INTRODUCTION TO WIRELESS SENSOR NETWORKS

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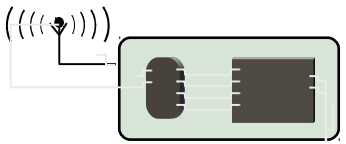
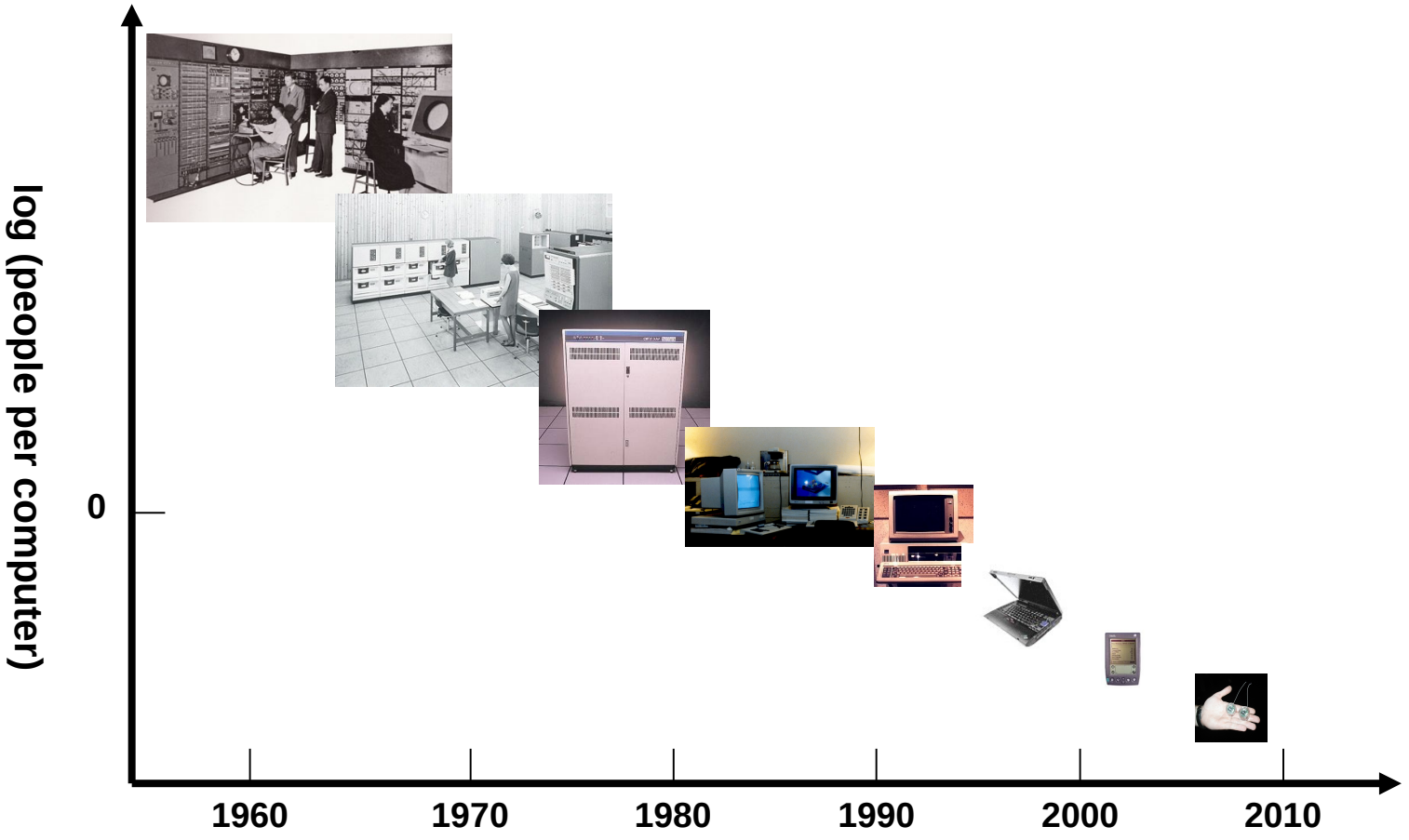
Wireless sensor networks

- 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**.



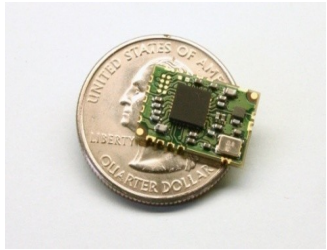
Wireless sensor networks



[Culler:2004]

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)

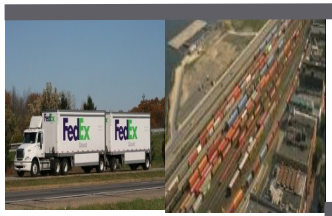


- Power consumption is critical
  - If battery powered then energy efficiency is paramount
- May operate in harsh environments
  - Challenging physical environment (heat, dust, moisture, interference)

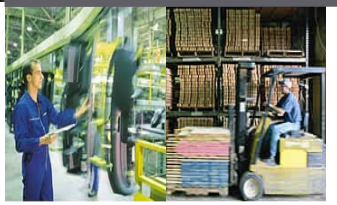
A World of Sensors

Predictive Maintenance

Energy Saving Smart Grid

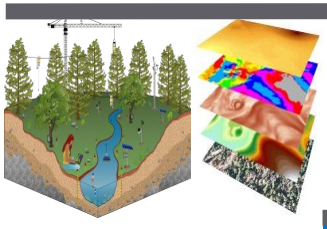


High-Confidence Transport and Asset Tracking



Improve Productivity

Intelligent Buildings



Enable New Knowledge

Enhanced Safety & Security

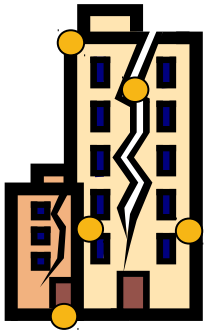
Improve Food and H_2O

Healthcare

Smart Home

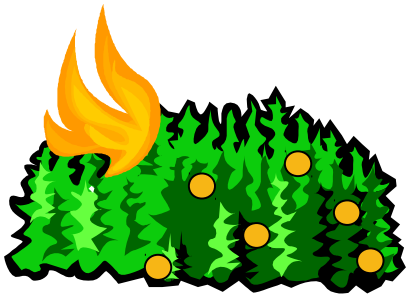
WSN application examples

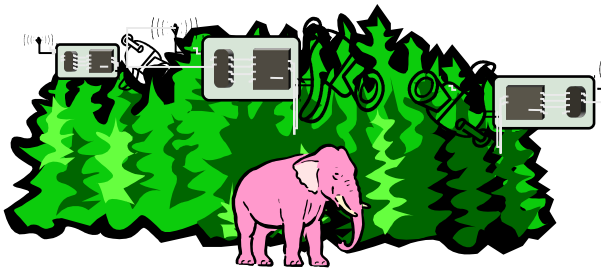
- Intelligent buildings (or bridges)
  - Reduce energy wastage by proper humidity, ventilation, air conditioning (HVAC) control
  - Needs measurements about room occupancy, temperature, air flow, …
  - Monitor mechanical stress after earthquakes



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 5 alternatives when it comes to wireless communications:
  - 802.15.4 or Zigbee
  - Low power WiFi
  - GPRS or SMS
  - Satellite
  - Bluetooth LE

Wireless communication

- The two 5 alternatives when it comes to wireless communications:

	Distance	Gateway
802.15.4/Zigbee	100m	Yes
Low Power WiFi	100m	Yes (AP)
GPRS/SMS	infinite	No
Satellite	infinite	No
Bluetooth LE	50m	No

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

IEEE Wireless Standards

- 802.11 – Wireless Local Area Networks (WiFi)
  - 802.11a, 802.11b, 80211g, 802.11n
- 802.15 – Wireless Personal Access 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 TG4)
  - 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

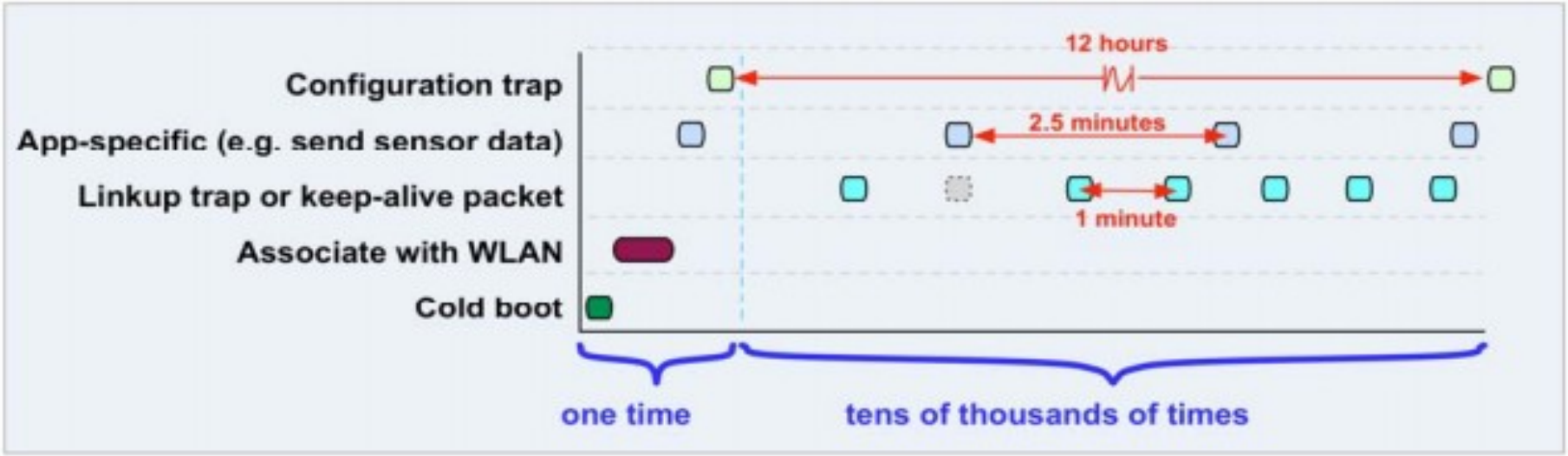
Wireless communication: 802.15.4

- 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

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

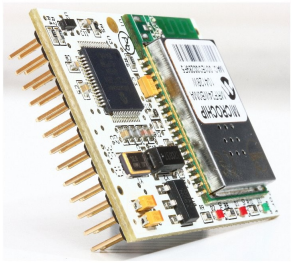


WiFi based WSN

Parameter		Conventional Wi-Fi	Low-Power Wi-Fi	units
Power consumption	Standby / Idle	NA*	<4	µW
	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.



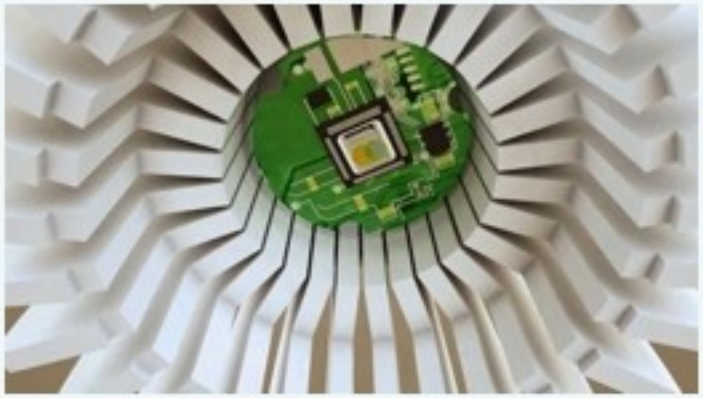
What is a Smart Object?

- 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



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.

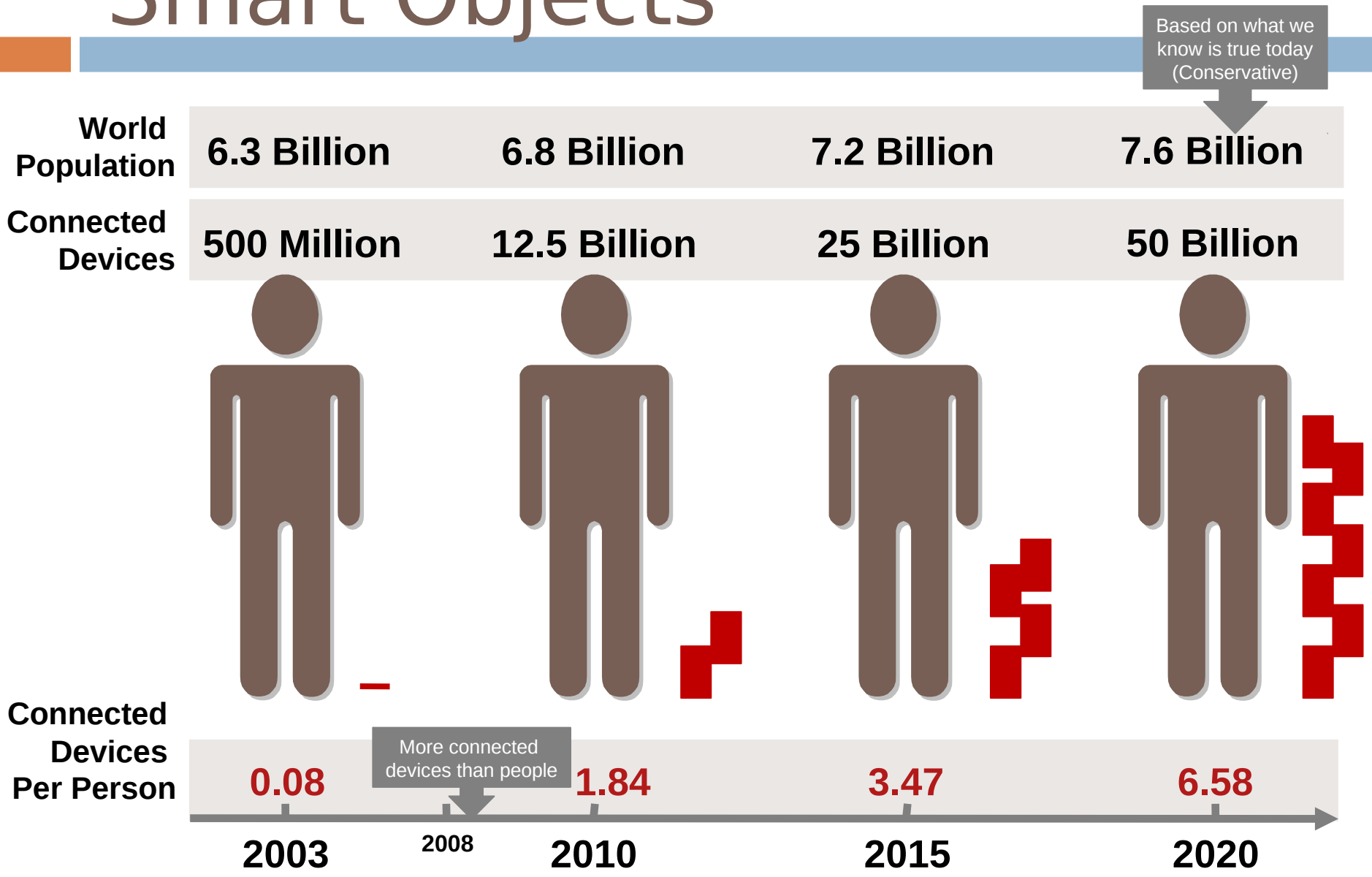
> "You'll also be able to control mood lighting "states" with a remote control, or via your iPad, as if you were a theatre lighting designer; you'll be able to quickly and easily incorporate movement sensing automated lighting, that could even turn on dimly if it detects you're stumbling to the bathroom 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

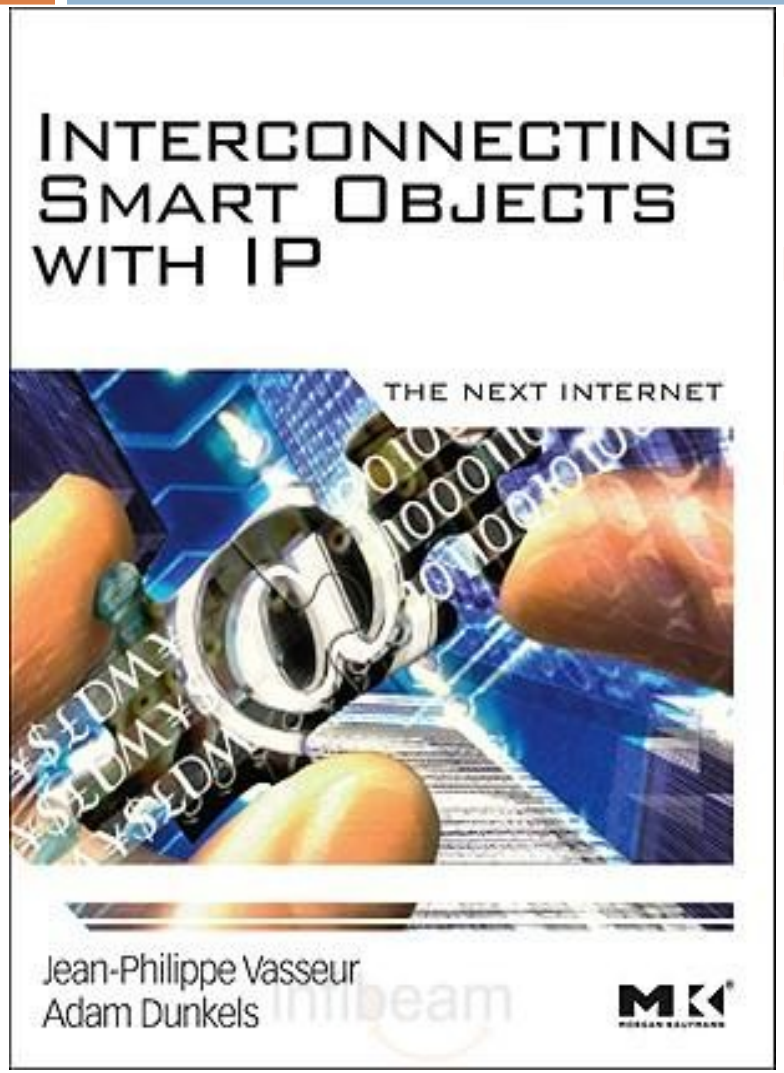
IPv4 or IPv6

- 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 Neighbor Discovery Protocol
  - Each embedded node can be individually addressed/accessed

Smart Objects



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)

Market: Sun SPOT

- Sun SPOT Processor Board
- 180 MHz **32 bit** ARM920T core - 512K RAM/**4M Flash**
- 2.4 GHz IEEE 802.15.4 radio with integrated antenna
- USB interface
- 32 uA deep sleep mode
- 2G/6G 3-axis accelerometer, Temperature sensor, Light sensor, 8 tri-color LEDs, 6 analog inputs, 2 momentary switches, 5 general purpose I/O pins and 4 high current output pins

Market: Sun SPOT

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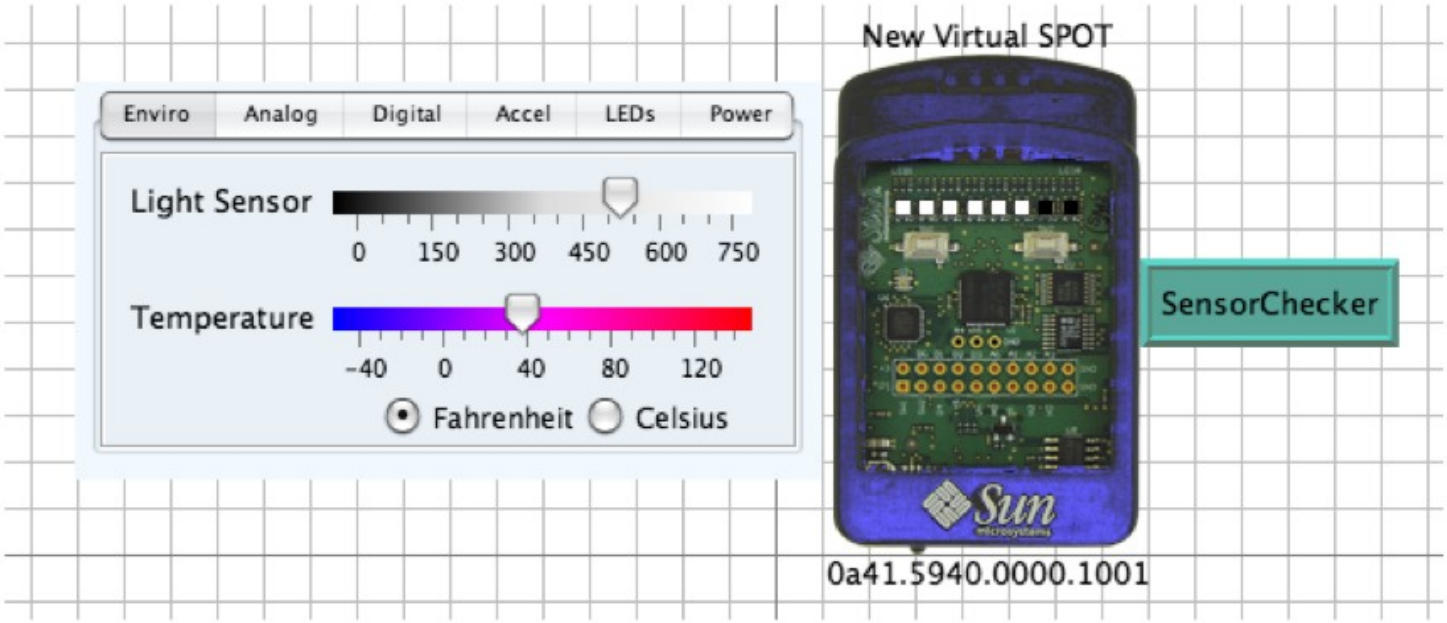
Market: Sun SPOT

- Pros:
  - Java based!
  - You can use NetBeans to develop your software
  - Good community base
  - Open Software and Hardware
  - Discount for Research Institutions
- Cons:
  - Price: 399$ (educational discount available)

Market: Sun SPOT



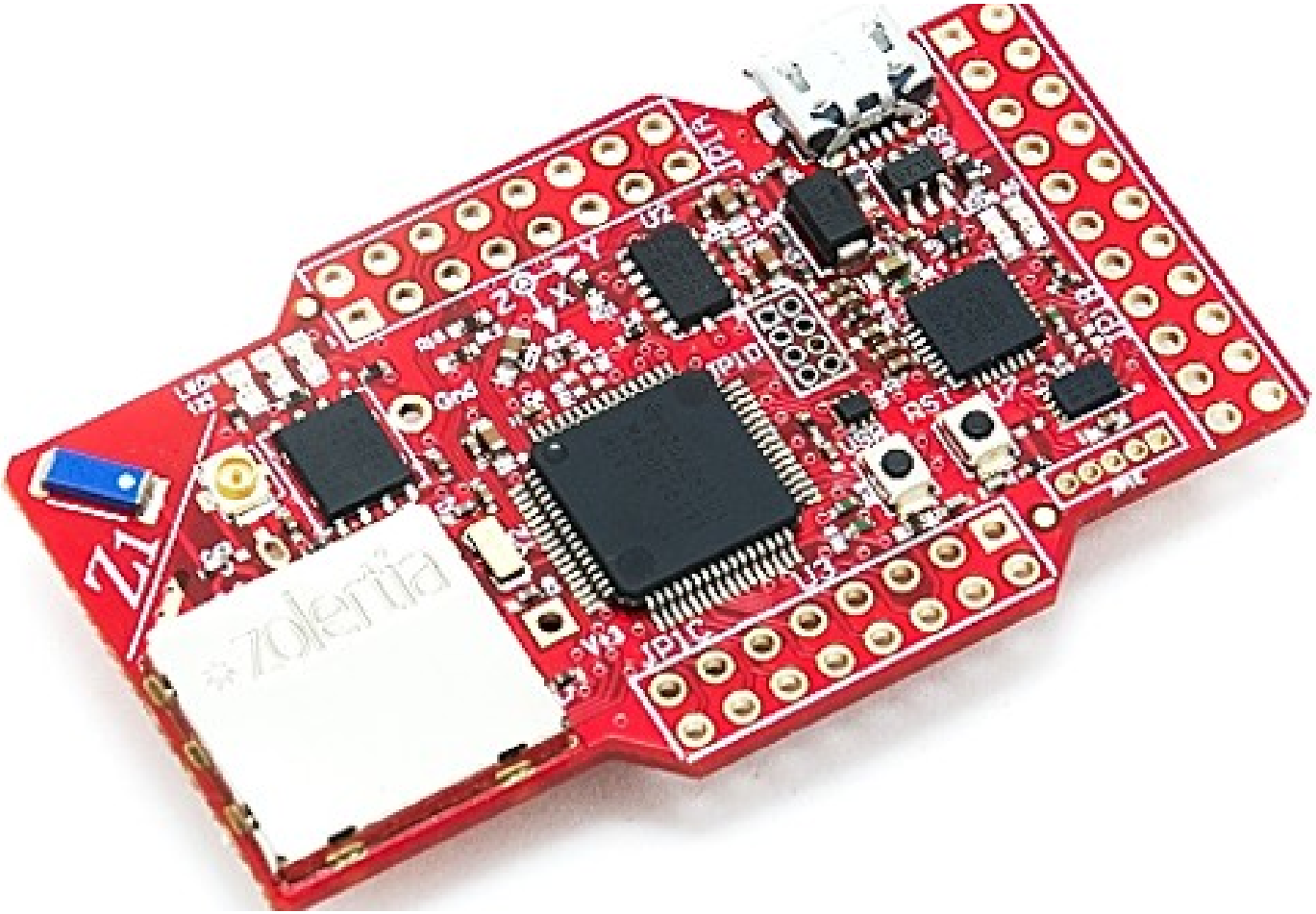
http://www.sunspotworld.com

Market: Zolertia Z1

- **Zolertia Z1**
- Backwards compatibility with motes based on MSP430+CC2420
- Can run TinyOS and Contiki
- Out of the box support for Phidgets
- 95 euros each (75 euros in +50)

- http://www.zolertia.com/

Market: Zolertia Z1



Market: Zolertia Z1

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- Input
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Motors
- Servo Controllers
- Servo Motors

Sensors

1015_0 - PhidgetLinearTouch
- Works through 1/8 inch of glass of plastic
- Recognizes both contact and proximity; can be used as a slider or as an array of buttons
- Connects directly to a computer's USB port

Quantity	Price
1	**$48.50**
5	$46.60
10	$45.15
25	$43.65
50	$41.25

In Stock
Qty: 100+
Add
1

1016_0 - PhidgetCircularTouch
- Works through 1/8 inch of glass or plastic
- Recognizes both contact and proximity; can be used as a slide-wheel or as an array of buttons
- Plugs directly into a computer's USB port

Quantity	Price
1	**$48.50**
5	$46.60
10	$45.15
25	$43.65
50	$41.25

In Stock
Qty: 100+
Add
1

1040_0 - PhidgetGPS
- Provides Position, Velocity and Direction
- Position Accuracy of 2.5m CEP (best case)
- Battery Life (fully charged): 1 month
- Connects directly to a computer's USB Port

Quantity	Price
1	**$92.15**
5	$88.50
10	$85.70
25	$82.95
50	$78.35

In Stock
Qty: 100+
Add
1

1045_0 - PhidgetTemperatureSensor IR
- Infra Red thermometer for non contact temperature measurements
- Thermometer is Factory calibrated
- Temperature range of -70 to 380°C
- Connects directly to a computer's USB Port

Quantity	Price
1	**$87.30**
5	$83.85
10	$81.20
25	$78.60
50	$74.25

In Stock
Qty: 100+
Add
1

Thanks

Marco Zennaro

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