Internet of Things (IoT)

Softwarized & Wireless Networks Research Group

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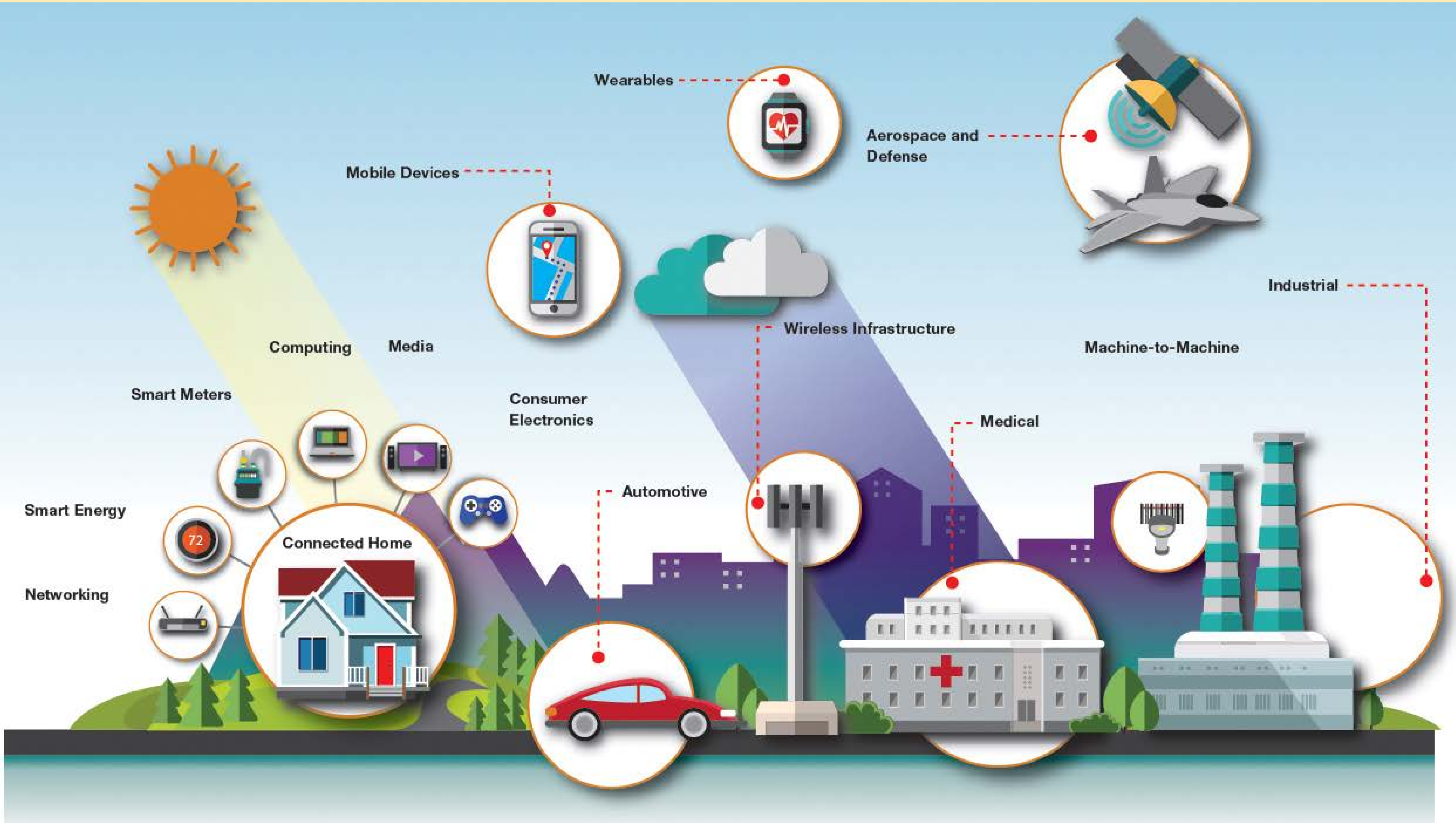
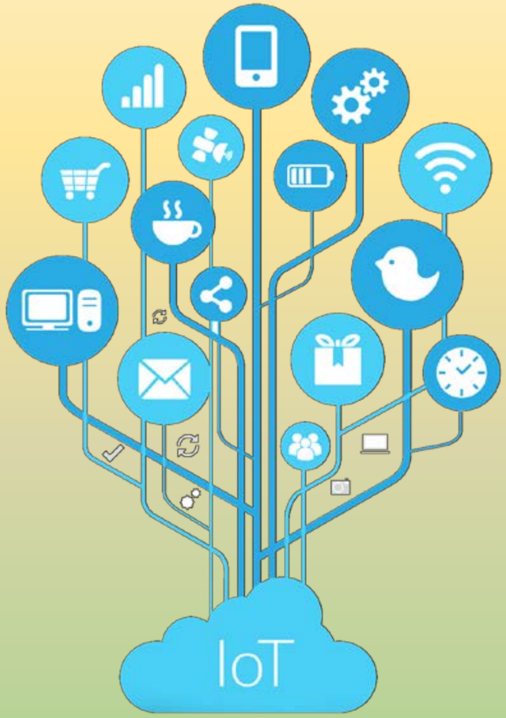


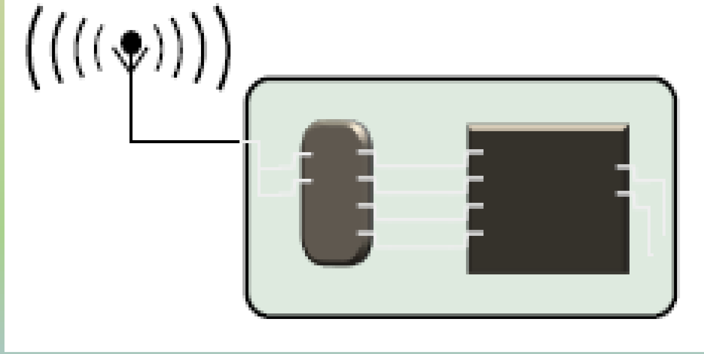
Contents

- **Internet of Things:** Trends, Benefits and Applications
- **IoT Software and Hardware** (Operating Systems, Sensors, Actuators and IoT Devices)
- **Hands-on Exercise (no1) in IoT:**
  - participants connect to our emulab IoT testbed, and
  - experiment with Contiki OS and Zolertia RE-Mote IoT devices



Wireless Sensor Networks

- A Wireless Sensor Network (WSN) is a self-configuring network of small sensor nodes communicating among themselves using radio signals, and deployed in quantity, to sense, monitor and understand the physical world
- Wireless Sensor nodes are called motes



Internet of Things

IoT is an infrastructure driving a number of applications enabled by a number of technologies such as:

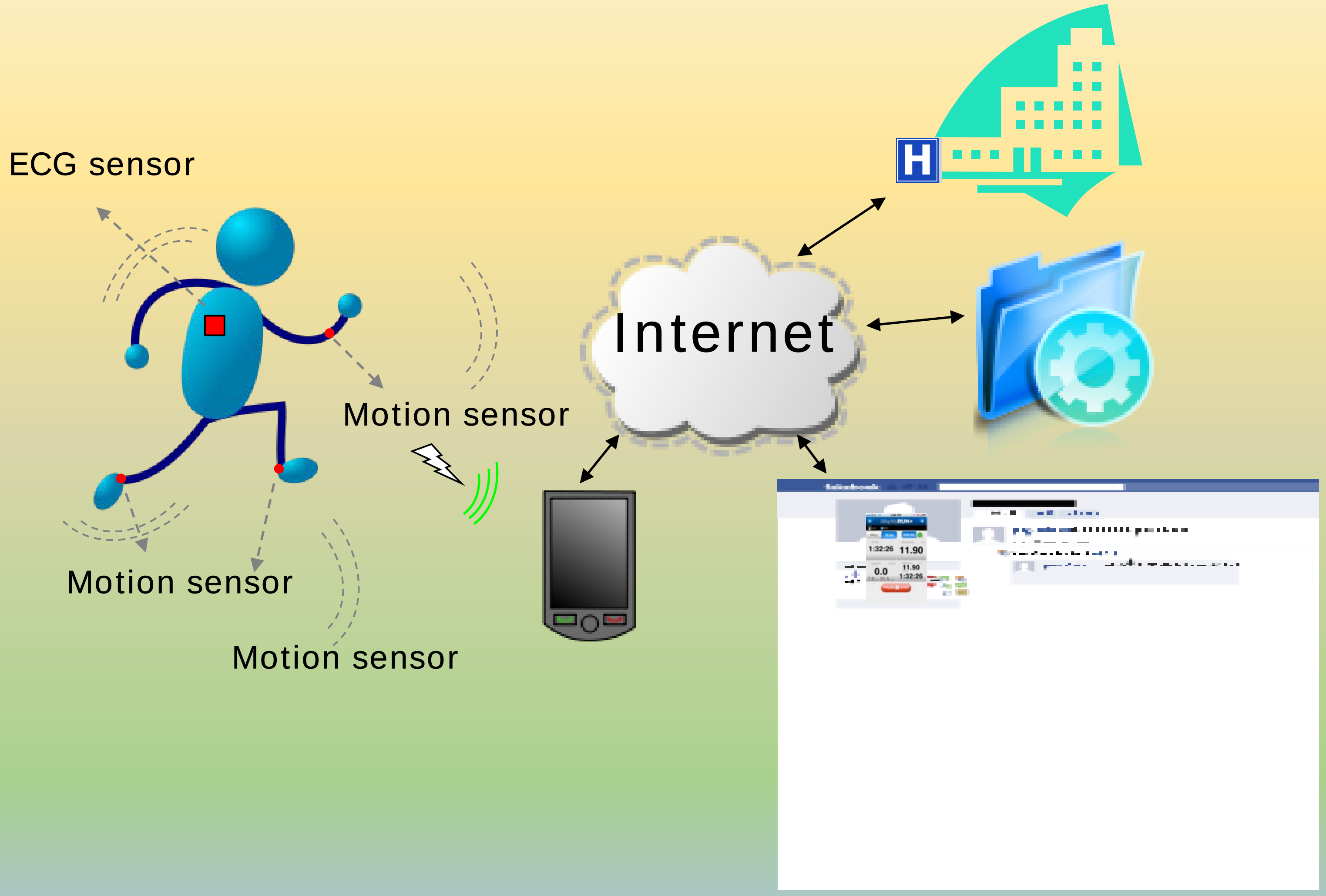
- Sensing
- Nanoeletronics
- wireless sensor network (WSN)
- radio frequency identification (RFID)
- Localization
- storage and cloud

Internet of Things

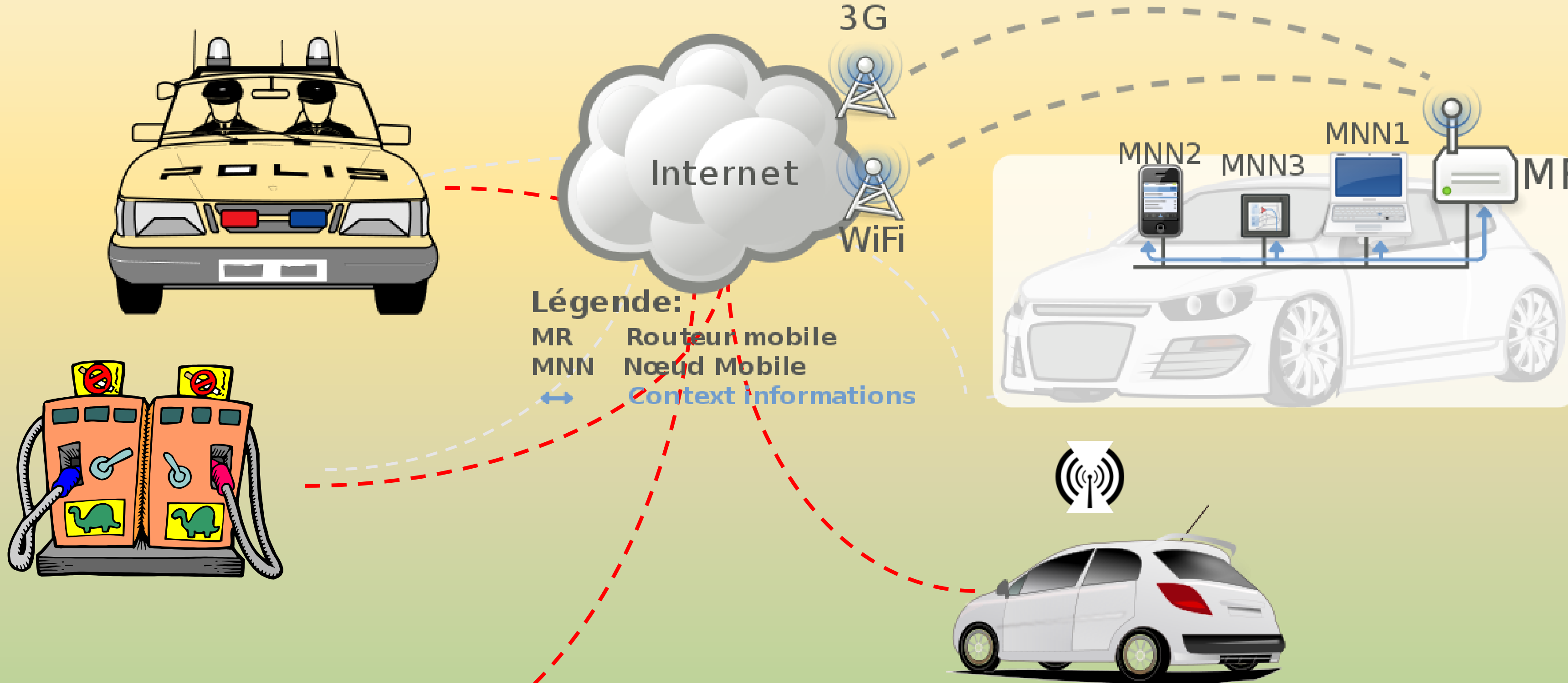
Application services:

- smart cities
- smart transport
- smart buildings
- smart energy
- smart industry
- smart health
- smart ....

People Connecting to Things



Things Connecting to Things



Complex and heterogeneous resources and networks

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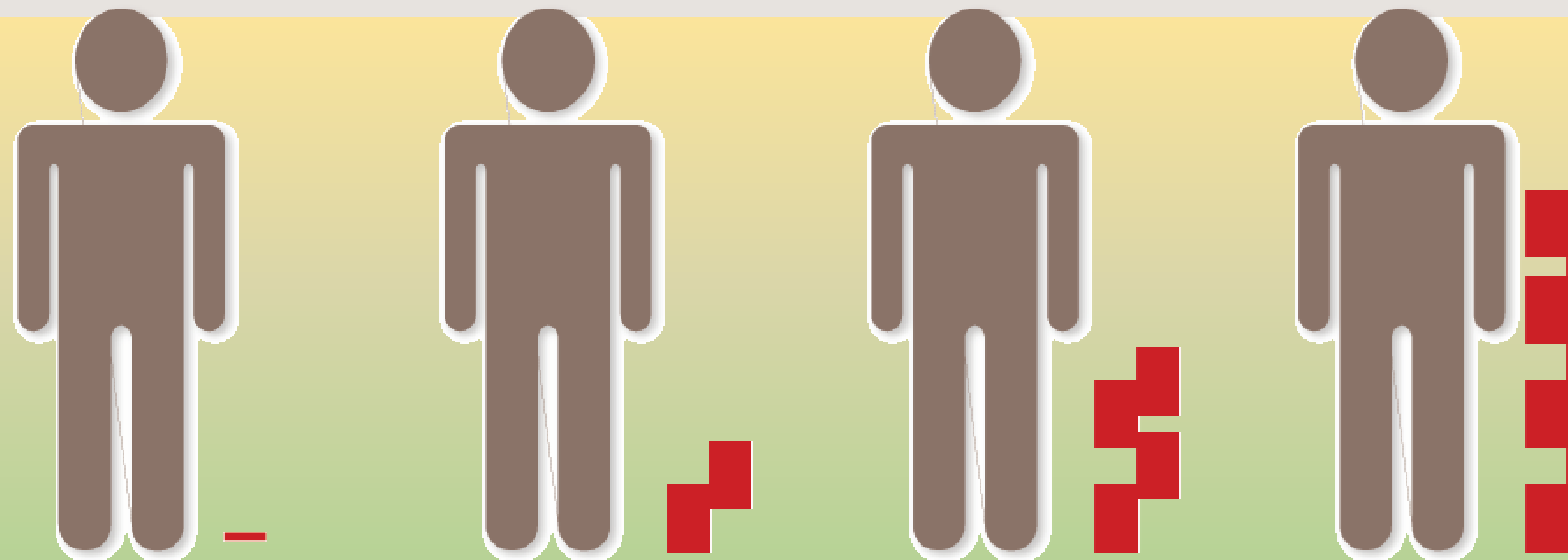
WSN & IoT market penetration

	2003	2010	2015	2020
World Population	6.3 Billion	6.8 Billion	7.2 Billion	7.6 Billion
Connected Devices	500 Million	12.5 Billion	25 Billion	50 Billion
Connected Devices Per Person	0.08	1.84	3.47	6.58



More connected devices than people — 2008

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WSN and IoT

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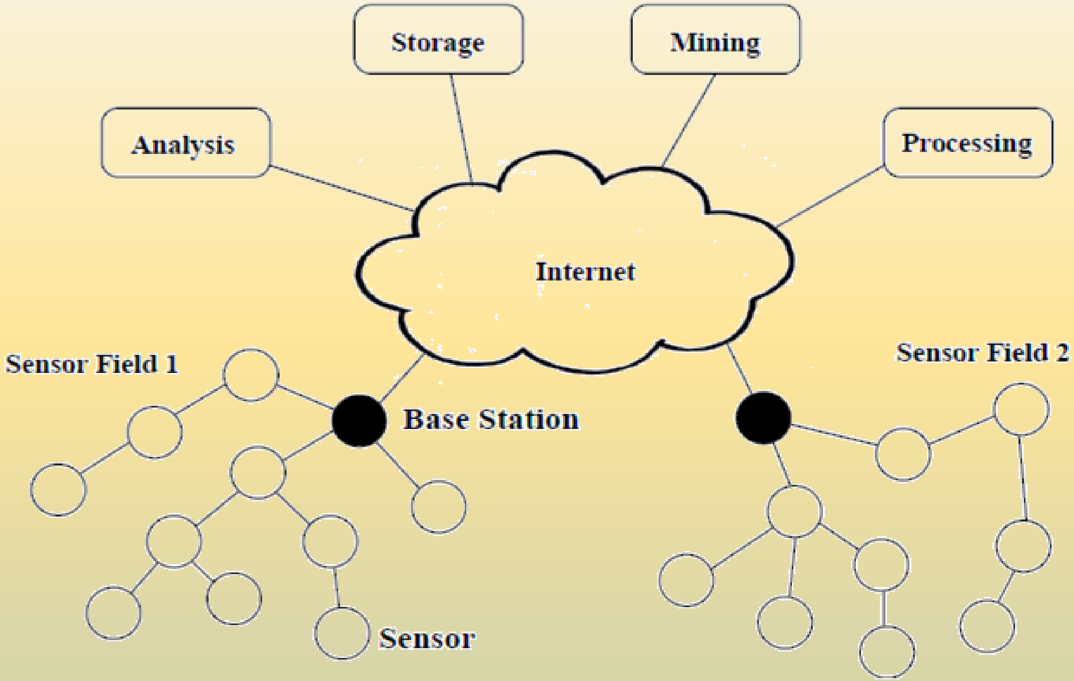
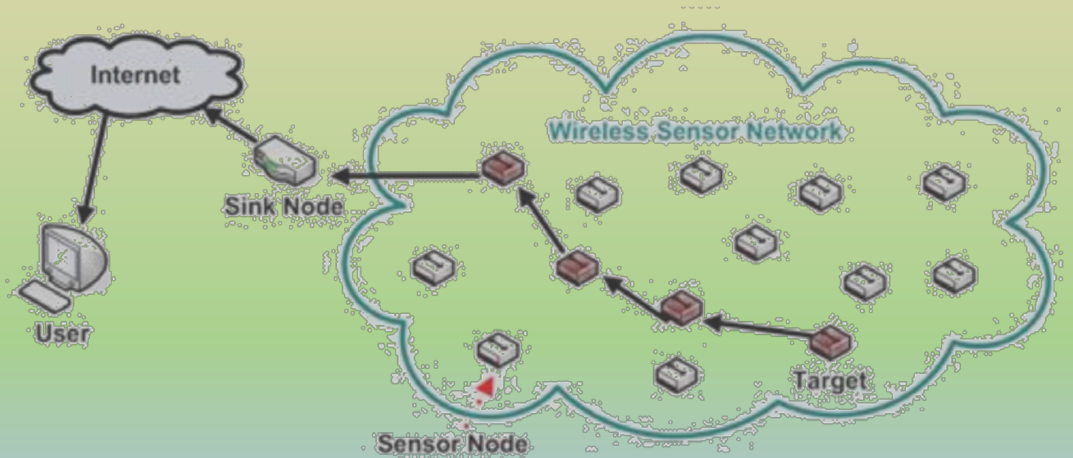
IoT main vision is to create an intelligent world where the physical, the digital and the virtual are converging to create smart environments, *providing more intelligence to the energy, health, transport, cities, industry, buildings,* and many other areas of our daily life.

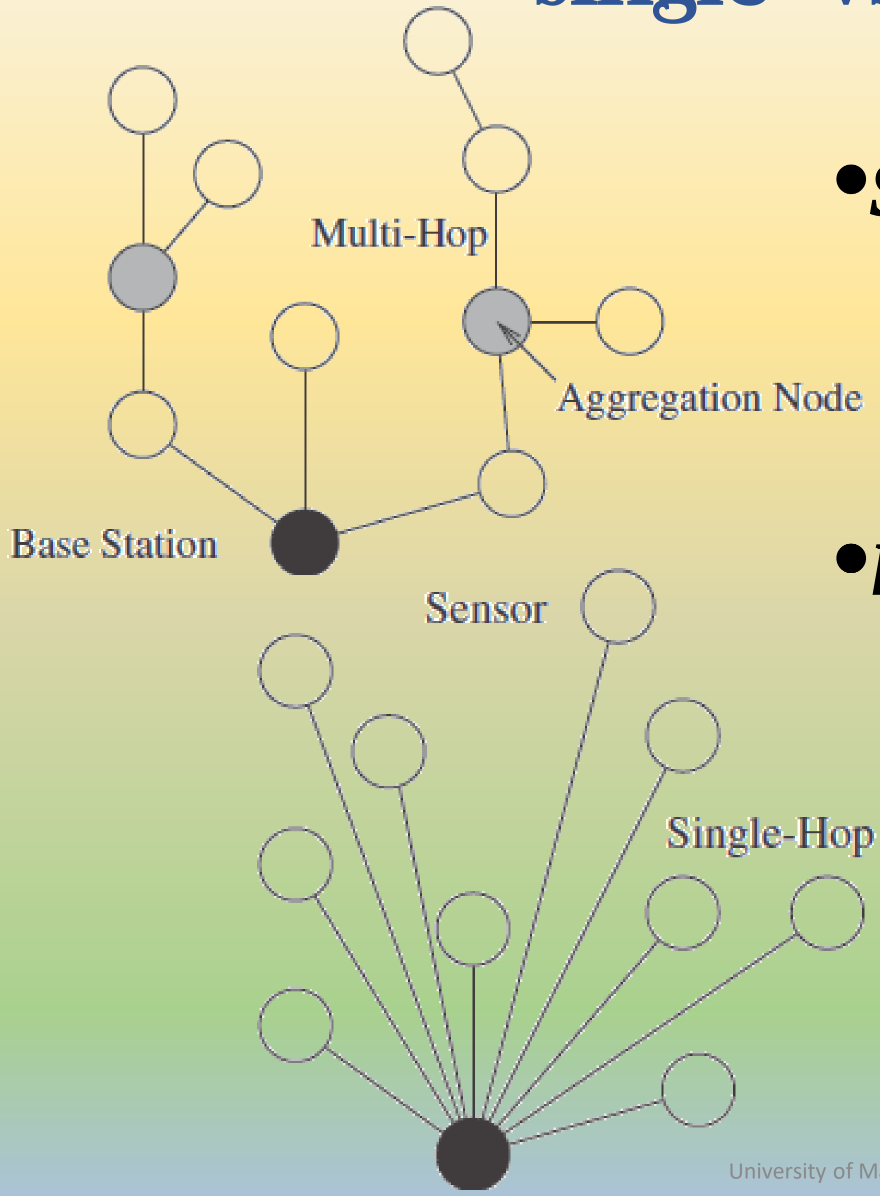
- *WSNs are an early form of ubiquitous information and communication networks.* ***WSNs are one of the building blocks of IoT***
- *WSNs are one* ***component of the IoT*** *that has received significant support from vendors and standardization organizations*

Typical WSNs





WSN
single- vs multi-hop



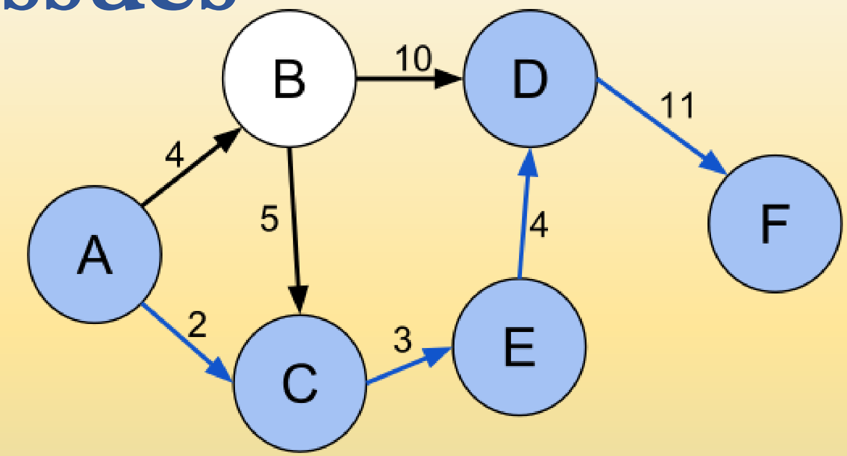
- ***star topology***
  - sensor nodes transmit their data directly to the base station
  - transmission ranges of the radios are large → large transmit power
- ***mesh topology***
  - sensors serve as relays for other sensor nodes
  - cover large geographic areas
  - reduce power consumption
  - introduce the problem of routing

Different points of view

- **Researcher's point of view:** it's a new technology, with a lot of research still to be done

- **Government's point of view:** many applications that can impact society
- **Business point of view:** fast growing market, many opportunities in emerging economies
- **Networking point of view:** sensors are the new members of the Internet

Research Issues

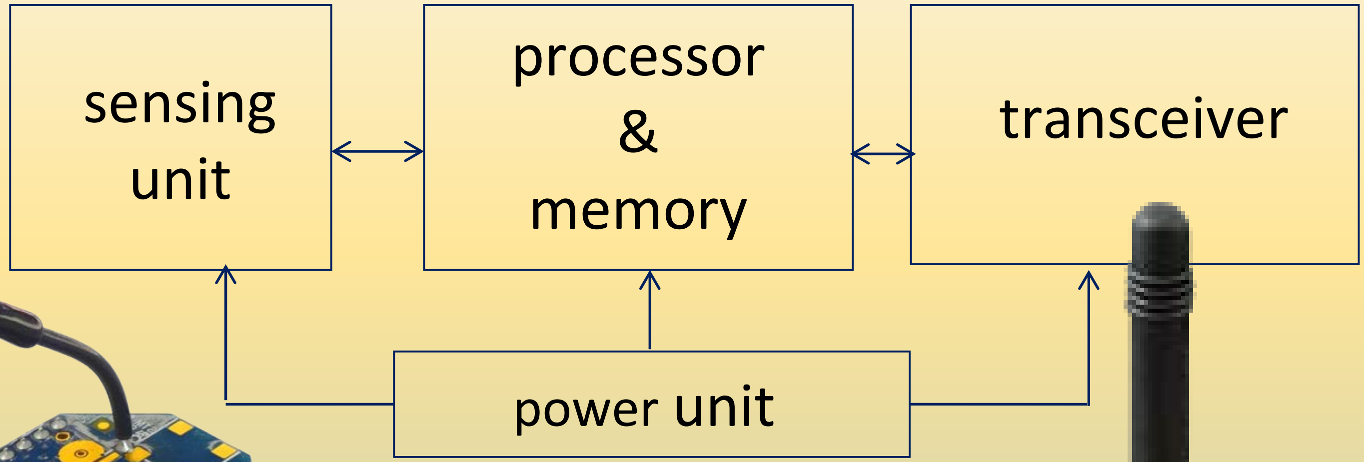


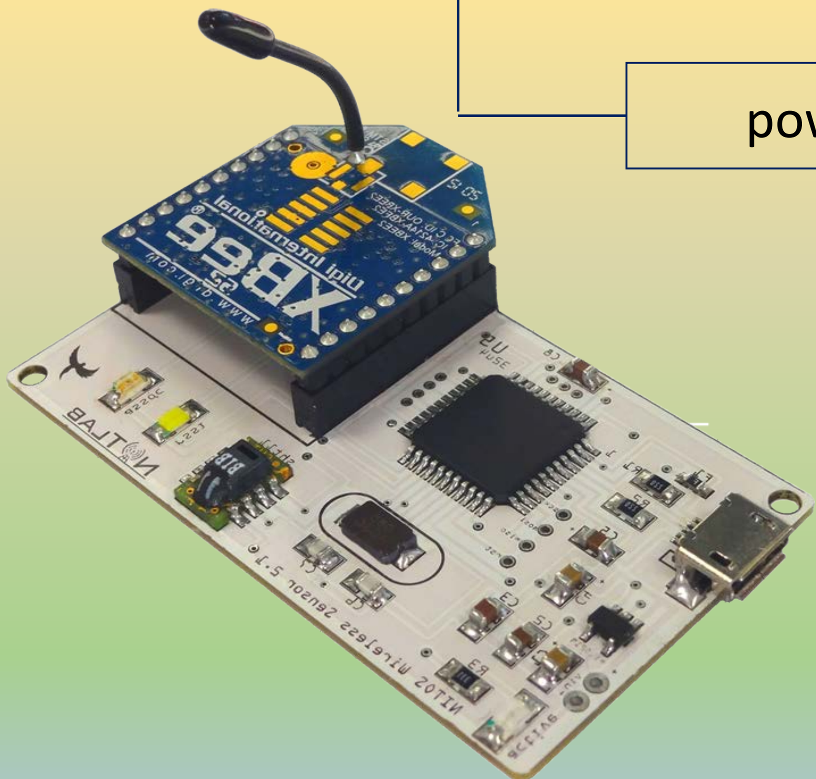
- Shortest path:

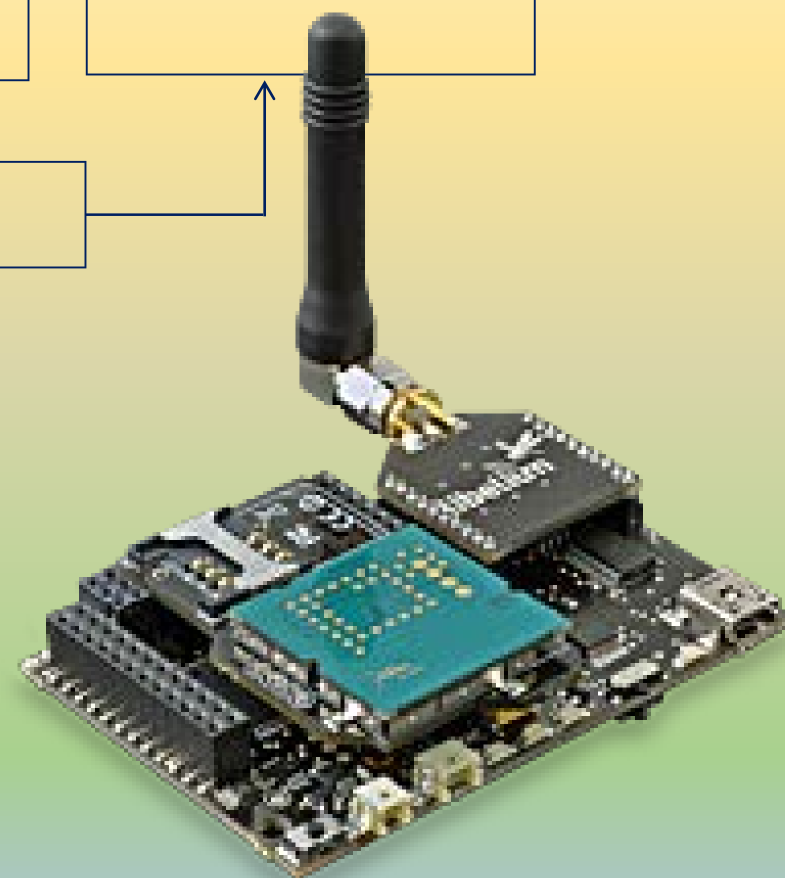
  What is the meaning?

- Motes could:
  - Be energy constrained (battery operated)
  - Provide sensitive information (bridges, medical)
  - Be slowing down due to too much traffic (Routing algorithms)
  - Be distant (far edges)
  - Be mobile (Chaotic behavior, predictions, big disconnection time(s), statistics, opportunistic setups)

Mote Anatomy (1)

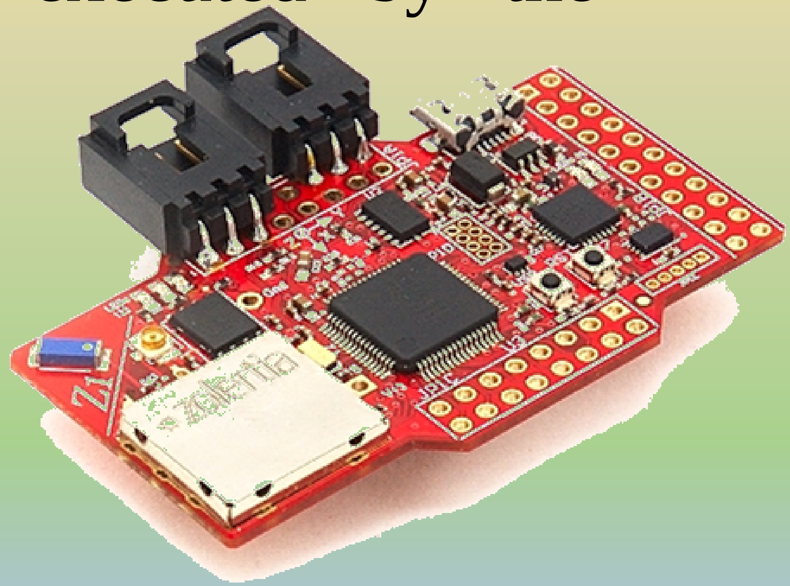






Mote Anatomy (2)

- Radio used for:
  - transmitting the acquired data to storage unit
  - **low-rate (10-100 Kbps), short-range (100 m)** wireless radio
  - the most power-intensive task(s) wake up modes
- Memory used for:
  - program code: instructions executed by the processor
  - buffering: raw or processed sensor measurements
- Sensors for temperature, light, humidity, etc.



Mote Anatomy (3)

- Motes are highly constrained in terms of:
  - physical size
  - CPU power
  - memory (few tens of kilobytes)
  - bandwidth (Max ~ 250 KB/s, lower rates the norm)
- Power consumption is critical
  - batteries might have to last for years
- May operate in harsh environments
  - challenging physical environment (heat, dust, moisture, interference)

Mote Anatomy (4)

- Processor
  - limited in terms of computational power
  - runs in different modes: sleep, idle, active
- Power source
  - little energy storage
  - rechargeable batteries, solar panels
  - networking protocols must emphasize power conservation
  - built-in mechanism to prolonging network life sacrificing metrics, e.g., throughput

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Research Issues

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- **Power:** Software to utilize efficient power consumption (Deep sleep, long periods of inactivity, beacons, etc.)
- **Maximize wireless coverage**
- **Security issues:** efficient cryptography, limited ability for complex/demanding algorithms
- **Security vs power:** fake motes drain power, claim to be the shortest path, jamming

Deployment options

- Dropped from aircraft: *Random deployment*
  - many sensor nodes may not survive
  - nodes autonomously setup & configure, establish communication with neighbors, determine position, start sensing
- Well planned, fixed: *Regular deployment*
  - e.g., in preventive maintenance or similar
  - not necessarily geometric structure: often a convenient assumption
- *Mobile sensor nodes*
  - move to compensate for deployment shortcomings
  - passively moved around by some external force (wind, water)
  - actively seek out “interesting” areas

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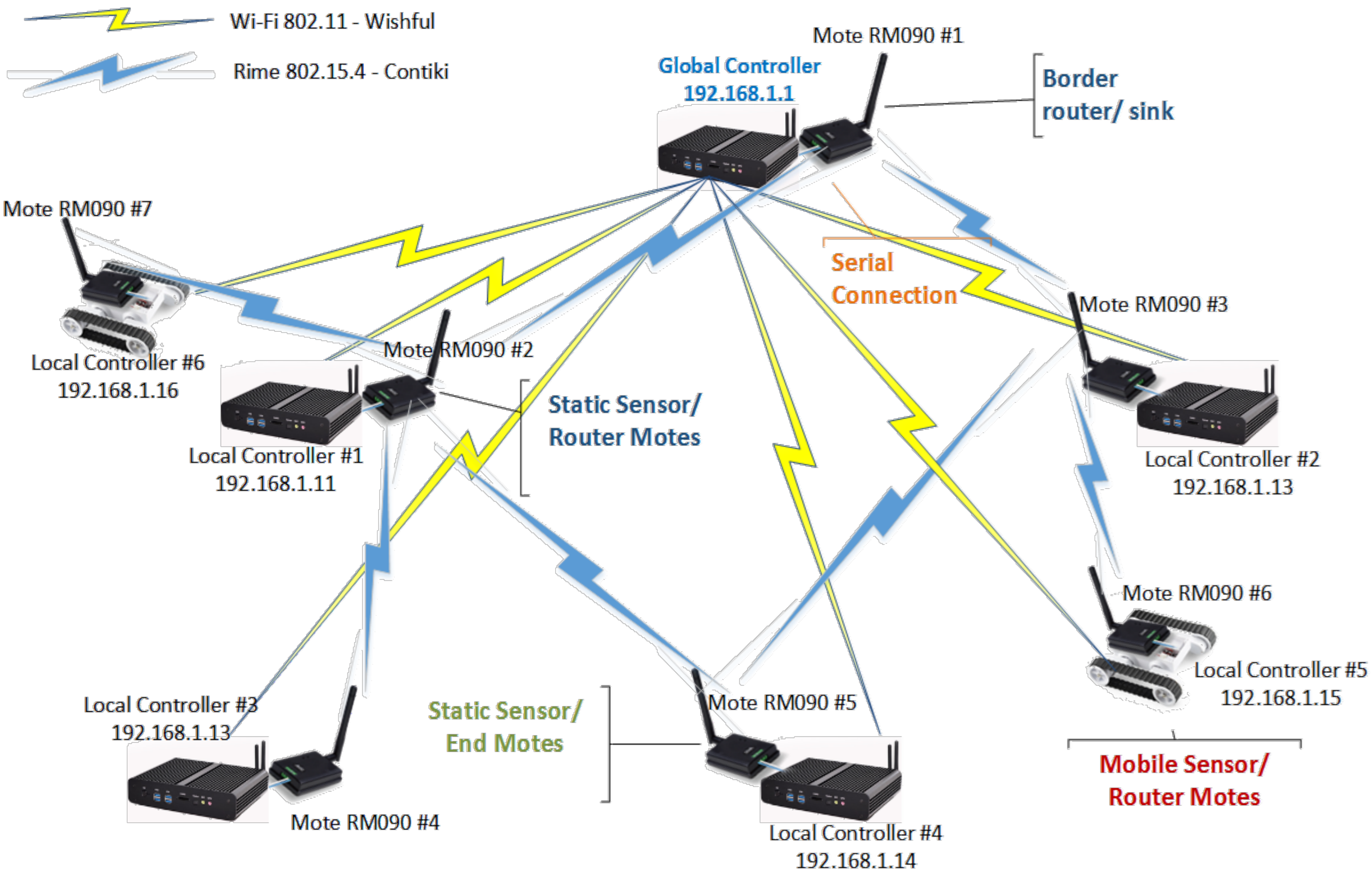
Mobility and heterogeneity

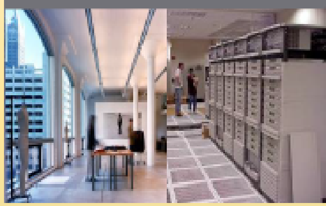


Research Issues

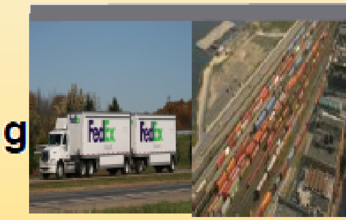
- Scalability (1,000s of motes)
- Self diagnostics, self recovery
- Abstraction in communication (hardware independency)
- Topology changes
- Data collection (e.g., from drones)
- Metrics (path, distance, criticality, etc.)
  - Neighbor discovery (top-down, down-top, proximity)
- Area Coverage

A world of sensors

Predictive Maintenance



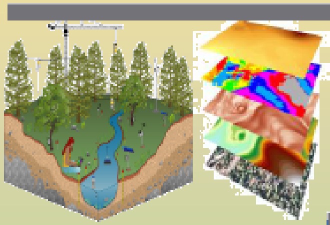
Energy Saving Smart Grid



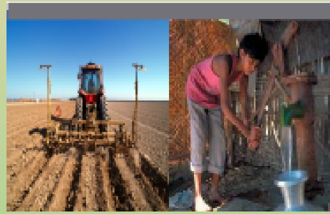
High-Confidence Transport and Asset Tracking

Intelligent Buildings

Improve Productivity



Enable New Knowledge



Improve Food and H_2O

Enhanced Safety & Security

Healthcare

Smart Home

Research Issues

- **Integration with cloud technologies** to support emerging paradigms:
  - Mobile Edge / Cloud & Fog Computing
- **Softwarized protocol stacks** adapting to different requirements, e.g.:
  - mobility, hardware-constraints, software requirements, integration with AI, etc.
- **Network slicing** for IoTs
- **SDN Data Flow Control** over heterogeneous fixed / wireless networks

Our research group investigates such aspects in the context of the MEC, CORAL & NECOS H2020 projects

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60 YEARS 1957-2017

Softwarized IoTs

- Our communication protocols:
  - RPL-SDN
  - CORAL-SDN
  - Backpressure Routing for Softwarized IoTs

- Which protocol to choose each time?
- Can fixed protocols and configurations support unified IoT environments?
- What is different in Softwarized IoTs?

Let's understand the basic protocols first

IEEE Wireless Standards

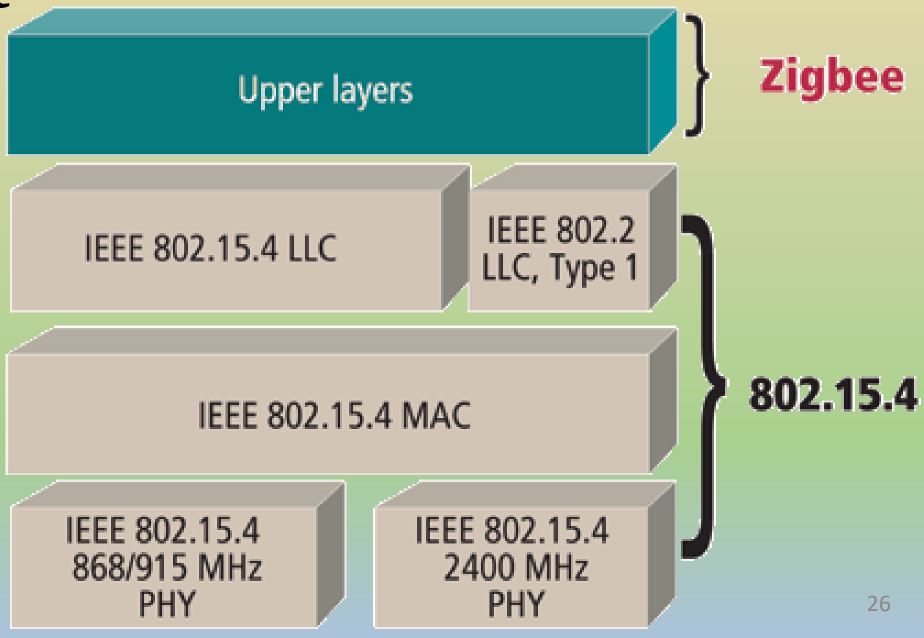
- IEEE 802.11 family of standards
  - most widely used WLAN protocols for wireless communications in general
  - found in early sensor networks or sensors networks without stringent energy constraints (multimedia sensors)
- IEEE 802.15.4: protocol designed specifically for short-range communications in WSNs
  - low data rates
  - low power consumption
  - widely used in academic and commercial WSN solutions

WSN: 802.15.4

This standard defines the physical layer (PHY) and media access control (MAC) layer of the Open Systems Interconnection (OSI) model

- PHY defines frequency, power, modulation, and other wireless conditions of the link
- MAC defines the format of the data handling

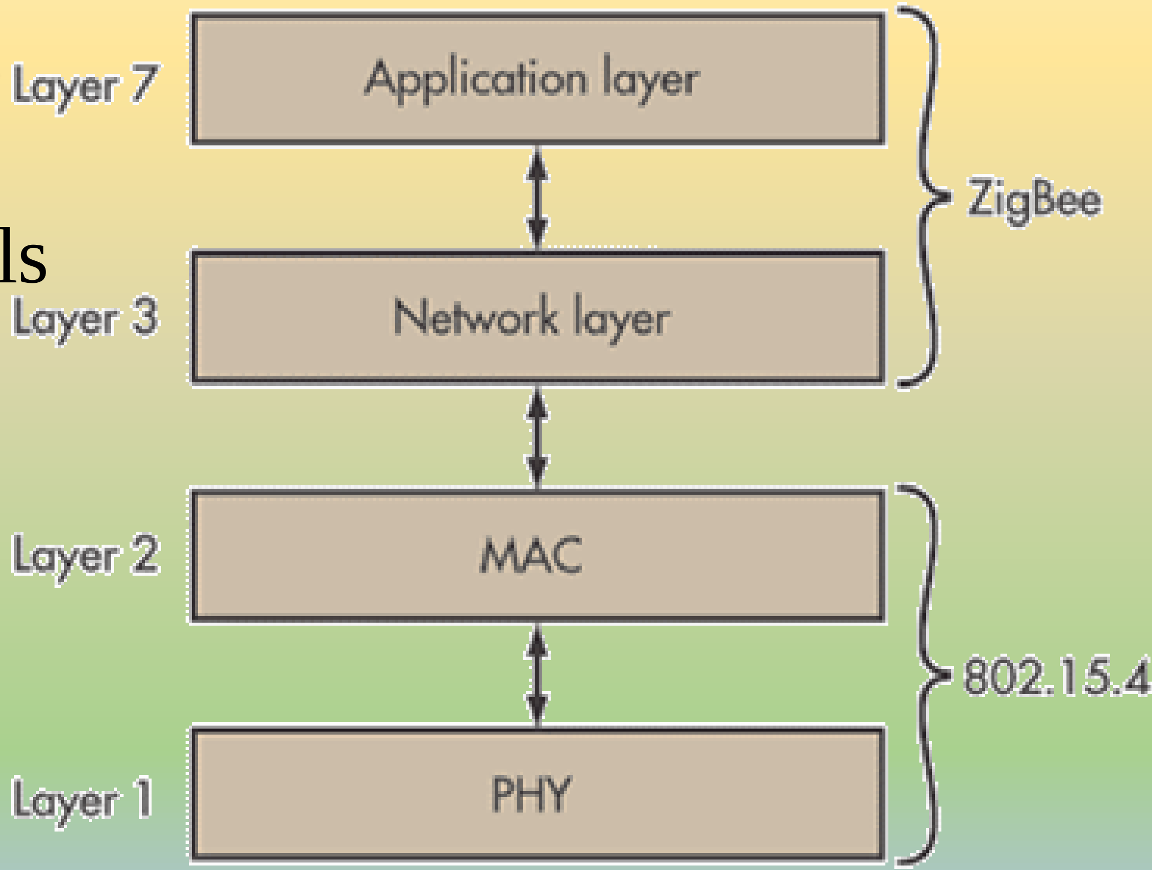
802.15.4 architecture



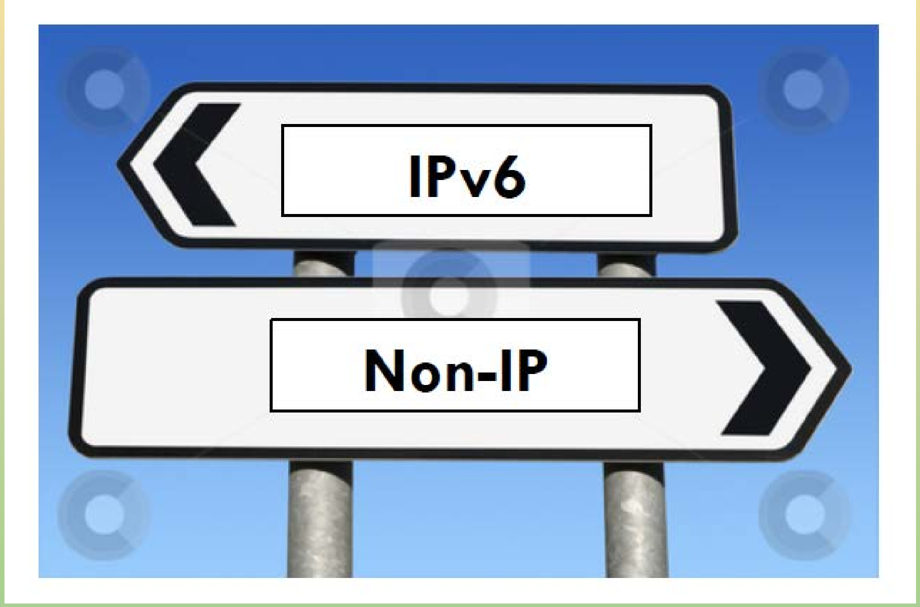
WSN communication

Two main wireless standards used by WSN are Zigbee and 802.15.4

- low-power protocols
- performance is an issue
- max distance is around 100m (at 2.4Ghz)



Sensor Families



IoT only works with IPv6

IoT Operating Systems short history

- 1999 – TinyOS (Berkeley)
- 2003 – Contiki (Dunkels)
- 2013 – RIOT
- 2016 – Ubuntu Core 16
- 2016 – Android Things (Google)

Open source IoT Operating Systems

- TinyOS
- RIOT
- Contiki
- Mantis OS
- Nano RK
- LiteOS
- FreeRTOS
- Apache Mynewt
- Zephyr OS
- Ubuntu Core 16 (Snappy)
- ARM mbed
- Android Things
- Yocto
- Raspbian

Commercial IoT Operating Systems

- Windows 10 IoT
- WindRiver VxWorks
- Micrium µC/OS
- Micro Digital SMX RTOS
- MicroEJ OS
- Express Logic ThreadX
- TI RTOS
- Freescale MQX
- Mentor Graphics Nucleus RTOS
- Green Hills Integrity

IoT OS characteristics

- **Footprint** (low memory, power and processing requirements. OS overhead minimal)
- **Scalability** (any type of device)
- **Portability** (applications – hardware isolation)
- **Modularity** (kernel + add-ons)
- **Connectivity** (different connectivity protocols)
- **Security** (add-ons that bring security to the device)
- **Reliability** (mission-critical systems)

Contiki OS

- Contiki is an open source operating system for the IoT
- Connects tiny low-cost, low-power microcontrollers to the Internet
- Is a powerful toolbox for building complex wireless systems
- Initially developed by Adam Dunkels at the Swedish Institute of Computer Science
- Licensed under a BSD style license
- Support of IP protocols (one of the first embedded operating systems to **provide IPv6 support**)

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Contiki OS in detail

http://www.contiki-os.org/

http://www.contiki-os.org/hardware.html

https://github.com/contiki-os/contiki

http://www.contiki-os.org/start.html

IoT Tutorial Hardware Zolertia RE-Mote

- Texas Instruments CC2538 ARM Cortex-M3 system on chip (SoC)
- 2.4 GHz IEEE 802.15.4 RF on-board interface
- 32 MHz speed
- 512 KB flash
- 32 KB of RAM
- Texas Instruments CC1200 868/915 MHz RF transceiver
- Dual band operation

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Emulab Platform

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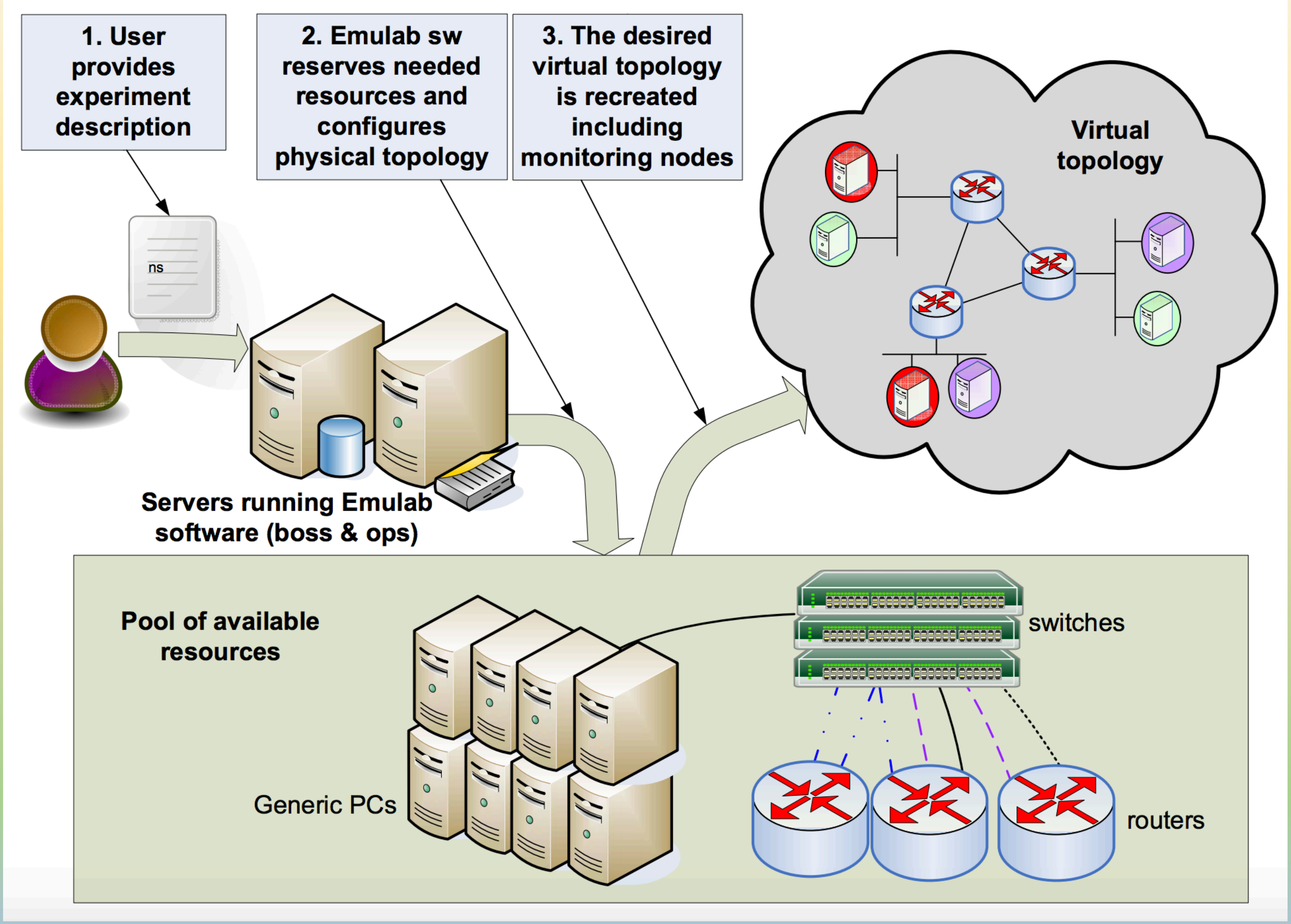
1957-2017



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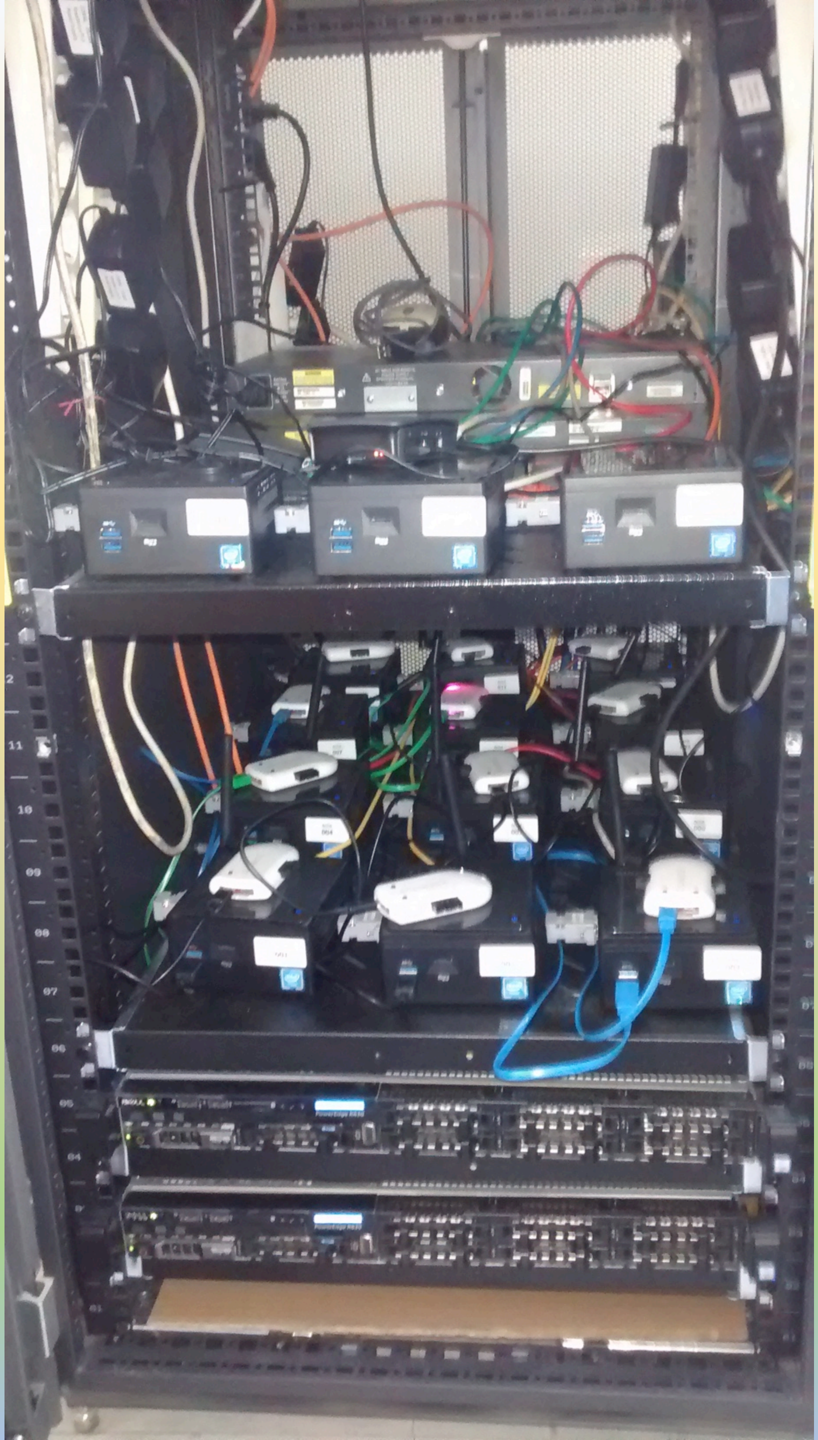
SWN Testbed



Switch

Nodes

Nodes Mini PCs

Zolertia Re-mote Nodes

Emulab Server OPS

Emulab Server BOSS

References

- *Introduction to Wireless Sensor Networks*, Marco Zennaro, ICTP Trieste-Italy
- *Fundamentals of Wireless Sensor Networks*, Waltenegus Dargie, Technical University of Dresden, Germany and Christian Poellabauer, University of Notre Dame, USA
- *Internet of Things in 5 days*, Antonio Liñán Colina, Alvaro Vives, Marco Zennaro, Antoine Bagula and Ermanno Pietrosemoli
- EEEM048- *Internet of Things*, Dr Payam Barnaghi, Dr Chuan H Foh, Institute for Communication Systems, Electronic Engineering Department, University of Surrey

Contiki IoT
Hands-on 1-1

Read Sensor Data from IoT Device