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Integration of Relay-Based LPWAN Network and Artificial Intelligence for Wildfires Detection and Prevention

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Outline

- Problem definition
- State of the arts
- Methods/Approach
- Results
- Conclusions

Problem definition

- **How to make an affordable and efficient system for wildfires detection and prevention?**
- **How to use integration of Internet of Things (IoT) and Artificial Intelligence (AI) to create Artificial Intelligence of Things (AIoT) in disaster response situations?**

State of the art

- Every year, wildfires destroy millions of hectares of forests around the world, causing billions of dollars in damage to the economies of the countries affected.
- Rapid climate changes, human negligence and carelessness, are the most common causes of these devastating disasters.
- Early detection and prevention of wildfires is crucial for the successful elimination of the threat, because in the initial phase it is easiest to extinguish a wildfire even in the most inaccessible terrains.
- Intelligent long-range LPWAN (Low Power WAN) IoT (Internet of Things) sensor's networks can help quickly and efficiently detect wildfires at an early stage when it is easiest and cheapest to bring them under control and prevent their further spread and incalculable damages.

State of the art

A. Environmental and Biochemical Triggers for Wildfire Detection

- The Fire Triangle: Oxygen, Heat and Fuel.
- Carbon monoxide (CO), Nitrogen dioxide (NO_2), Ozone (O_3), Sulphur dioxide (SO_2), Volatile Organic Compounds (VOCs), particulate matter ($PM_{2.5}$), bio-feedback (sap flow) can be detected by IoT sensors.

State of the art

B. IoT-Based Sensor Nodes for Wildfire Detection

- Modular – different sensor modules inside the probe
- Standalone or Sensor Hub based
- Low power – batteries operational lifespan 2 – 10 years
- Solar power backed-up
- Photo-voltaic panel + Energy Harvesting (supercapacitors)
- Gas, eco-physiological and visual sense (AI)
- TinyML ready, pre-trained models (AI-Studio, Edge Impulse, Roboflow, ...)
- Open-source hardware (seeed studio, RAK Wireless, etc.)
- Position of sensors is crucial!

State of the art

C. Communication

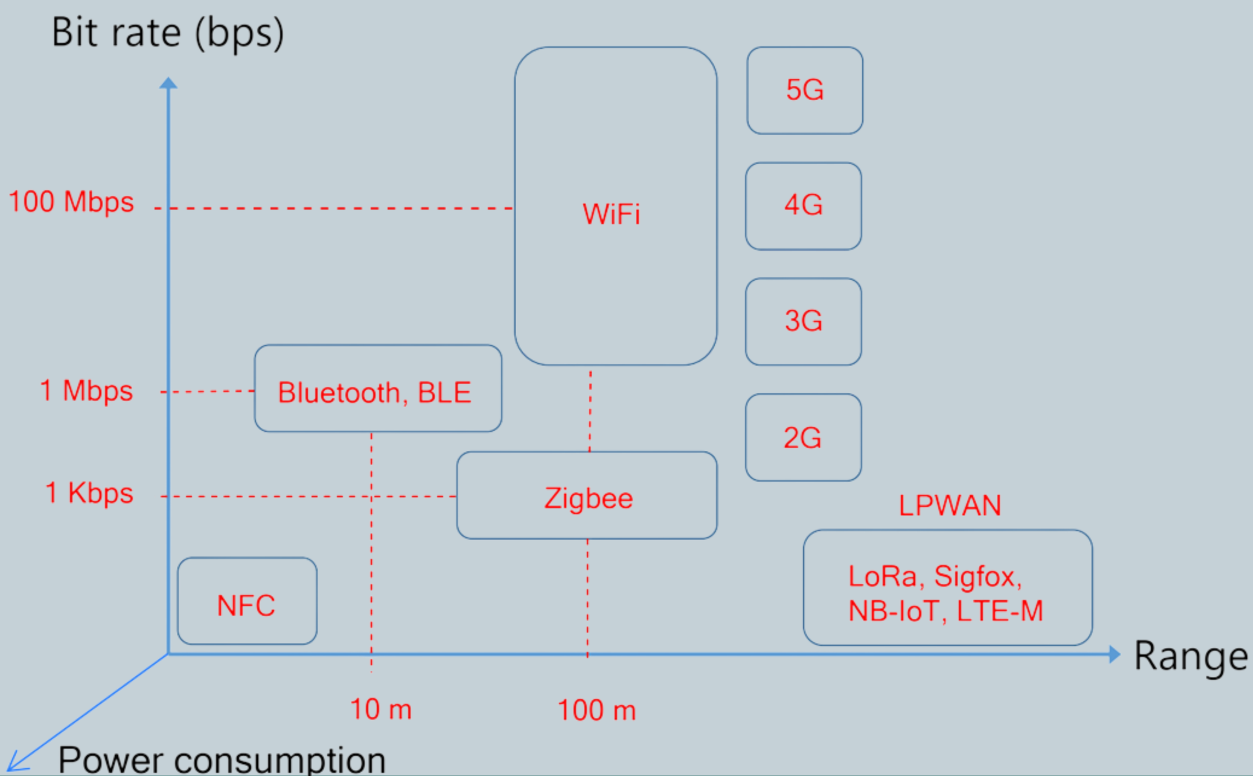
- LPWAN (Low Power Wide Area Network)
- LoRa – EU433 and EU868, Chirp Spread Spectrum modulation, ISM band
- 1–5 km in urban zones, 5–10 km in hilly terrains, and up to 15 km in open flat areas. Record 1336 km.
- LoRaWAN - LoRa-based protocol.
- LoRaWAN is not LoRa

LoRa Alliance®

State of the art

C. Communication

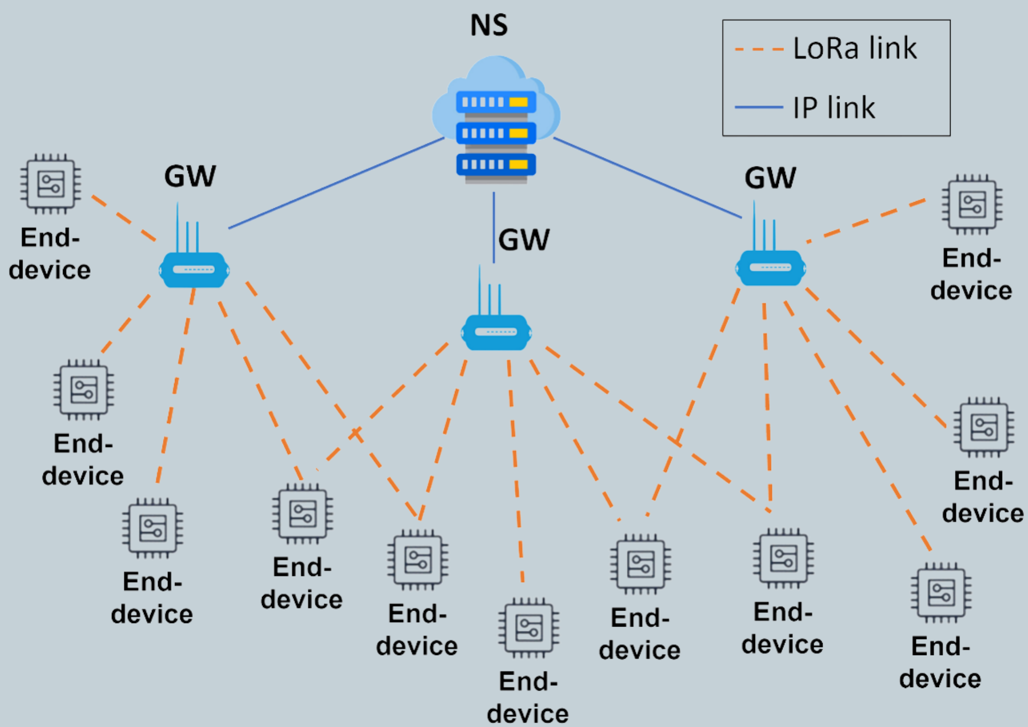
- LPWAN (Low Power Wide Area Network)



State of the art

C. Communication

- LoRaWAN – Star of Stars topology



State of the art

C. Communication

- Relay LPWAN serves to bridge long distances in off-grid scenarios
- **LoRaWAN Relay** - bridging gateways and end nodes, low cost, low power
- **ChirpStack Gateway Mesh** – open source, hardware agnostic
- **ChirpStack** – the open source LoRaWAN Network Server:
  - ChirpStack Network Server (Application Server)
  - ChirpStack Gateway Bridge
  - ChirpStack Gateway ConcetratorD
  - ChirpStack Gateway MQTT Forwarder
  - Web dashboard

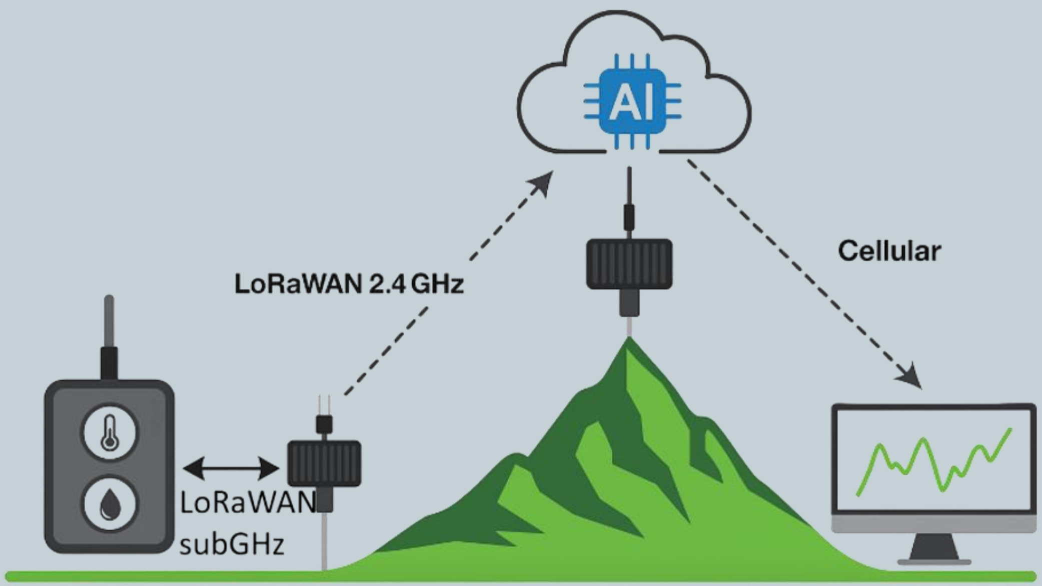
Works on Raspberry Pi

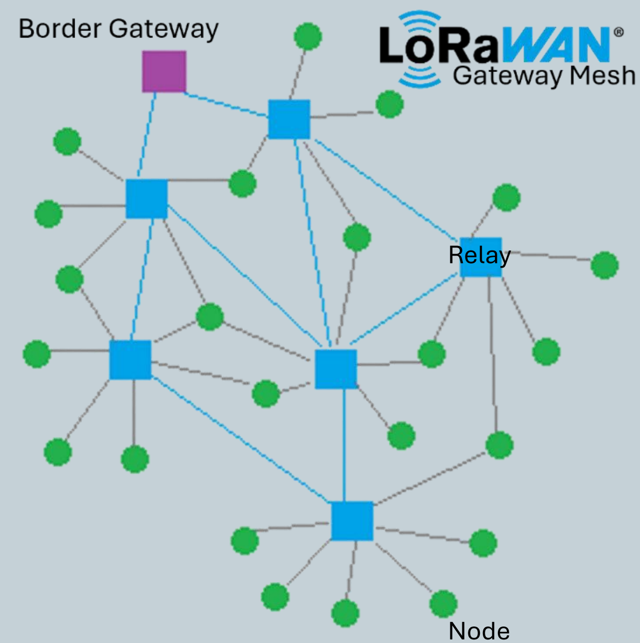
ChirpStack

State of the art

C. Communication

- Relay LPWAN to bridge long distances in off-grid scenarios

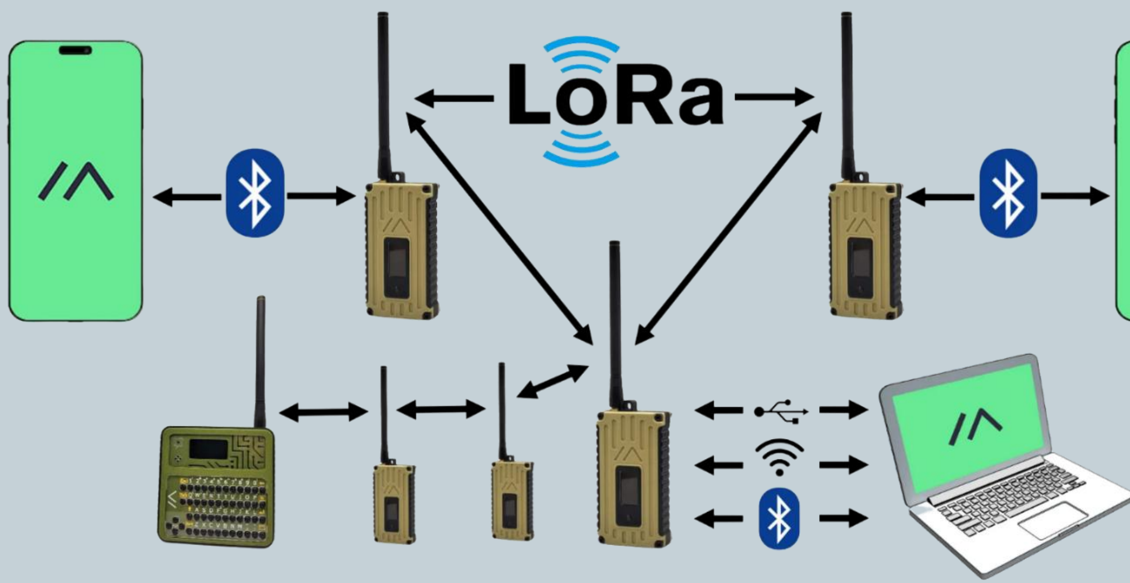




State of the art

C. Communication

Meshtastic - decentralized off-grid system for disaster response



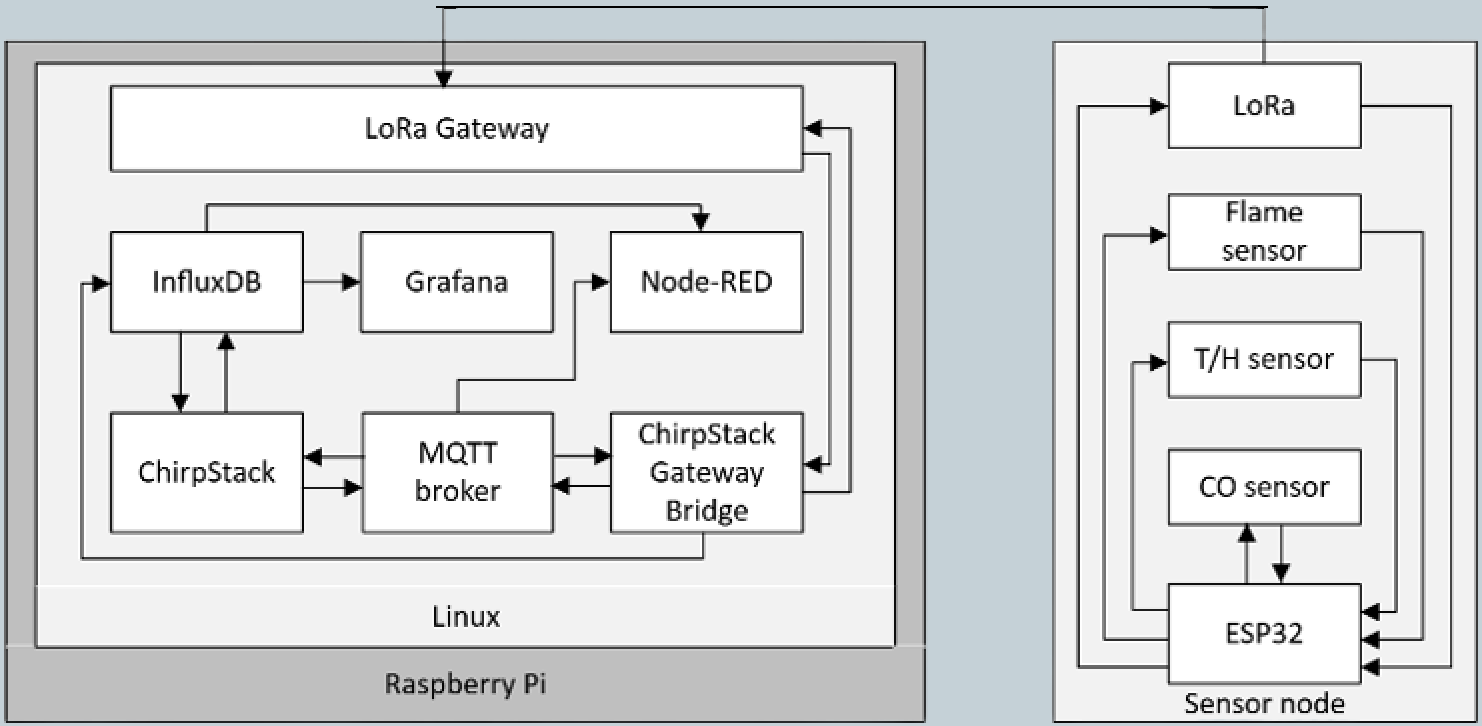
Methods/Model/Approach

- Affordable system
- Open-source hardware and software
- Gateway Mesh LoRaWAN + Meshtastic (hybrid)

- Specific placement of sensors and gateways across the region of interest,
- Mix of gas, eco-physilologicl and visual AI sensors for better accuracy
- Edge AI processing – low LoRa bandwidth
- Cloud AI processing – real time video - Long Range (10 miles) Wireless Bridges (1.5 Gbps),
- Optional deployment of network of AIoT fire-fighting drones (for higher budgets)

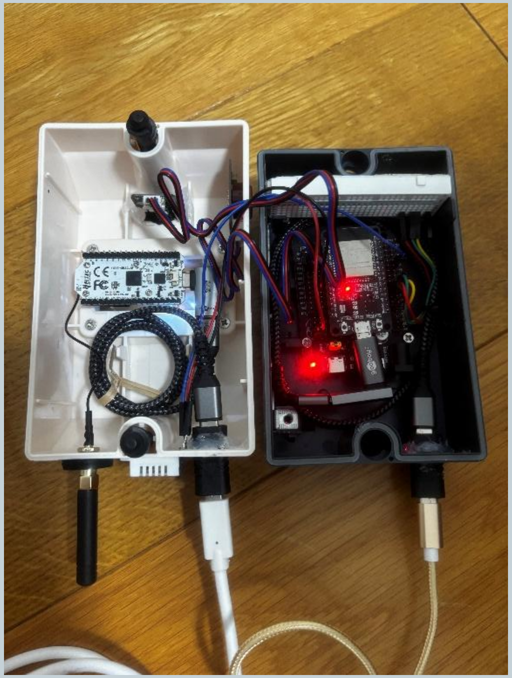
Experiments/Testings

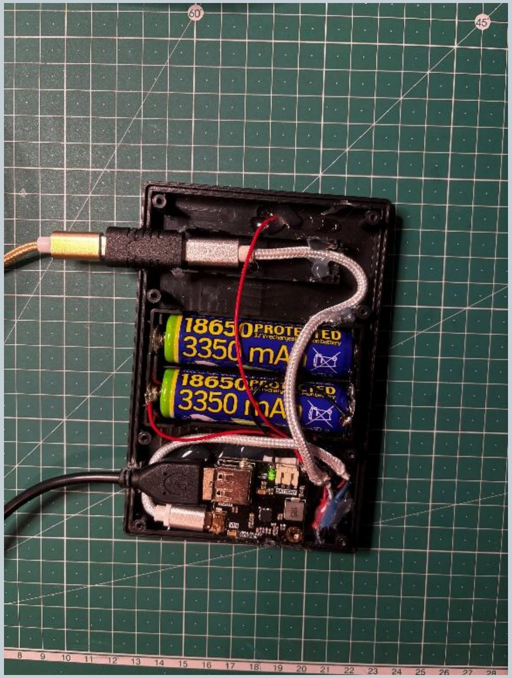
- Prototype



Experiments/Testings

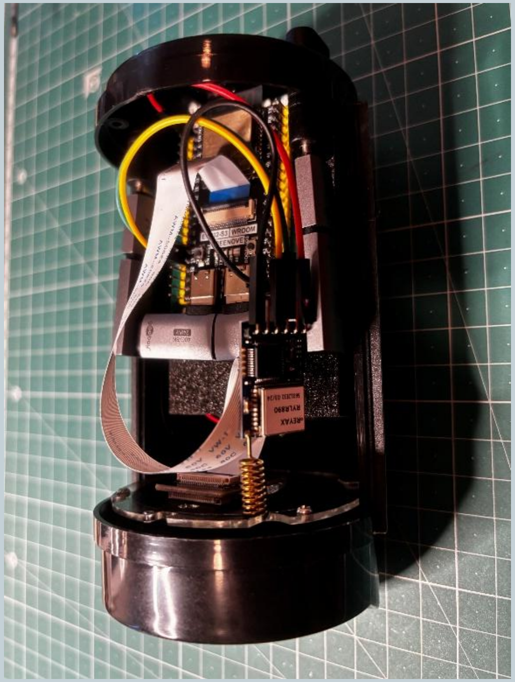
- Hybrid SensorPrototype

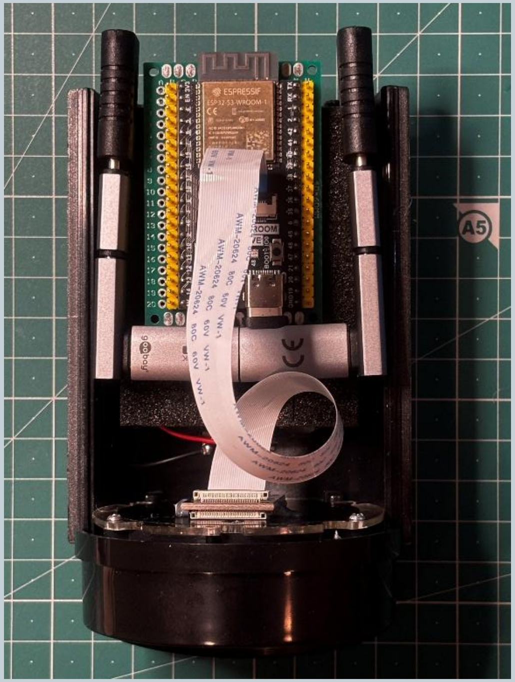




Experiments/Testings

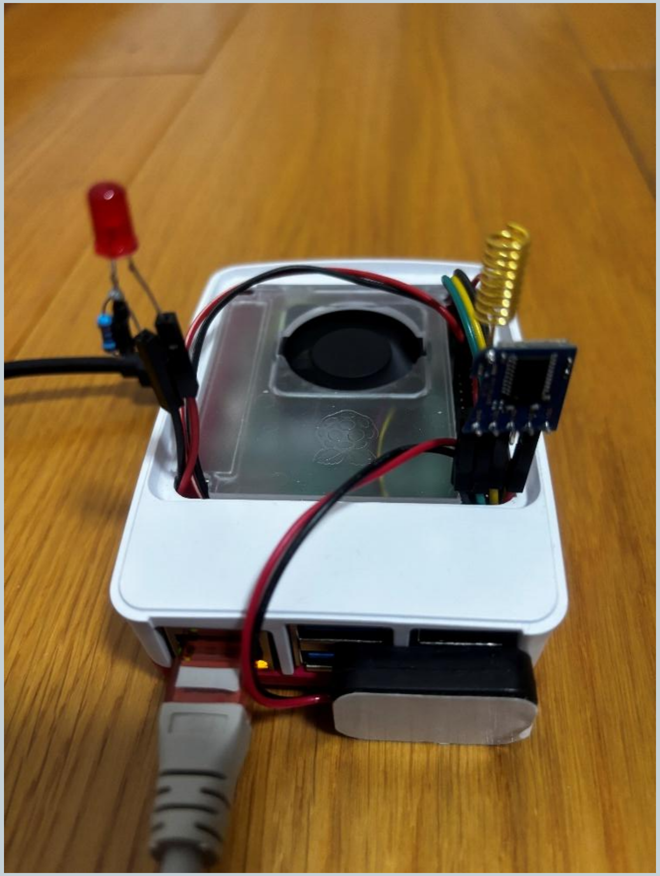
- AI Vision detector Prototype





Experiments/Testings

- Raspberry Pi LoRaWAN Network server



Results

TESTING RESULTS OF TESTING PILOT CONCEPT

Criteria	Value	Conditions
Communication Range	0.65-1.0 km	Till first gateway or host, medium- density urban area,
Battery life (per charge)	2-6 days	Low message rate (>=10s)
Basic system price	≈300 EUR	Basic configuration of node-host
Sending latency	≈1s	Including preparation time

Future work

- AI Site planning
- Energy Harvesting

Future Work

- Hybrid model
  - AI video surveillance
  - AI Gas & Eco-physiological sensors

Conclusions

- This work presents a step towards development and use of IoT and LPWANs system for early detection and prevention wild fires in Montenegro, as a typical rural area.
- The concept differs from existing in the following: application of ChirpStack Gateway Mesh LoRaWAN, sensors and gateways placement across the region of interest, fusion of standard, biochemical and visual AI sensors for better insight, using of Long Range Industrial Wireless Ethernet radio links on the backbone, deployment of network of AI fire-fighting drones, integration with existing AI cloud systems, and other solutions at the point or system levels.
- The concept is open and should be further developed in visual fire recognition using the AI, as well in integration with drones. To overcome bandwidth limitation of LPWANs we recommend combining high-speed wireless point-to-point links with LoRaWAN using gateways, and use of 4G/LTE backup where possible. We shown that even with very small investments one can do the proof of concept and implement the system that can help.

THANK YOU

Q&A

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