

# CARI'2014 TUTORIAL

## IMAGE AND AUDIO TRANSMISSION ON HETEROGENEOUS WIRELESS SENSOR NETWORKS

### PART I - INTRODUCTION

Digital eco-system, Wireless sensor networks,  
Internet of Things

### PART II

Images and Audio challenges

### PART III

Demonstration



PROF. CONGDUC PHAM  
[HTTP://WWW.UNIV-PAU.FR/~CPHAM](http://www.univ-pau.fr/~cpham)  
UNIVERSITÉ DE PAU, FRANCE



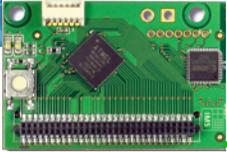
# DIGITAL ECO-SYSTEM, WIRELESS SENSOR NETWORKS, INTERNET OF THINGS

CARI 2014 TUTORIAL - PART I  
GASTON BERGER UNIVERSITY  
OCTOBER, 17<sup>TH</sup>, 2014  
SAINT-LOUIS, SENEGAL



PROF. CONGDUC PHAM  
[HTTP://WWW.UNIV-PAU.FR/~CPHAM](http://www.univ-pau.fr/~cpham)  
UNIVERSITÉ DE PAU, FRANCE

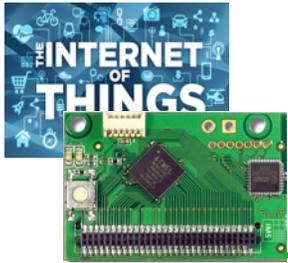




# DIGITAL DEVICES...



... AND WHY WE CALLED IT AN ECOSYSTEM

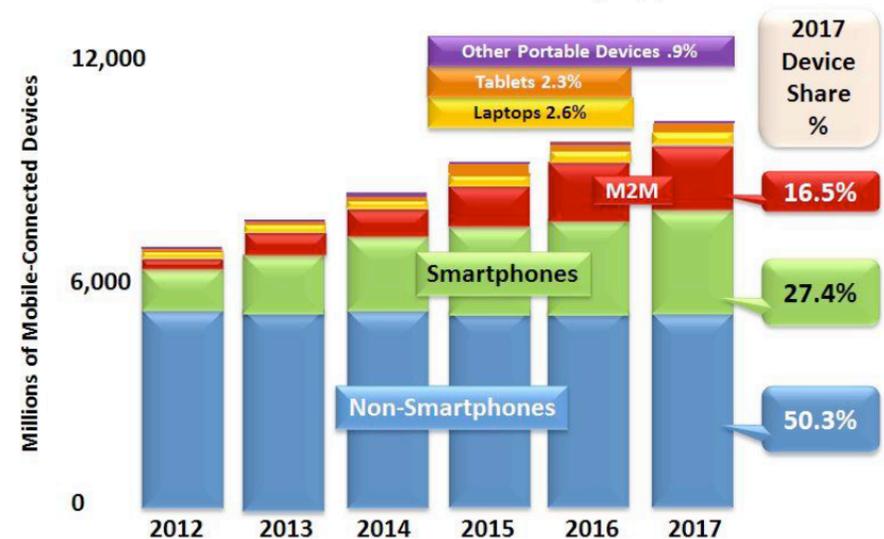


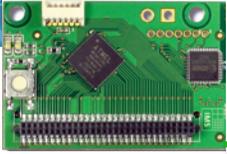
# MOBILE DEVICES



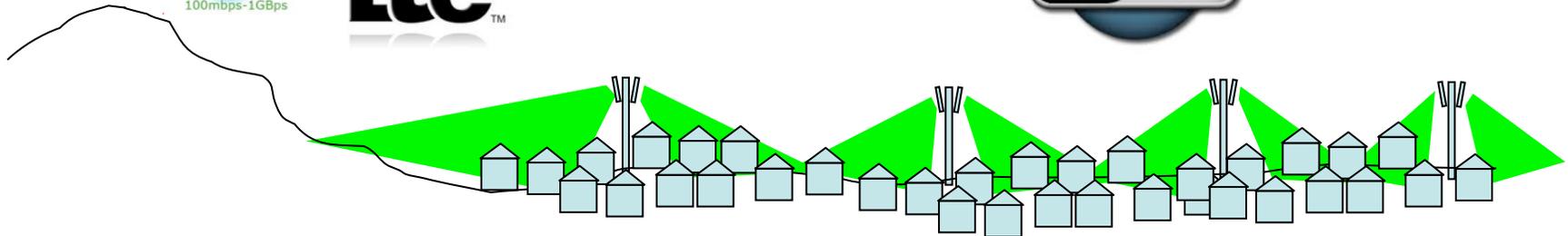
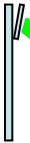
4G Americas / 4G Mobile Broadband Evolution: 3GPP Release 11 & Release 12 and Beyond / February 2014

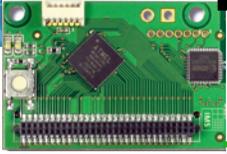
## Global Mobile Device Growth by Type



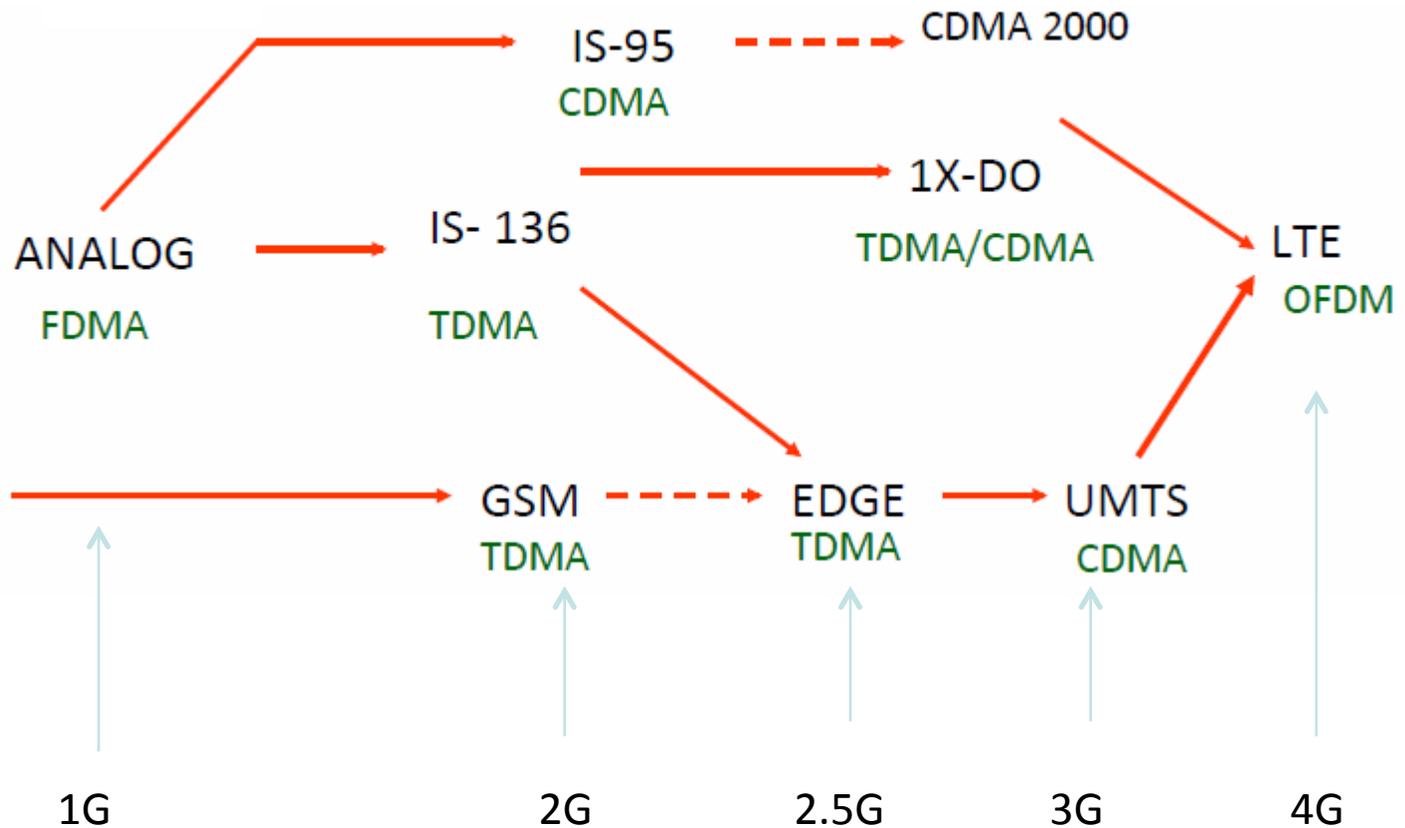


# CELLULAR MODEL





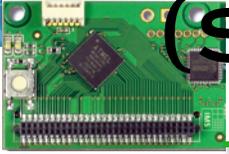
# EVOLUTION OF CELLULAR NETWORKS



CDMAone->CDMA2000

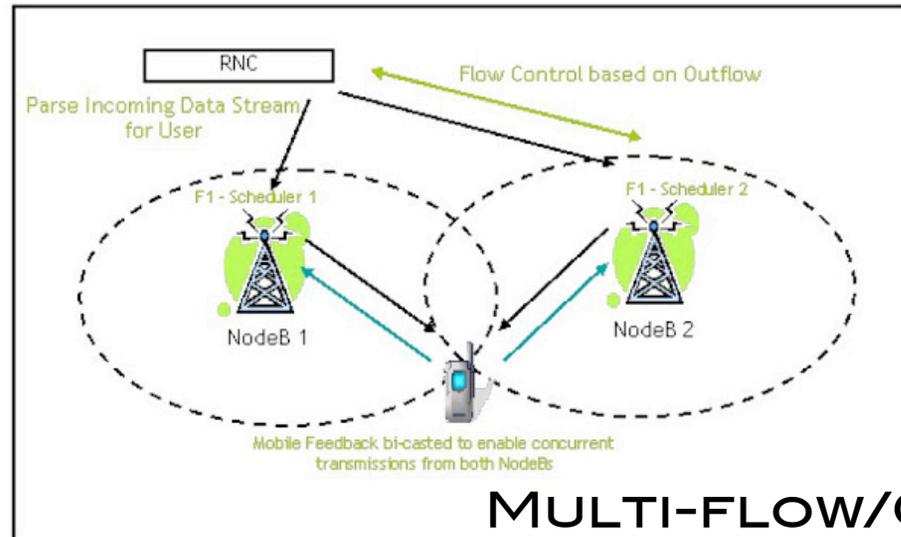
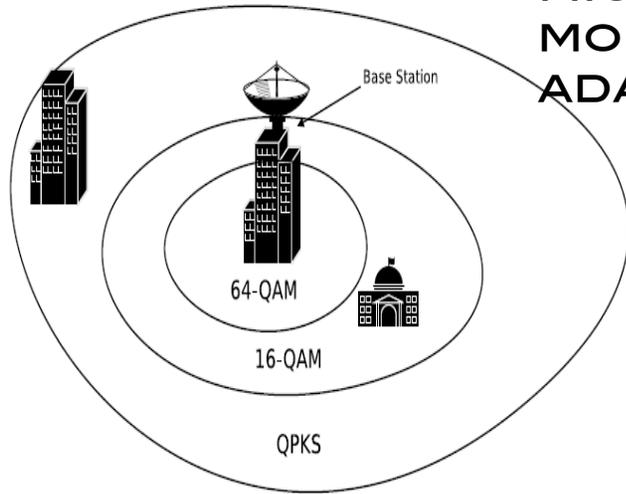
EGDE: Enhanced Data Rates for GSM Evolution

UMTS: Universal Mobile Telecommunications System (W-CDMA)



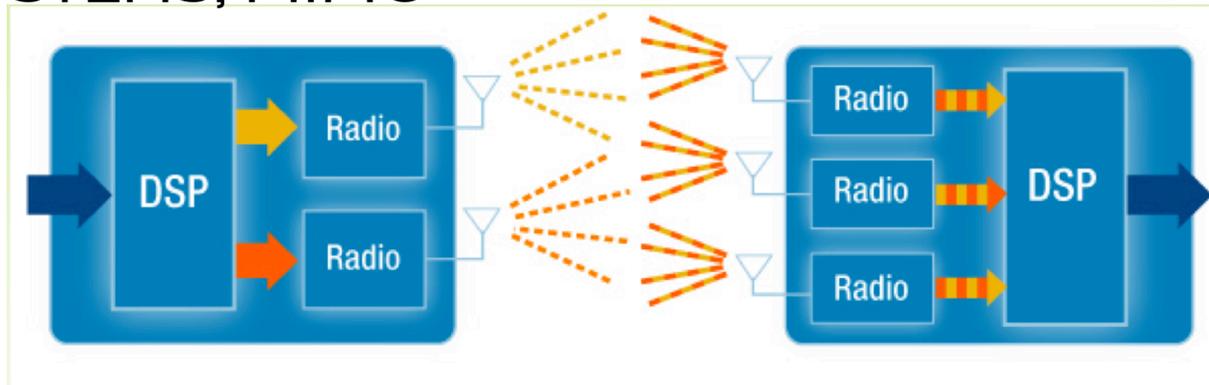
# (SOME) KEY TECHNOLOGIES

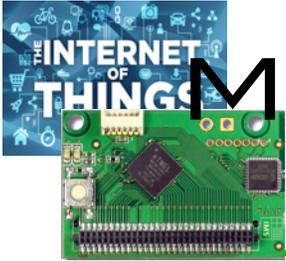
## HIGHER ORDER MODULATION AND ADAPTIVE MODULATION



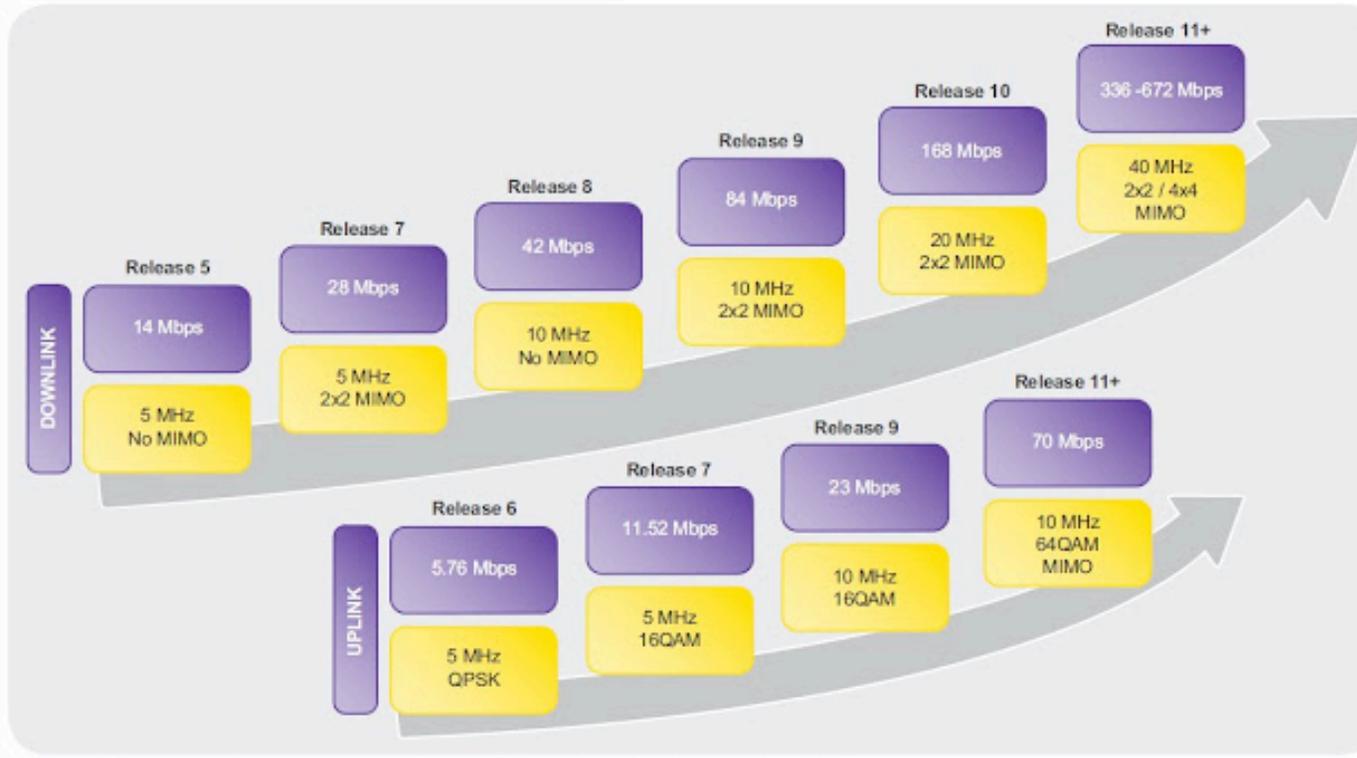
## MULTIPLE ANTENNA SYSTEMS, MIMO

## MULTI-FLOW/CELL SYSTEM

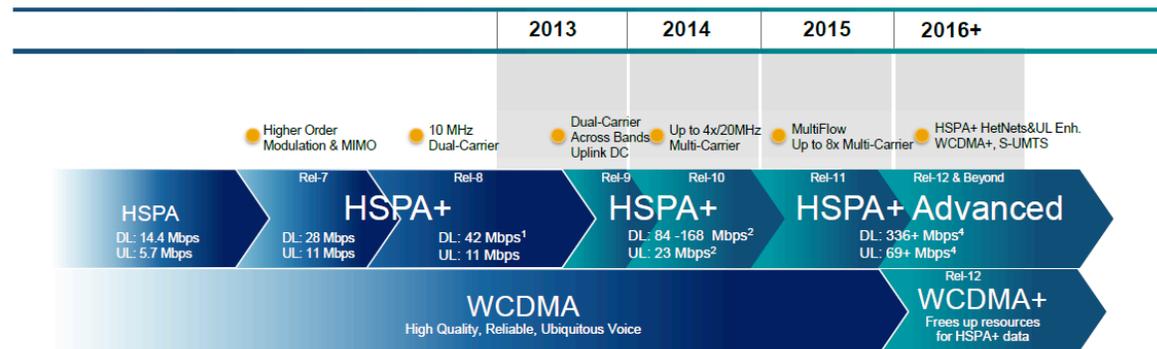




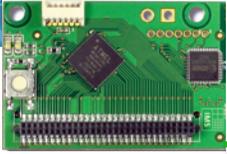
# MORE THROUGHPUT IN NEAR FUTURE!



FROM NSN WHITE PAPER ON HSPA EVOLUTION

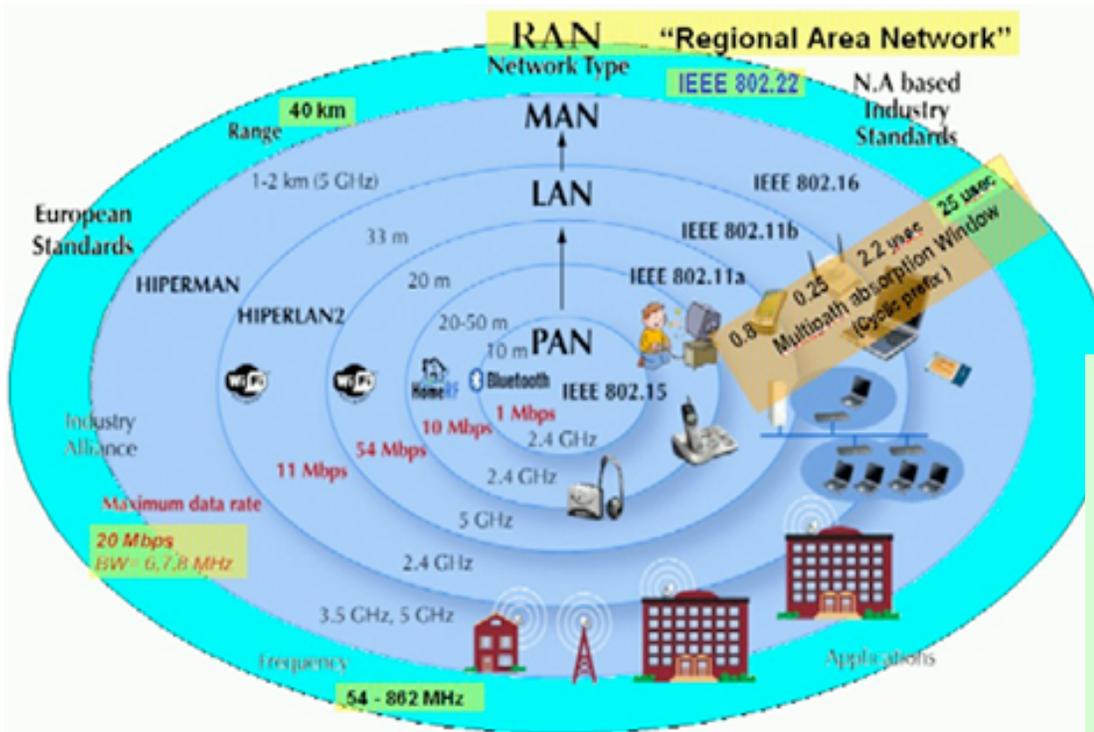


FROM QUALCOMM



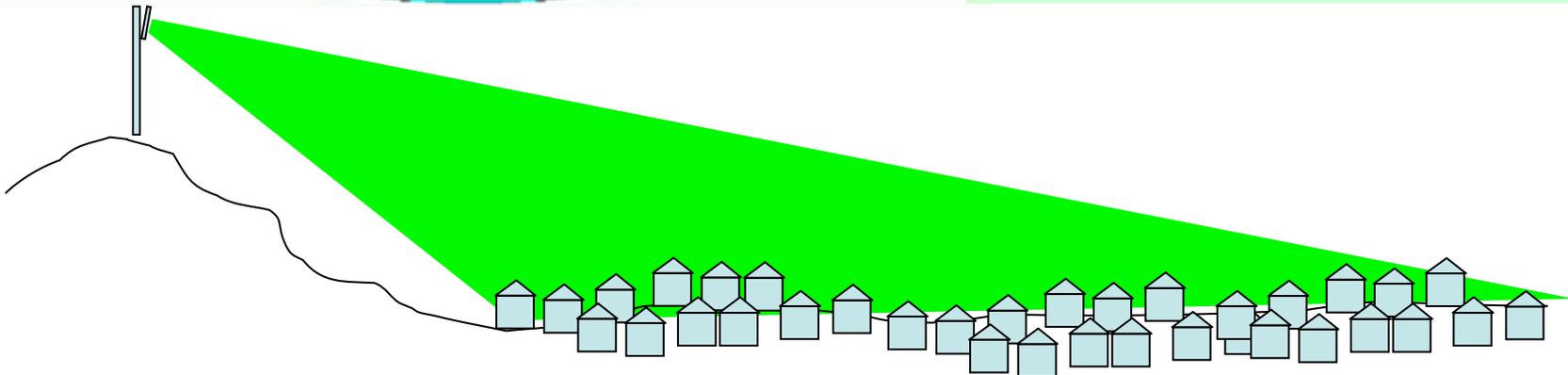
# TOWARDS 802.22 WRAN

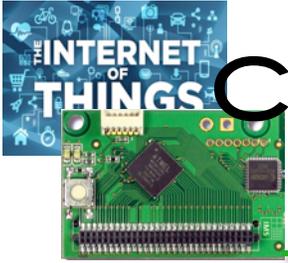
## WIRELESS REGIONAL AREA NETWORKS



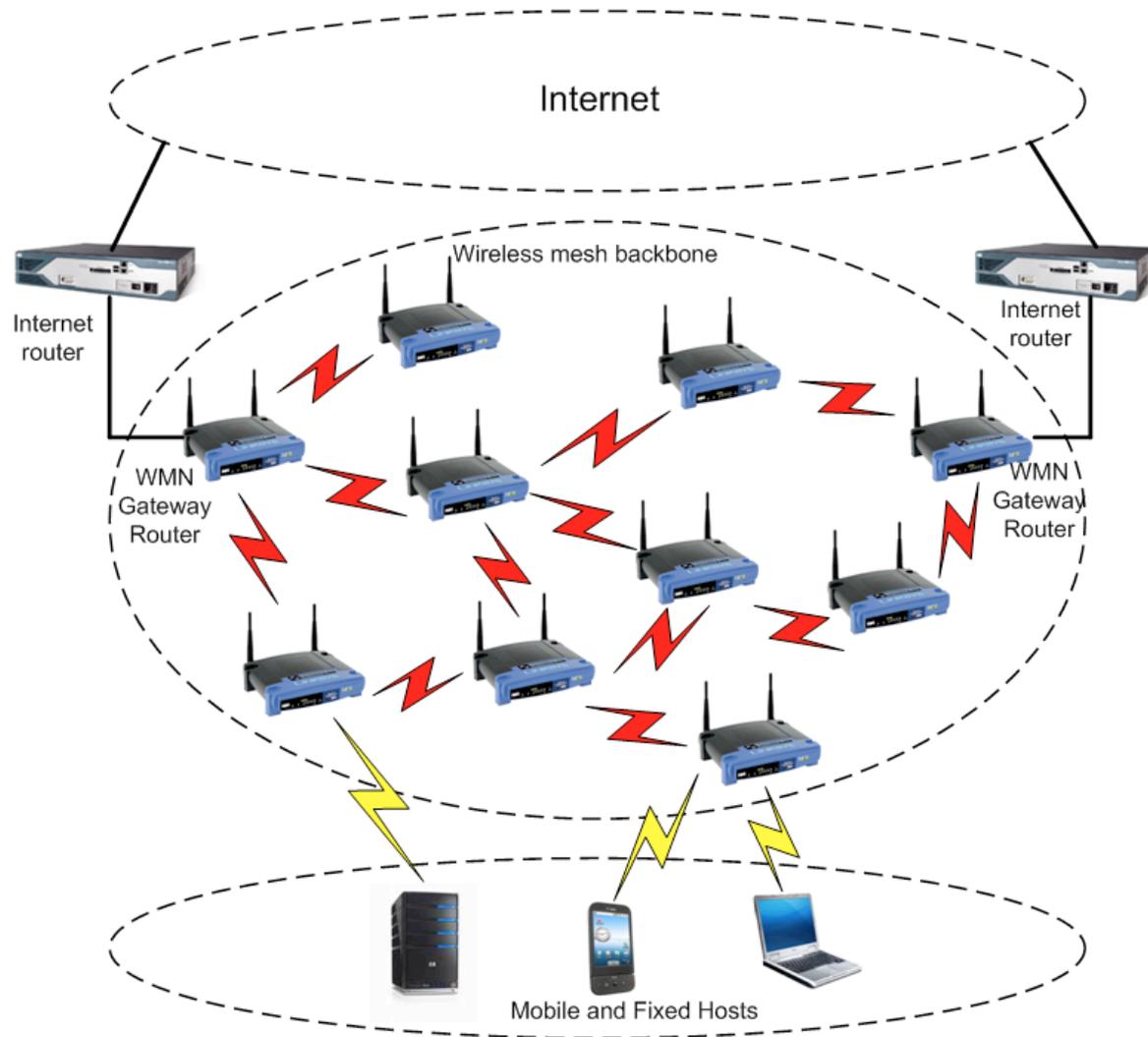
uses white spaces in the television (TV) frequency spectrum.

using cognitive radio (CR) techniques to allow sharing of geographically unused spectrum allocated to the television broadcast service.





# COGNITIVE RADIO WIRELESS MESH NETWORKS



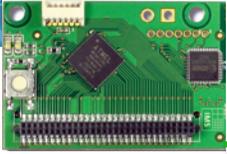
Cognitive, opportunistic, multi-channel radio for large-scale wireless infrastructures



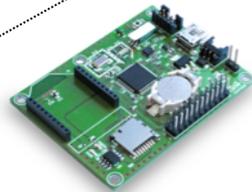
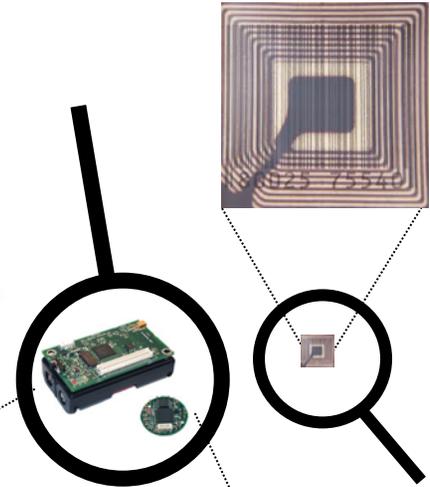
# EVERYTHING, EVERYWHERE

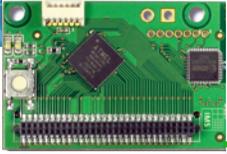


Take into account that in a near future, we will have more throughput with our mobile wireless devices than our wired home internet access



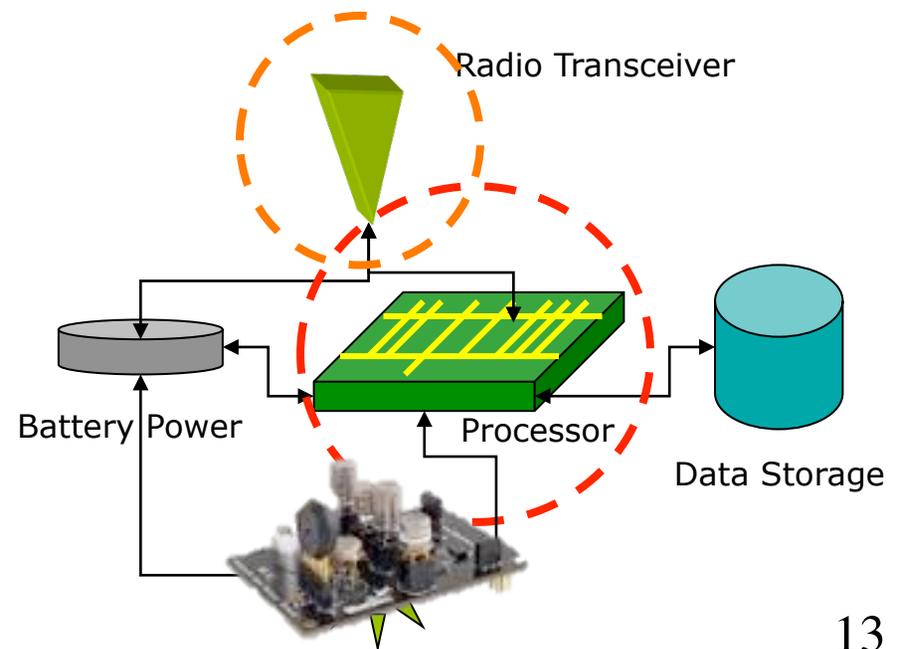
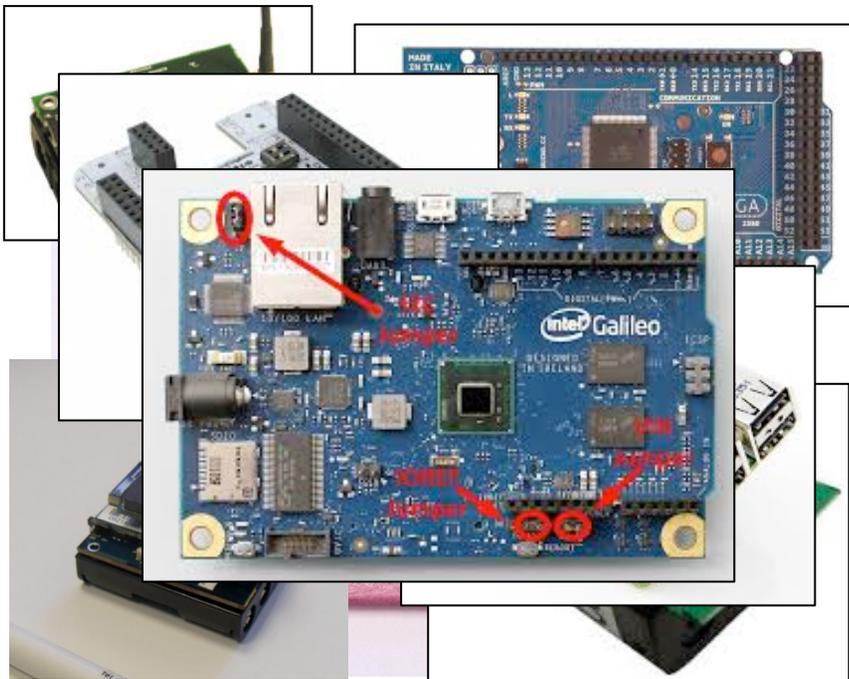
# MORE DIGITAL DEVICES!

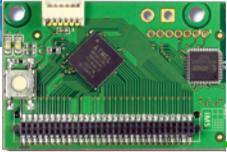




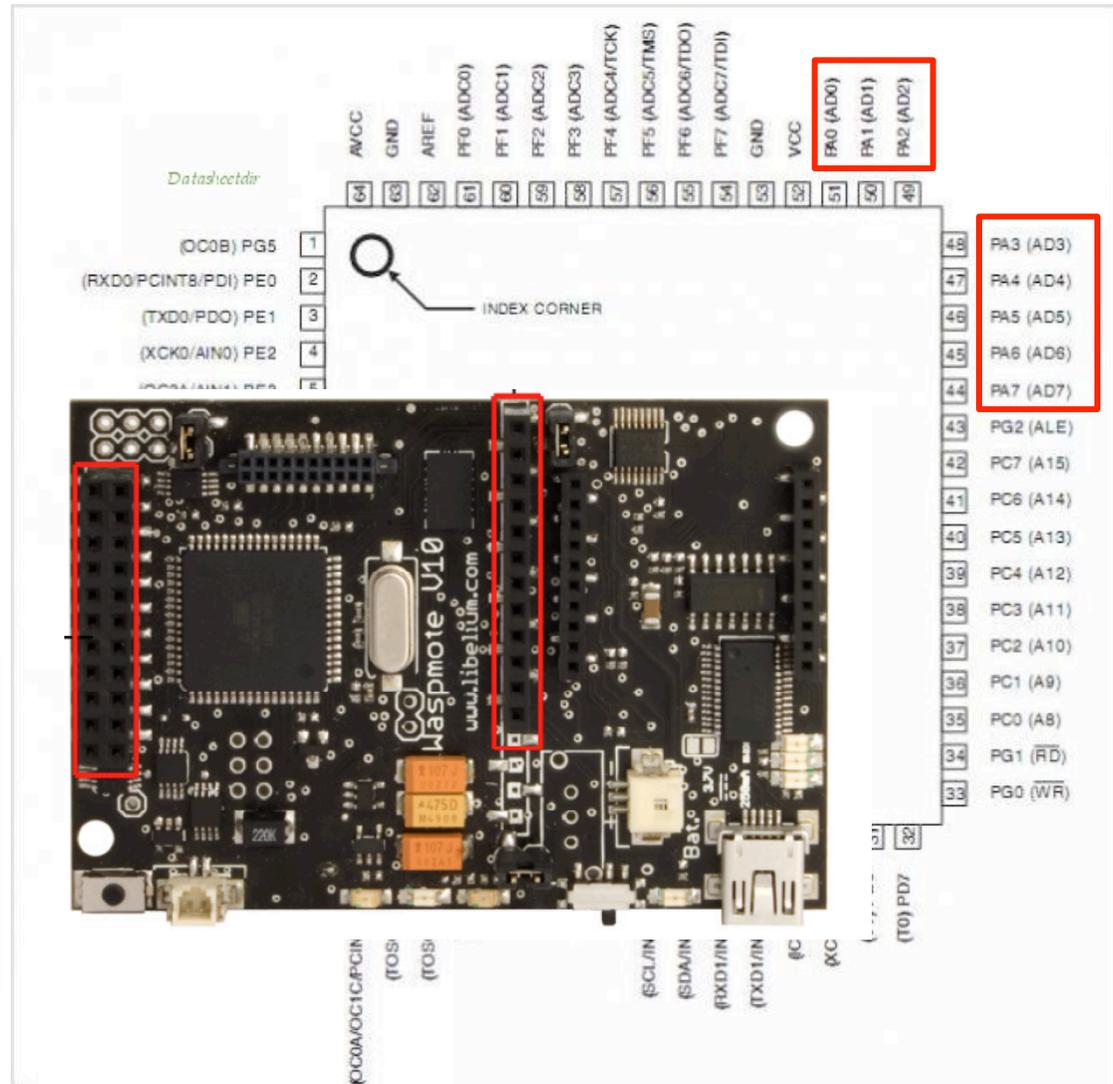
# WIRELESS AUTONOMOUS SENSORS

- ❑ 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





# MICRO-CONTROLLER VS MICRO-PROCESSOR





# BEYOND SENSOR NETWORKS: COMMUNICATING OBJECTS!

❑ NATIVE COMMUNICATION:

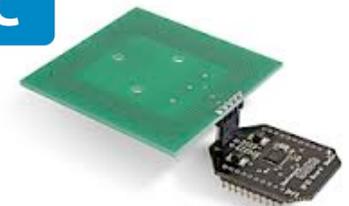


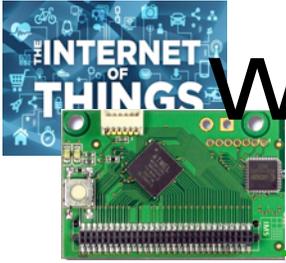
❑ ADDED COMMUNICATION

❑ ACTIVE COMMUNICATION



❑ PASSIVE COMMUNICATION





# WIRELESS COMMUNICATION MADE EASY

Wi-Fi

Bluetooth

WiMAX

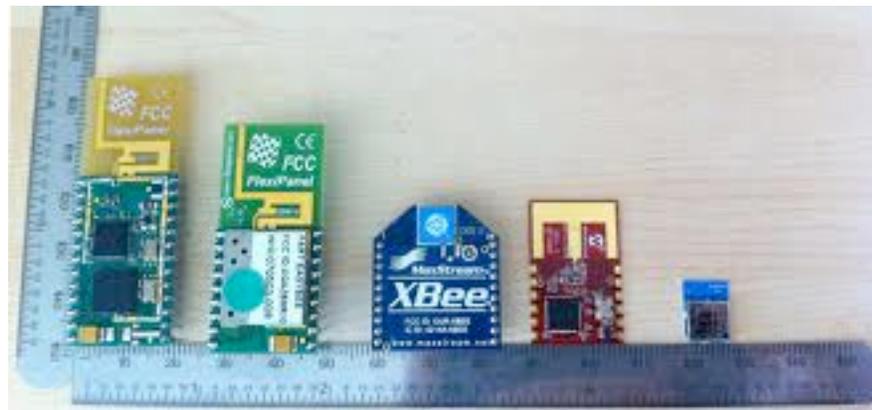
ZigBee®  
Member

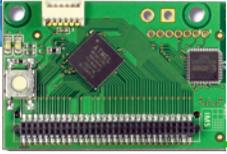
4G  
100mbps-1Gbps

3G

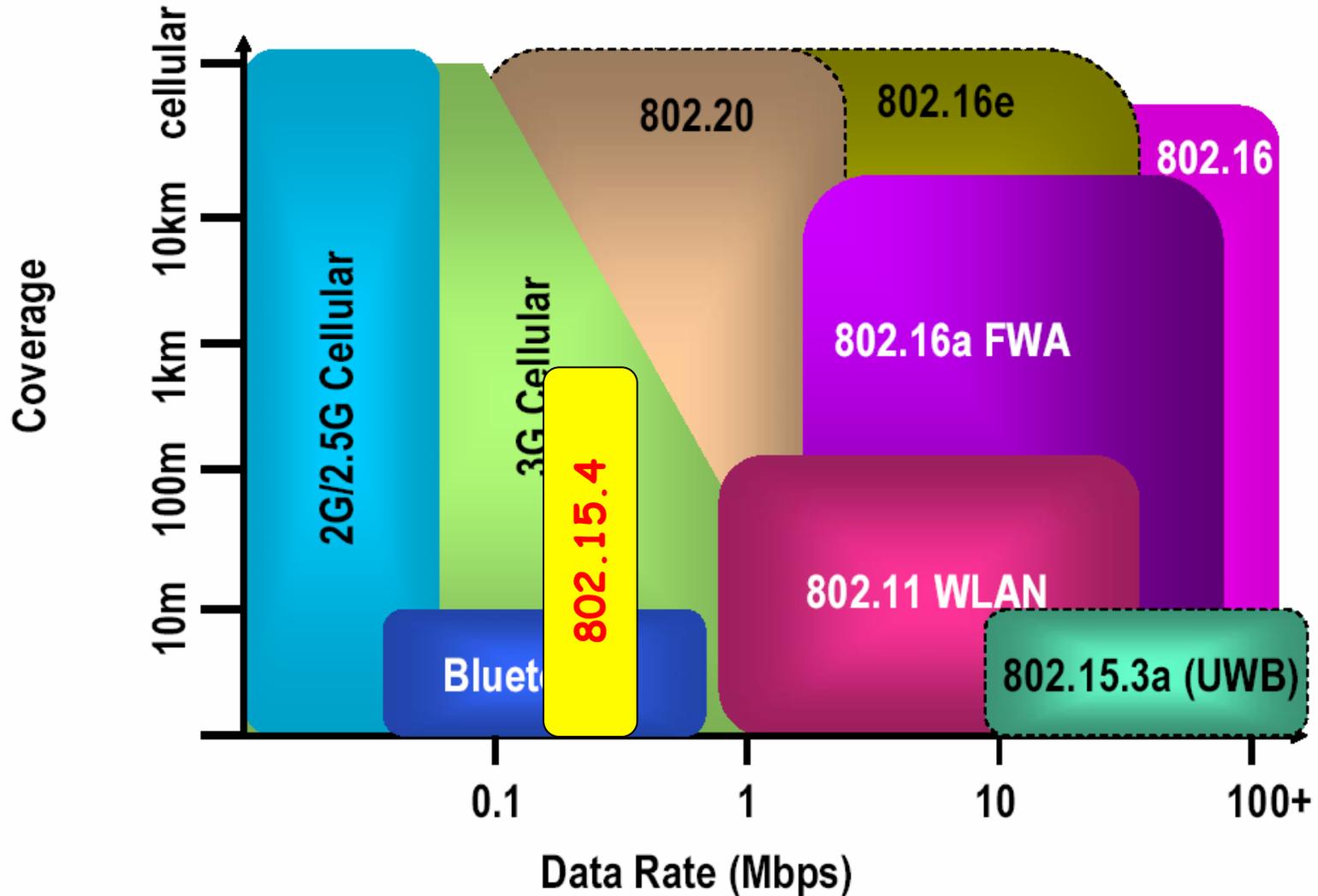
LTE™

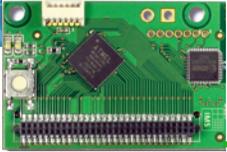
WiMedia  
ALLIANCE





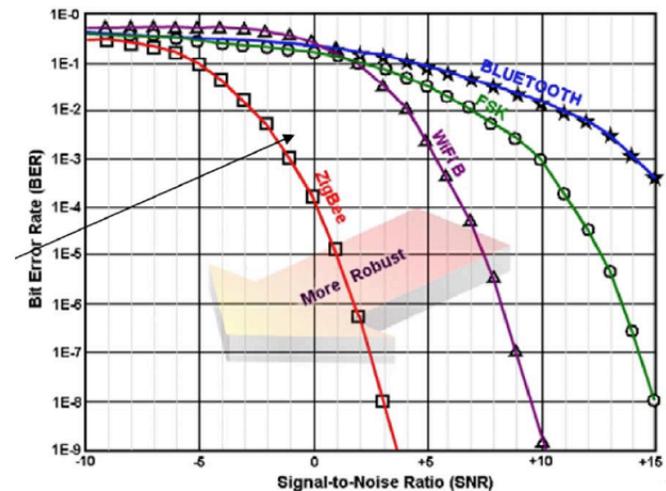
# SUMMARY OF WIRELESS TECHNOLOGIES

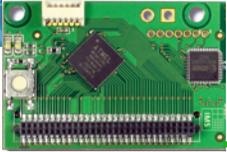




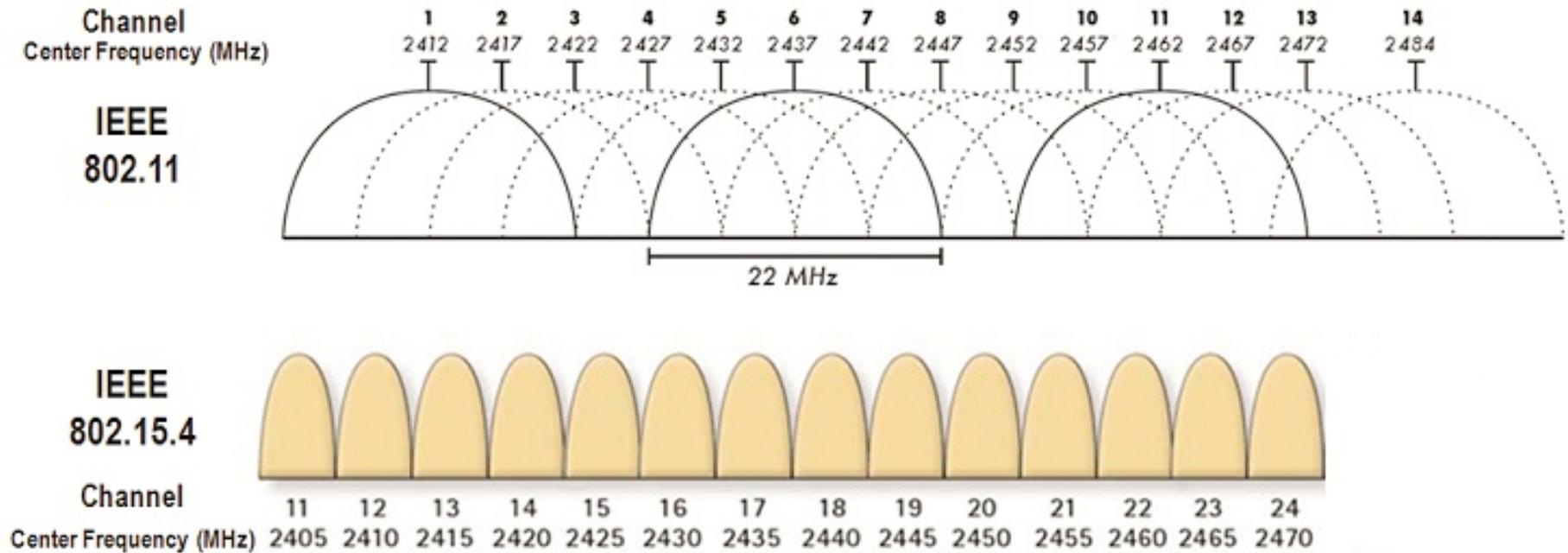
# IEEE 802.15.4

- LOW-POWER RADIO IN THE 2.4GHZ BAND OFFERING 250KBPS THROUGHPUT AT PHYSICAL LAYER
- 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 ZIGBEE



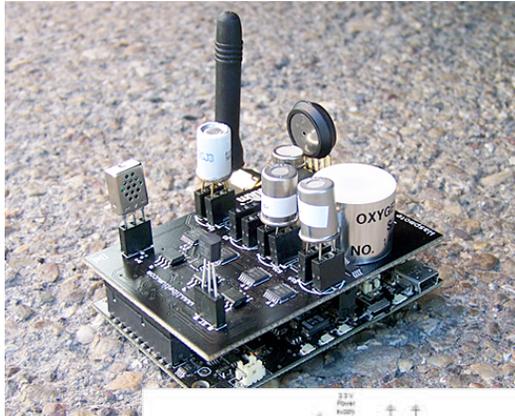


# SPECTRUM BAND





# ENERGY CONSIDERATION



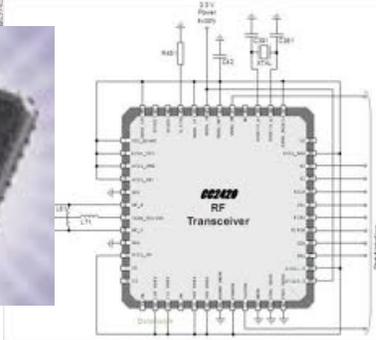
18720 JOULES

TX power 0dbm: 17.4mA

$$P = I \times V = 17.4 \times 3.3 = 57.42\text{mW}$$

$$E = P \times t \rightarrow t = E/P$$

326018s or 90.5h



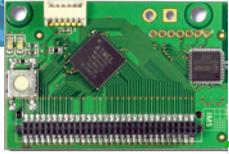
Chipcon Products  
from Texas Instruments

**CC2420**

Parameter	Min.	Typ.	Max.	Unit	Condition / Note
Current Consumption, transmit mode:					
P = -25 dBm		8.5		mA	The output power is delivered differentially to a 50 Ω singled ended load through a balun, see also page 55.
P = -15 dBm		9.9		mA	
P = -10 dBm		11		mA	
P = -5 dBm		14		mA	
P = 0 dBm		17.4		mA	

Haven't considered:

- Baseline power consumption of the sensor board
- RX consumption: 18.8mA!
- Event capture consumption
- Event processing consumption



# ARE YOU I-O-T OR WSN?



IP integration, WWW  
IPv6  
Inter-operability  
Interactions (all kind)  
Semantic, Ontology  
Data representation  
Data logging  
WebServices, RDF, OWL, ...



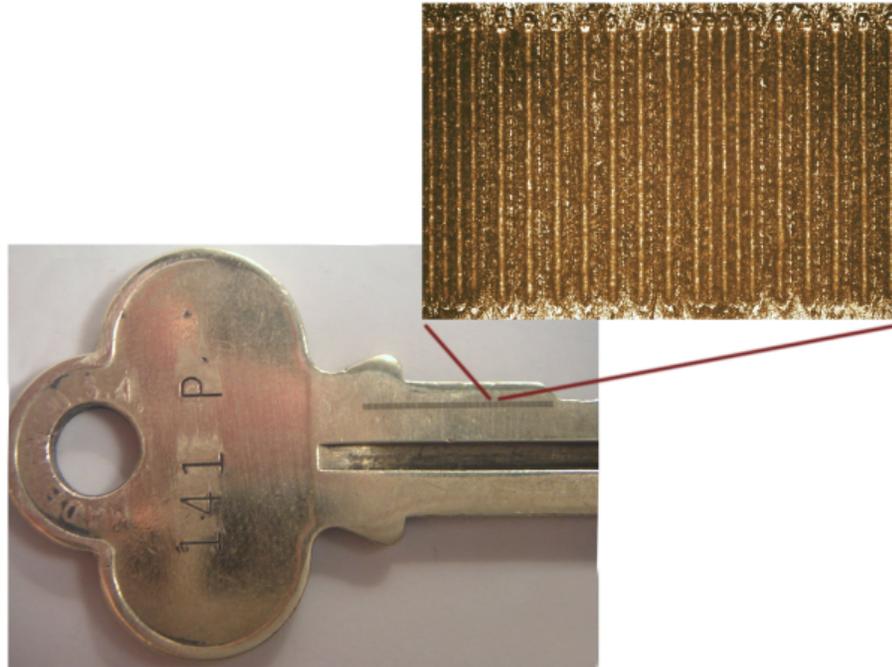
Organization  
Programmability  
Energy saving  
Scheduling  
Efficient MAC, routing  
Congestion control  
Data transmission

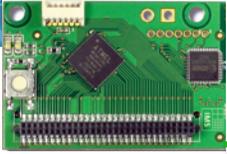




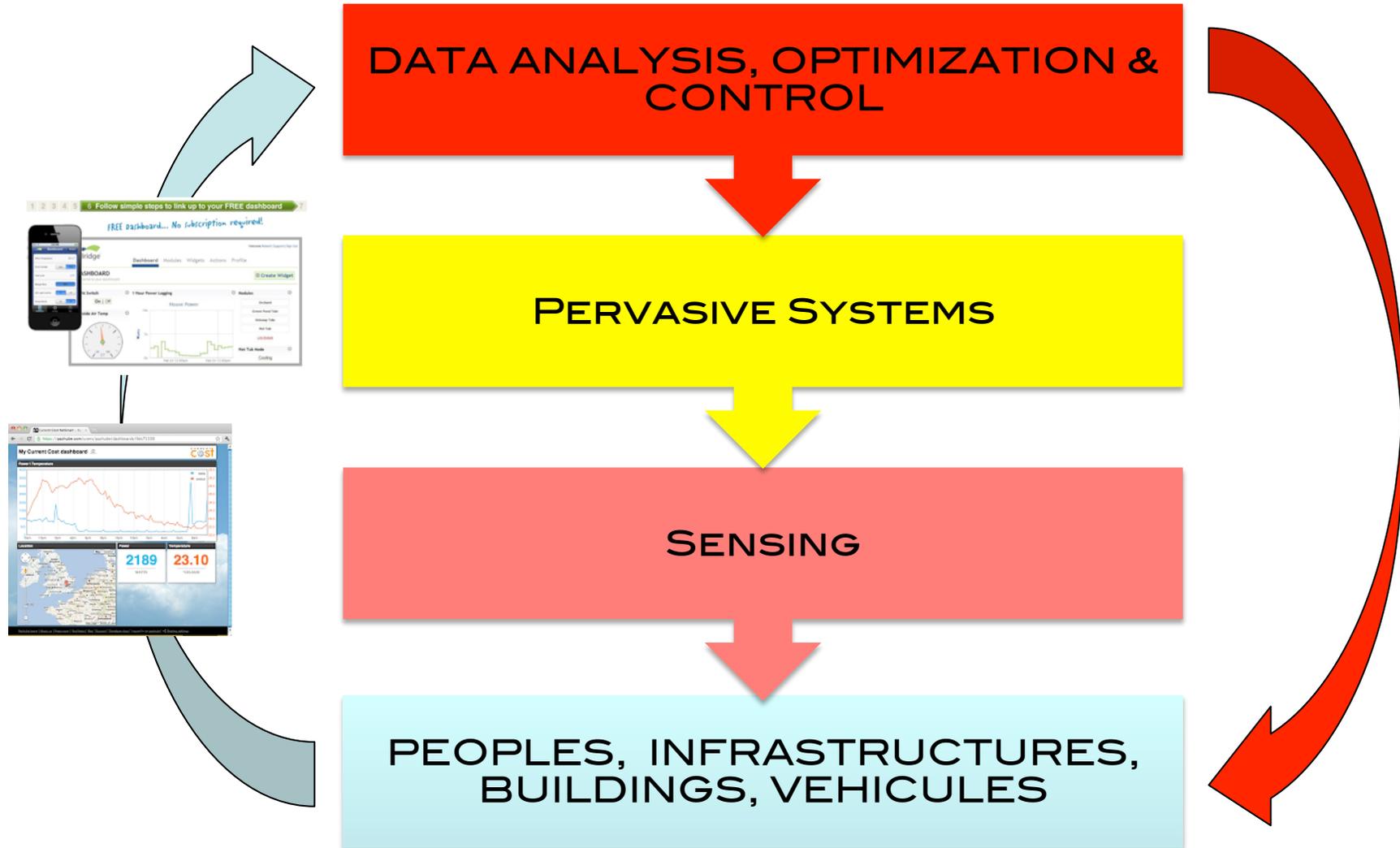
# INTERACTION CAN TAKE MANY (UNEXPECTED) FORMS!

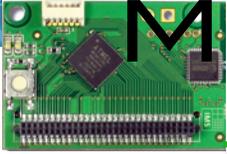
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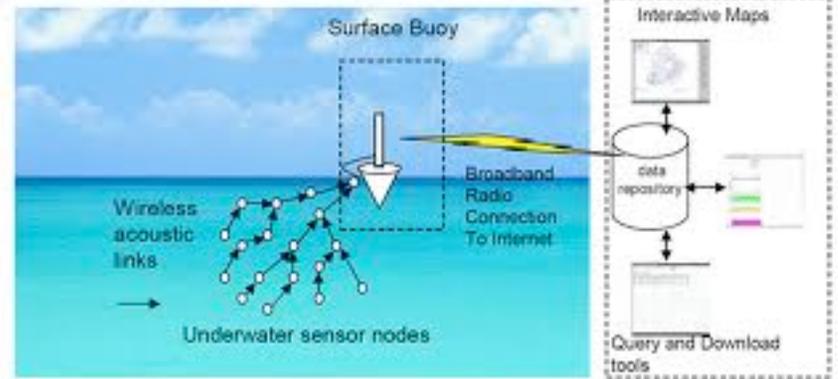


# CONTROL, OPTIMIZE & INSTRUMENT !



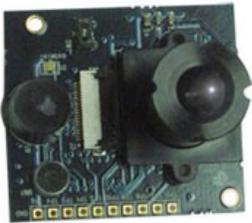
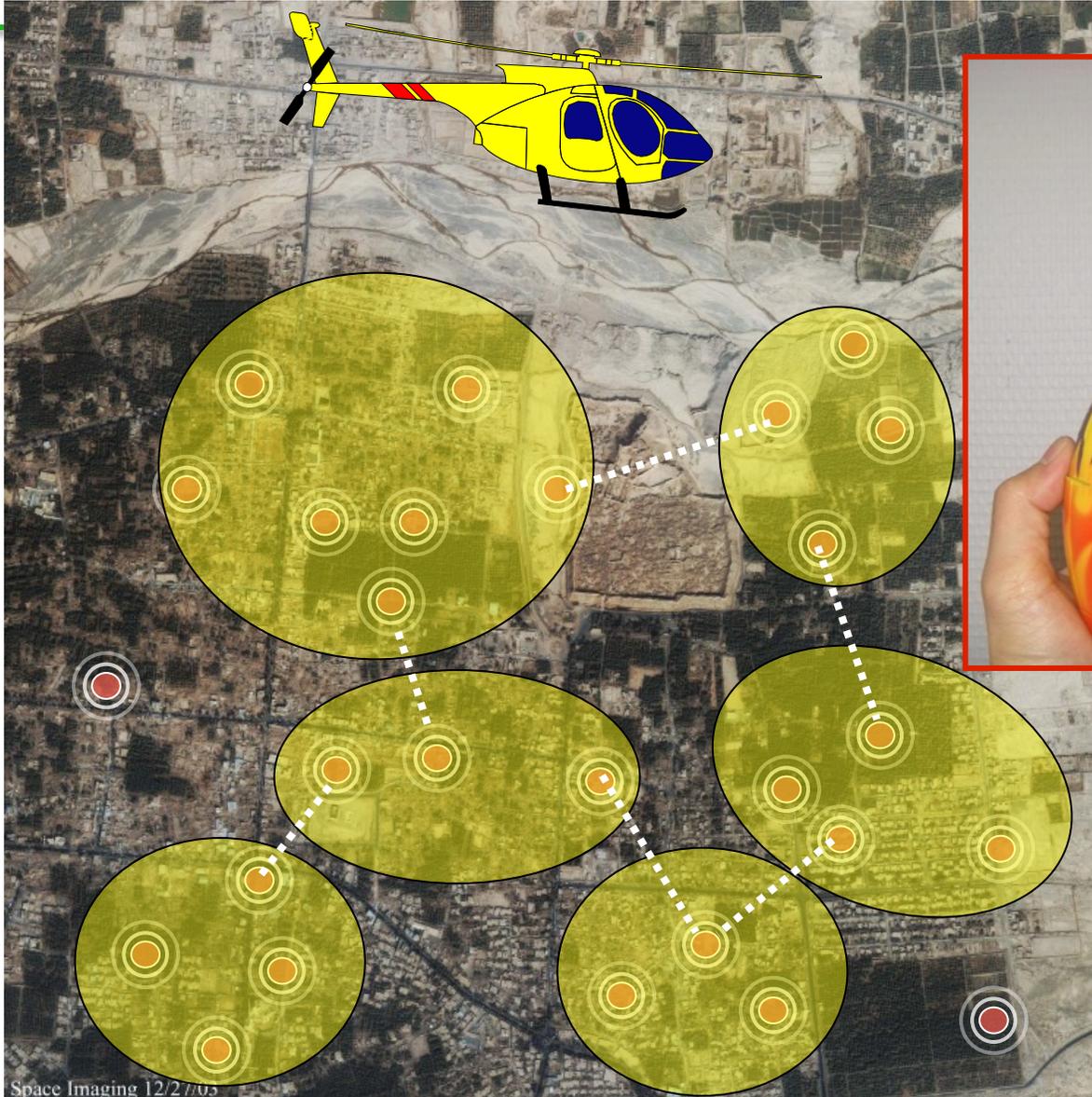


# MONITORING/SURVEILLANCE





# SEARCH & RESCUE, SECURITY

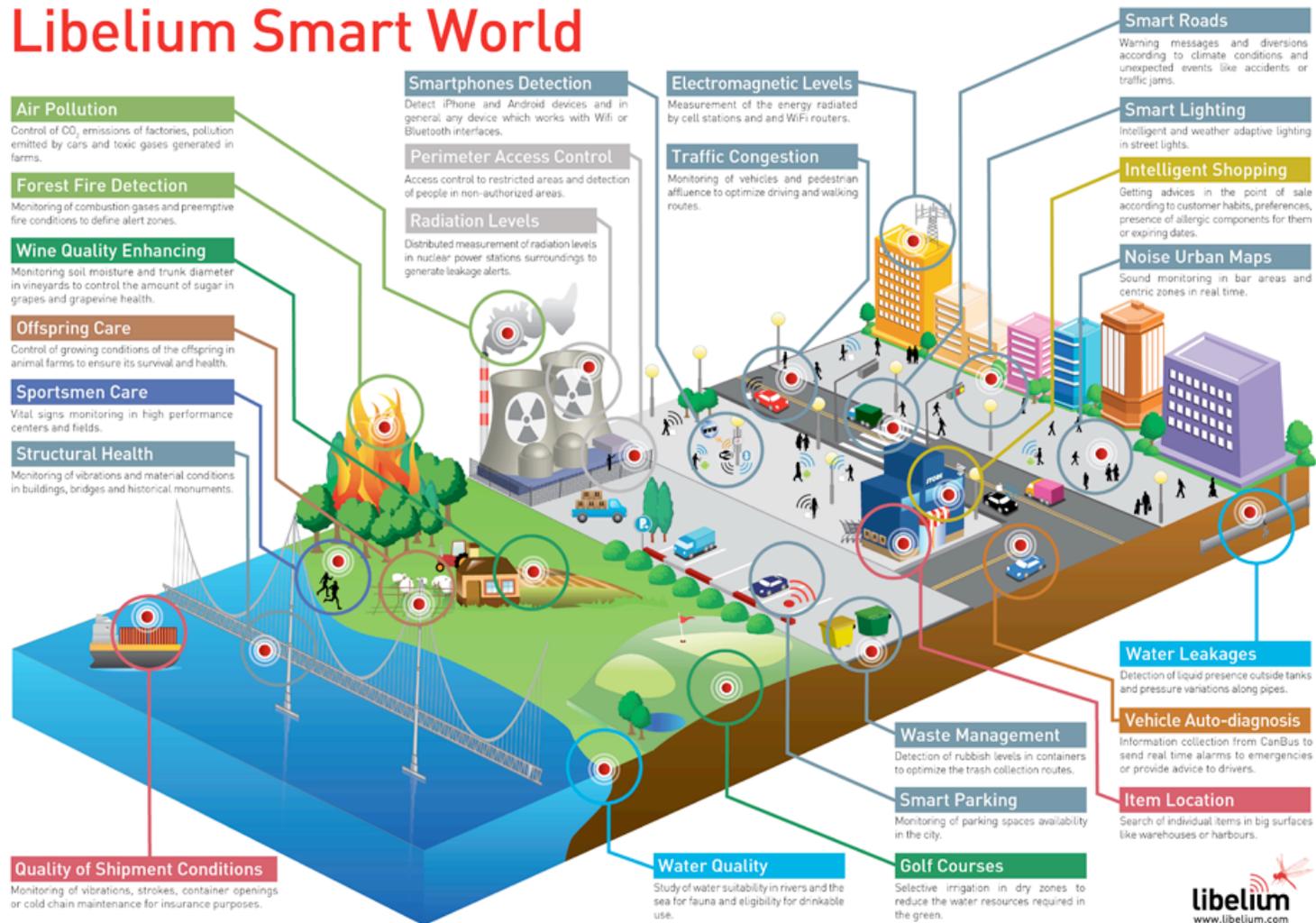


Space Imaging 12/2//03



# SMART CITIES

## Libelium Smart World

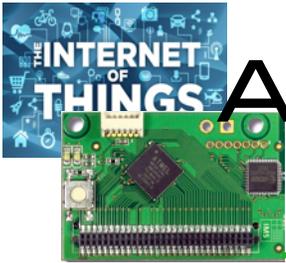




# SMARTSANTANDER

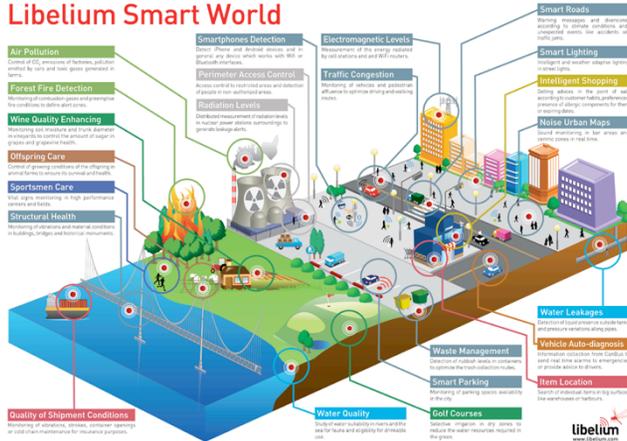
[WWW.SMARTSANTANDER.EU](http://WWW.SMARTSANTANDER.EU)





# A REAL BUSINESS MODEL IN SMARTCITIES

## Libelium Smart World



## KEEP STREETS CLEAN

Products like the cellular communication enabled Smart Belly trash use real-time data collection and alerts to let municipal services know when a bin needs to be emptied. This information can drastically reduce the number of pick-ups required, and translates into fuel and financial savings for communities service departments. // [Visit](#)



## STOP DRIVING IN CIRCLES

With the use of installed sensors, mobile apps, and real-time web applications like those provided in Streetline's ParkSight service, cities can optimize revenue, parking space availability and enable citizens to reduce their environmental impact by helping them quickly find an open spot for their cars. // [Visit](#)



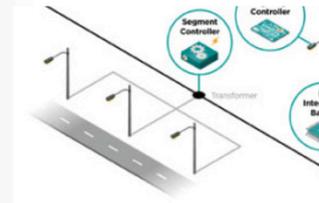
## RECEIVE POLLUTION WARNINGS

The DontFlushMe project by Leif Percifield is an example that combines sensors installed in Combined Sewer Overflows (CSOs) with alerts to local residents so they can avoid polluting local waterways with raw sewage by not flushing their toilets during overflow events. // [Visit](#)



## USE ELECTRICITY MORE EFFICIENTLY

The SenseNET system uses battery-powered clamp sensors to quickly measure current on a line, calculate consumption levels, and send that data to a hosted application for analysis. Significant financial and energy resources are saved as the clamps can easily identify meter tampering issues, general malfunctions, and any installation issues in the system. // [Visit](#)



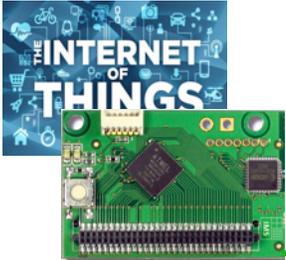
## LIGHT STREETS MORE EFFECTIVELY

This smart lighting system from Echelon allows a city to intelligently provide the right level of lighting needed by time of day, season, and weather conditions. Cities have shown a reduction in street lighting energy use by up to 30% using solutions like this. // [Visit](#)



## SHARE YOUR FINDINGS

AirCasting is a platform for recording, mapping, and sharing health and environmental data using your smartphone. Each AirCasting session lets you capture real-world measurements (Sound levels recorded by their phone microphone; Temperature, humidity, carbon monoxide (CO) and nitrogen dioxide (NO<sub>2</sub>) gas concentrations), and share it via the CrowdMap with your community. // [Visit](#)



# CONTROL, OPTIMIZE & INSTRUMENT

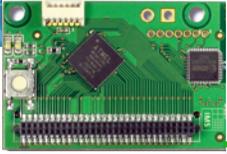


**PERVASIVE SYSTEMS**

**SENSING**

**PEOPLES, INFRASTRUCTURES, BUILDINGS, VEHICULES**





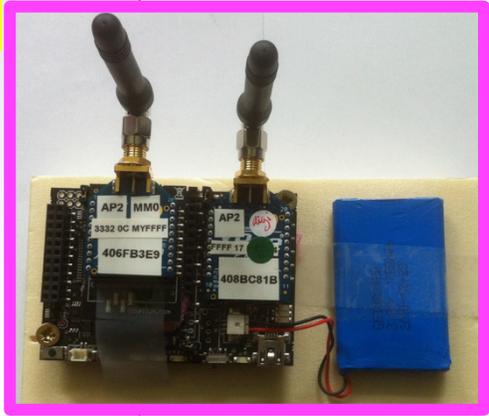
# MASS-MARKET SENSORS

8MHz Atmega1281  
8kB SRAM, 128kB Flash  
Xbee radio



**COST:  
~100€**

LIBELIUM WASPMOTE



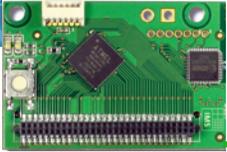
**COST:  
~80€**



16MHz Atmega1281  
8kB SRAM, 128kB Flash  
Xbee radio

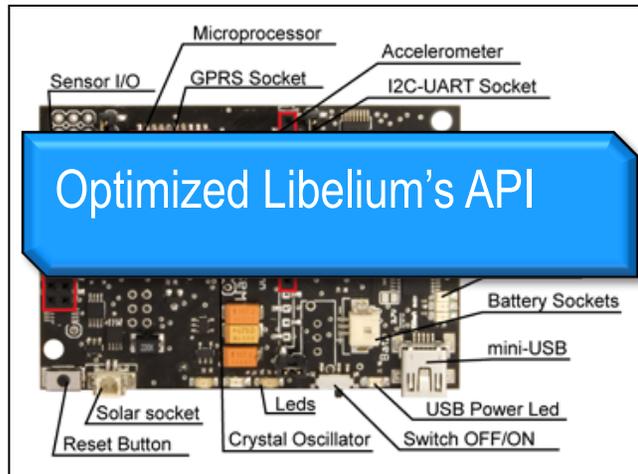


ARDUINO MEGA2560



# SENSOR'S HW&SW

## LIBELIUM WASPMOTE



UART-based connection to micro-controller

Default speed is usually 38400 bauds

Higher baud rate are possible but...

```

WaspXbee802.2_traffic_generator | WaspMote-IDE 02
-----WaspMote XBee 802.15.4 Traffic Generator-----
Version: 0.33
Design: C. Pham
Implementation: C. Pham

"Z100" : set packet size to 20 bytes
"Z2000" : increases pkt size from 5 bytes to 100 bytes (or 400 bytes with Libelium API) every 20pkt
"Z2000" : set frequency to 1pk/200ms
"TX010A20000B0C01F" : set destination address to 0010A20000B0C01F, broadcast by default 000000000000FFFF
"API" "off" : enable/disable Libelium API with WSPF as mode ID
"PI" "off" : enable/disable print sent data

Jun, 14th, 2013, v0.33
  adds command string prefix to "/0". All existing command should be prefixed such as: "/0Z100"
March, 19th, 2013, v.032
  adds support for unsigned long time, fixes wrap around inter-packet time, adds beacon print for long inter-packet time
March, 1st, 2013, v.031a
  adds support SmartSantander test-bed
  adds support for periodic size increase feature
Jan, 10th, 2013, v.031
  adds reception cad with Digimesh radio module, enable this with USE_UART1, RCV_O0_UART0, RCV_O0_UART0. This 2nd Xbee module
  adds support for Digimesh radio module, enable this with USE_UART1, RCV_O0_UART0, RCV_O0_DIGIMESH
  and GPS support
Dec, 21st, 2012, v0.2
  improves version 0.1 with better timing features and statistics

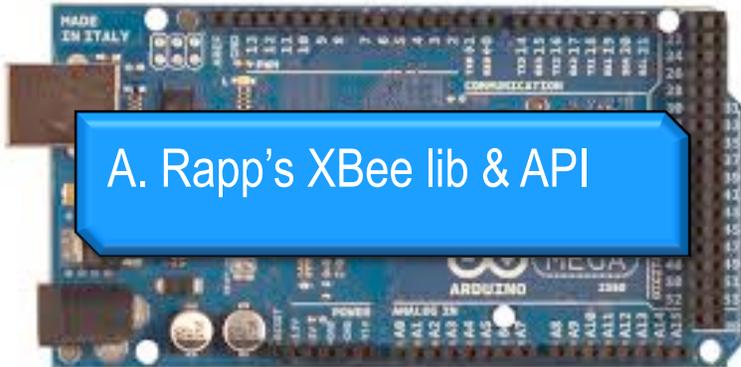
/* TODO
 * basic LCD and GPS support need more debugging

// BEGIN of compilation #define statements
// uses advanced timing of the Libelium send API. CAUTION: need modified version of the API
#define SEND_API_TIMING

```

## ARDUINO-BASED IDE

## WITH C++-LIKE LANGUAGE



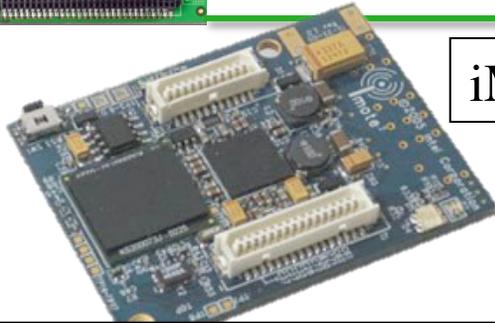
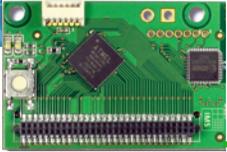
ARDUINO MEGA2560



XBEE 802.15.4



# « ACADEMIC » SENSORS



iMote2

8MHz Atmega128L  
4kB SRAM, 128kB Flash  
CC2420 radio



Radio module  
CC2420 is

13-416MHz PXA271 Xscale  
Wireless MMX DSP  
256kB SRAM, 32MB  
32MB SDRAM  
CC2420 radio

Motes are programmed under the  
TinyOS operating (NesC, component-  
based C-like language) system & lib or  
Contiki (C language)



Advanticsys CM5000 & CM3000  
TelosB-like mote

hundredth kbps



iMote2 with IMB400  
multimedia board

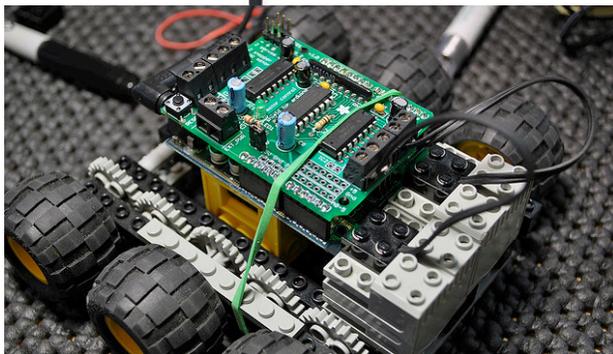
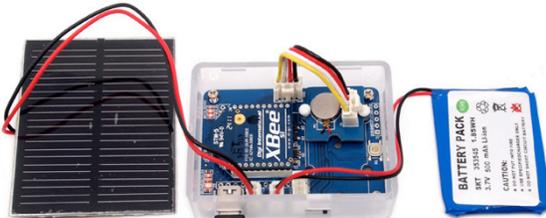
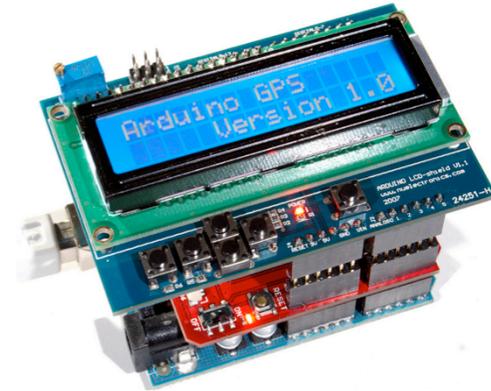


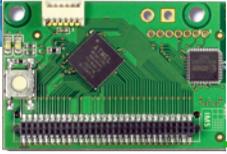
TelosB

8Mhz MSP430F1611  
10K SRAM, 48K flash  
CC2420 radio

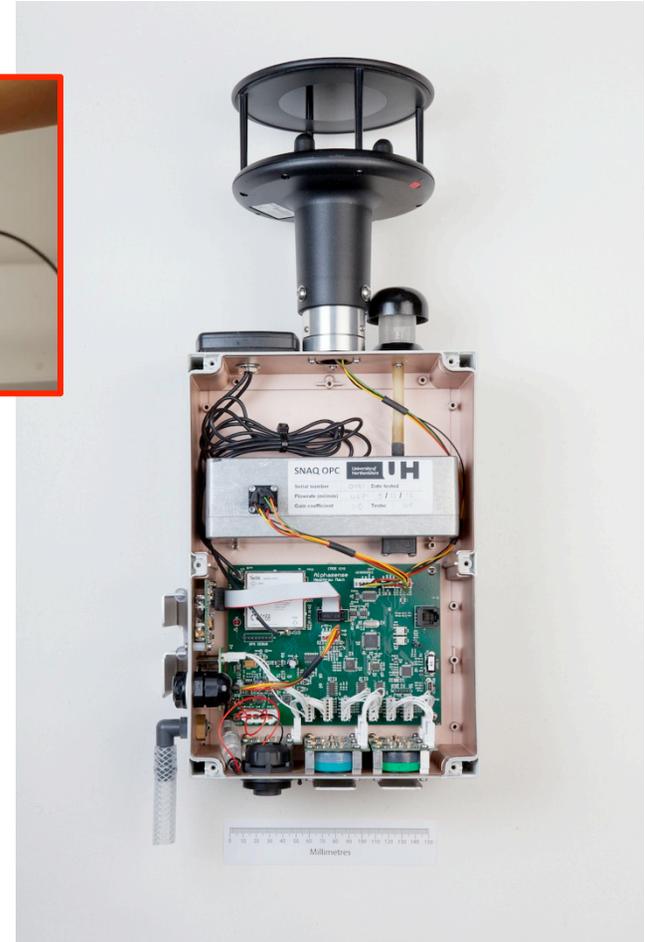


# FROM CUSTOM DEVELOPMENTS...





# ...TO COMMERCIAL PRODUCTS





# DEPLOYMENT IN PRACTICE

## Libelium Smart World

### Air Pollution

Control of CO<sub>2</sub>, emissions of factories, pollution emitted by cars and toxic gases generated in farms.

### Forest Fire Detection

Monitoring of combustion gases and preemptive fire conditions to define alert zones.

### Wine Quality Enhancing

Monitoring soil moisture and trunk diameter in vineyards to control the amount of sugar in grapes and grapevine health.

### Offspring Care

Control of growing conditions of the offspring in animal farms to ensure its survival and health.

### Sportsmen Care

Vital signs monitoring in high performance centers and fields.

### Structural Health

Monitoring of vibrations and material conditions in buildings, bridges and historical monuments.

### Quality of Shipment Conditions

Monitoring of vibrations, strokes, container openings or cold chain maintenance for insurance purposes.

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

### Smart Roads

Warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams.

### Smart Lighting

Intelligent and weather adaptive lighting in street lights.

### Intelligent Shopping

Getting advices in the point of sale according to customer habits, preferences, presence of allergic components for them or expiring dates.

### Noise Urban Maps

Sound monitoring in bar areas and centric zones in real time.

### Water Leakages

Detection of liquid presence outside tanks and pressure variations along pipes.

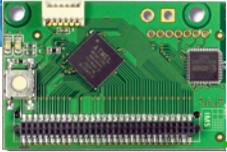
### Vehicle Auto-diagnosis

Information collection from CanBus to send real time alarms to emergencies or provide advice to drivers.

### Item Location

Search of individual items in big surfaces like warehouses or harbours.

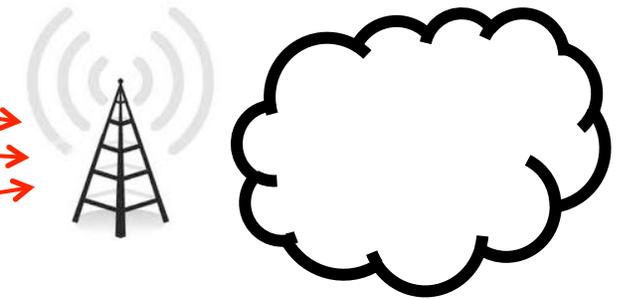
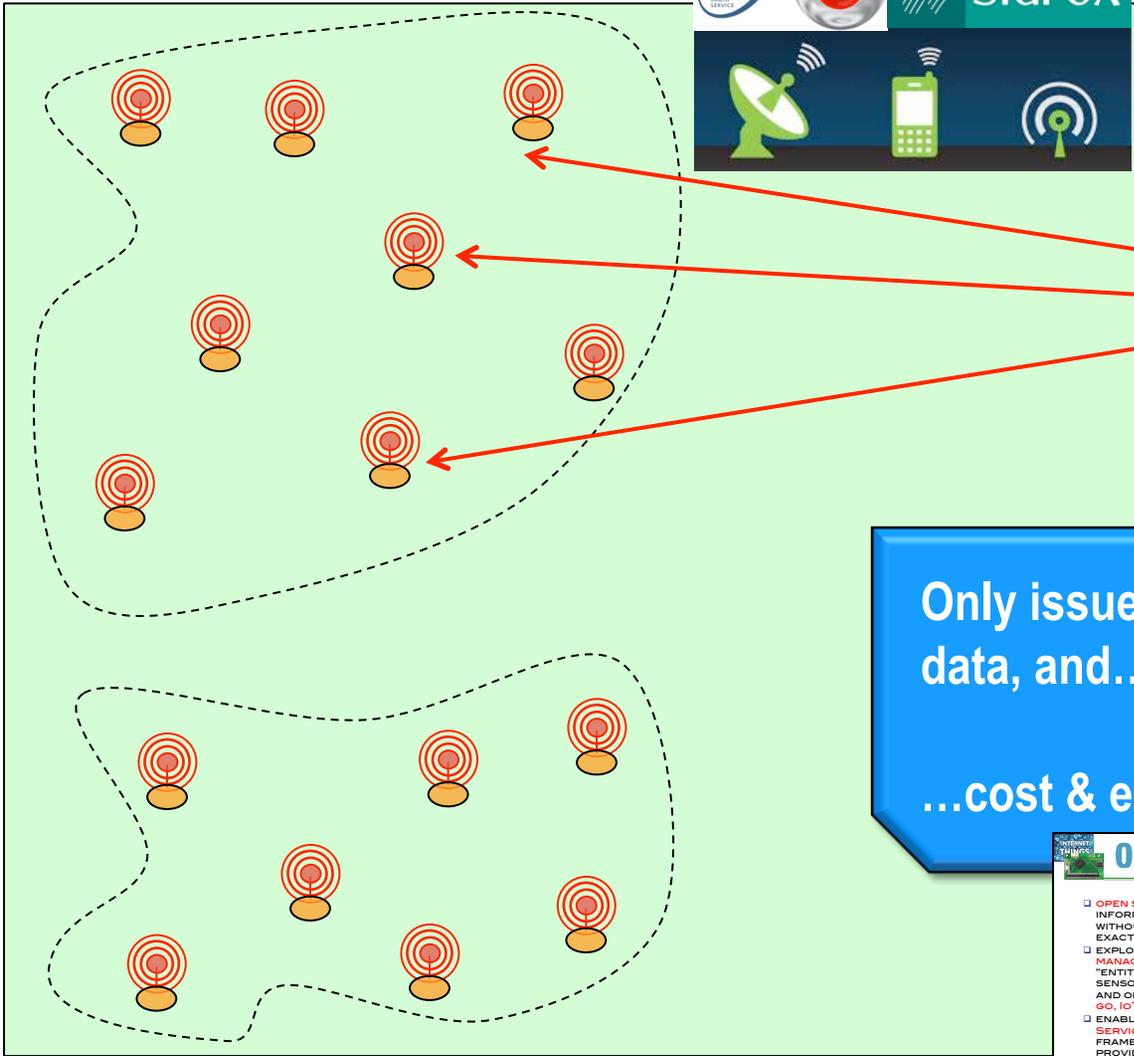




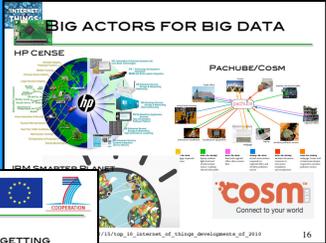
# 1-HOP COMMUNICATION (CELLULAR MODEL)



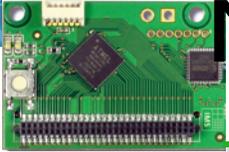
Most of telemetry systems



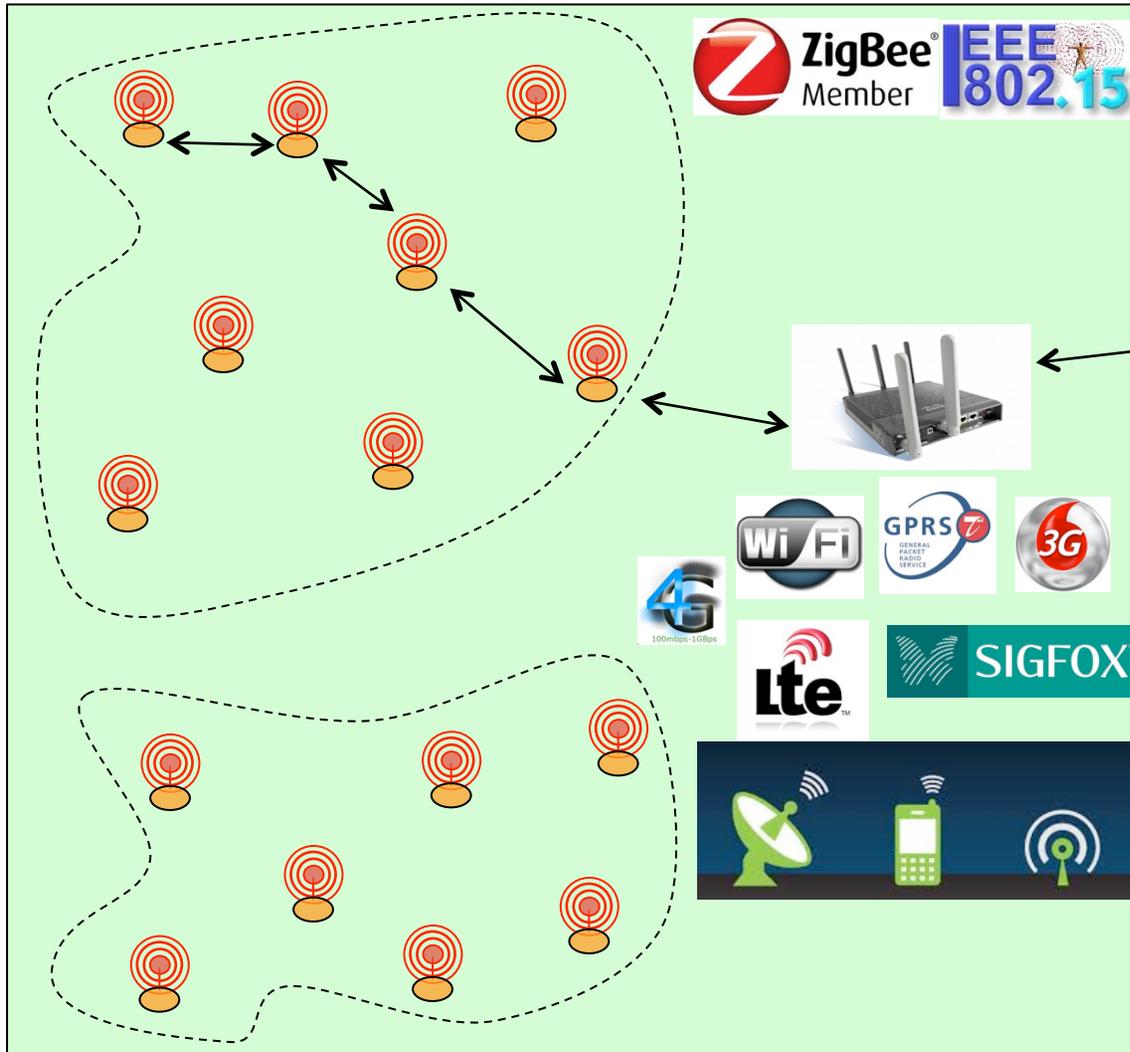
Only issue is to process data, and...  
...cost & energy



- OPEN SOURCE MIDDLEWARE FOR GETTING INFORMATION FROM SENSOR CLOUDS, WITHOUT HAVING TO WORRY ABOUT WHAT EXACT SENSORS ARE USED.
- EXPLORES EFFICIENT WAYS TO USE AND MANAGE CLOUD ENVIRONMENTS FOR IOT "ENTITIES" AND RESOURCES (SUCH AS SENSORS, ACTUATORS AND SMART DEVICES) AND OFFERING UTILITY-BASED, PAY-AS-YOU-GO, IOT SERVICES.
- ENABLES THE CONCEPT OF "SENSING-AS-A-SERVICE", VIA AN ADAPTIVE MIDDLEWARE FRAMEWORK FOR DEPLOYING AND PROVIDING SERVICES IN CLOUD ENVIRONMENTS



# MULTI-HOP TO GATEWAYS



MAC & Routing issues, well-known to WSN community...  
...but can we interoperate?



# FROM AD-HOC TO STANDARDIZED PROTOCOLS





# THE BENEFIT OF IP



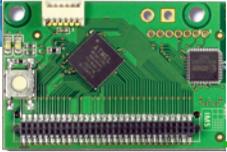
IPv6



## Don't reinvent the wheel!

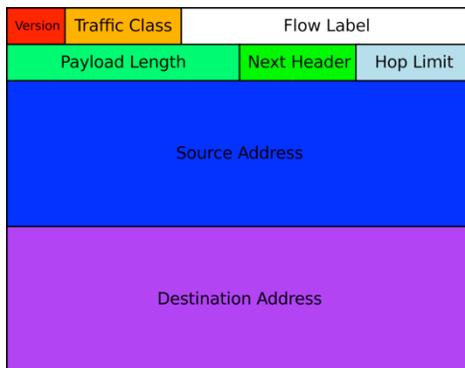
RFC 768	UDP - User Datagram Protocol	[1980]
RFC 791	IPv4 – Internet Protocol	[1981]
RFC 792	ICMPv4 – Internet Control Message Protocol	[1981]
RFC 793	TCP – Transmission Control Protocol	[1981]
RFC 862	Echo Protocol	[1983]
RFC 1101	DNS Encoding of Network Names and Other Types	[1989]
RFC 1191	IPv4 Path 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]
<b>RFC 4944</b>	<b>Transmission of IPv6 Packets over IEEE 802.15.4 Networks</b>	<b>[2007]</b>



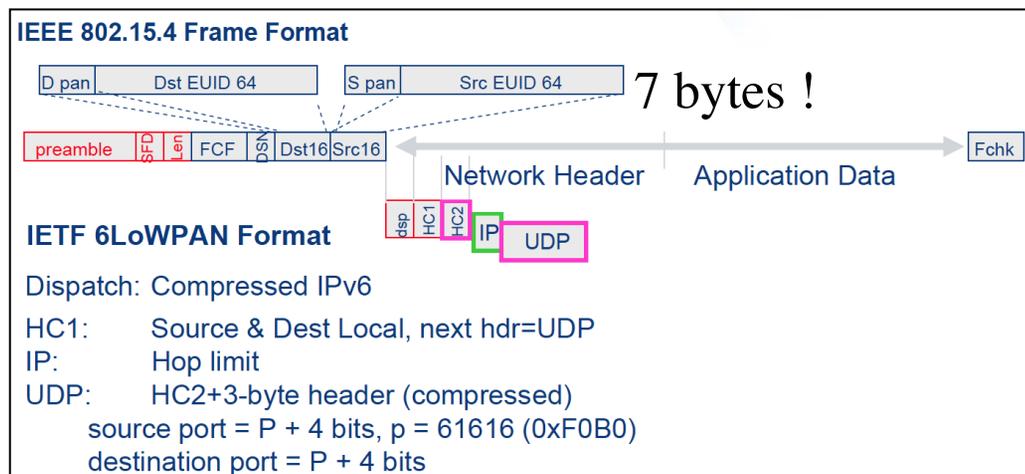


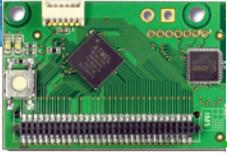
# IP NEED IP ADDRESSES!

- ❑ 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





# INTERNET FOR THINGS

CoAP: Constrained  
Application Protocol

UDP

RPL  
Routing Protocol for Low  
power & Lossy Networks

6LowPan  
802.15.4



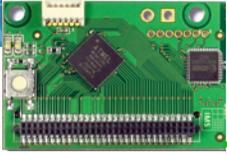
HTTP

TCP, UDP

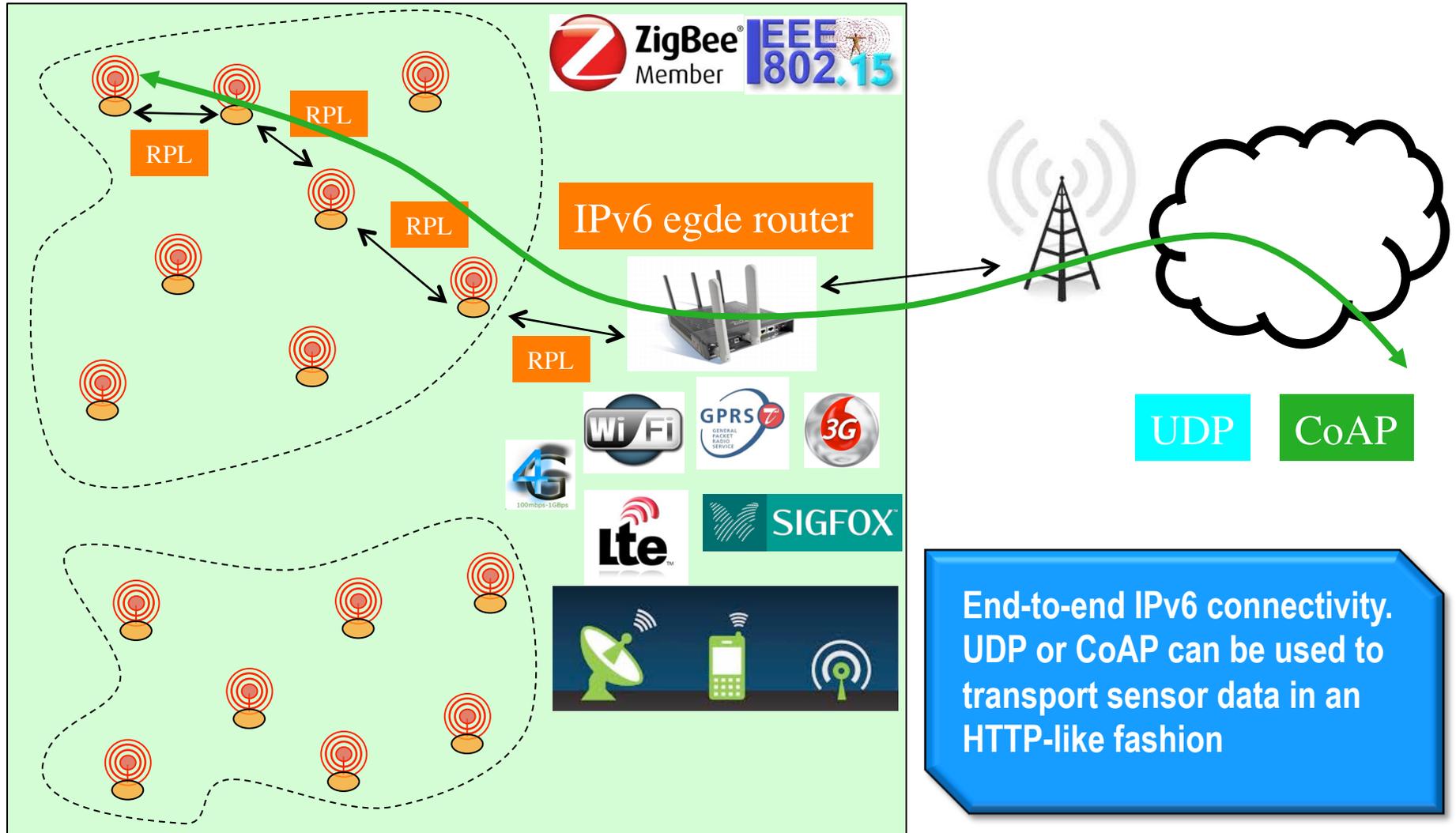
Internet Routing  
Protocols: RIP, OSPF,  
BGP,...

IPv4, IPv6





# USING IP PROTOCOLS



# DIGITAL WIRELESS WORLD

