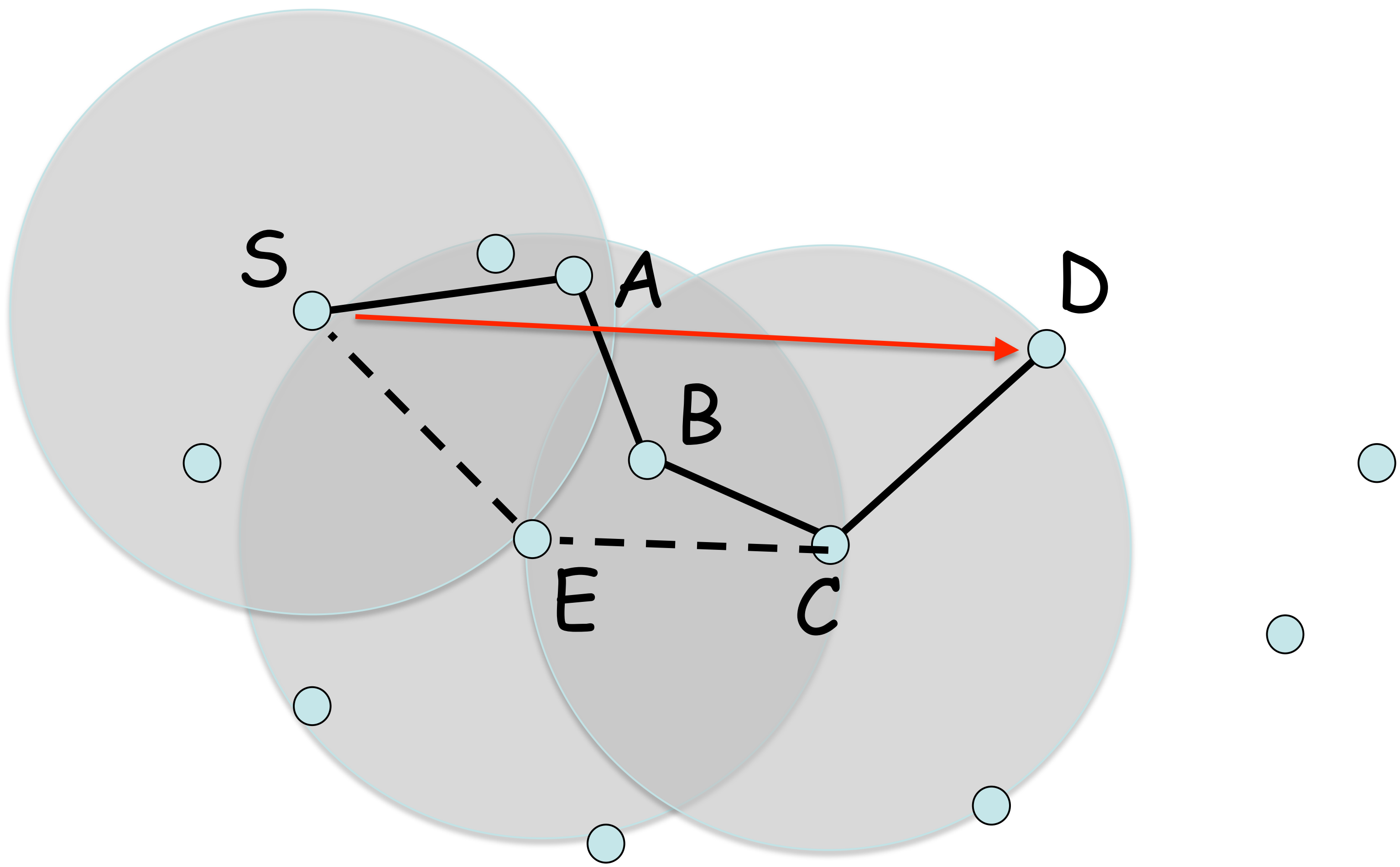
Intermediate nodes that are more sollicited die first

Adapted from Ahmed Helmy, "Robust Geographic Routing and Location-based Services"

Greedy=shortest path?



Greedy=shortest path?



Organizing the Network

- The network is no longer useful when node's battery dies

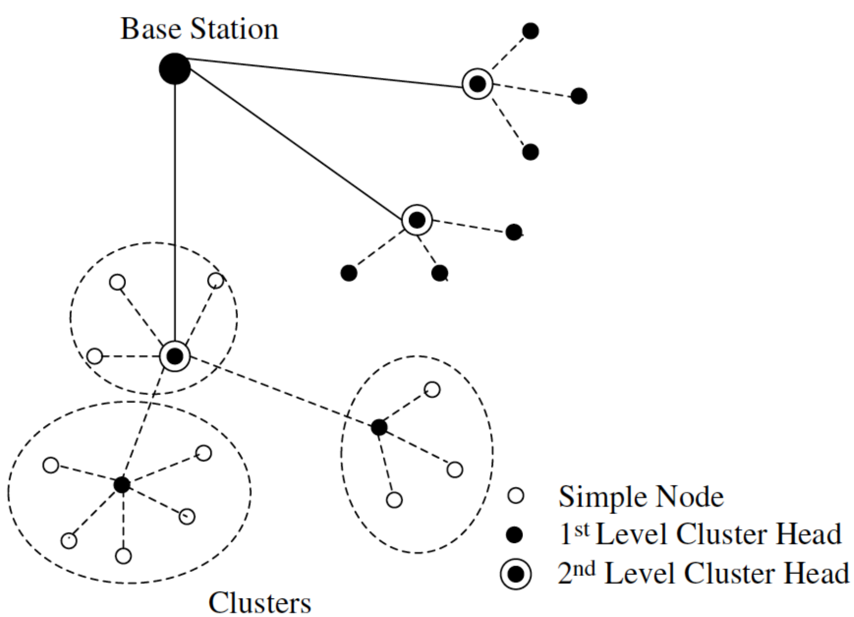
- Organizing the network allows for spacing out the lifespan of the nodes

- Hierarchical routing protocols often give priority to energy

- Ex: Low-Energy Adaptive Clustering Hierarchy (LEACH)

Clustering

- A cluster-head collect data from their surrounding nodes and pass it on to the base station
- The job of cluster-head rotates



LEACH cluster-head

- Cluster-heads can be chosen *stochastically* (randomly based) on this algorithm:

$$T(n) = \frac{P}{1 - P \times (r \bmod P^{-1})} \qquad \forall n \in G$$

$$T(n) = 0 \qquad \forall n \notin G$$

Where n is a random number between 0 and 1
P is the cluster-head probability and
G is the set of nodes that weren't cluster-heads the previous rounds

- If n < T(n), then that node becomes a cluster-head
- The algorithm is designed so that each node becomes a cluster-head at least once

W.B. Heinzelman, A.P. Chandrakasan, H. Balakrishnan, Application specific protocol architecture for wireless microsensor networks, IEEE Transactions on Wireless Networking (2002).

Example

```
p=0.05,
draw N a random number [0,1[ at each
round

N < 0.0500 = 0.05/(1-0.05*0) ?
N < 0.0526 = 0.05/(1-0.05*1) ?
N < 0.0555 = 0.05/(1-0.05*2) ?
N < 0.0588 = 0.05/(1-0.05*3) ?
N < 0.0625 = 0.05/(1-0.05*4) ?
N < 0.0666 = 0.05/(1-0.05*5) ?
N < 0.0714 = 0.05/(1-0.05*6) ?
N < 0.0769 = 0.05/(1-0.05*7) ?
N < 0.0833 = 0.05/(1-0.05*8) ?
N < 0.0909 = 0.05/(1-0.05*9) ?
N < 0.1000 = 0.05/(1-0.05*10) ?

N < 0.5000 = 0.05/(1-0.05*18) ?
N < 1.0000 = 0.05/(1-0.05*19) ?
```

- Number of clusters may not fixed in any round.

$$T(n) = \begin{cases} \dfrac{P}{1 - P[r \bmod (1/P)]} & \text{if } n \in G, \\ 0 & \text{otherwise,} \end{cases}$$

Optimize selection

- A modified version of this protocol is known as LEACH-C (or LEACH Centralized)
- This version has a *deterministic* threshold algorithm, which takes into account the amount of energy in the node

$$T(n)_{new} = \frac{P}{1 - P \times (r \bmod P^{-1})} \frac{E_{n\_current}}{E_{n\_max}}$$

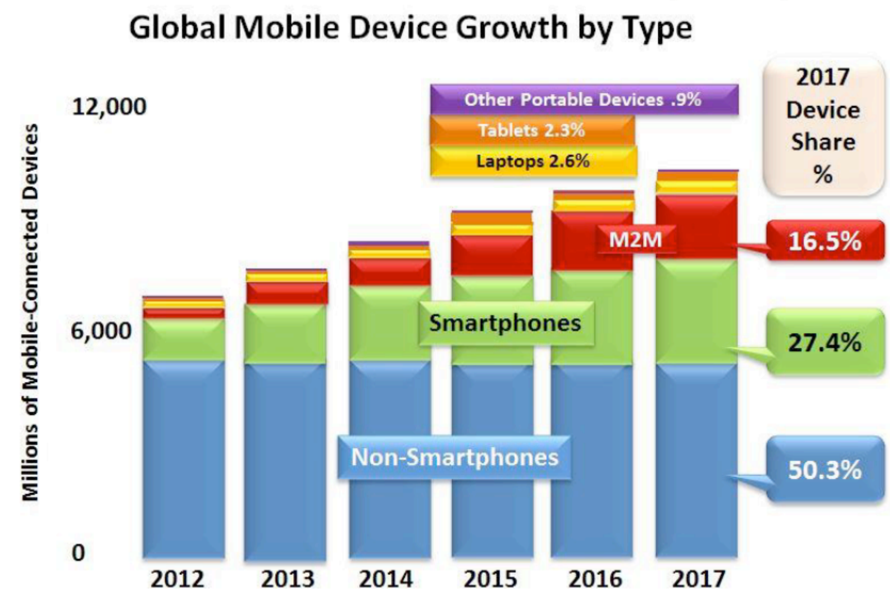
Where $E_{n\_current}$ is the current amount of energy and
E_{n_max} is the initial amount of energy

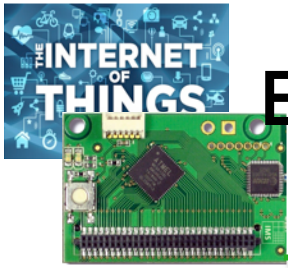
More readings

- Routing probably one of the most covered topic in WSN!
- Many variants for
  - Coverage, k-coverage
  - Cluster-size
  - Latencies, interferences
  - Multi-paths
  - …
- Objective here is to give some insight on routing objectives/issues in WSN
- To go further, read some routing survey papers

Mobile Internet

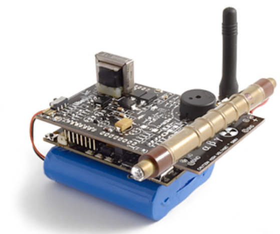
4G Americas / **4G Mobile Broadband Evolution: 3GPP Release 11 & Release 12 and Beyond** / February 2014





Beyond Sensor Networks: Communicating Objects!

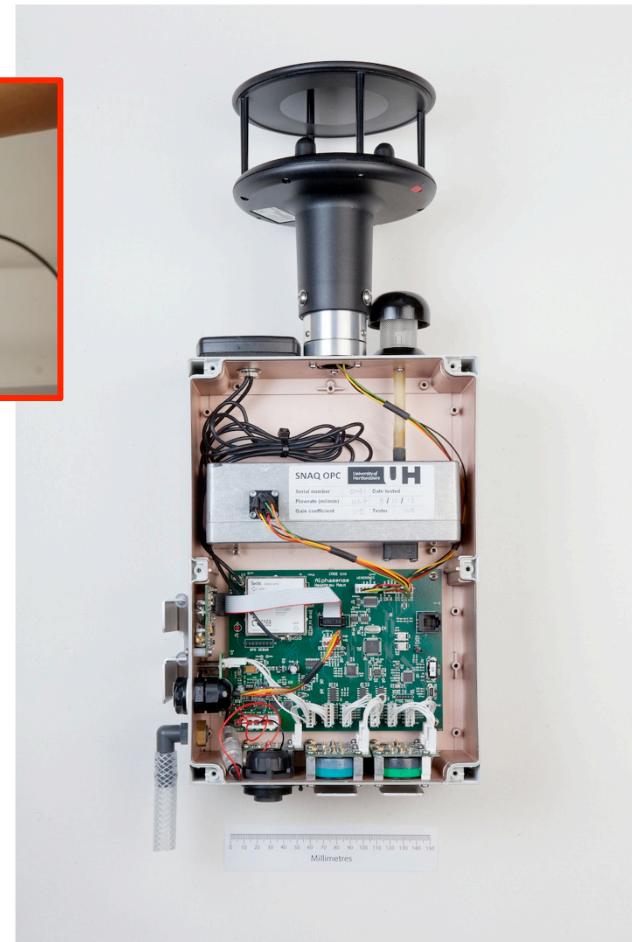
- Native communication:



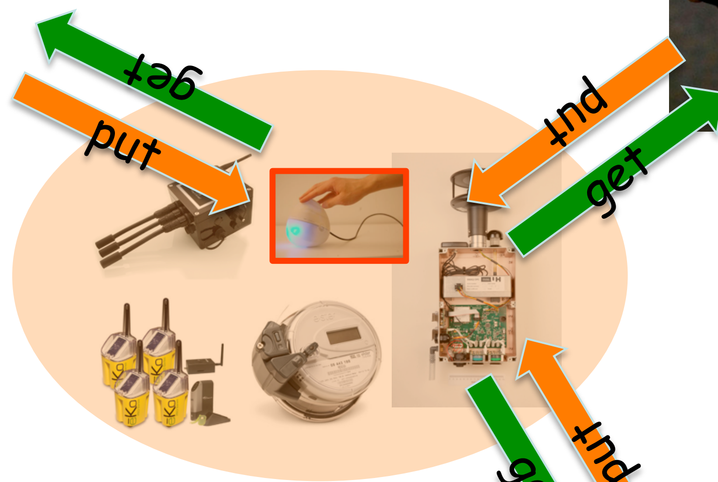
- Added communication
  - Active communication

  - Passive communication

Promising surveillance market



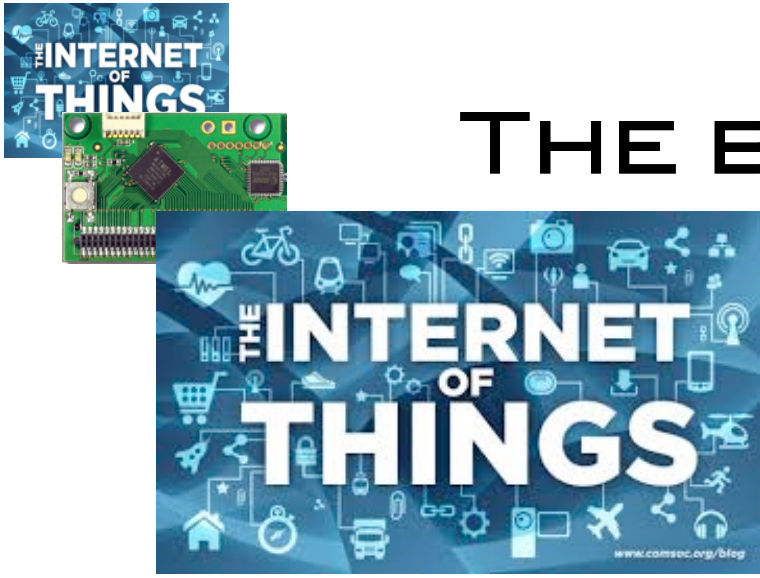
Integration into the Internet of Things



Internet of Things for People

From ad-hoc to standardized protocols

The benefit of IP



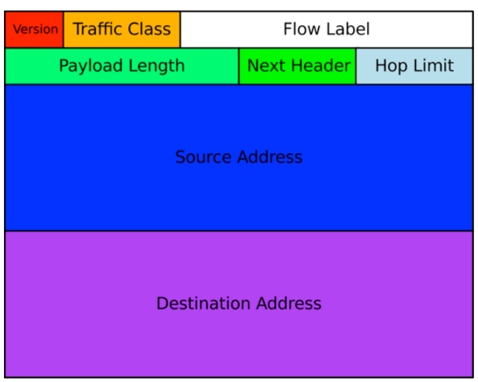
Don't reinvent the wheel!

RFC 768	UDP - User Datagram Protocol	[1980]
RFC 791	IPv4 – Internet Protocol	[1981]
RFC 792	ICMPv4 – Internet Control Message Protocol	[1981]
RFC 793	TCP – Transmission Control Protocol	[1981]
RFC 862	Echo Protocol	[1983]
RFC 1101	DNS Encoding of Network Names and Other Types	[1989]
RFC 1191	IPv4 Path MTU Discovery	[1990]
RFC 1981	IPv6 Path MTU Discovery	[1996]
RFC 2131	DHCPv4 - Dynamic Host Configuration Protocol	[1997]
RFC 2375	IPv6 Multicast Address Assignments	[1998]
RFC 2460	IPv6	[1998]
RFC 2765	Stateless IP/ICMP Translation Algorithm (SIIT)	[2000]
RFC 3068	An Anycast Prefix for 6to4 Relay Routers	[2001]
RFC 3307	Allocation Guidelines for IPv6 Multicast Addresses	[2002]
RFC 3315	DHCPv6 - Dynamic Host Configuration Protocol for IPv6	[2003]
RFC 3484	Default Address Selection for IPv6	[2003]
RFC 3587	IPv6 Global Unicast Address Format	[2003]
RFC 3819	Advice for Internet Subnetwork Designers	[2004]
RFC 4007	IPv6 Scoped Address Architecture	[2005]
RFC 4193	Unique Local IPv6 Unicast Addresses	[2005]
RFC 4291	IPv6 Addressing Architecture	[2006]
RFC 4443	ICMPv6 - Internet Control Message Protocol for IPv6	[2006]
RFC 4861	Neighbor Discovery for IP version 6	[2007]
RFC 4944	Transmission of IPv6 Packets over IEEE 802.15.4 Networks	[2007]
RFC6282	Compression Format for IPv6 Datagrams over IEEE 802.15.4-Based Networks	[2011]

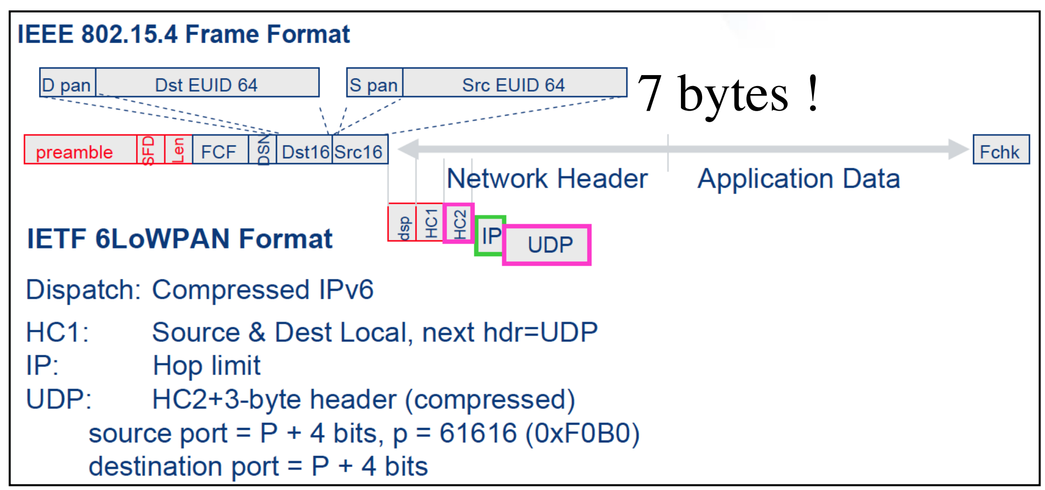
From ArchRock "6LowPan tutorial"

IP need IP addresses!

- IPv4 has no more addresses!
- IPv6 gives plenty of addresses
  - 128bit address=16bytes!
- 6LowPan adapts IPv6 to resource-constrained devices
  - Compressed IPv6 header



40 bytes



From ArchRock "6LowPan tutorial"

IPv4 vs. IPv6 Addressing

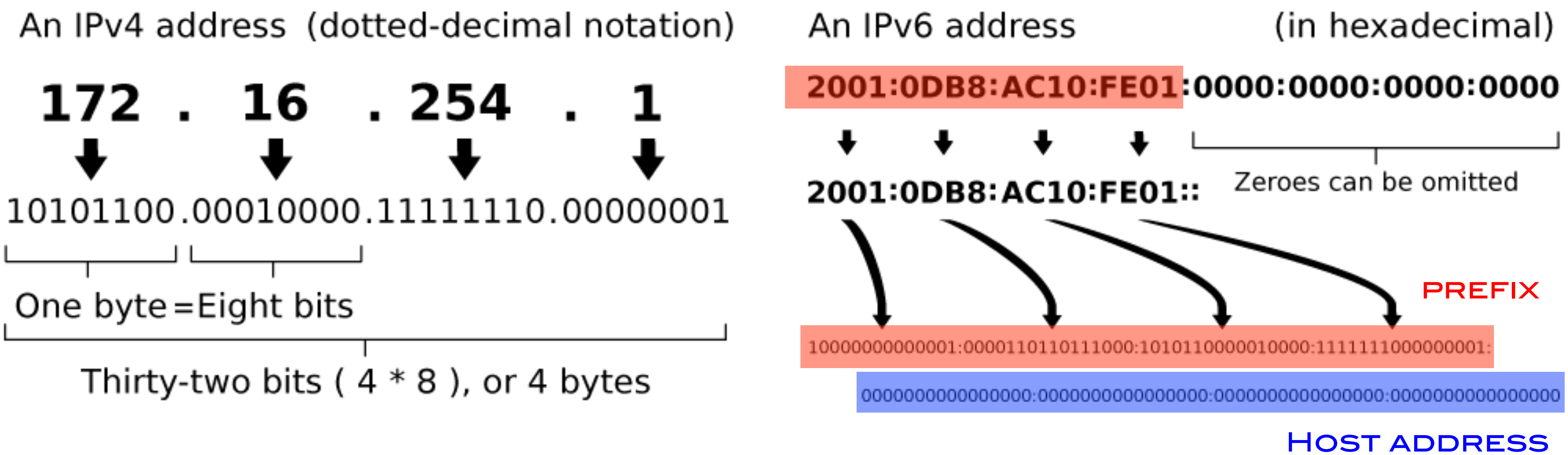
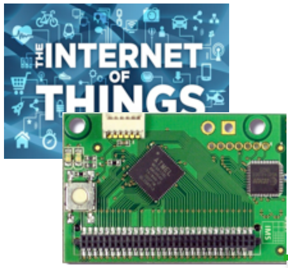


Image source: Indeterminant (Wikipeida) GFDL

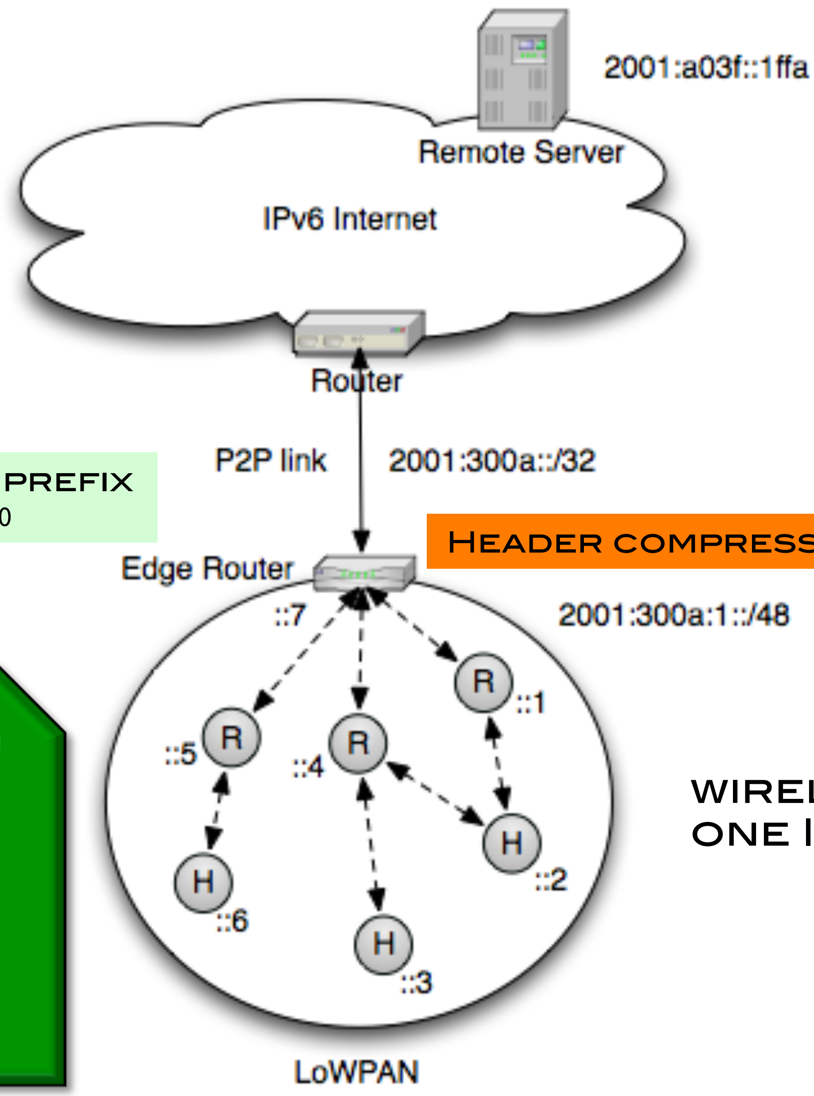


6LoWPAN Addressing

- IPv6 addresses are compressed in 6LoWPAN
- A LoWPAN works on the principle of
  - flat address spaces (wireless network is one IPv6 subnet)
  - with unique MAC addresses (e.g. 64-bit or 16-bit: 0x0013A20040568B34 or 0x0220)
- 6LoWPAN compresses IPv6 addresses by
  - Eliding the IPv6 prefix
    - Global prefix known by all nodes in network
    - Link-local prefix indicated by header compression format
  - Compressing the Interface ID
    - Elided for link-local communication
    - Compressed for multihop dst/src addresses
  - Compressing with a well-known "context"
  - Multicast addresses are compressed

From "6LoWPAN: The Wireless Embedded Internet, Shelby & Bormann"

Addressing Example



Advertise prefix
2001:300a:1:0

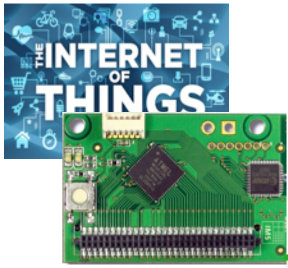
Header compression

Build an IPv6 address with prefix and a combination of 802.15.4:
- PANID
- 16-bit address

or
- 64-bit address

Wireless network is one IPv6 subnet

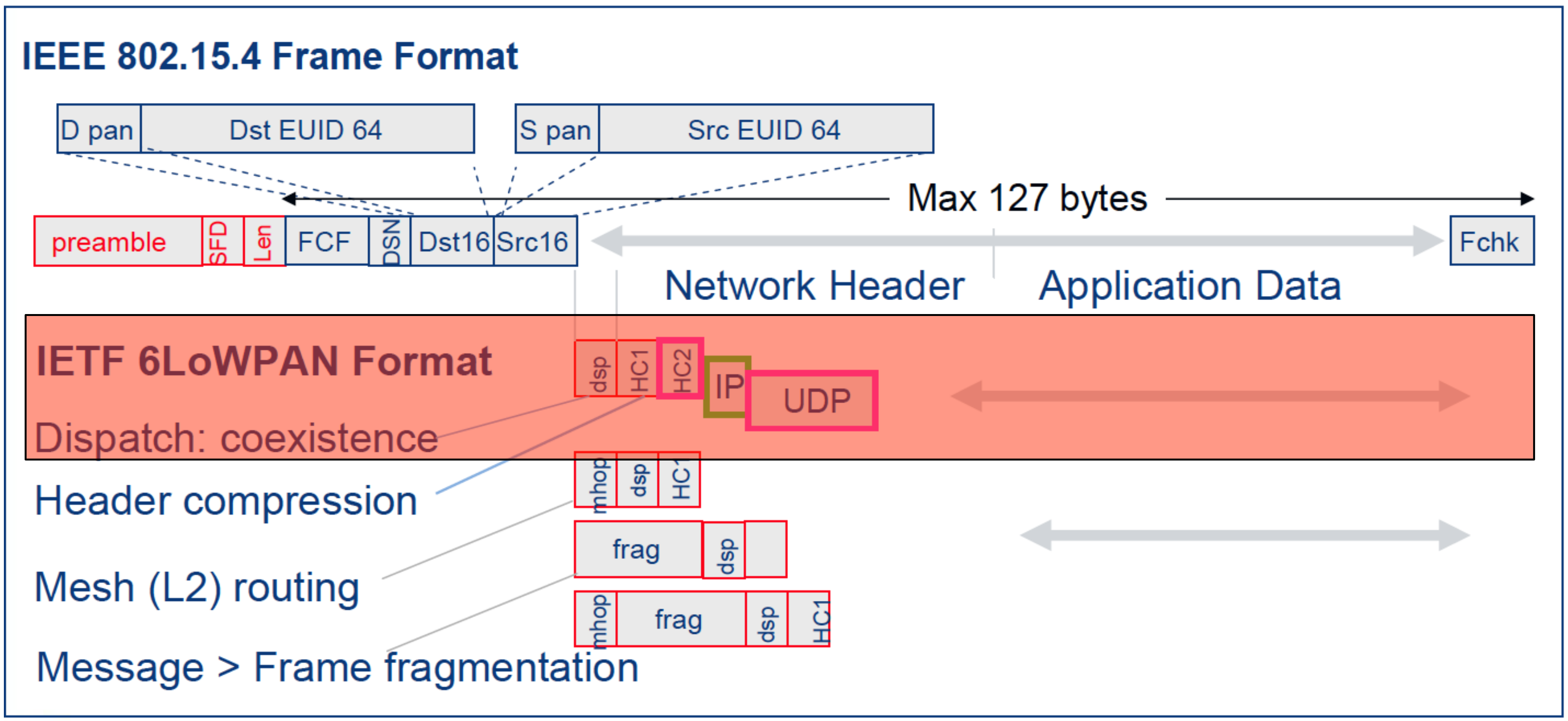
Based from "6LoWPAN: The Wireless Embedded Internet, Shelby & Bormann"



Use RFC4944 compression scheme for simplicity. New scheme should follow RFC6282

6LoWPAN Format Design

- Orthogonal stackable header format
- Almost no overhead for the ability to interoperate and scale.
- Pay for only what you use

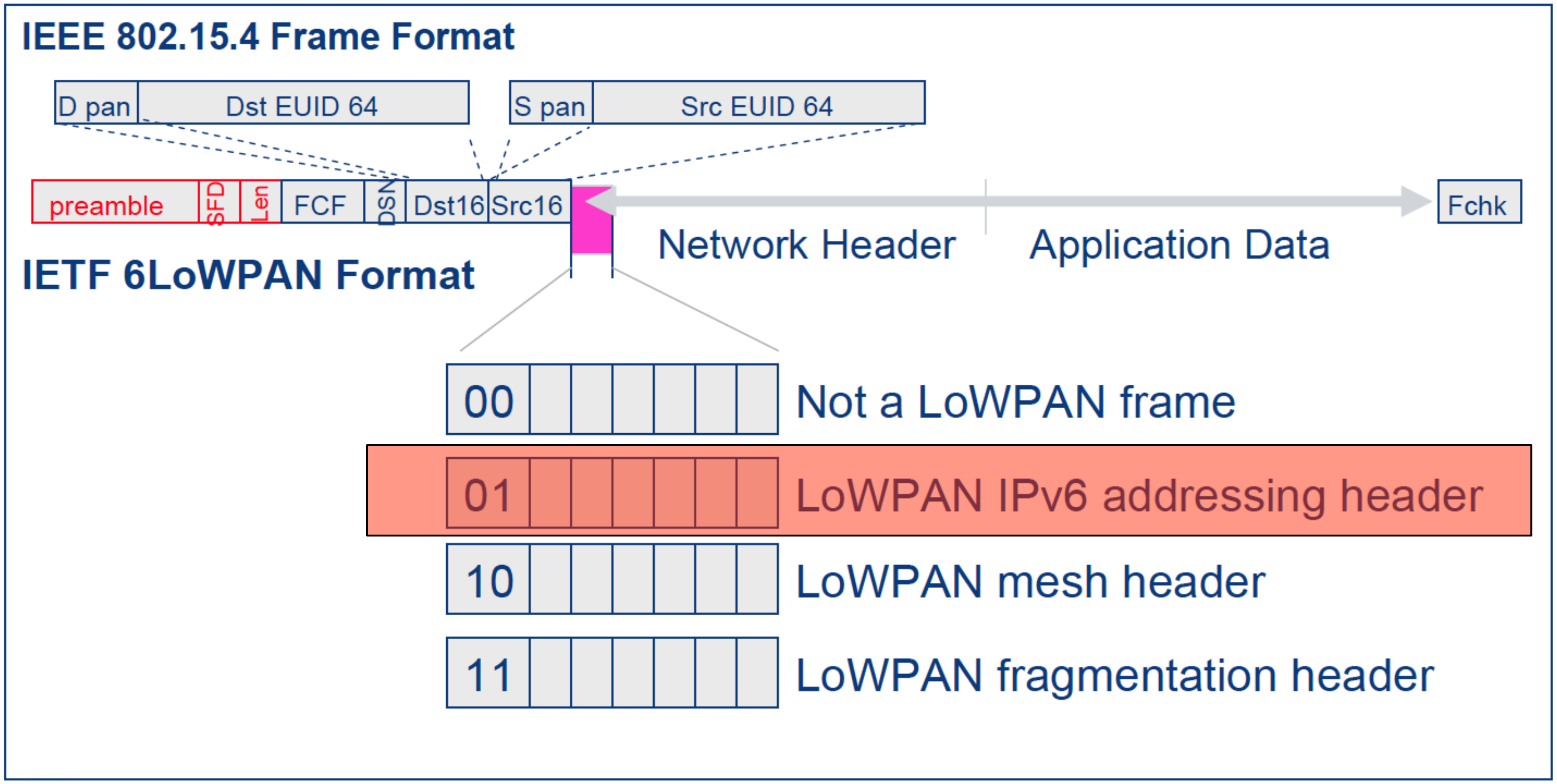


From ArchRock "6LowPan tutorial"

6LoWPAN – The First Byte

Use RFC4944 compression scheme for simplicity. New scheme should follow RFC6282

- Coexistence with other network protocols over same link
- Header dispatch - understand what's coming

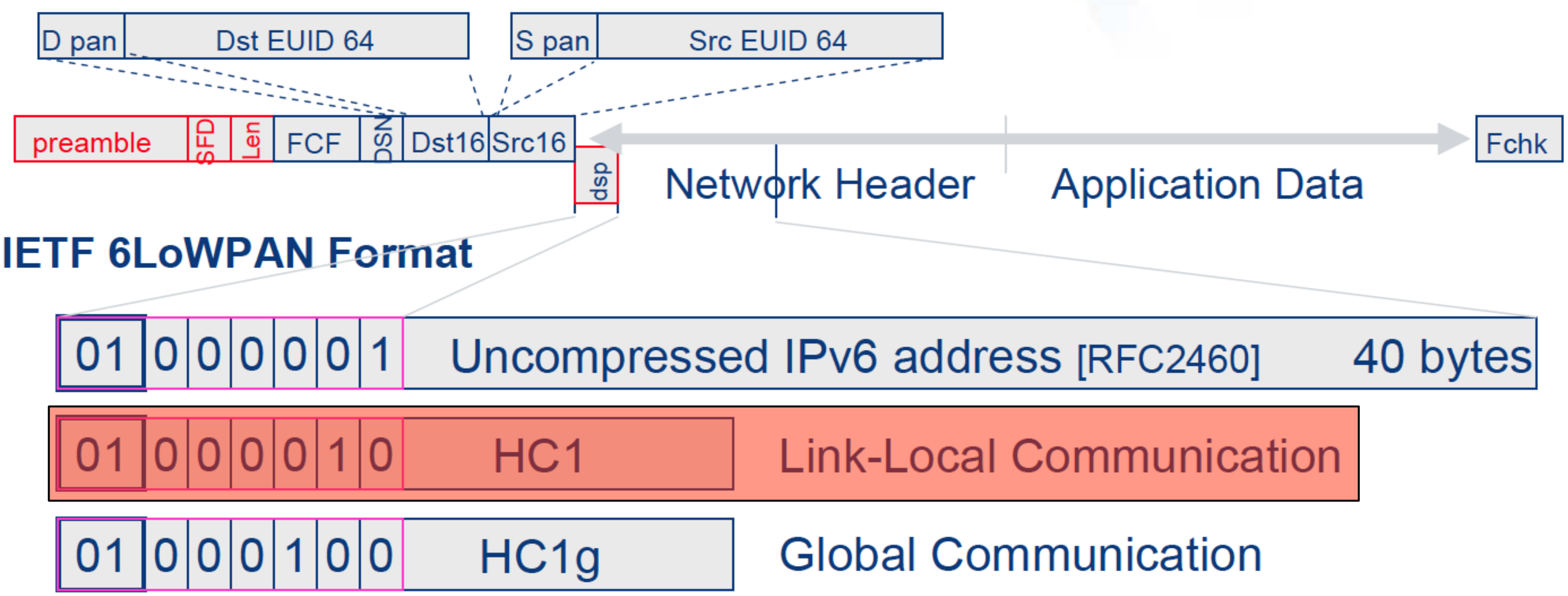


From ArchRock "6LowPan tutorial"

6LoWPAN – IPv6 Header

Use RFC4944 compression scheme for simplicity. New scheme should follow RFC6282

IEEE 802.15.4 Frame Format



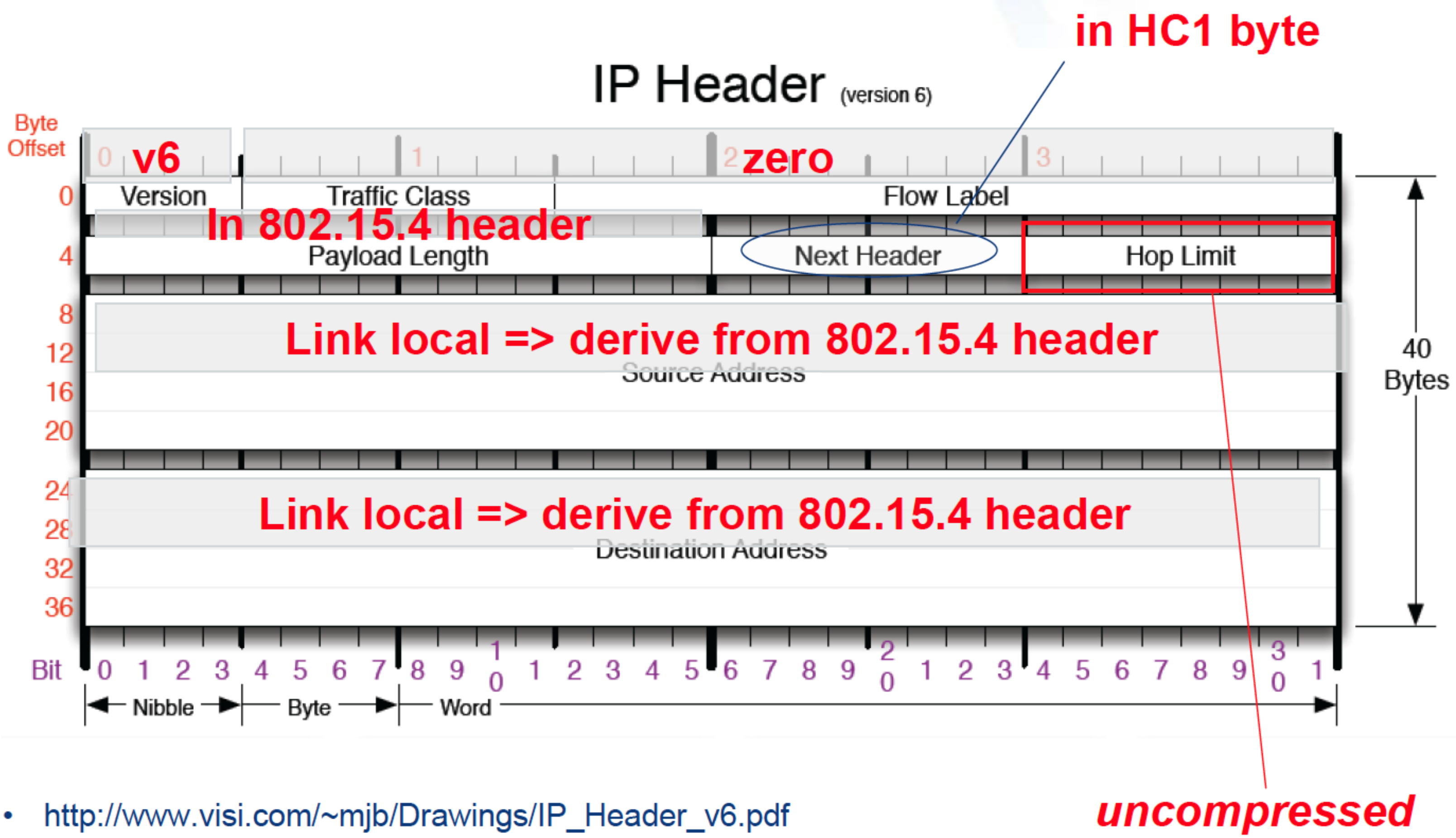
➔ *Fully compressed: 1 byte remains from uncompressed header*

Source address	: derived from link address or common prefix
Destination address	: derived from link address or common prefix
Traffic Class & Flow Label	: zero
Next header	: UDP, TCP, or ICMP
Hop Limit	: uncompressed

From ArchRock "6LowPan tutorial"

IPv6 Header Compression

Use RFC4944 compression scheme for simplicity. New scheme should follow RFC6282



- http://www.visi.com/~mjb/Drawings/IP_Header_v6.pdf

From ArchRock "6LowPan tutorial"

Use RFC4944 compression scheme for simplicity. New scheme should follow RFC6282

HC1 Compressed IPv6 Header

For Link-Local Communication

- Source prefix compressed (to L2)
- Source interface identifier compressed (to L2)
- Destination prefix compressed (to L2)
- Destination interface identified compressed (to L2)
- Traffic and Flow Label zero (compressed)
- Next Header
  - 00 uncompressed, 01 UDP, 10 TCP, 11 ICMP
- Additional HC2 compression header follows

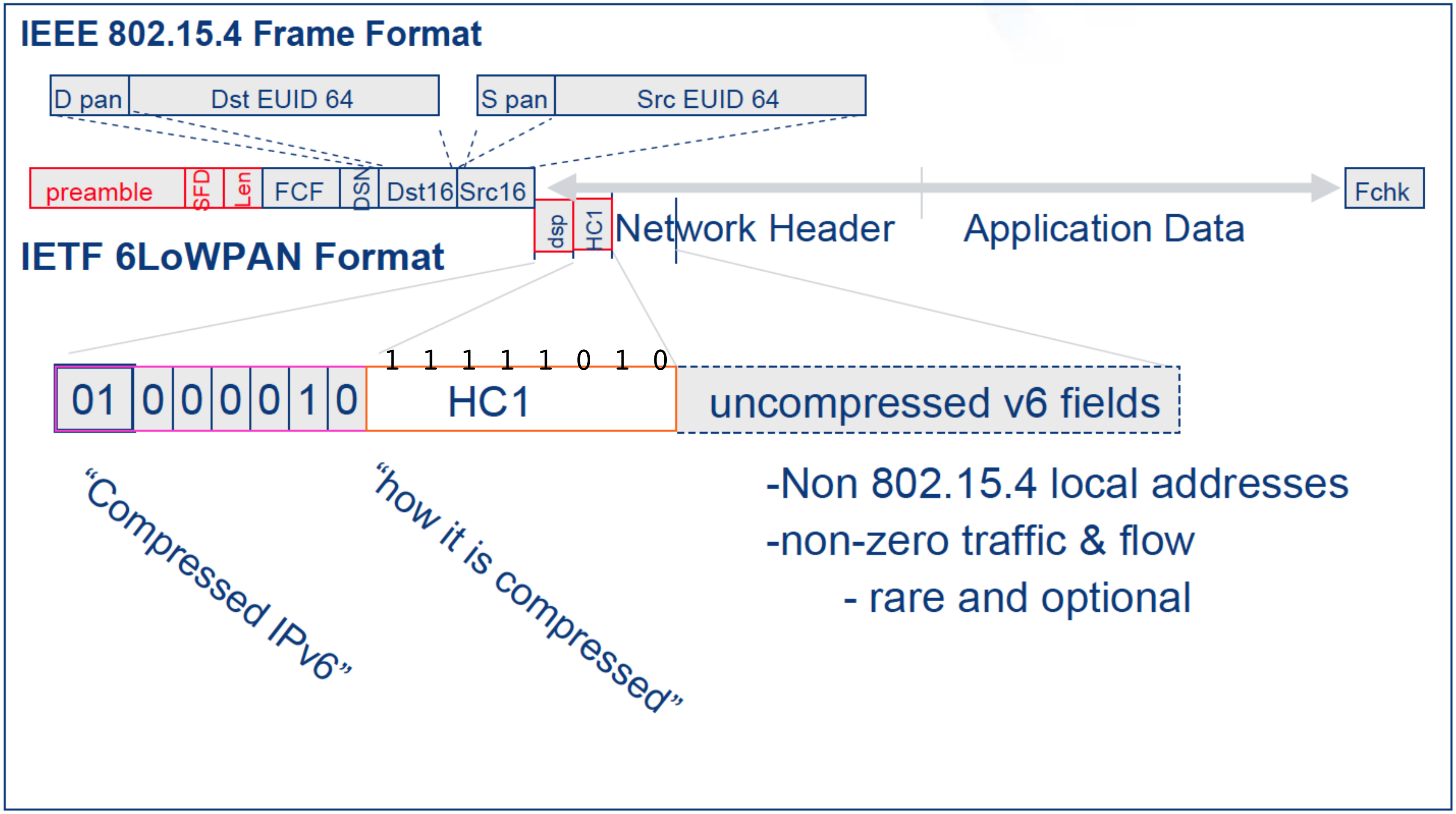
HC1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | Zero or more uncompressed fields follow in order

0 … 7

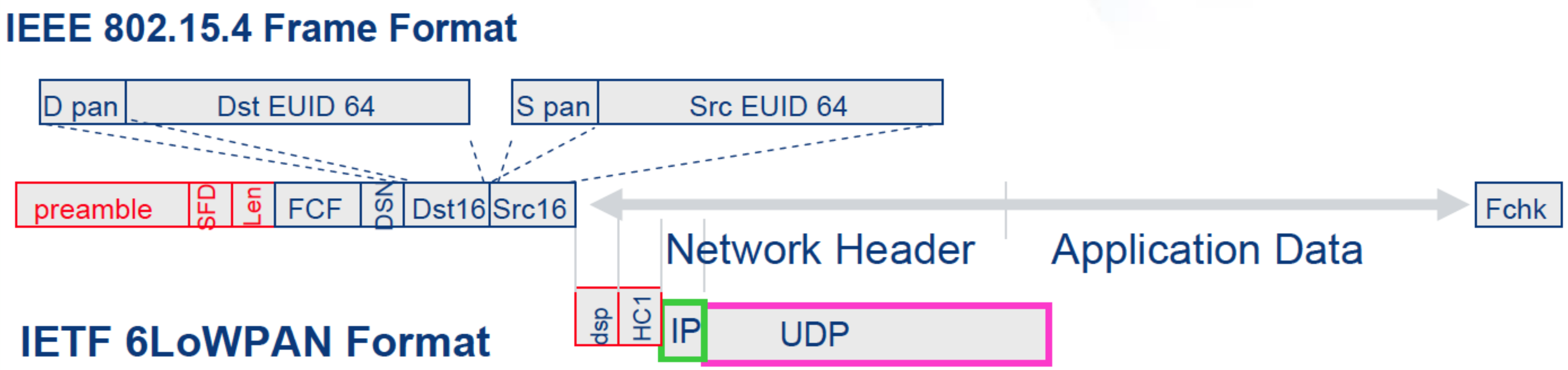
- Efficient communication with link-local IPv6 addresses
- IPv6 address <prefix64 || interface id> for nodes in 802.15.4 subnet derived from the link address.
  - PAN ID maps to a unique IPv6 prefix
  - Interface identifier generated from EUI-64 or short address
- Hop Limit is the only incompressible IPv6 header field

From ArchRock "6LowPan tutorial"

6LoWPAN: Compressed IPv6 Header

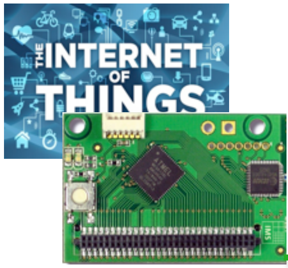


6LoWPAN – Compressed / UDP



Dispatch:	Compressed IPv6
HC1:	Source & Dest Local, next hdr=UDP
IP:	Hop limit
UDP:	8-byte header (uncompressed)

UDP header can be further compressed



Internet for things

UDP, TCP?

RPL
Routing Protocol for Low power & Lossy Networks

6LowPan
802.15.4

IPv6 egde router

LBR (6lowPAN)

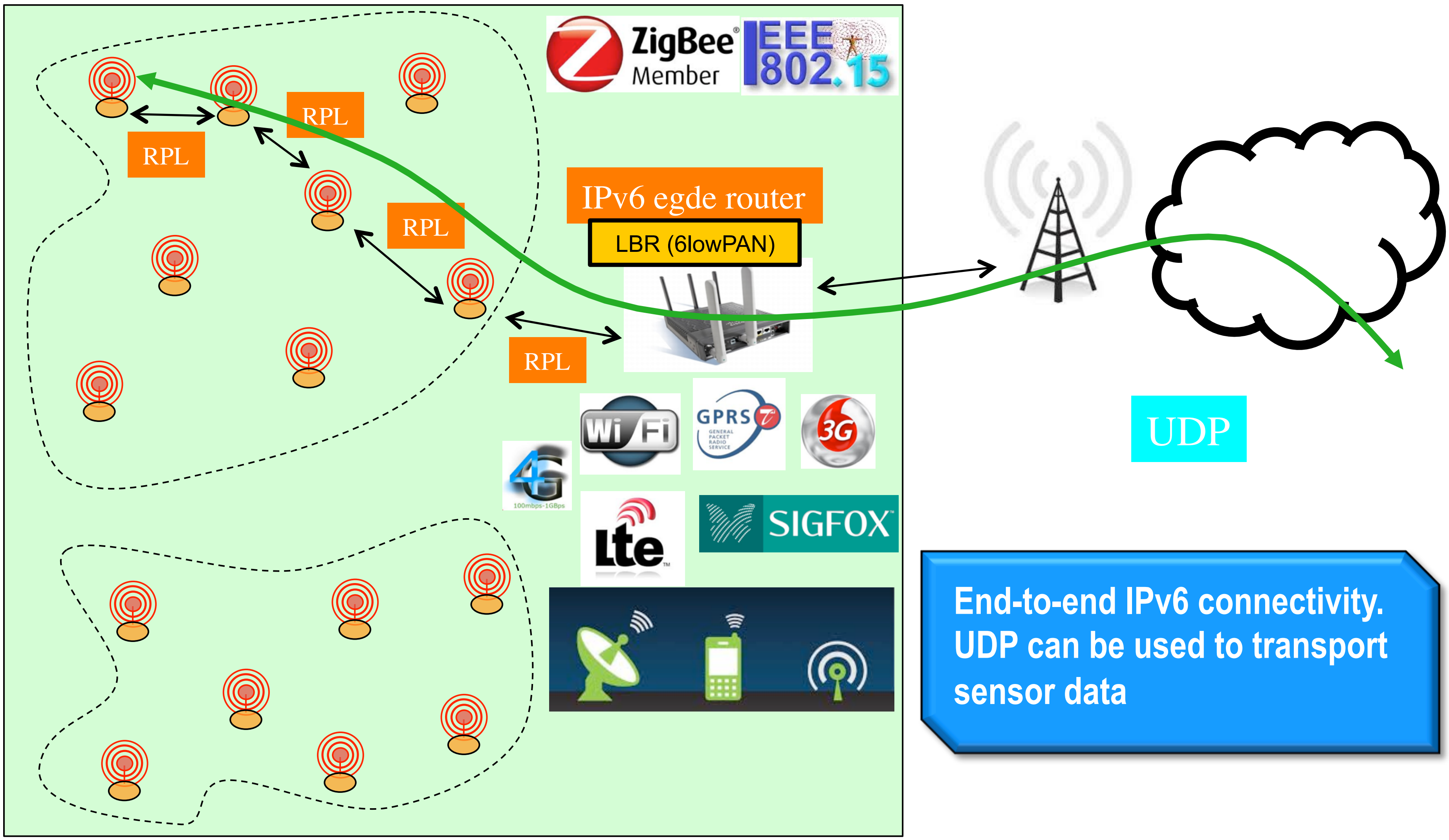
TCP, UDP

Internet Routing Protocols: RIP, OSPF, BGP,…

IPv4, IPv6

3G 4G Lte Wi Fi

Using IP protocols



End-to-end IPv6 connectivity. UDP can be used to transport sensor data

RPL (ripple)
Routing Protocol for Low Power and Lossy Networks

Walkthrough

`draft-dt-roll-rpl-01.txt`

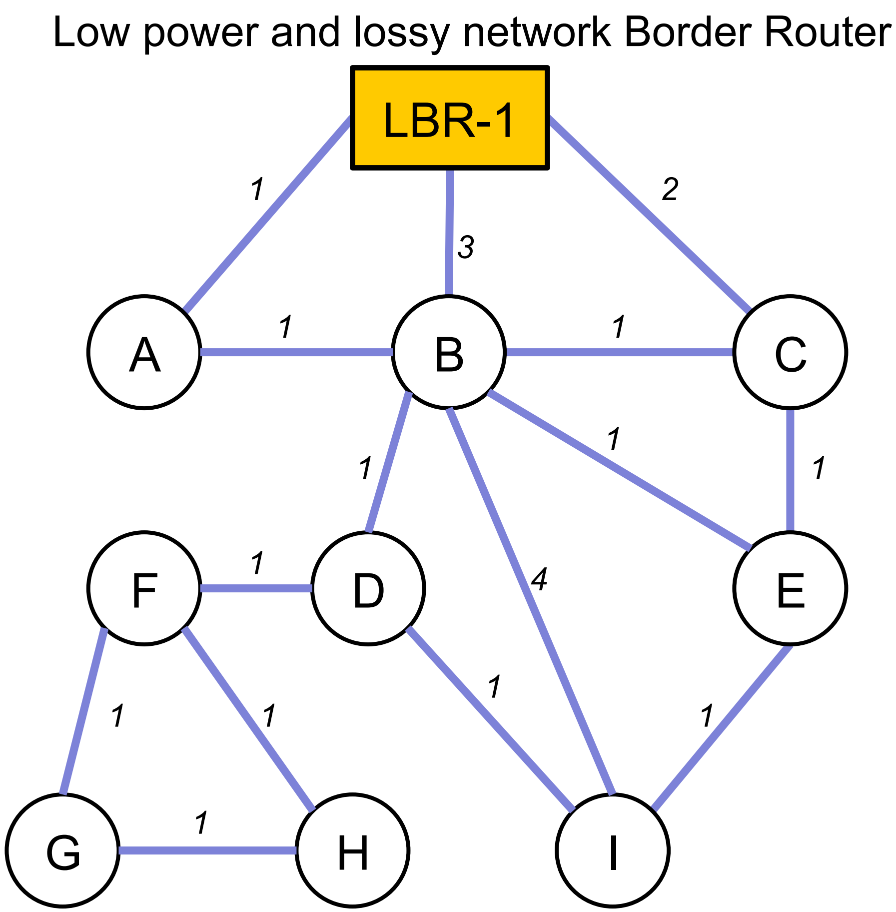
Anders Brandt
Thomas Heide Clausen
Stephen Dawson-Haggerty
Jonathan W. Hui
Kris Pister
Pascal Thubert
Tim Winter

IETF 75 – Roll WG – July 2009

Approach - Forwarding

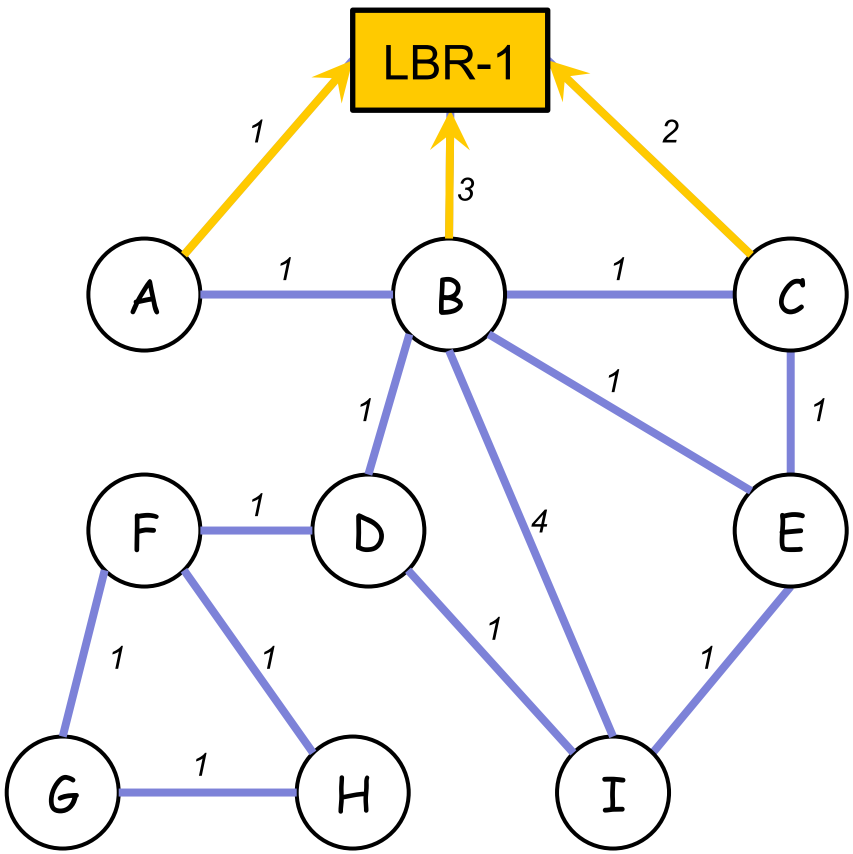
- Forwarding MP2P traffic to nodes of lesser depth avoids loops
  - only occur in presence of depth inconsistency, which is avoided or discovered and resolved
  - Ample redundancy in most networks
- Forwarding traffic to nodes of equal depth (DAG siblings) may be used if forwarding to lesser depth is temporarily failed
  - Increases redundancy, but additional protection against loops, e.g., id’s, should be added
- Forwarding MP2P traffic to nodes of deeper depth is unlikely to make forward progress and likely to loop

DAG Construction



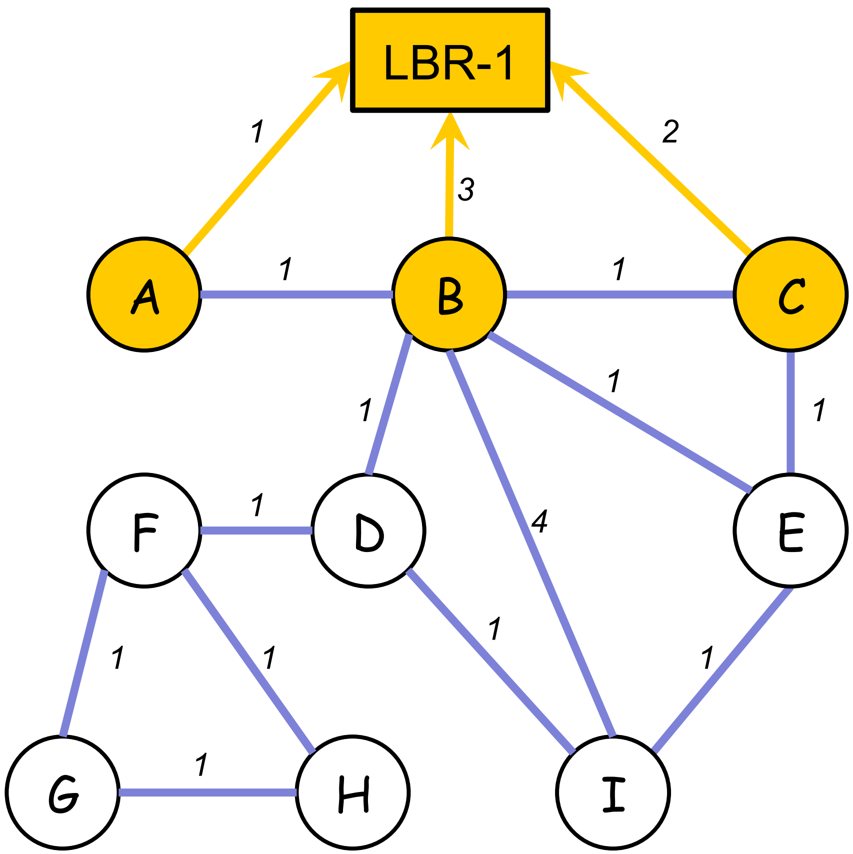
- LLN links are depicted
- LBR form a Destination Object DAG (DODAG)
- Links are annotated w/ ETX (Expected Transmission Count)
- It is expected that ETX variations will be averaged/filtered as per [ROLL-METRICS] to be stable enough for route computation

DAG Construction



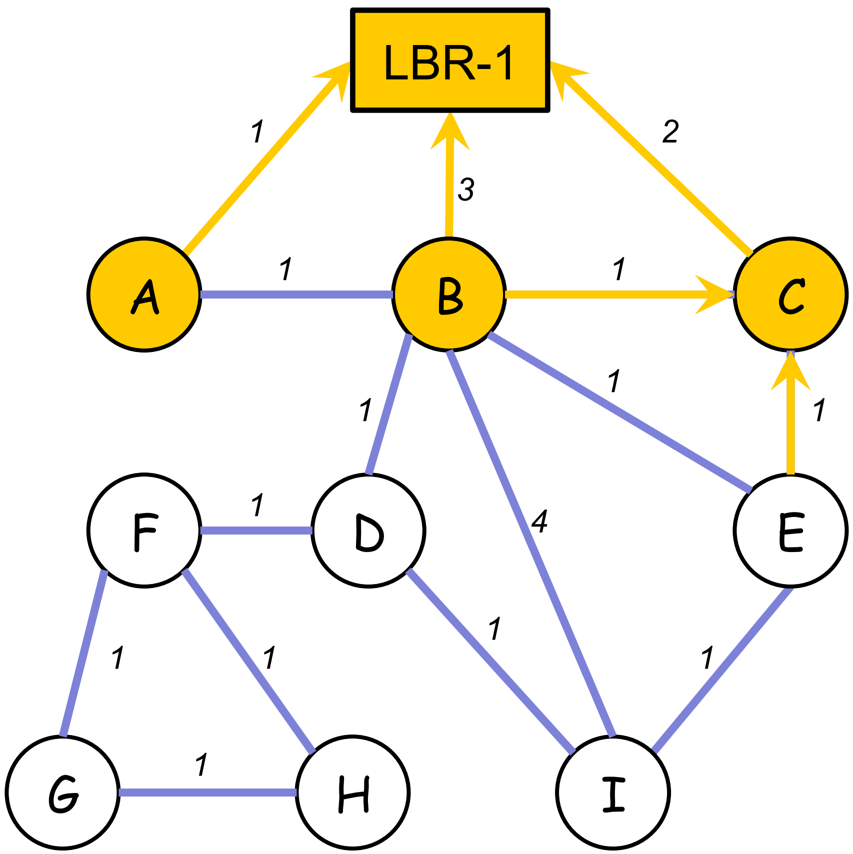
- LBR-1 multicasts RA-DIO (Router Advertisement DODAG Information Object)
- Nodes A, B, C receive and process RA-DIO
- Nodes A, B, C consider link metrics to LBR-1 and the optimization objective
- The optimization objective can be satisfied by joining the DAG rooted at LBR-1
- Nodes A, B, C add LBR-1 as a DAG parent and join the DAG

DAG Construction



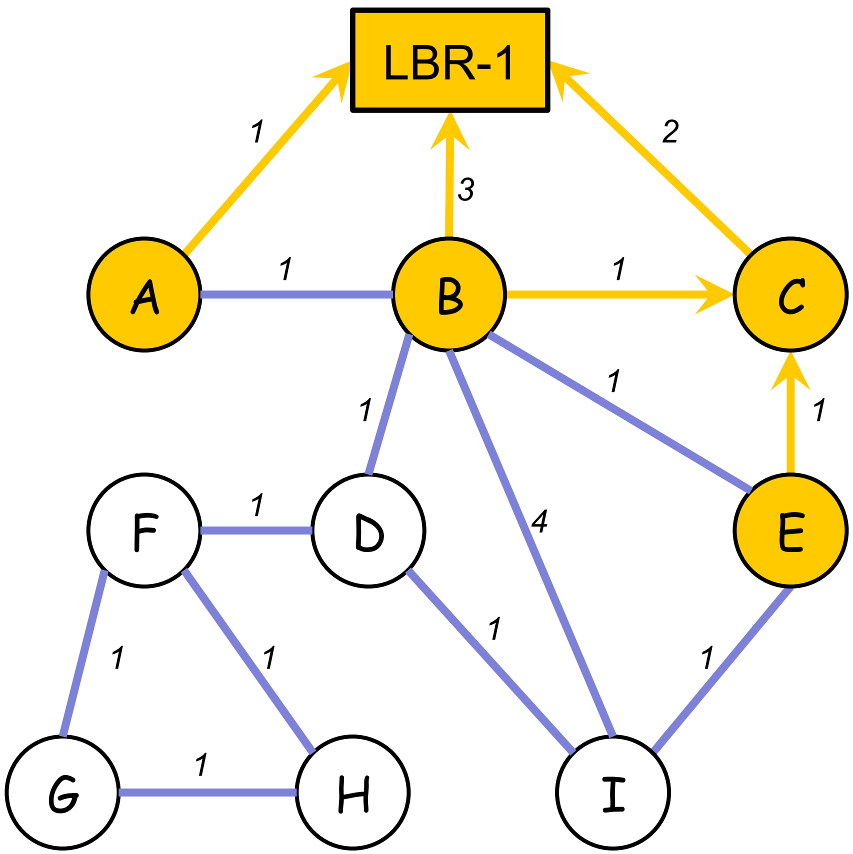
- Node A is at Depth 1 in the DAG, as calculated by the routine indicated by the example OCP (Depth ~ ETX)
- Node B is at Depth 3, Node C is at Depth 2
- Nodes A, B, C have installed default routes (::/0) with LBR-1 as successor

DAG Construction



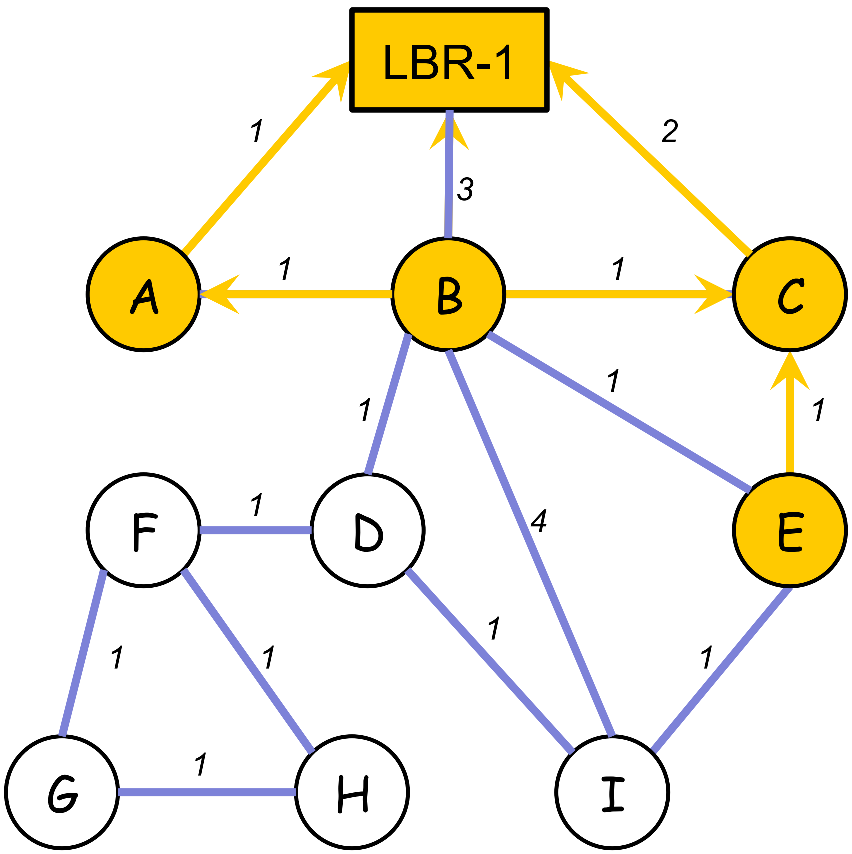
- The RA timer on Node C expires
- Node C multicasts RA-DIO
- LBR-1 ignores RA-DIO from deeper node
- Node B can add Node C as *alternate* DAG Parent, remaining at Depth 3
- Node E joins the DAG at Depth 3 by adding Node C as DAG Parent

DAG Construction



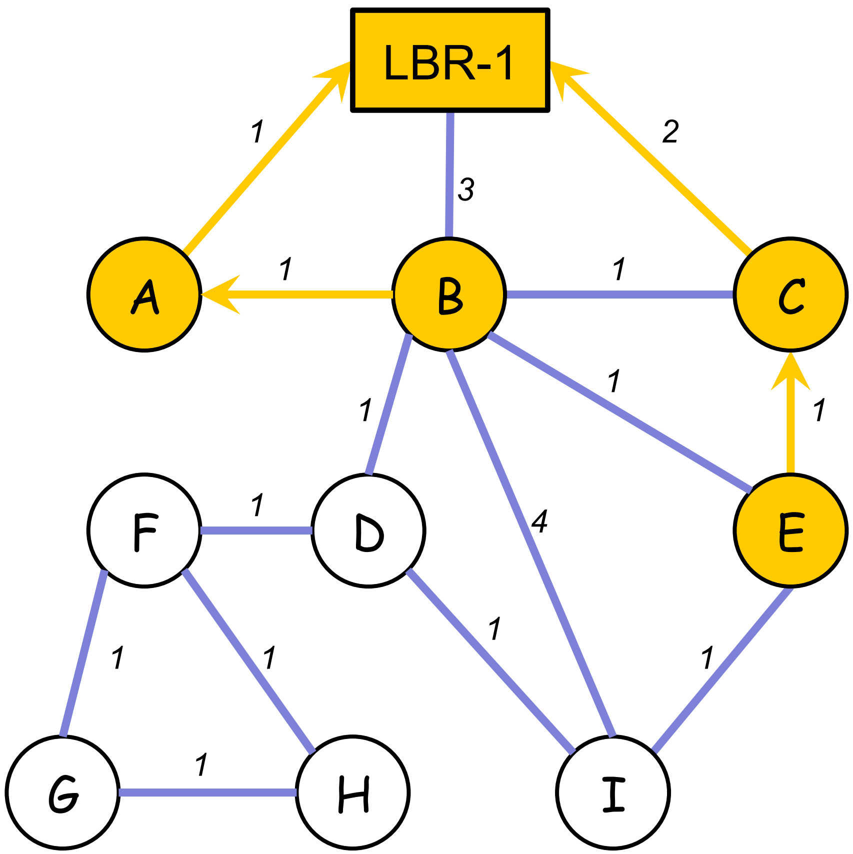
- Node A is at Depth 1, and can reach ::/0 via LBR-1 with ETX 1
- Node B is at Depth 3, with DAG Parents LBR-1, and can reach ::/0 via LBR-1 or C with ETX 3
- Node C is at Depth 2, ::/0 via LBR-1 with ETX 2
- Node E is at Depth 3, ::/0 via C with ETX 3

DAG Construction



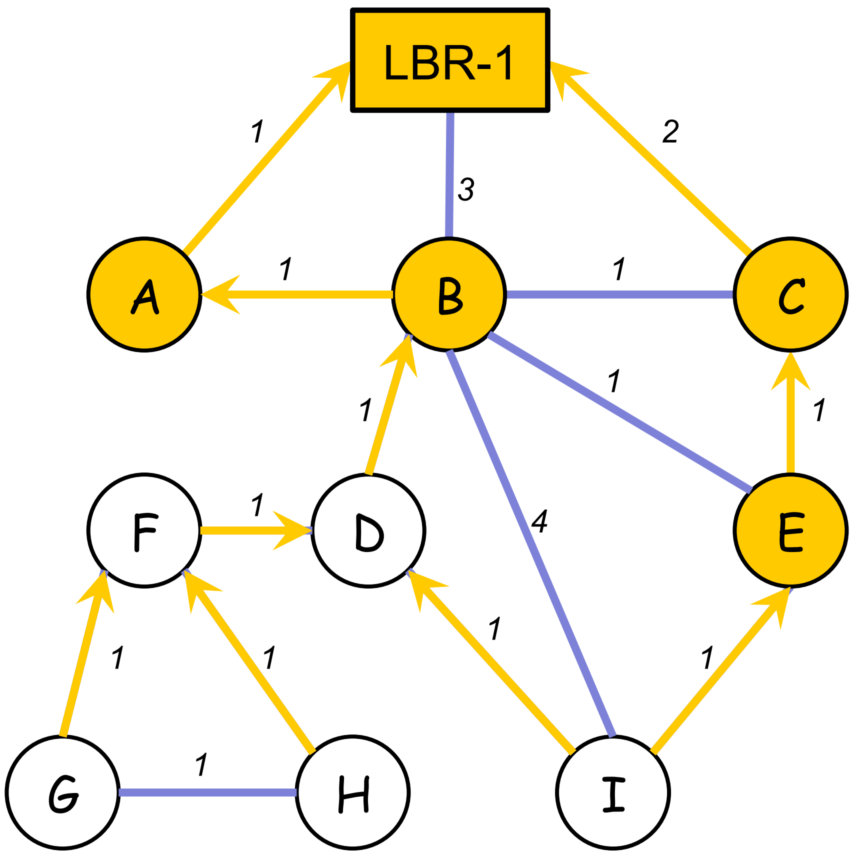
- The RA timer on Node A expires
- Node A multicasts RA-DIO
- LBR-1 ignores RA-DIO from deeper node
- Node B adds Node A
- Node B can improve to a more optimum position in the DAG
- Node B *removes* LBR-1, Node C as DAG Parents

DAG Construction

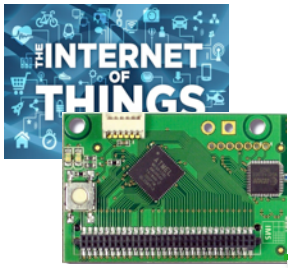


- Node A is at Depth 1, ::/0 via LBR-1 with ETX 2
- Node B is at Depth 2, ::/0 via A with ETX 2
- Node C is at Depth 2, ::/0 via LBR-1 with ETX 2
- Node E is at Depth 3, ::/0 via C with ETX 3

DAG Construction



- DAG Construction continues…
- And is continuously maintained



Internet for things

CoAP: Constrained Application Protocol

UDP, TCP?

RPL
Routing Protocol for Low power & Lossy Networks

6LowPan
802.15.4

IPv6 egde router

LBR (6lowPAN)

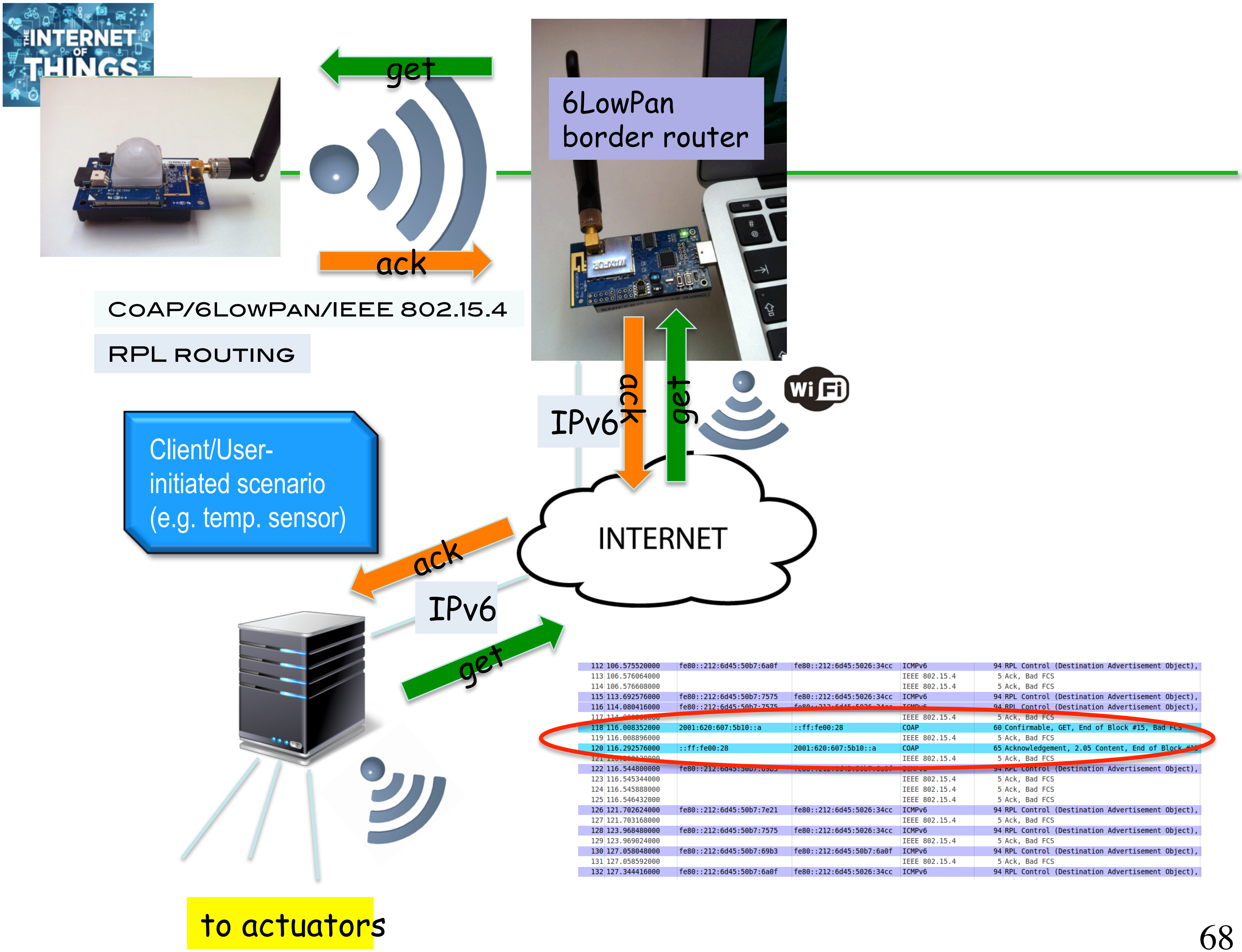
HTTP

TCP, UDP

Internet Routing Protocols: RIP, OSPF, BGP,…

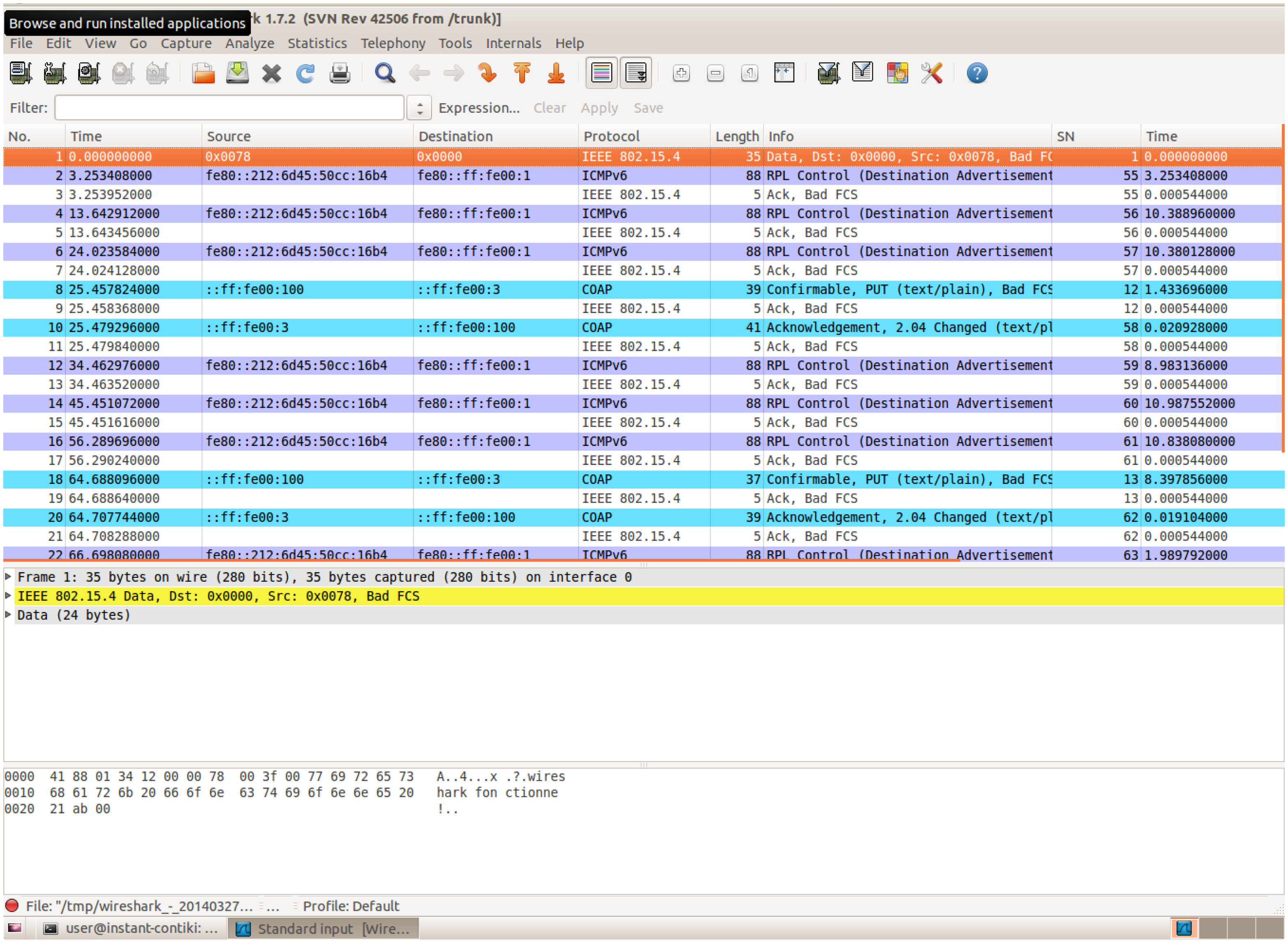
IPv4, IPv6

3G 4G Lte Wi Fi

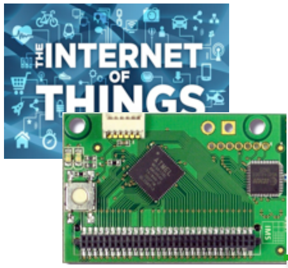


112	106.575520000	fe80::212:6d45:50b7:6a0f	fe80::212:6d45:5026:34cc	ICMPv6	94	RPL Control (Destination Advertisement Object),
113	106.576064000			IEEE 802.15.4	5	Ack, Bad FCS
114	106.576608000			IEEE 802.15.4	5	Ack, Bad FCS
115	113.692576000	fe80::212:6d45:50b7:7575	fe80::212:6d45:5026:34cc	ICMPv6	94	RPL Control (Destination Advertisement Object),
116	114.080416000	fe80::212:6d45:50b7:7575	fe80::212:6d45:5026:34cc	ICMPv6	94	RPL Control (Destination Advertisement Object),
117	[illegible]			IEEE 802.15.4	5	Ack, Bad FCS
118	116.008352000	2001:620:607:5b10::a	::ff:fe00:28	COAP	60	Confirmable, GET, End of Block #15, Bad FCS
119	116.008896000			IEEE 802.15.4	5	Ack, Bad FCS
120	116.292576000	::ff:fe00:28	2001:620:607:5b10::a	COAP	65	Acknowledgement, 2.05 Content, End of Block #15
121	[illegible]			IEEE 802.15.4	5	Ack, Bad FCS
122	116.544800000	fe80::212:6d45:50b7:69b3	fe80::212:6d45:50b7:6a0f	ICMPv6	94	RPL Control (Destination Advertisement Object),
123	116.545344000			IEEE 802.15.4	5	Ack, Bad FCS
124	116.545888000			IEEE 802.15.4	5	Ack, Bad FCS
125	116.546432000			IEEE 802.15.4	5	Ack, Bad FCS
126	121.702624000	fe80::212:6d45:50b7:7e21	fe80::212:6d45:5026:34cc	ICMPv6	94	RPL Control (Destination Advertisement Object),
127	121.703168000			IEEE 802.15.4	5	Ack, Bad FCS
128	123.968480000	fe80::212:6d45:50b7:7575	fe80::212:6d45:5026:34cc	ICMPv6	94	RPL Control (Destination Advertisement Object),
129	123.969024000			IEEE 802.15.4	5	Ack, Bad FCS
130	127.058048000	fe80::212:6d45:50b7:69b3	fe80::212:6d45:50b7:6a0f	ICMPv6	94	RPL Control (Destination Advertisement Object),
131	127.058592000			IEEE 802.15.4	5	Ack, Bad FCS
132	127.344416000	fe80::212:6d45:50b7:6a0f	fe80::212:6d45:5026:34cc	ICMPv6	94	RPL Control (Destination Advertisement Object),

RPL and CoAP exchanges

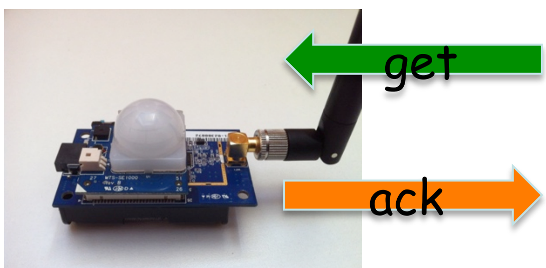


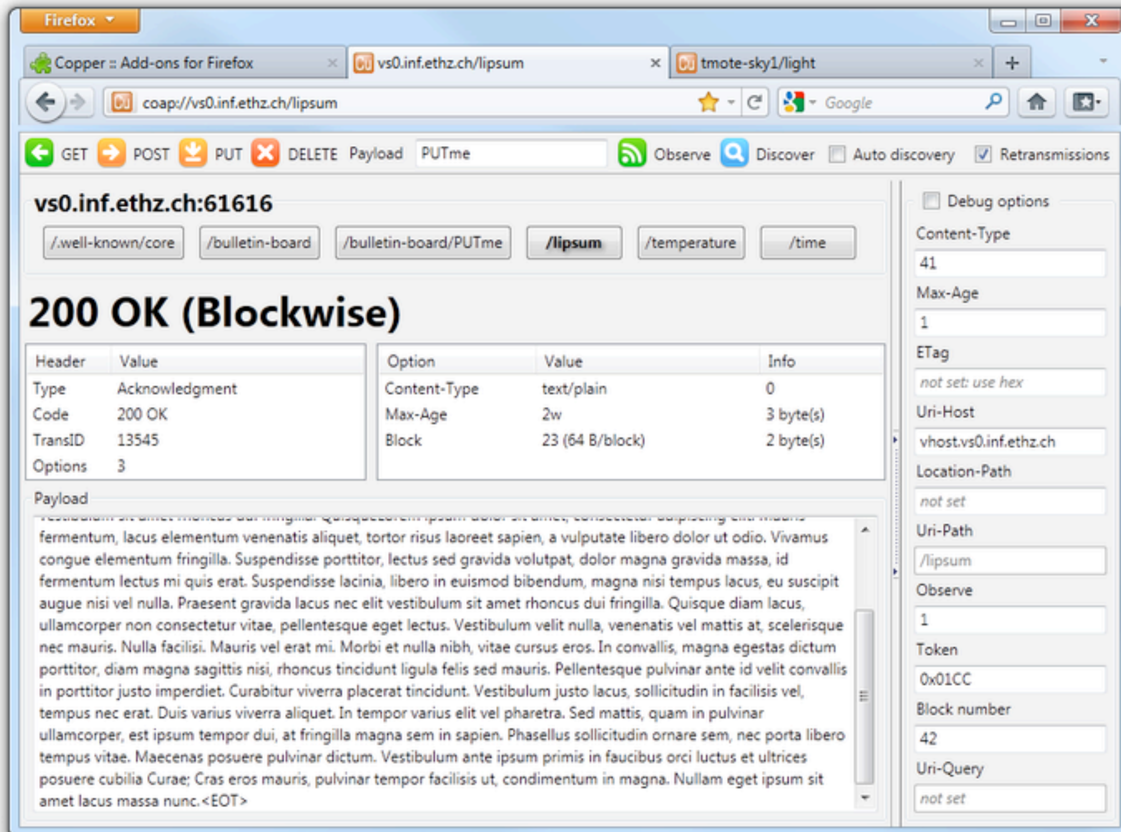
No.	Time	Source	Destination	Protocol	Length	Info	SN	Time
1	0.000000000	0x0078	0x0000	IEEE 802.15.4	35	Data, Dst: 0x0000, Src: 0x0078, Bad FC	1	0.000000000
2	3.253408000	fe80::212:6d45:50cc:16b4	fe80::ff:fe00:1	ICMPv6	88	RPL Control (Destination Advertisement	55	3.253408000
3	3.253952000			IEEE 802.15.4	5	Ack, Bad FCS	55	0.000544000
4	13.642912000	fe80::212:6d45:50cc:16b4	fe80::ff:fe00:1	ICMPv6	88	RPL Control (Destination Advertisement	56	10.388960000
5	13.643456000			IEEE 802.15.4	5	Ack, Bad FCS	56	0.000544000
6	24.023584000	fe80::212:6d45:50cc:16b4	fe80::ff:fe00:1	ICMPv6	88	RPL Control (Destination Advertisement	57	10.380128000
7	24.024128000			IEEE 802.15.4	5	Ack, Bad FCS	57	0.000544000
8	25.457824000	::ff:fe00:100	::ff:fe00:3	COAP	39	Confirmable, PUT (text/plain), Bad FCS	12	1.433696000
9	25.458368000			IEEE 802.15.4	5	Ack, Bad FCS	12	0.000544000
10	25.479296000	::ff:fe00:3	::ff:fe00:100	COAP	41	Acknowledgement, 2.04 Changed (text/pl	58	0.020928000
11	25.479840000			IEEE 802.15.4	5	Ack, Bad FCS	58	0.000544000
12	34.462976000	fe80::212:6d45:50cc:16b4	fe80::ff:fe00:1	ICMPv6	88	RPL Control (Destination Advertisement	59	8.983136000
13	34.463520000			IEEE 802.15.4	5	Ack, Bad FCS	59	0.000544000
14	45.451072000	fe80::212:6d45:50cc:16b4	fe80::ff:fe00:1	ICMPv6	88	RPL Control (Destination Advertisement	60	10.987552000
15	45.451616000			IEEE 802.15.4	5	Ack, Bad FCS	60	0.000544000
16	56.289696000	fe80::212:6d45:50cc:16b4	fe80::ff:fe00:1	ICMPv6	88	RPL Control (Destination Advertisement	61	10.838080000
17	56.290240000			IEEE 802.15.4	5	Ack, Bad FCS	61	0.000544000
18	64.688096000	::ff:fe00:100	::ff:fe00:3	COAP	37	Confirmable, PUT (text/plain), Bad FCS	13	8.397856000
19	64.688640000			IEEE 802.15.4	5	Ack, Bad FCS	13	0.000544000
20	64.707744000	::ff:fe00:3	::ff:fe00:100	COAP	39	Acknowledgement, 2.04 Changed (text/pl	62	0.019104000
21	64.708288000			IEEE 802.15.4	5	Ack, Bad FCS	62	0.000544000
22	66.698080000	fe80::212:6d45:50cc:16b4	fe80::ff:fe00:1	ICMPv6	88	RPL Control (Destination Advertisement	63	1.989792000



Copper for Firefox

- CoAP pluggin to query CoAP nodes in an HTTP-like fashion





What do you need? Everything is here!

CoAP
Constrained Application Protocol

→ Need a CoAP implementation

RPL
Routing Protocol for LLN
LLN: Low power & Lossy Networks

→ Need an RPL implementation

6LowPan
802.15.4

→ Not difficult, just formatting of packets

TinyOS

Contiki

Arduino (Telecom Bretagne)

Conclusions

- Part I
  - Present various ways to connect your sensors and build sensor networks
  - 1-hop communication model should also be considered because there are new technologies to do so
  - Multi-hop is challenging but allows much finer grain tuning of performances
  - Present the IoT protocols
- Part II
  - Data-intensive surveillance applications with WSN