

Free parking spaces detector

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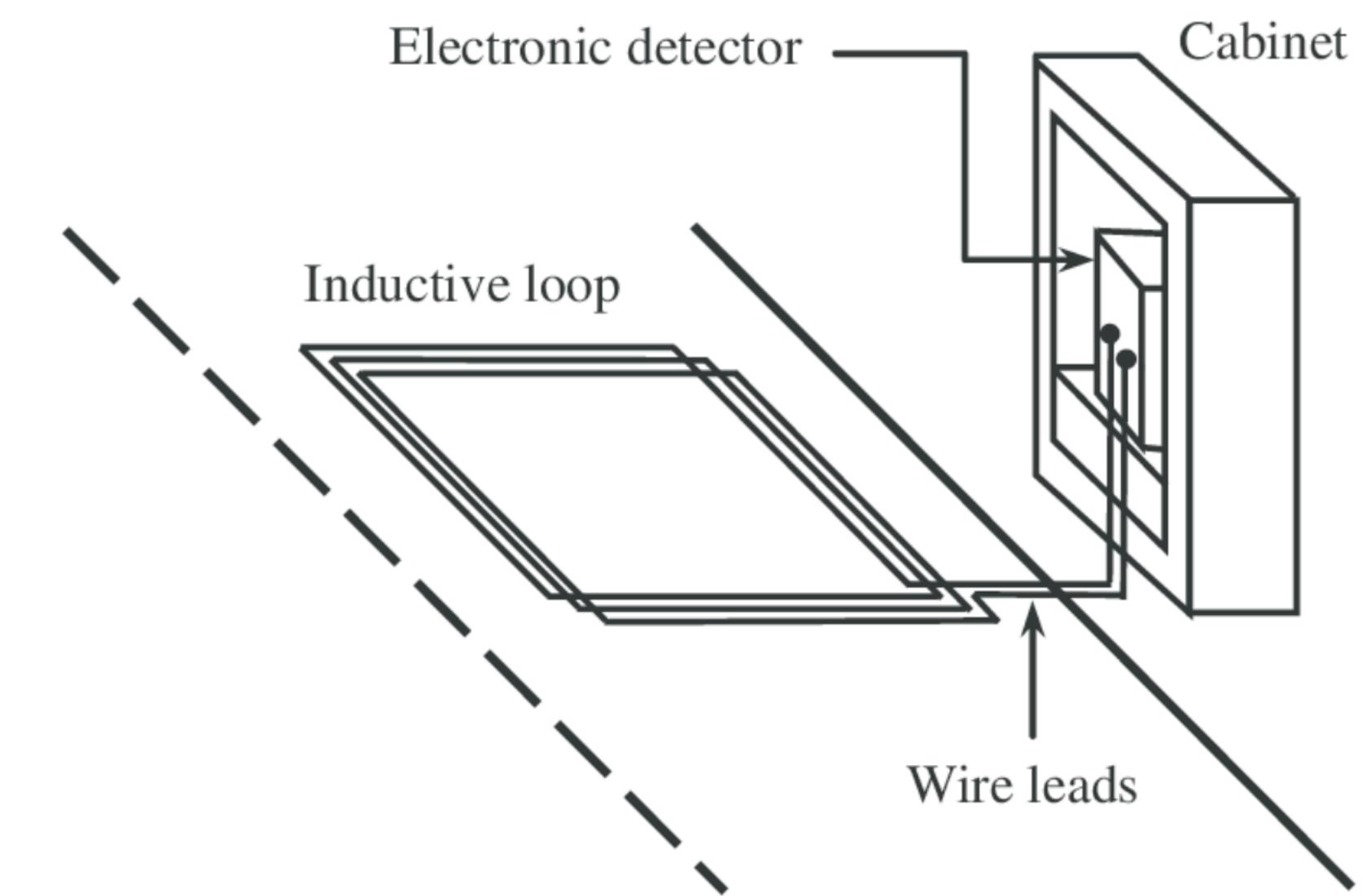
Requirements

- The system shows the availability of free parking spaces, consists of a main unit and a sensor device.
- The main unit provides operation to up to **200** sensor devices.
- Sensor device:
 - detects whether the parking space is free and sends information to the main device using the **wireless protocol**
 - is **insensitive** to dirt, swamp, snow, etc
 - has a **long battery life** (at least 1 year) or the ability to charge wirelessly.

Car detection

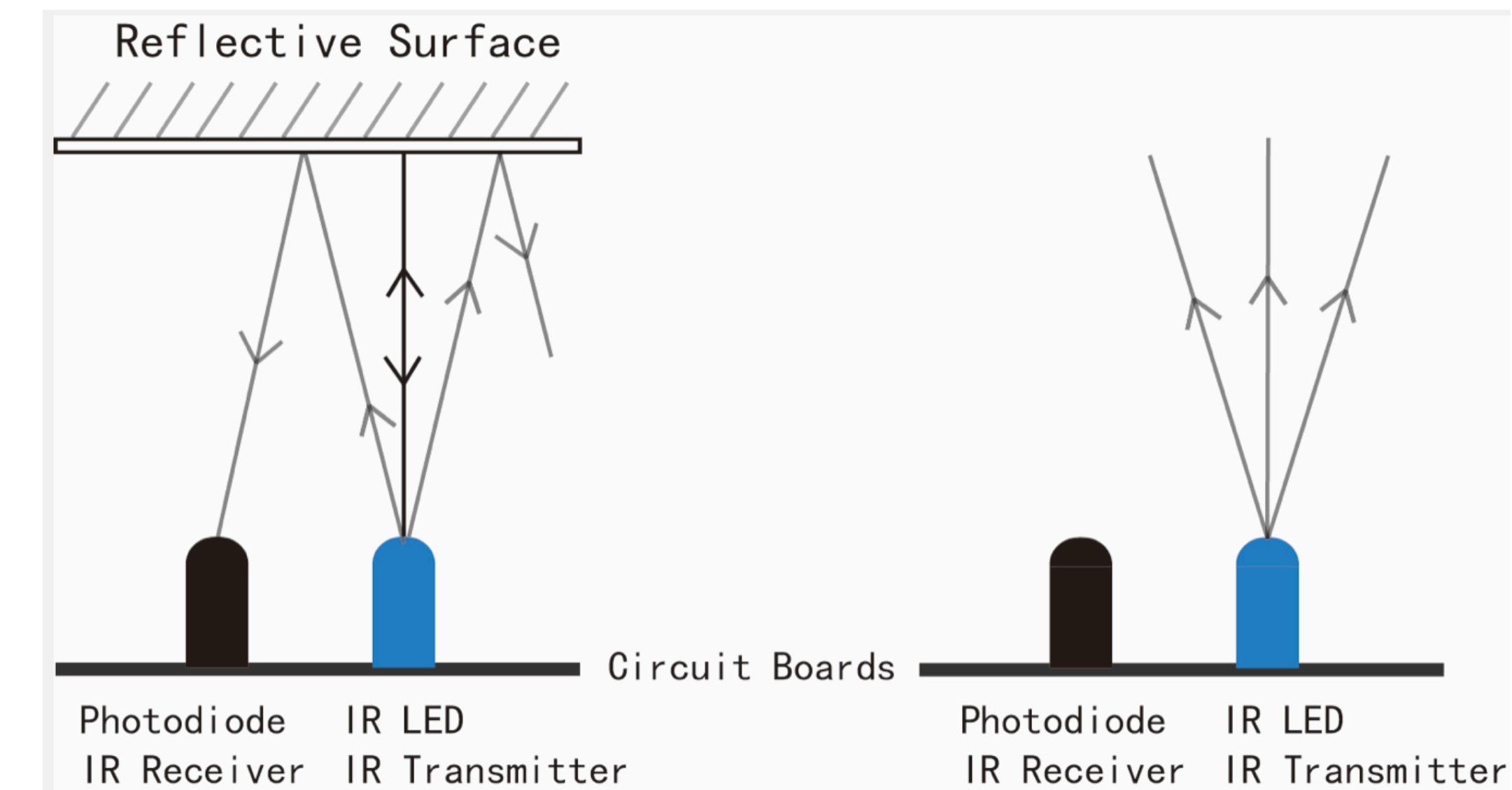
Inductive loops

- note disturbance in the magnetic field, generated by the loop (electromagnetic induction).
- Hard to install: either requires underground electrical wire or cab be really hard to achieve needed sensitivity (inductive loop becomes too small).



Infrared detectors

- Infrared sensors or the IR sensors are low frequency light emitting diodes.
- Sensitivity of the sensor is reduced in heavy rain, snow, leaves or dense fog.
- It may be hard to come up with the solution for the covered parking.

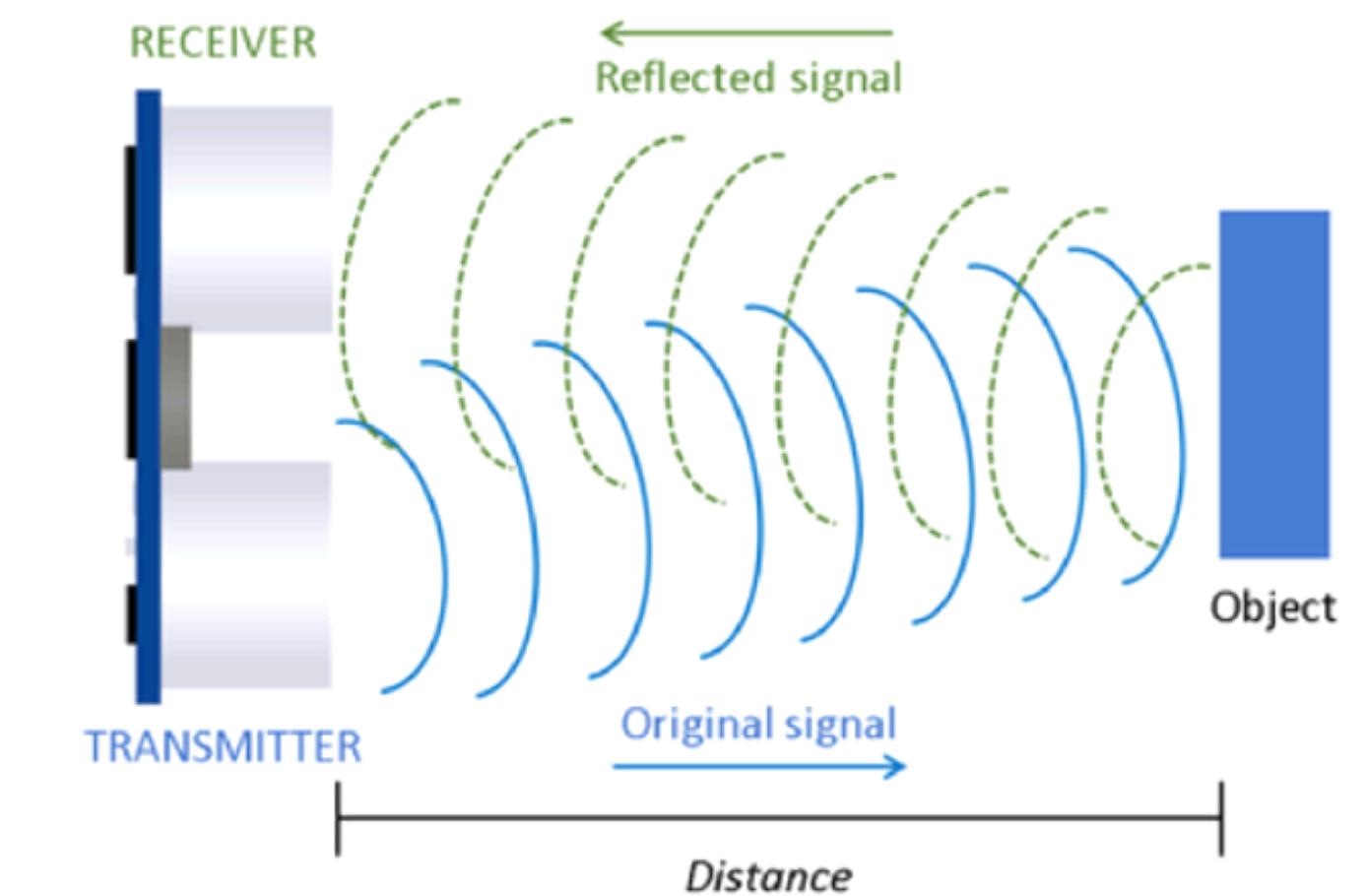
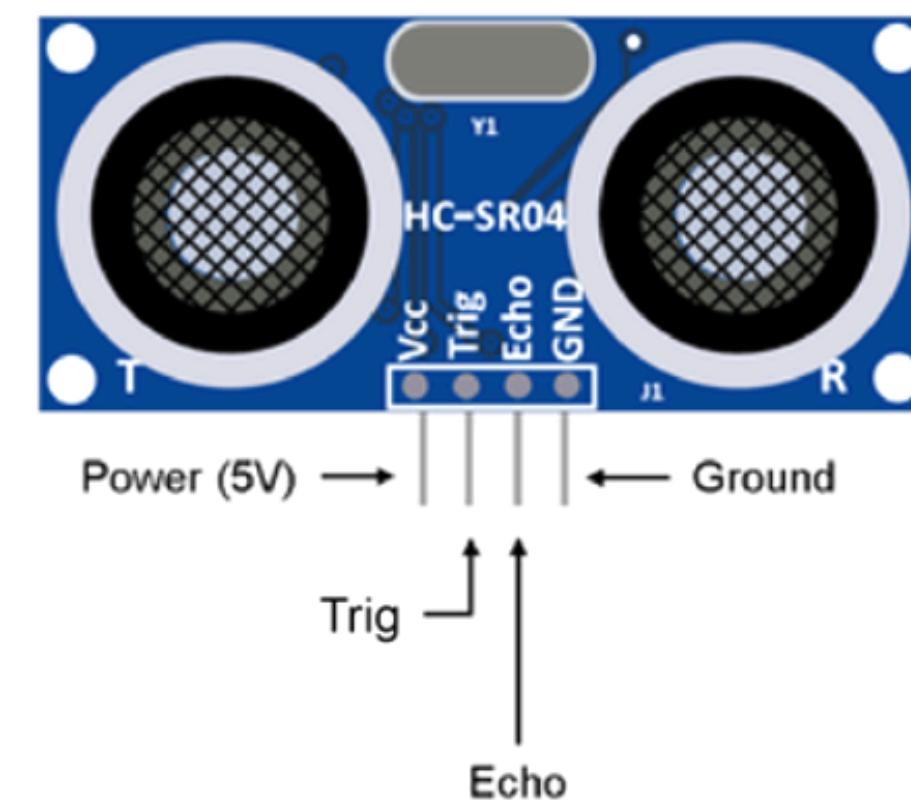


Ultrasonic Range meters.

- Use a sonar-like sound pulse (detectors are calibrated with the known distance from detector to pavement and can then note a difference in echo time to determine the presence of a vehicle)

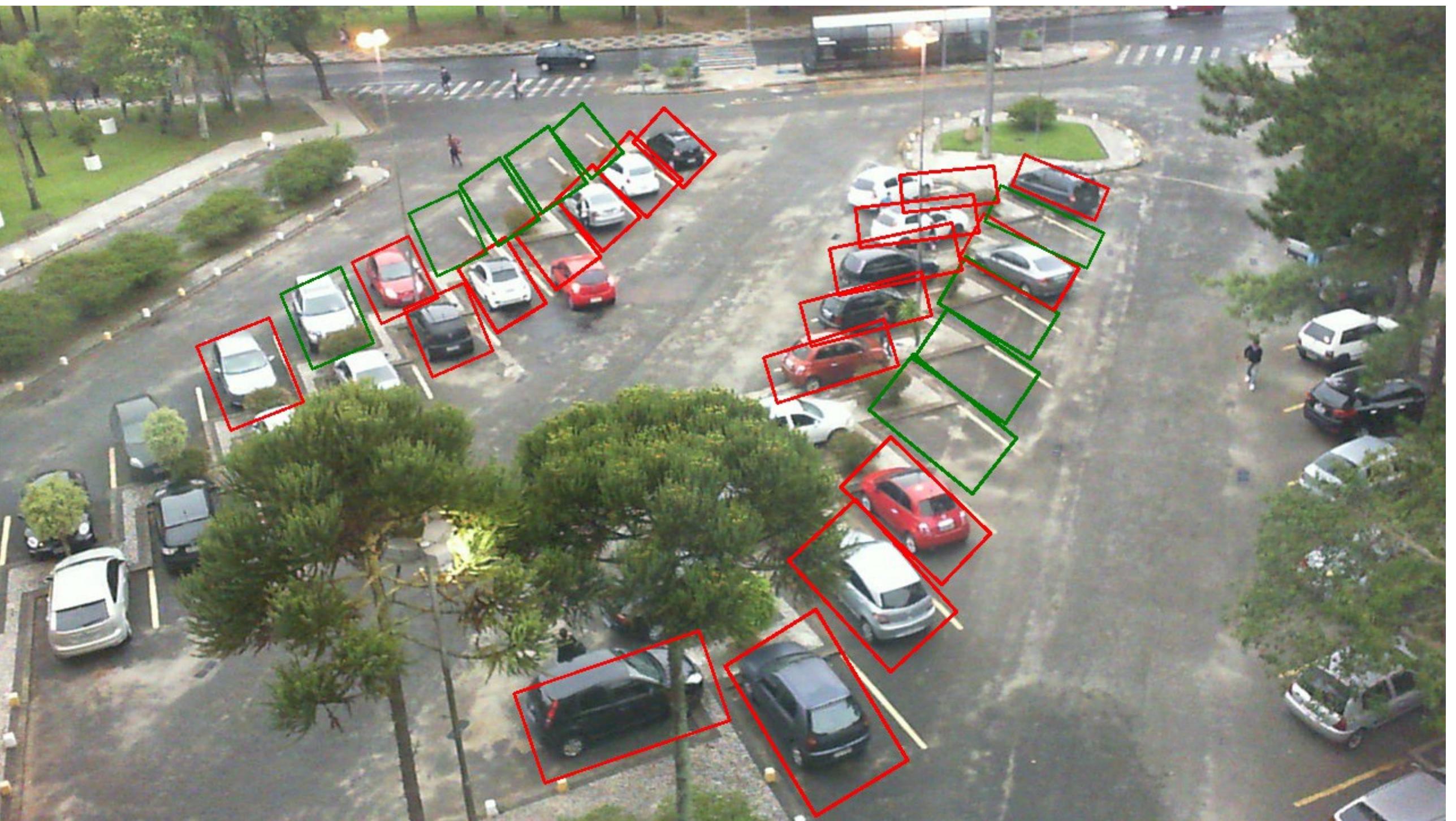
• performance can be impacted by extreme wind and temperature

- Will be affected by the weather conditions (snow, rain, temperature and extreme wind).



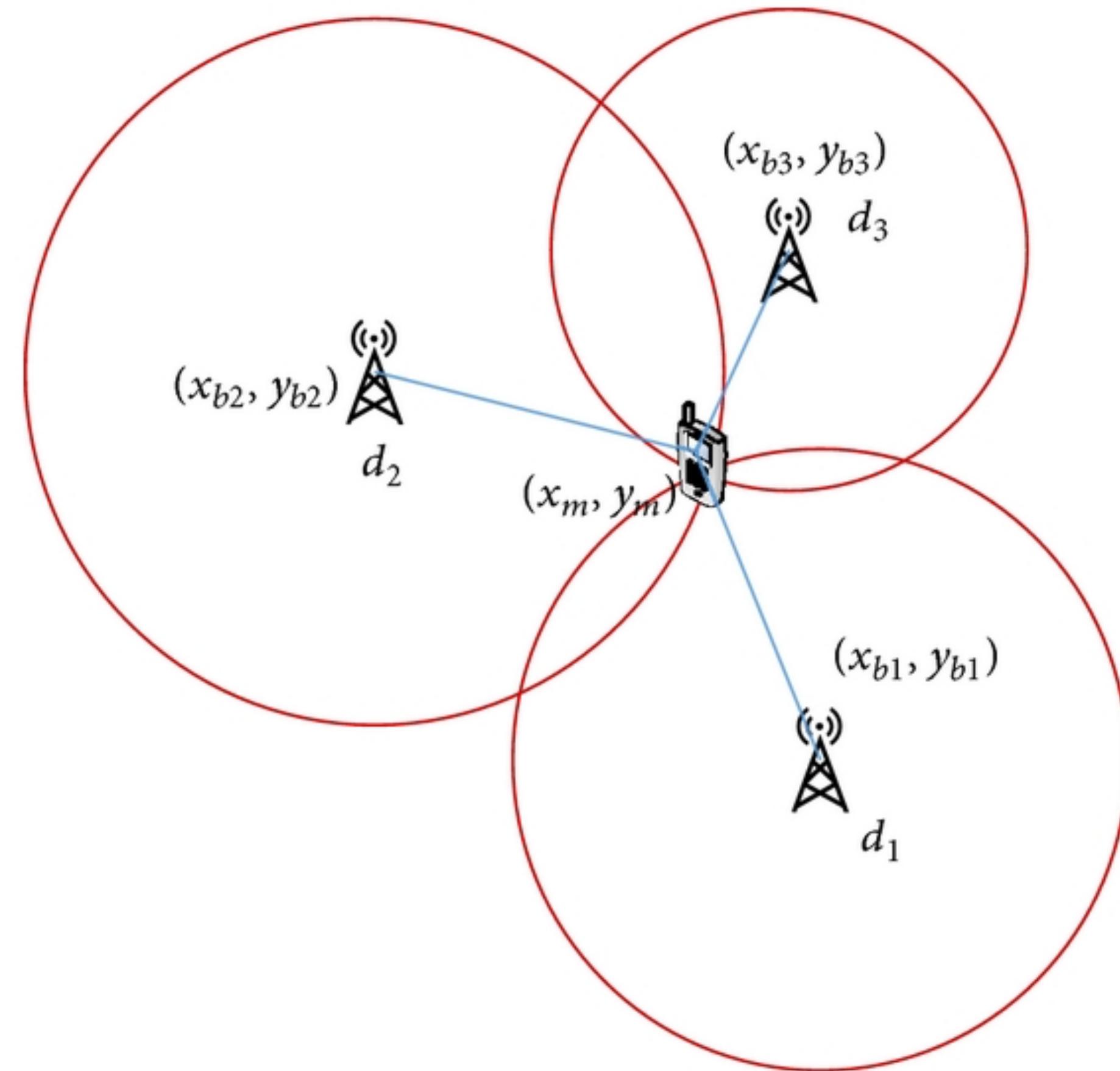
Video-detection

- Expensive
- May be affected by the level of light etc.
- There is a risk of drivers' privacy violation
- Cameras should be installed above the level of parking - problem with covered parkings.



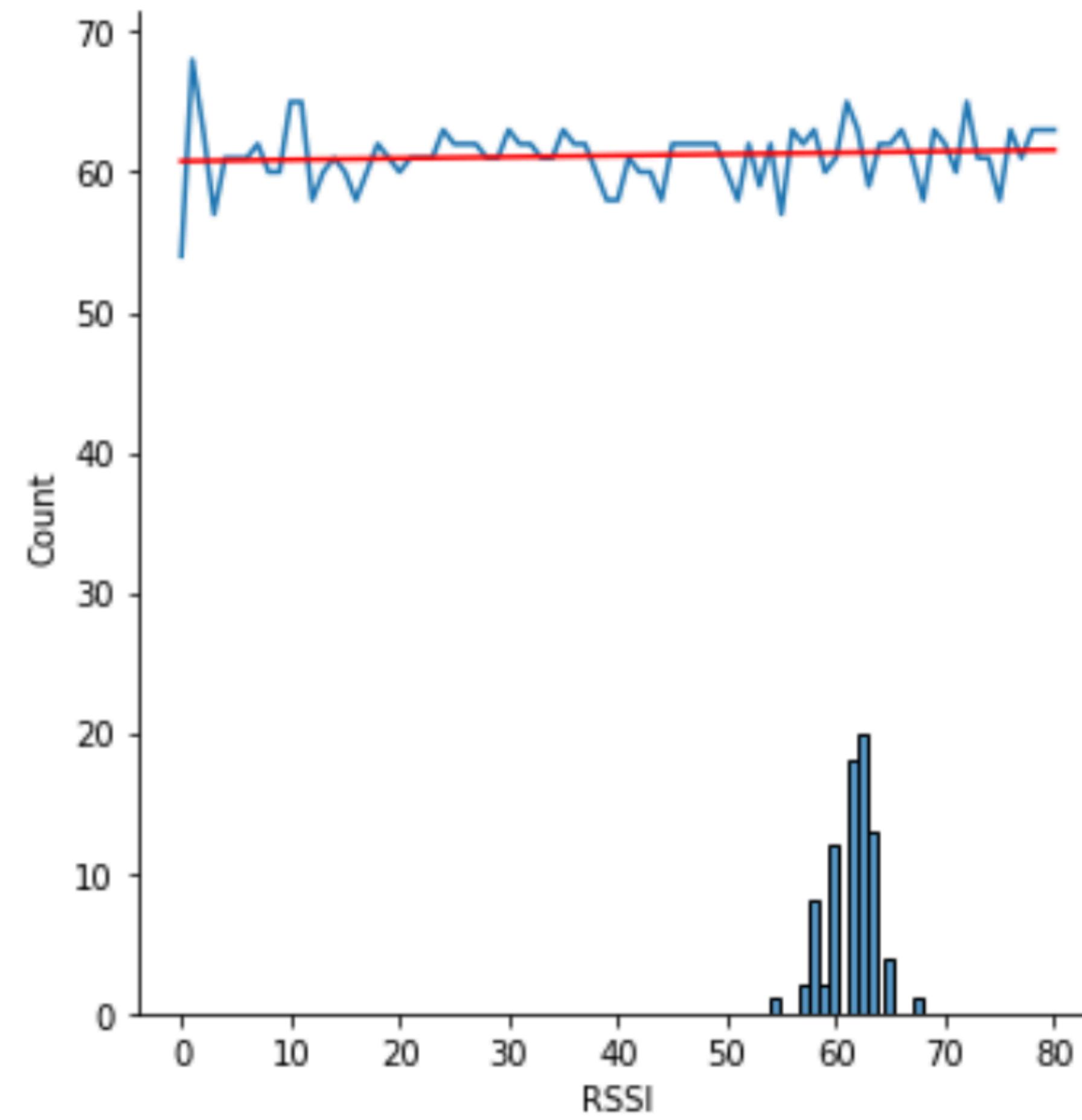
BLE RSSI for user detection

- indoor localisation approach
- Initial plan to experiment with triangulation based on BLE RSSI
- RSSI - indicates the energy loss in the process of signal transmission
- User-system direct interaction to minimise the delays and improve reliability



$$PL = P_{Tx_{dBm}} - P_{Rx_{dBm}} = PL_0 + 10\gamma \log_{10} \frac{d}{d_0} + X_g$$

- Absorption, reflection and defraction
- Computational cost
- We rely on user, not on machinery
- Timing problems
- Scientific works mainly investigate this issue without obstacles and in two-dimensional space



RSSI measurements at distance of one meter with one sample in two seconds

What to do?

Magnetometer

- Measures the projection of the magnetic field induction* on the axis of sensitivity (unit of measurement - tesla).
- It is exposed to hard-iron (eg: permanent magnet action) and soft-iron distortions.

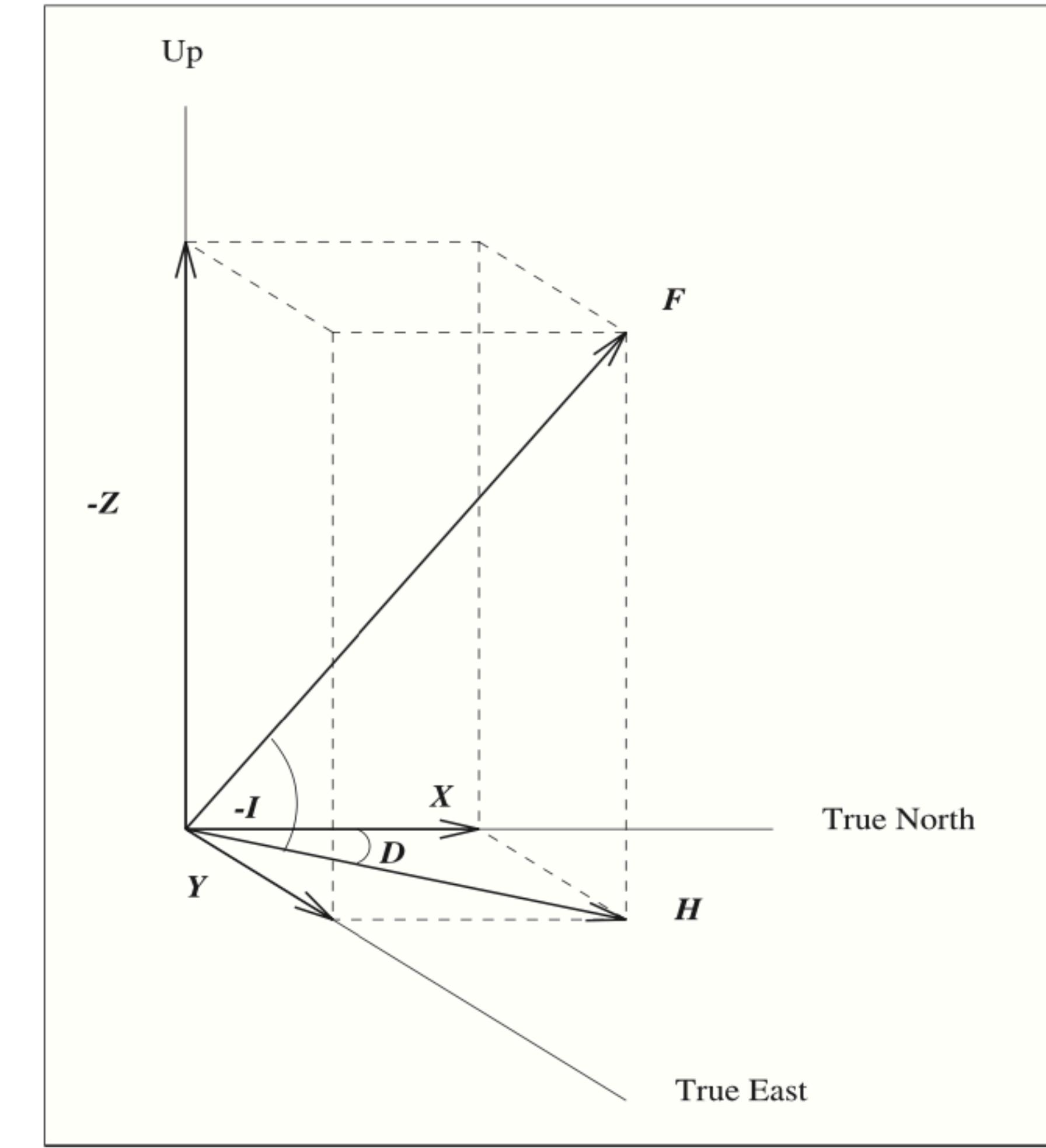


Fig. 1. Components of Earth's magnetic field (total field F , horizontal component H , vertical component Z , north component X , east component Y , declination D , inclination I). The orientation of the vertical component, which results in both Z and I having negative values, describes the southern-hemisphere magnetic field direction.

* (Magnetic induction - vector physical quantity, the main characteristic of the magnitude and direction of the magnetic field)

Why?

- They allow to detect the presence of ferromagnetic objects (iron, cobalt and nickel). Massive components like engine, gearbox, driveshaft, axles and wheel suspensions contain a lot of steel, therefore will greatly influence magnetometer.
- Not requires no energy to be emitted, thus minimising both energy consumption and risk of electromagnetic interference

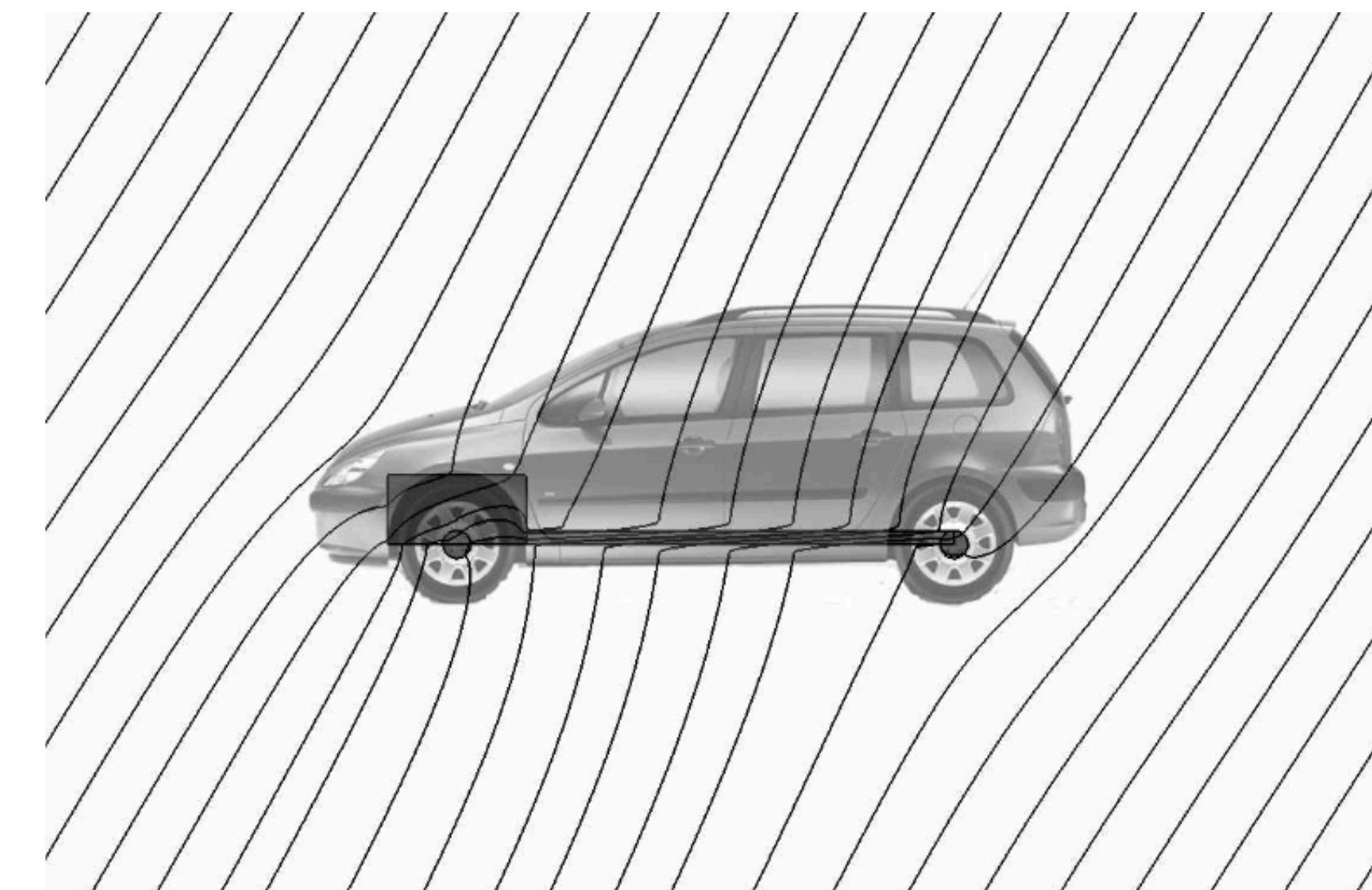
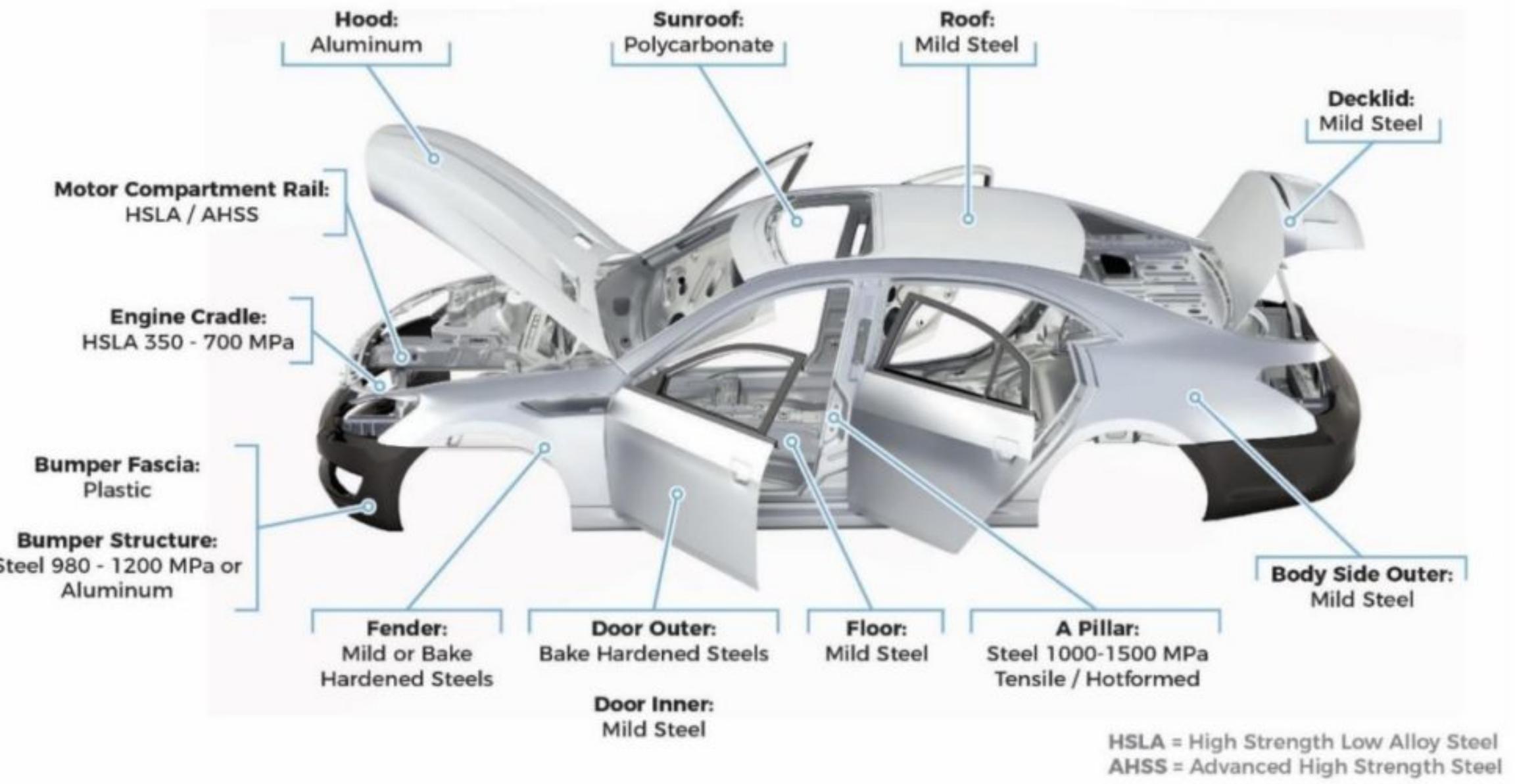
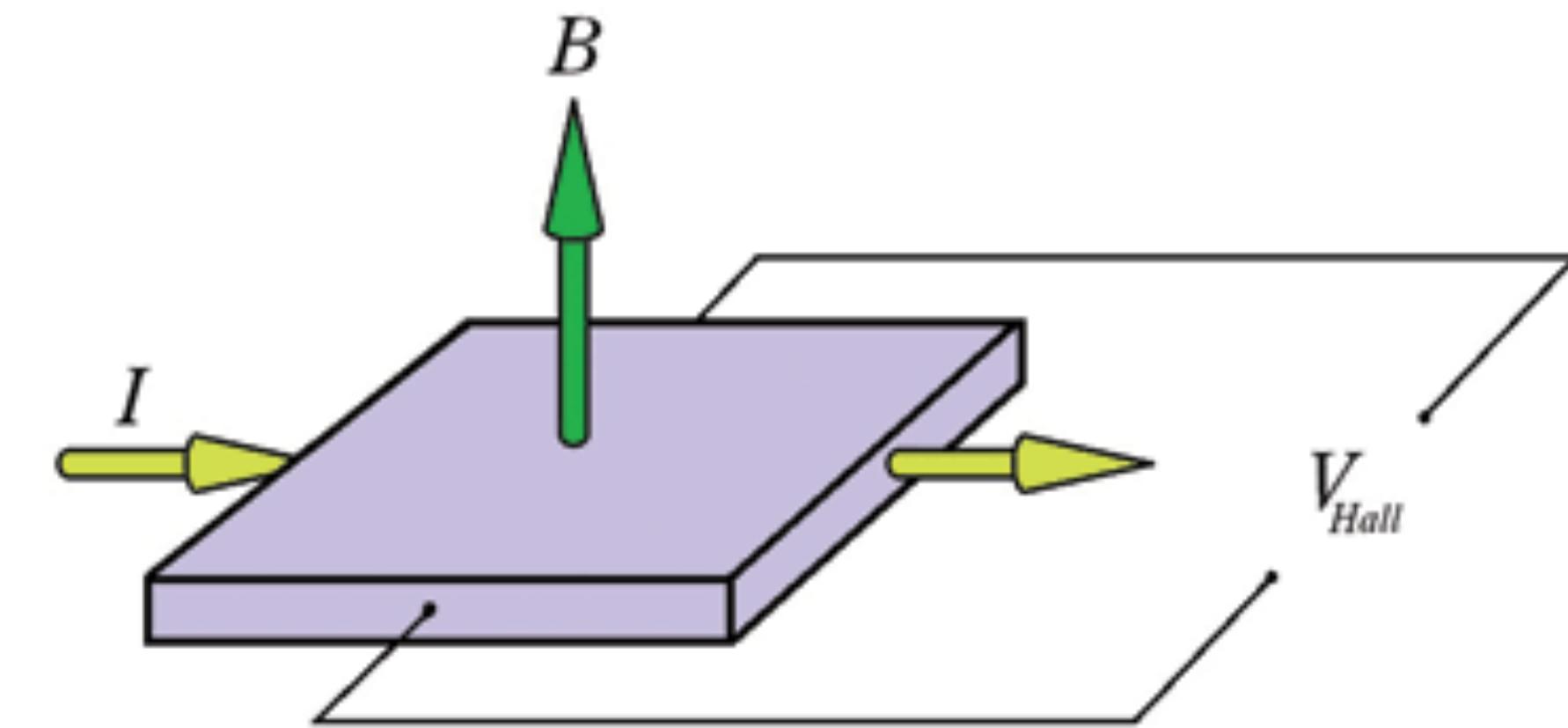


Fig. 1. Simulation of the deformation of the Earth's magnetic field by a car

Hall Effect

- Principle: voltage (Hall voltage) can be detected across a thin metallic element, when the element is placed in a strong magnetic field perpendicular to the element's plane
- Comparatively low sensitivity and temperature stability.

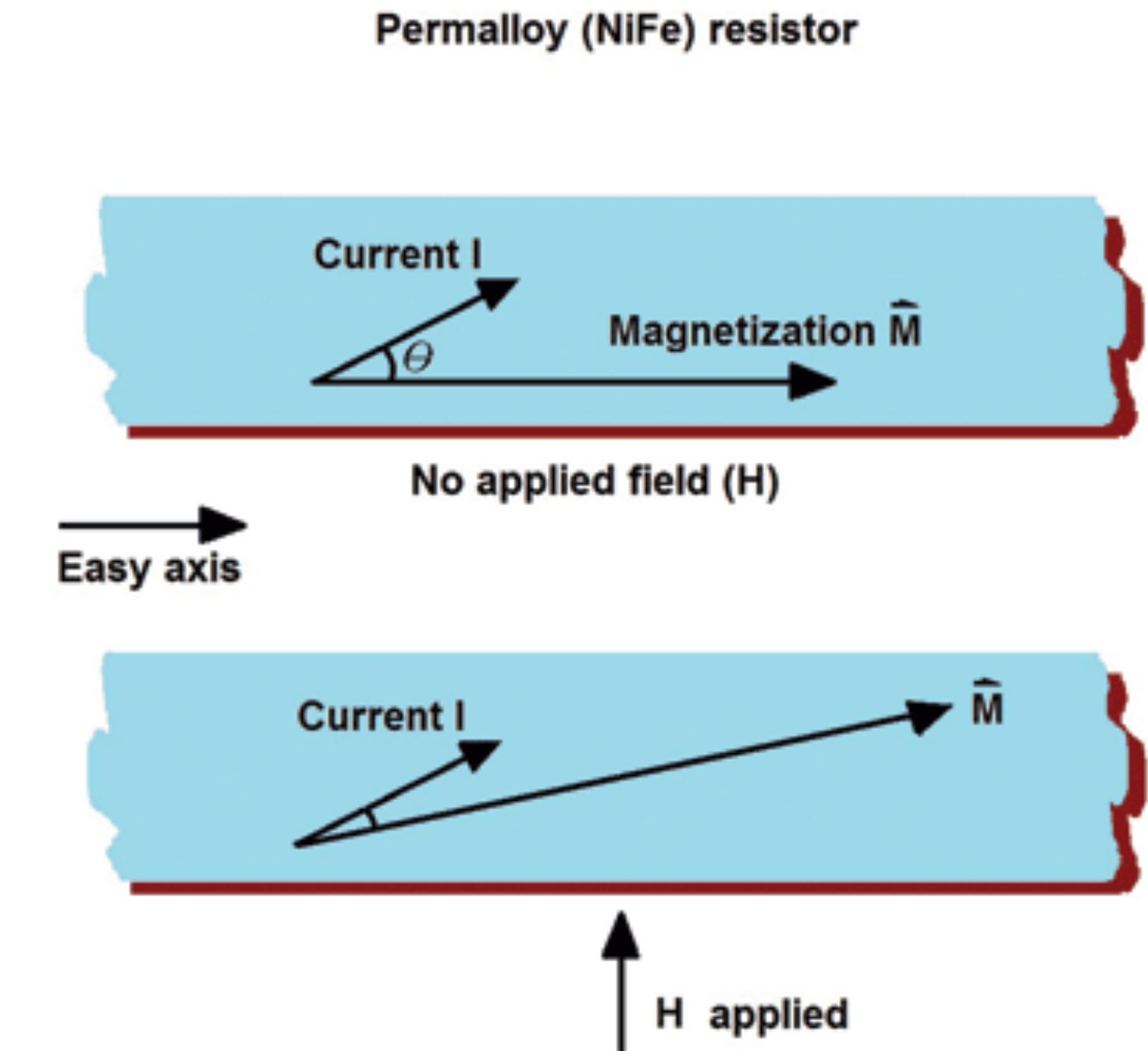


$$V_{Hall} = k |I \times B|$$

AMR

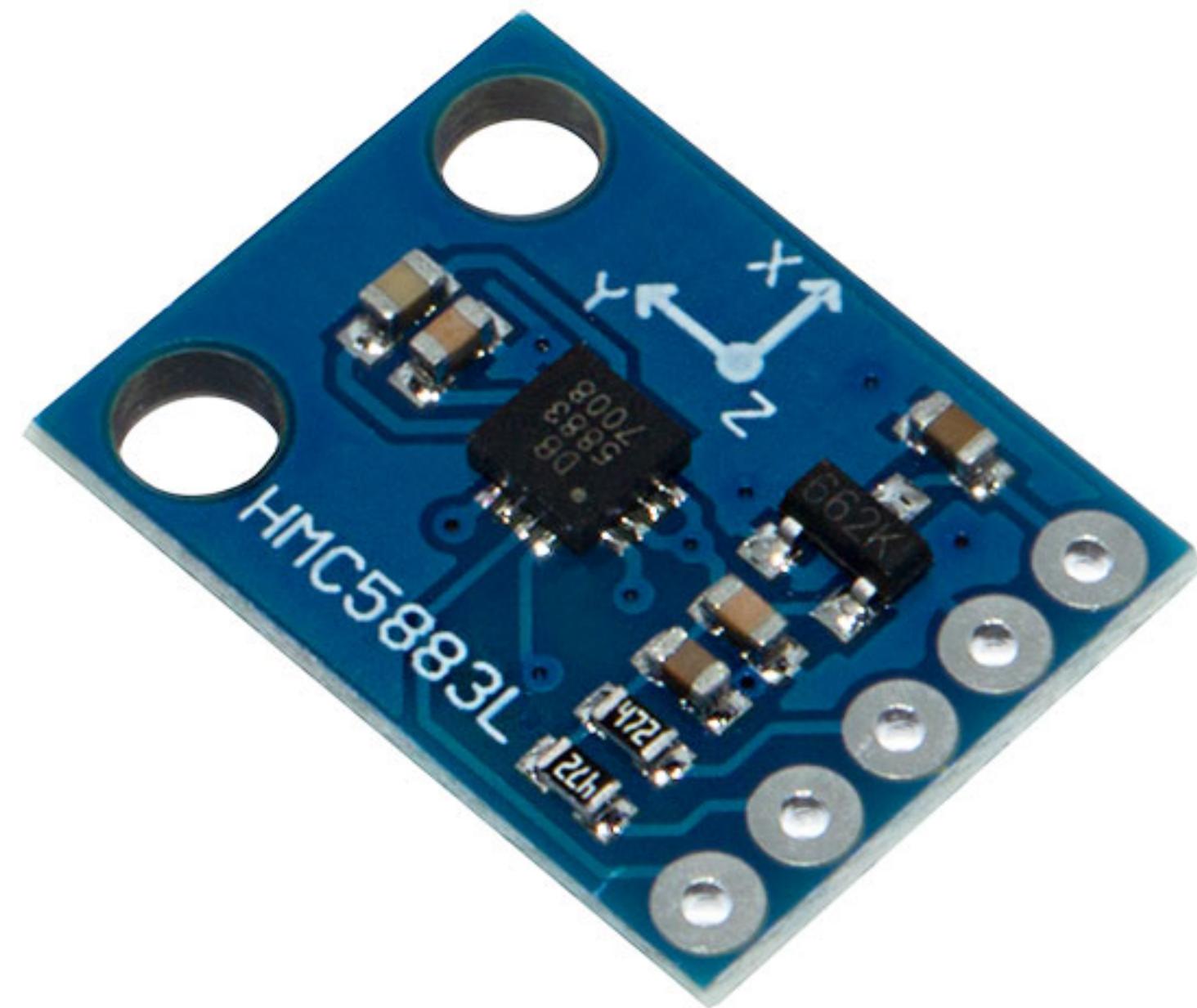
Anisotropic magnetoresistance

- Utilises object's capacity to change electrical resistance upon exposure to an external magnetic field.
- Concept makes use of permalloy (80% nickel and 20% iron). Its resistance depends on the angle between the magnetisation and the direction of current flow



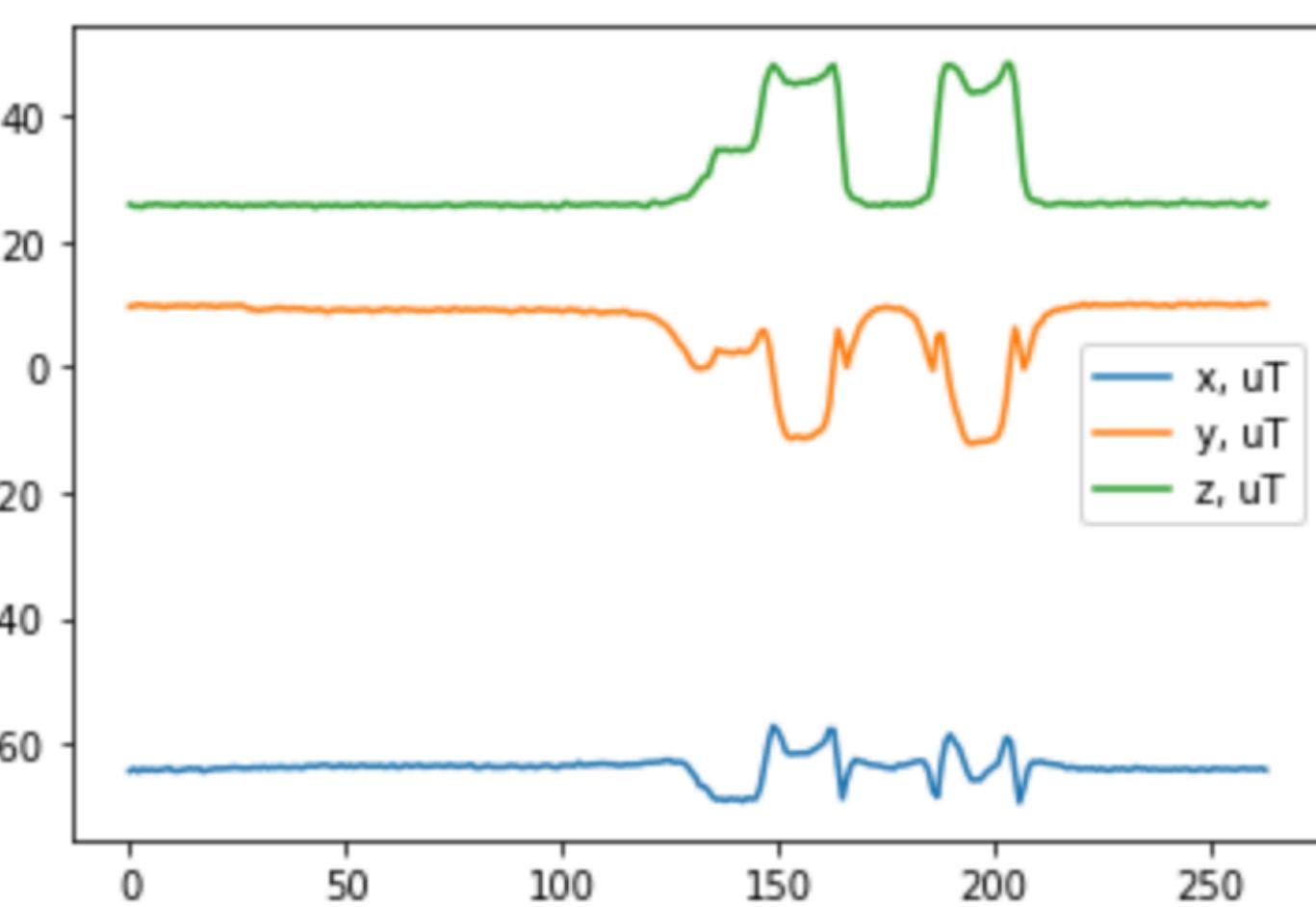
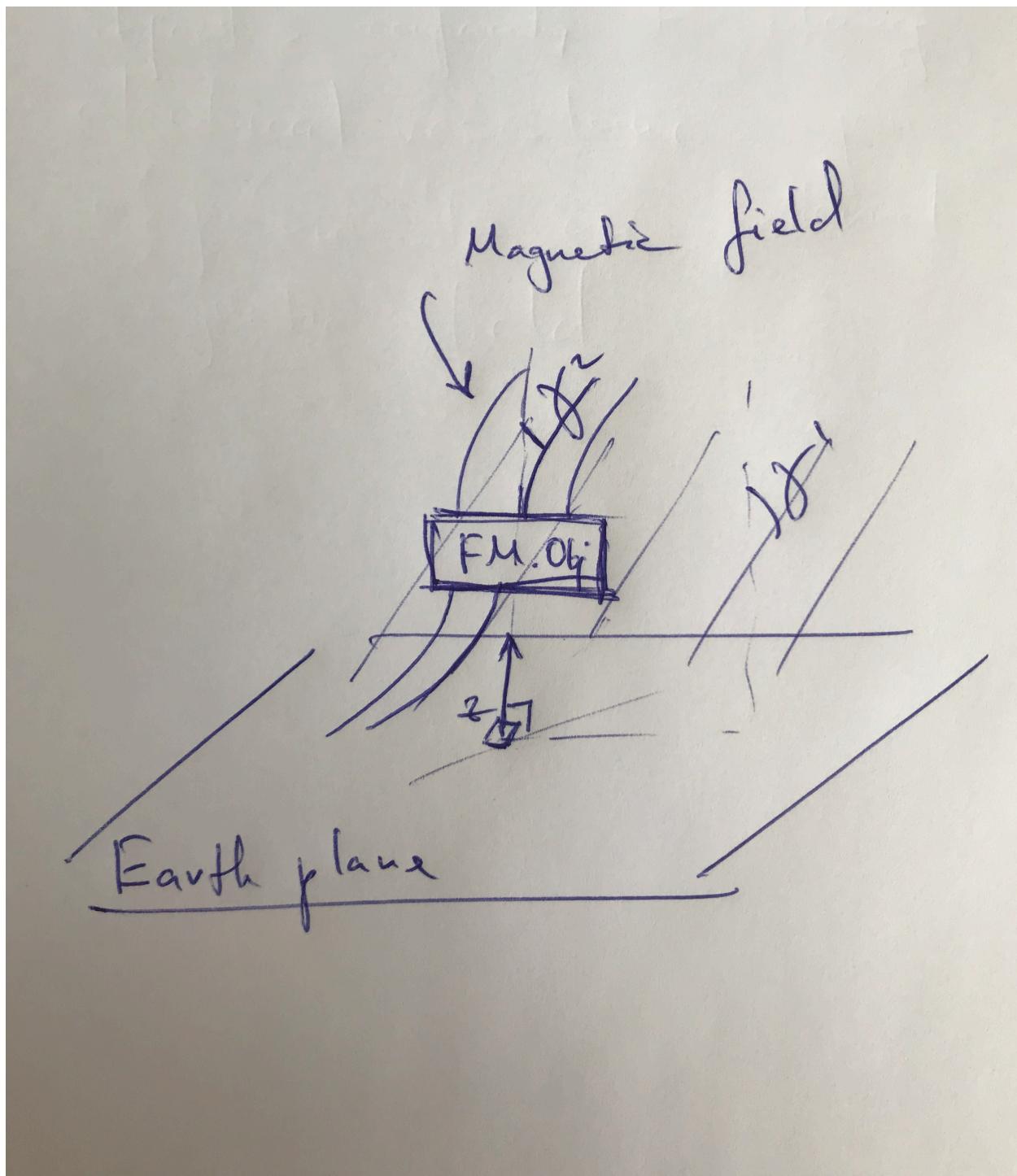
HMC5883L

- HMC5883L magnetoresistive sensor circuit is a trio of sensors and application specific support circuits to measure magnetic fields.
- Supply voltage: 2.16 - 3.6 V
- Field range: -8 to +8 gauss (average field strength of the Earth's magnetic field is between 30uT (0.3 Gauss))
- Digital resolution: 2 milli-gauss
- Supports I2C communication protocol



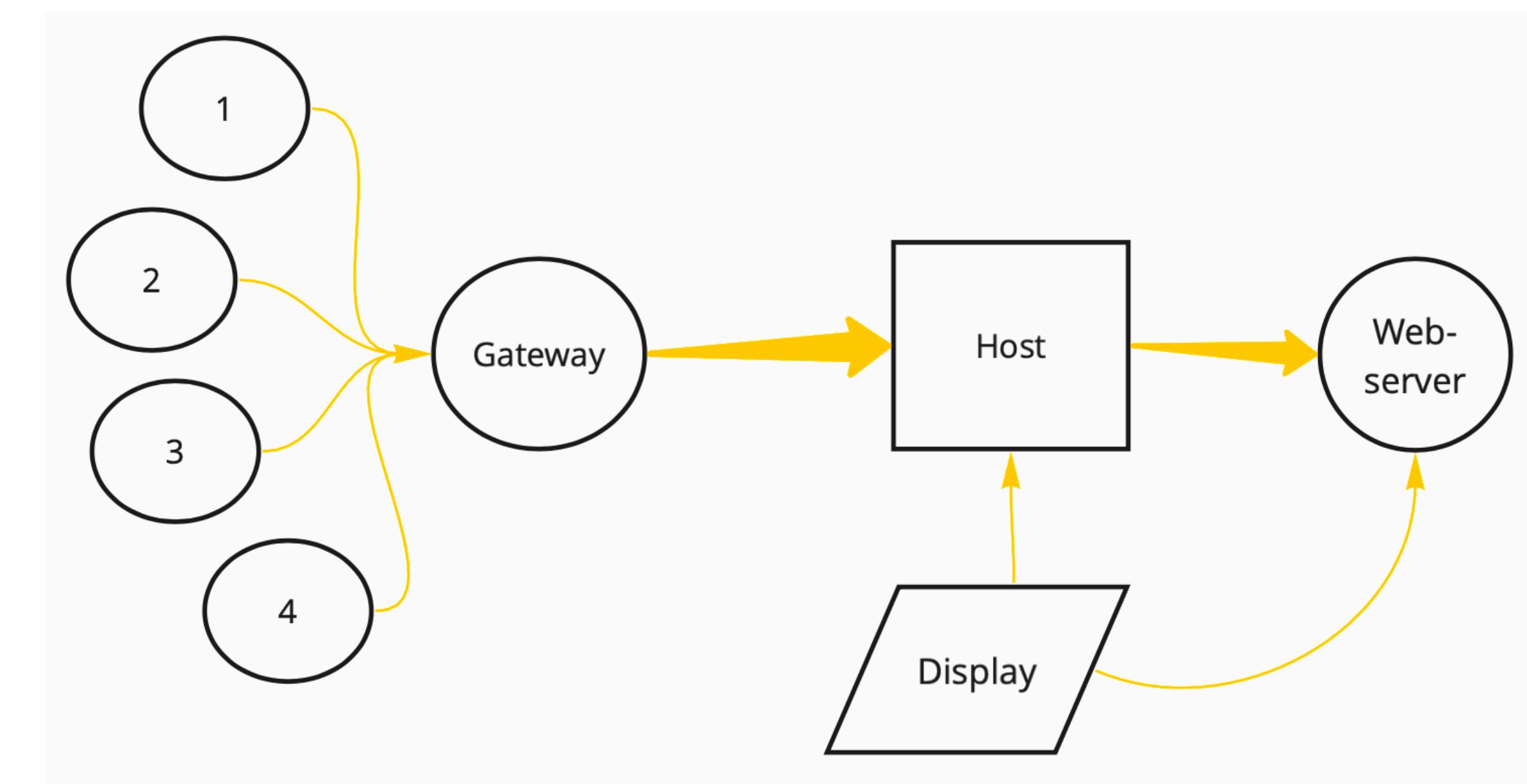
Proof of concept

- The Z-axis of the AMR sensor is perpendicular to the plane of Earth.
- As with the appearance of ferromagnetic object the angle between the Z-axis and the local magnetic field becomes smaller, we wait for the sensors' readings to increase as the resistance becomes smaller.



System specification

- Each parking space is equipped with a **sensor** (magnetometer and periphery for its support).
- Data from several sensors is transmitted to a **gate-way** that then passes it further to host-machine.
- **Host**-machine is responsible for management of free parking spaces.
- **Display** fetches data from host-machine directly or via remote web-server.



Data transmission

nRF24L01+

- Very low current consumption: 9mA for transmission
- Power down mode support
- Support of star-topology
- Possibility to receive acknowledging basing on node's unique id
- Up to 100m range
- Up to 32 bytes in one transmission



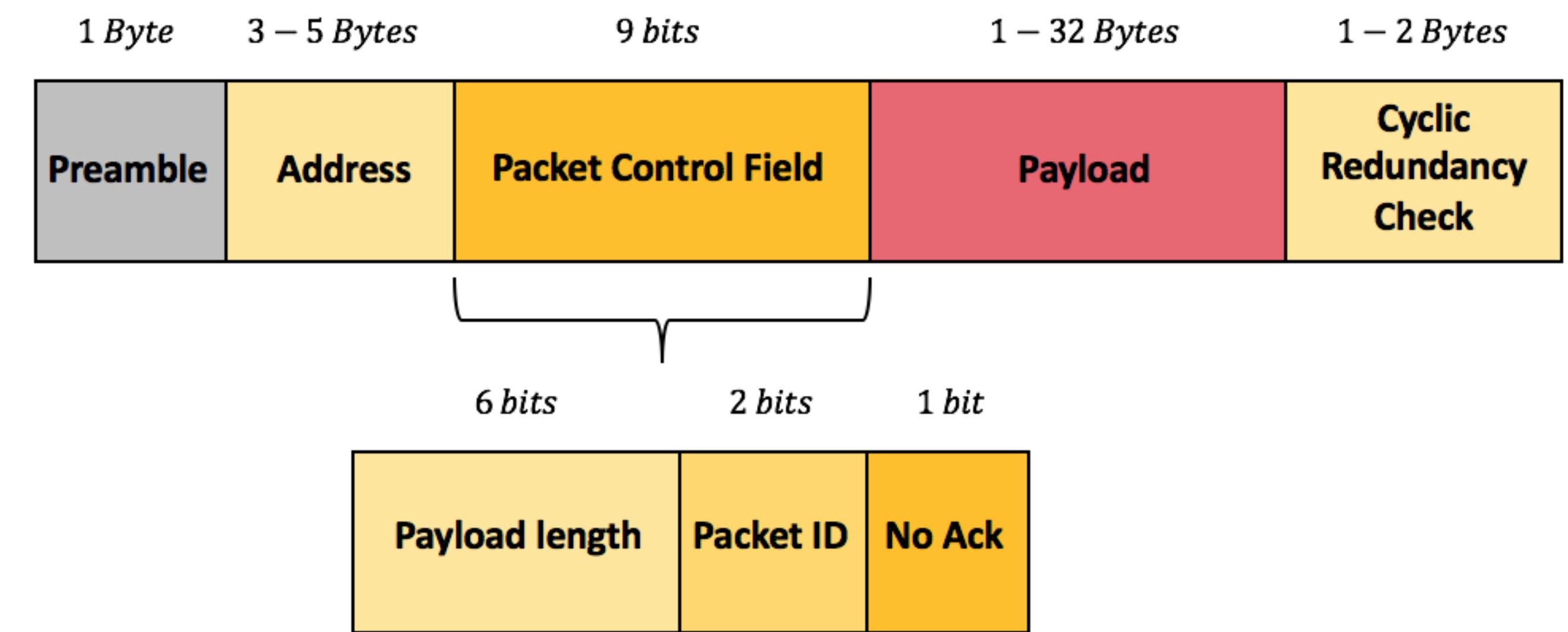


- 39 mA
 - Much greater range: up to 15km
 - Much greater sensitivity
 - Much greater cost
 - Brings complexity to the system as LoRaWAN is needed to manage star topology



Enhanced ShockBurst Protocol

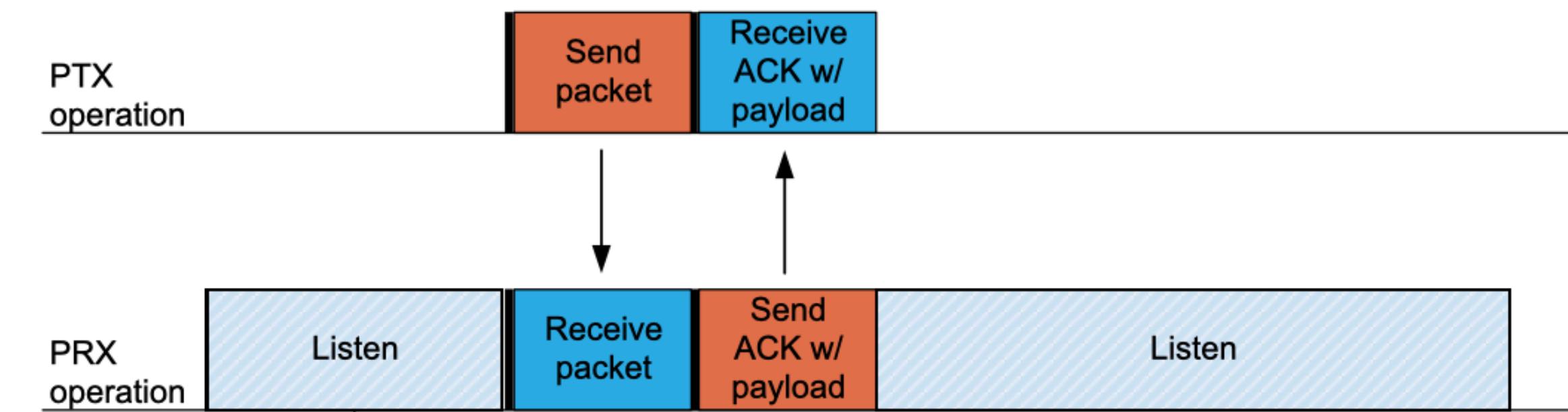
- Up to 32 bytes payloads that support dynamic change.
- Each sent packet with a packet ID, which allows the receiving device to determine whether a message is new or whether it has been retransmitted.
- Each message can request an acknowledgement to be sent when it is received by another device



How the automatic packet handling works?

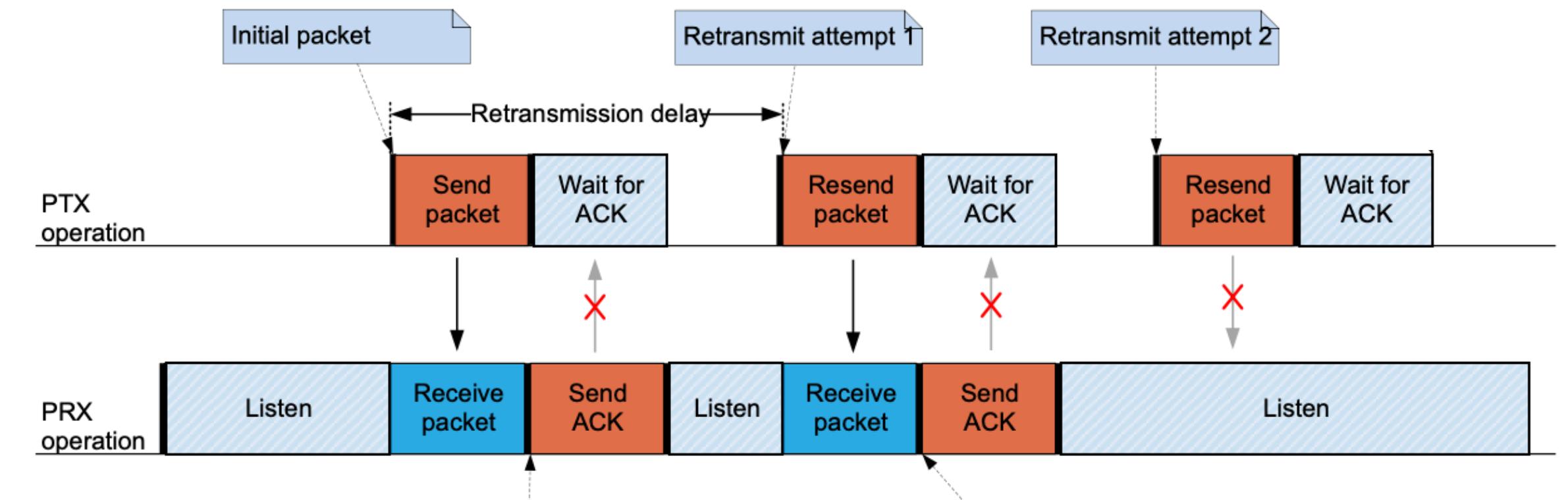
Transaction with acknowledgement and interrupt.

- TX sends a data packet to the receiver.
- Once the packet is transmitted, it waits ($130 \mu\text{s}$) for the ACK packet.
- When the receiver receives the packet, it sends ACK packet to the transmitter.
- On receiving the ACK packet the transmitter asserts interrupt (IRQ) signal to indicate the new data is available.



Transaction with data packet lost

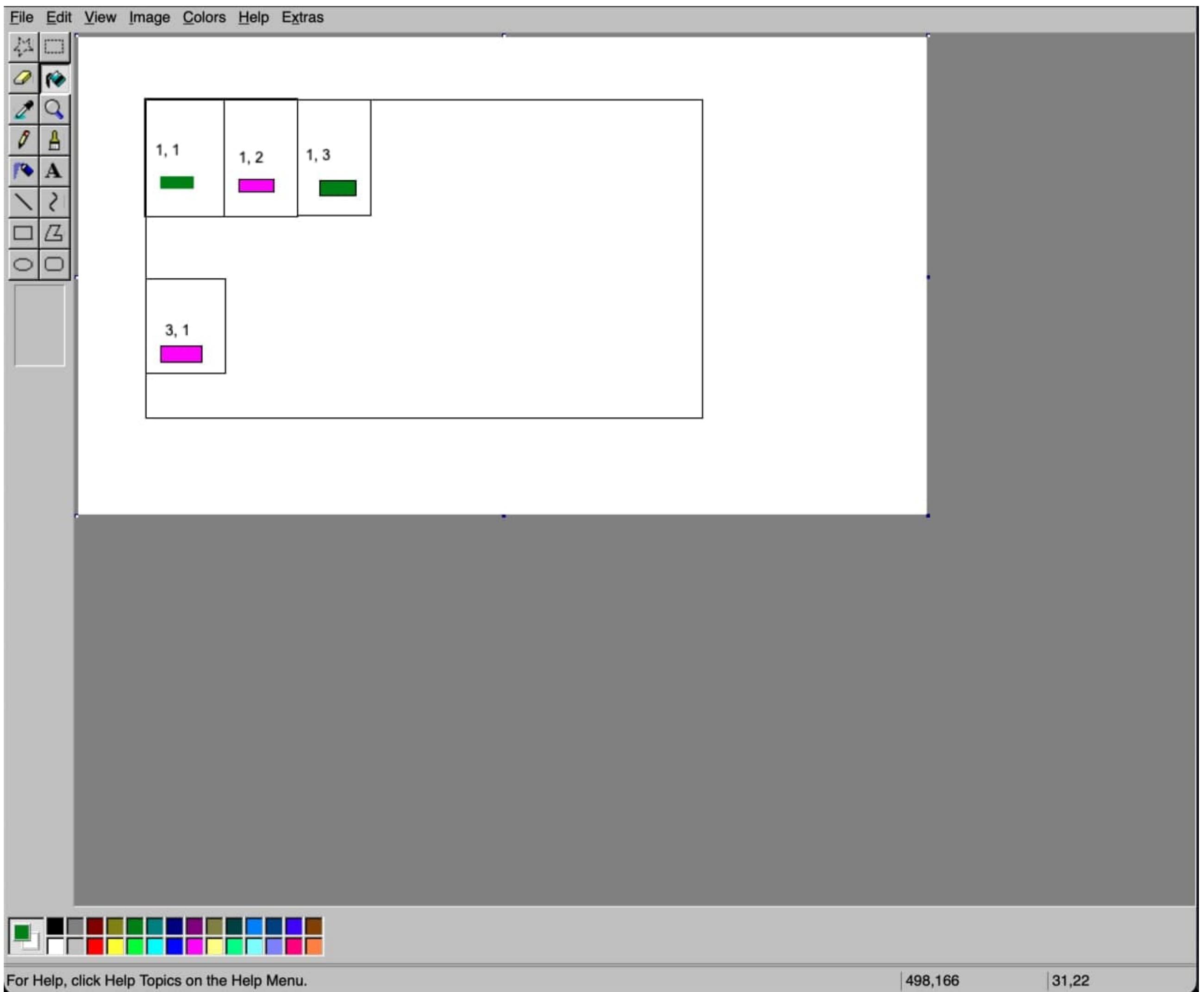
- After the packet is transmitted, the transmitter waits for the ACK packet to receive.
- If the transmitter doesn't get it within Auto-Retransmit-Delay (ARD) time, the packet is retransmitted.
- When the retransmitted packet is received by the receiver, the ACK packet is transmitted which in turn generates interrupt at the transmitter.



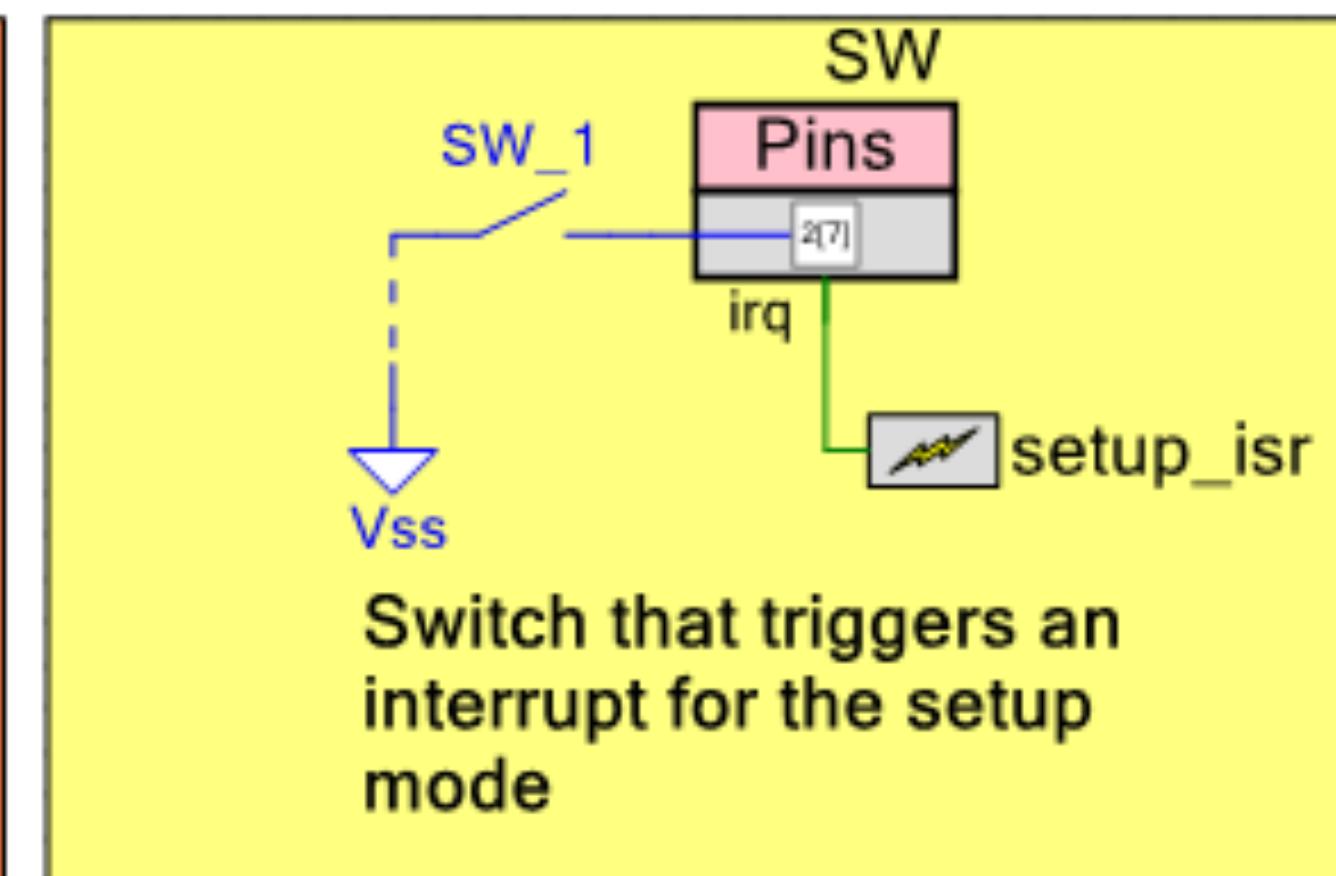
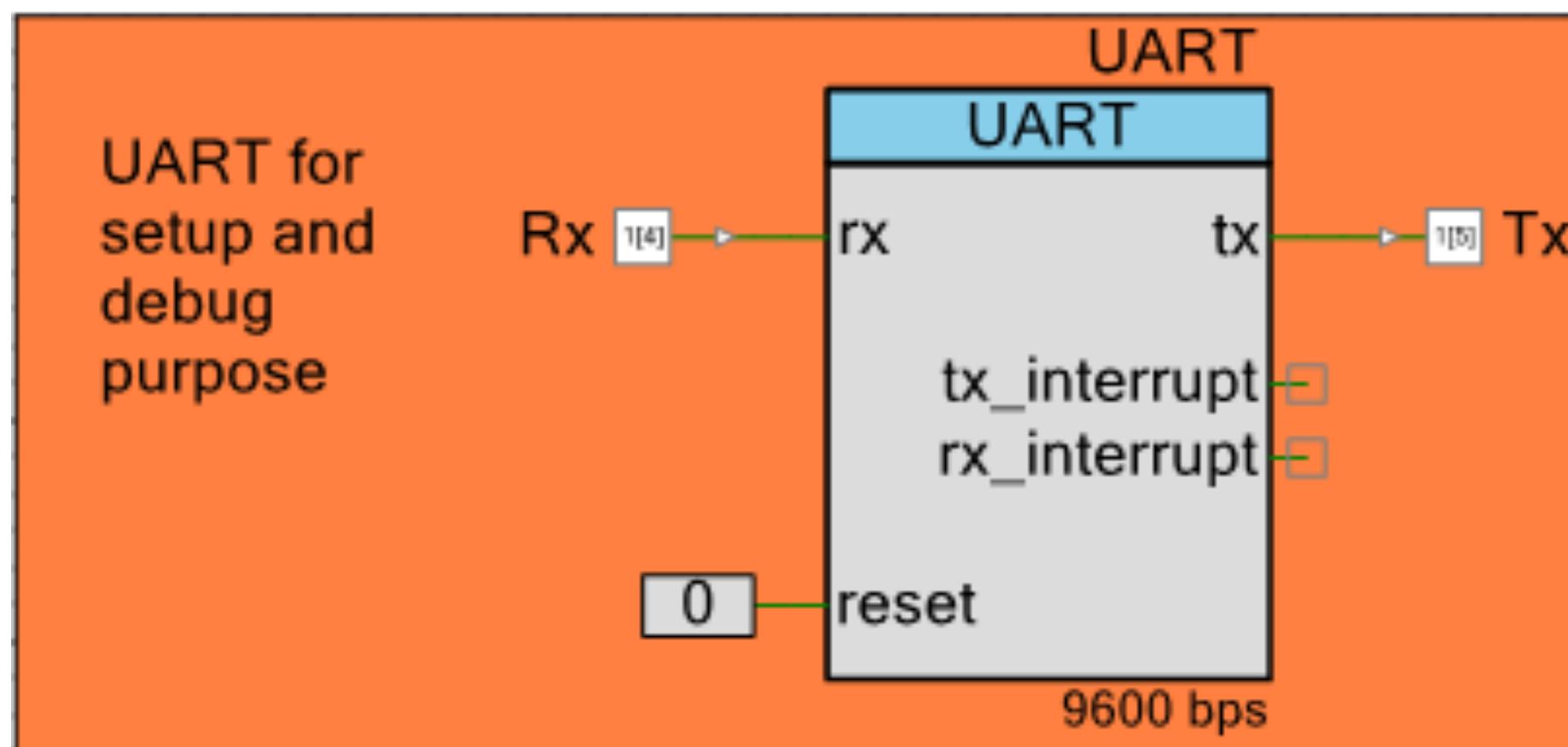
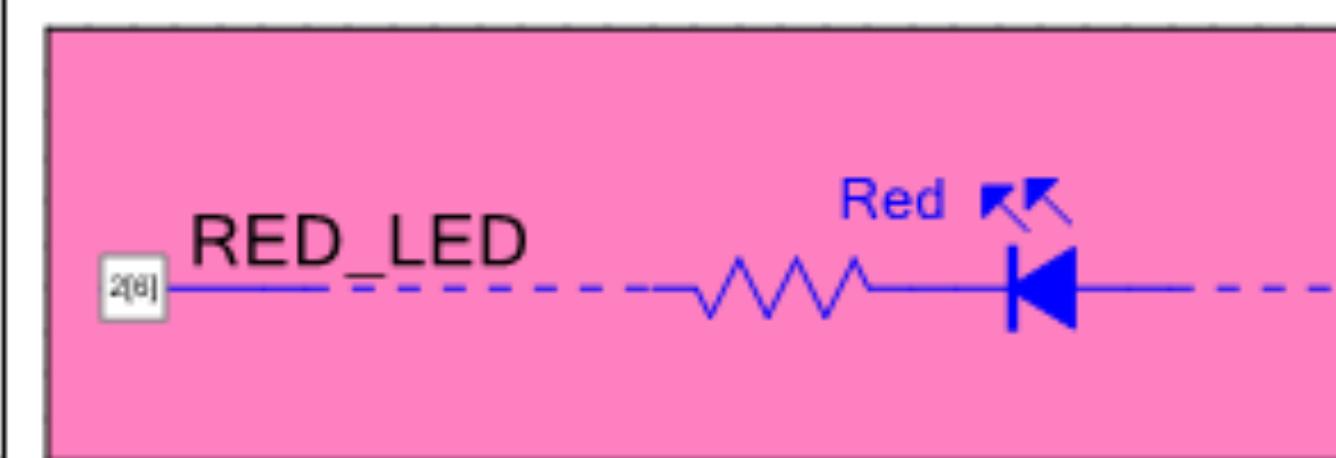
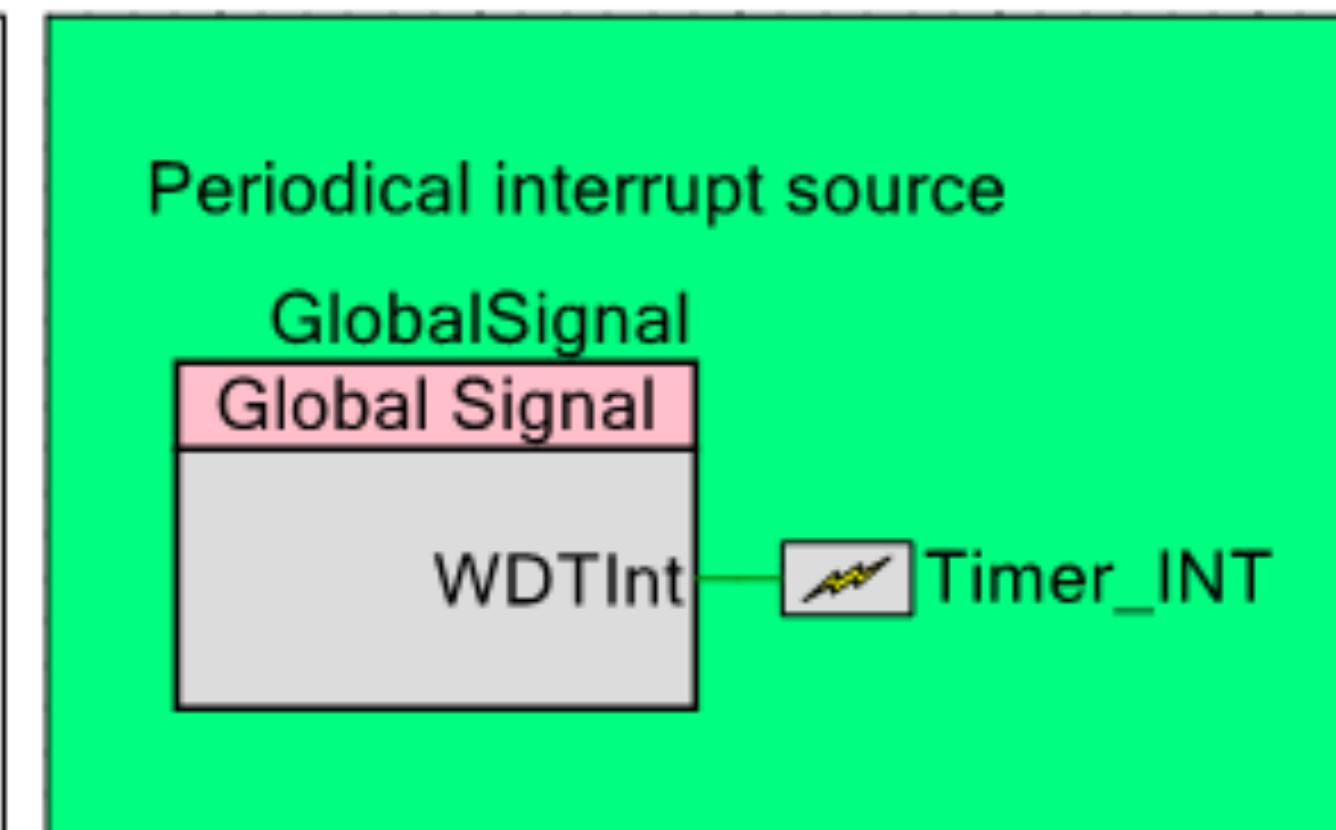
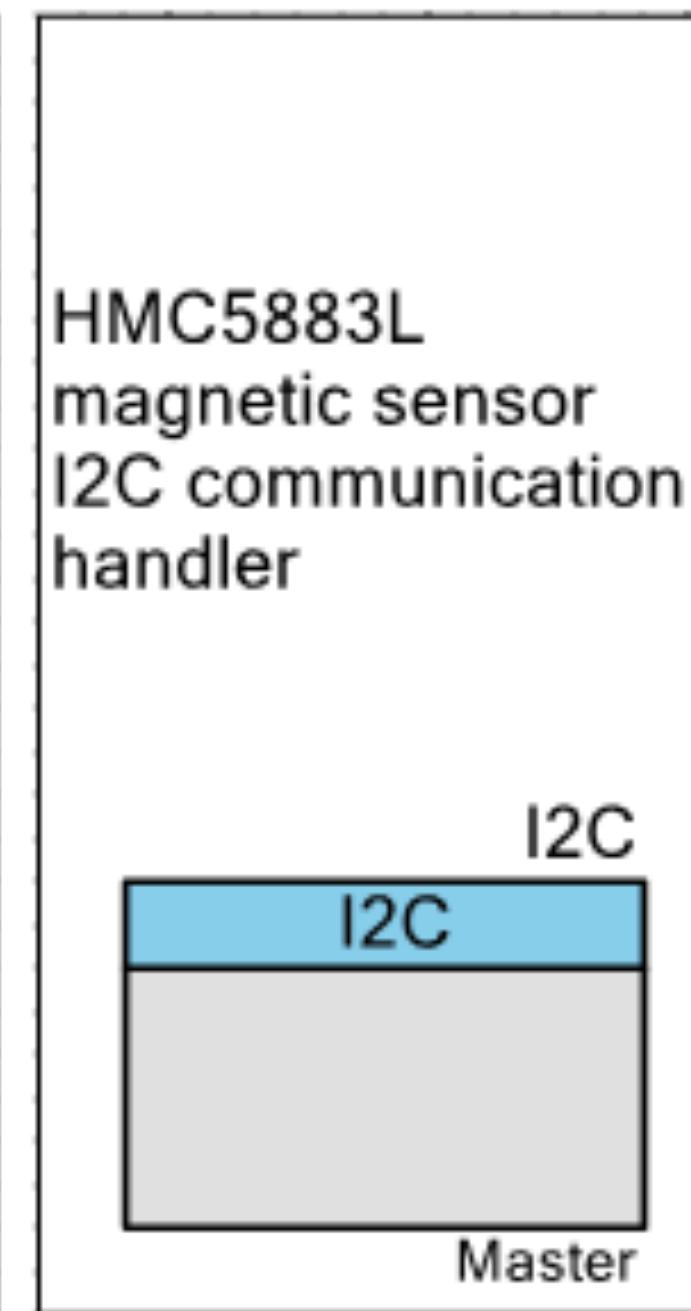
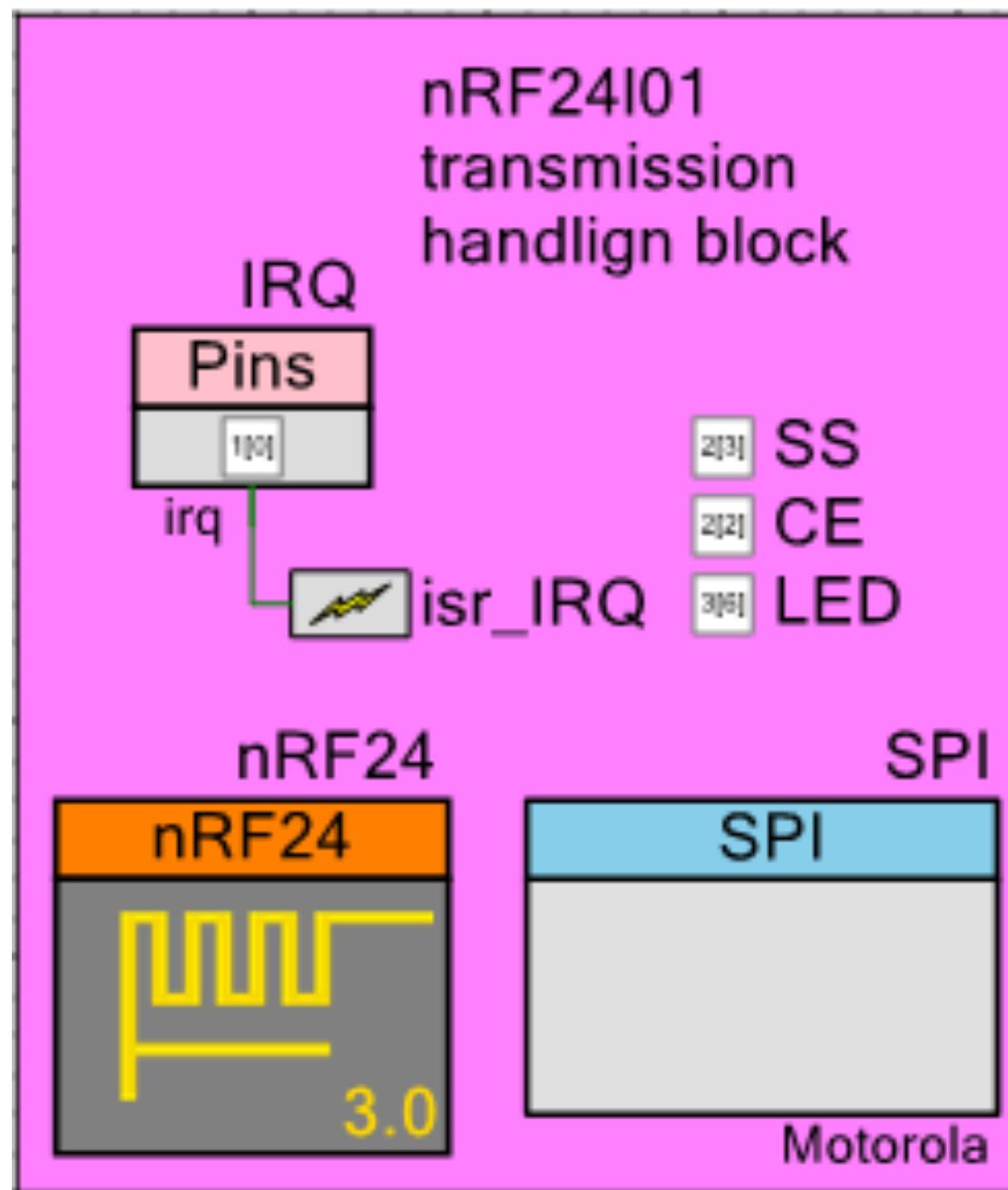
Transaction with acknowledgement lost

- When receiver receives the packet containing same packet ID as previous, it discards it and sends ACK packet again.

Displaying



End-node



Host-Display

nRF24L01 communication handlers, as well as UART used for debug purposes.

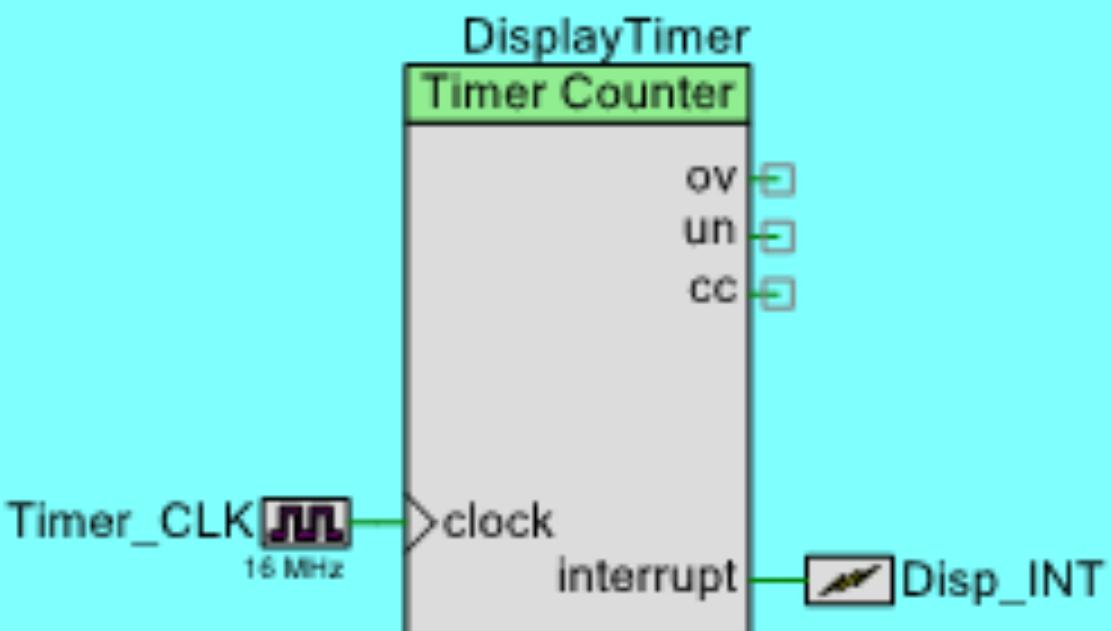


LED Indications



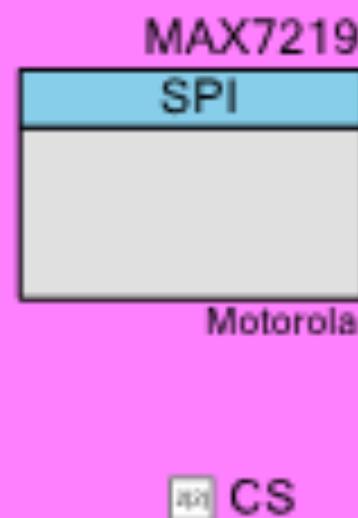
Display Timer

A TCPWM based timer is used to generate regular interrupts to refresh the display. Since the display is handled in the ISR for the interrupt, the processor is free to do other things.



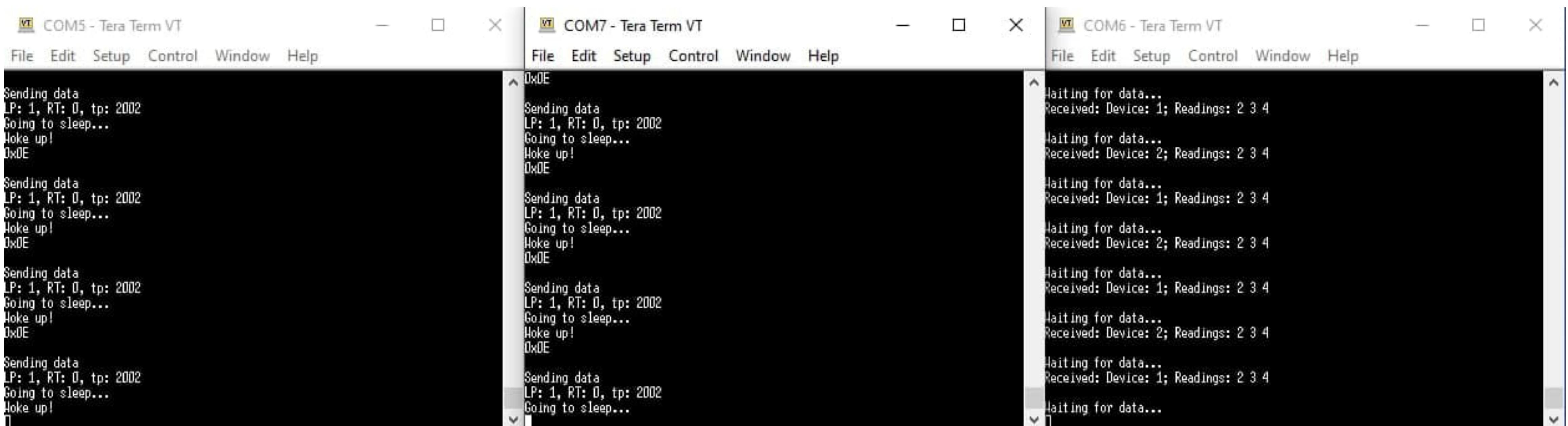
Matrix Display

Project uses MAX7219 based modules, cascaded together to form a bill-board. Scrolling messages are shown on the display. MAX7219 is controlled via SPI.



Example of execution

does-not-affect-neighbours proof



Power consumption

What to improve?

- Port host functionality to PSoC 6 with WiFi support, so to make the remote web-server possible.
- Possibility of wireless charge
- Ability to get the information about the charge of an end-node
- Consider using PSoC's silicon id to identify an end-node, rather than setup each node manually via proposed solution.
- Develop display realisation based on a LED-screen

Q&A