

Supporting ITS through Cooperative/Opportunistic Networking: on-going activities at GRC



Pietro Manzoni

www.grc.upv.es/members/pmanzoni/

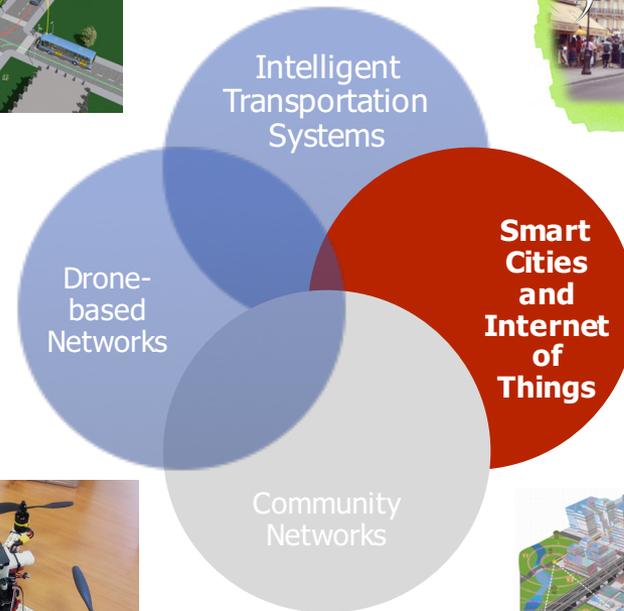
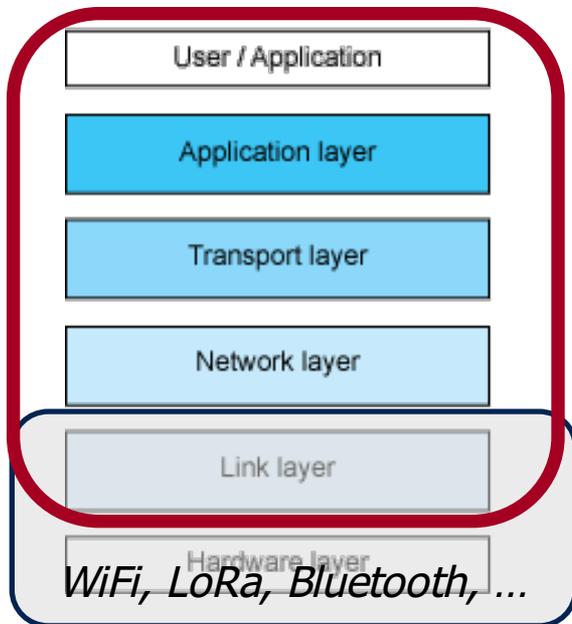




- ❑ The *Universitat Politècnica de València* (UPV) is a Spanish public educational institution founded in 1968.
- ❑ Its academic community comprises 36.823 students, almost 2.661 lecturers and researchers, and 1.422 administration and services professionals.
- ❑ It has three fully equipped campuses. One in the city of Valencia (Vera) and the other two in Alcoy and Gandia.
- ❑ The Vera Campus covers around 840.000 m² and is almost 2 km long. It is a pedestrian campus with over 123.000 m² of green areas.



Data Communication Solutions for Mobile Wireless Systems → "Solutions" = Protocols + Applications



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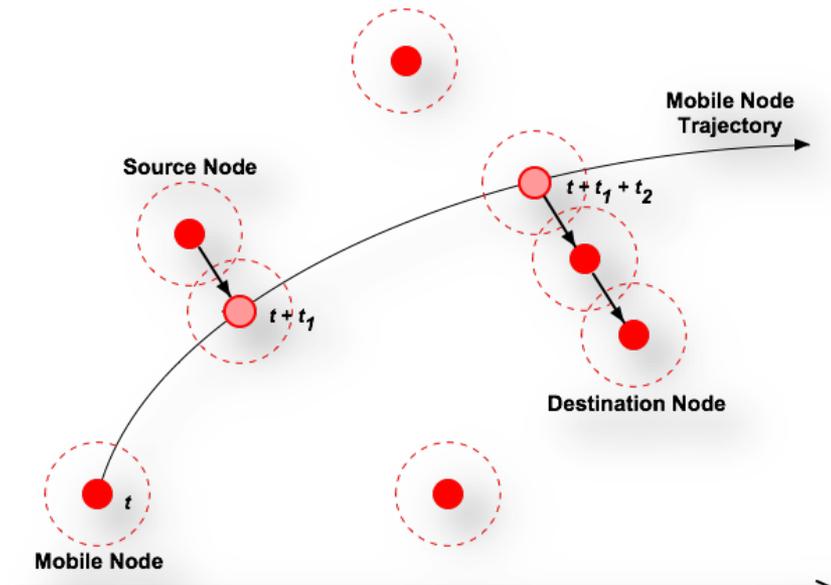
- ❑ **Some basic ideas**
- ❑ The GRCbox
- ❑ Crowdsensing activities
- ❑ Drones et al
- ❑ Improving opportunistic contacts efficacy
- ❑ A proposal for a publish/subscribe, disruption tolerant content island



Cooperative/Opportunistic networking

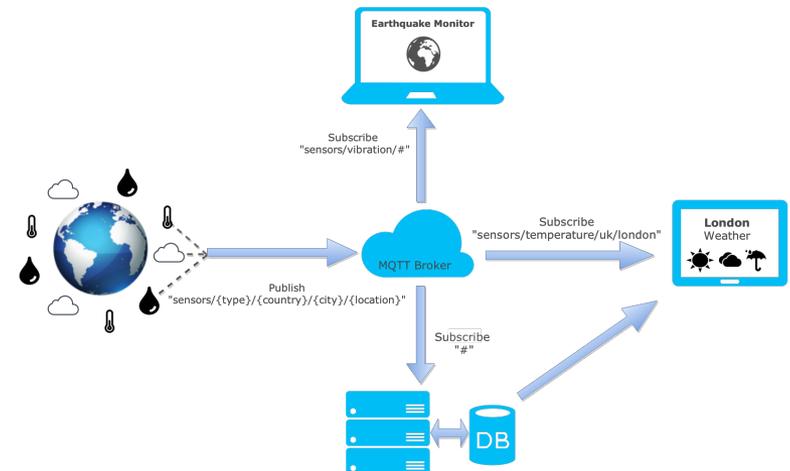
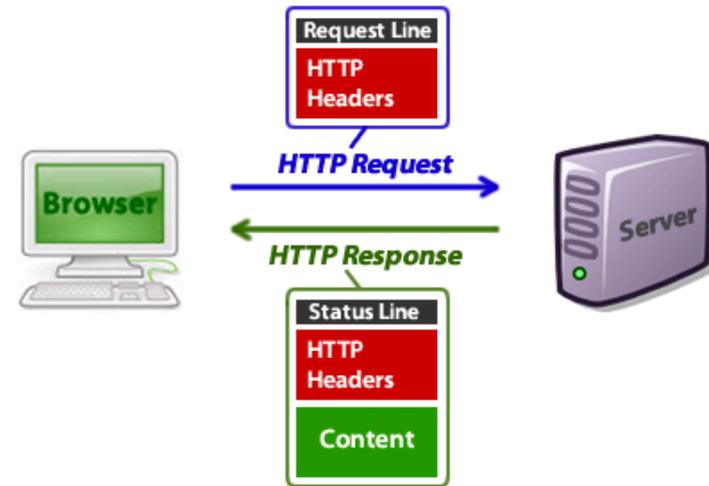
- Increase feasibility to provide new services (e.g., messaging, crowdsensing) without a fixed infrastructure
 - Mobile data offloading
- Provide connectivity where no infrastructure is available (e.g., emerging countries)

- Using DTN (Disruption Tolerant Networks) technology
 - enable seamless communication by hiding discontinuity of the possibly heterogeneous end-to-end communication channels

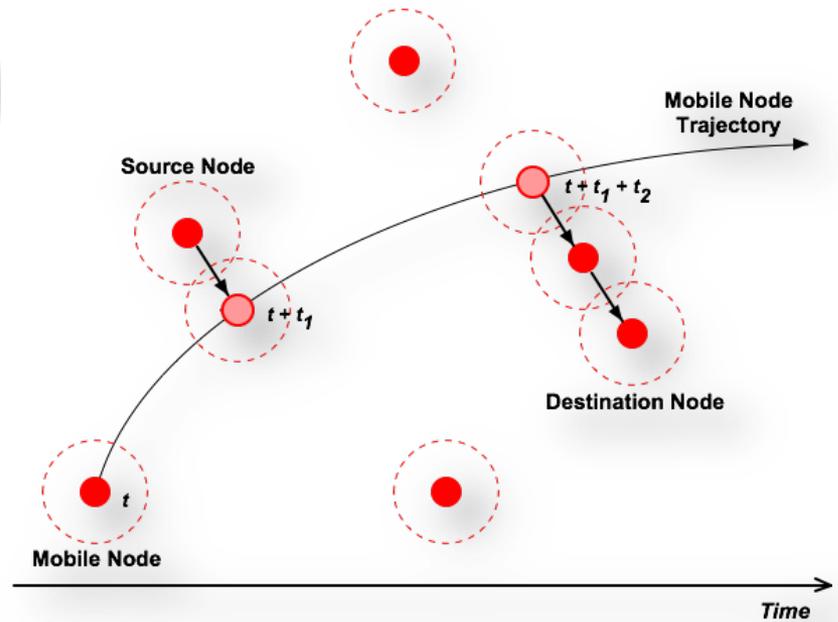
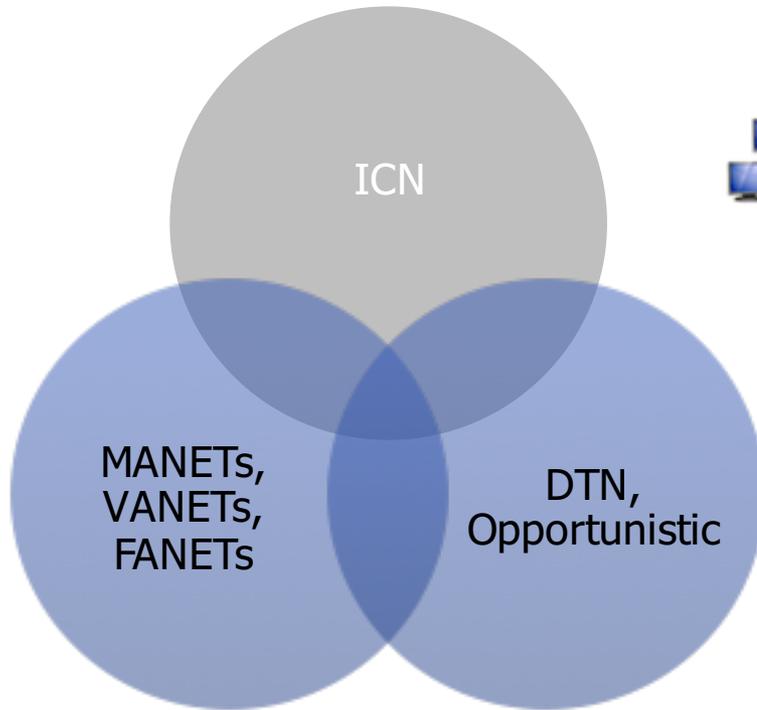


Message based communications

- Pure client/server approach based on TCP is leaving room to other communications schemes
 - TCP is a reliable stream-based transport protocol
- HTTP is becoming the new “transport” protocol
 - Request/response paradigm
 - Firewall friendly
 - Similar solutions: REST, CoAP
- **But there other growing protocols based on a producer/consumer paradigm**
 - **→ MQTT**

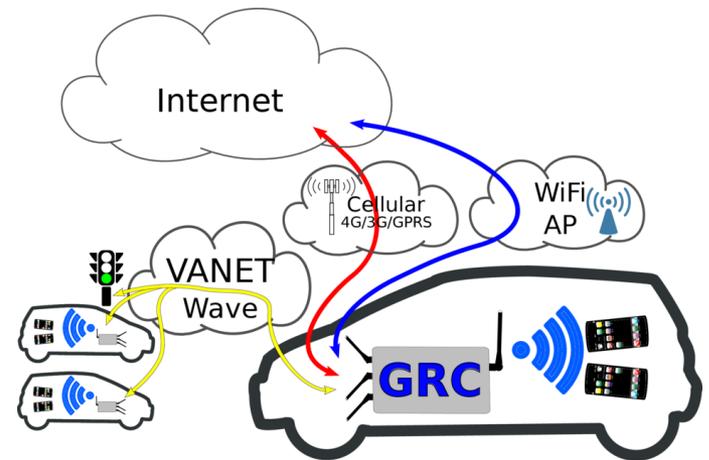


The big picture



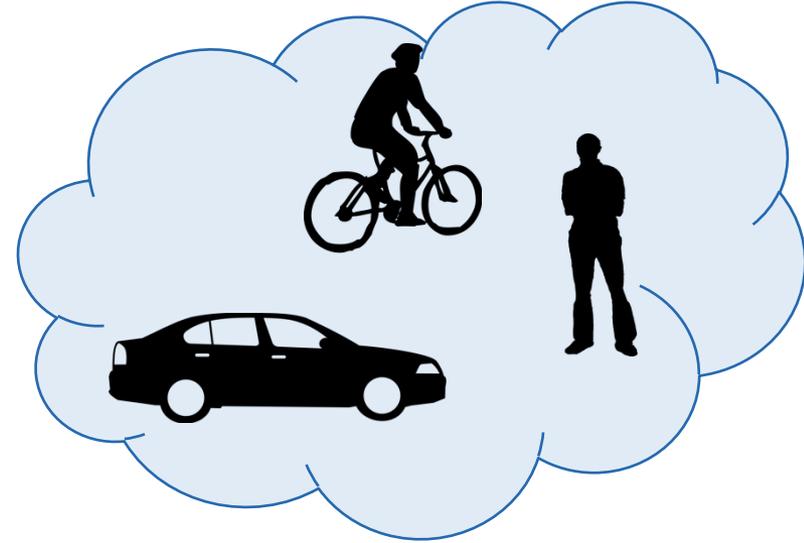
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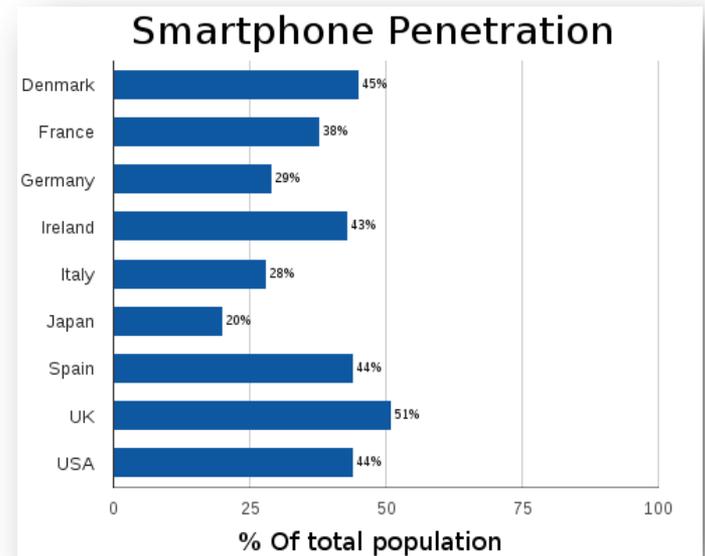
Why Smartphones?

- ❑ Smartphones are an **integrated environment**
- ❑ They are **cheaper** than OBUs
- ❑ The car will **not be the only** node type.
- ❑ Smartphones contain your **digital identity**
- ❑ OBUs vs smartphone **penetration**



BUT:

- ❑ No standard support to ad-hoc mode
- ❑ No standard support to multiple active interfaces
- ❑ No support for specific standards like IEEE 802.11p, at least for the near future

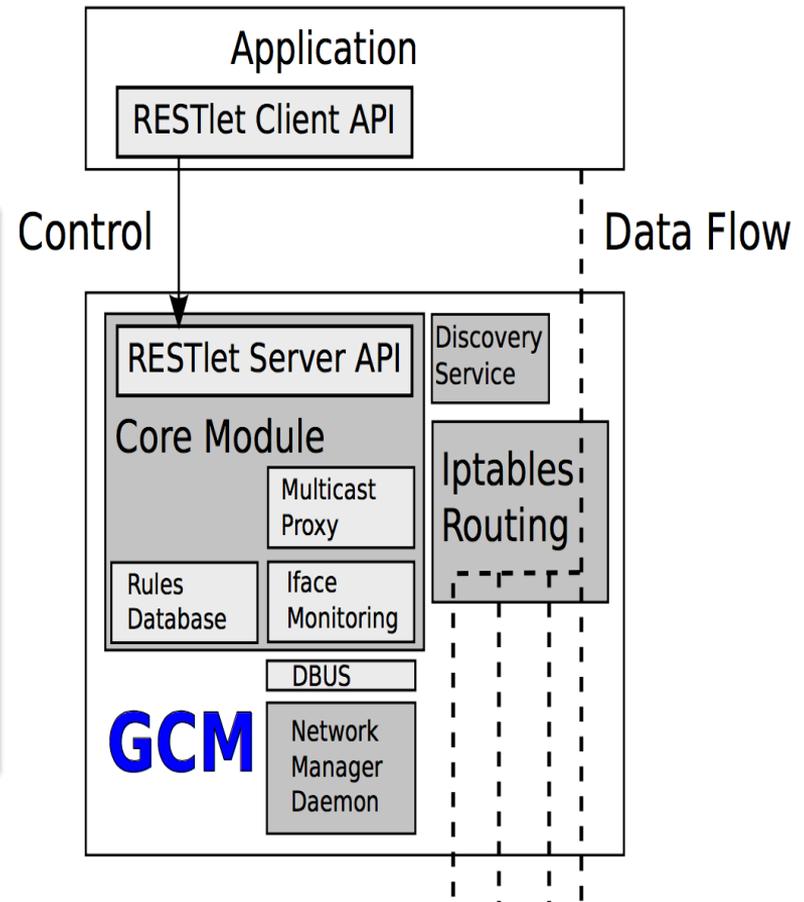


<http://www.thinkwithgoogle.com/mobileplanet/en/>

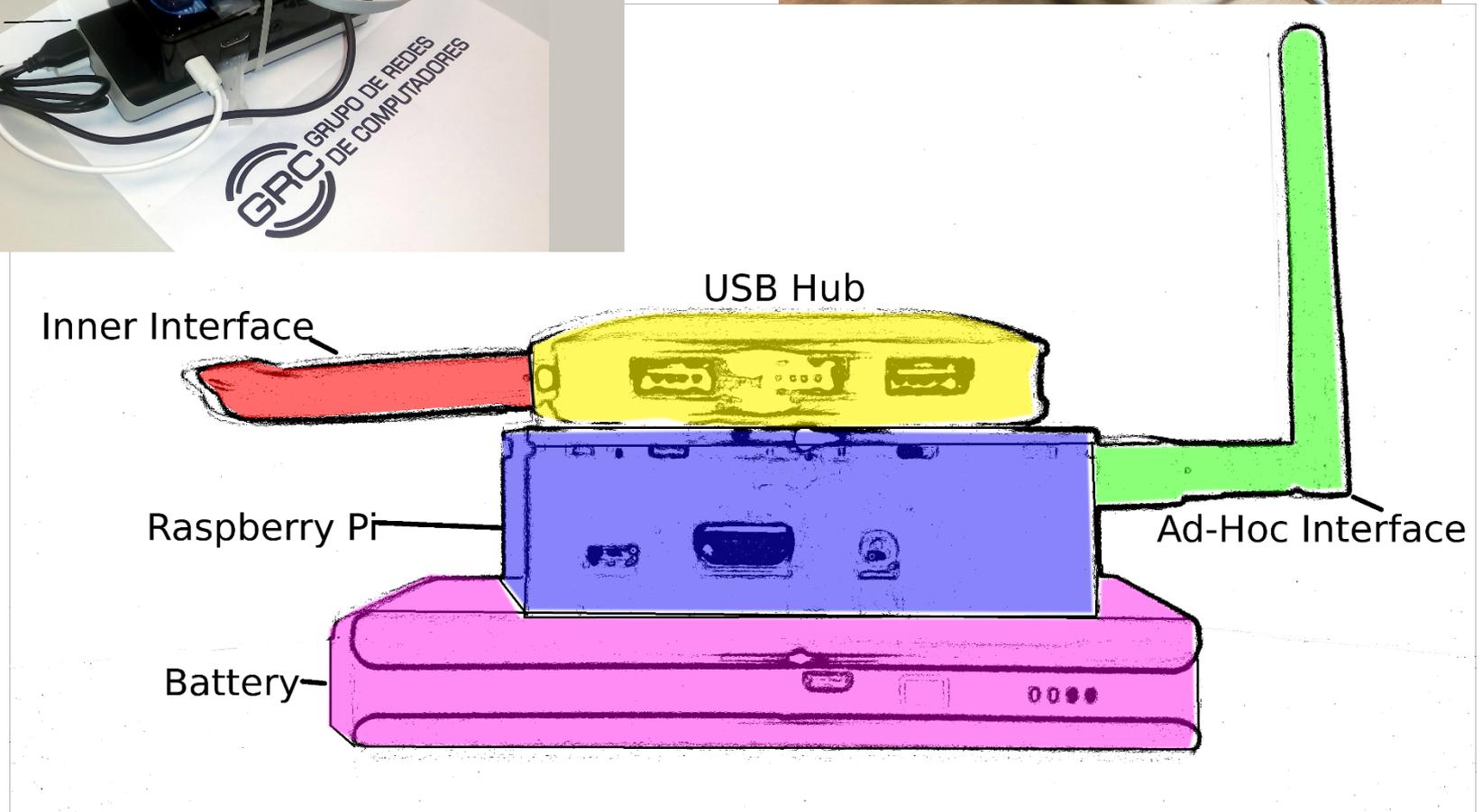
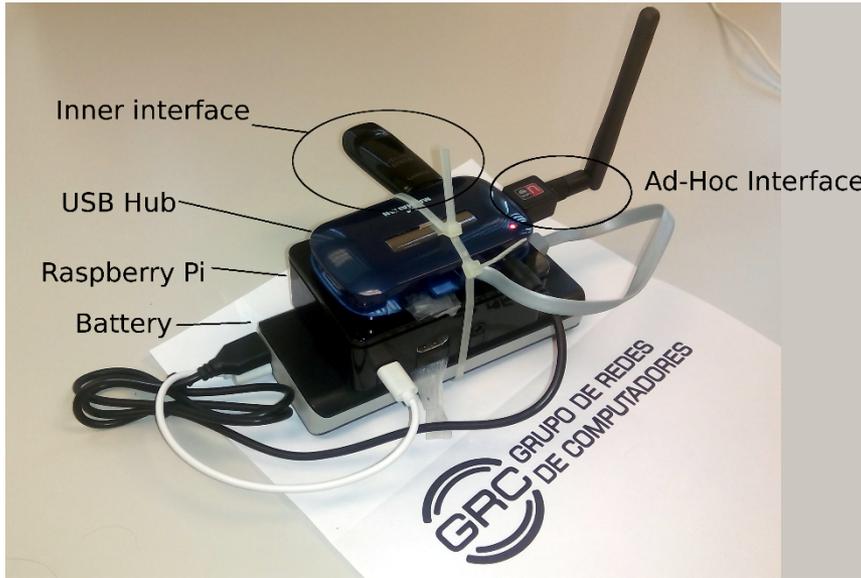
GRCBox architecture

- ❑ The GRCBox offers an architecture that extends the in-vehicle connectivity by providing both inter- and intra-vehicular communication support.

- > The **GRCBox Connectivity Manager (GCM)**
 - > 1 inner interface
 - > n external interfaces
- > **Discovery Service:** *dnsmasq* is used to answer DHCP and DNS requests. It is configured to resolve the "grcbox" domain name to the GCM inner interface. Clients on the inner network can connect to the GCM without information about its IP address by connecting to "http://grcbox/".
- > **Packet Forwarding:** To define fine grained, per connection routing, GCM uses Iptables for connection filtering and labelling, and the Linux kernel support for "Policy Routing".
- > **Ifaces Monitoring:** To monitor the status of the network interfaces, GCM connects to the NetworkManager daemon using the DBUS interface to perform event- subscribing tasks.
- > **Core Module:** The core module mainly listens to clients' requests through the REST API, maintains a database of all registered rules, starts and stops multicast proxies when needed, and performs actions when events on the interfaces are notified.



The basic prototype



GRCBox performance evaluation

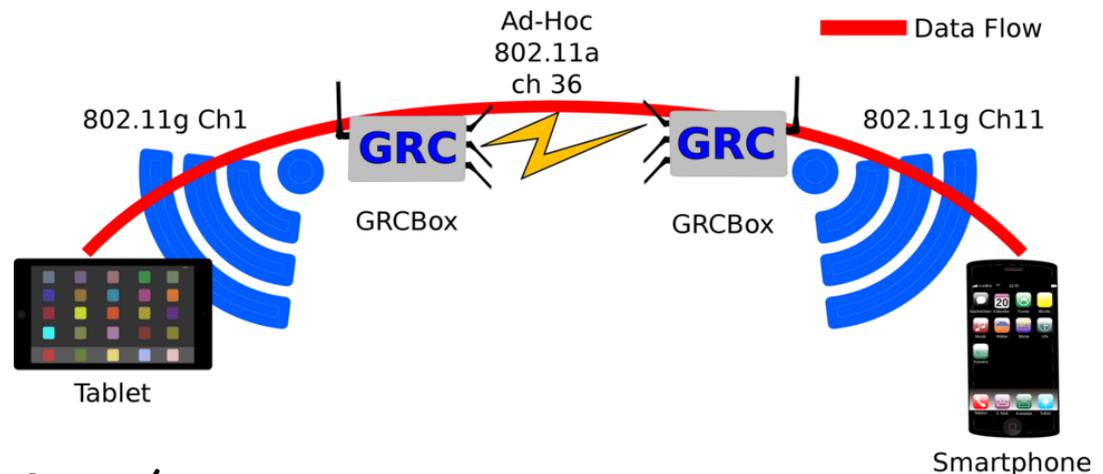
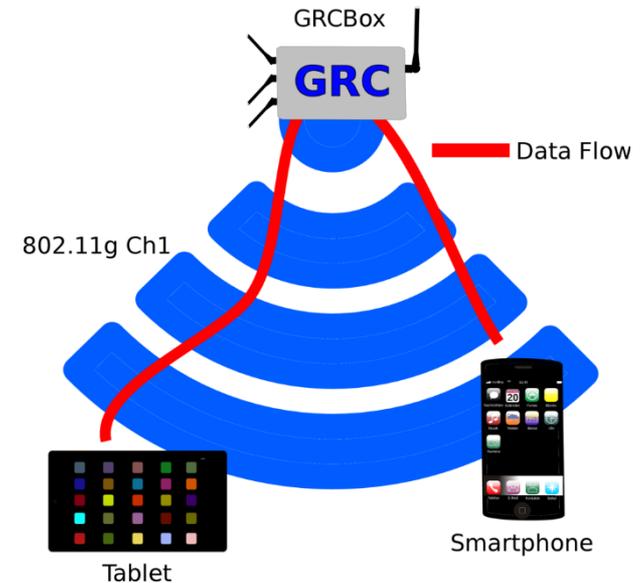
- Two scenarios:
 - Scenario 1: plain AP mode
 - Scenario 2: with the GrcBox

- TCP/UDP

- Throughput
- Round Trip Time

- DTN based on Scampi(*)

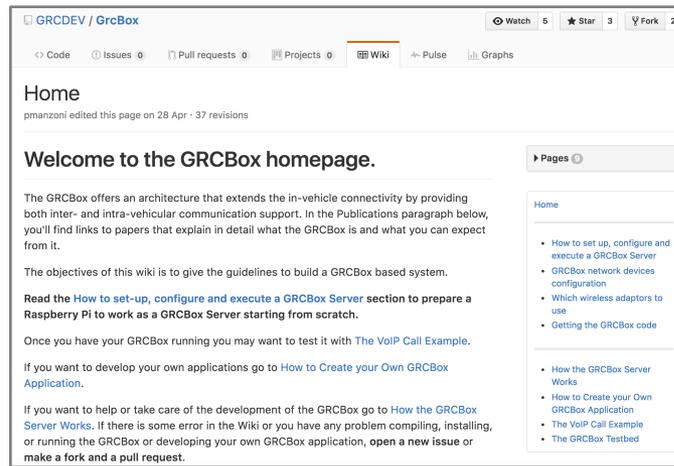
- Throughput
- Round Trip Time



(*) <http://www.ict-scampi.eu/>

Some conclusions

- ❑ GRCBox implementation has negligible impact in the performance
- ❑ The software is available:
 - ❑ <http://github.com/grcdev/grcbox>
 - ❑ <http://grcdev.github.io/GrcBox/doc/>



- ❑ Still room for a lot of improvements... 😊

Currently working on

❑ Improving the code

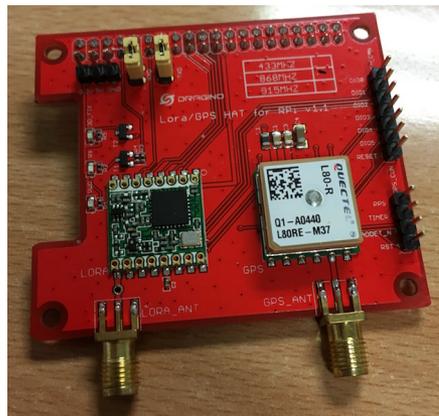
- ❑ Evaluating the use of 802.21 standard (<http://atnog.github.io/ODTONE/>) to handle vertical handover

❑ Integrating more technologies

- ❑ IEEE 802.11p
- ❑ LoRA

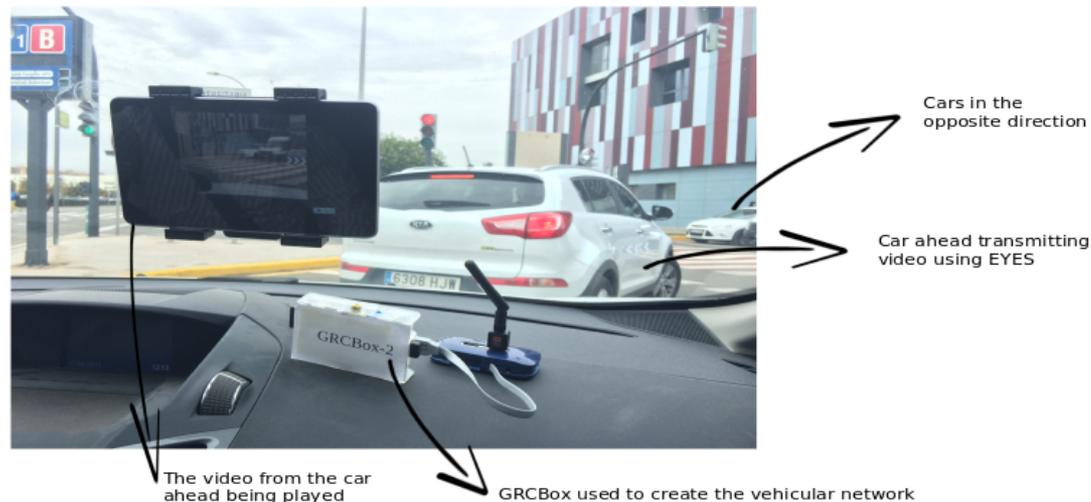
SW from i-GAME Project (<http://www.gcdc.net/en/i-game>)

- 802.11p kernel: <https://github.com/CTU-IIG/802.11p-linux>
- GeoNetworking Stack: <https://github.com/alexvoronov/geonetworking>



Study case (1): EYES

- ❑ Providing real-time video streams among vehicles without relying upon fixed video sources
- ❑ Applications:
 - ❑ providing local drivers with a clearer view about an accident
 - ❑ Drivers support in platooning
 - ❑ ...
- ❑ The camera is used to capture the view of the car ahead and streams it over the vehicular network.



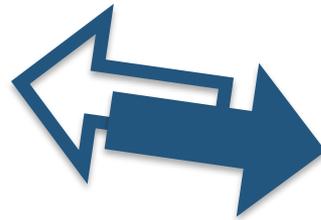
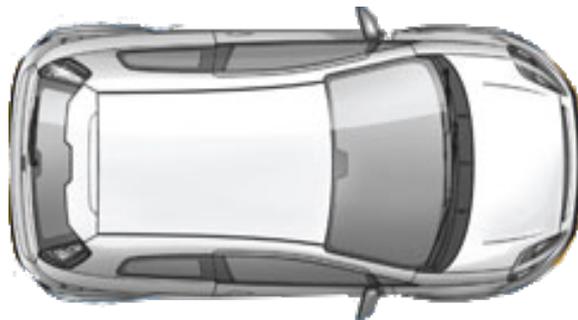
- ❑ The device in the car following, receives it and plays on-screen.

Study case (2): digital traffic sign-posts

Tolerant in response to changes

Decentralized data

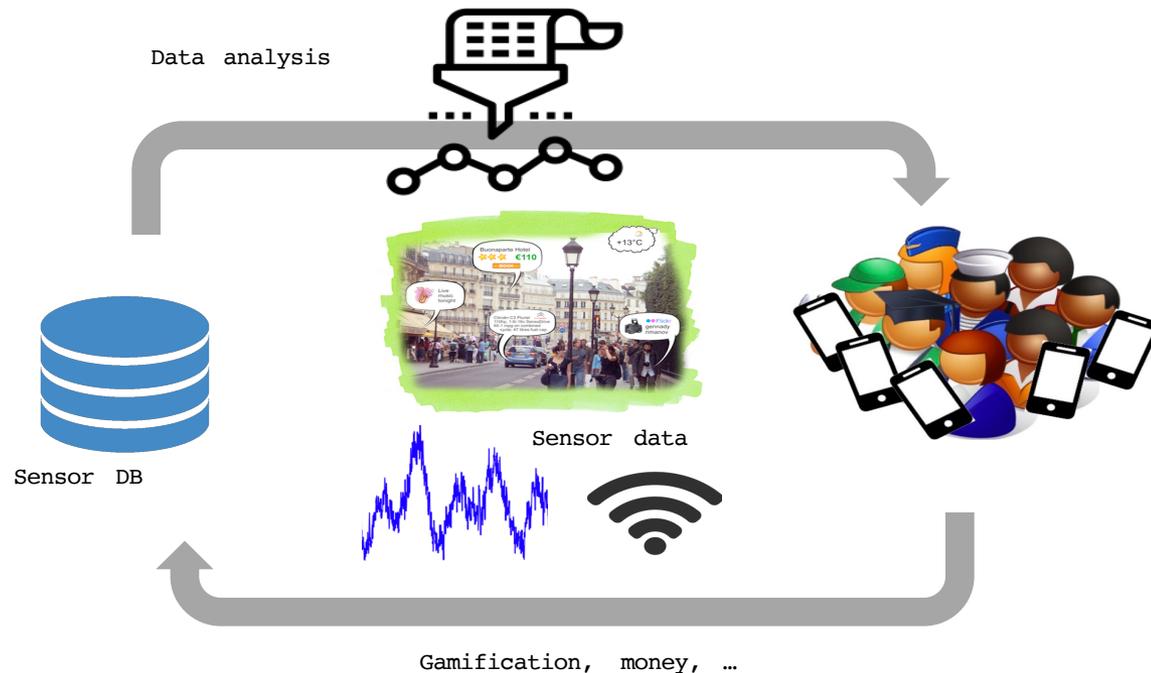
Flexible in size and types of data



No calibration required

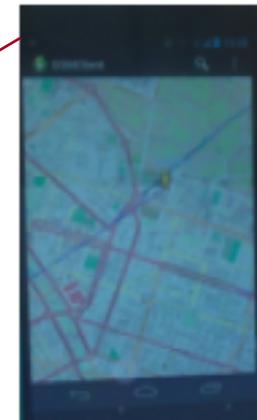
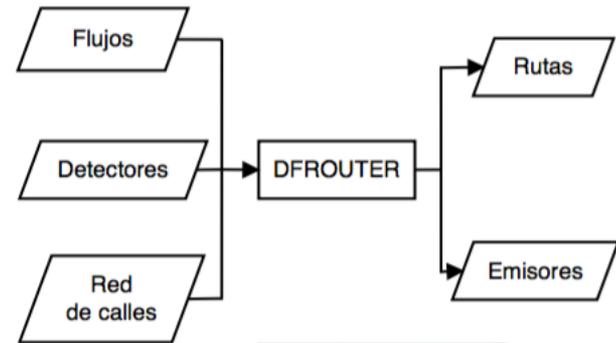
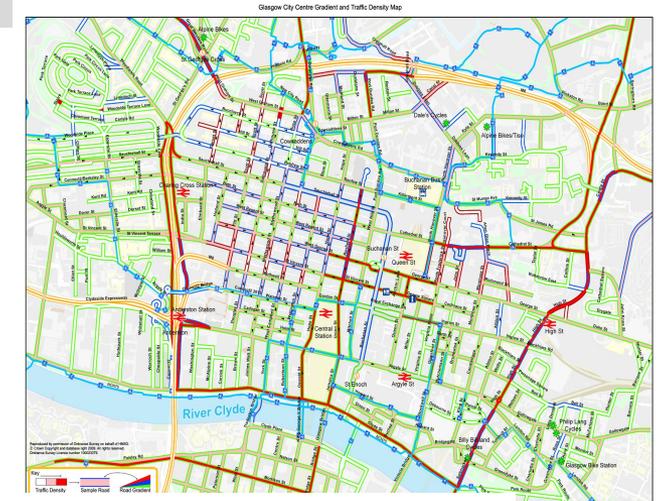
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Traffic monitoring and management

- ❑ **ABATIS Project:** Traffic monitoring and management
- ❑ Global traffic balancing
- ❑ Based on:
 - ❑ Historic data
 - collaboration with Valencia City Council
 - ❑ Real time data

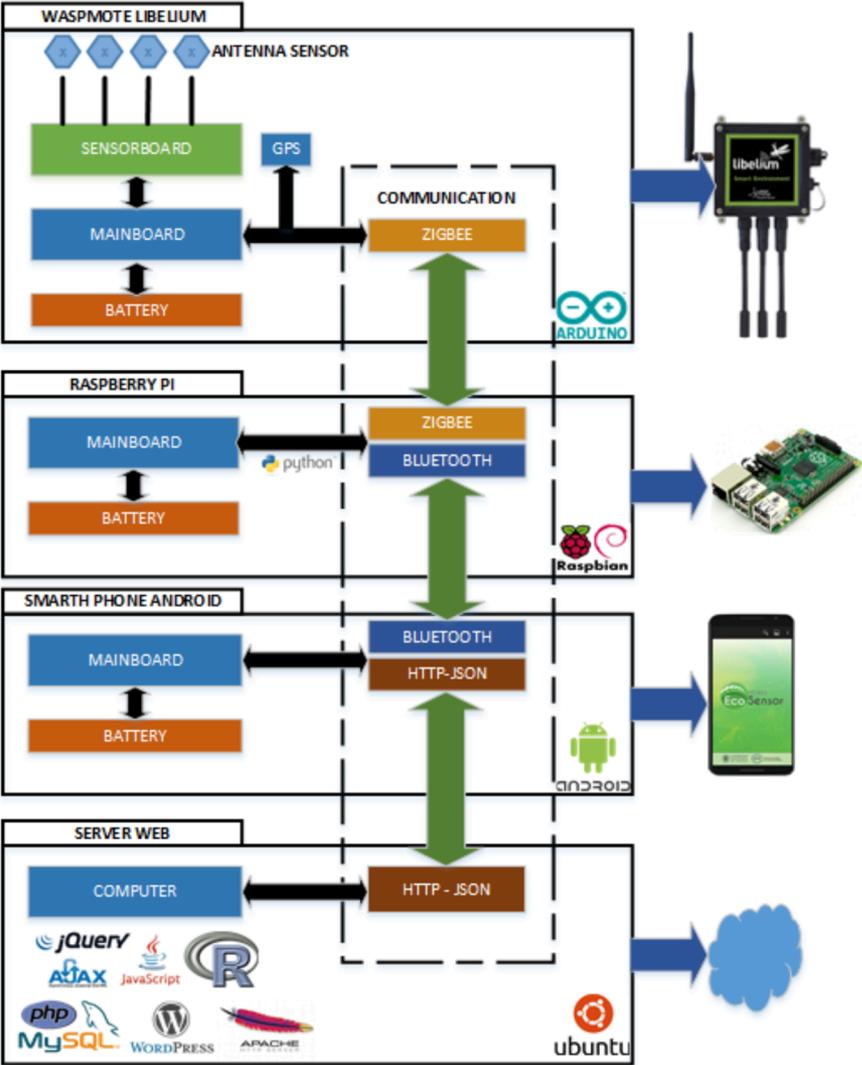
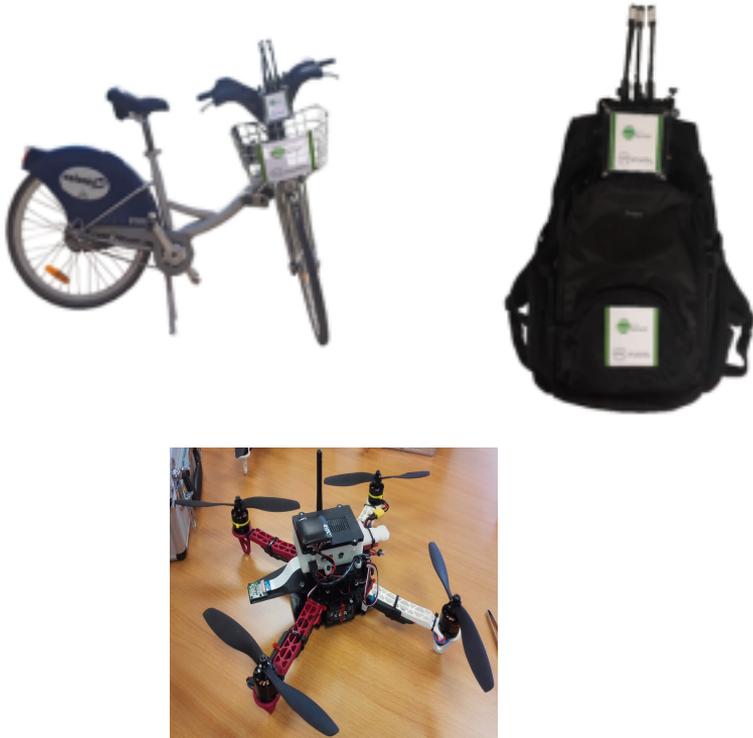


Noise analysis



EcoSensor: Air quality sensing:

- ▣ O₃, CO₂, and other factors (C₆H₅CH₃, H₂S, CH₃CH₂OH, NH₃, H₂)



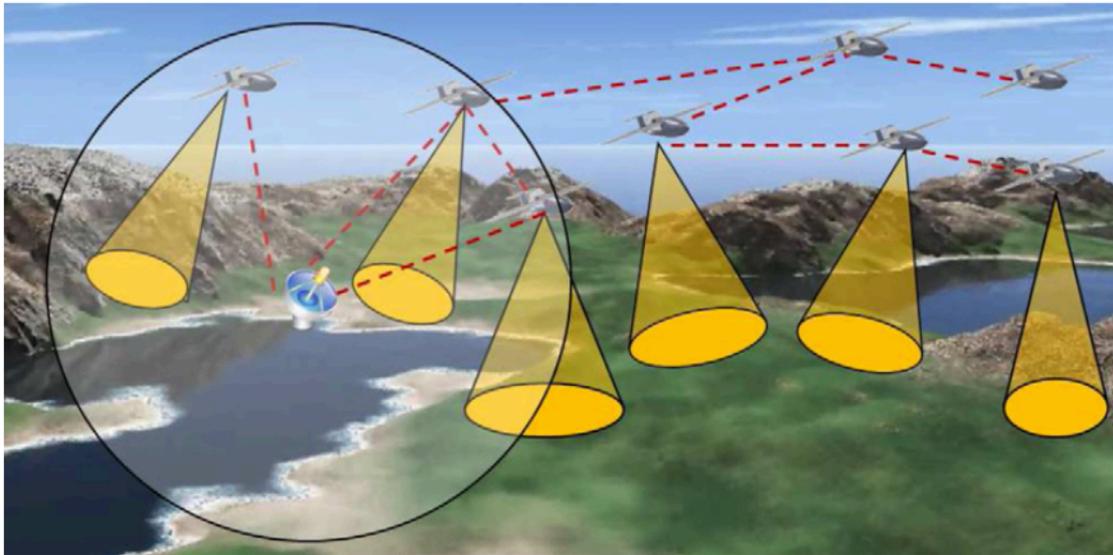
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Context

- ❑ MANETs (Mobile Ad Hoc Networks):
a continuously self-configuring, infrastructure-less network of mobile devices connected wirelessly.
- ❑ VANETs: Vehicular Ad Hoc network
- ❑ **FANETs: Flying Ad-Hoc Networks**

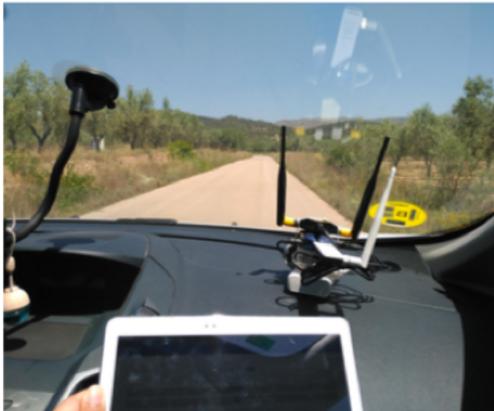


FANETs vs MANETs and VANETs

- ❑ Mobility degree of FANET nodes is **much higher** than the mobility degree of MANET or VANET nodes.
 - ❑ While typical MANET and VANET nodes are walking men and cars respectively, FANET nodes fly in the sky 😊
- ❑ Depending on the high mobility of FANET nodes, the **topology changes more frequently** than the network topology of a typical MANET or even VANET.
- ❑ Typical distances between FANET nodes are **much longer** than in the MANETs and VANETs.
- ❑ The existing ad hoc networks aim to establish peer-to-peer connections. FANET also needs peer-to-peer connections for coordination and collaboration of UAVs.
 - ❑ Besides, most of the time, it also collects data from the environment and relays to the command control center, as in WSN. Consequently, FANET must support peer-to-peer communication and converge cast traffic at the same time.

Drone as AP

- ❑ Drone as Transmitter
 - ❑ Car as Receiver with GRCBox inside
- ❑ Drone: static; Car: moving
- ❑ Car will record its own location at the time it receives packet from drone
- ❑ Goal: measuring Packet Delivery Ratio



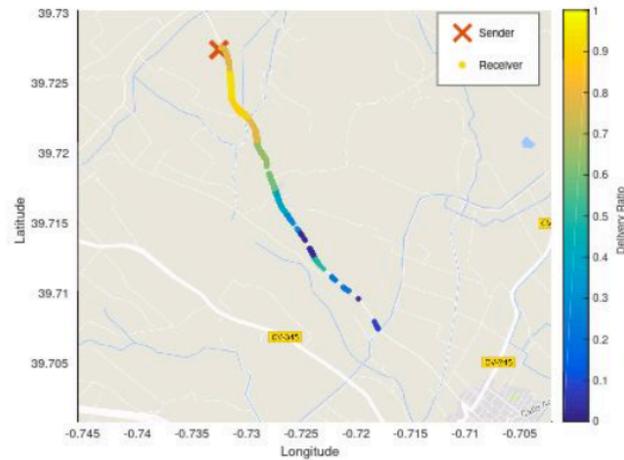
Some result



(a) Scenario 1: Ant. Position Outside, Ant. Orientation Vertical.



(b) Scenario 2: Ant. Position Inside, Ant. Orientation Vertical



(c) Scenario 3: Ant. Position Outside, Ant. Orientation Horizontal.



(d) Scenario 4: Ant. Position Inside, Ant. Orientation Horizontal.

Simulation activities

- Facilitate the testing and validation of wireless technologies for inter-UAV communications
- We propose:
 - 1) an evaluation methodology specifically designed for communications between UAVs,
 - 2) a tool developed to automate this process.
- Currently, our tool supports UAVs equipped with a navigation board compatible with the MAVLink protocol
 - to retrieve all critical navigation parameters like position, speed, pitch, roll, yaw, etc.
 - can be used with any wireless technology supporting the TCP/IP protocol stack.

Our Tool

□ Dronning GUI (controller)

The screenshot displays the Dronning GUI interface. At the top, a status bar shows the following states: logging, logged, connected, configured, started, running, and stopped. The 'Server' and 'Client' rows are highlighted in green and red respectively, indicating they are active.

Test configuration:

- Base filename: x100m
- Duration (sec): 60
- Tx rate (packets/sec): 50
- Packet size (B): 1500

Broadcast Unicast

Distance: 21,090 m
Server altitude: 18,700 m Client altitude: 15,020 m (dif: 3,680 m)

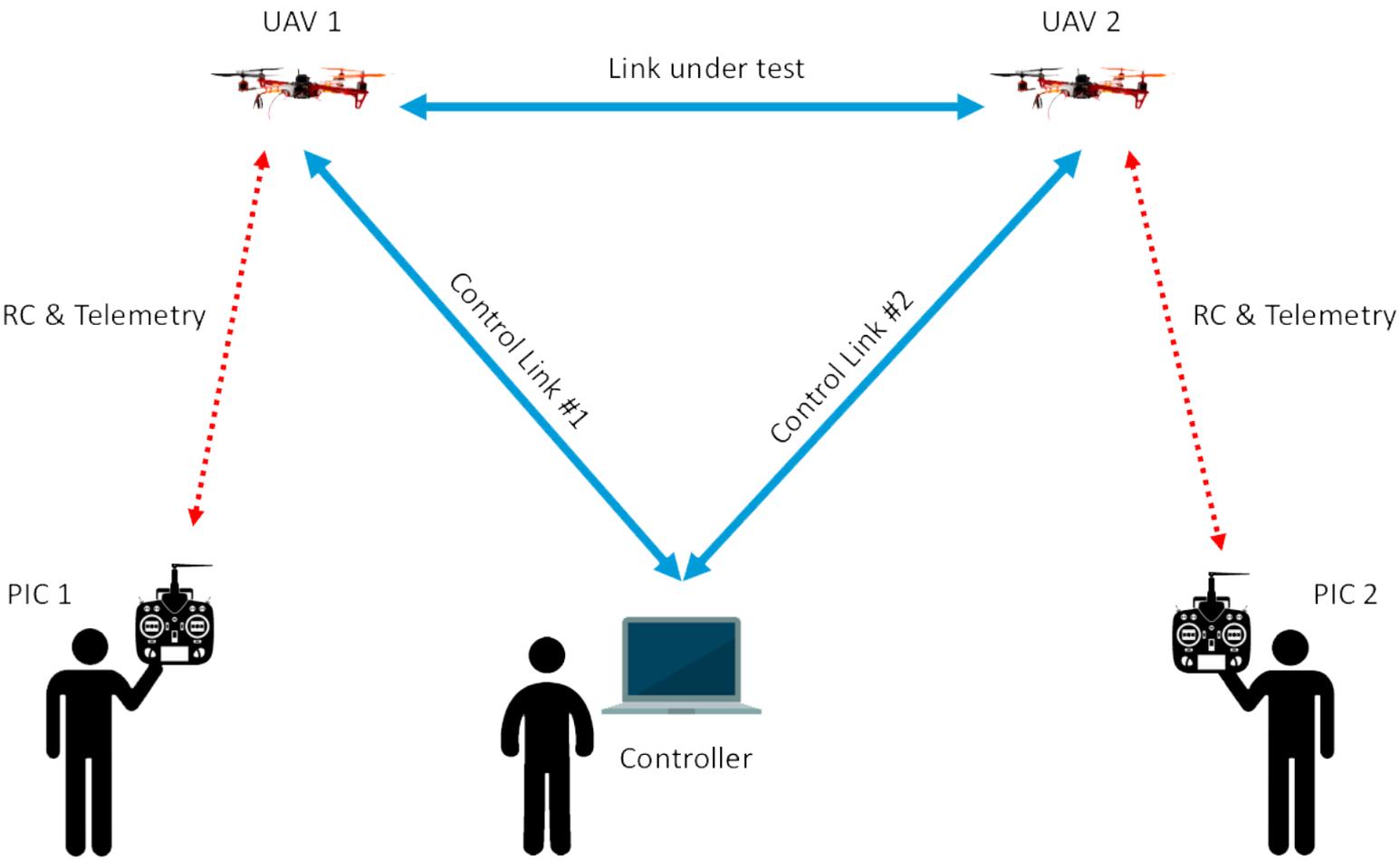
Buttons: Send configuration, Start test

Current throughput 48,29 p/sec
Loss ratio 4,6223 %
Packets lost 134

Server yaw: -100,71 °

Client yaw: 74,59 °

Structure of a test



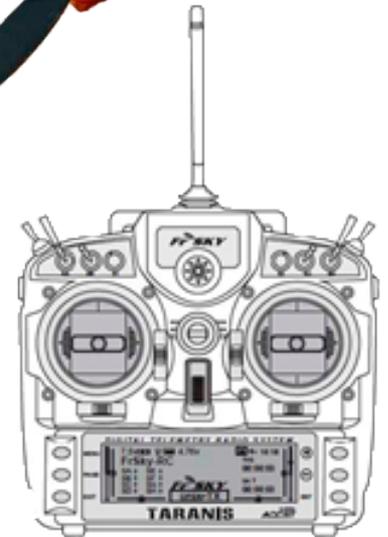
Validation And Results

□ Hardware

- Two radio-controlled quadcopters
- Pixhawk flight controller
- Embedded Raspberry Pi 2

□ Wireless links

- IEEE 802.11g 2.4 GHz Ad-hoc network
- Radio-control link 2.4 GHz
- Telemetry radio link 433 MHz



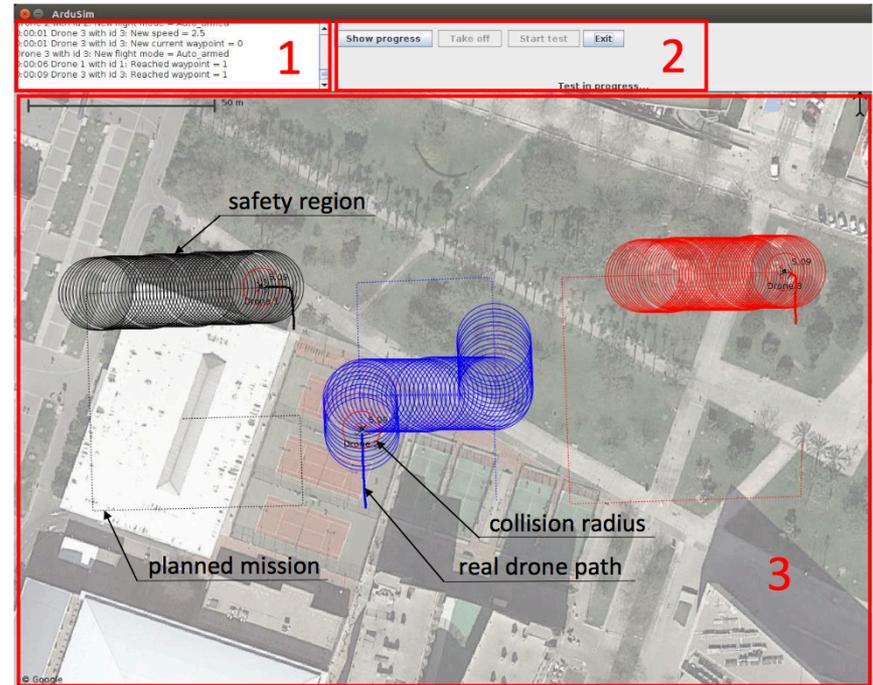
Future Work

- Import data into simulators (Omnet++) to ease the simulation of these types of systems



ArduSim simulator

- ❑ Based on SITL, a single UAV simulator
- ❑ It is capable of simultaneously simulating a group of drones with great accuracy
- ❑ Uses the MAVLink protocol to communicate with each virtual UAV.
 - ❑ MAVLink is a de facto communications standard with the flight controllers currently available in the market, allowing to port the proposed solution to real UAVs easily and quickly.



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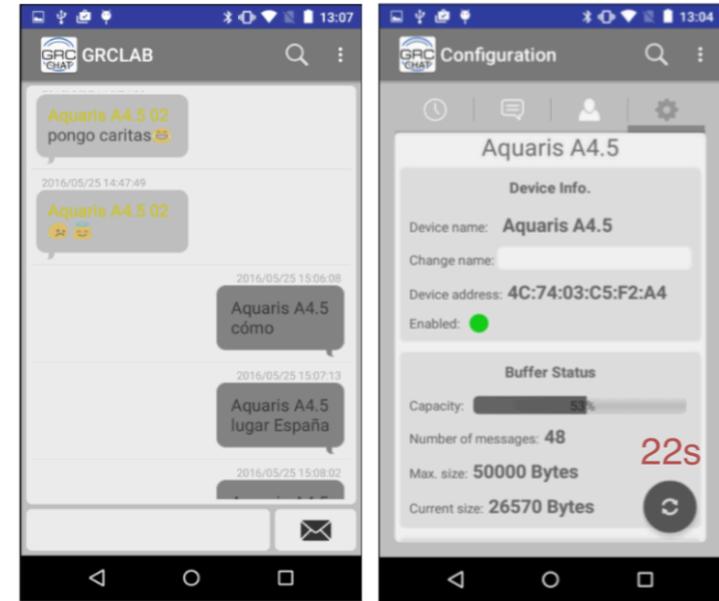
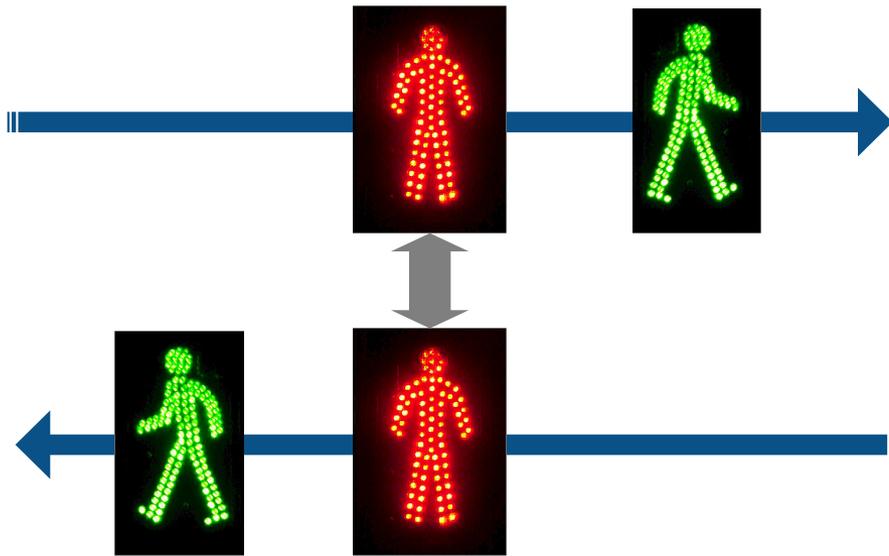
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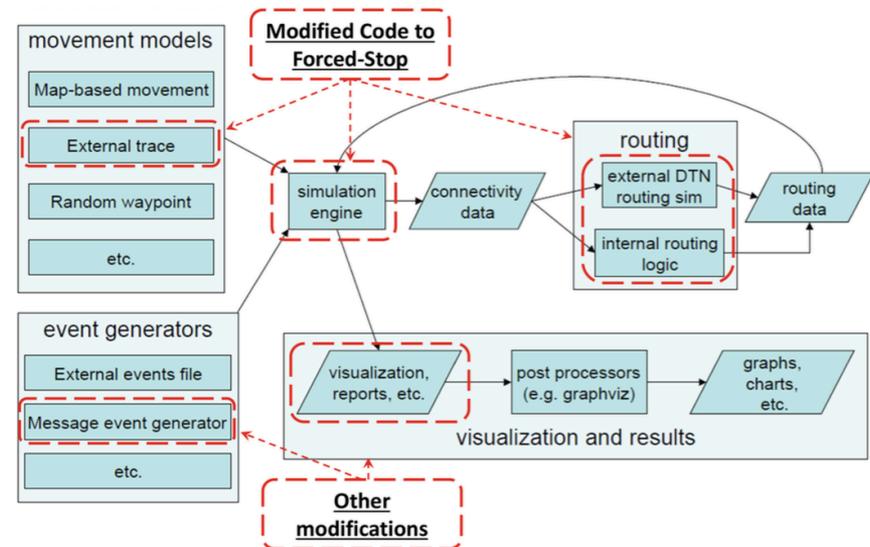
Make Contacts \approx Encounters

Extend Contacts duration

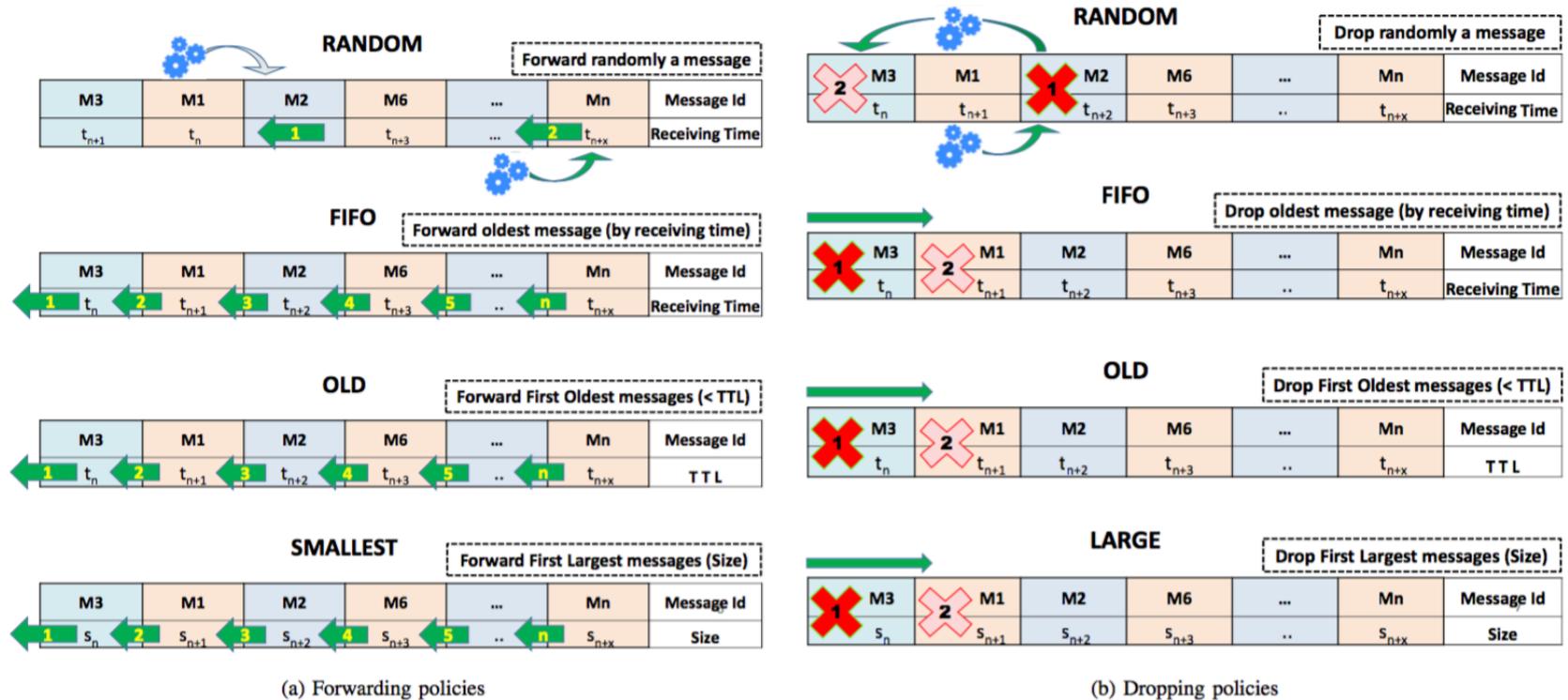
Forced-stop approach



- The basic assumption is that installing and being interested in using such an application indicates that the user wants to actively collaborate in the diffusion of the information.
- Moreover, our proposal allows the applications to inform the users about how much time is needed for interchanging the messages, thus providing a friendly way to stop for a short time.



Buffer management



“Friendly-Sharing: Improving the Performance of City Sensing through Contact-Based Messaging Applications”
Sensors 2016, 16(9), 1523; doi:10.3390/s16091523

Some comment

- ❑ The main factor for a good delivery probability is how long messages are available in the network (TTL), for larger times, the probability of arrival increases
- ❑ The buffer size also plays an important role, as the buffer size increases the buffer management policies have a smaller impact on the message delivery
- ❑ When the buffer size is large enough to keep almost all messages, the dropping policy is no longer relevant
- ❑ The best values are for the combination of *smallest* forwarding and *largest* dropping policies.

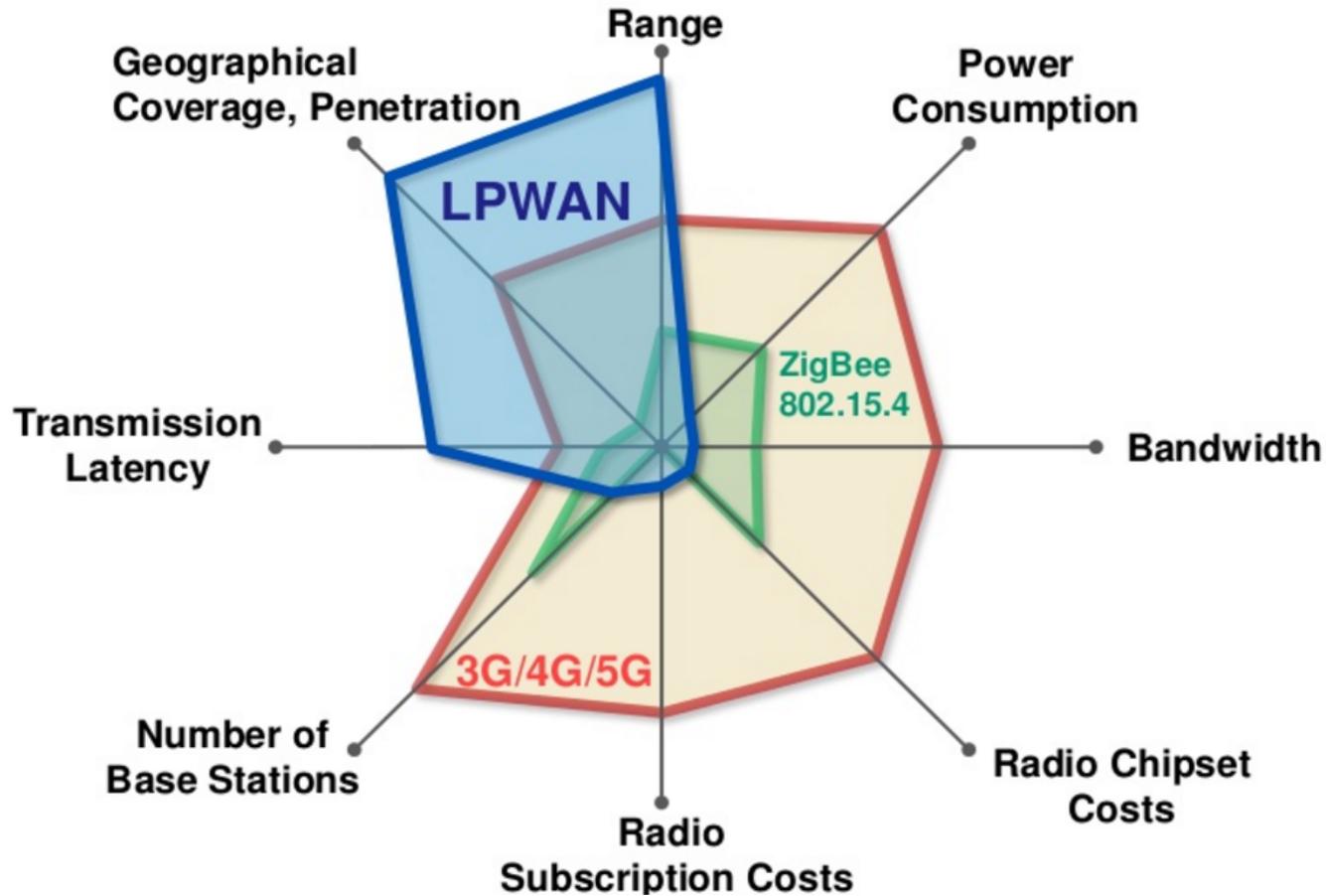
Extending contacts: using LPWAN

- LoRaWAN™ is a Low Power Wide Area Network (LPWAN) specification intended for wireless battery operated Things in a regional, national or global network
- LoRaWAN™ defines the communication protocol and system architecture for the network, while the **LoRa physical** layer enables the long-range communication link.

Data	The Things Network Conversion, APIs
MAC Packets	LoRaWAN + Class B and C extensions
Frame Modulation and data rate	LoRa GFSK (in Europe)
Regional ISM Bands and channel plans	EU: 863-870 AU: 915-928 US: 902-928 CN: 779-787



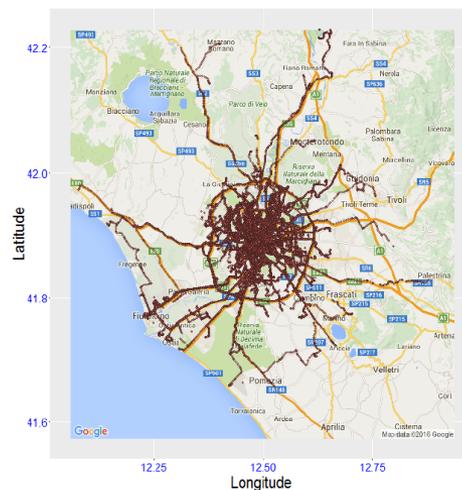
Technologies comparison



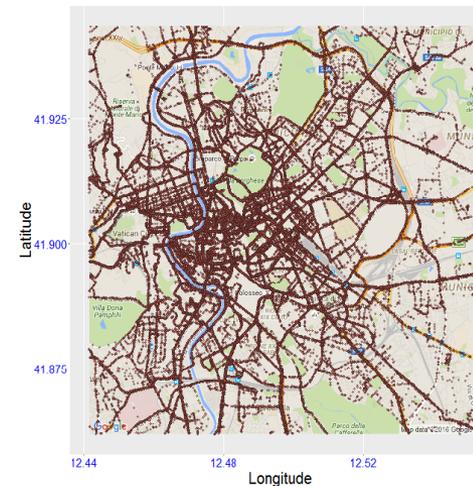
SOURCE: PETER R. EGLI, 2015,
<http://www.slideshare.net/PeterREgli/lpwan>

Traces used

- The vehicular trace (about 21 million of records) comes from a network formed by 370 taxi cabs in the vicinity of Rome during a whole month. Area covered of 100km x 100km (complete dataset).
- R. Amici, M. Bonola, L. Bracciale, A. Rabuffi, Pierpaolo Loreti, Giuseppe Bianchi, "Performance assessment of an epidemic protocol in VANET using real traces", in proceedings of the Fourth International Conference on Selected Topics in Mobile & Wireless Networking MoWNet'2014, (Roma, Italy), Procedia Computer Science 40, pp. 92 – 99, 2014.

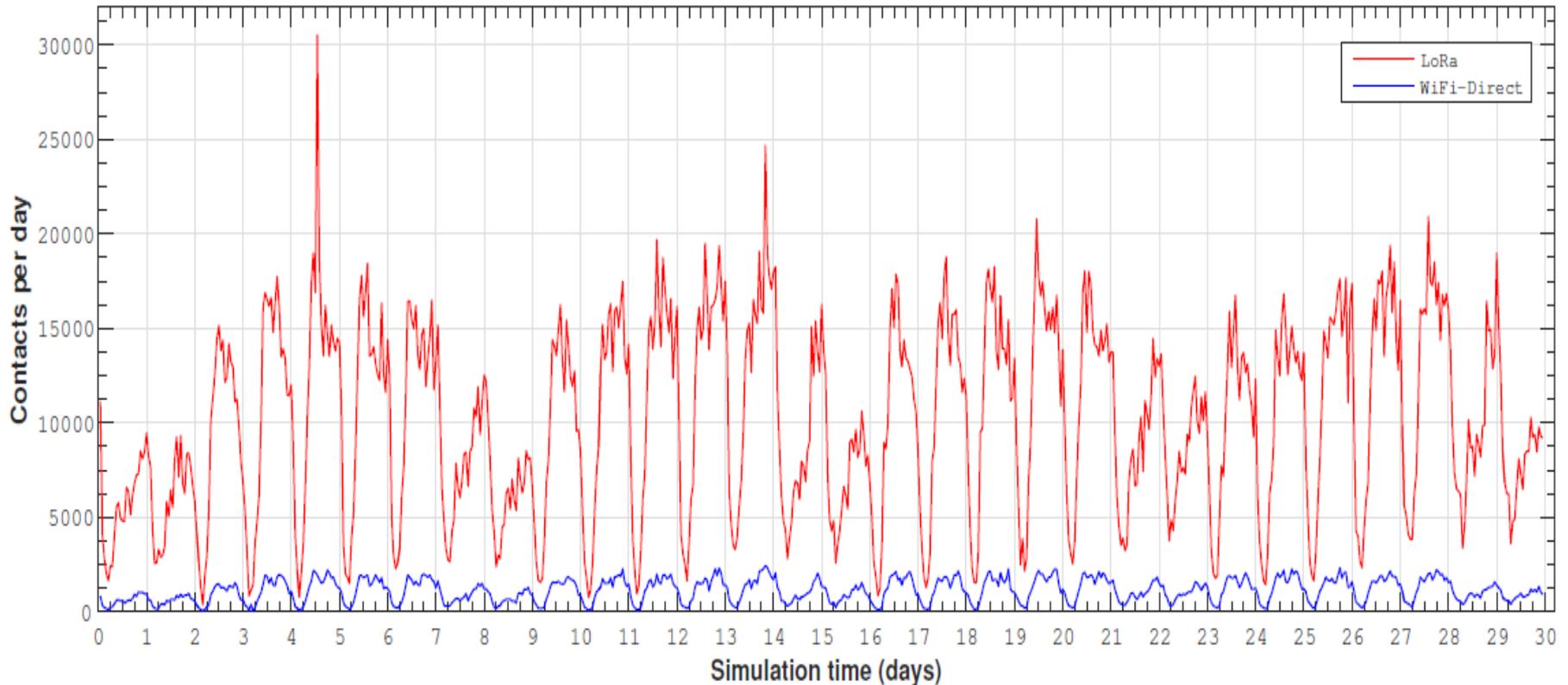


(a) Metropolitan area of Rome (Zoom 10)

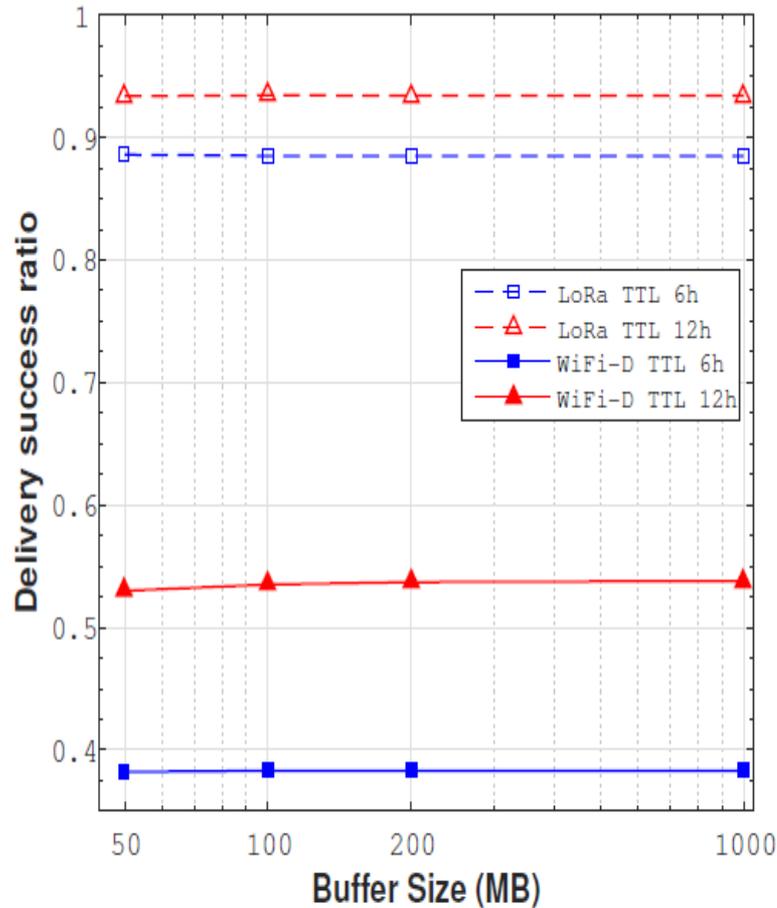


(b) Rome city center (Zoom 13)

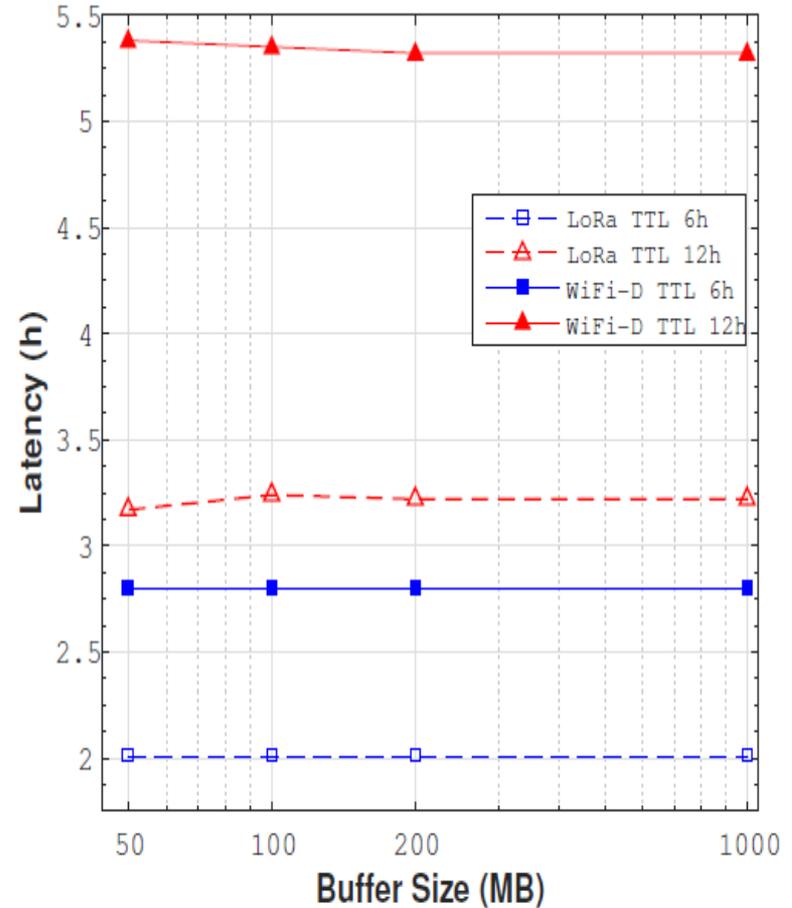
Number of contacts per hour generated by the simulation for each transmission technology.



Average delivery success ratio and latency.



(a) Delivery probability.



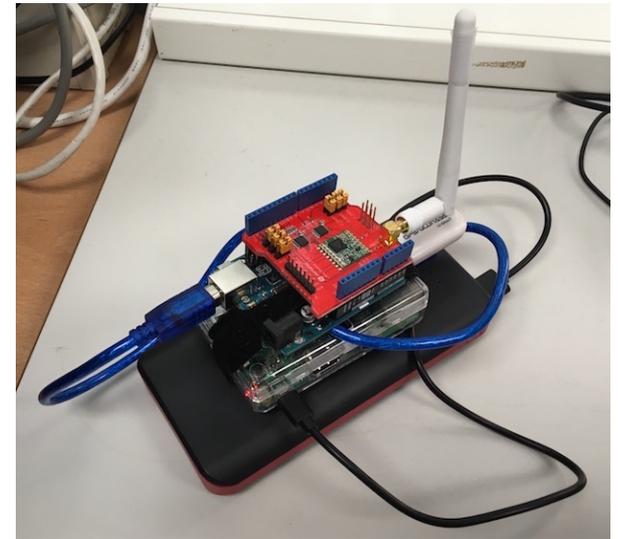
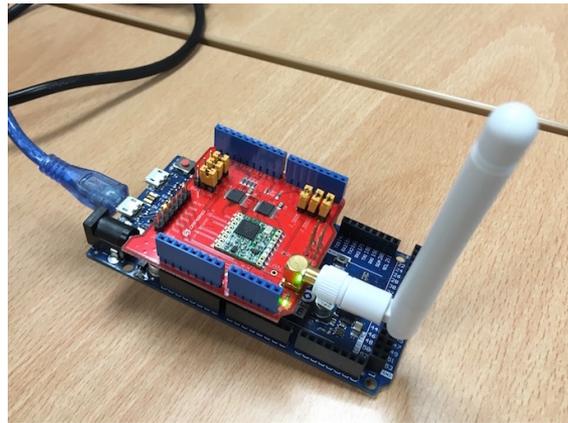
(b) Latency time (hours).

Conclusions

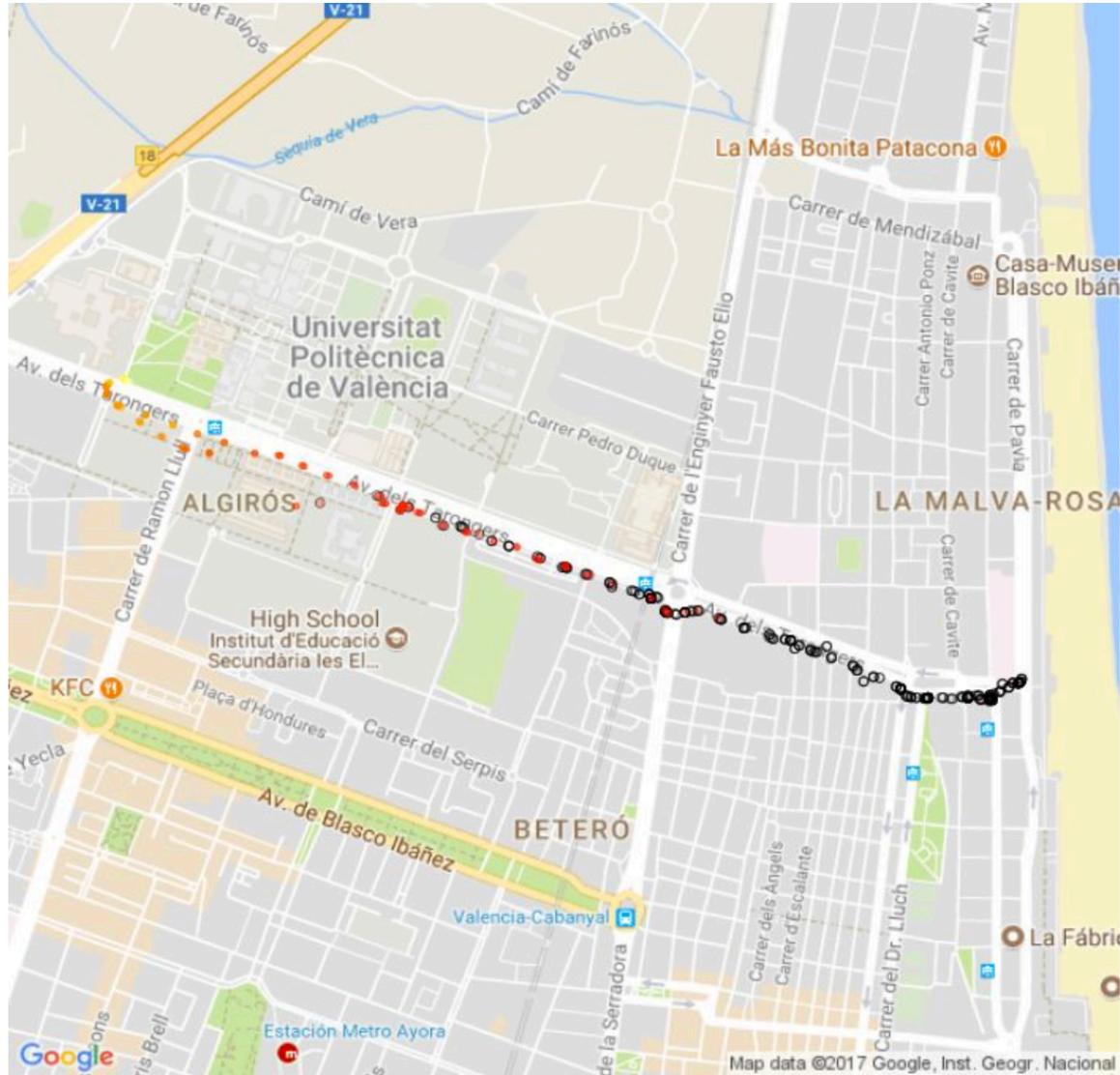
- We evaluated the impact of a sub-gigahertz wireless technologies, in our case the novel Long Range (LoRa) technology, in a opportunistic network using the Epidemic protocol, using a real world movement trace from taxis of Rome and a workload from typical multimedia message applications.
- In the studied scenario, **LoRa improves significantly the message delivery ratio over WiFi** in the range of about 40% to 50% for TTLs of 12 and 6 hours respectively.
 - a wider communication range allows not only more contacts but also those contacts will have greater durations.
- As we can see, **in opportunistic networks, the delivery ratio is limited by the number of contacts** so the communication range becomes the most important factor after message TTL or buffer size, leaving the available bandwidth as a no-crucial factor.

Current status: reality strikes...

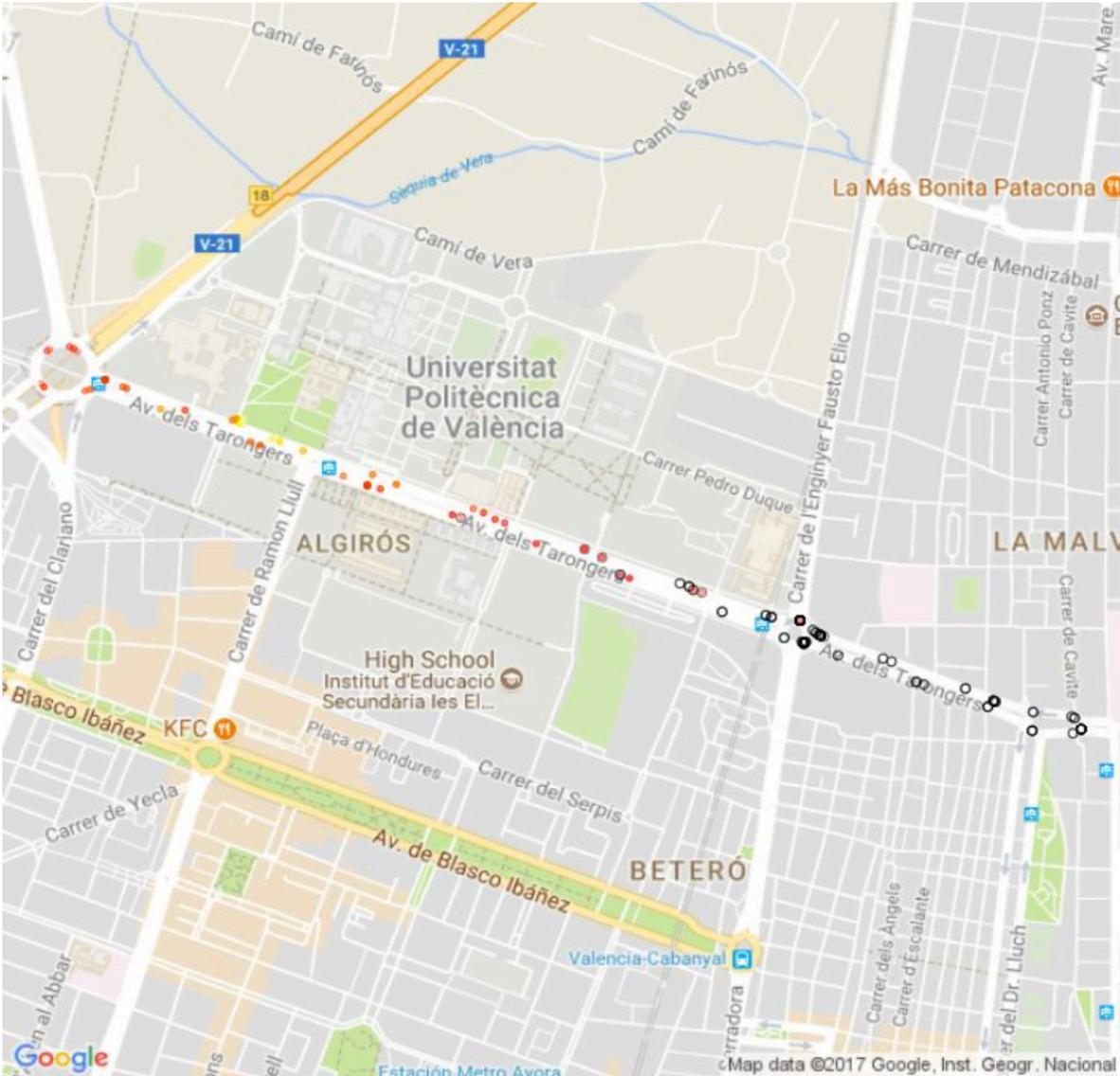
- We are currently performing experiments with a real prototype implementation using embedded devices with LoRa data transmission to validate our simulation setup.



Bike

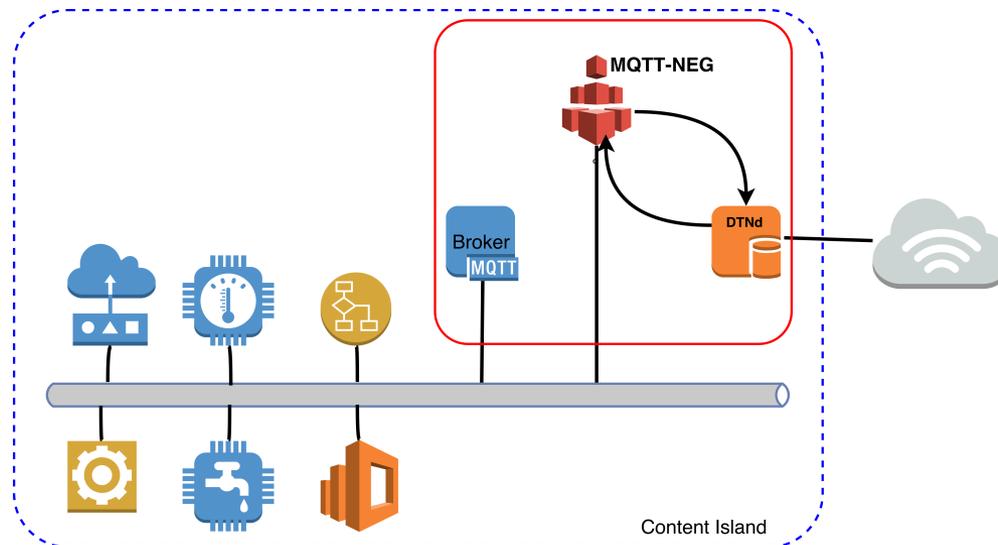


Motorcycle



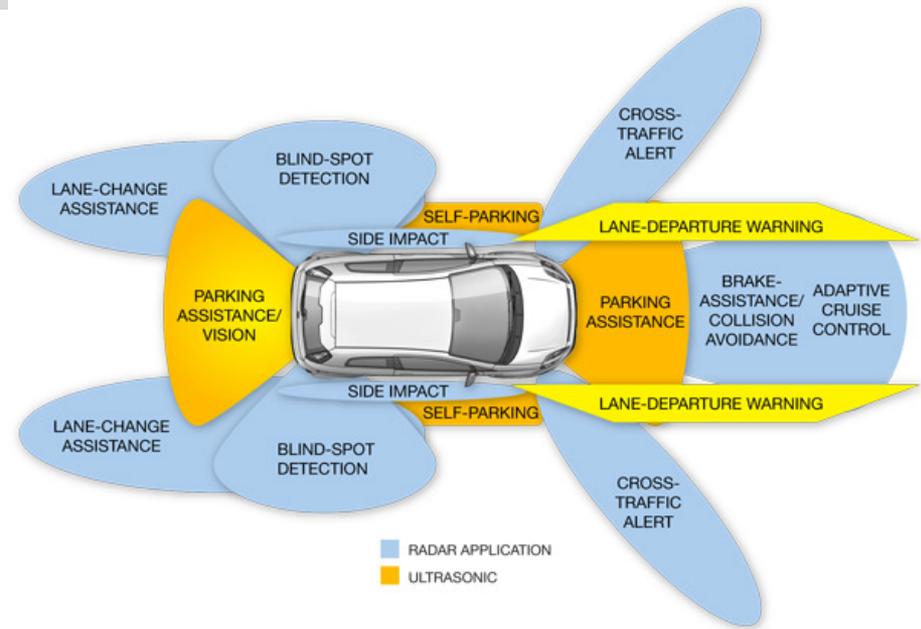
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Objective

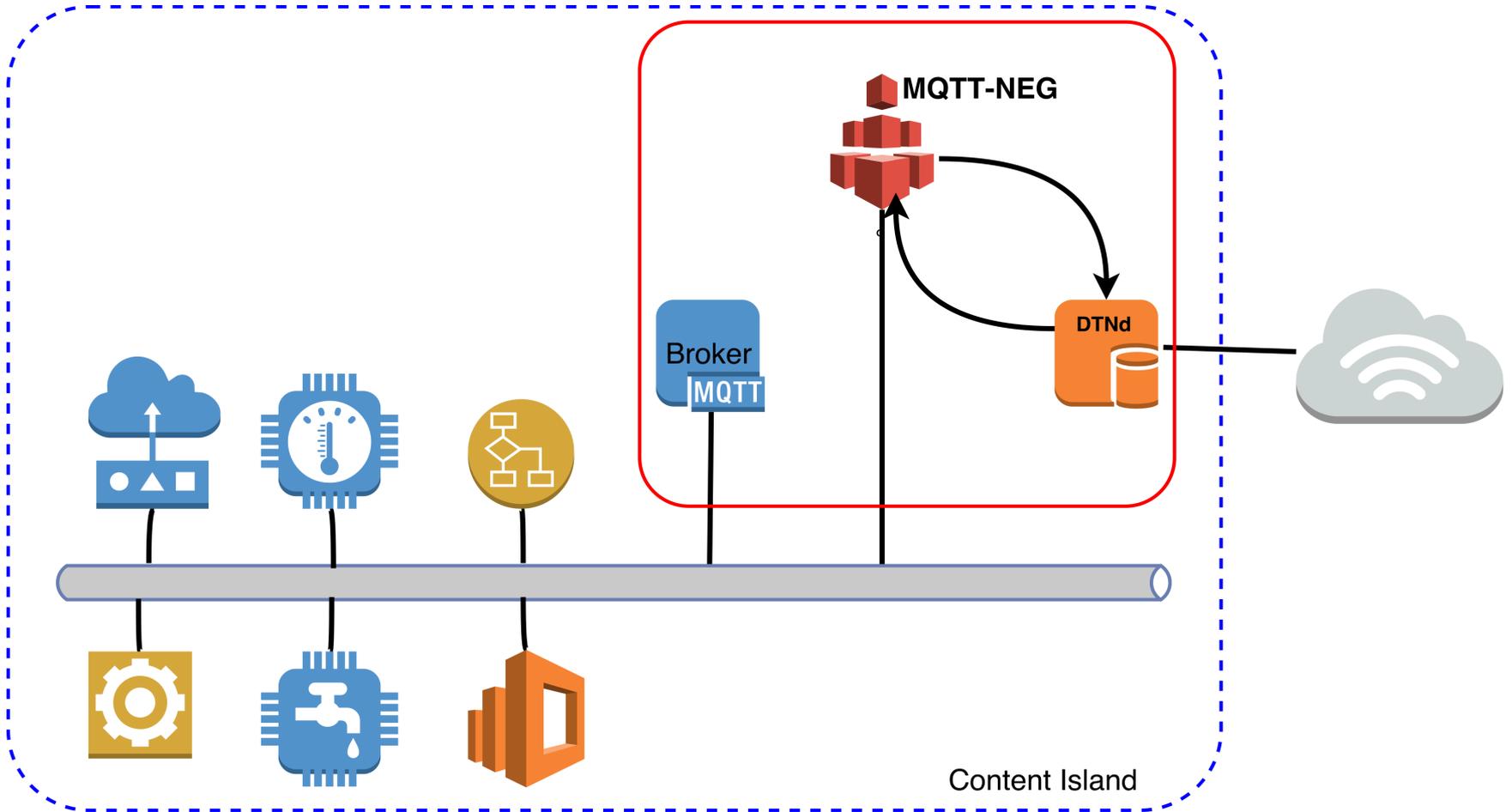
- Design of an architecture of a fog computing oriented “content island”
- Interconnect groups of “things” packed-up together to interchange data and processing among themselves and with other content islands.
- Examples of these islands could be:
 - a vehicle on the road with all the possible sensors and data capture devices it has installed, or
 - a patient that is wearing multiple bio-signal monitoring sensors.



Background

- ❑ Based on pioneering works by Carriero, Gelernter et al. related with Linda
 - ❑ a distributed programming language that is intended for system programming in distributed settings,.
- ❑ The original Linda model offered four operations that “workers” could perform on “tuples” and the tuple space, namely:
 - ❑ in that atomically reads and removes (consumes) a tuple from a tuple space,
 - ❑ rd that non-destructively reads a tuple space,
 - ❑ out that produces a tuple, writing it into the tuple space (tuple may be duplicated in the tuple space), and finally
 - ❑ eval that creates new processes to evaluate tuples, writing the result into the tuple space.
- ❑ We consider that a MQTT message with its associated topic can easily represent a tuple.
 - ❑ subscribing to a topic is the equivalent to the Linda rd operation
 - ❑ publishing a tuple is equivalent to the out operation. Like in Linda, various messages with the same topic can exist.
 - ❑ The eval operation is substituted by a sequence of two messages published: one with a specific topic (e.g., compute/average) that is consumed by a node that is subscribed to that topic, since it can offer that service, and one with the result obtained after executing the operation.

The overall architecture of an island



Definitions

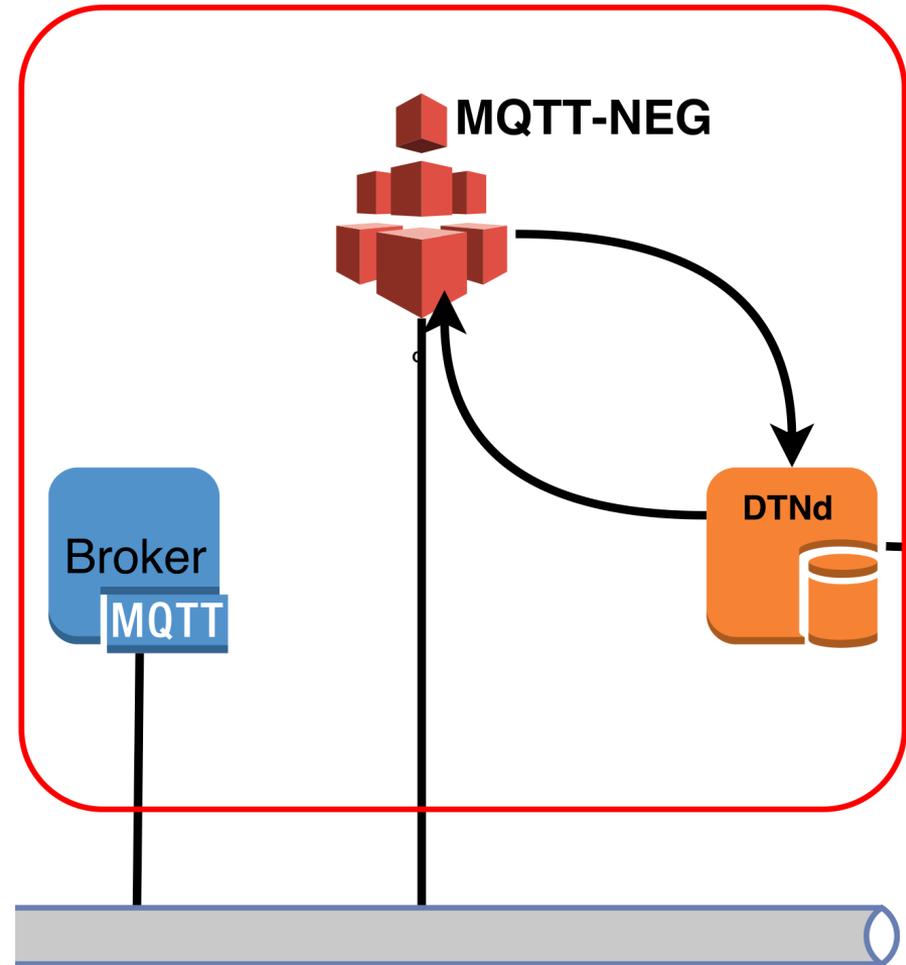
- ❑ We define a content island as a publish/subscribe based system where a set of nodes (“things”) that are capable of some type of processing and sensing, interchange messages inside the island and with other islands, “talking” MQTT.
- ❑ A message, in this context, can represent:
 1. **a collection of data**; e.g., a set of values obtained from a source inside an island, like a time series of the nitrogen and phosphorus content in soil coming from a sensor, or the evolution of the battery charge in an electric vehicle.
 2. **a processing or data analysis request**; e.g., indicate the need for data intensive processing over a data-set, like for example computing the linear relationship between a response (humidity) and one or more predictive terms (temperature).
 3. **an action trigger**; e.g., a request to, if certain conditions hold, turn off a device, take a photo, or publish a message to Twitter.

The island core components

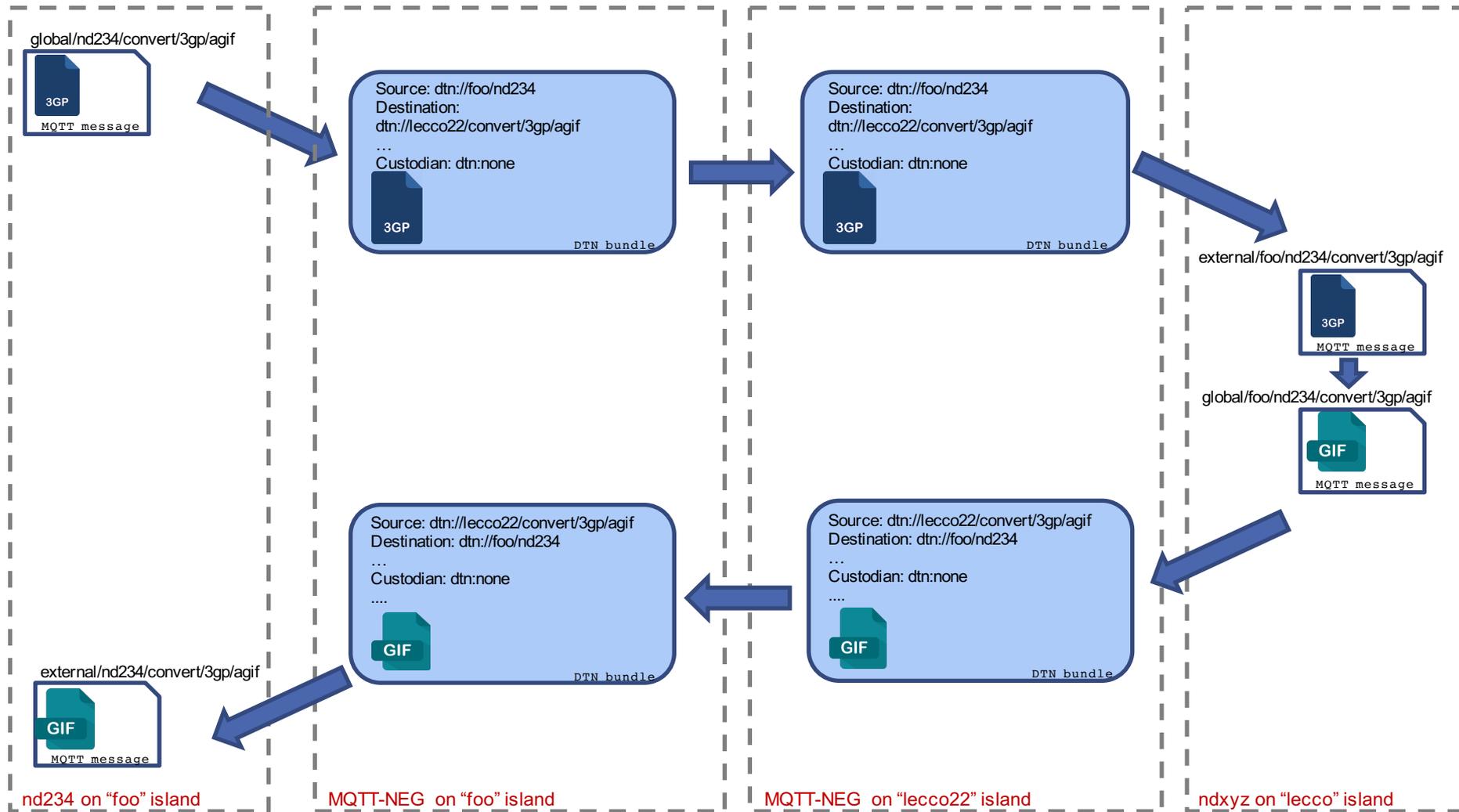
- (1) the MQTT broker,
- (2) the DTN daemon, and
- (3) the MQTT near-user edge gateway (MQTT-NEG)

Two classes of messages are used: local messages and global messages.

- To distinguish between local and global messages, the topic of the latter must be preceded by the **global/** topic value.
- Global messages are both distributed inside the island and forwarded to other islands by the DTN daemon.



MQTT-NEG operations



an island called lecco22 is offering the service of converting a 3GP video into an animated GIF. The service will typically be offered by a unique node inside that island (in this case node ndxyz).

Playing with topics

- The service will typically be offered by a unique node inside that island. The island will advertise it as:

dtm://lecco22/convert/3gp/agif

- Another example could be of an island (e.g., vlc88) that offers the service of publishing the message content through a Telegram bot; this end-point could be advertised as

dtm://vlc88/publish/telegram/bot ILV

- Requesting the service:

global/nd234/convert/3gp/agif

- In case node nd234 wanted that service from that specific island, the notation would have been:

global/nd234:lecco22/convert/3gp/agif

- The node that provides the service will receive the request since it will be subscribed to:

#/convert/3gp/agif

Island core prototype implementation

We implemented a prototype of an island core based on:

- the **Mosquitto MQTT broker**
- the **IBR-DTN** implementation of the DTN bundle protocol.
 - To ease the interfacing with the API of the IBR-DTN implementation we created a wrapper class called `ddtalker`
- **MQTT-NEG** implemented in Python. The code is available <https://github.com/GRCDEV/mqtt-neg/>
 - The MQTT-NEG is composed of two threads executing in parallel that manage the flow of the ingoing and outgoing bundles from the DTN daemon.
 - A third thread manages the communication within the local island (through the MQTT broker).