Universal system of long range radio communication for mobile detectors

Katarzyna Smelcerz
Cracow University of Technology, Poland

Agenda

Introduction
CREDO
- Smaprtphones
- Mobile Scintillator Based Detectors

Data acquisition problem
Carrier
System
- Features
- Topology
- Protocol
- Time Synchronization

History of the versions
Tests results
Obstacle Avoiding
Summary

Introduction

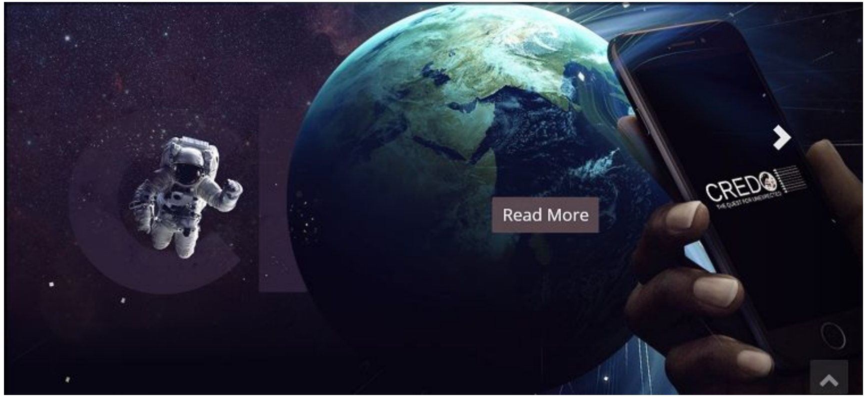
- Graduated Cracow University of Technology, Computer Science, master program in 2012

- PhD student, Faculty of Computer Science and Telecommunications

Back to the beginning

- CREDO Collaboration (march 2017 - June 2019)

  https://credo.science/

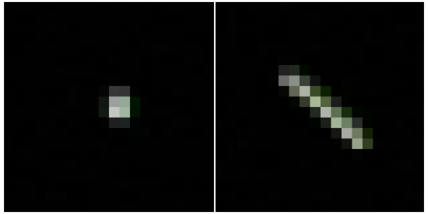


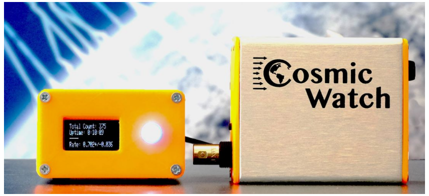
CREDO project

The study of Cosmic-Ray Ensembles (CRE) in large areas and the correlation between specific events:

- Requires a large and widely dispersed research infrastructure
- Not only specialized detectors
- Citizen science - detectors that could be used by people who are not necessarily scientists (cheap, easy to use and available)

Smartphones & Mobile Cheap Scintillator Based Detector (similar to Cosmic Watch)





Source: http://www.cosmicwatch.lns.mit.edu/

CREDO: Scintillator Based Detectors

Network of mobile detectors

How to collect data?

🤷🏻‍♀️

Scenarios



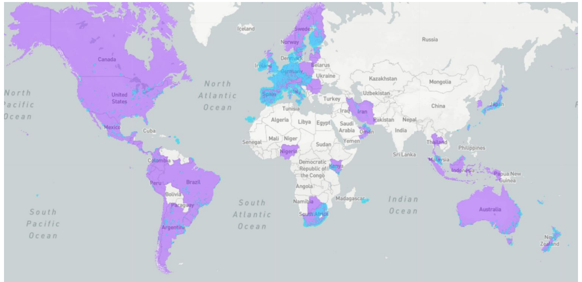
Currently available carriers

Maybe we could use something that already exists?

- Internet
- LoRa
- SigFox
- GSM
- FSK

Currently available carriers

SigFox coverage



Source: https://www.sigfox.com/en/coverage

Maybe we could use something that already exists?

- Internet - not available everywhere
- LoRa - it processes the signal. Offers a receiving (mobile) station, but **only at 868 433MHz.** No access to the software of the receiving station, however it can decode simultaneously many transmissions on many bands.
- SigFox - has good results, but receiving station is something ready to go solution, it cannot be modified or customized, and requires significant power supply. This is not mobile solution.
- GSM - same as the Internet, not available on the desserts for example
- FSK - short range, about 3 times less than LoRa.

Currently available carriers

Maybe we could use something that already exists?

- Internet
- LoRa
- SigFox
- GSM
- FSK

DENIED

Different scenarios - universal carrier

System features

Carrier: ISM 169MHz radio frequency

Star topology

Unidirectional transmission (from sensors to sink) in specific time slots. requires time synchronisation for all the sensors.

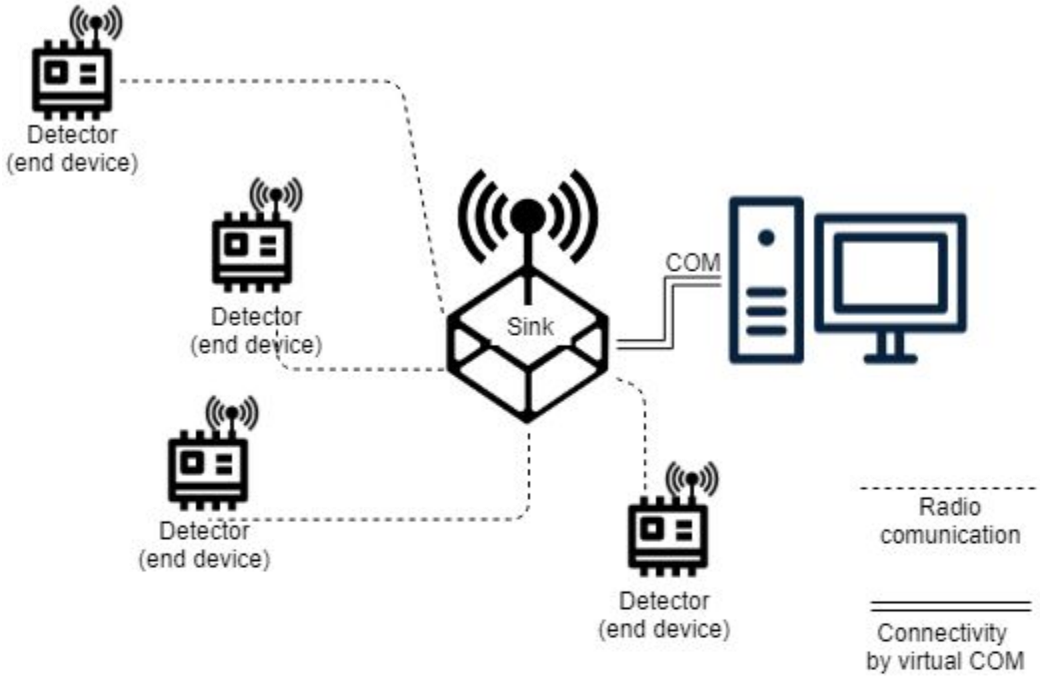
Small packet size - at the moment: 8 bytes

Low energy consumption, battery operation;
~2 years on battery in a scenario where the data is sent once per hour from a detector, and the frame transmission time is 2.2 s.

Sink: 5V, ~0.5A

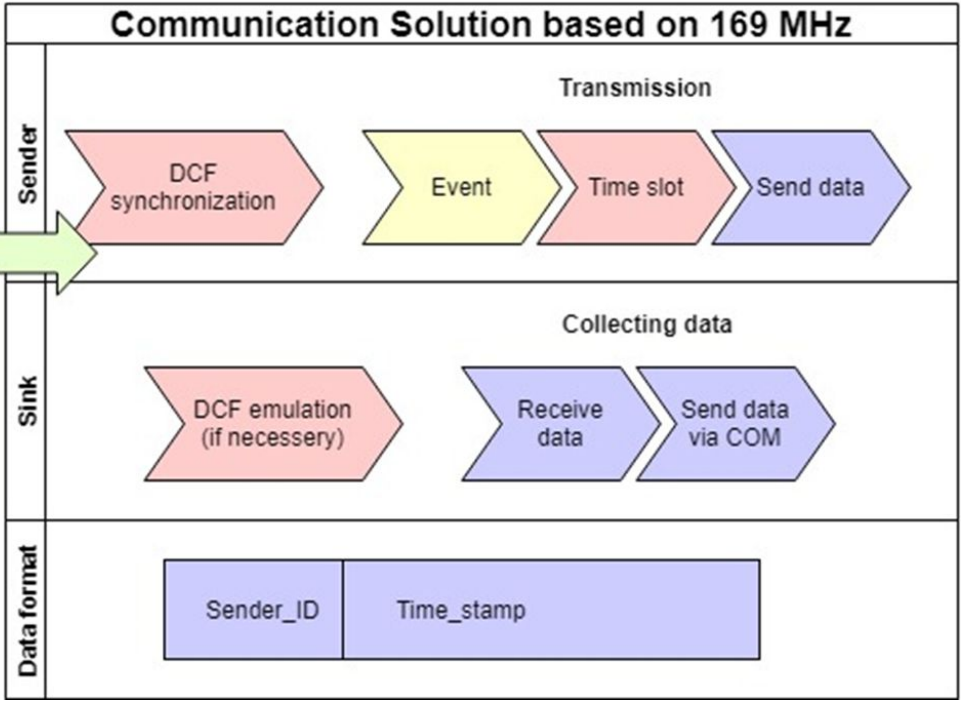
Sender: 3.4V

System topology



Protocol

DCF77 is a German longwave time sygnal and standard-frequency radio station.
It is controlled by Gemany's national physics laboratory and transmits in continous operation (24h)

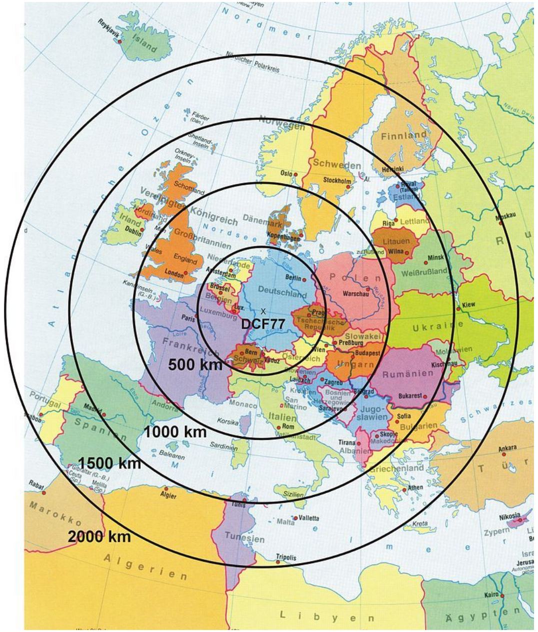


Time synchronization

- **DCF**: Broadcast time and date information is repeated every minute with a marker at the end of each minute. The accuracy of the end of minute marker is ±2 millisecond.
  Frequency: 77.5 kHz, Power: 50 kW

- **WhiteRabbit:** Synchronous Ethernet (SyncE) to achieve syntonization and IEEE 1588 (1588) Precision Time Protocol (PTP). Sub-nanosecond accuracy

- **GPS:** 10ns jitter
  https://cdn-shop.adafruit.com/datasheets/GlobalTop-FGPMMOPA6H-Datasheet-V0A.pdf



It was a long, long way...

It started on the **Spirit1** FSK chip and it turned out that even on the evaluation kit the range is **100-150m.**

Over a year of struggling with Spirit1, STM. Starter-kits worked better than the own designed system, although theoretically the same elements were used. The system was **tested on bands 169, 433 and 868 MHz** with similar range, which was inconsistent with the theory (lower frequency should have higher range).

Discovery **SX1276 (Semtech)** - had better range than Spirit1.

At the starter-kit from Semtech, range about **300m** on the same route as Spirit1, but nothing more.

Tests on a changed modulation parameters - no significant progress...

Long, long way…
The idea

To build a **preamplifier (low-noise amplifier)** that catches the signal from the antenna, amplifies it and passes it on to the system (time> 2 years). At first, the amplifiers behaved like oscillators instead like amplifiers, than this problem had been fixed (it was a bad PCB layout). The next version had too high noise, so there was no change in range (still 300m).

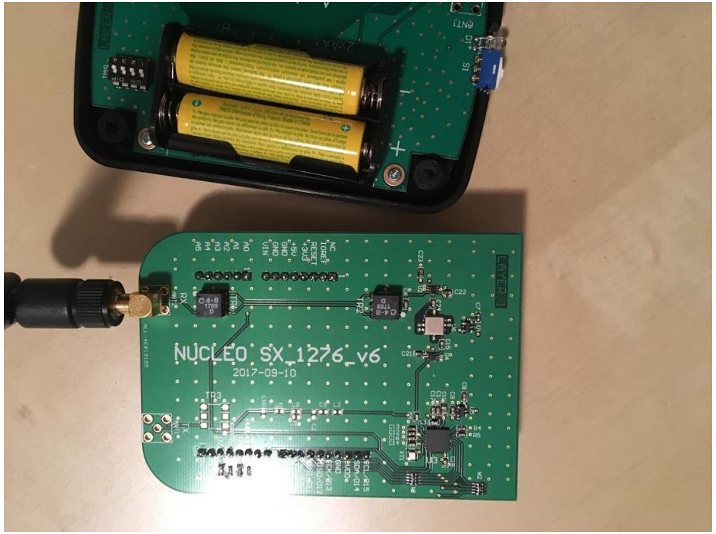
The 7th version of the amplifier had range of about **1.5 km at the beginning of 2019**

At the same time, the antennas were constantly improved better and better), the concept of the receiving station was also changed, which at first was assembled as a cover mounted on a nucleo plate, but later **it was switched to a larger plate, which is having uC itself.**

Work continued on reducing the amplifier's own noise, cutting off the processor noise and improving the signal from the antenna.

The recently built amplifier works stable, does not excite and allows establishing communication **in built-up area for about 4km**, as long as there is no obstacle such as hill

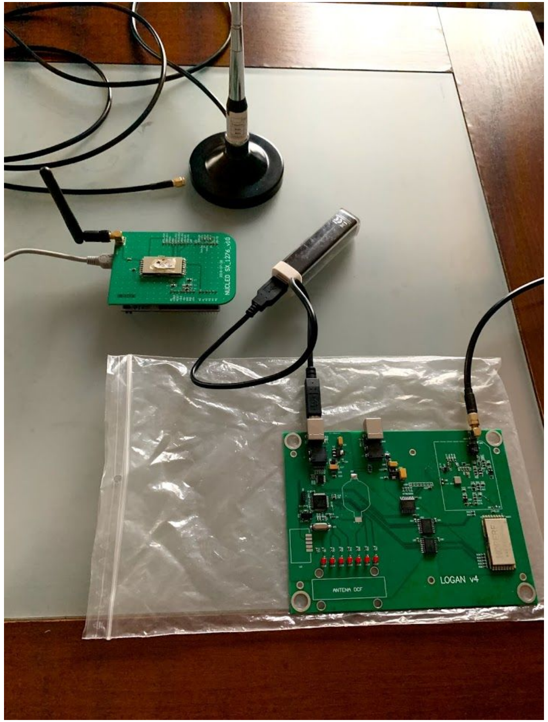
Versions over last 2 years > 15

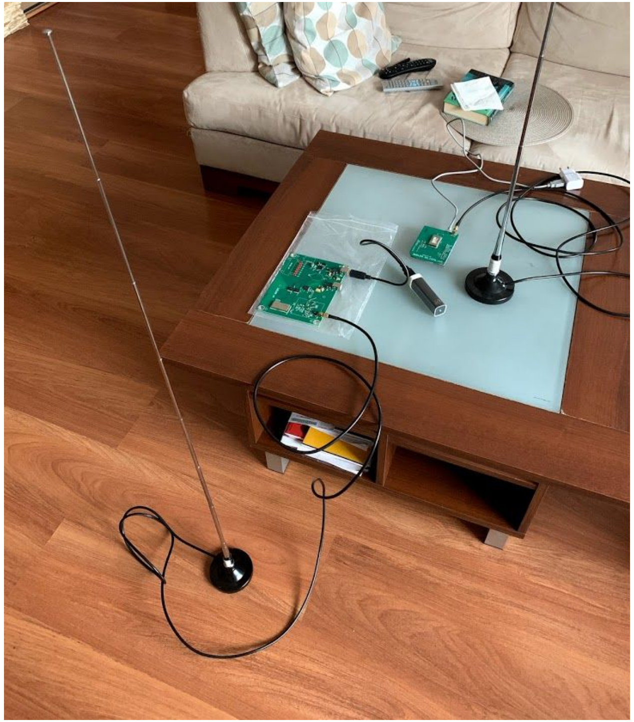


Current System: Sender and Sink

Sender cost: ~50$

Sink cost: ~200$





Tests results in the city

February 2019, ~1.5km

Transmission parameters

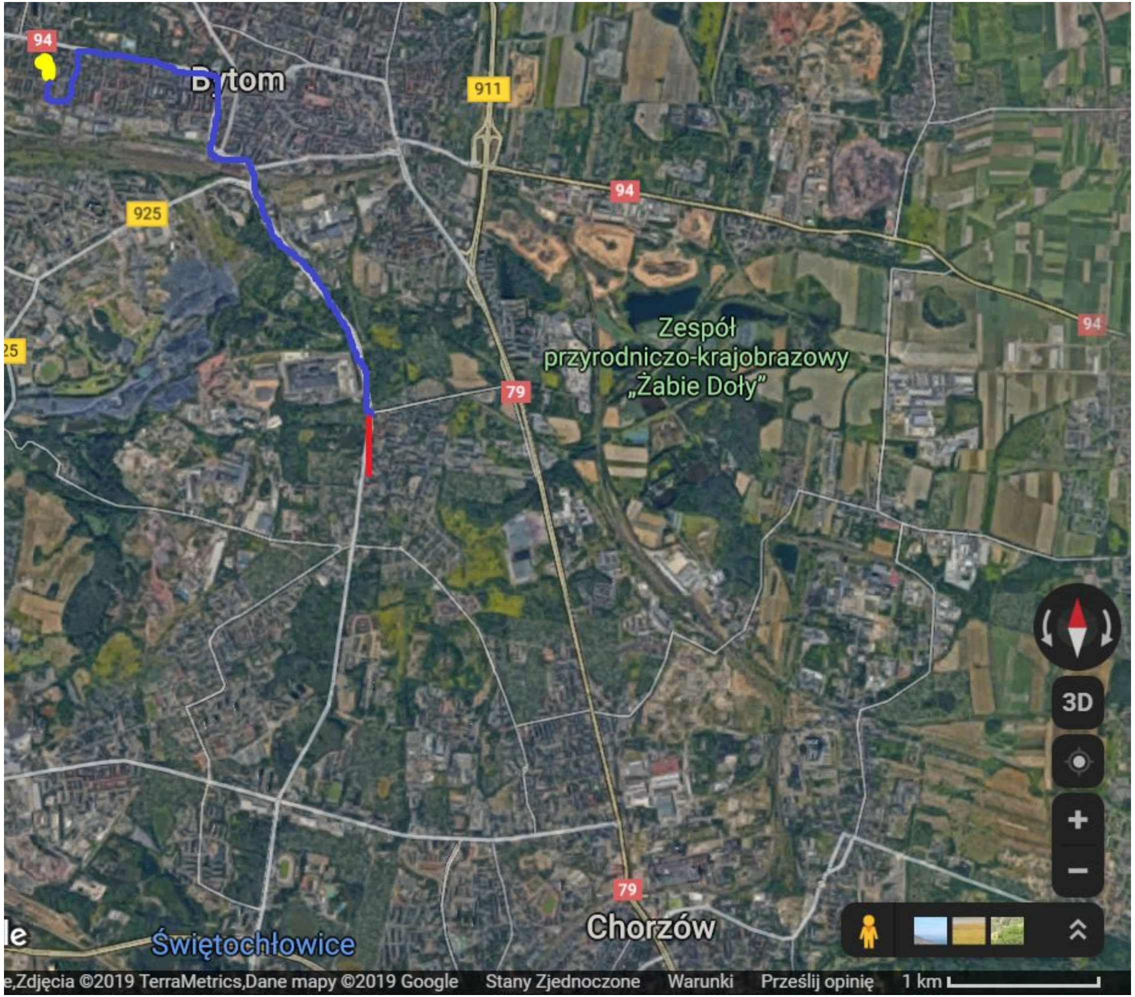
n	ID	frame	RSSI	SNR	n	ID	frame	RSSI	SNR
392	12	597	-49	6	1	x	160	-69	-16
393	12	598	-55	12	2	x	165	-70	-15
394	12	599	-55	11	3	12	167	-69	-15
395	12	600	-54	11	4	12	168	-69	-15
396	12	601	-50	7	5	x	169	-69	-16
397	12	602	-47	6	6	x	x	-69	-17
398	12	603	-45	9	7	x	176	-69	-15
399	12	604	-44	7	8	12	x	-69	-16
400	12	605	-44	7	9	x	x	-68	-17
401	12	606	-44	7	10	x	x	-76	-17
402	12	607	-44	6	11	x	x	-69	-16
403	12	608	-44	7	12	12	182	-69	-15
404	12	609	-55	7	13	x	x	-77	-17
405	12	610	-52	12	14	12	186	-68	-17
406	12	611	-53	11	15	12	4	-68	-17
407	12	612	-52	11	16	x	189	-69	-15

Transmission parameters from the range limit area (red) compared with transmission parameters for the very good range area (blue)

SNR (Signal Noise to Radio)

$$SNR(dB) = P_{signal}(dB) - P_{noise}(dB)$$

RSSI (Received Signal Strength Indication), that is the value of the signal measured in decibels (dB) from 0 to -120. The closer to 0, the stronger the signal is.



September 2019: ~4km

Comparison of Universal System of Long Range Radio Communication vs. LoRa

Feature	USLRRC	$LoRa^{TM}$
Requires special infrastructure	No	Yes
Range in urban area	~~1 – 1.5 km~~	3 - 5 km
ISM bands	Yes	Yes
Frequency	169 MHz	Various, sub-gigahertz

~4 km

LoRa tests in urban area

LoRa system single-cell coverage in Padova, Italy.

Connectivity was achieved at approx. 2 km.

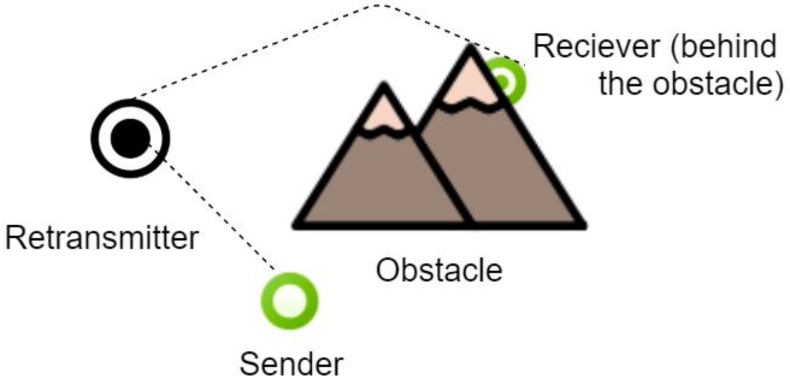
For more details see:

Marco Centenaro, Lorenzo Vangelista, Andrea Zanella, and Michele Zorzi, *Long-Range Communications in Unlicensed Bands: The Rising Stars in the IoT and Smart City Scenarios*, IEEE Wireless Communications (Volume: 23 , Issue: 5 , October 2016)

Avoiding obstacles

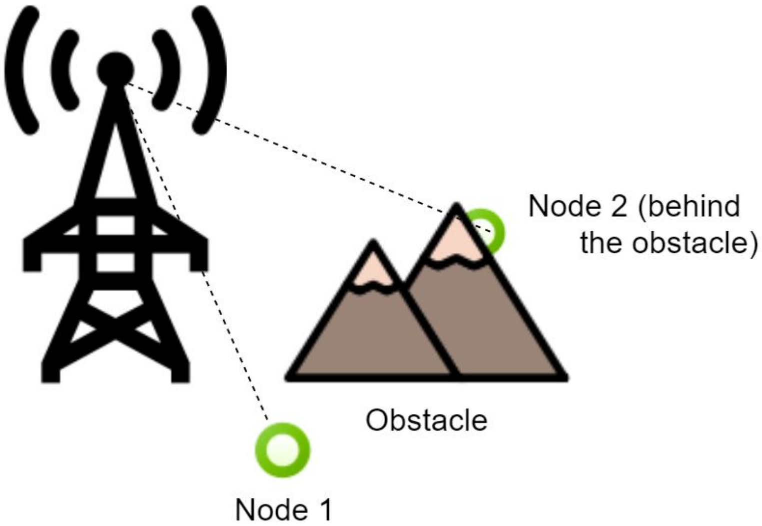
Basic problem in long range wireless communication is how to avoid obstacles. Nowadays it is done by the following ways :

- using mesh topology, that bypasses by the obstacle



Avoiding obstacles

- using for receiver station high placed antenna on some hill or pole, which is above the obstacles

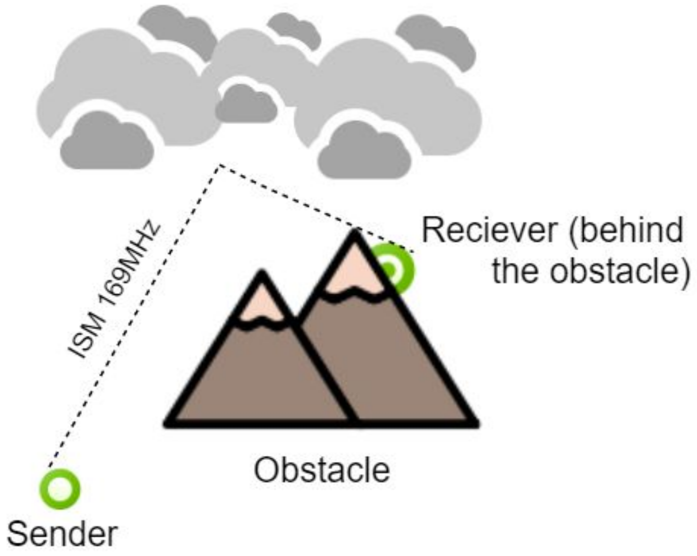


Skywave reflection

In this application, nether mesh topology nor antennas placed high on poles can be used.

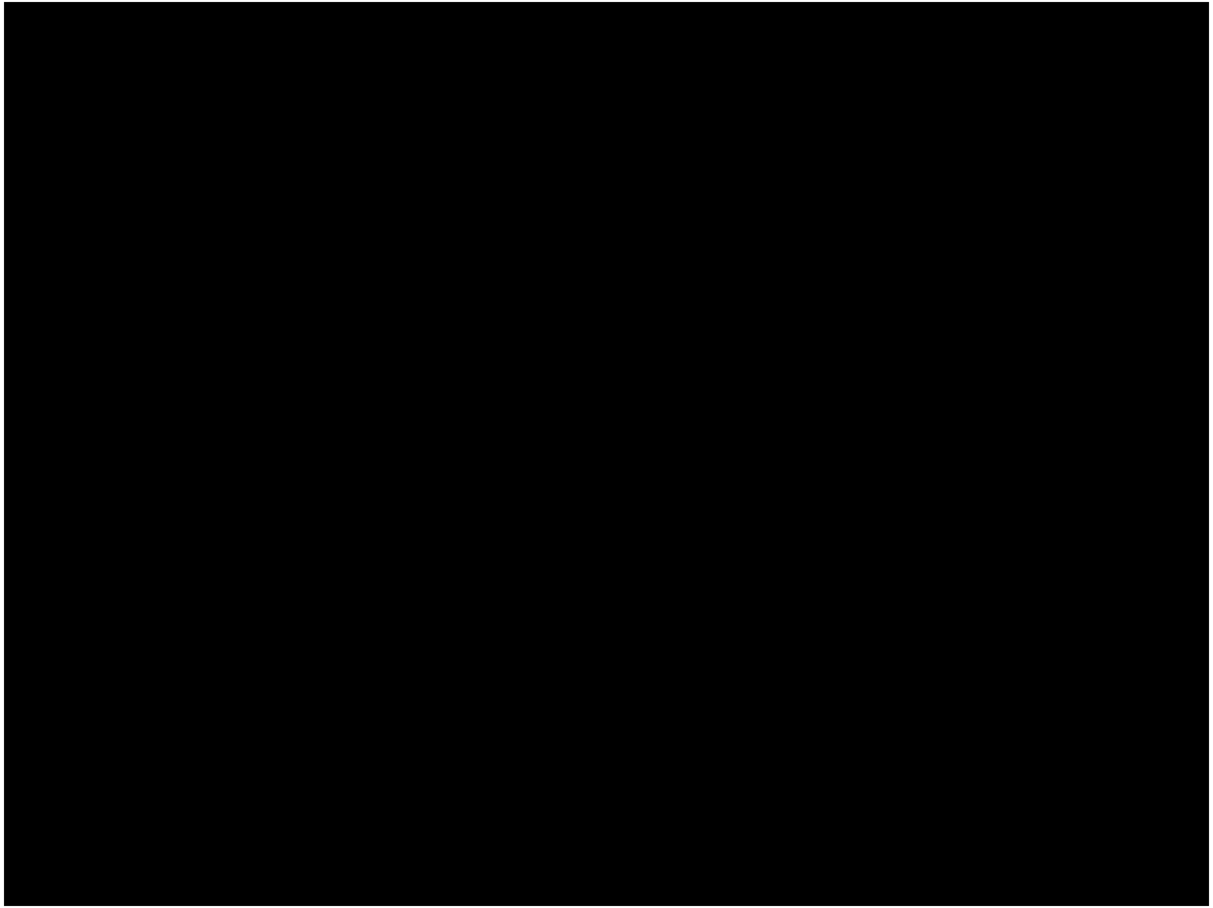
Reflection signal from the air.

If this works, communication is possible above obstacles if only transmitter and sink can see the sky. At this stage of the project, reflection from the clouds was seen with good signal quality. Now the challenge is communication on the cloudless sky.

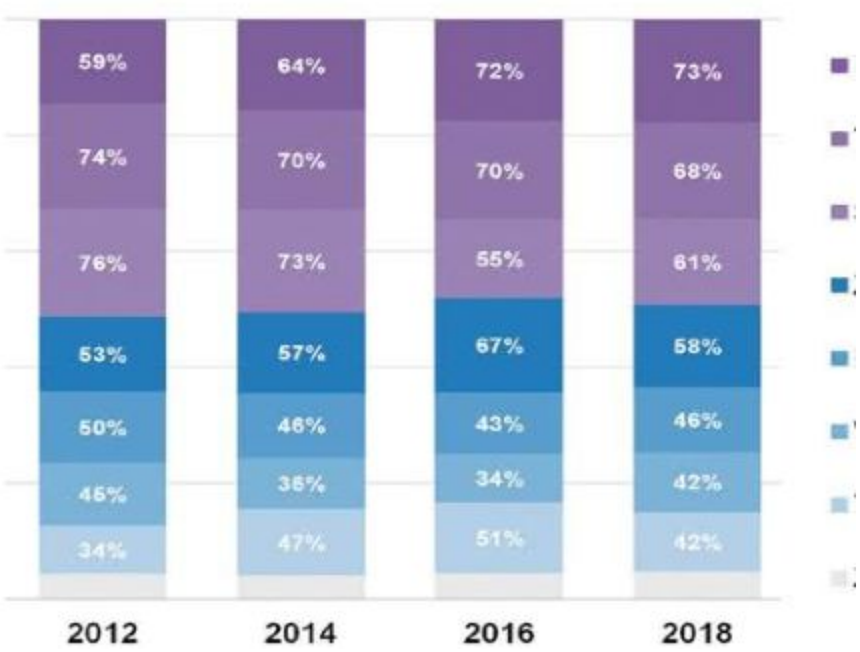


Problematic place


HOPERF
LOGAN v4
ANTENNA DCF



Why is the system interesting?



Monitoring and diagnostics

Telemetry

Alarm and security system

Remote control of systems operation

Energetics

Sewage

Transportation

Custom and trade

Source: https://automatykab2b.pl/raporty/49178-sieci-bezprzewodowe-przemyslowe-raport-rynek

Future work

- Publishing a paper
- Improvement of the range

- Improvement of the protocol and tests over it - including simulations
- Optimization of power consumption

Thank you

for your attention