Wireless Sensor Networks

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Wireless Sensor Networks (WSN)

- Invented for the monitoring of
  - Spaces
  - Things
  - Interactions
- Examples:
  - Eco-system monitoring
  - Habitat monitoring
  - Disaster management
  - Asset tracking

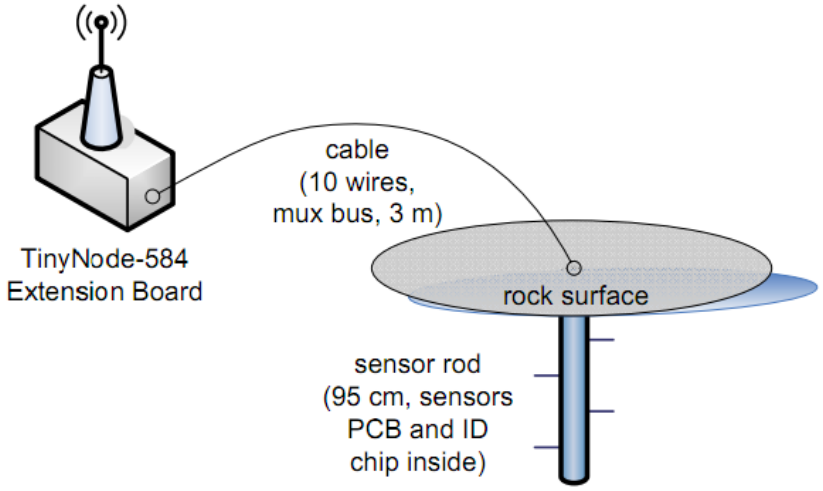
- First WSN: SmartDust project 2001 Berkeley/UCLA

Example: PermaSense project (2007)

- Global warming's effect on permafrost in the high swiss alps
- Inaccessible 7 of 12 months, -30° C, high winds
- Collect data for calibration of geo-science models

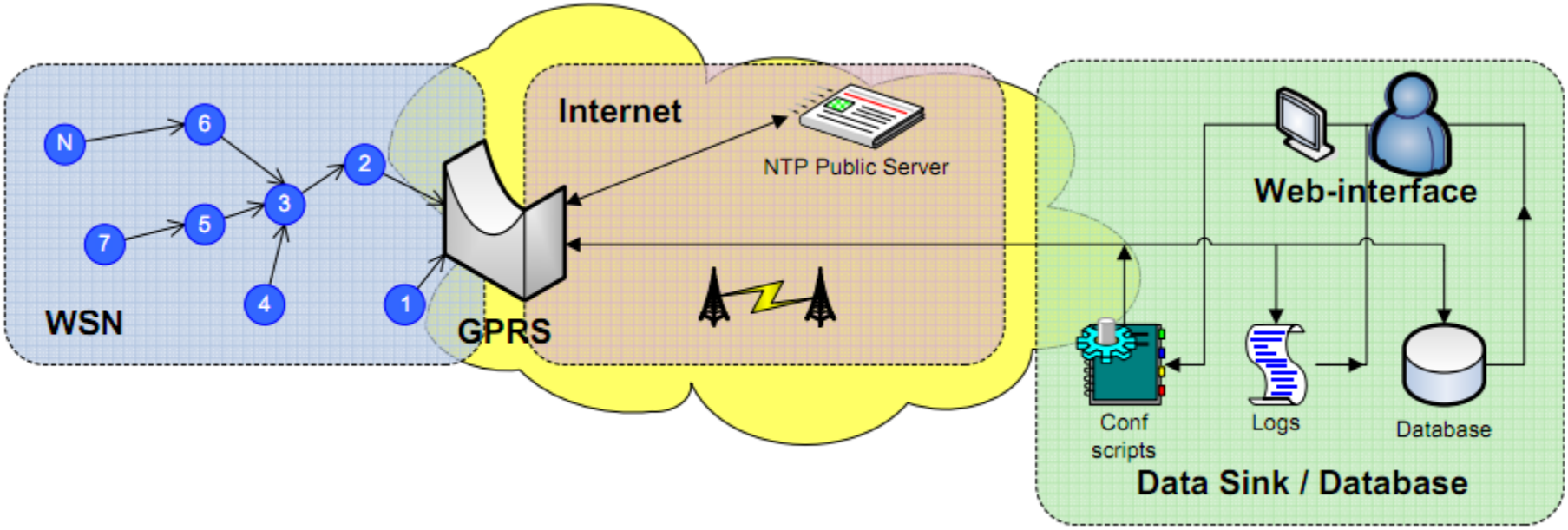
Shockfish

- Well-protected “Shockfish TinyNode 584” board with small microcontroller
- External sensor for temperature & water content attached to rock (via cable)
- 2 “Lithium-thionyl chloride (Li-SOCl2)” type batteries in parallel
- Optimized HW (12 µA sleep, 14 mA during transmissions)

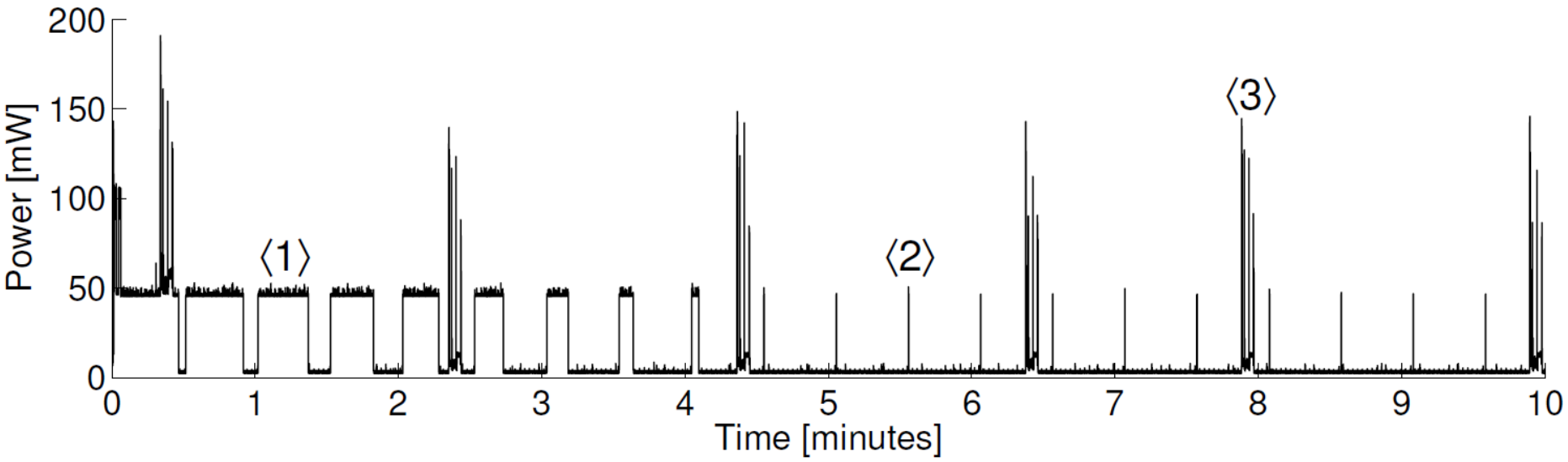


Challenge: Resource-constrained Communication

- How can sensors send their data to the servers?
- Not enough power to reach server directly
- Multihop wireless network
  - Own position and neighbors initially unknown or dynamic, nodes can disappear! → Robust routing algorithms&protocols needed



Power Profile of a device



<1> Repeatedly turn on radio to scan for other nodes

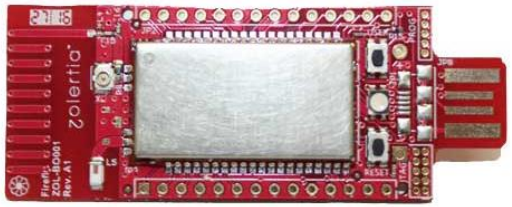
<2> Nothing found → reduce listening time

<3> Read out sensors, write data to SD card. Don‘t attempt to send

In this use case, energy saving is more important than communication speed!

Modern WSN hardware

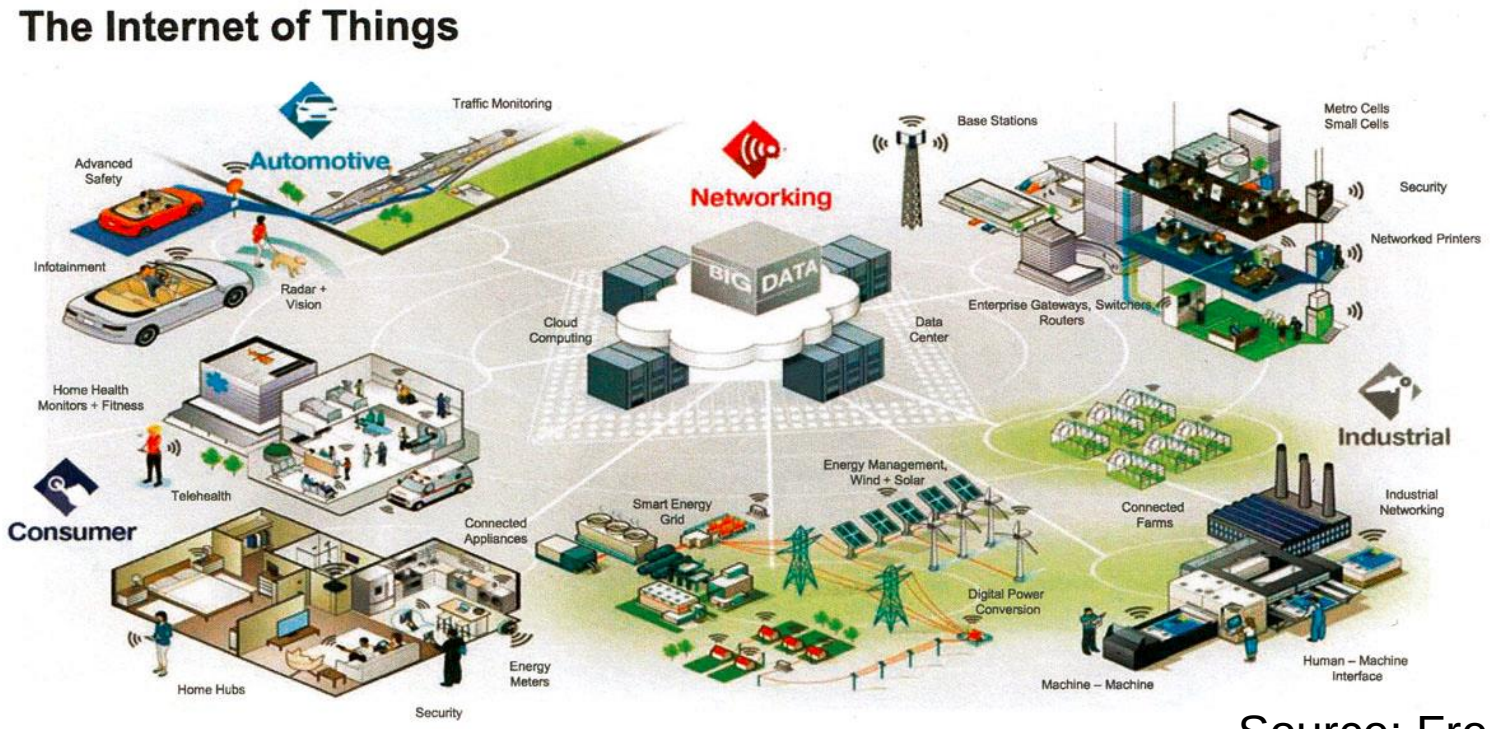
- The design principles of WSN hardware has not much changed since the SmartDust project in 2001:
  - Low-power microcontroller or SoC
  - Wireless network interfaces
  - Sensors on board or directly attached
- Typical modern low-power design
  - IEEE 802.15.4 wireless network
  - ARM CortexCPU, 32MHz
  - 32KBytes RAM, 512kB flash
- If power-consumption is not an issue:
  - Bluetooth, WiFi or LoRa on board
  - ESP32: Two CPU cores, 150MHz
  - 500kBytes RAM, 4MB flash



Internet of Things

Internet of Things (IoT)

- IoT = network of physical objects equipped with electronics and network connectivity that can be sensed and controlled remotely
  - Devices send data to servers in cloud where it is processed and analyzed
- So, basically: IoT = WSN + Data analytics in the cloud



Source: Freescale

Enablers of Internet of Things (1)

Technological enablers of the IoT: Advancements in many fields in the past two decades

1. From embedded systems, WSNs, Ad-hoc communication:
   - Low-power computing and battery technology
   - Wireless communication, communication protocols for ad-hoc and self-organizing networks
   - Dedicated operating systems
2. From automation:
   - Protocols for machine-to-machine communication
3. From Cloud Computing/Big Data:
   - Clouds for data storage and processing
   - Data mining to analyze large-scale sensor data

Enablers of Internet of Things (2)

4. From distributed computing, web services
   - Grid computing
   - Service discovery
   - REST
5. Addressability of billions of devices: RFID, IPv6
6. Autonomous systems: agents, self-organization