Overview of existing sensor nodes

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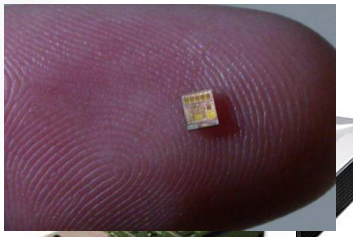
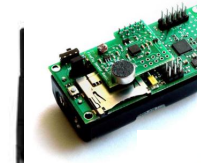
Overview

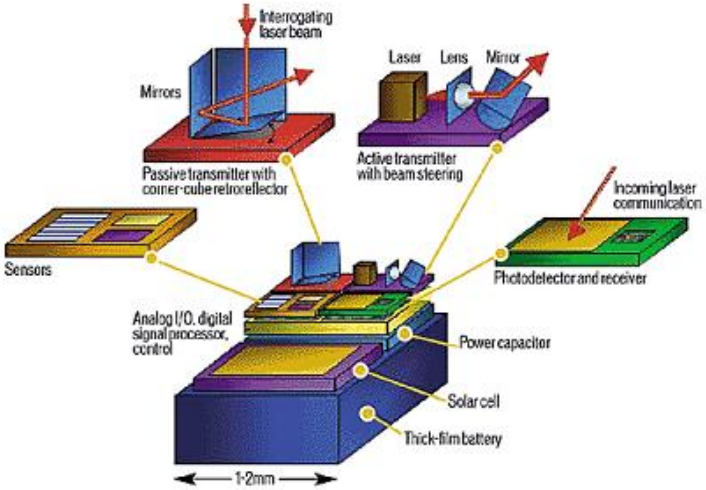
- Sensor nodes
- Sensor node basic building structure
  - Power supply
  - Processing unit
  - Programming / debugging
  - Sensors / actuators
  - Memory storage
  - Communication interface
- Nodes roles and their estimated capabilities
- General gateway basic building structure
- Hardware analysis procedure
- Hardware analysis results

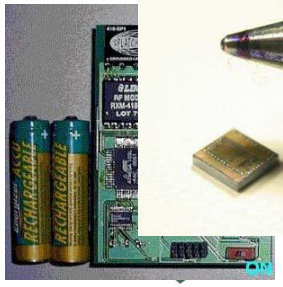
Sensor nodes

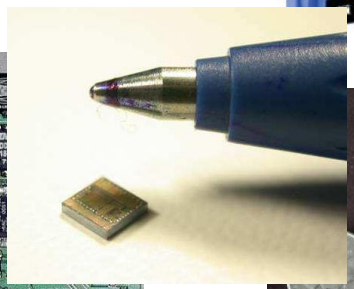
- adapted / augmented general purpose computers
- embedded sensor modules
- system on chip (SoC) solutions

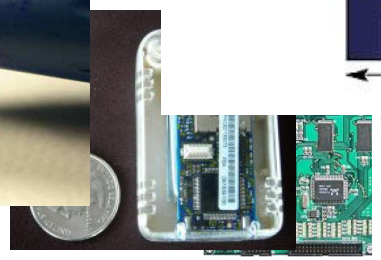


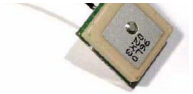




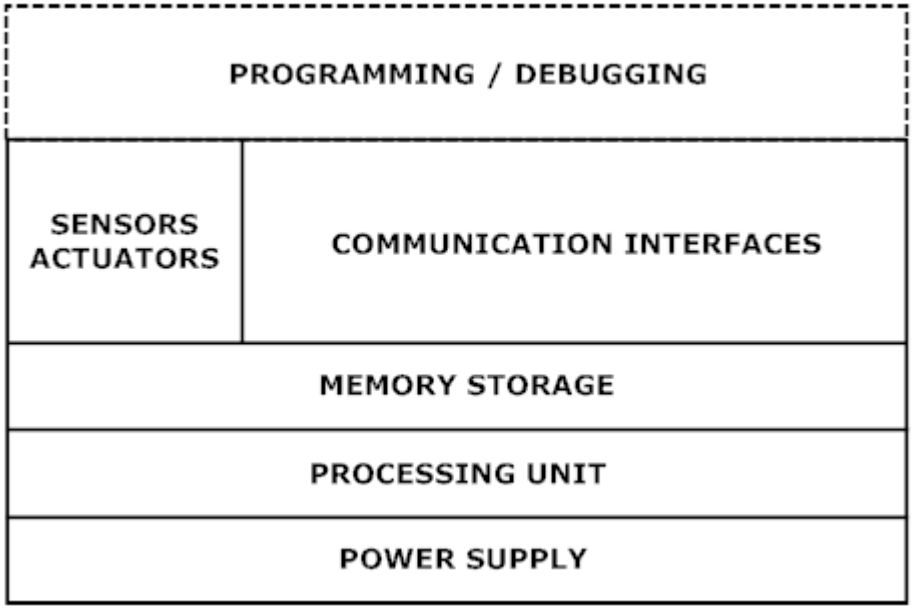








Sensor node basic building structure



Power supply

- constant power supply (AC-DC, DC-DC, USB)
- energy storage devices
  - rechargeable batteries, non-rechargeable batteries, capacitors, super capacitors, ultracapacitors, fuell cells, etc.
- energy harvesting
  - solar, thermal, wind, vibration, electromagnetic, kinetic, etc.

Processing unit

- Microcontrollers
- Field-Programmable Gate Arrays (FPGAs)
- Digital Signal Processors (DSPs)

- 8 bit, 16 bit, 24 bit or 32bit architecture
- Atmel, PIC, Texas Instruments, etc.

Programming /debugging

- JTAG
- Serial
- Parallel
- Over the air

Sensors / actuators

Å Sensors: temperature, humidity, light, pressure, etc.

Others ???

Sensor groups	Sensor types	Typical stimulus
Acoustic sensors	- Microphones (air) - capacitive microphones - fiber-optic microphones - piezoelectric microphones - piezoceramic microphones - electrets microphones - acoustic wave sensors - Hydrophones (underwater)	Wave - amplitude - phase - polarization Spectrum Wave velocity Other
Biosensors	- Acoustic wave biosensors - Calorimetric biosensors - Potentiometric biosensors - Amperometric biosensors - Optical biosensors - Immunosensors	Mass of the biological components - types - concentrations - states Other
Chemical sensors	- Interdigital transducer sensors - Conductivity sensors - Optical chemical sensors - Ion sensitive FET sensors - Piezoelectric chemical sensors	Components - identities - concentrations - states Other
etc.	etc.	etc.

Å Actuators: relays, speakers, etc.

Memory storage

- Memory:
  - Internal / external
  - Volatile / non-volatile

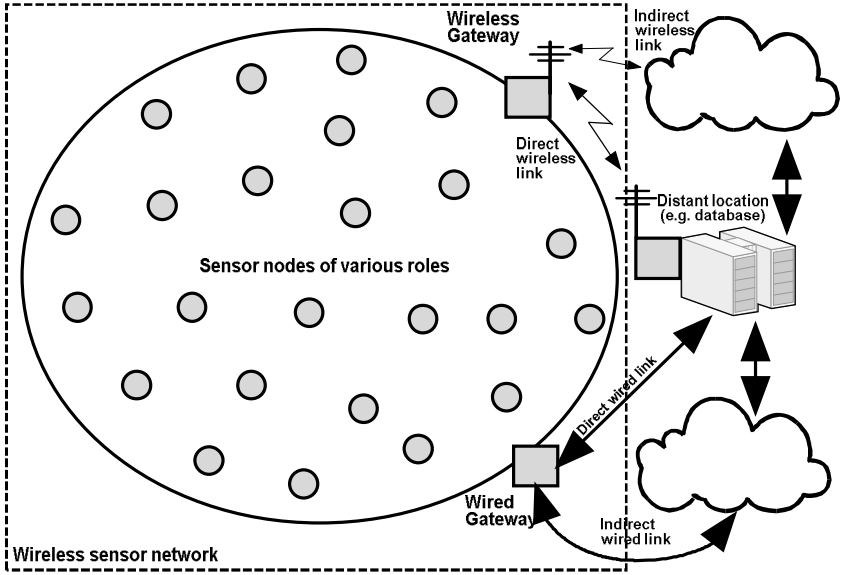
- Relative large capacity is needed
  - Compact Flash, SD, mini SD, micro SD, PCMCIA, etc.
- Smaller capacity is needed
  - FLASH, SDRAM, EEPROM, etc.

Communication interfaces

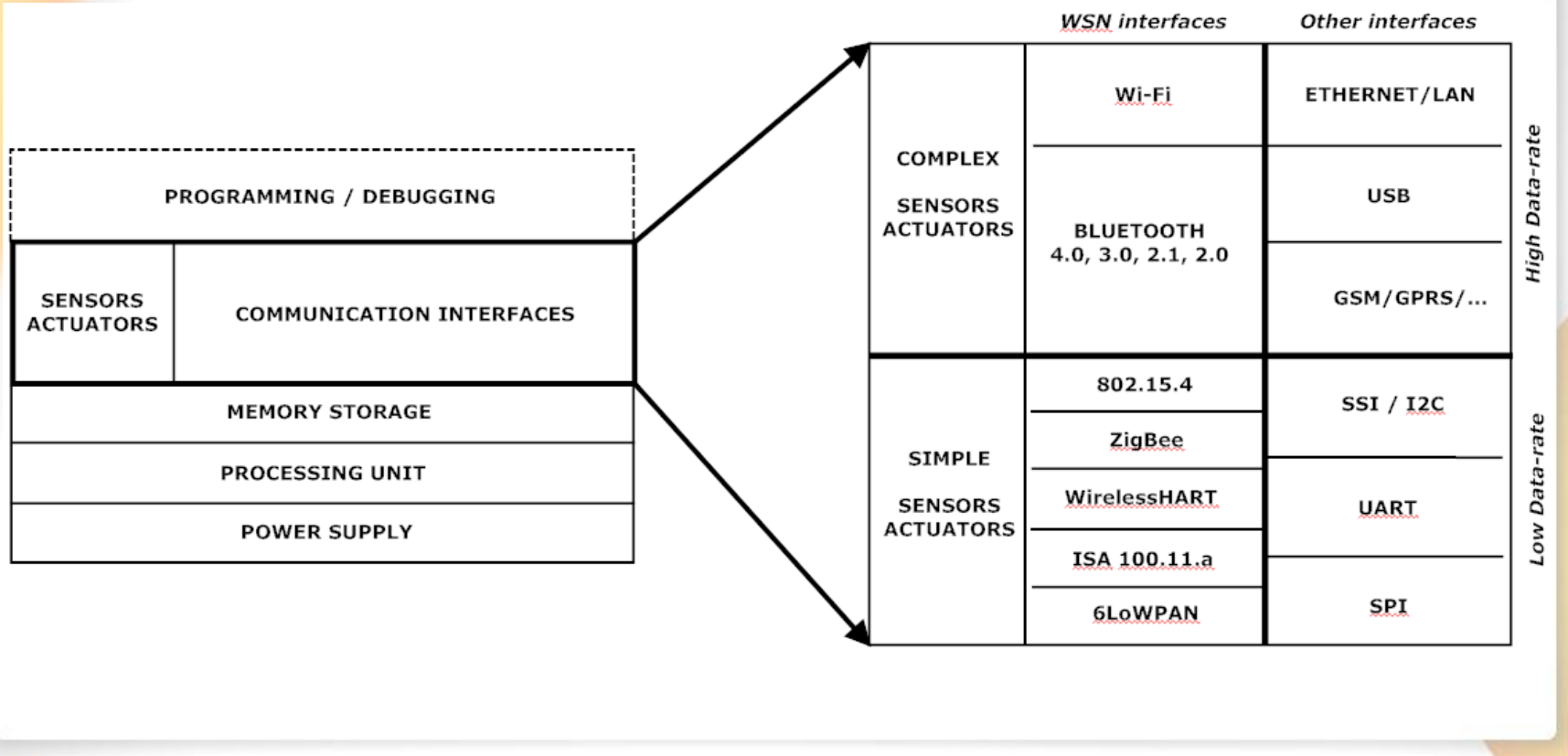
- Wired communication interfaces
  - RS232, Ethernet, I^2C, SPI, etc.
- Wireless
  - RF interfaces (ISM band - interference)
    - Sensor networks dedicated
    - GSM/GPRS
    - etc.
  - optical interfaces (sensitive to atmospheric conditions)
  - ultrasound (underwater)

Nodes roles and their estimated capabilities according to standards

HW capability	Wireless sensor networks standards				
	IEEE 802.15.4	ZigBee	Wireless HART	ISA 100.11a	6LoWPAN
highest	PAN coordinators (FFDs)	coordinators (ZCs)	gateways, network managers, security managers	gateways, system managers, security managers	coordinators (FFDs)
high	coordinators (FFDs)	routers (ZRs)	access points	backbone routers	routers (FFDs)
medium	network devices (FFDs and RFDs)	end-devices (ZEDs)	field devices (WFDs)	routers , input/output devices	end-devices (FFDs and RFDs)
low			adapters, handhelds	handhelds	



General gateway basic building structure



Hardware analysis procedure

- > 125 sensor nodes identified
- 100 nodes were considered (due to incomplete node information)

  - **processing units (number, type, clock, FLASH, ROM, RAM, SRAM, EEPROM),**
  - power consumption (minimum operation voltage, receive and transmit power, total active power),
  - wakeup times,
  - communication standards/technologies,
  - **communication interfaces (number, unit types, frequency, data-rates, antenna types, modulations),**
  - **external memory units (number, unit types, connection interfaces, storage size),**
  - **programming interfaces (wired, over the air),**
  - expansion types,
  - **sensors**/actuators sensors (number, type),
  - communication interfaces,
  - **power supplies (constant power supply, USB, energy harvesting, batteries),**
  - special remarks,
  - **year of development,**
  - **developers and/or manufacturers.**

Hardware analysis results

- together 118 processing units
  - the most used microcontroller (**Atmel ATmega128L)**
  - the most used DSP (**Coolflux DSP NxH1200)**
  - FPGAs are exceptions **(Xilinx XC3S200 Spartan-III)**

- and 112 communication interfaces
  - the most used RF **(TI / Chipcon CC2420)**
  - the most used optical **(IrDa transceivers)**

Results – processing units

- nodes with one processing unit **(Mica mote, Livenode, etc.)**
- 4 % of analysed nodes have multiple processing units **(UCLA Medusa MK-2, AVR Raven, etc.)**
- 7 % of all are based on various processing units **(Ember, SquidBee, etc.)**
- 12 % use processing units as part of SoC (processing unit/radio) chips **(RFRAIN, RISE, etc.)**

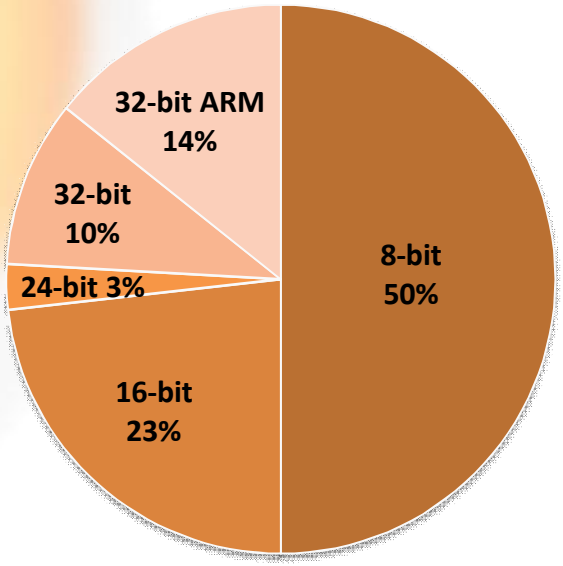
Results – processing units

According to observed clock frequencies, Flash, ROM, RAM, and SRAM memories processing units can be divided in to:

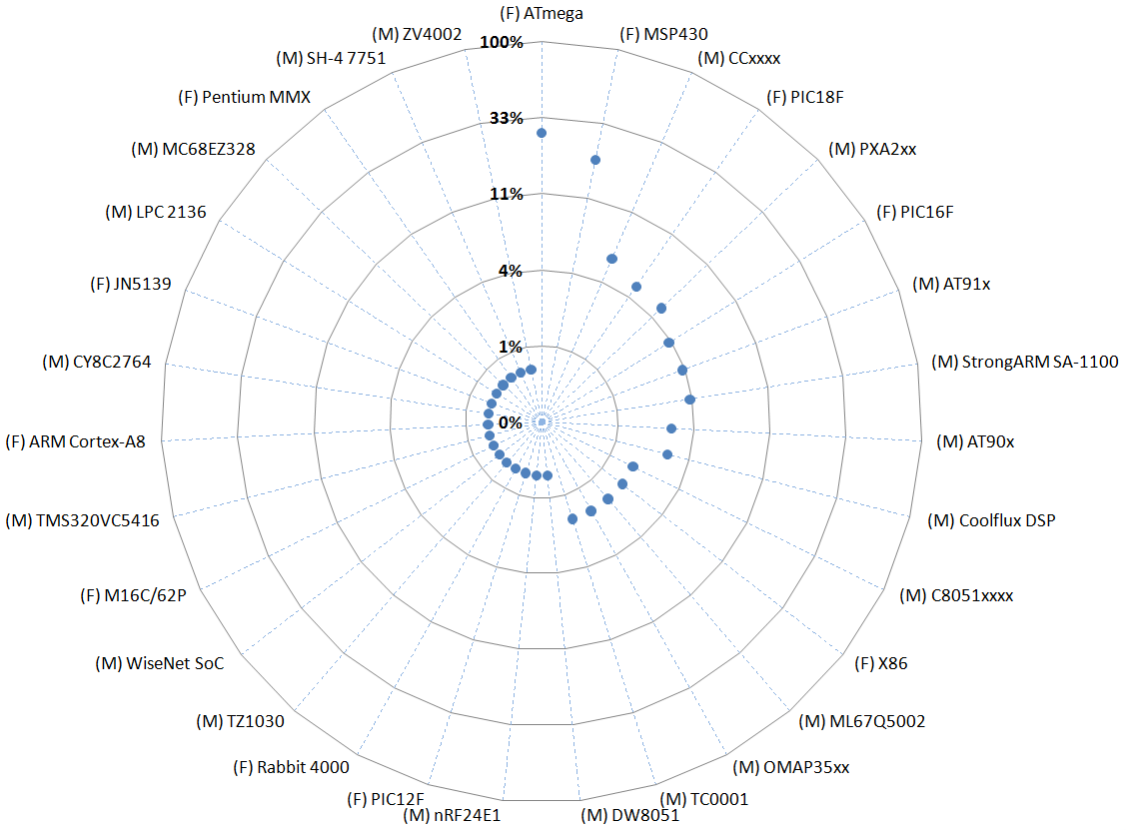
- average and low capability units **(BSN node, Kmote, etc.)**
  - Clock frequencies in average extend between 4 MHz and 32 MHz
  - Flash and ROM memory frontier around 256 kB
- more advanced units (basically based on ARM architecture) **(Cerfcube 255, GumStix, etc.)**
  - Clock frequencies rise up to 600 MHz
  - Flash and ROM memory up to 4MB or in exceptional cases up to 32 MB

RAM and SRAM memory comparison does not reveal specifities

Results – processing units



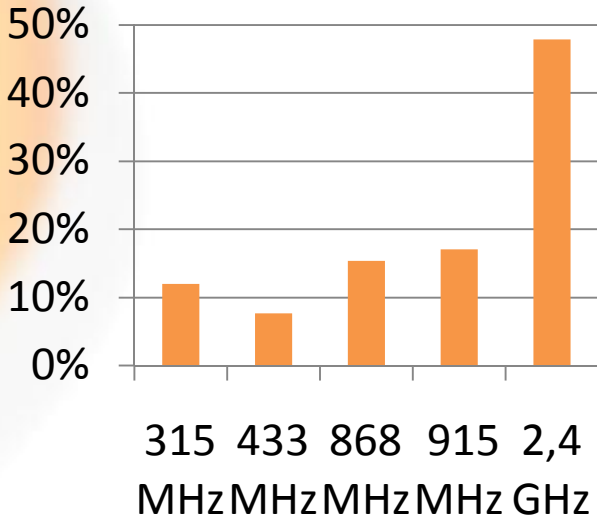
distribution of architectures



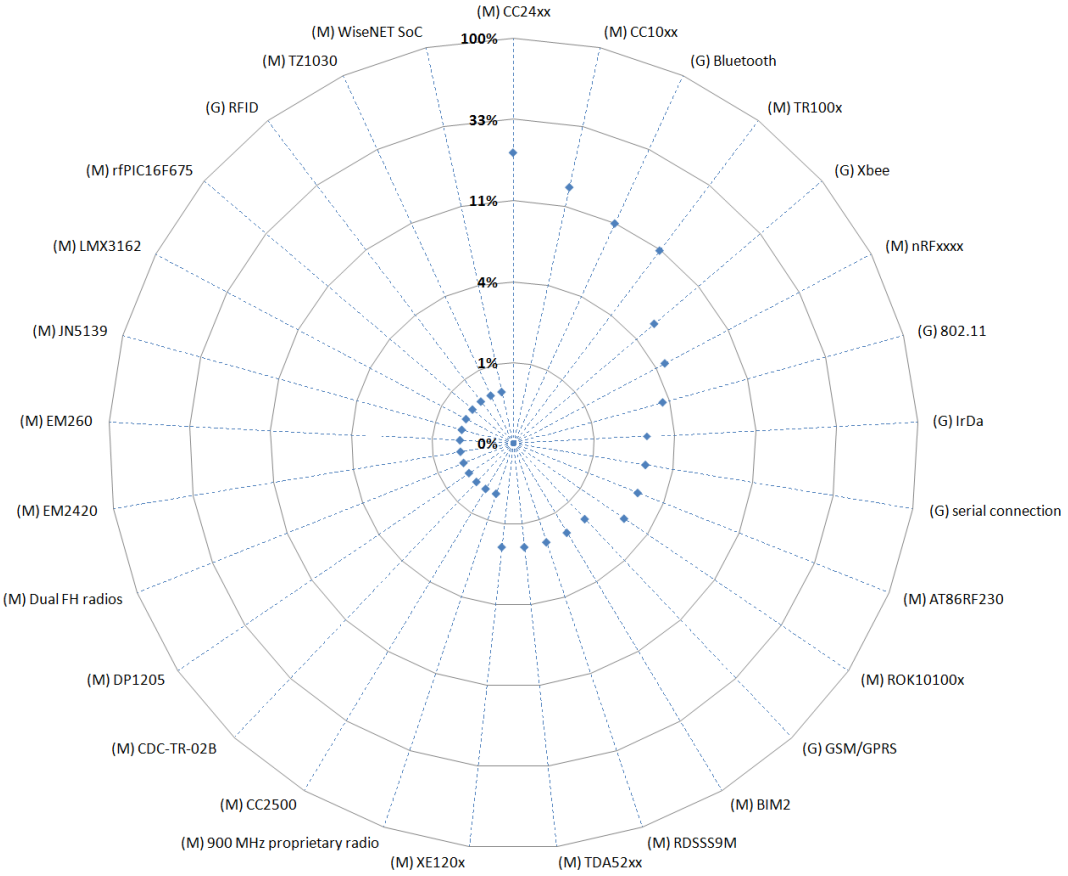
usage of processing units

(F) - *family*
(M) – *model*

Results – communication interfaces



distribution of frequency bands



usage of communication interfaces

Results – communication interfaces

- Data-rates
  - high data-rates (i.e. > 1000 bps) **(Stargate, Sensoria WINS NG 3.0, etc.)**
    - **IEEE 802.11 units**
      - adapted general-purpose computers (Wi-Fi routers)
        - usually constant power supply
      - adapted general-purpose computers (smartphones) and embedded sensor nodes
        - rapidly consume battery power
  - medium data-rates (i.e. ~1000 bps) **(Smart-its, BTNode rev3, etc.)**
    - **Bluetooth radios**
      - usually do not require constant power supply and can last on battery power for a while
  - low data-rates (i.e. ~100-250 bps) **(Sentio, iSense, etc.)**

    data-rates < 100 bps **(PushPin, cPart, etc.)**

    data-rates of only few bps **(SpotON, PC 104+, etc.)**

    - **dedicated RF interfaces**

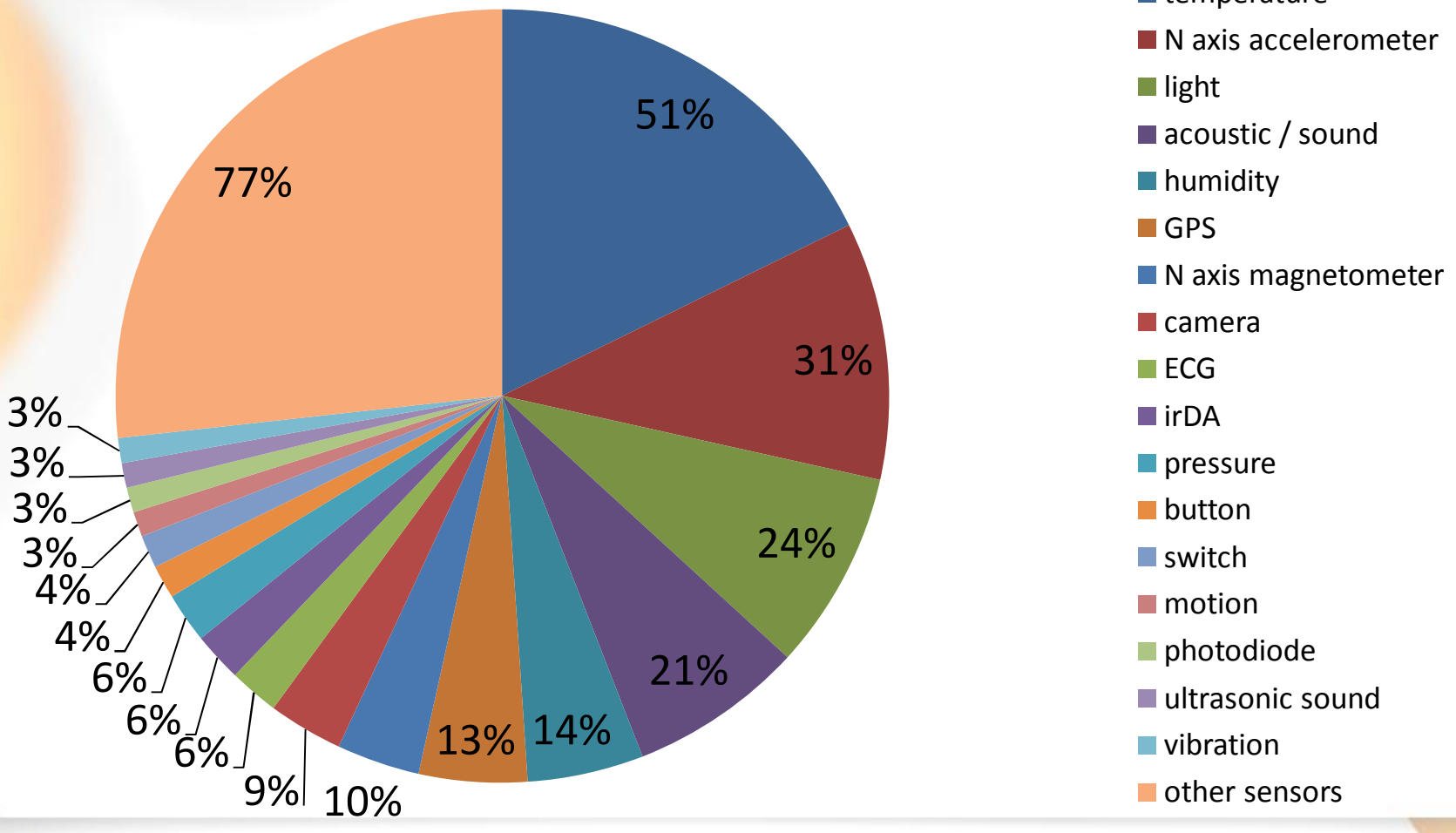
Should be interpreted as real “low-data rates”.

Results – communication interfaces

- **13 %** SoC (processing unit/radio) chips operating as RF units **(RFRAIN, RISE, etc.)**
- **5 %** more than one communication unit **(BTNode rev3, Shimmer, etc.)**
- **13 %** produced in various hardware versions with various RF units **(SquidBee, Mulle v3, etc.)**

- **44 %** external antenna (whip) **(WiseNet, cPart, etc.)**
- **36 %** onboard antennas (PCB, chip) **(Toumaz ECG, Intel Zeevo, etc.)**
- **17 %** both antenna types supported at the same time) **(eyesIFXv2, Cricket, etc.)**
- **3 %** of the nodes do not have antenna, but are equipped with optical or wired communication interfaces **(PushPin, PC 104 node, etc.)**

Results – sensors



Results –categories of sensor nodes

- Identified sensor nodes can be presented with 7 categories:

- Category 1: (SoC-stack)
- Category 2: (ePU/eCU-stack)
- Category 3: (ePU-stack/eCU)
- Category 4: (mPU/CU)
- Category 5: (cPU/CU)
- Category 6: (PU/mCU)
- Category 7: (PU/cCU)

PU - *processing unit*
ePU - *external processing unit*
CU - *communication unit*
eCU - *external communication unit*
SoC - *system on chip (PU and CU)*
stack - *protocol stack*
m - *multiple units used simultaneously*
c - *unit choice*

Thank you!

Questions?

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