

# INTRODUCTION TO WIRELESS SENSOR NETWORKS

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# Wireless sensor networks

- Alternative concept in MANETs:

Instead of focusing interaction on humans, focus on interacting with **environment**

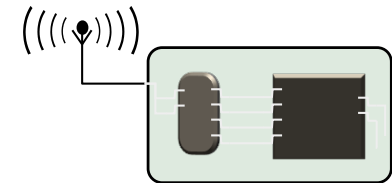
- Network is **embedded** in environment
- Nodes in the network are equipped with **sensing** and **actuation** to measure/influence environment
- Nodes process information and communicate it wirelessly

## **Wireless sensor networks (WSN)**

- Or: **Wireless sensor & actuator networks (WSAN)**

# Wireless sensor networks

- A Wireless Sensor Network 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**.

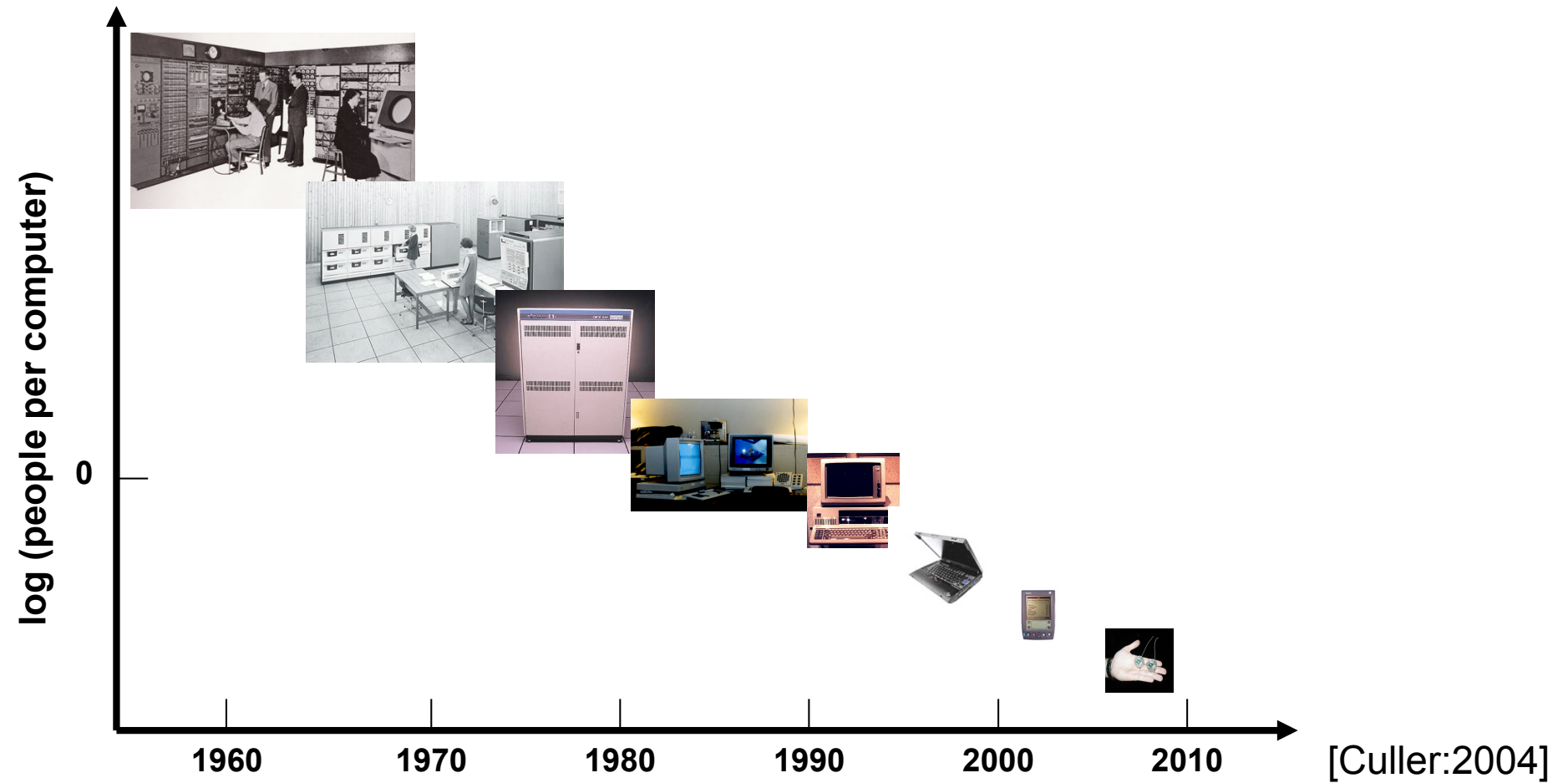


# Wireless sensor networks



- WSN provide a bridge between the real physical and virtual worlds.
- Allow the ability to observe the previously unobservable at a fine resolution over large spatio-temporal scales.
- Have a wide range of potential applications to industry, science, transportation, civil infrastructure, and security.

# Wireless sensor networks



# Wireless sensor networks



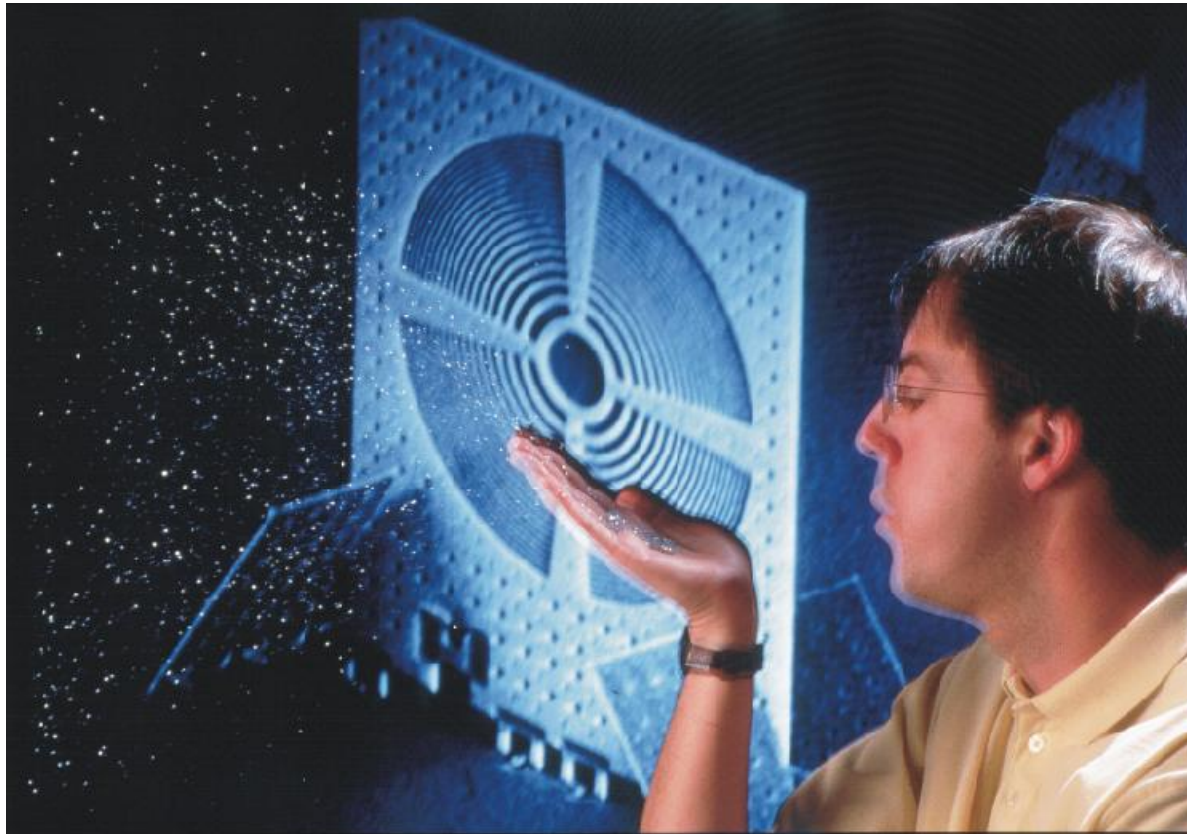
1980s: the PC revolution

1990s: the Internet revolution

2000s: the mobile revolution

2010s: the Internet of Things

# Wireless sensor networks

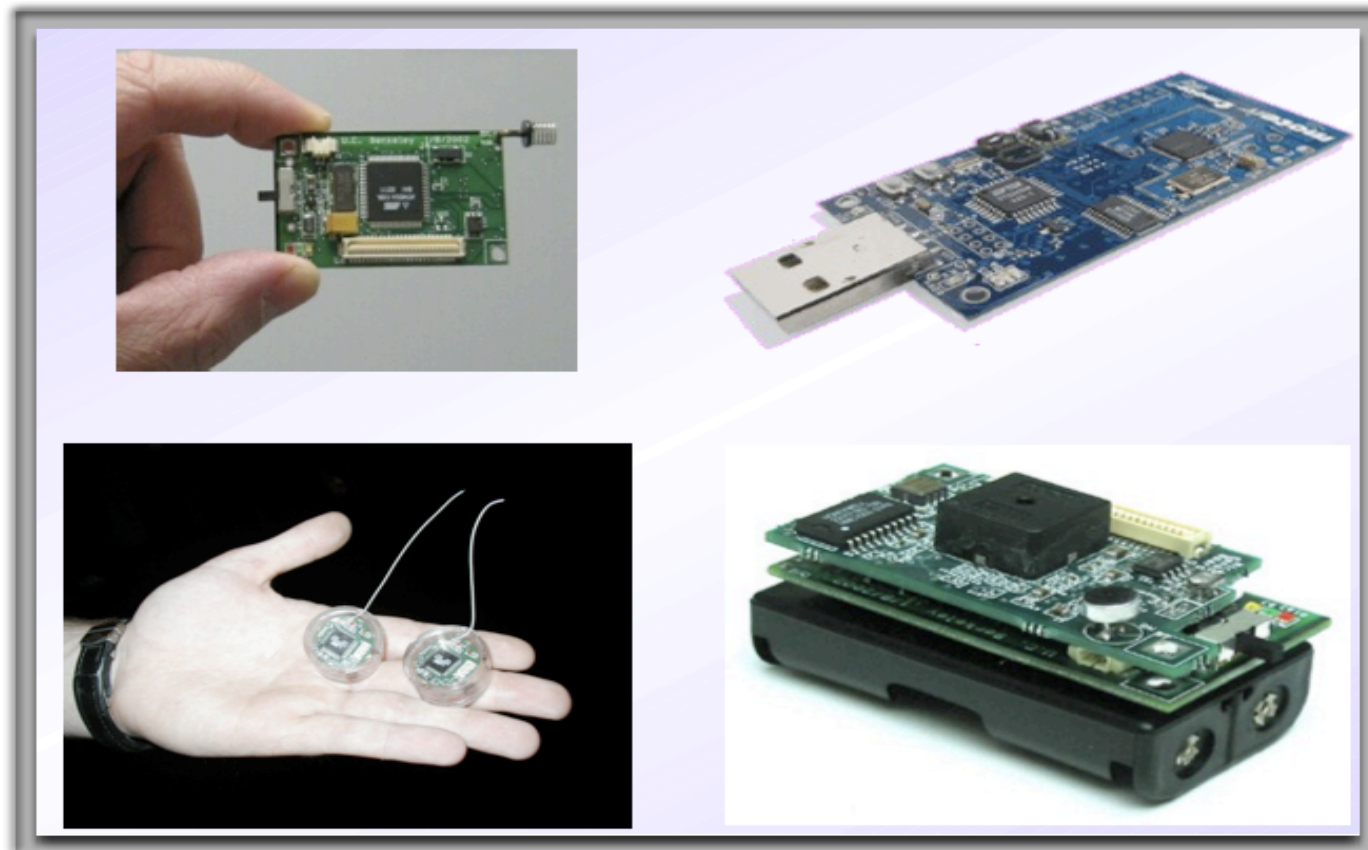


Next Century  
Challenges: Mobile  
Networking for  
“**Smart Dust**”

J. M. Kahn,  
R. H. Katz,  
K. S. J. Pister

(MobiCom 1999)

# Mote Anatomy



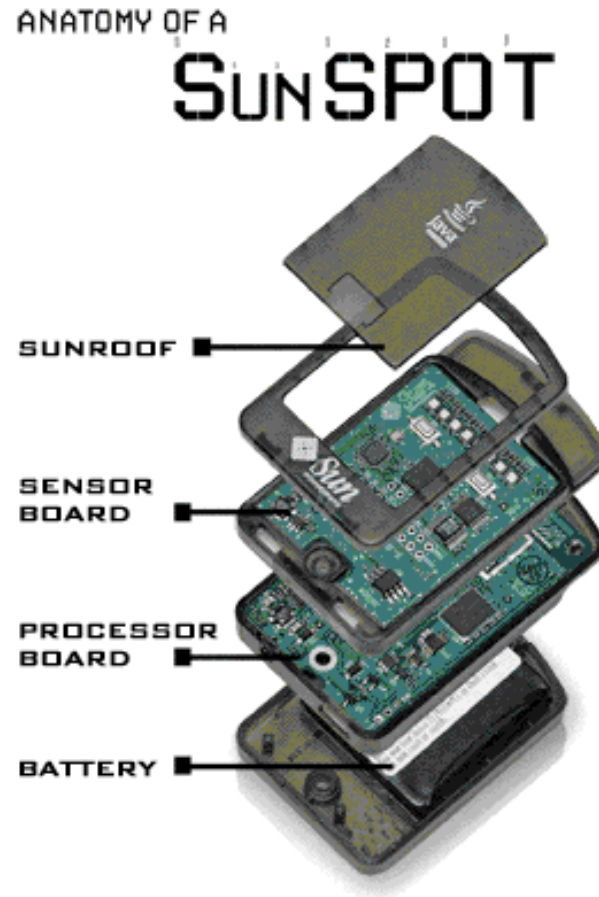


# Mote Anatomy

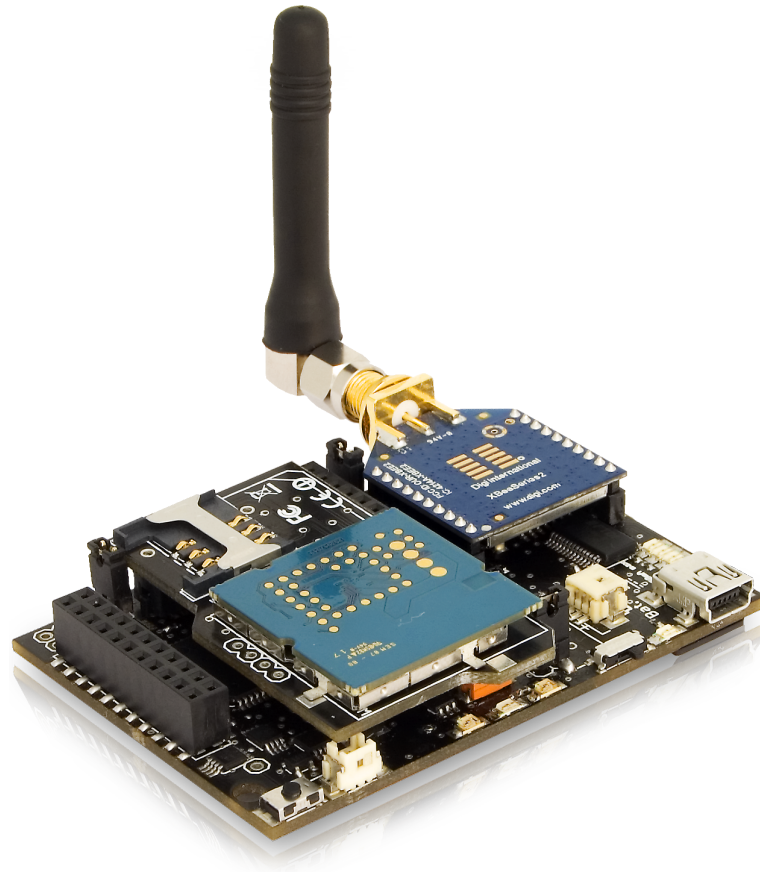


- **Processor** in various modes (sleep, idle, active)
- **Power source** (AA or Coin batteries, Solar Panels)
- **Memory** used for the program code and for in-memory buffering
- **Radio** used for transmitting the acquired data to some storage site
- **Sensors** for temperature, humidity, light, etc

# Mote Anatomy

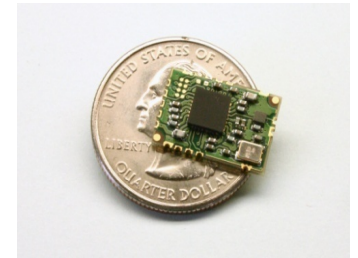


# Mote Anatomy



# Mote Anatomy

- These motes are **highly constrained** in terms of
  - ▣ Physical size
  - ▣ CPU power
  - ▣ Memory (few tens of kilobytes)
  - ▣ Bandwidth (Maximum of 250 KB/s, lower rates the norm)
- Power consumption is critical
  - ▣ If battery powered then energy efficiency is paramount
  - ▣ Batteries might have to last for years
- May operate in harsh environments
  - ▣ Challenging physical environment (heat, dust, moisture, interference)



# A World of Sensors



**Predictive Maintenance**



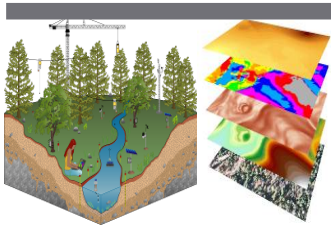
**Energy Saving Smart Grid**



**High-Confidence Transport and Asset Tracking**



**Improve Productivity**



**Enable New Knowledge**



**Intelligent Buildings**



**Enhanced Safety & Security**



**Improve Food and H<sub>2</sub>O**



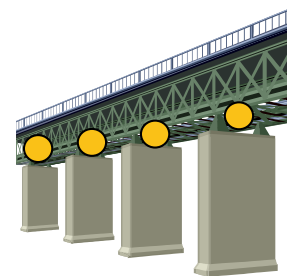
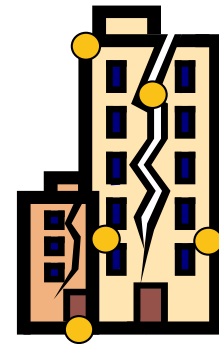
**Smart Home**



**Healthcare**

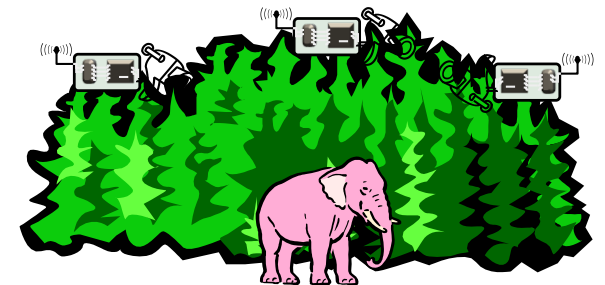
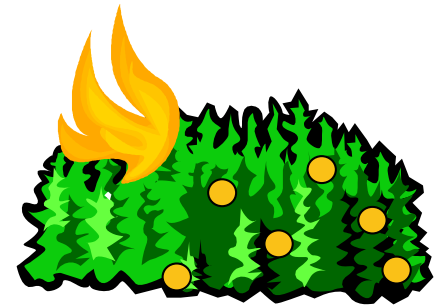
# WSN application examples

- Intelligent buildings (or bridges)
  - ▣ Reduce energy wastage by proper humidity, ventilation, air conditioning (HVAC) control
  - ▣ Needs measurements about room occupancy, temperature, air flow, ...
  - ▣ Monitor mechanical stress after earthquakes



# WSN application examples

- Disaster relief operations
  - ▣ Drop sensor nodes from an aircraft over a wildfire
  - ▣ Each node measures temperature
  - ▣ Derive a “temperature map”
- Biodiversity mapping
  - ▣ Use sensor nodes to observe wildlife



# Wireless communication



- The two main wireless standards used by WNS are 802.15.4 and Zigbee
- They are low-power protocols
- Performance is an issue
- Max distance is around 100 m



# Low Power Lossy Network (LLN)

- LLNs comprise a large number of highly constrained devices interconnected by predominantly wireless links of unpredictable quality
- LLNs operate with a hard, very small bound on state
- In most cases LLNs optimised for saving energy
- Traffic patterns can be MP2P, P2P and P2MP flows

# IEEE Wireless Standards

- 802.11 – Wireless Local Area Networks (WiFi)
  - ▣ 802.11a, 802.11b, 802.11g, 802.11n
- 802.15 – Wireless Personal Area Networks (WPAN)
  - ▣ Task Group 1 – Bluetooth (802.15.1)
  - ▣ Task Group 2 – Co-existence (802.15.2)
  - ▣ Task Group 3 – High Rate WPAN (802.15.3)
  - ▣ Task Group 4 – Low Rate WPAN (802.15.4 or 802.15.4.2)
  - ▣ Task Group 5 – Mesh Networking (802.15.5)
- 802.16 – Wireless Metropolitan Area Networks (WiMax)
- 802.20 – Mobile Broadband Wireless Access (Mobile-Fi) - Defunct
- 802.22 – Wireless Regional Access Network (WRAN)
  - ▣ Utilise free space in the allocated TV spectrum

# Wireless communication: 802.15.4



- This standard defines a communication layer at **level 2** in the OSI (Open System Interconnection) model. Its main purpose is to let the communication between two devices. It was created by the Institute of Electrical and Electronics Engineers (IEEE), entity which main task is to set standards so that technological developments can count with a common platform of rules to be set over.

# IEEE 802.15.4 Features

- Designed for low bandwidth, low transmit power, small frame size
  - ▣ More limited than other WPAN technologies such as Bluetooth
  - ▣ Low bit rate and packet size to ensure reasonably low packet error rates
  - ▣ Packet size (127 bytes) reflects minimal buffering capabilities
  - ▣ Low power allows batteries to last for years
- Communicates over multiple hops

# Wireless communication: 802.15.4

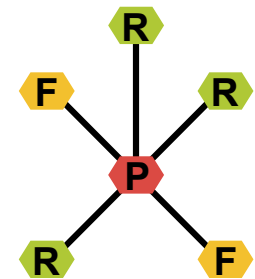
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- Why is it **low power**:

- It is ready to work with low-duty cycles. It means that the transceiver can be sleeping most of the time (up to 99% on average) while the receiving and sending tasks can be set to take just a small part of the devices' energy.
- This percentage depends on the kind of communication model used.

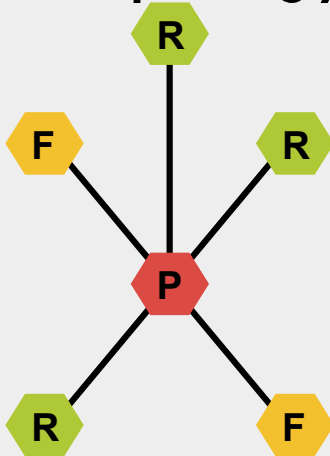
# IEEE 802.15.4 Node Types

- Full Function Device (FFD)
  - ▣ Can operate as a PAN co-ordinator (allocates local addresses, gateway to other PANs)
  - ▣ Can communicate with any other device (FFD or RFD)
  - ▣ Ability to relay messages (PAN co-ordinator)
  
- Reduced Function Device (RFD)
  - ▣ Very simple device, modest resource requirements
  - ▣ Can only communicate with FFD
  - ▣ Intended for extremely simple applications



# IEEE 802.15.4 Topologies

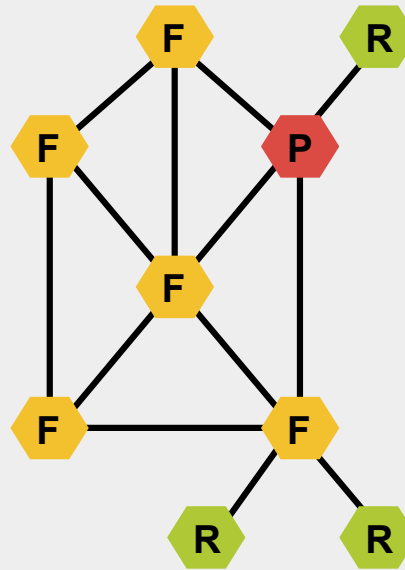
## Star Topology



All devices communicate to PAN co-ordinator which uses mains power

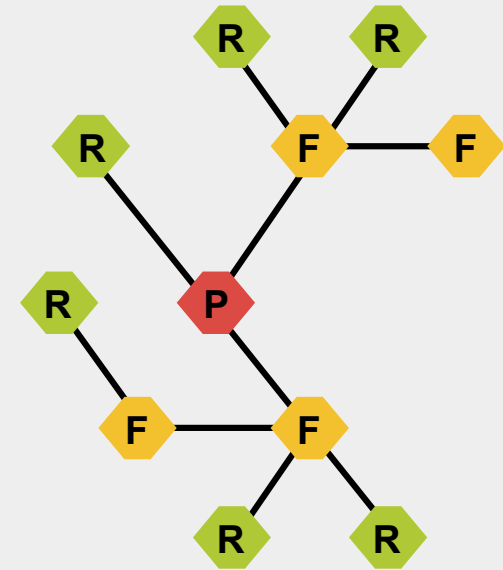
Other devices can be battery/scavenger

## Mesh Topology



Devices can communicate directly if within range

## Cluster Tree



Higher layer may create their own topology that do not follow 802.15.4 topologies

Single PAN co-ordinator exists for all topologies

# Wireless communication: 802.15.4

## □ Channels:

- 868.0 - 868.6MHz -> 1 channel (Europe)
- 902.0-928.0MHz -> 10 channels (EEUU)
- 2.40-2.48GHz -> 16 channels (Worldwide)

## □ Bit Rates:

- 868.0 - 868.6MHz -> 20/100/250 Kb/s
- 902.0-928.0MHz -> 40/250 Kb/s
- 2.40-2.48GHz -> 250 Kb/s



# Wireless communication: Zigbee

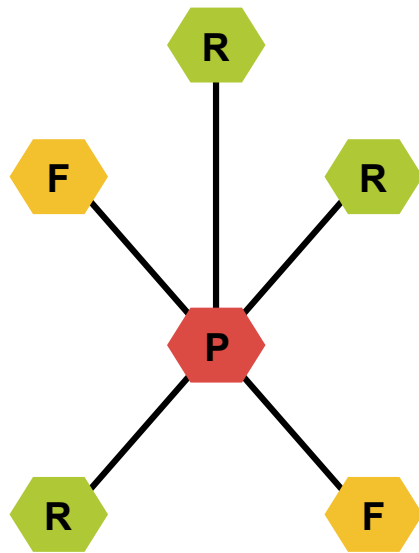


- This standard defines a communication layer at **level 3 and uppers** in the OSI model. Its main purpose is to create a network topology (hierarchy) to let a number of devices communicate among them and to set extra communication features such as authentication, encryption, association and in the upper layer application services. It was created by a set of companies which form the ZigBee Alliance.

# Wireless communication: Zigbee

- ZigBee offers basically four kinds of different services:
  - **Encryption** services (application and network keys implement extra 128b AES encryption)
  - Association and **authentication** (only valid nodes can join to the network).
  - **Routing** protocol: AODV, a reactive ad hoc protocol has been implemented to perform the data routing and forwarding process to any node in the network.
  - **Application** Services: An abstract concept called "cluster" is introduced. Each node belongs to a predefined cluster and can take a predefined number of actions. Example: the "house light system cluster" can perform two actions: "turn the lights on", and "turn the lights off".

# Gateway based design



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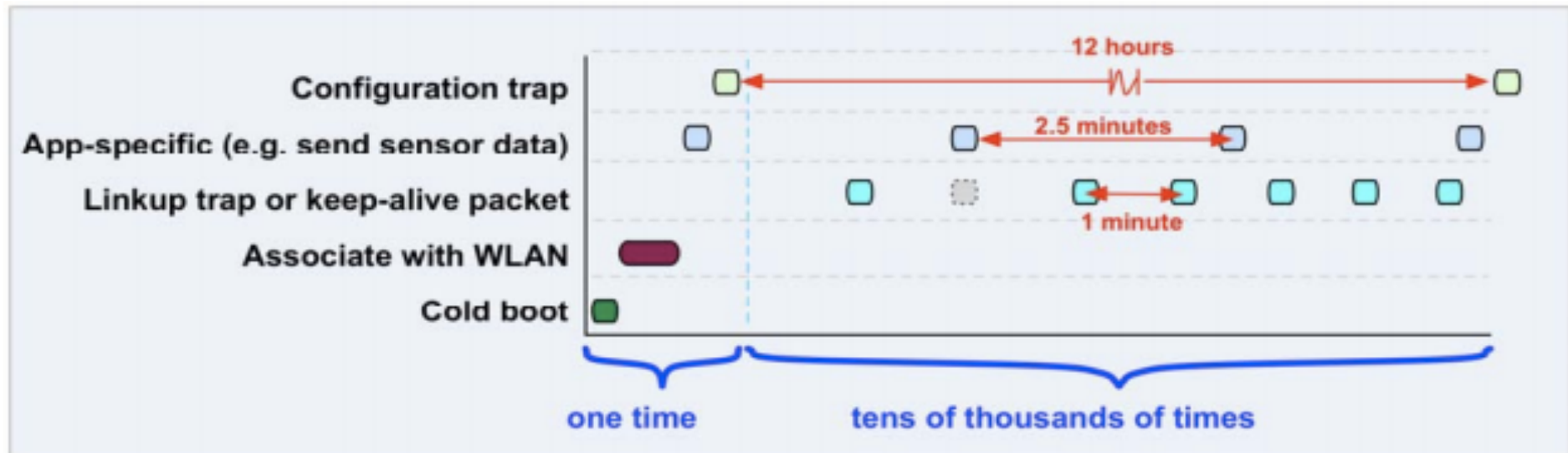


# WiFi based WSN



- Advantage: use existing WiFi networks.
- High power Wi-Fi chips are optimized for fast response, low latency, and high data rates.
- Low power Wi-Fi chips are optimized for low power consumption, particularly when the device is in Standby mode.

# WiFi based WSN



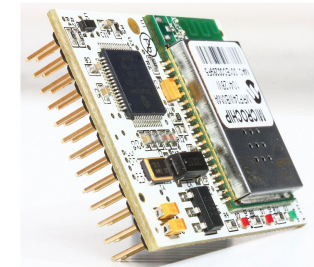
# WiFi based WSN

Parameter		Conventional Wi-Fi	Low-Power Wi-Fi	units
Power consumption	Standby / Idle	NA*	<4	$\mu$ W
	Processor + clock sleep	13	0.2	mW
	Data processing	115	56	mW
Receive sensitivity, 1 Mbps		-91	-91	dBm
Time to wake from Standby		NA*	10	ms
Time to wake from processor+clock sleep		75	5	ms

# WiFi based WSN

## □ Examples

- The **XBee Wi-Fi** modules from Digi International come in 1mW and 2mW versions.
- The **Flyport** provides the following services: Webserver (even Ajax apps can be run), TCP Socket, UDP Socket, SMTP Client.
- The **Gainspan** modules.



**GS1500M**

802.11b/g/n  
Wi-Fi Module



# What is a Smart Object?

- A tiny and low cost computer that may contain:
  - ▣ A **sensor** that can measure physical data (e.g., temperature, vibration, pollution)
  - ▣ An **actuator** capable of performing a task (e.g., change traffic lights, rotate a mirror)
  - ▣ A **communication device** to receive instructions , send data or possibly route information
- **This device is embedded into objects**
  - ▣ For example, thermometers, car engines, light switches, gas meters
- We now talk about **Internet of Things**



# Internet of Things

## All Our Lightbulbs Will Have IP Addresses

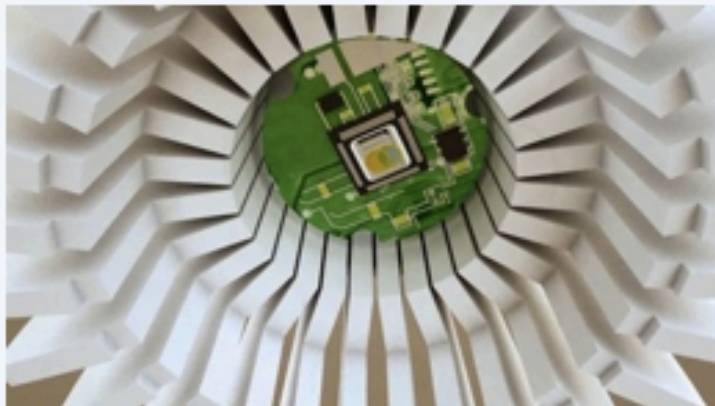
By Adrian Covert on May 20, 2011 at 12:00 PM



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When we remarked that home automation technology was a reason **we needed IPv6 technology**, we weren't kidding. If Netherlands-based NXP has it their way, we'll all be using networked LED lightbulbs, each with their own IPv6 address.

According to Fast Company, this GreenChip technology operates on the 802.15.4 wireless protocol, which means it doesn't use the same bandwidth as 802.11 wi-fi gadgets. Cool.

But what do you do with networked bulbs? Automate your home, of course.

“ You'll also be able to control mood lighting “states” with a remote control, or via your iPad, as if you were a theatre lighting designer; you'll be able to quickly and easily incorporate movement sensing automated lighting, that could even turn on dimly if it detects you're stumbling to the bathroom at midnight; and you'll be able to download apps to hone and polish your home's lighting energy needs so that you end up with a smaller power bill.

# Internet of Things



# Internet of Things

## Bits

Business ■ Innovation ■ Technology ■ Society

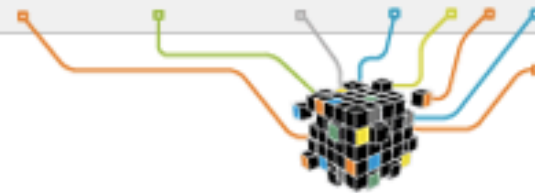
October 13, 2011, 8:26 AM

### The Next Boom in Mobile Devices Is the Car

By [QUENTIN HARDY](#)

SAN DIEGO — Cars, one of the great mobile devices to begin with, are about to get connected to the Internet like never before. It will change not just how we drive, but the economics of the car business.

“Five percent of cars are connected today,” said Glenn Lurie, president of AT&T’s Emerging Devices business. He was speaking of new vehicles, not all cars on the road. “Three to five years from now, 100 percent will be connected. You’ll see diagnostics, calls when the airbag goes off, real-time traffic reports, entertainment in the back seat.”

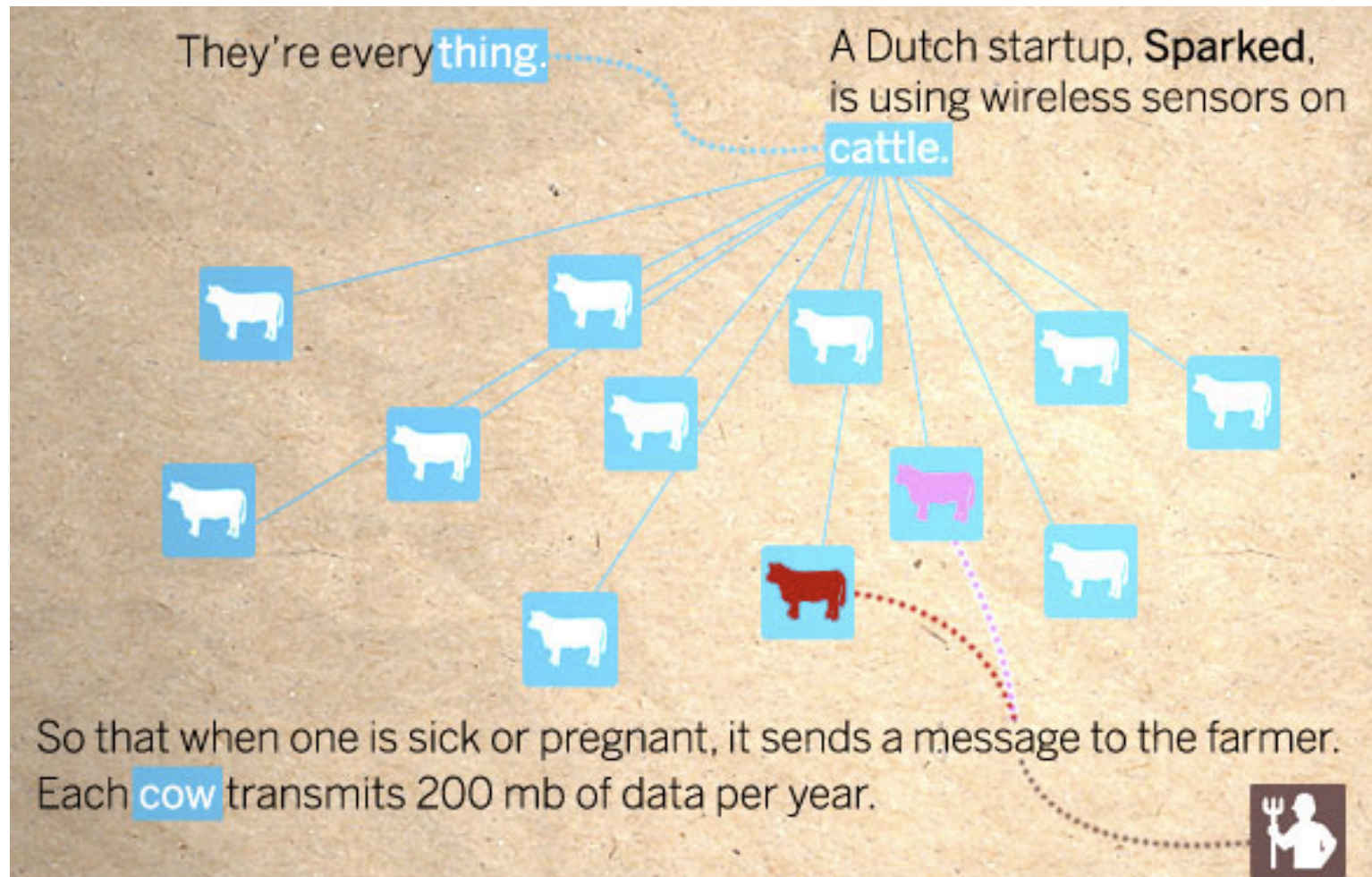


# Internet of Things





# Internet of Things

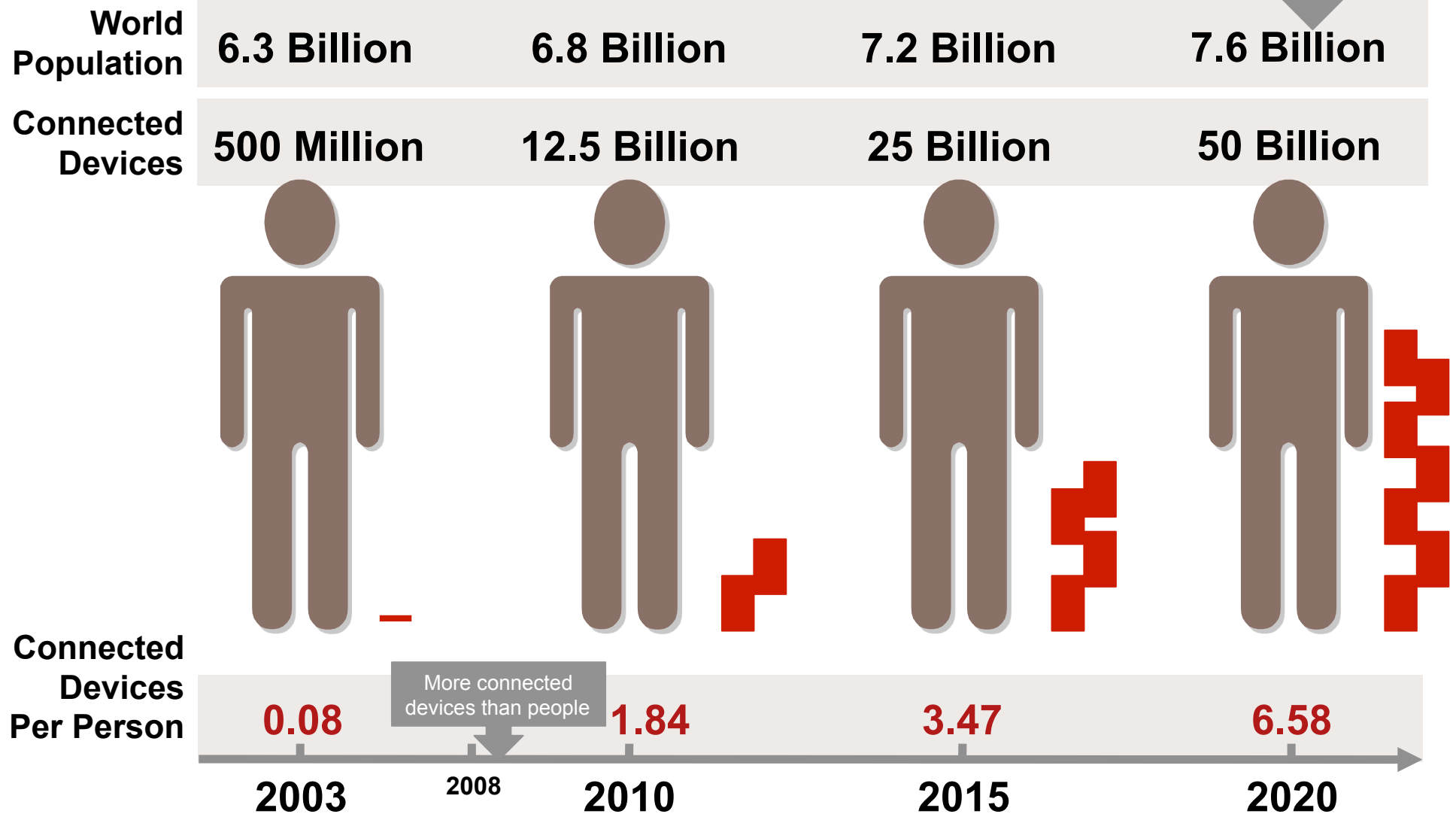


# IPv4 or IPv6

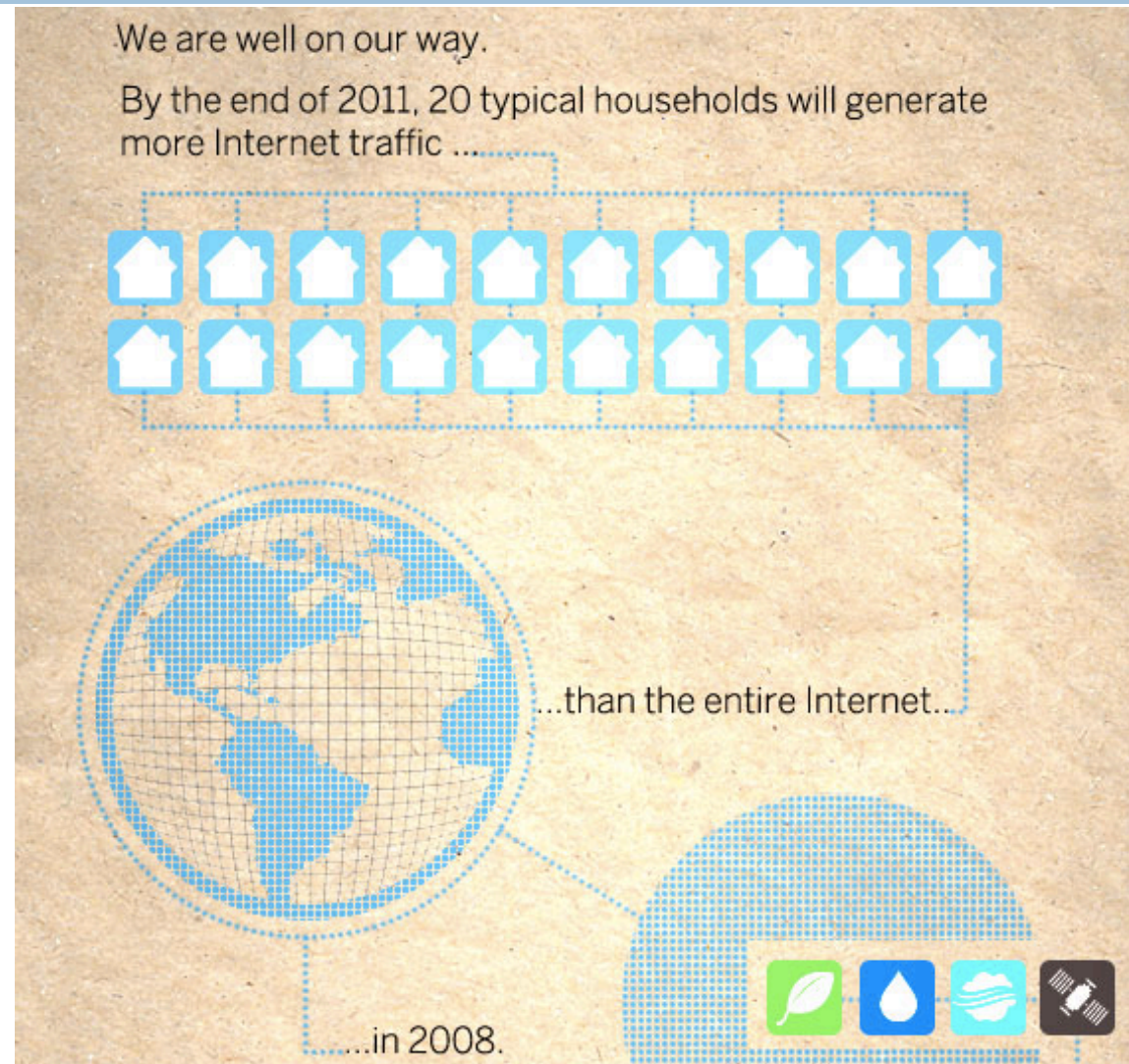
- Smart Objects will add tens of billions of additional devices
- There is no scope for IPv4 to support Smart Object Networks
- IPv6 is the only viable way forward
  - ▣ Solution to address exhaustion
  - ▣ Stateless Auto-configuration thanks to Neighbour Discovery Protocol
  - ▣ Each embedded node can be individually addressed/accessed

# Smart Objects

Based on what we  
know is true today  
(Conservative)



# Internet of Things

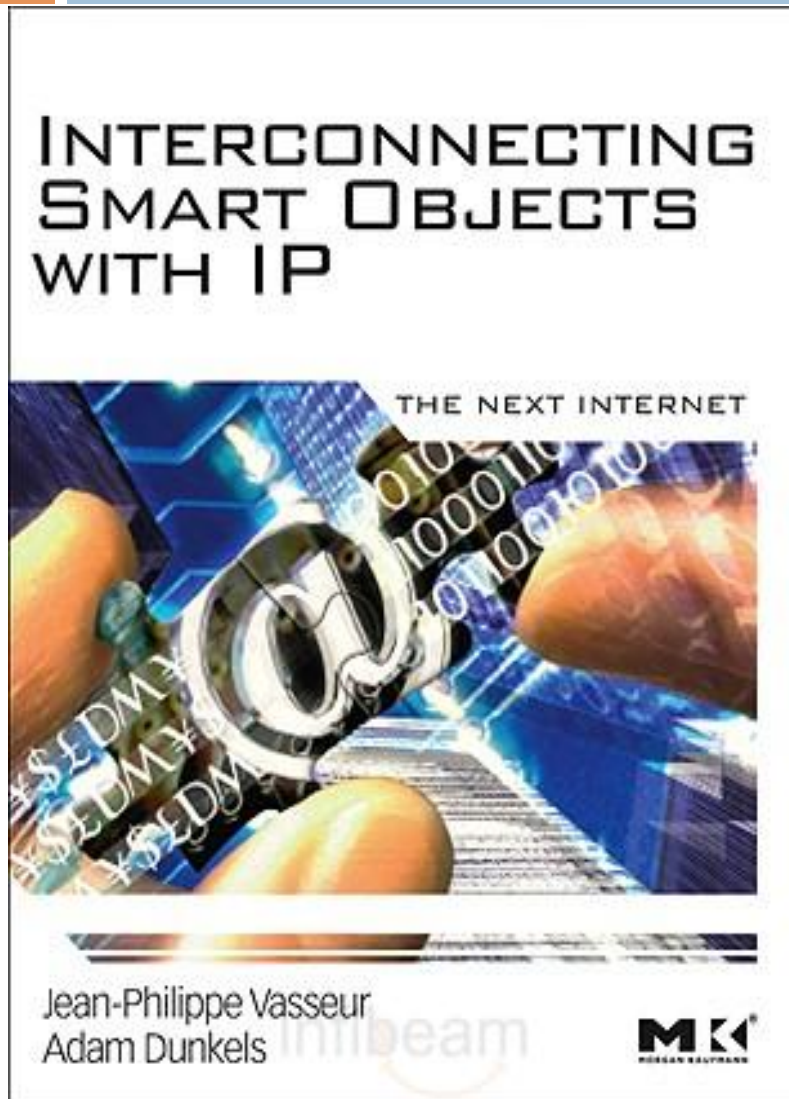




# IPv4 or IPv6

- Some issues with IPv6 address size
  - ▣ Smart Object Networks use low power wireless with **small frame size**
  - ▣ IPv6 over Low power Wireless Personal Area Networks = 6LoWPAN
  - ▣ An adaptation layer for IPv6 over IEEE 802.15.4 links
  - ▣ IEEE 802.15.4 MTU is only 127 bytes, IPv6 minimum MTU is 1280 bytes
  - ▣ IPv6 does not do fragmentation, left to end nodes or lower layers

# Recommended reading



- Covers the trends in Smart Objects
- Detailed application scenarios
- Written by
  - ▣ JP Vasseur (Cisco DE)
  - ▣ Adam Dunkels (Inventor of Contiki O/S, uIPv6)

# Internet of Things



[internet of things - You#BF7153](#)

# Conclusion



- WSN are here to stay!
- It's an interesting, complex, new technology
- Lots of research still to be done
- Applications are what is needed!

# Credits



- Credits for the slides go to:
  - ▣ Bhaskar Raman
  - ▣ Muneeb Ali
  - ▣ Holger Karl
  - ▣ David Gascon
  - ▣ Antoine Bagula
  - ▣ Claro Noda
  - ▣ Jeff Apcar

# Thanks



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