Evaluating the Performance of CoAP, MQTT, and HTTP in Vehicular Scenarios

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Reference at the paper: https://goo.gl/2r6RMJ
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Outline

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3. Testbed Setup
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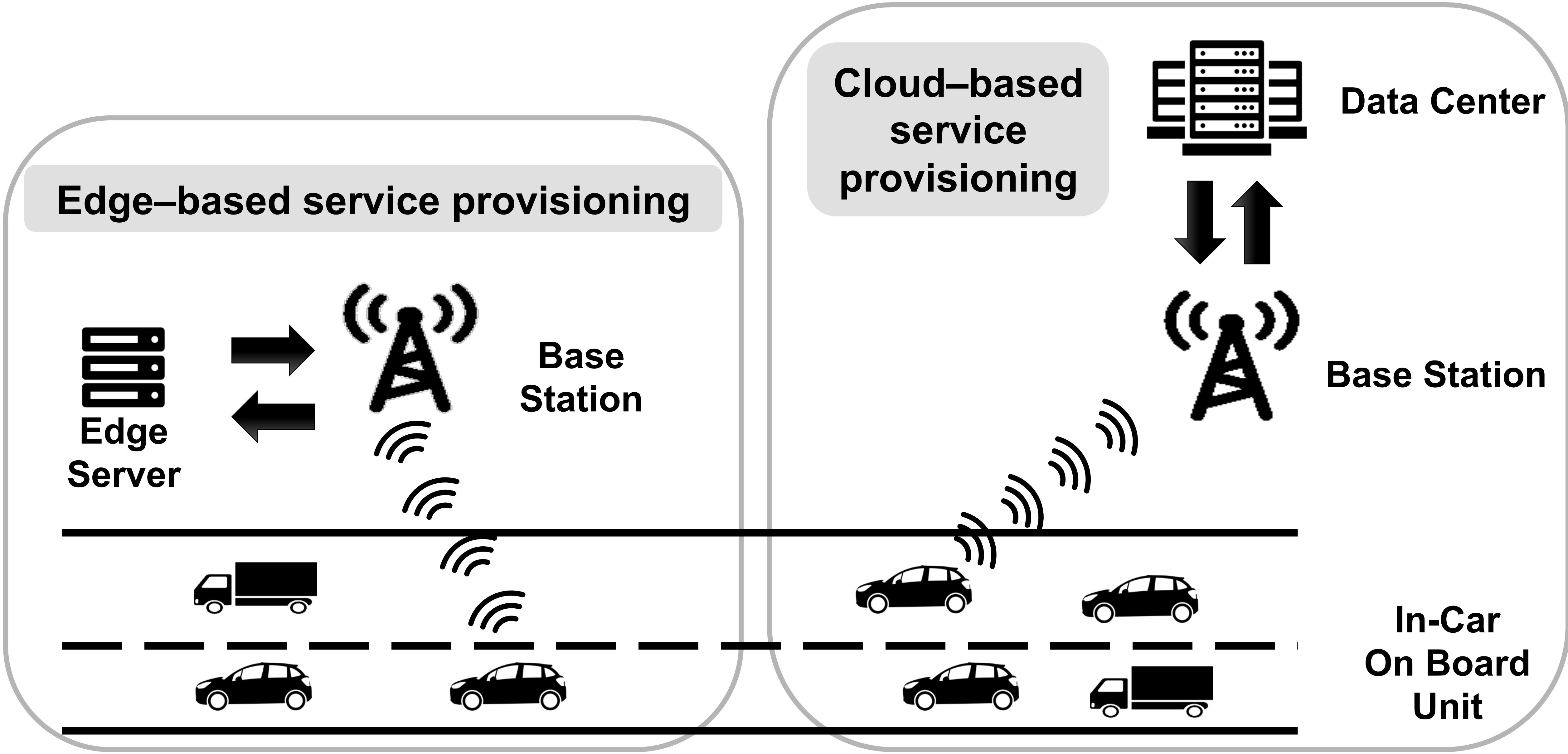
Introduction

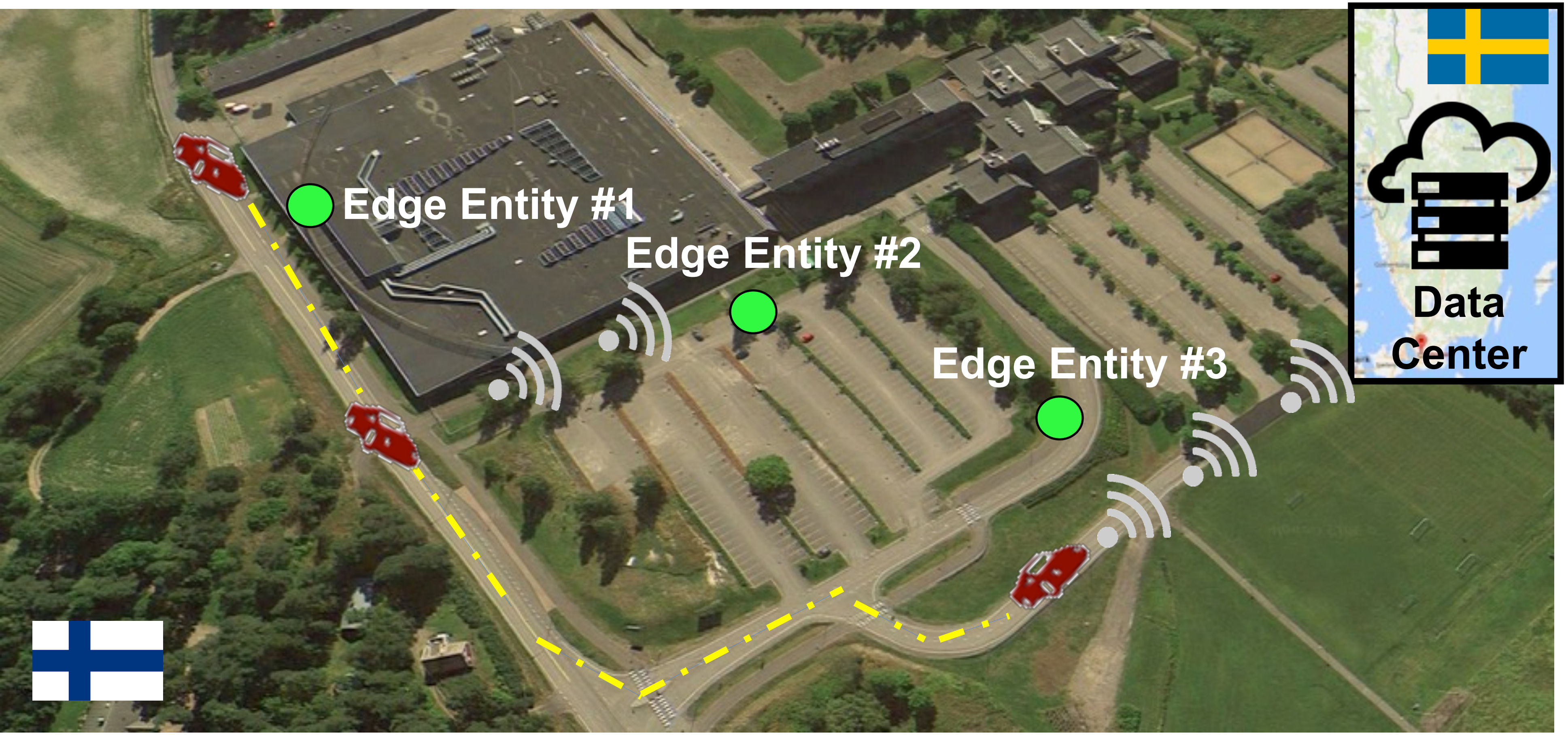
- **Purpose of the Study**
  - Evaluating the performance (throughput and latency) of MQTT, CoAP, and HTTP in vehicular scenarios.
    - It can be considered a preliminary performance evaluation.
  - Empirically demonstrate whether there are performance differences when comparing edge-based service provisioning and cloud-based service provisioning.

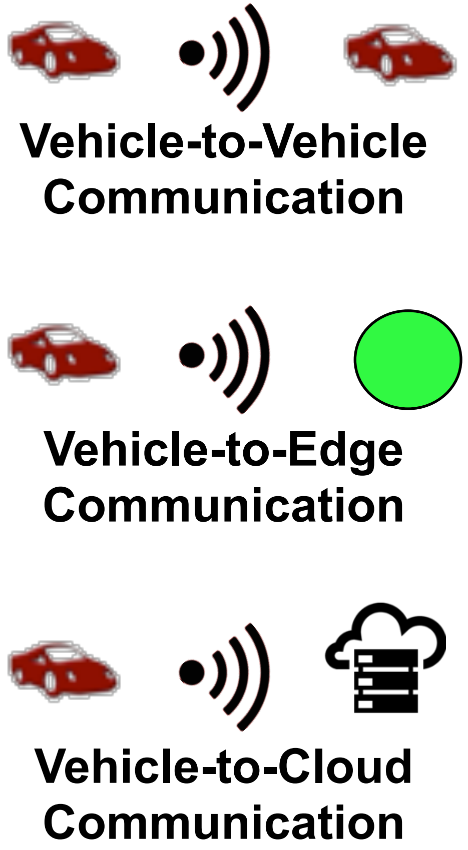
Scenario



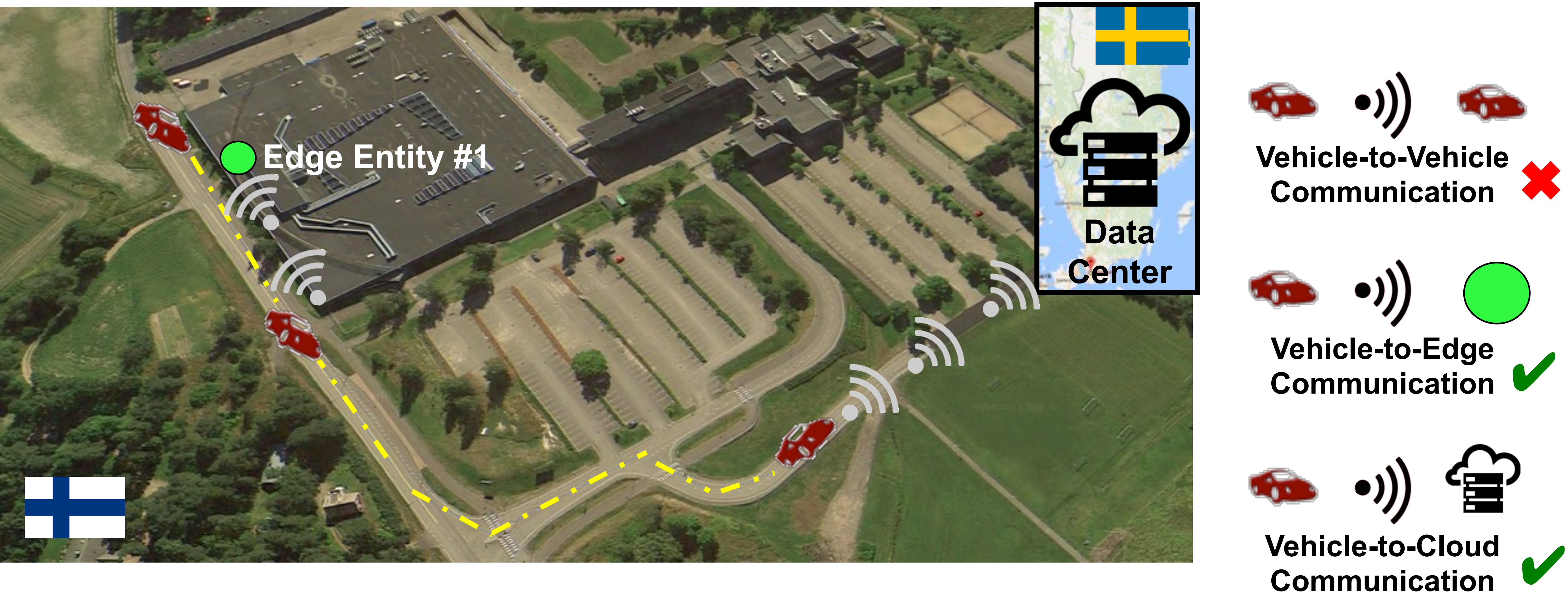
Edge–based service provisioning
Edge Server
Base Station
Cloud–based service provisioning
Data Center
Base Station
In-Car On Board Unit

Testbed Setup – Implementation Plan

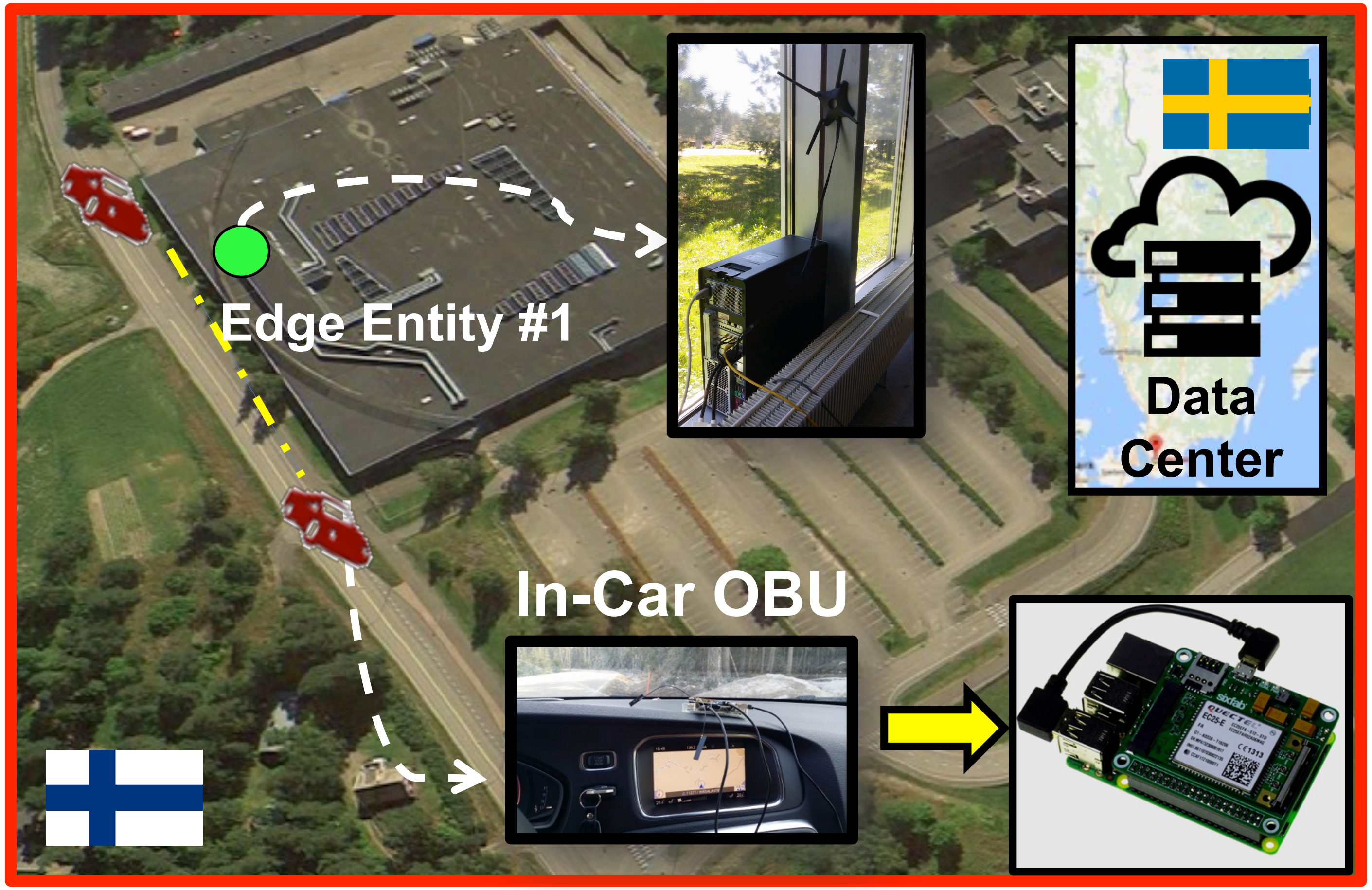




Testbed Setup – Current Status

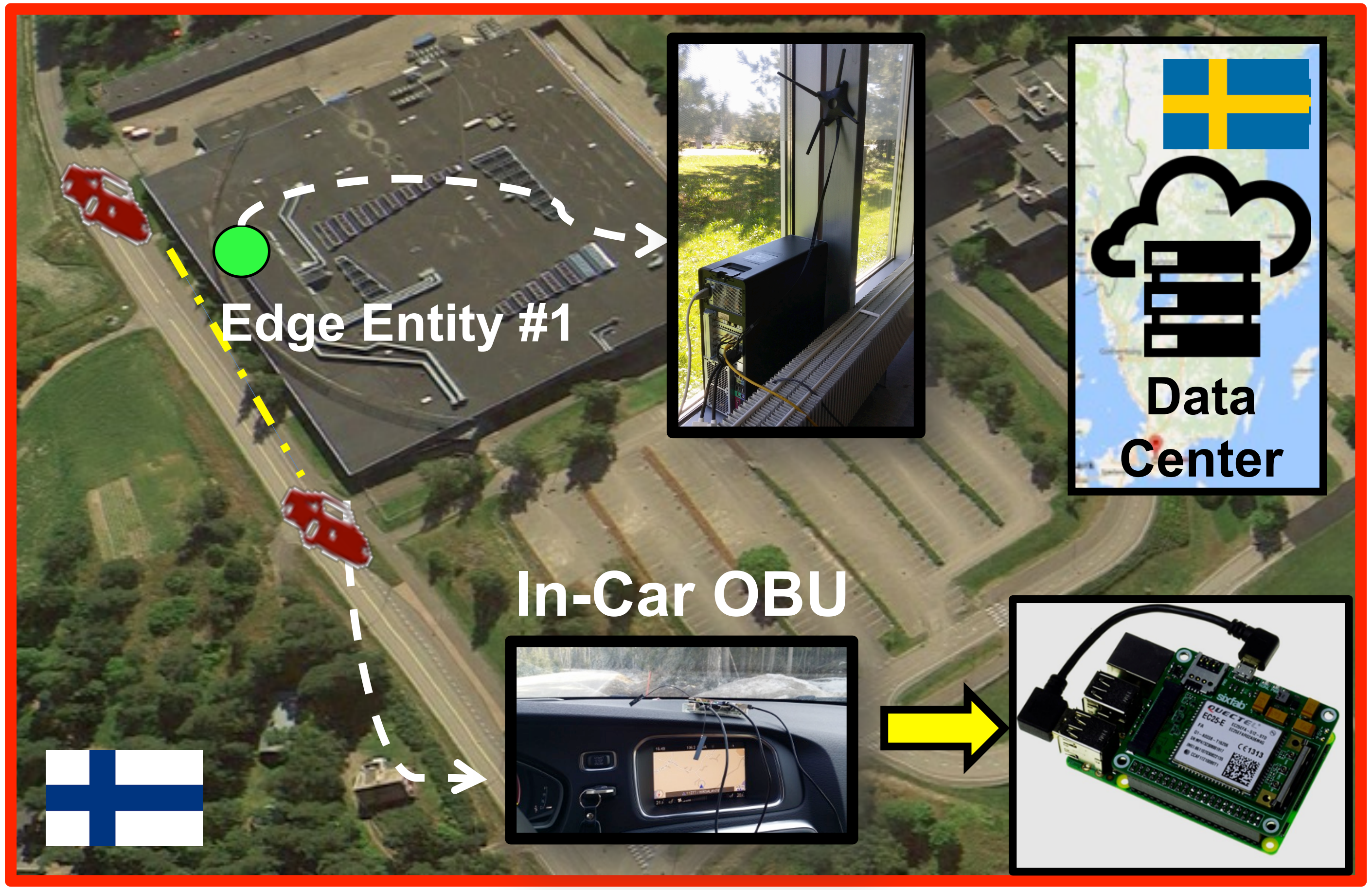


Testbed Setup – More details (i)



- **Data Center**
  - Located in Lund (Sweden).
  - OpenStack environment.
- **Edge Entity**
  - Located in Jorvas (Finland).
  - Dell Precision T5500 server.
  - Connection with the base station through the mobile network of a Finnish operator.
  - No local breakout between base station and edge server (we fully rely on the network setup provided by the mobile network operator).

Testbed Setup – More details (ii)



- **In-Car On-Board Unit**
  - Deployed in a general-purpose board, such as Raspberry Pi 3.
  - Connectivity is provided by a system combining a Sixfab base shield and a Quectel EC25 Mini PCIe 4G/LTE module. Both boards are in turn connected to the RPi3 through GPIO interface.

Testbed Setup – Ongoing studies

- **Cloud-based vs. Edge-based service provisioning** ✔
  - Shed light on the performance impact that a service provisioning provided from the cloud or from the edge introduces
- **Comparison among different application layer protocols** ✔
  - MQTT | CoAP | HTTP (through 4G connection)
  - Transmission of small-sized payloads
- **Service provisioning of large-sized payloads** ✔✖
  - The testbed is already set up for providing additional services to the vehicle (e.g., Multimedia contents)
  - Empirical evaluation must still be made
- **Testing and comparing different Radio interfaces** ✔✖
  - 4G vs. Wi-Fi
  - 802.11p for Car-to-Car communication

Performance Evaluation – Background

- **Main goals**
  - Evaluate two service provisioning approaches
    - Cloud-based vs. Edge-based
  - Application layer comparison
    - Transmission of small-sized messages
    - CoAP, MQTT, HTTP
  - Impact of additional factors
    - Vehicle’s speed
    - Number of clients
    - QoS in MQTT

Performance Evaluation – Background*

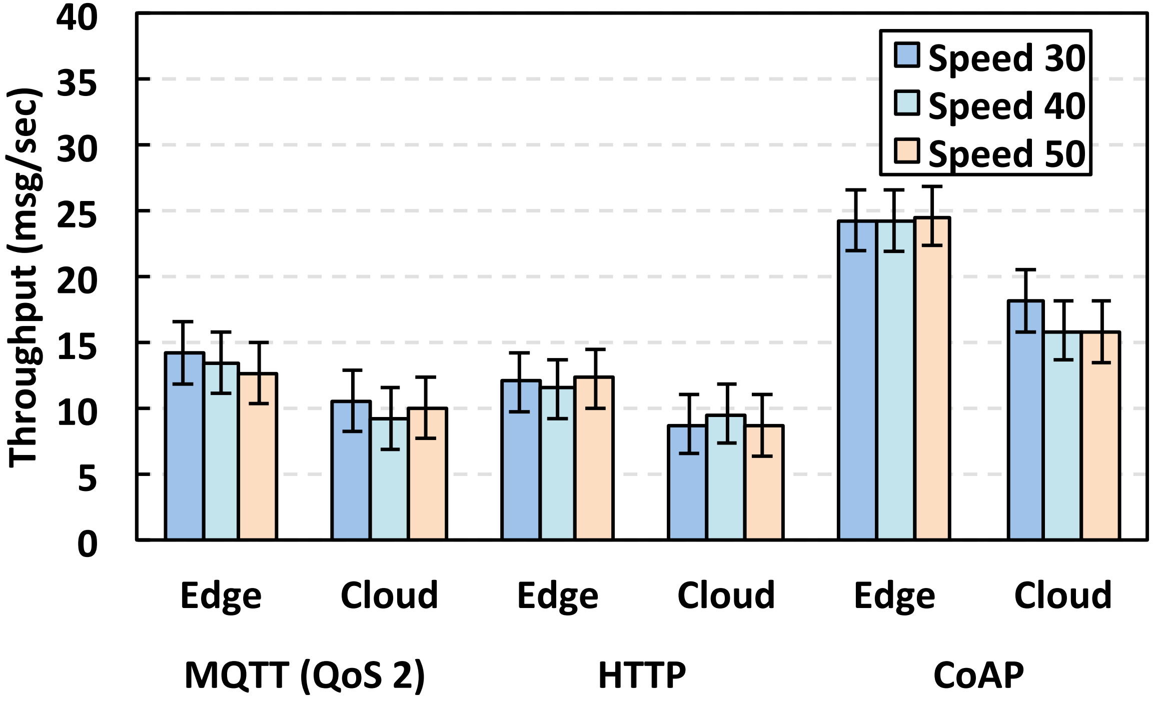
Criteria	HTTP	CoAP	MQTT
Architecture	Client/Server	Client/Server or Client/Broker	Client/Broker
Abstraction	Request/Response	Request/Response or Publish/ Subscribe	Publish/Subscribe
Header Size	Undefined	4 Byte	2 Byte
Message size	Large and Undefined (depends on the web server or the programming technology)	Small and Undefined (normally small to fit in single IP datagram)	Small and Undefined (up to 256 MB maximum size)
Semantics/Methods	Get, Post, Head, Put, Patch, Options, Connect, Delete	Get, Post, Put, Delete	Connect, Disconnect, Publish, Subscribe, Unsubscribe, Close
Quality of Service (QoS) /Reliability	Limited (via Transport Protocol - TCP)	Confirmable Message or Non-confirmable Message	QoS 0 - At most once QoS 1 - At least once QoS 2 - Exactly once
Transport Protocol	TCP	UDP, TCP	TCP (MQTT-SN can use UDP)
Security	TLS/SSL	DTLS/IPSEC	TLS/SSL
Default Port	80/443 (TLS/SSL)	5683 (UDP)/5684 (DTLS)	1883/8883 (TLS/SSL)

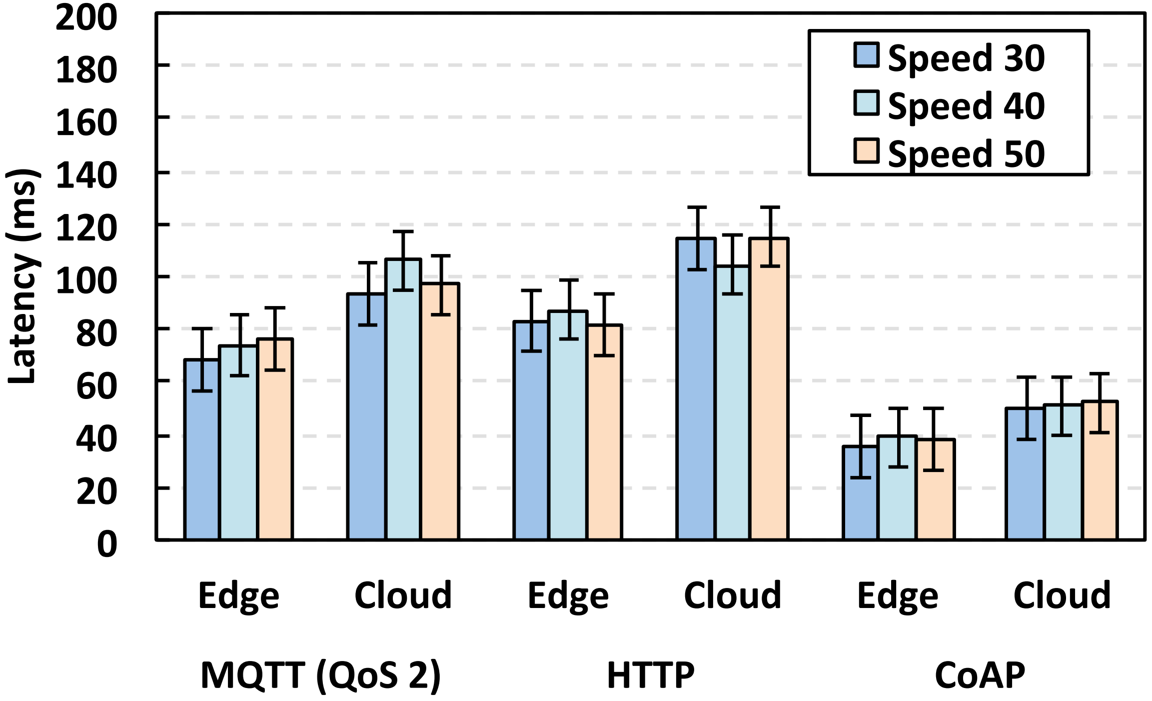
* N. Naik, "Choice of effective messaging protocols for IoT systems: MQTT, CoAP, AMQP and HTTP," 2017 IEEE International Systems Engineering Symposium (ISSE), Vienna, 2017, pp. 1-7.

Performance Evaluation – Background

- **Application later protocols – Setup**
  - MQTT
    Mosquitto (https://mosquitto.org/)
    MQTT benchmark tool (https://github.com/krylovsk/mqtt-benchmark)
  - HTTP
    Apache HTTP Server Project (https://httpd.apache.org/)
    ab benchmark tool (https://httpd.apache.org/docs/2.4/programs/ab.html)
  - CoAP
    libcoap (https://libcoap.net/)
    CoAPBench (https://www.eclipse.org/californium/)

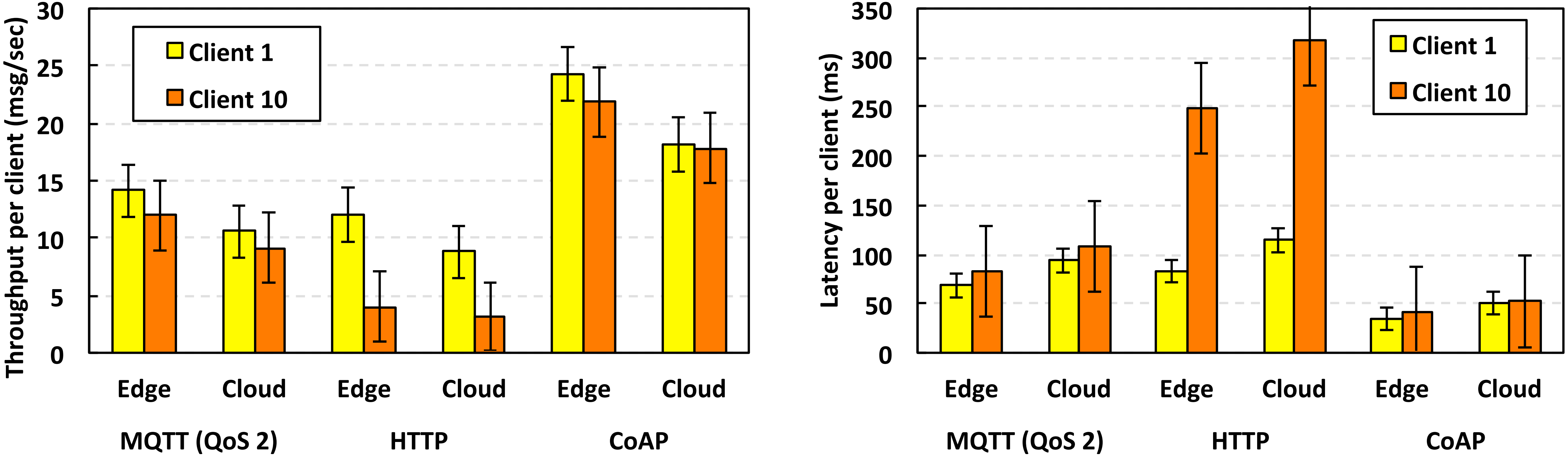
Empirical Results – Impact of **vehicle's speed**





- No strict dependence between vehicle's speed increase and throughput/latency variation.
- CoAP is outperforming both MQTT (with QoS 2) and HTTP.
- Edge-based service provisioning shows performance benefits when compared to the cloud-based approach.

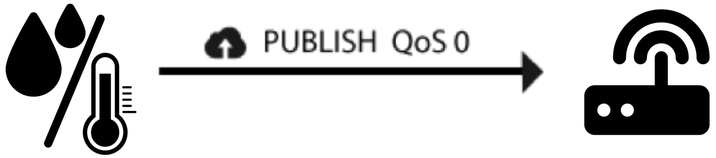
Empirical Results – Impact due to **number of connected clients.**



- Average throughput delivered to each client decreases when the number of connected clients grows
- CoAP still the most efficient protocol (10% throughput decrease)

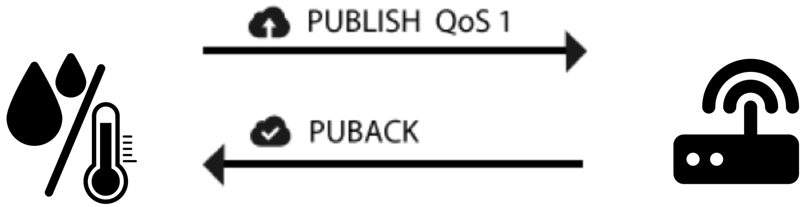
Empirical Results – Impact of **QoS** in **MQTT***

QoS 0



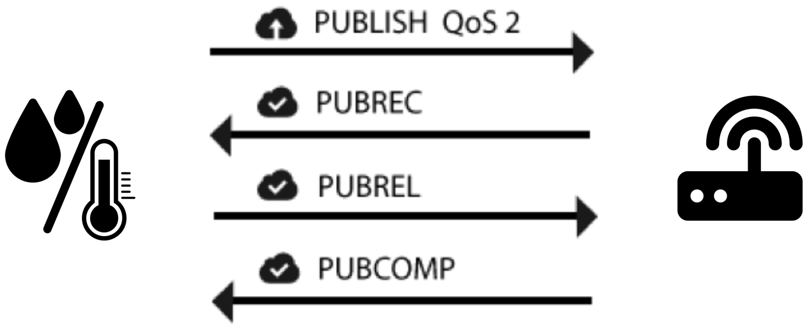
- Best-effort delivery.
- No guarantee of delivery.
- Recipient does not acknowledge receipt of the message and the message is not stored and re-transmitted by the sender

QoS 1



- It guarantees that a message is delivered at least one time to the receiver.
- The sender stores the message until it gets a packet from the receiver that acknowledges receipt of the message.
- Message can be sent or delivered multiple times.

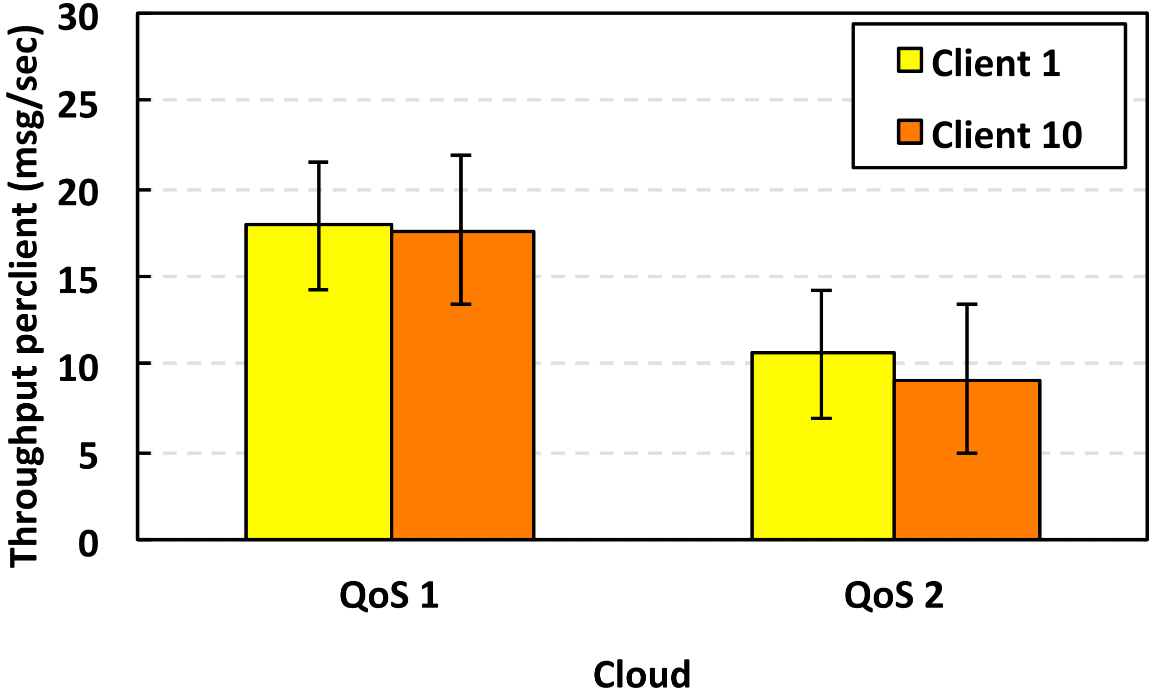
QoS 2

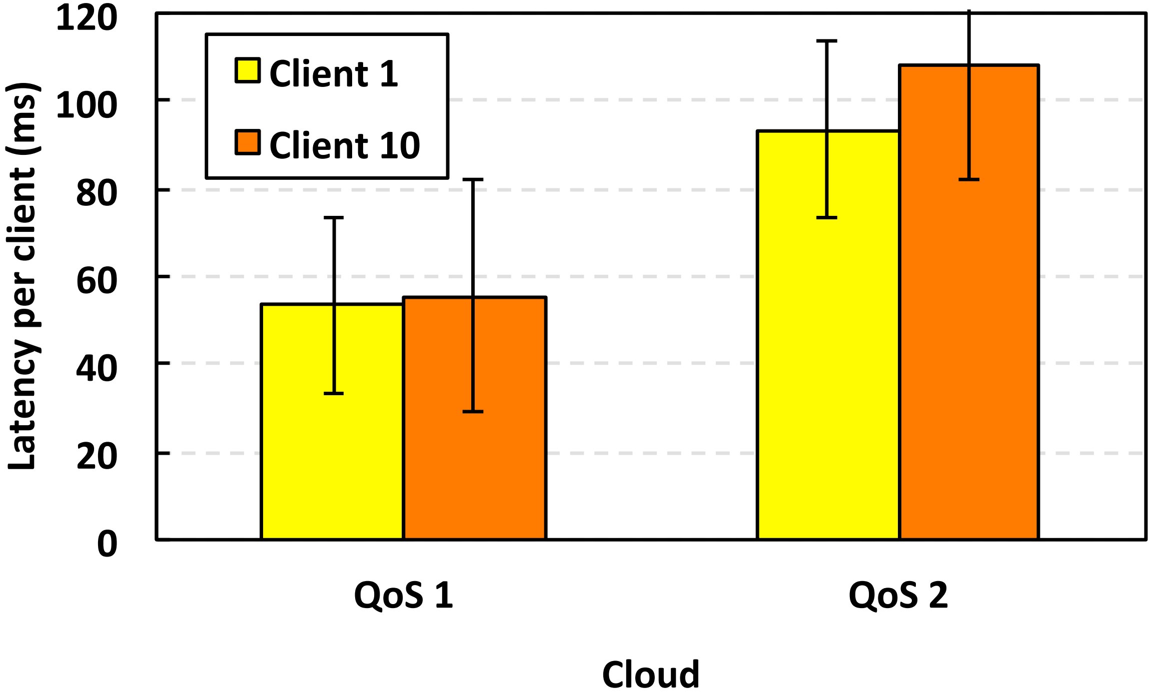


- It guarantees that each message is received only once by the intended recipients.
- Safest and slowest QoS.
- Guarantee is provided by at least two request/response flows (a four-part handshake) between the sender and the receiver

* https://www.hivemq.com/blog/mqtt-essentials-part-6-mqtt-quality-of-service-levels

Empirical Results – Impact of **QoS** in **MQTT.**





- Higher QoS produces a throughput reduction in the order of 40%.
- Higher QoS slows down the message transmission by approximately 75%

Conclusion

- **Conclusion**
  (small-sized messages transmission…to be kept in mind…)
  - CoAP outperforms MQTT (both QoS 1 and QoS 2) and HTTP, both from throughput and latency perspective in different case studies.
  - In MQTT, the choice of the QoS has effects in the produced performance.
  - Tangible performance gains when exploiting edge-based service provisioning.

Conclusion and Future Perspectives

- **Future Work**
  - Large-sized workloads.
  - Evaluate the impact of Object Security for Constrained RESTful Environments (OSCORE).
  - Additional network interfaces.
  - Different placement for the edge entity.

As a general rule, the choice of using a protocol over another highly depends on the use case under examination and the workloads intrinsically generated within them, without also neglecting the implementation choices of different service providers.

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