



Conference

Warsaw, 15 October 2019

**Novel technological innovations
for occupational safety and health**

WIRELESS SENSOR NETWORKS FOR MONITORING AND REDUCTION OF NOISE HAZARDS

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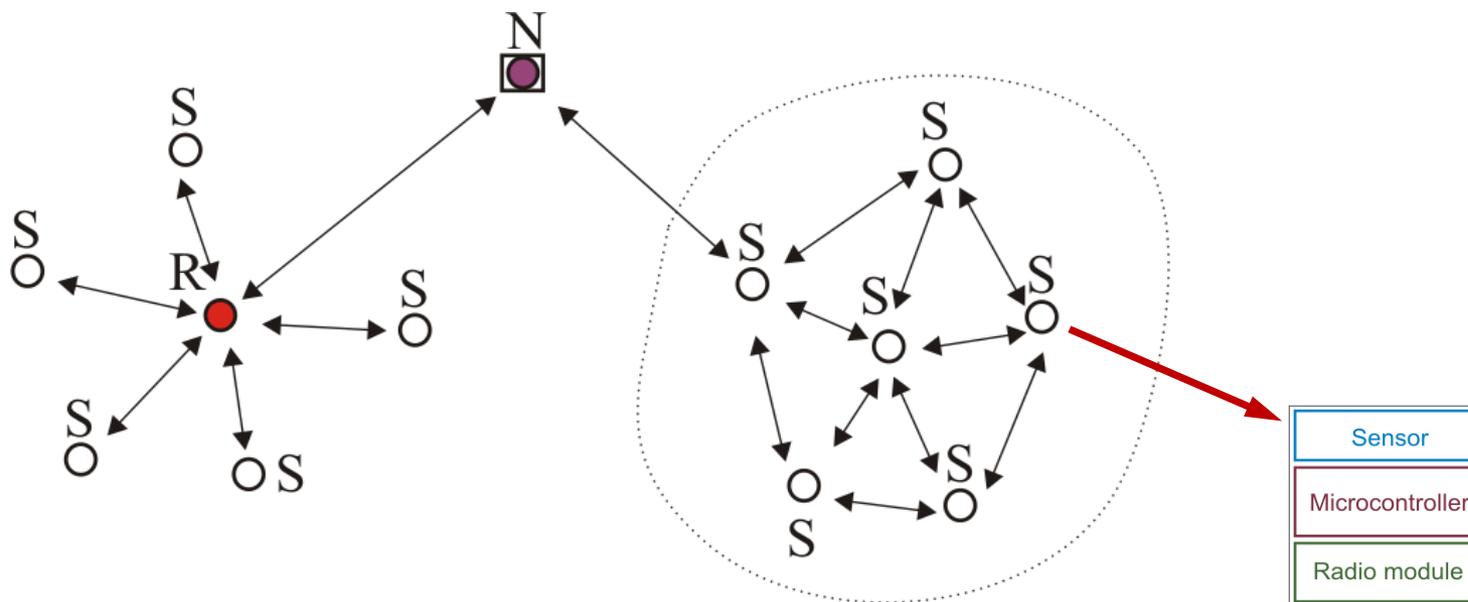
Outline

- Introduction to wireless sensor networks
- Applications of wireless sensor networks
- The use of renewable energy sources to power wireless sensor networks
- Conclusions

Introduction to wireless sensor networks

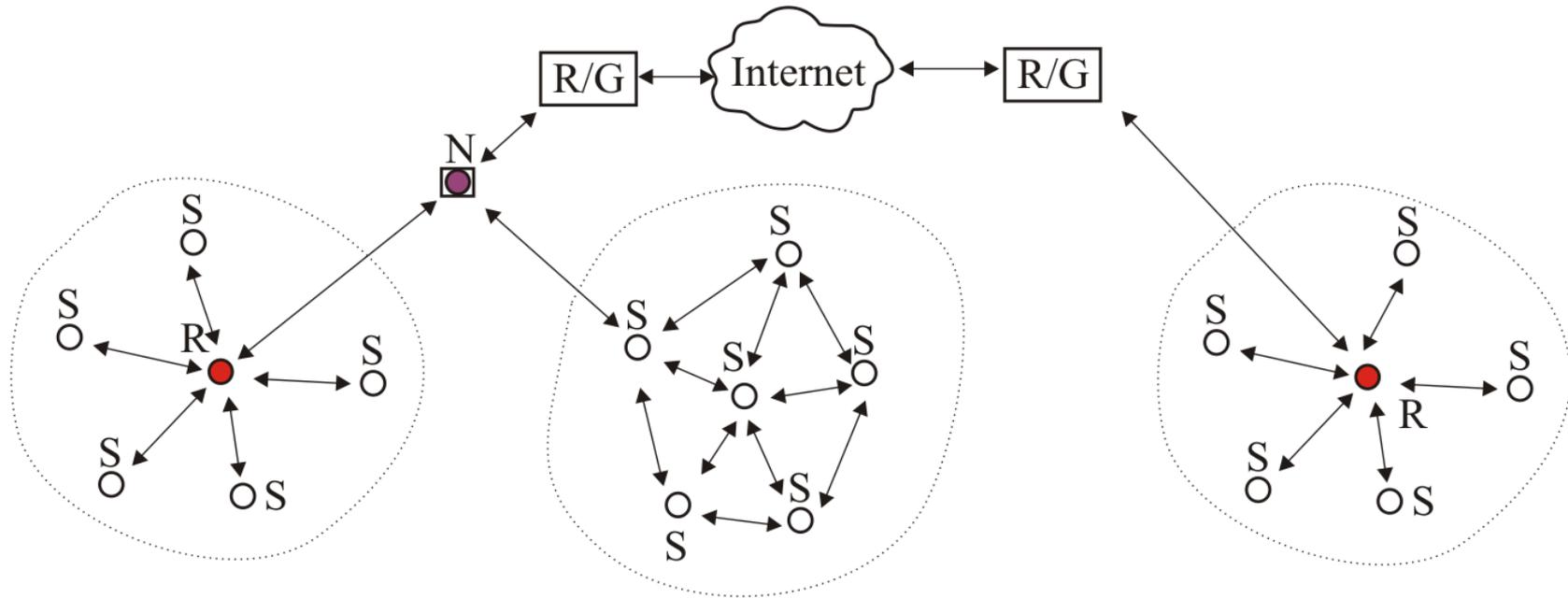
Wireless Sensor Network (WSN)

Wireless Sensor and Actuator Network (WSAN)



A group of specialized sensors and actuators with infrastructure for wireless communication, designed to monitor and control the state of physical systems or the environment in various locations, forming a network through which data and control commands are transmitted

Internet of Things (IoT)



Kevin Ashton, 1999, Procter & Gamble

Ashton K., That 'Internet of Things' Thing, RFID Journal, <http://www.rfidjournal.com/articles/view?4986>

Standards of wireless communication

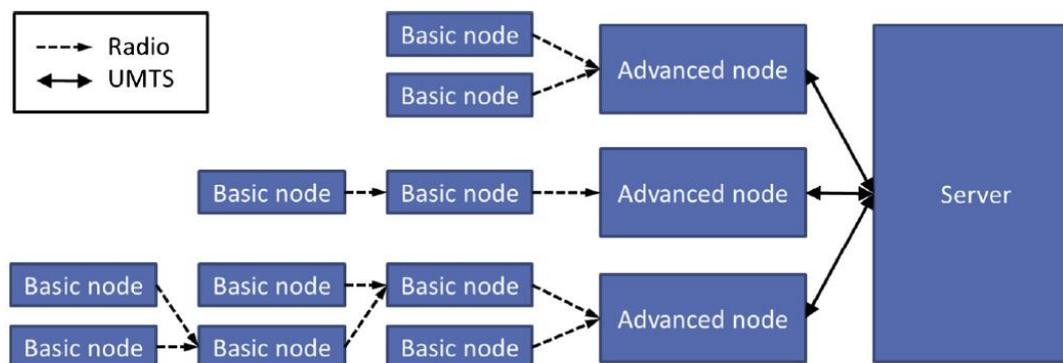
Standard	Bluetooth	Bluetooth LE	Wi-Fi	ZigBee	Z-Wave	Thread / 6LoWAPN
Network	PAN	PAN / BAN	LAN	PAN / LAN	LAN	LAN
Topology	Star	Star	Star	Star Mesh Tree	Mesh	Mesh Star
Power consumption	Low	Very low	Low to high	Very low	Very low	Very low
Bandwidth	700 Kb/s	1 Mb/s	11 – 100 Mb/s	250 Kb/s	40 Kb/s	250 Kb/s
Range [m]	30	5 – 10	4 – 20	10 – 300	30	800

WSNs applications

- *industrial automation*
- *smart homes / buildings / cities*
- *health care / health monitoring*
- *weather monitoring*
- *construction monitoring*
- *agriculture and forestry*
- ***environmental monitoring***

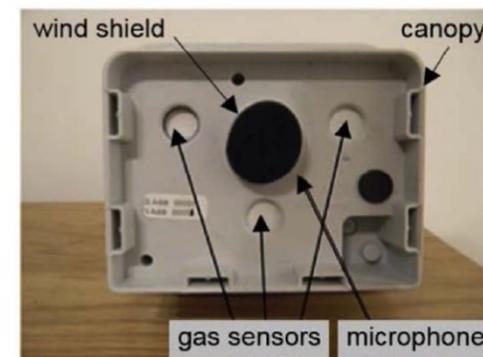
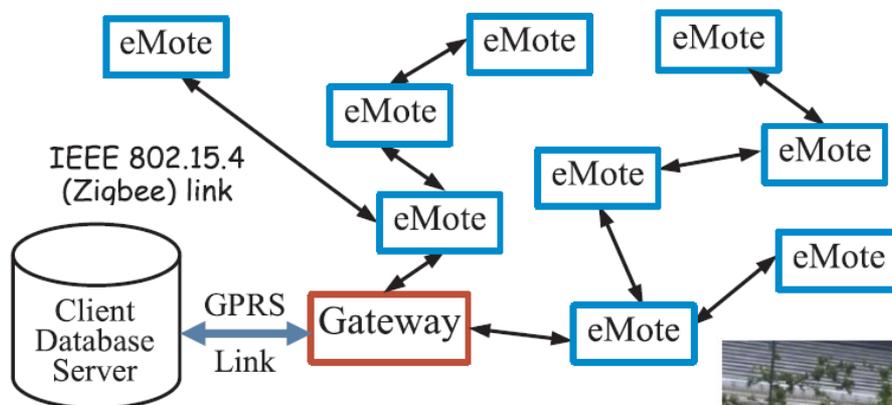
Examples of WSN applications for noise monitoring

WSN applications for noise monitoring



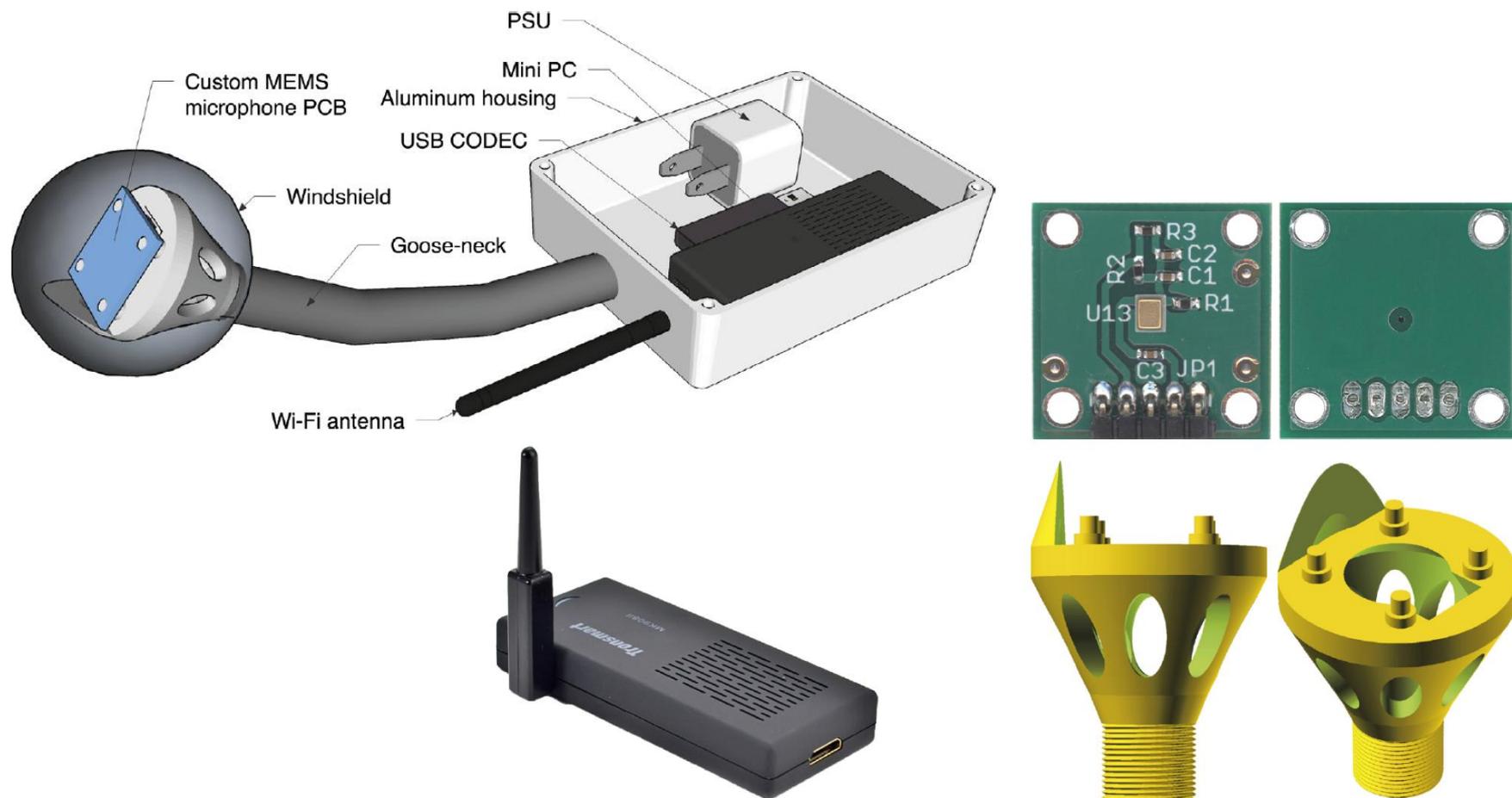
Wessels P. W., Basten T. G. H., Design aspects of acoustic sensor networks for environmental noise monitoring, Applied Acoustics, 110, 2016

WSN applications for noise monitoring



Marouf S., Bell M. C., Goodman P., Namedo A., Neasham, Pervasive wireless sensors: A new monitoring tool for road traffic noise evaluation, Applied Acoustics, 135, 2018

WSN applications for noise monitoring



Mydlarz Ch., Salamon J., Bello J. P., The implementation of low-cost urban acoustic monitoring devices, Applied Acoustics, 117 part B, 2017

WSNs applications for monitoring and reduction of noise hazards - CIOP-PIB research works

Wireless monitoring system supporting correct use of earmuffs

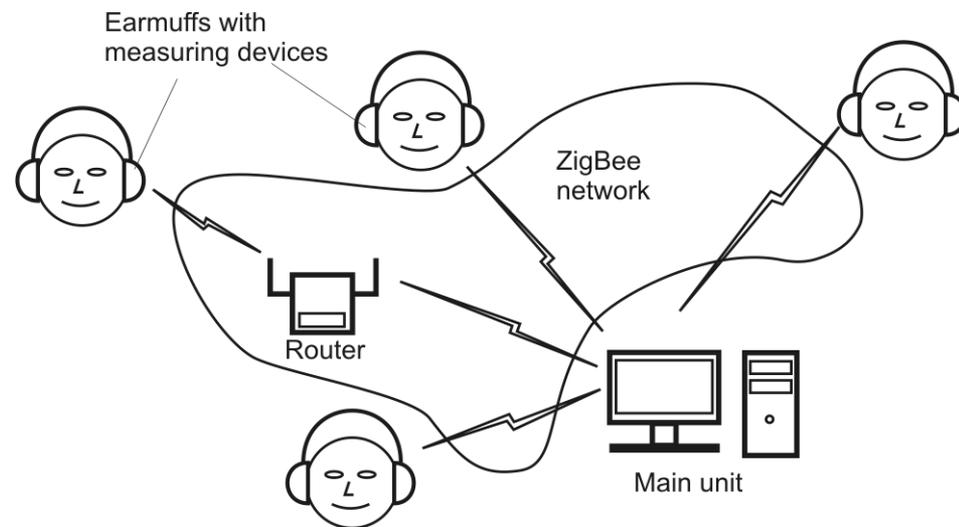
Earmuffs with electronic circuits



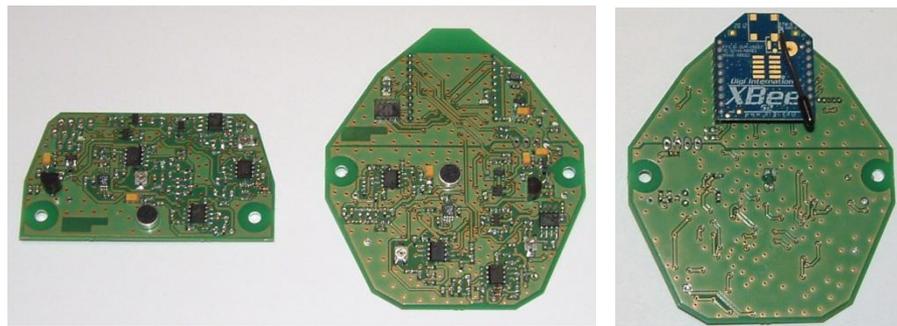
Structure of the system

The system consists of:

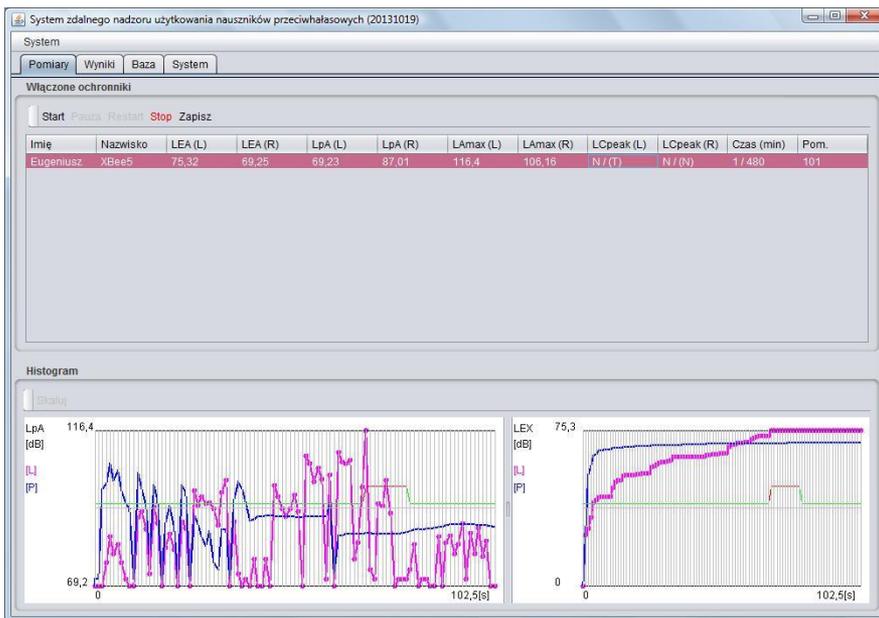
- earmuffs, including measuring devices integrated with a radio module for wireless data transmission,
- a wireless data transmission network (ZigBee),
- a main unit of the system processing noise data.



Construction of the earmuffs with measuring devices

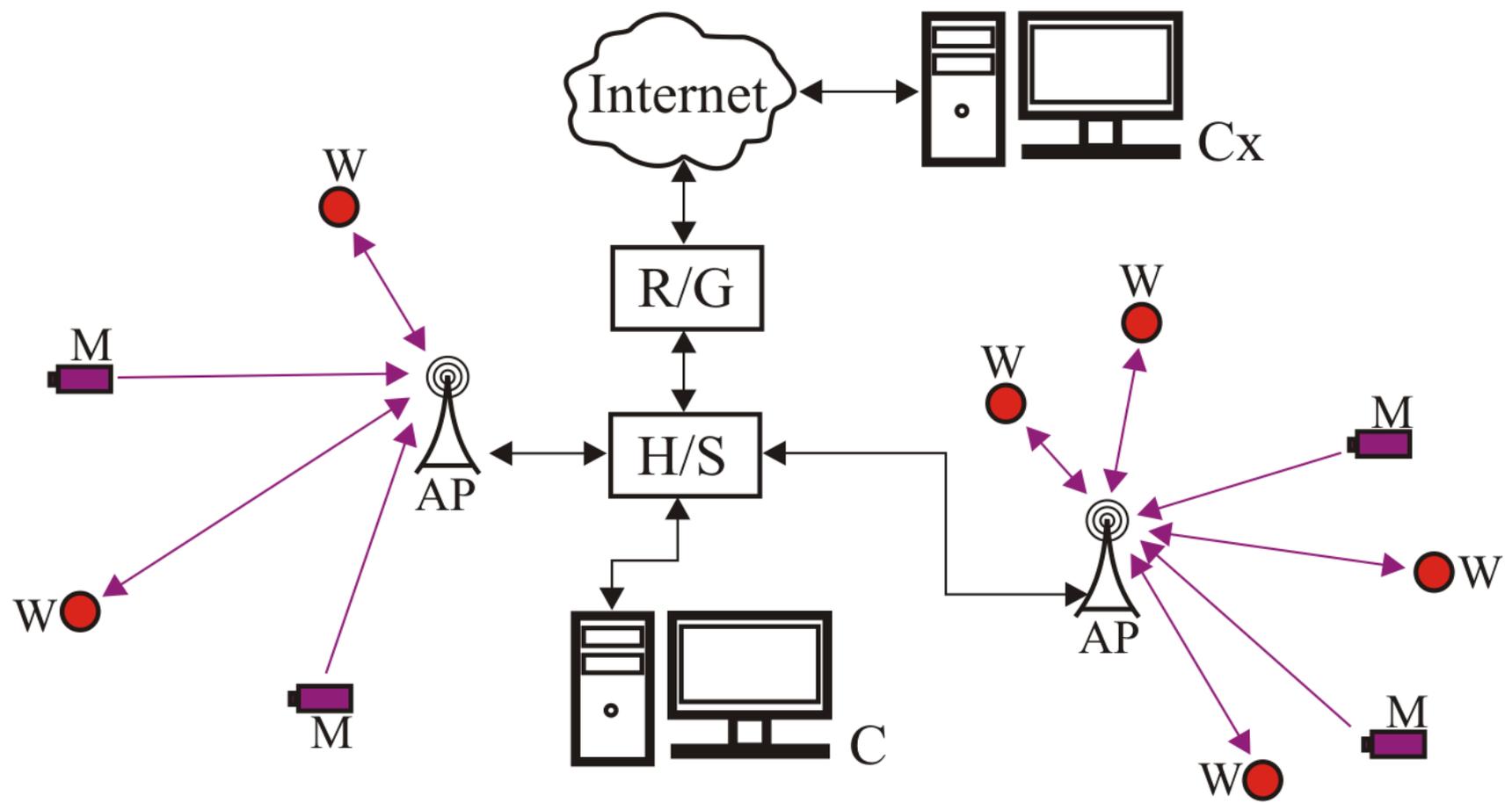


Measurement examples

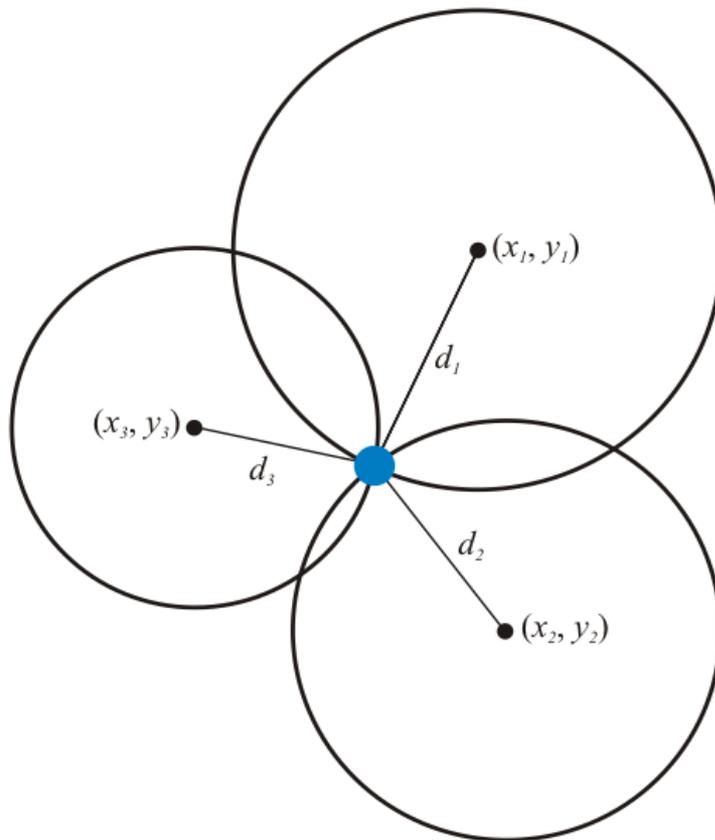


The system for monitoring the working environment and warning employees about hazards

Structure of the system



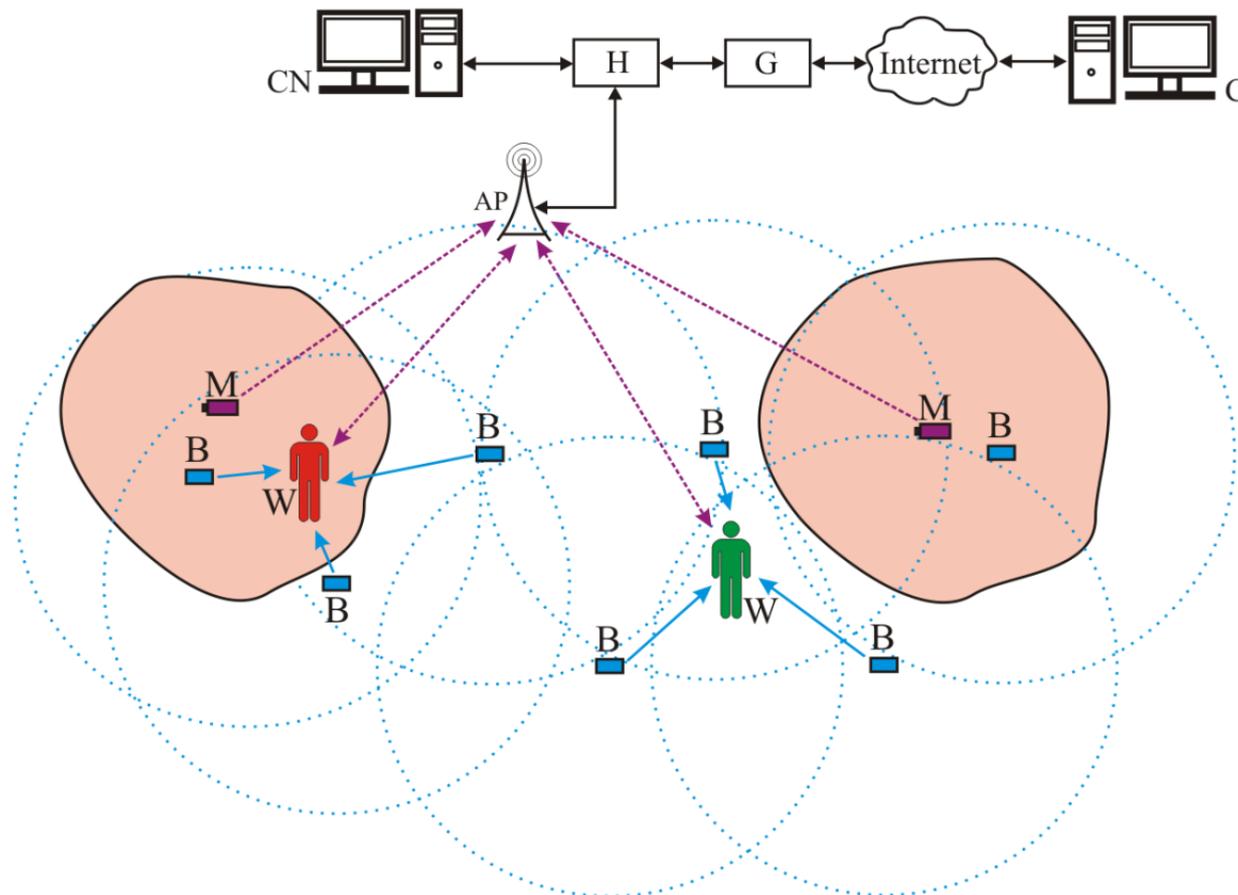
Location assessment methods - triangulation



$$P_{RX} = P_{TX} \cdot G_{TX} \cdot G_{RX} \left(\frac{\lambda}{4\pi d} \right)^2 \quad [\text{W}]$$

$$RSSI = 10 \cdot \log \frac{P_{RX}}{P_{Ref}} \quad [\text{dBm}]$$

Structure of the system

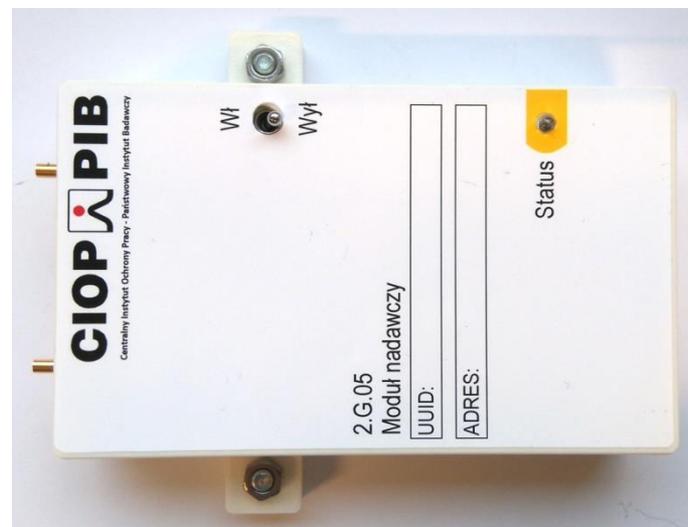
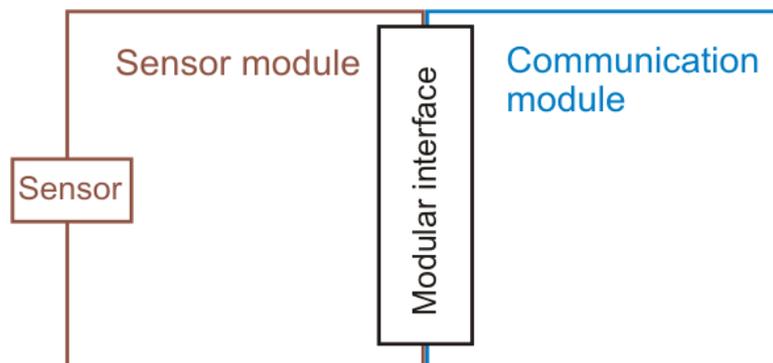


Basic structure of the system (M – measuring device, W – a person with a wearable device, B – beacon, AP – Wi-Fi access point, H – Ethernet hub, G – network gateway, CN – main unit, C – computer, blue arrows – Bluetooth LE transmission, violet arrows – Wi-Fi transmission, black arrows – Ethernet connections, pink areas – hazard zones, blue dashed circles – beacon radio transmission range).

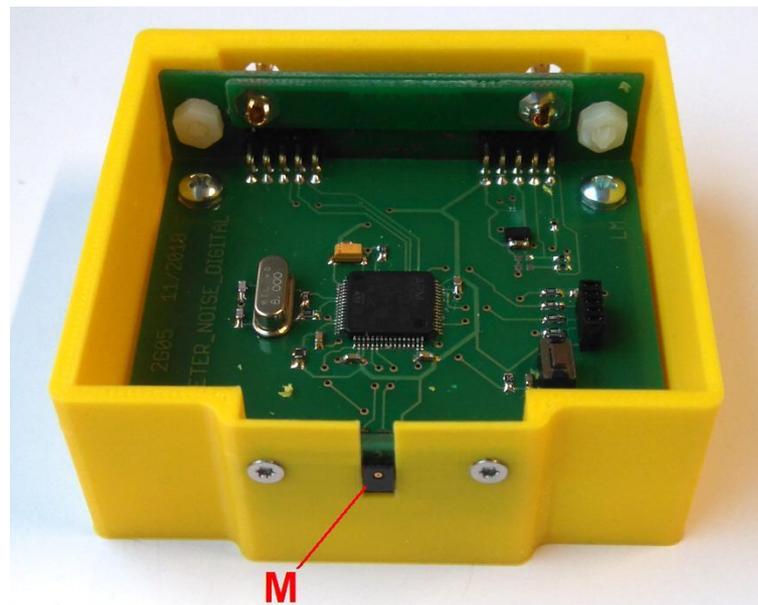
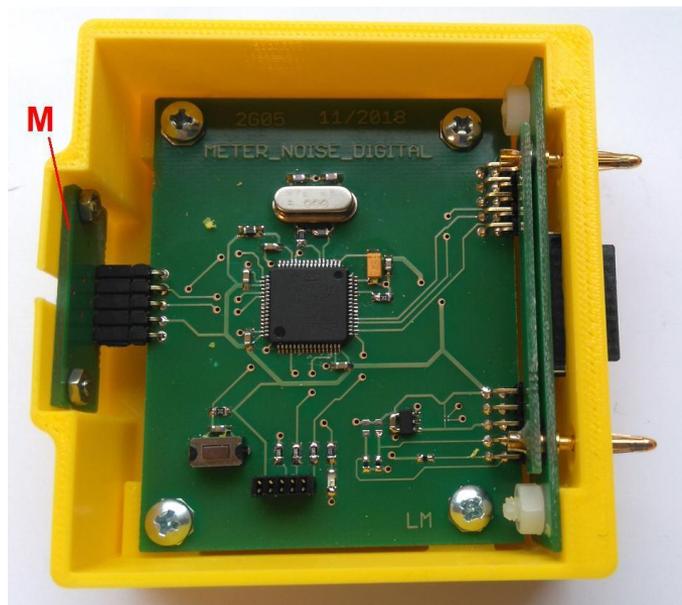
RSSI measurements

Measure ment	Distance [m]							
	0.5	1	2	3	4	5	6	7
1	-50	-56	-55	-62	-60	-58	-65	-67
2	-52	-50	-47	-64	-61	-60	-64	-65
3	-53	-51	-55	-60	-77	-61	-60	-63
4	-54	-52	-62	-59	-68	-60	-72	-63
5	-52	-51	-57	-64	-58	-60	-60	-64
6	-47	-50	-54	-61	-62	-59	-61	-64
7	-45	-54	-55	-59	-63	-60	-61	-62
8	-45	-50	-56	-64	-61	-58	-66	-64
9	-48	-51	-55	-61	-64	-61	-65	-64
10	-50	-51	-57	-58	-69	-57	-65	-64
11	-50	-52	-56	-56	-60	-62	-64	-69
12	-50	-55	-56	-61	-65	-61	-69	-67
13	-50	-51	-57	-59	-57	-58	-60	-62
14	-48	-51	-54	-60	-65	-60	-68	-62
15	-53	-53	-54	-60	-62	-60	-61	-70
16	-50	-54	-56	-58	-65	-71	-62	-64
Av.	-49,81	-52,00	-55,38	-60,38	-63,56	-60,38	-63,94	-64,63

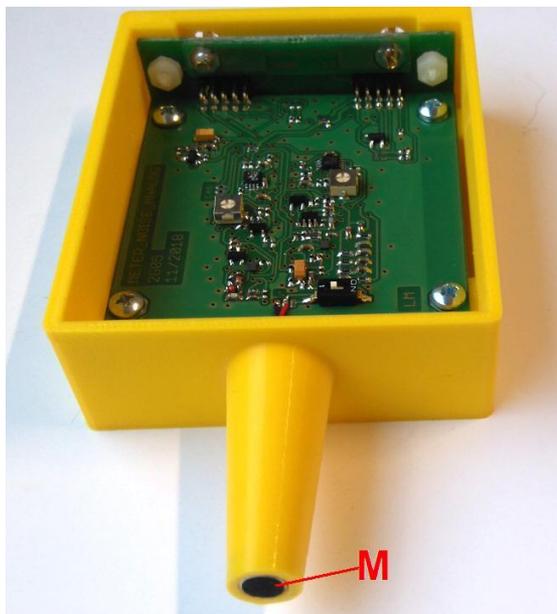
Noise measuring device - communication module



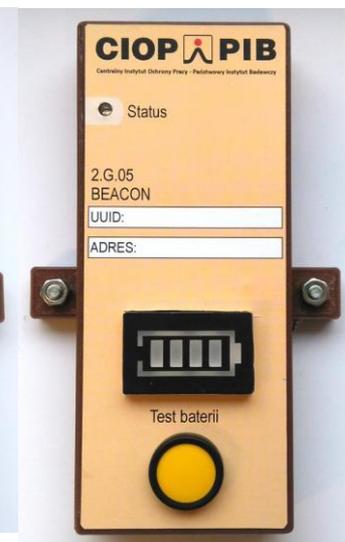
Noise measuring devices



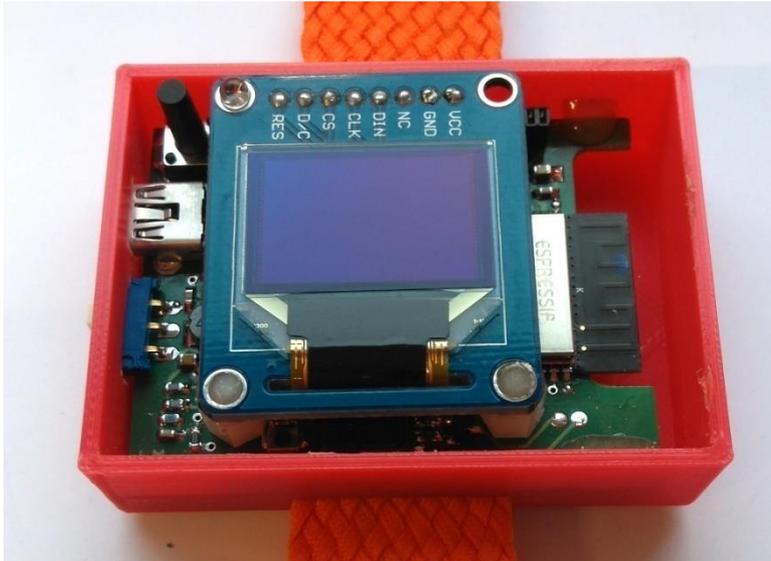
Noise measuring devices



Bluetooth beacons

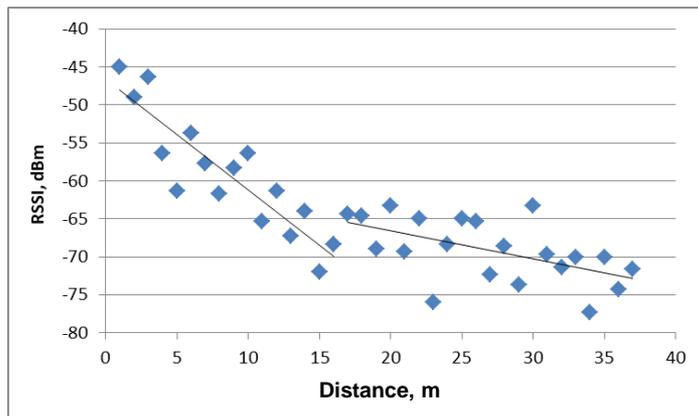
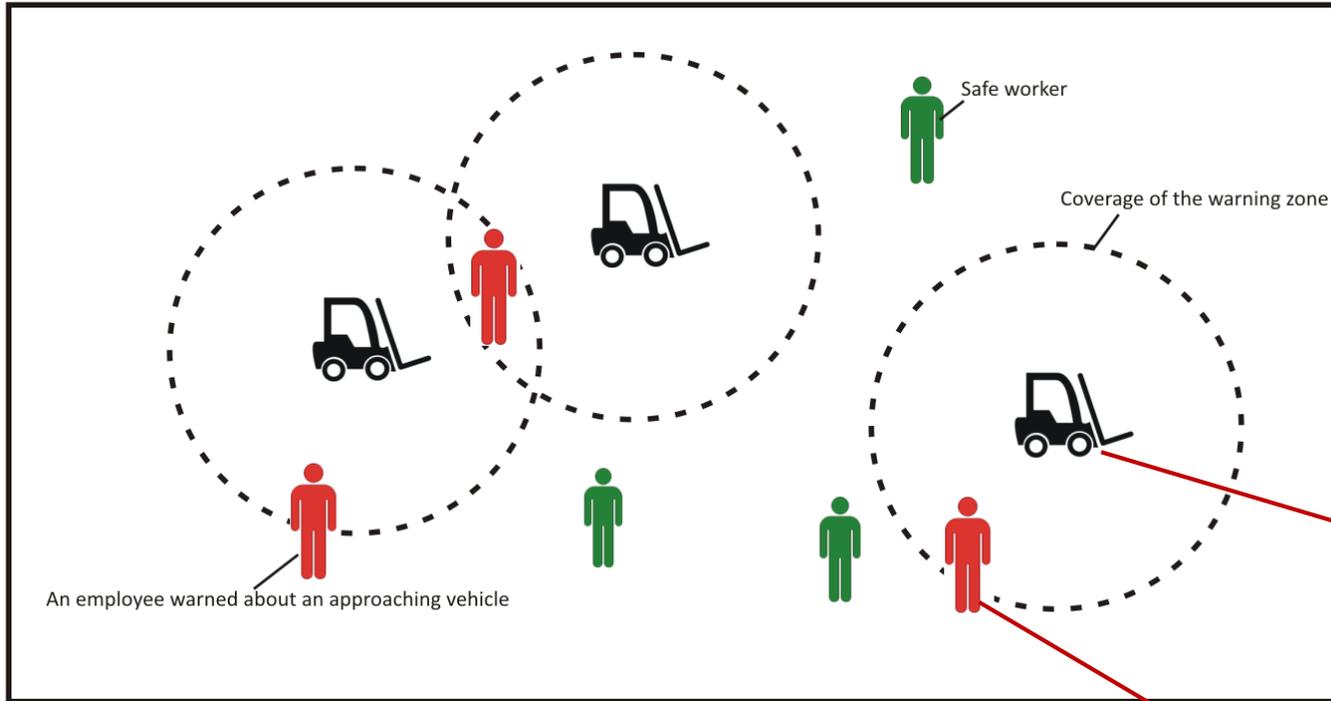


Wearable device



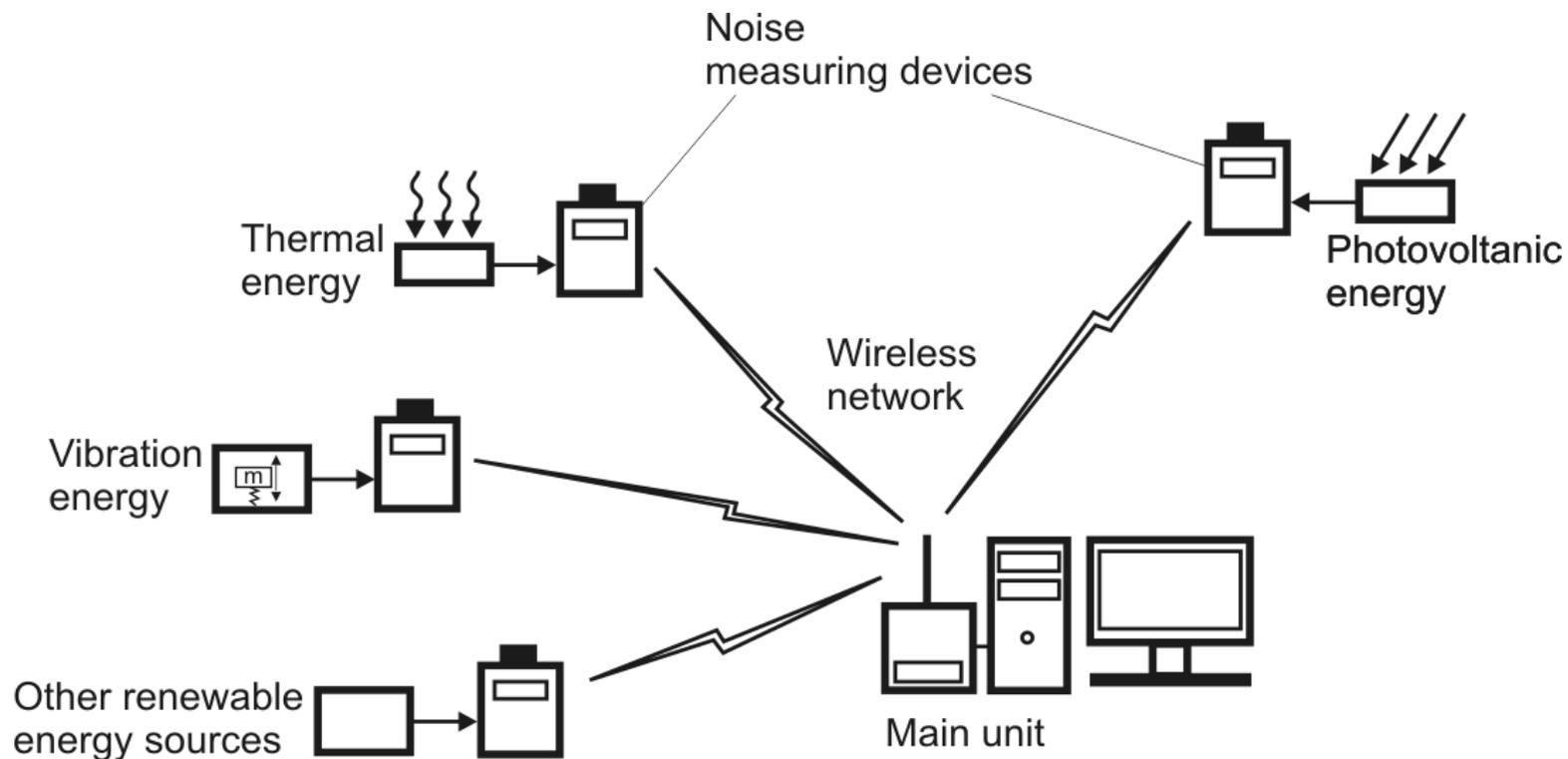
Warning system against approaching vehicles for workers using hearing protectors

The structure and operation of the system

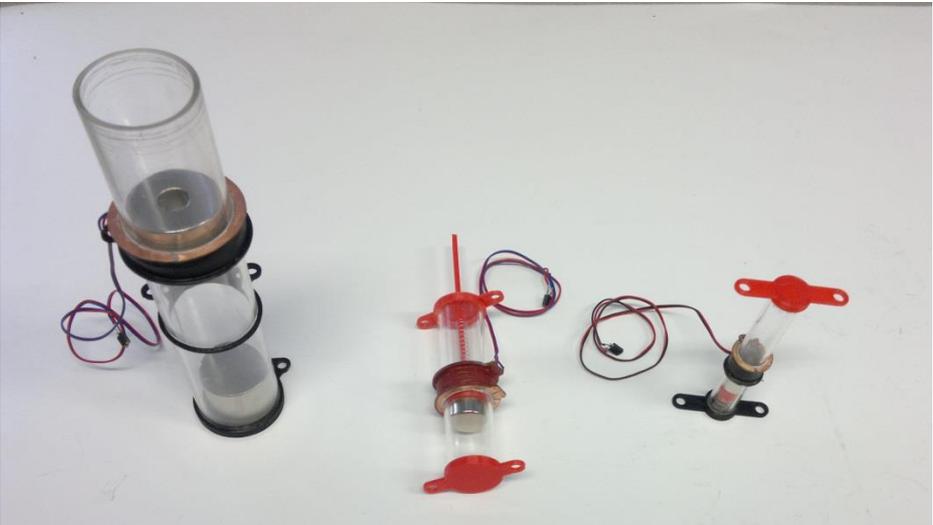
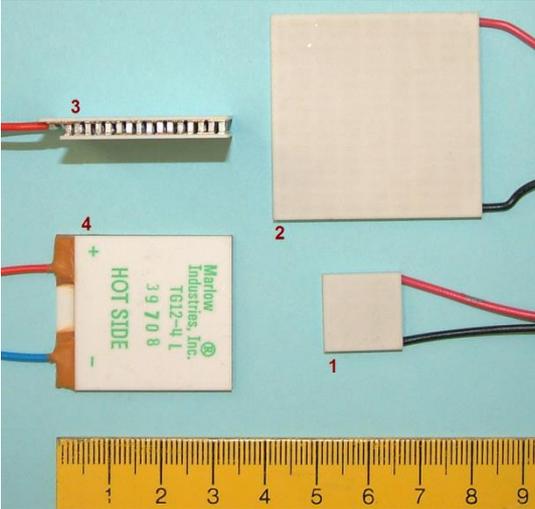


WSNs supply with the use of renewable energy sources

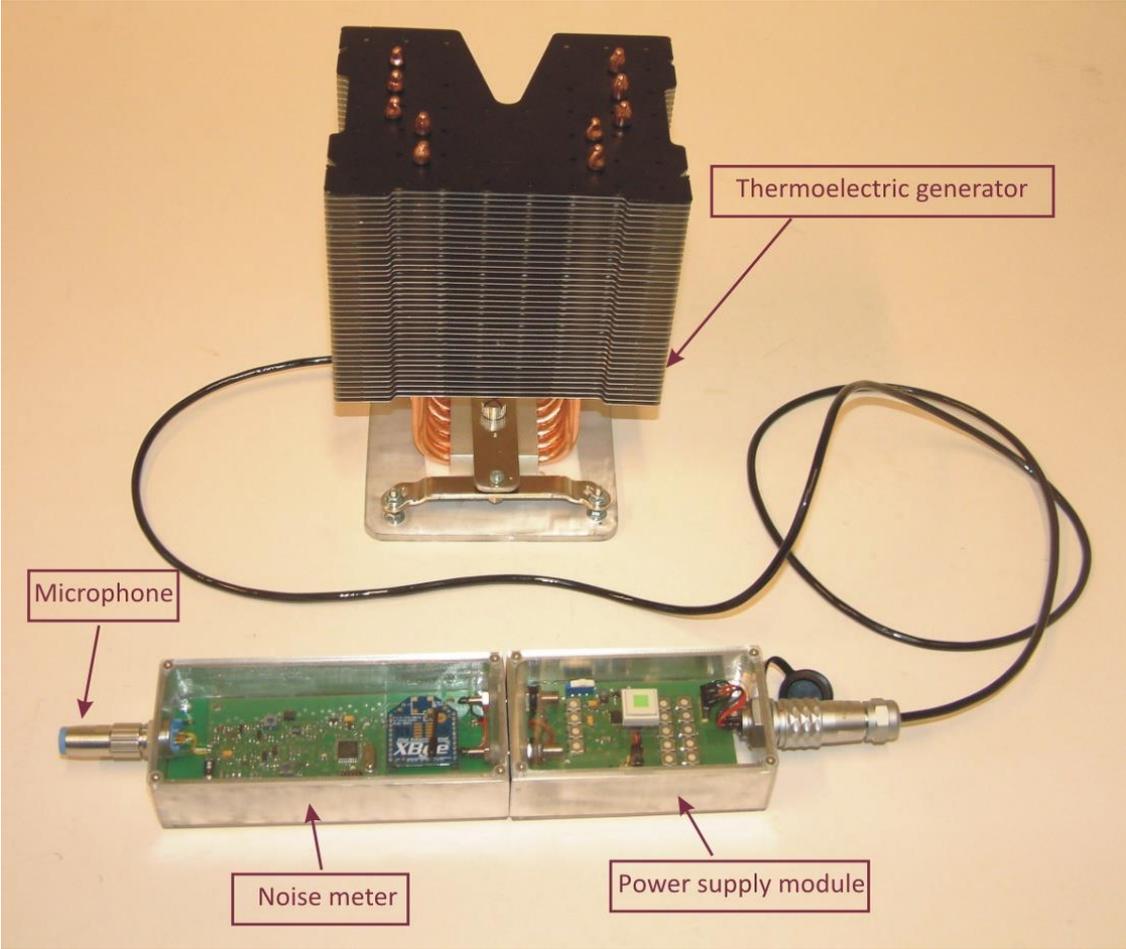
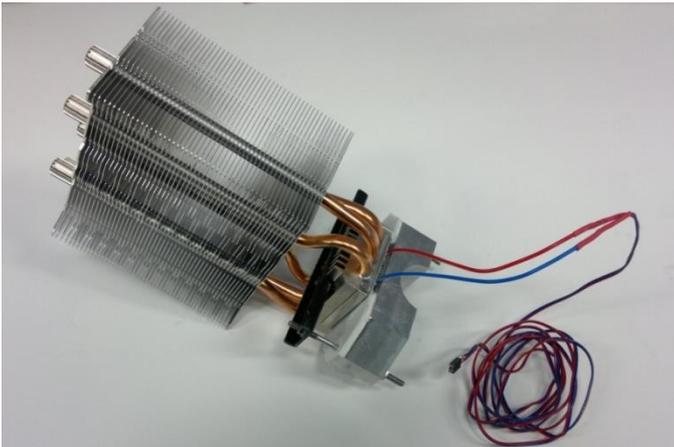
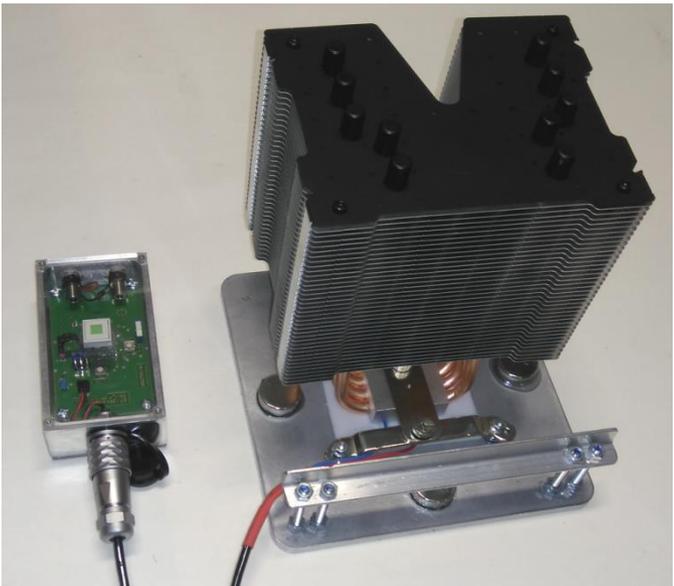
The concept of system



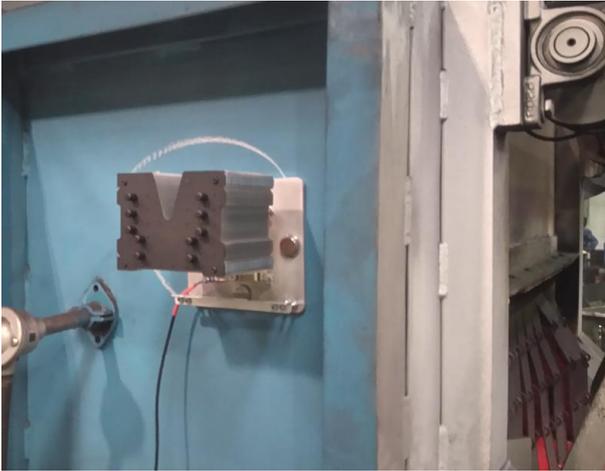
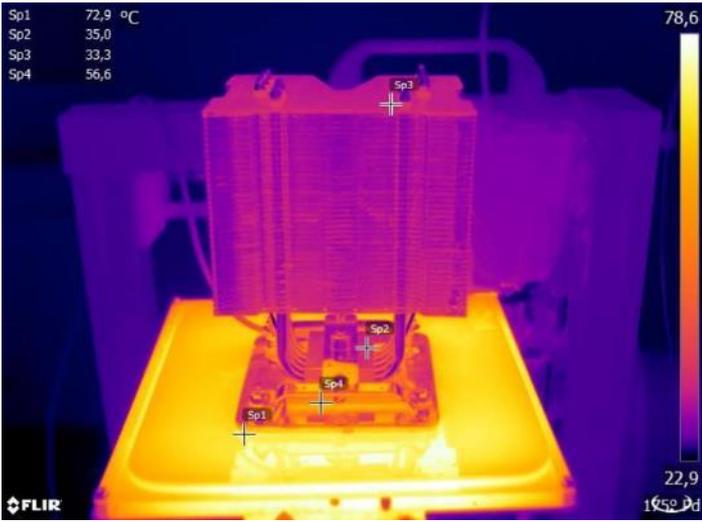
Electric generators



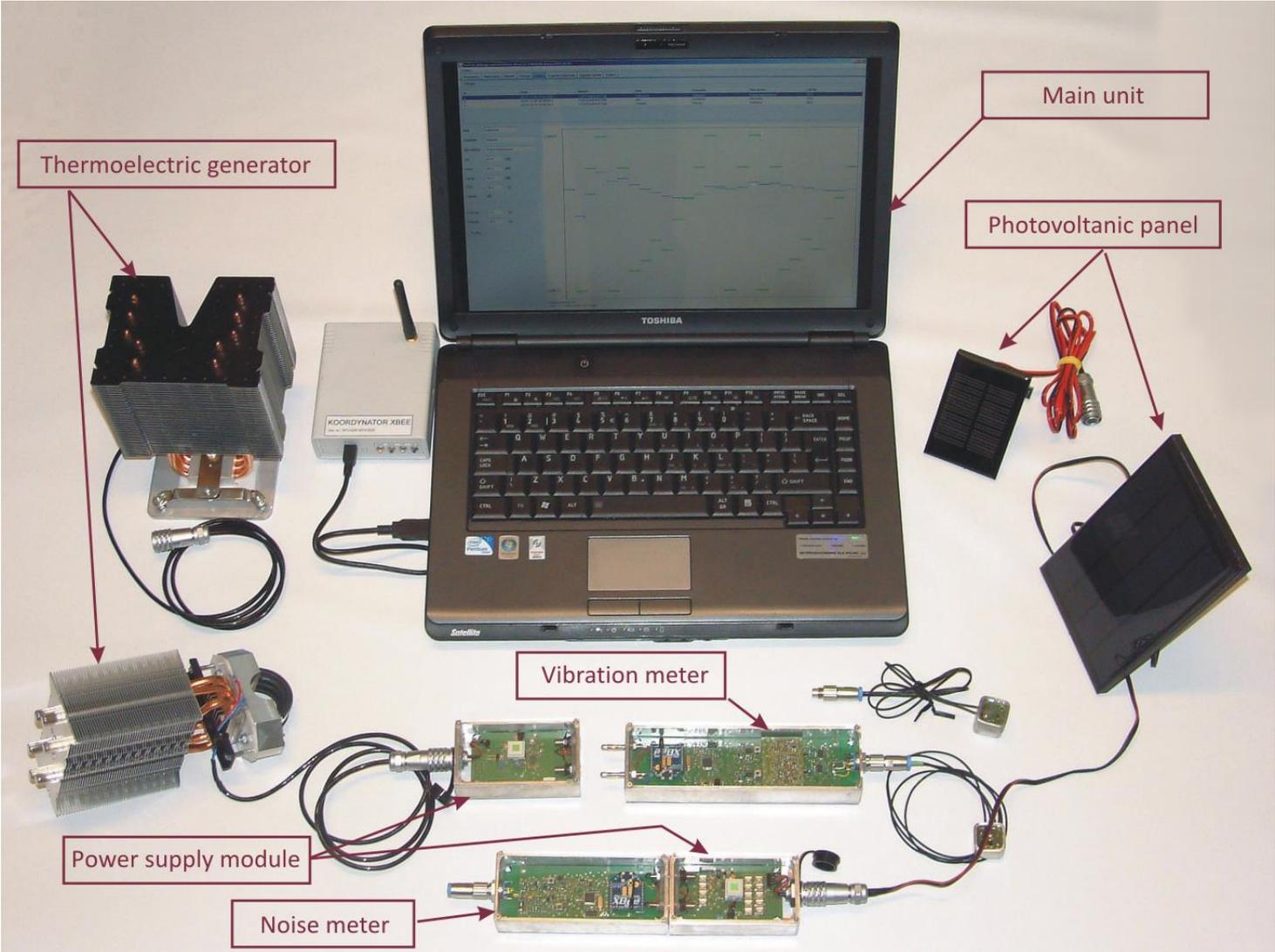
Thermoelectric generators



Thermoelectric generators



Model of the system



Conclusions

Wireless sensor networks, including those using the Internet of Things, can be an excellent tool to monitor the work environment and warning employees about hazards. Such monitoring will enable immediate reaction to emerging new hazards or changes in the already existing intensity. Data on hazards present in the workplace, collected at many of its points and in longer periods of time, will also enable appropriate design of work processes or preventive activities, limiting the exposure of employees to harmful agents in the work environment.

