# Free parking spaces detector

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# Motivation

According to Libelium, applying Smart Parking technology reduces traffic volume by 8%, gas emissions by 40%, kilometers travelled by a car to park by 30% and time spent parking by 43%

## Parking Search Time

| City | On-street search time (mins per trip) | Off-street search time (mins per trip) | Parking trips (per week) |
|---|---|---|---|
| New York City | 15 | 13 | 10 |
| San Francisco | 12 | 11 | 9 |
| Los Angeles | 12 | 11 | 9 |
| Washington D.C. | 10 | 9 | 9 |
| Chicago | 9 | 8 | 8 |
| Seattle | 9 | 8 | 9 |
| Boston | 8 | 8 | 8 |
| Atlanta | 8 | 8 | 8 |
| Dallas | 8 | 8 | 8 |
| Detroit | 6 | 6 | 7 |

SOURCE: INRIX

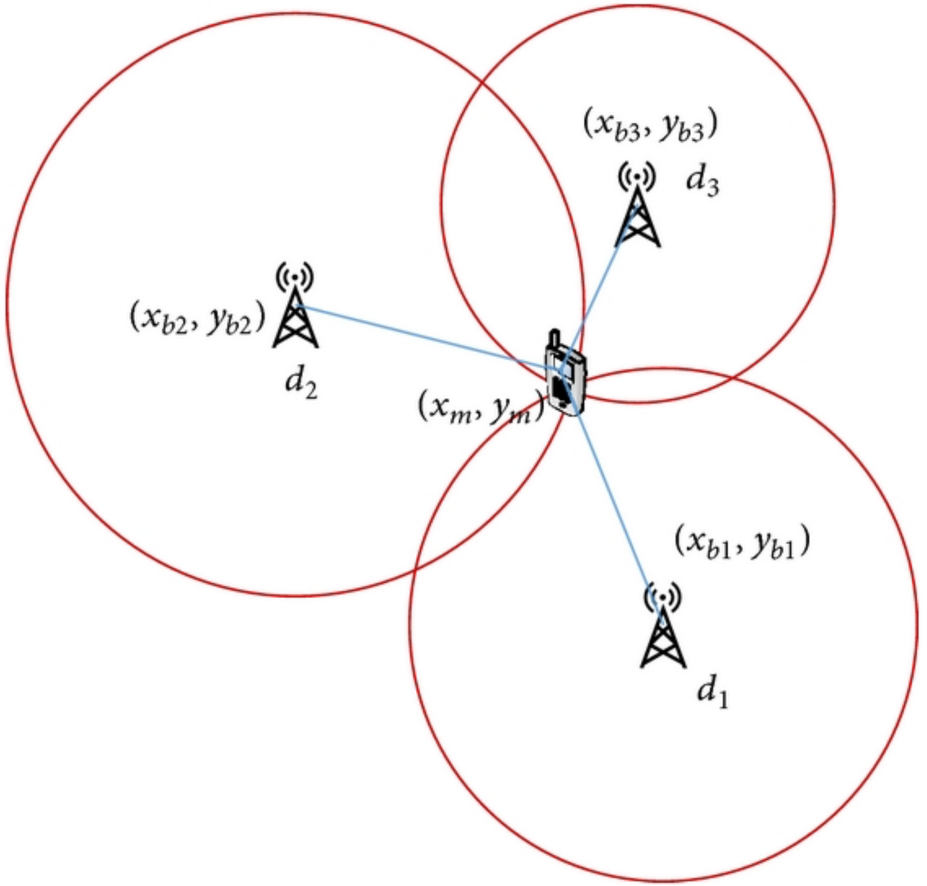
# Requirements

- The system shows the availability of free parking spaces, consists of a main unit and sensor devices.
- 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

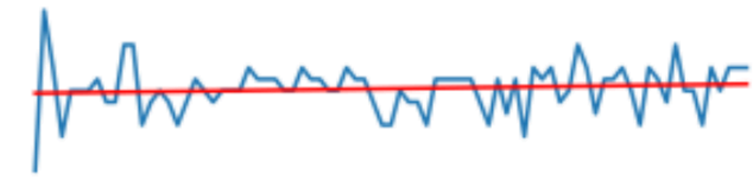
# BLE RSSI for user detection

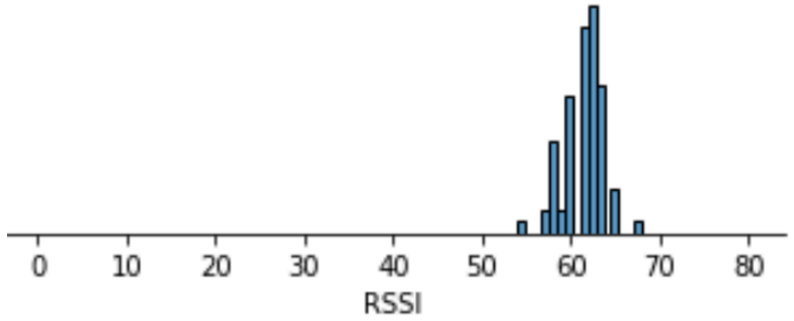
- Indoor localisation approach.
- Initial plan to experiment with triangulation based on BLE RSSI.
- RSSI - indicates the energy loss in the process of signal transmission.
- Direct interaction with user to minimise the delays and make the system real-time.




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

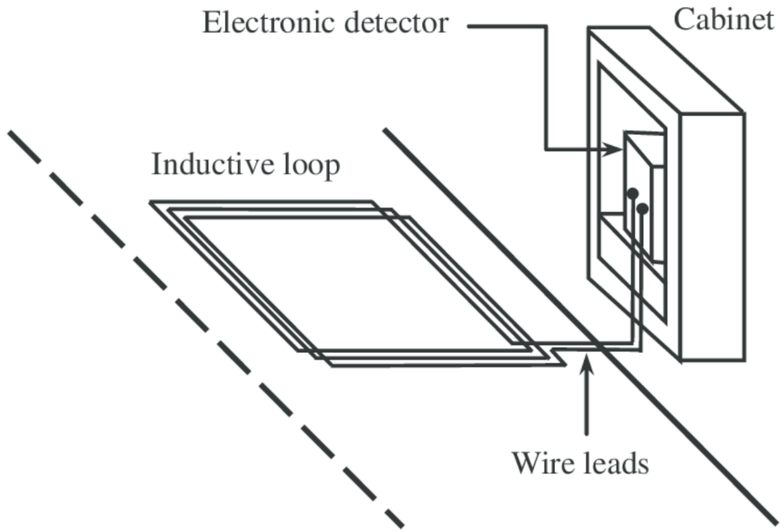
- Requires a lot of time to collect RSSI samples.
- Scientific works mainly investigate this issue without obstacles and in two-dimensional space.
- Absorption, reflection and defraction.
- Computational cost.
- We rely on an agreement with the user, not on the clear presence of a car.



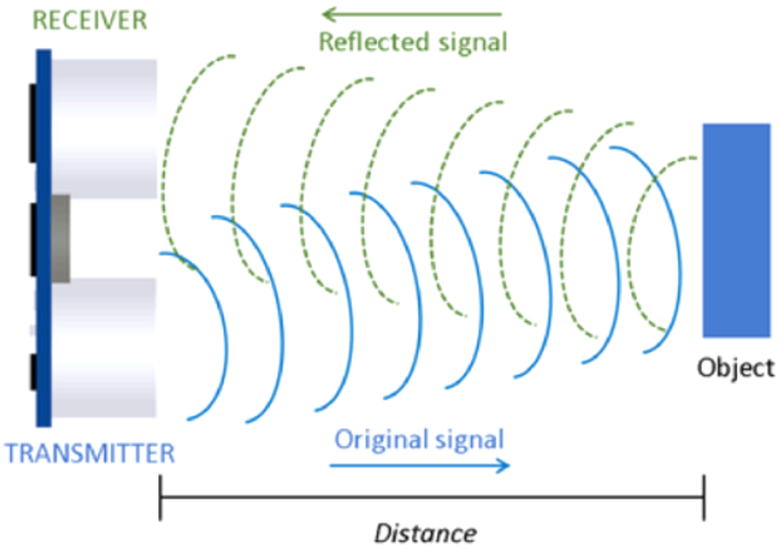



RSSI measurements at distance of one meter with one sample in two seconds

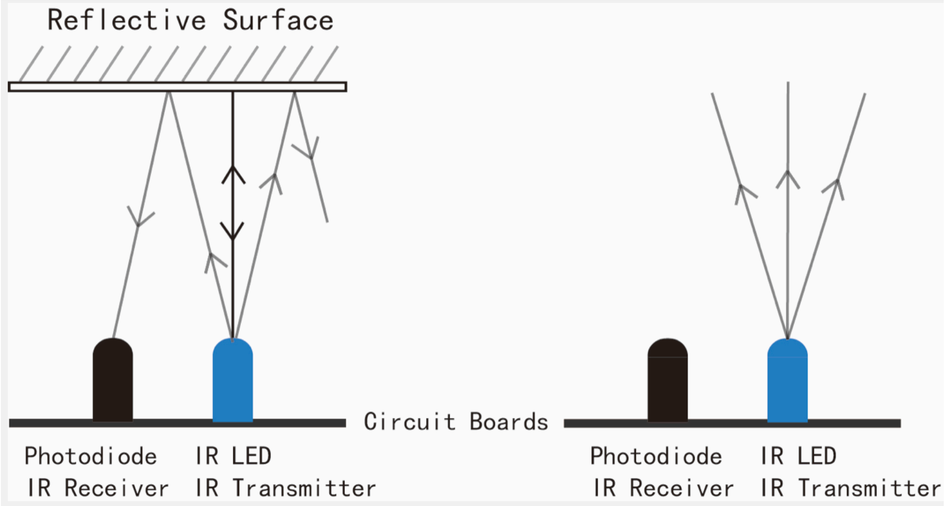
# What to do?



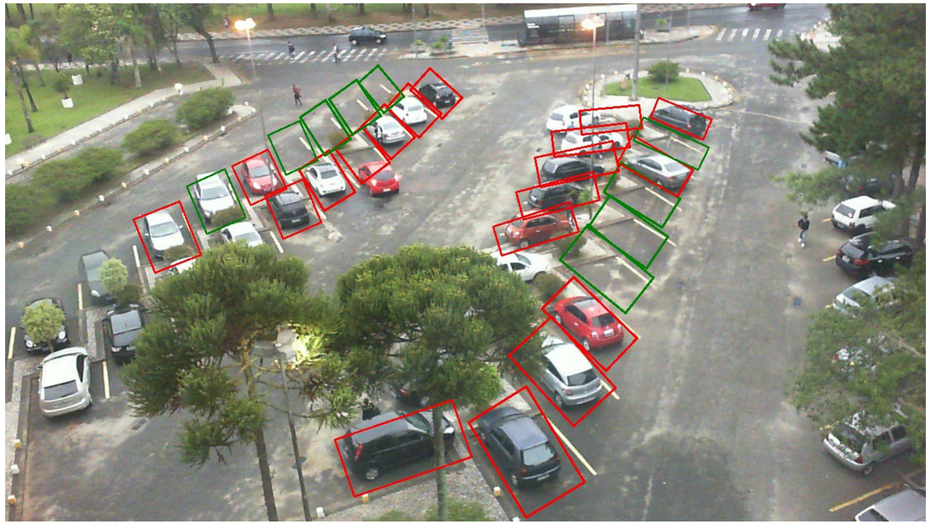

# Inductive loops




# Ultrasonic




# Infrared detection



# Video detection

# 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.

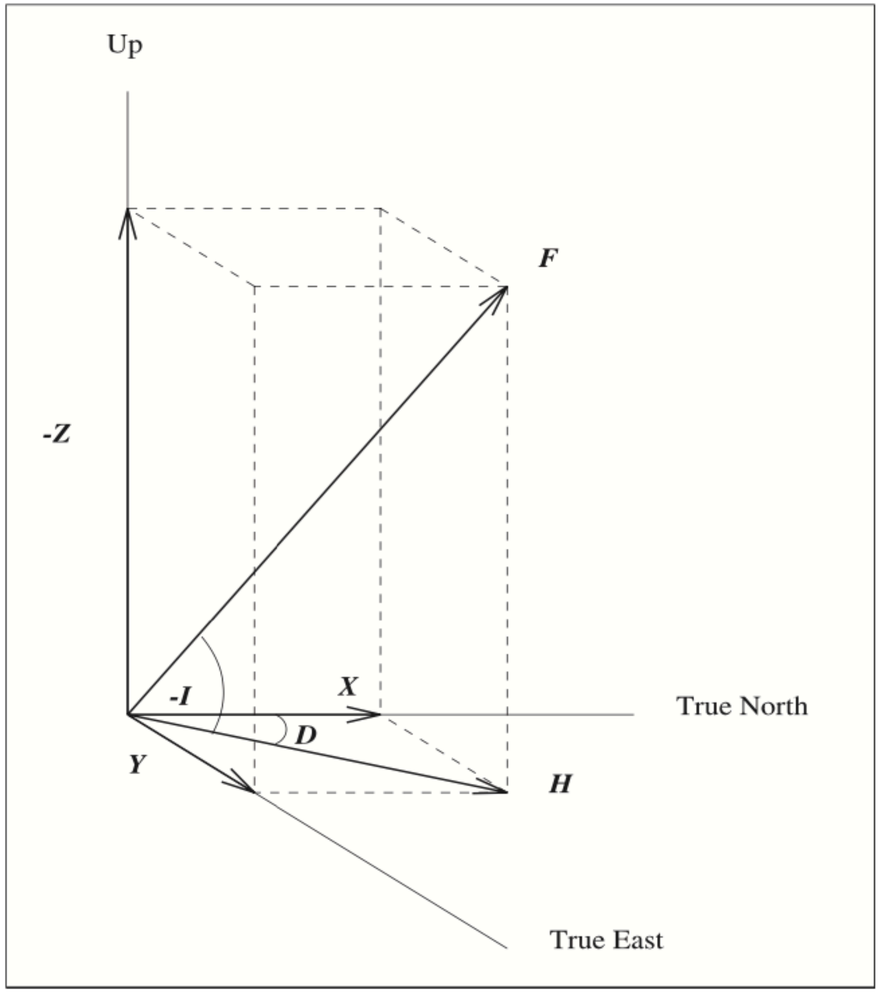


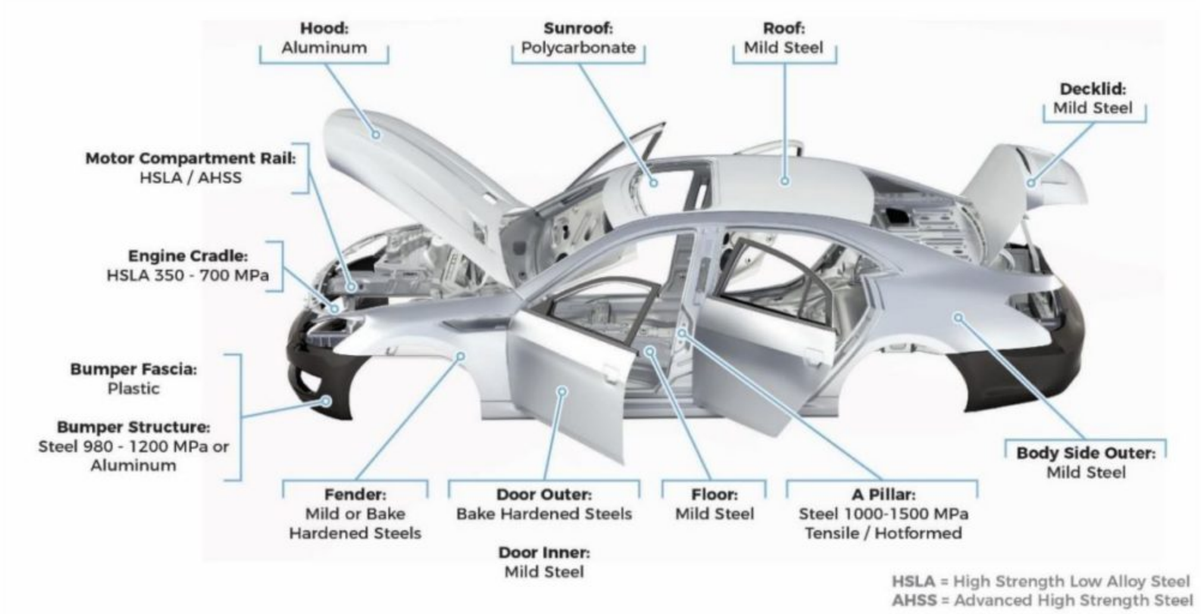

**Fig. 1. Components of Earth's magnetic field (total field *F*, horizontal component *H*, vertical component *Z*, north component *X*, east component *Y*, declination *D*, inclination *I*). The orientation of the vertical component, which results in both *Z* and *I* having negative values, describes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

- Not requires any energy to be emitted, thus minimising both energy consumption and risk of electromagnetic interference



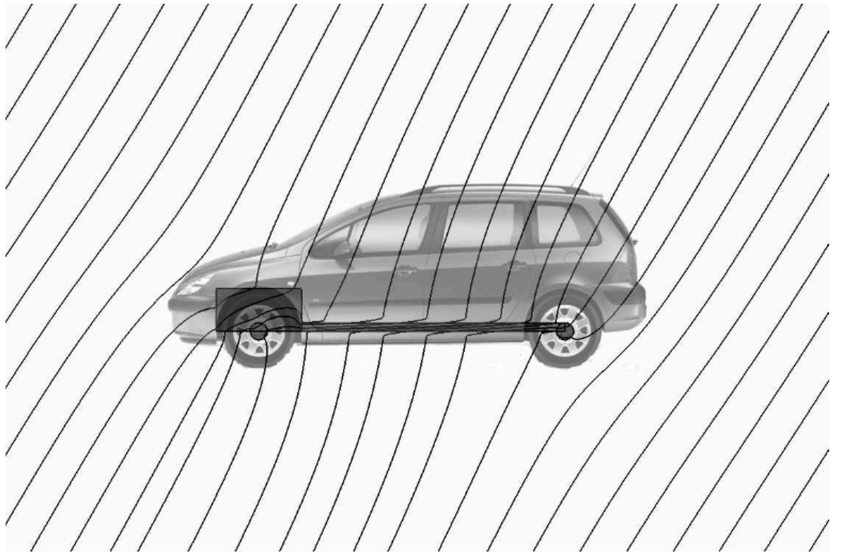
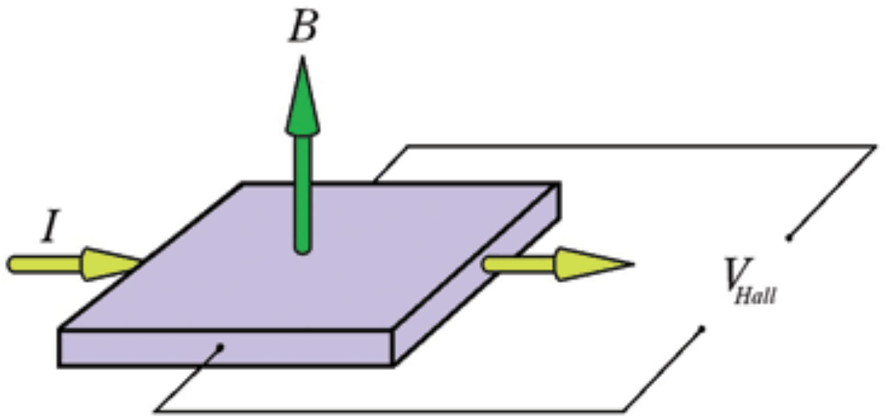



Fig. 1. Simulation of the deformation of the Earth's magnetic field by a car

# 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.
- Good temperature stability.

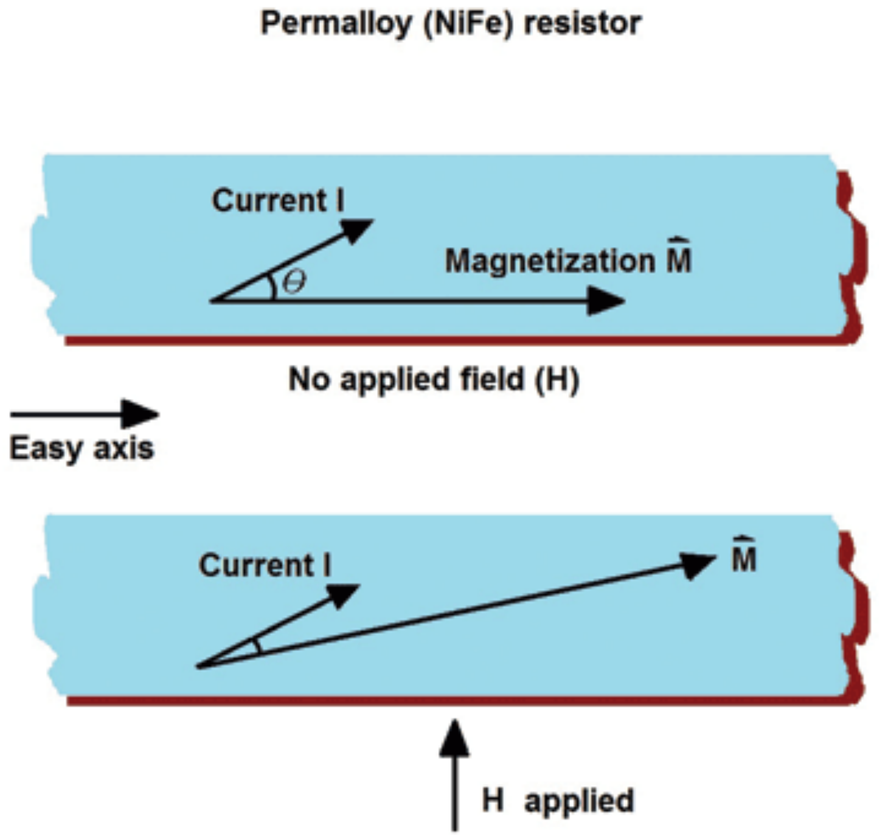



$$V_{Hall} = k\,|\,I \times B\,|$$

# AMR

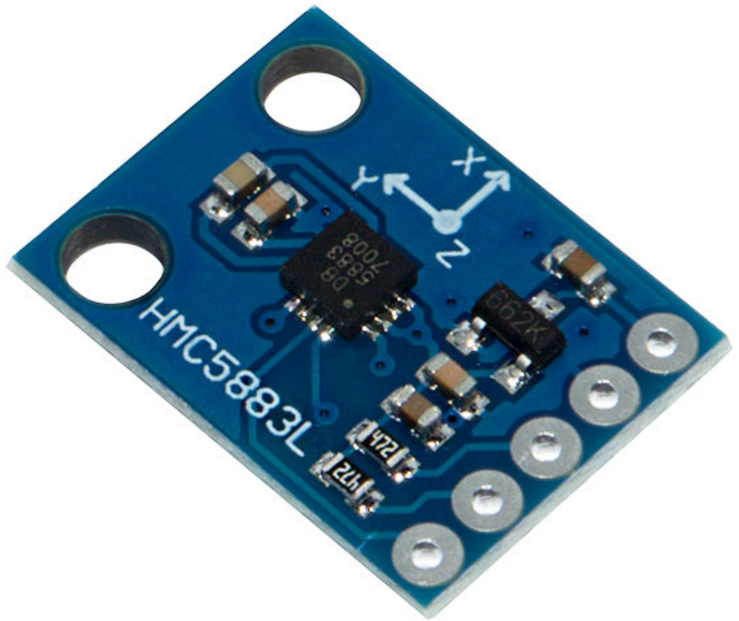
## Anisotropic magnetoresistance

- 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.



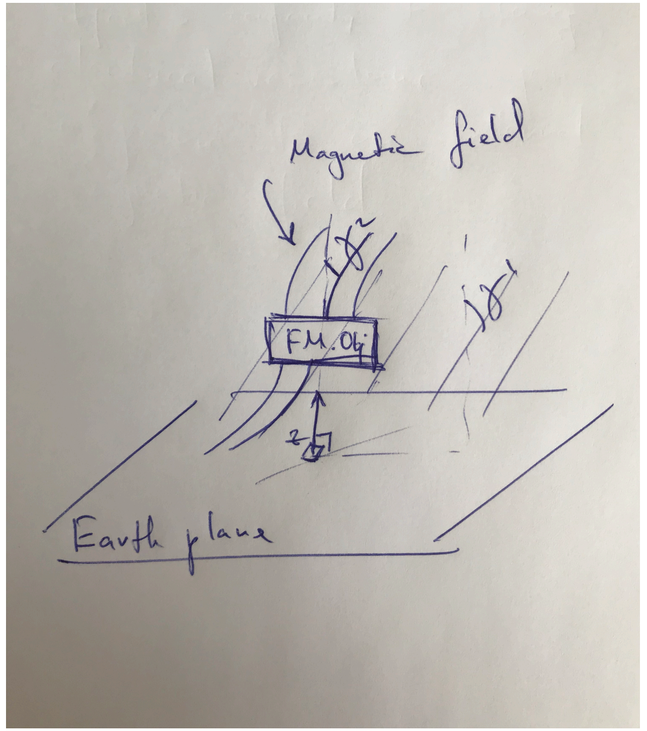
# HMC5883L

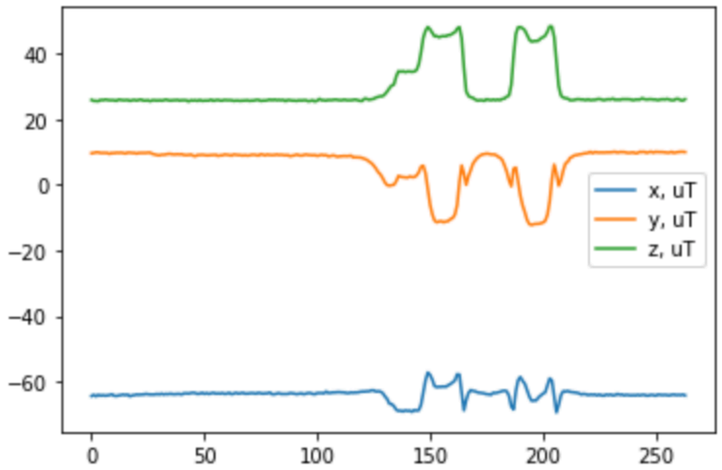
- HMC5883L magnetoresistive sensor circuit is a trio of sensors and application specific support circuits to measure magnetic fields.
- Supply voltage: 2.16 - 3.6 V.
- Field range:  -8 to +8 gauss (average field strength of the Earth's magnetic field is between `30uT` (0.3 Gauss)).
- Digital resolution: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



# Proof of concept

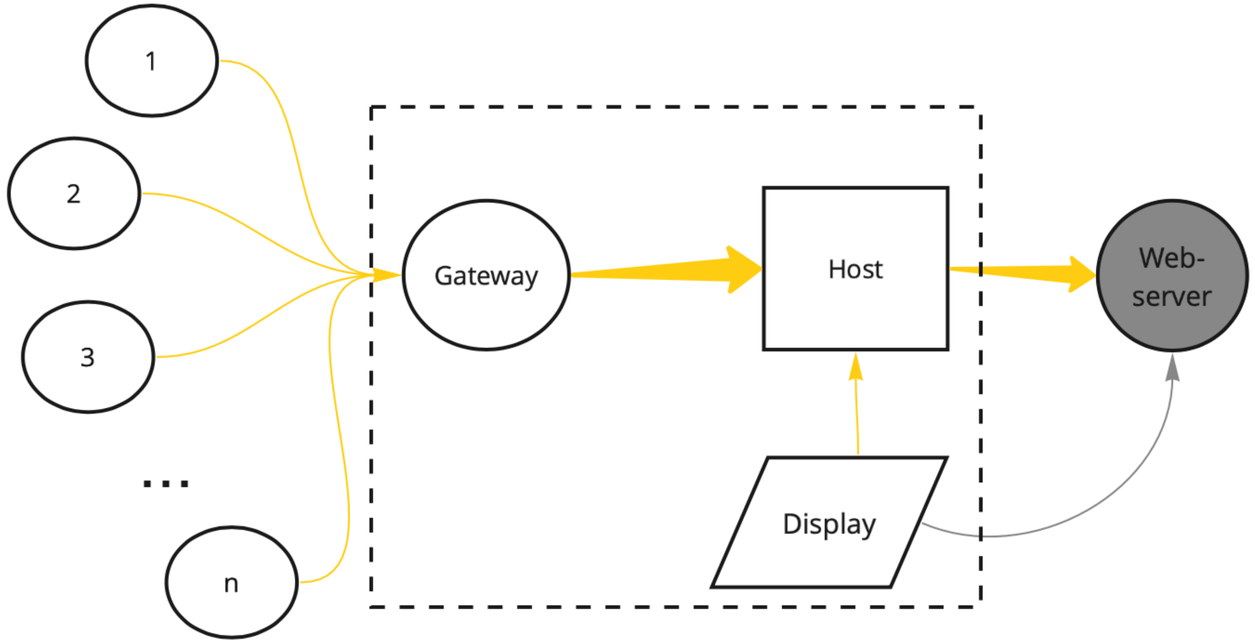
- The Z-axis of the AMR sensor is perpendicular to the plane of Earth.
- As with the appearance of ferromagnetic object the angle between the Z-axis and the local magnetic field becomes smaller, we wait for the sensors' readings to increase as the resistance becomes smaller.



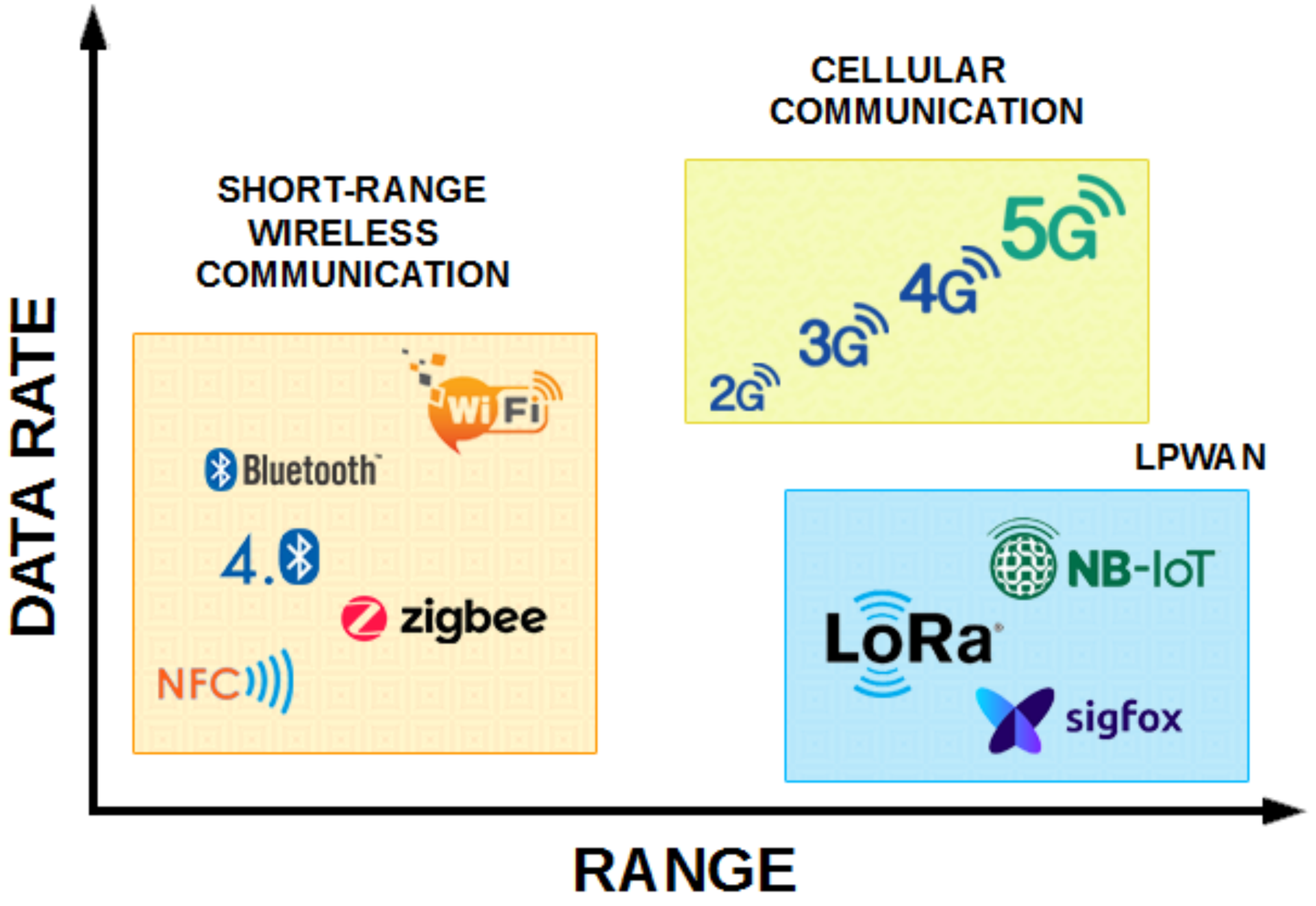




# System overview

- Each parking space is equipped with a sensor (magnetometer and periphery that it requires) that transmits the state of parking space occupancy to a gateway.
- Gateway receives data from sensor-nodes and passes it further to host-machine.
- Host-machine is responsible for system state logging.
- Display fetches data from host-machine directly or via remote web-server and shows it to user.



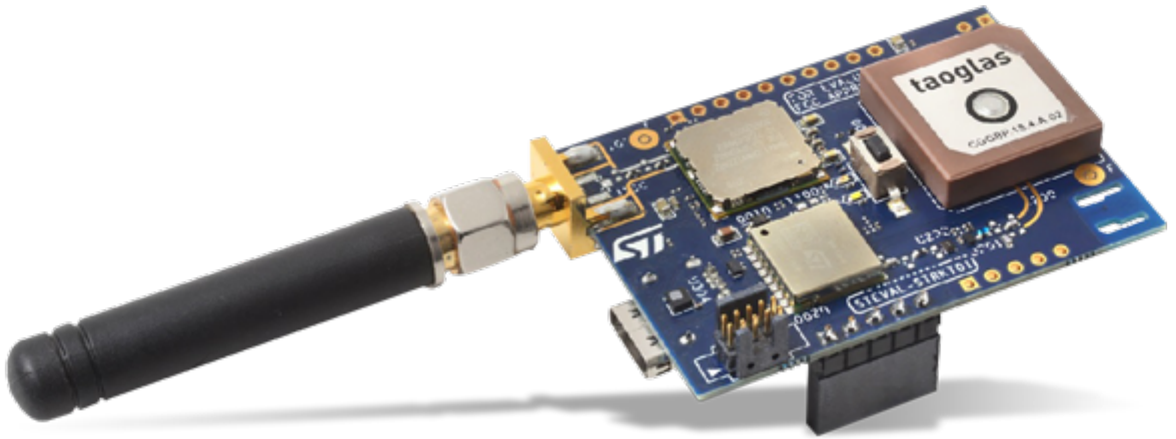
# Data transmission


DATA RATE
RANGE
SHORT-RANGE
WIRELESS
COMMUNICATION
CELLULAR
COMMUNICATION
LPWAN
Wi Fi
Bluetooth
4.
zigbee
NFC
2G
3G
4G
5G
NB-IoT
LoRa
sigfox

# nRF24L01+

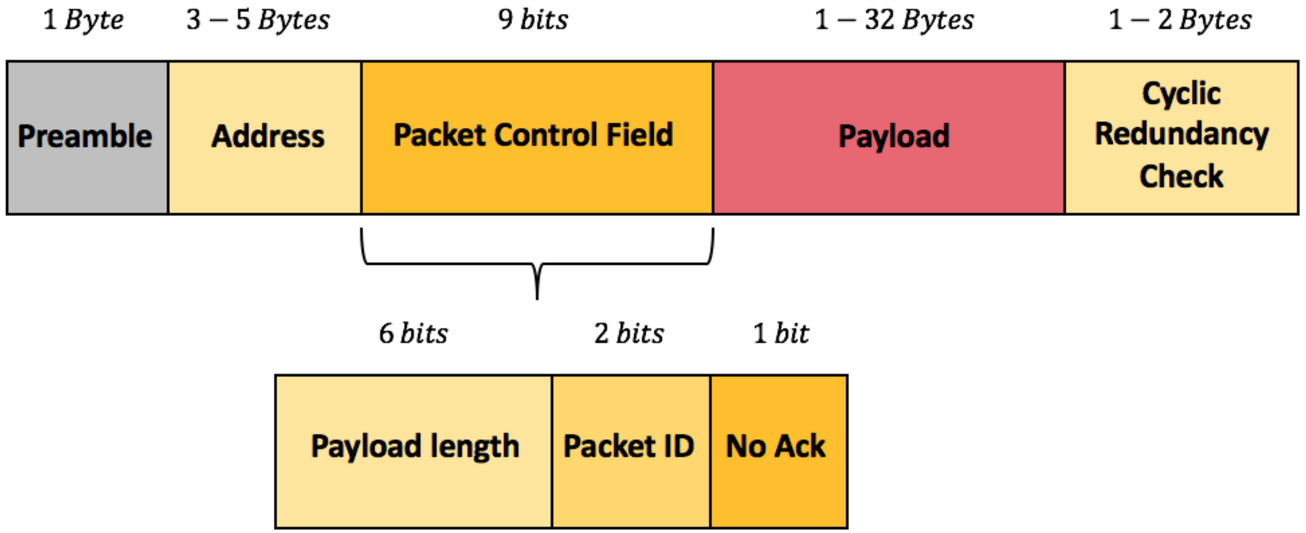
- Very low current consumption: 9mA for transmission.
- Power down mode support.
- Support of star-topology.
- Possibility to receive acknowledging basing on node’s unique id.
- Up to 100m range.
- Up to 32 bytes in one transmission.

- 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

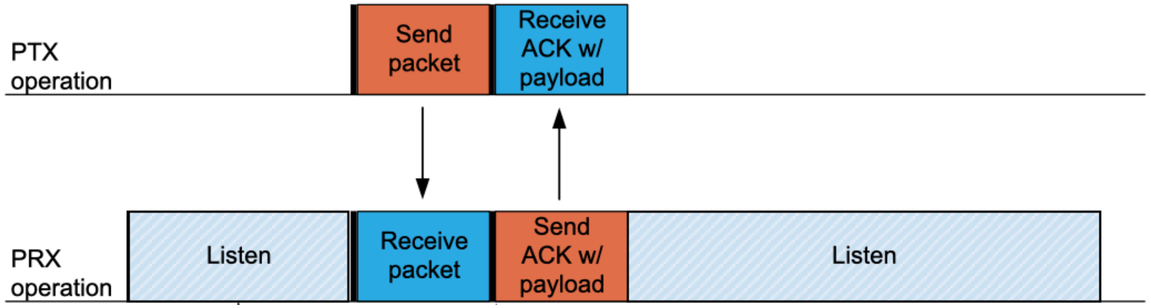
- Up to 32 bytes payloads that support dynamic change.
- Each sent packet with a packet ID, which allows the receiving device to determine whether a message is new or whether it has been retransmitted.
- Each message can request an acknowledgement to be sent when it is received by another device.



# How the automatic packet handling works?

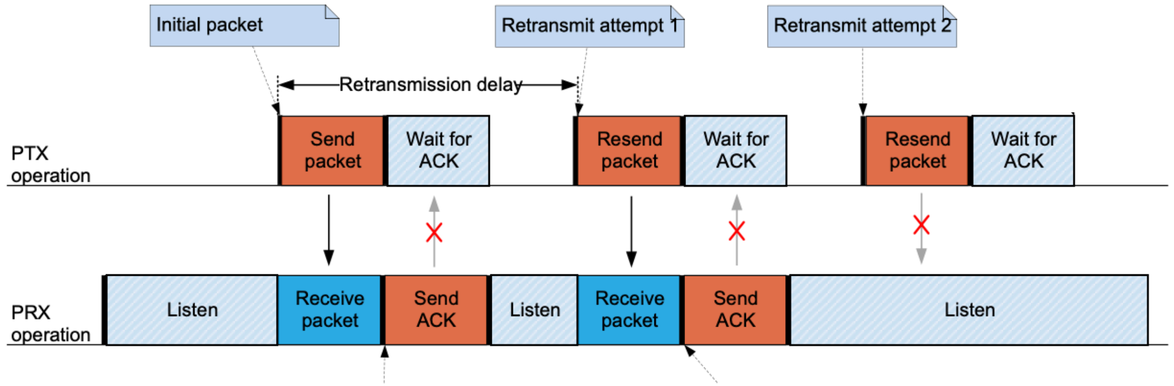
**Transaction with acknowledgement and interrupt**.

- TX sends a data packet to the receiver.
- Once the packet is transmitted, it waits (130 µs) 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

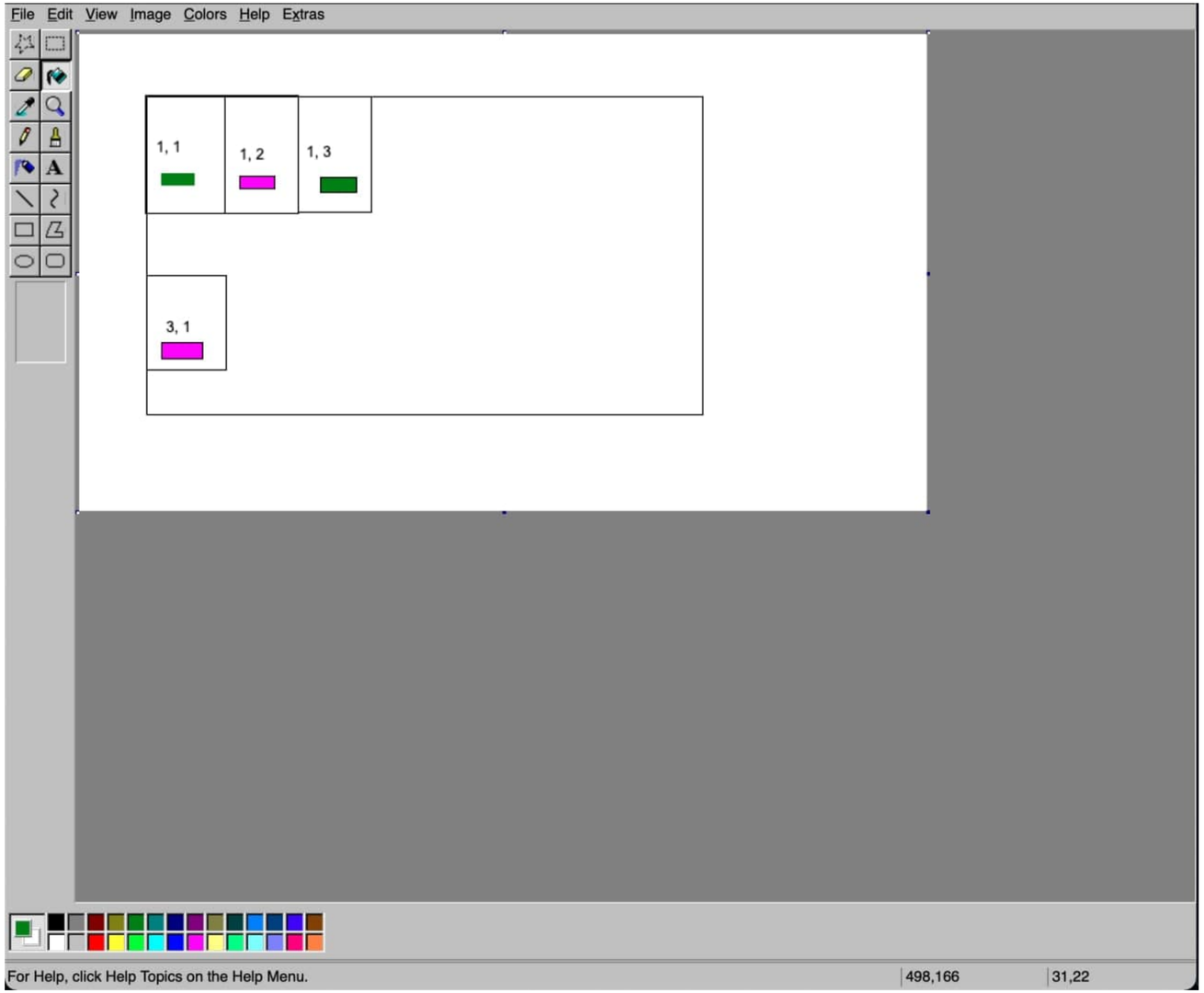
- After the packet is transmitted, the transmitter waits for the ACK packet to receive.
- If the transmitter doesn’t get it within Auto-Retransmit-Delay (ARD) time, the packet is retransmitted.
- When the retransmitted packet is received by the receiver, the ACK packet is transmitted which in turn generates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

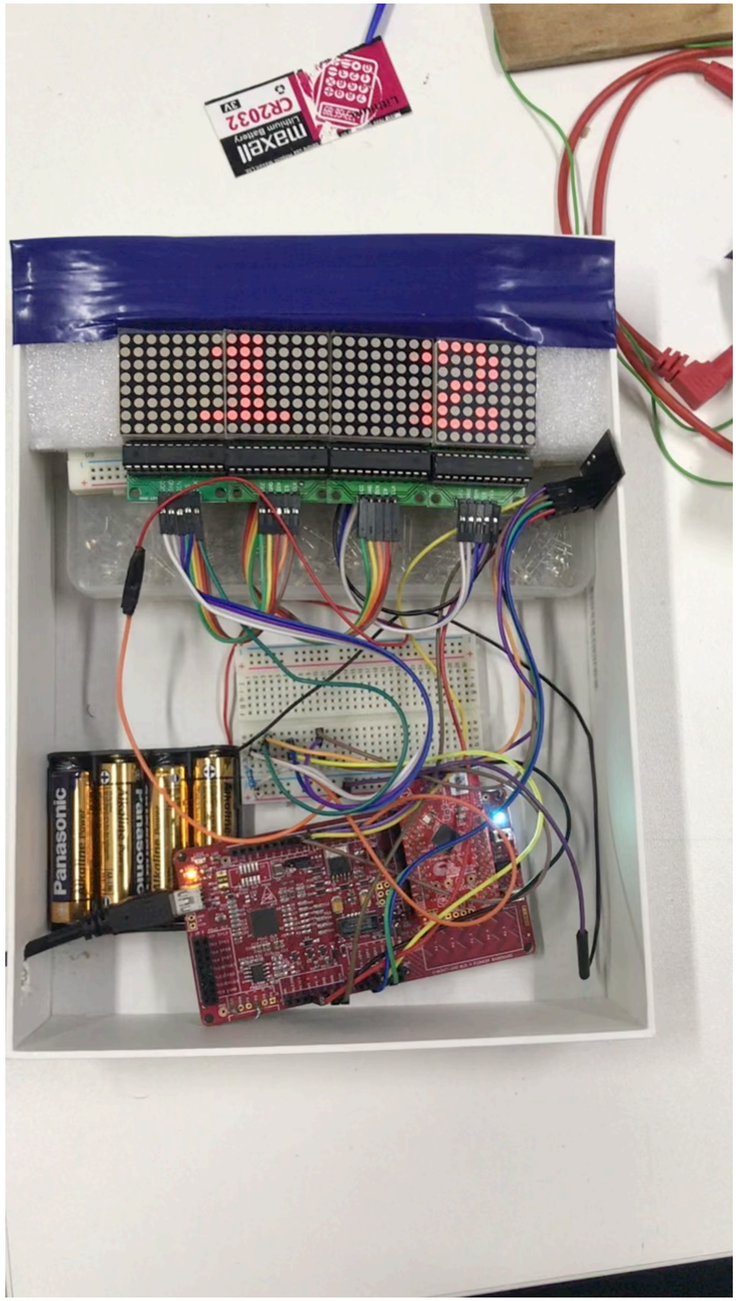



## Transaction with acknowledgement lost

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

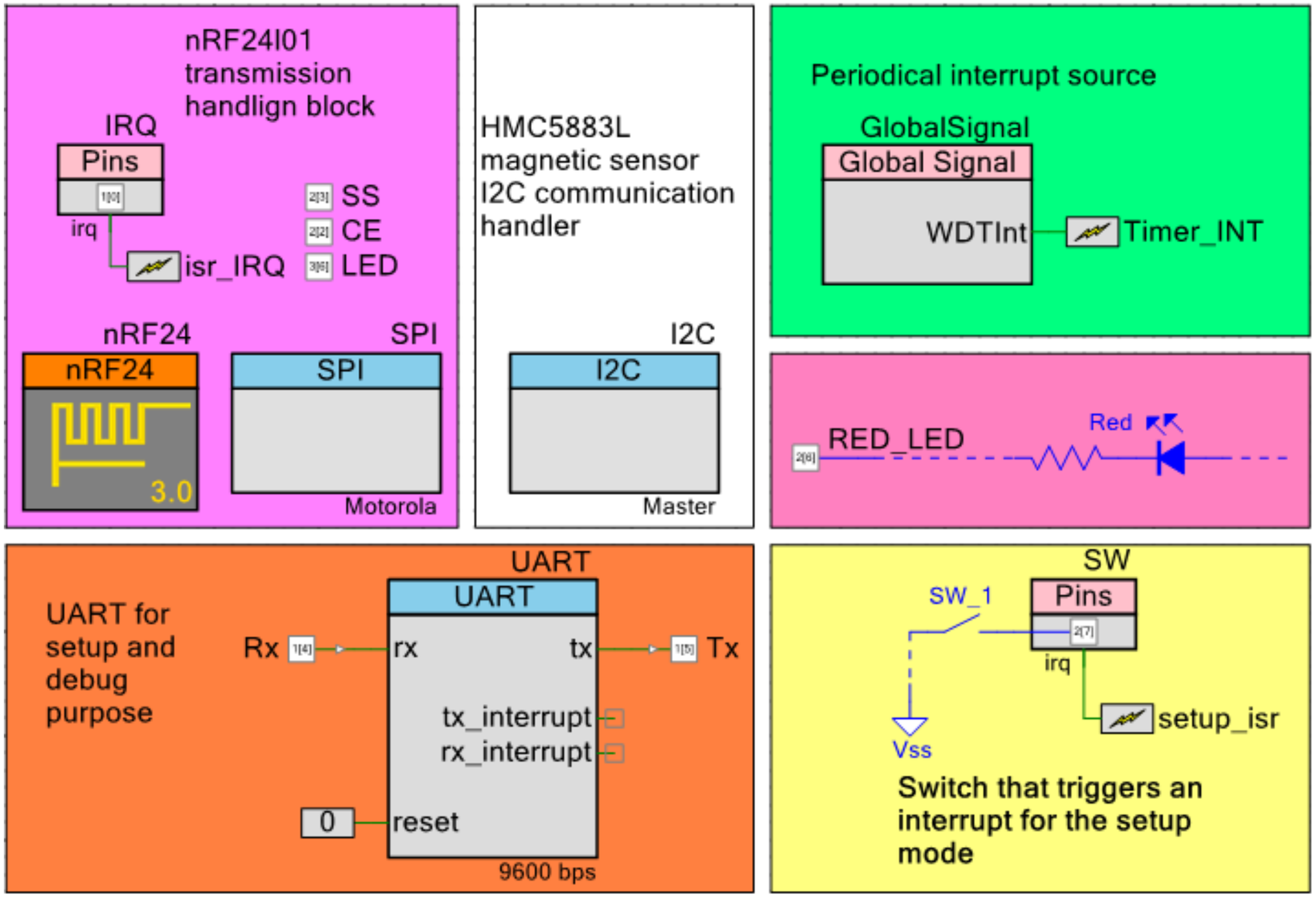
# Displaying


File Edit View Image Colors Help Extras
1, 1
1, 2
1, 3
3, 1
For Help, click Help Topics on the Help Menu.
498,166
31,22


maxell
CR2032
Panasonic

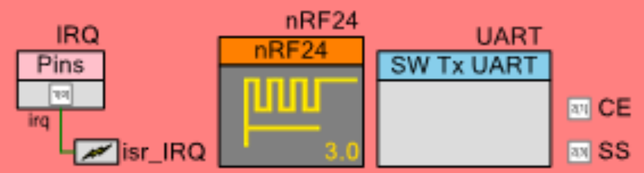
# Scheme

# End-node


nRF24l01
transmission
handlign block
IRQ
Pins
irq
isr_IRQ
SS
CE
LED
nRF24
SPI
3.0
Motorola
HMC5883L
magnetic sensor
I2C communication
handler
I2C
Master
Periodical interrupt source
GlobalSignal
Global Signal
WDTInt
Timer_INT
RED_LED
Red
UART for
setup and
debug
purpose
UART
Rx
rx
tx
Tx
tx_interrupt
rx_interrupt
0
reset
9600 bps
SW
SW_1
Pins
irq
setup_isr
Vss
Switch that triggers an
interrupt for the setup
mode

# Host-Display

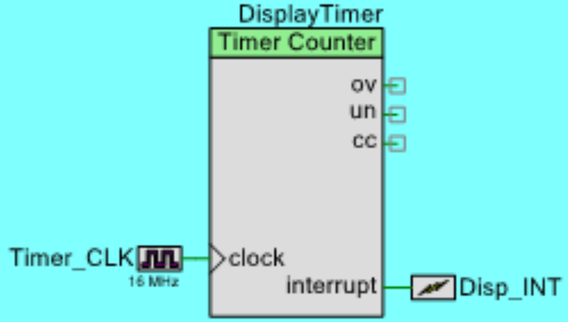
nRF24L01 communication handlers, as well as UART used for debug purposes.




## LED Indications

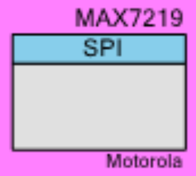

## Display Timer

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.

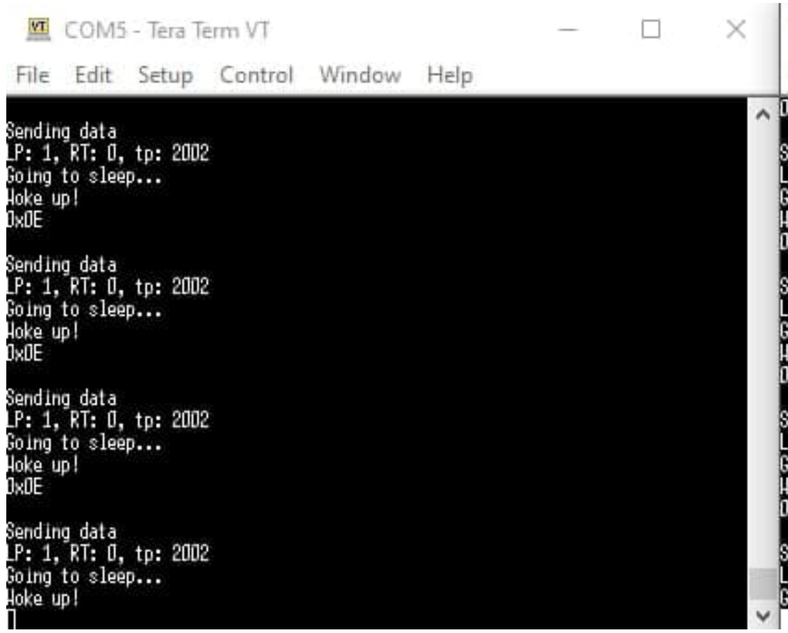



CS

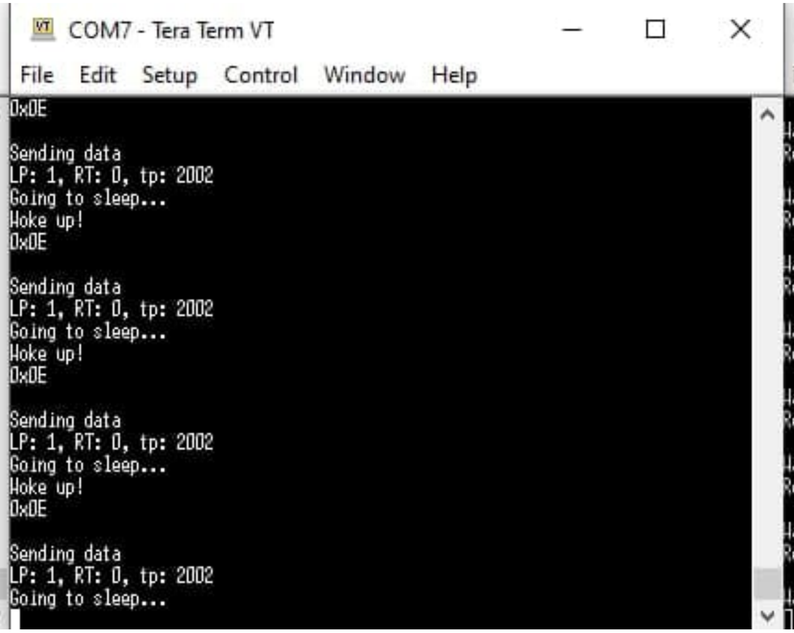
# Example of execution

# does-not-affect-neighbours proof

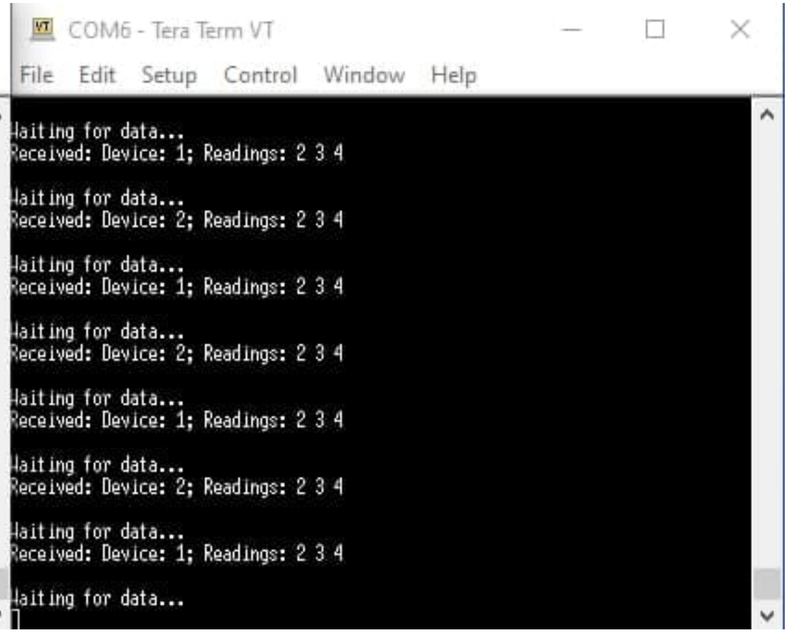
First sensor-node terminal




Second sensor-node terminal



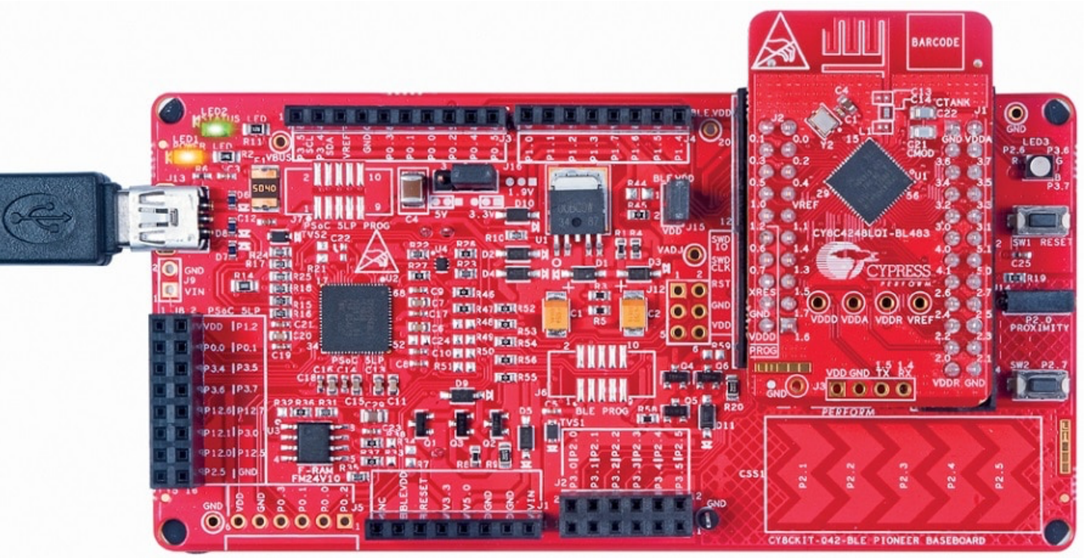

Host terminal output




## Conclusion

Sensor nodes does not affect each other as one can see from the timestamps displayed in the sensor-nodes' terminals. Such an experiment was also conducted under the condition of second-node filling in radio wave as much as it can. It showed the same result.

# Power consumption




- System is waken from deep-sleep via Watchdog Timer.
- Sensor-nodes transmit the data only if the state of parking space occupancy has changes.
- Radio transmitter was chosen with respect to its power consumption, which is competitively low - 9.8mA during transmission
- Magnetometer and radio-module both support idle mode
- Measuring power from the Pioneer Kit directly cannot show true results as it also includes the consumption of PSoC5 LP

# Second generation

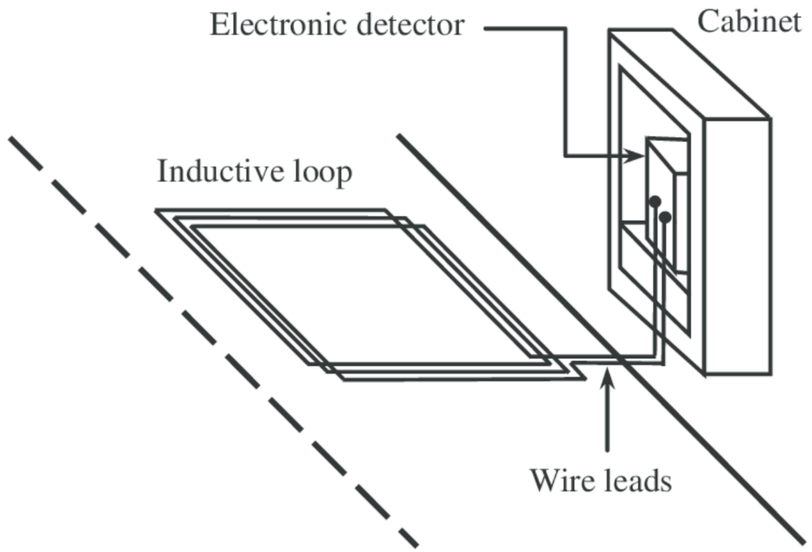
- Port host functionality to PSoC 6 with WiFi support, so to make the remote web-server possible.
- Possibility of wireless battery charging
- Ability to get the information about the battery charge of an sensor-node
- Consider using PSoC’s silicon id to identify an end-node, rather than setup each node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

# Q&A

# Appendix

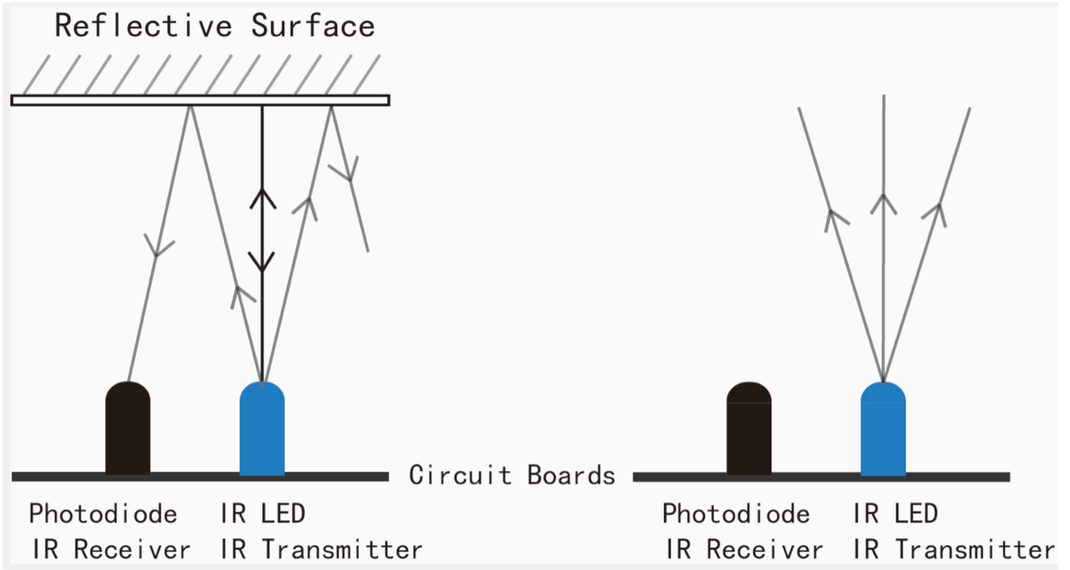
# Inductive loops

- Detects 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).



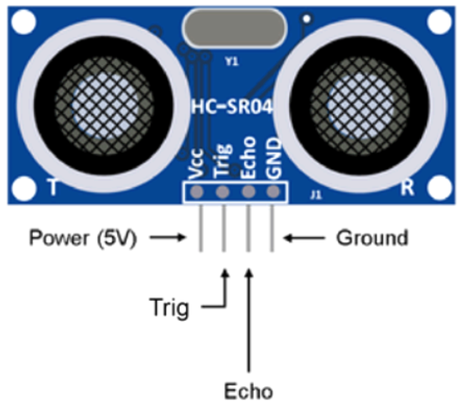
# Infrared detectors

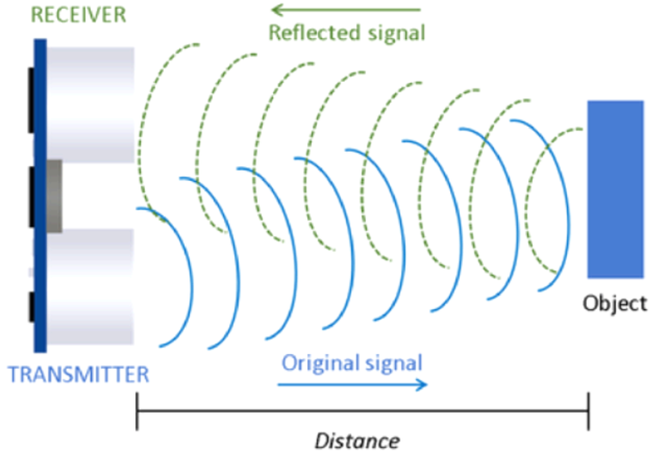
- Infrared sensors or the IR sensors are low frequency light emitting diodes.
- Sensitivity of the sensor is reduced in heavy rain, snow, leaves or dense fog.
- It may be hard to come up with the solution for the covered parking.



# Ultrasonic Range meters.

- Use a sonar-like sound pulse (detectors are calibrated with the known distance from detector to pavement and can then measure 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.