Simulation Framework for Multi-Vehicle Autonomous Systems

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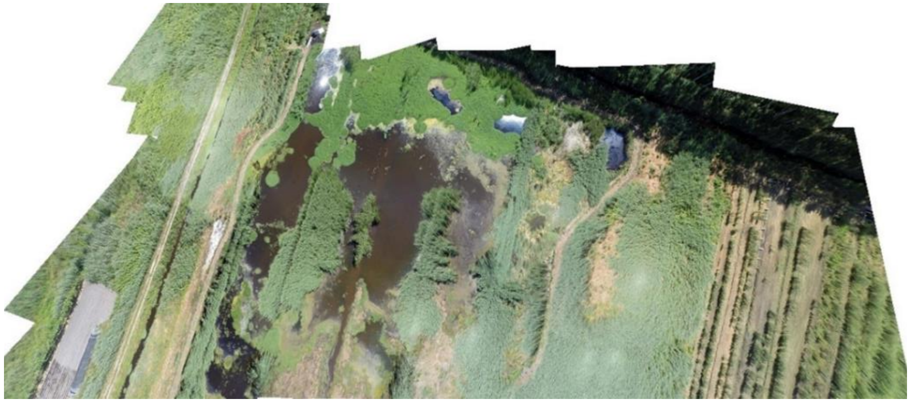
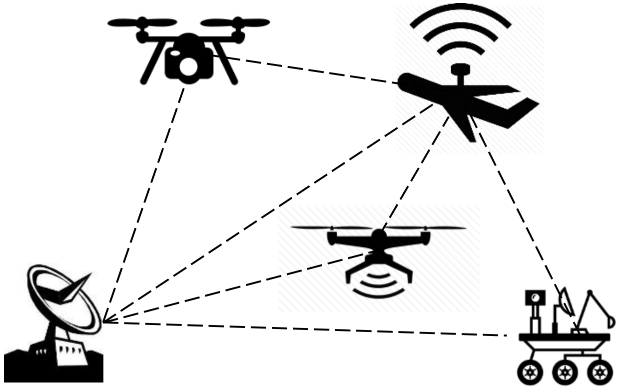
Context of the Application

Unmanned Autonomous Vehicles constitute an emerging field in different sectors



Benefits

- They can operate in hazardous environment
- Low cost
- Low maintenance
- Capability of being used in a multi agent framework



Possible Applications

- Surveillance of large areas
- Support for ground personnel
- Geo-Surveys (State of the vegetation, pollution, etc.)
- Search and rescue

Challenges

High performances and capabilities

↓

Complex Tasks

↓

Complex Design and Testing

Need for ***Development Support Framework***

Testing on the final plant is risky, expensive, time consuming...

Requirements

What do we **need** from a development framework?

- Realistic simulation of the vehicles and sensors behavior;
- Support for testing high-level functions of the vehicles;
- Support for multi-agent scenario;
- Good maintainability and interoperability.

Related Works

Often all those aspects are not considered as a whole.

- There are works that implement realistic simulator framework without supporting multi-agent scenario;

C. Kamali and S. Jain, “Hardware in the loop simulation for a mini uav”, ACODS 2016

- Some simulator uses dedicated simulation/visualization tools like flight simulators, losing the capability to model heterogeneous vehicles;

S. R. Barros dos Santos, S. Givigi, C. L. J. Nascimento, and N. Oliveira, “Modeling of a hardware-in-the-loop simulator for uav autopilot controllers”, COBEM 2011

- Often the proposed frameworks are not characterized in terms of timing accuracy;

O. Parodi, L. Lapierre, and B. Jouvencel, “Hardware-in-the-loop simulators for multi-vehicles scenarios: survey on existing solutions and proposal of a new architecture”, IEEE/RSJ 2009

Contributions

- Hardware-in-the-loop simulation environment supporting heterogeneous ***multi-vehicle configuration***;
- **Synthetic environment** for rapid prototyping of complex testing scenario;
- ***Timing accuracy and precision***, together with a low simulation latency.

Simulation

Realism is important to make the simulation results representative of the real behavior of the system.

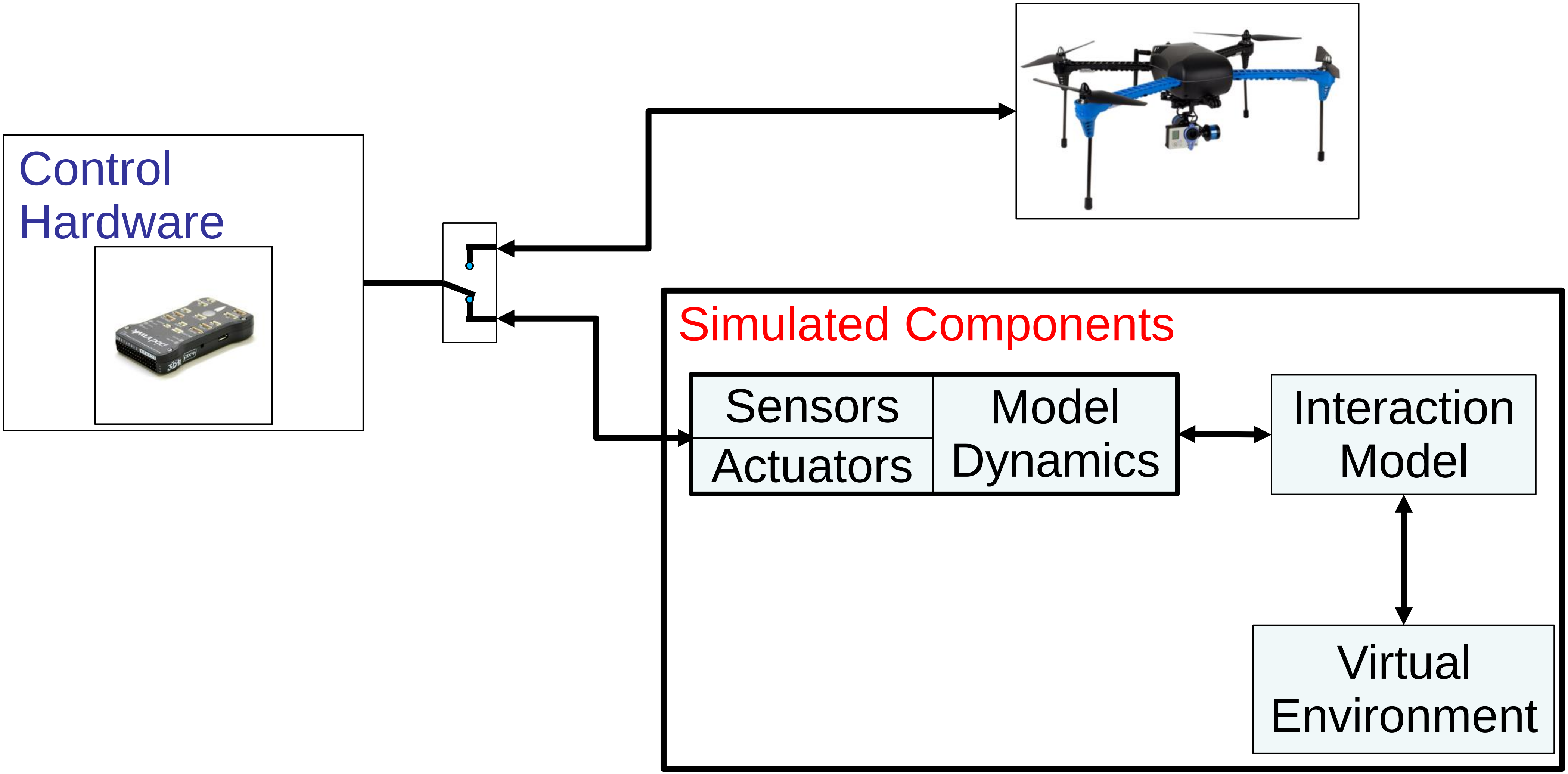
Simulation Model

MATLAB

Computing Hardware

Simulation

“***Hardware in the Loop***”



System Architecture

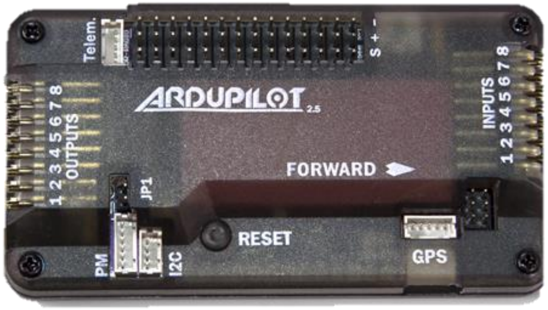
Autopilot Boards

Support for all the boards that communicate with the *MAVLink* protocol.

MAVLINK

MICRO AIR VEHICLE COMMUNICATION PROTOCOL

Ardupilot
8-bit Microcontroller
(16 Mhz)



Pixhawk
32-bit Microcontroller
(168 Mhz)

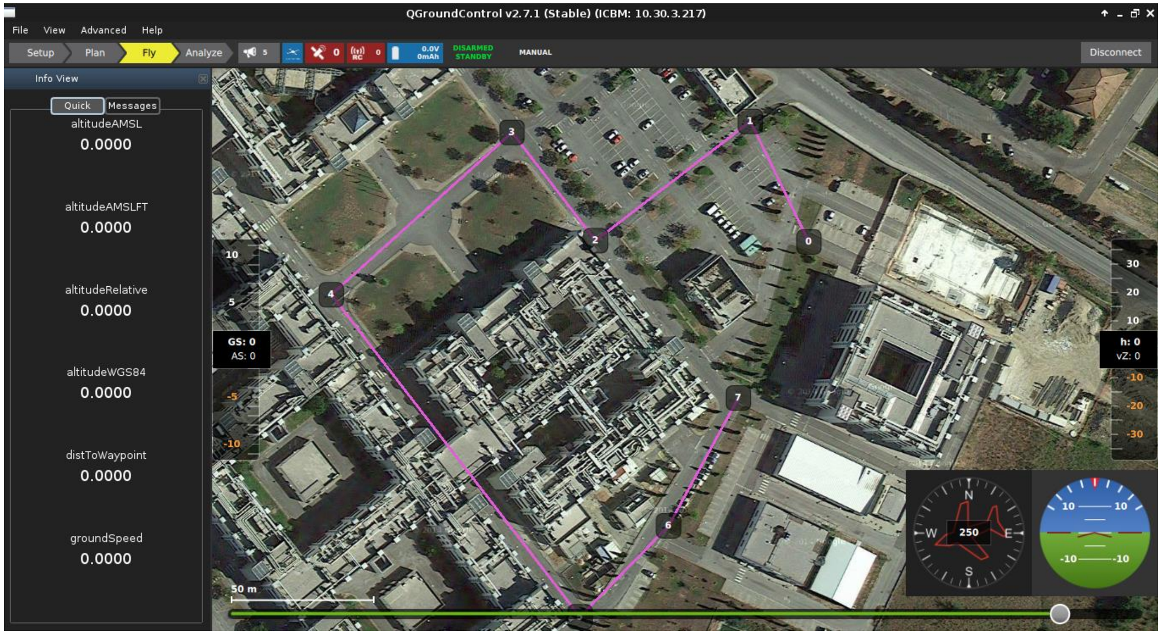
Navio+
64-bit Microprocessor
(quad-core @ 1.2 Ghz)

System Architecture

Ground Station

Solutions involving autonomous vehicles always include ground stations.

The framework can include any ground station implementing the *MAVLink* protocol over UDP.

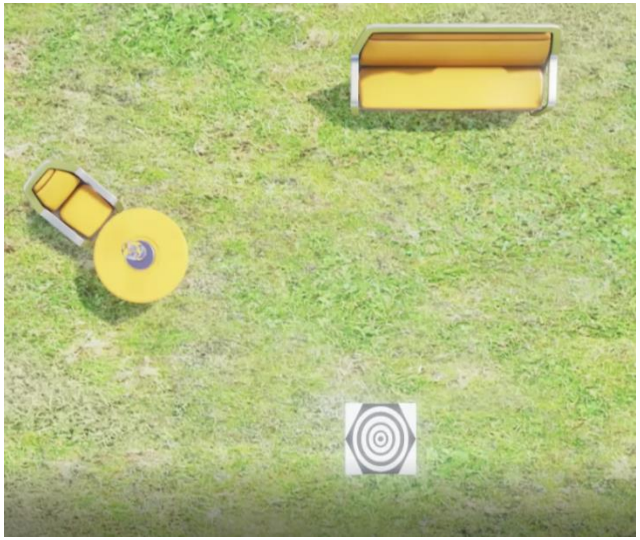


System Architecture

Synthetic Environment

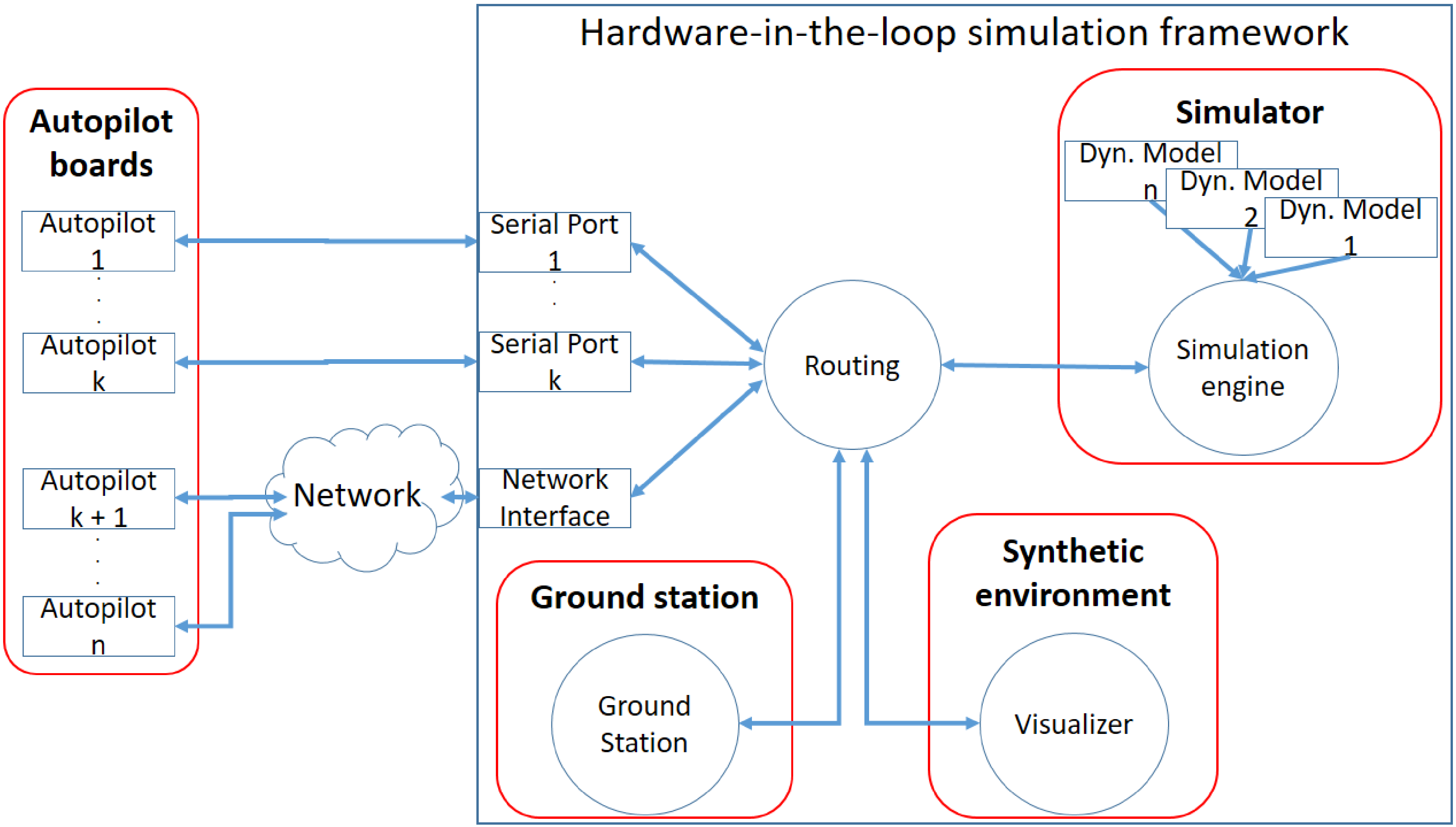
It provides visual feedback and it is necessary for the testing of developed solutions.

- Design complex testing environments
- Simulate the output of cameras
- Simulate moving objects



System Architecture

Overview



System Implementation

Routing

Managing multiple agents entails exchanging data between different entities.

It is necessary to:

- Performs message exchange considering the priority of different activities;
- Guarantee the precise timing execution of the routines.

Experiments

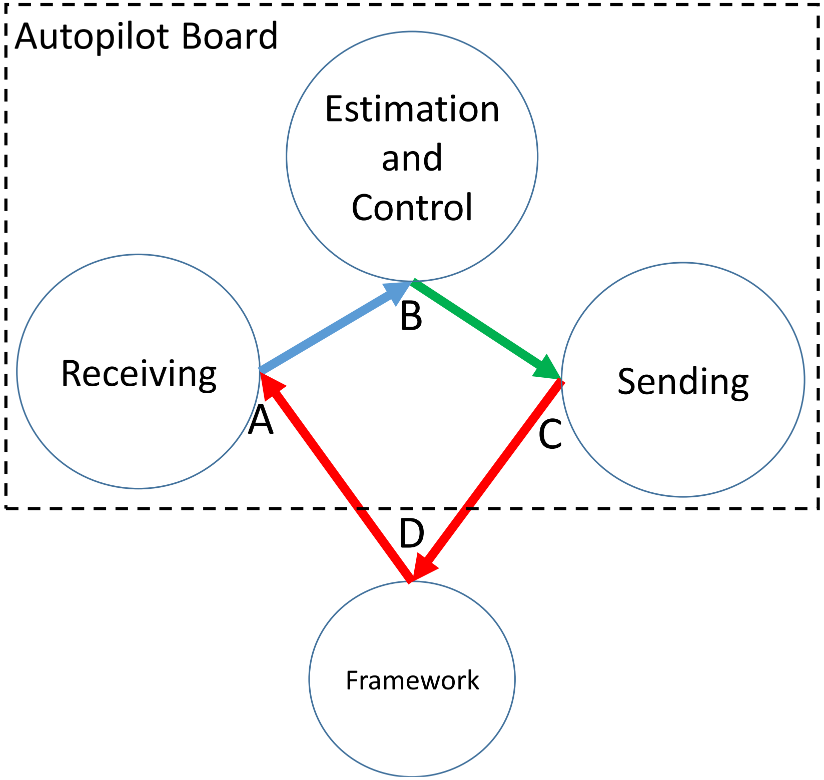
The system has been characterized in terms of introduced delays and capability to trigger the autopilot board with a given frequency.

t_{CA} : Simulator Latency

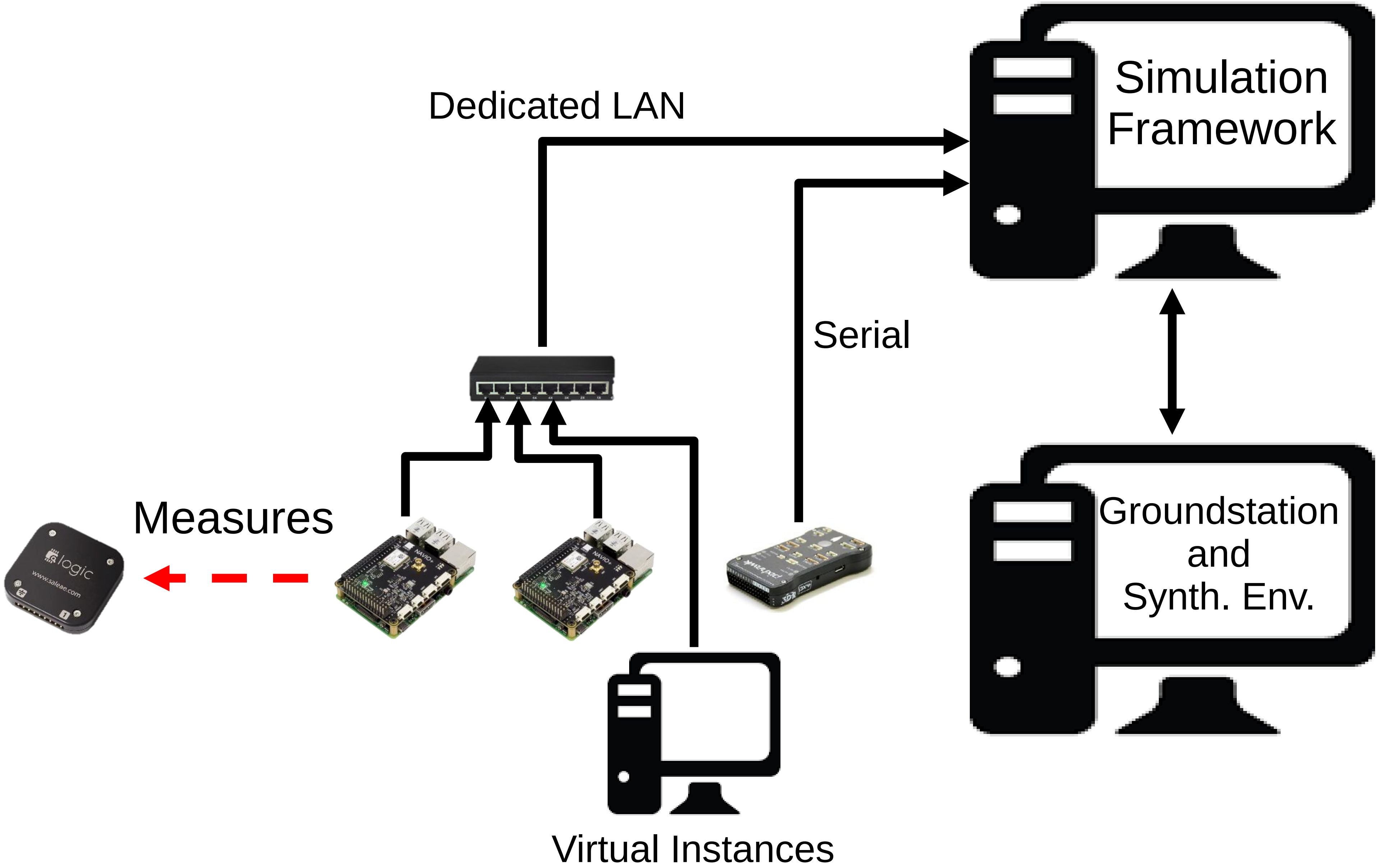
t_{AB} : Control Latency

t_{BC} : Transmission Latency

T_A : Sensor data sending Period



Experiments



Results

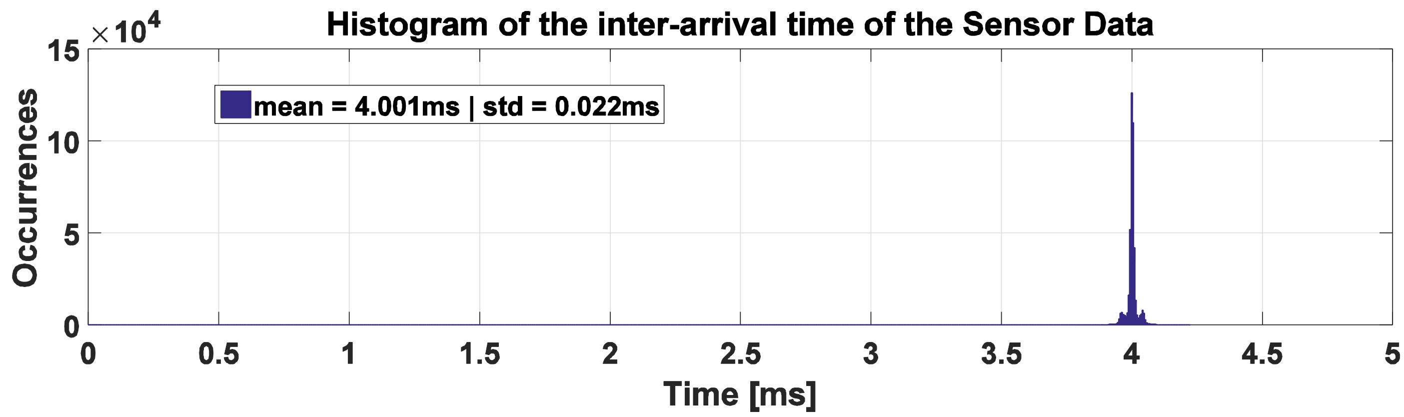
Latency of the framework response as a function of connected vehicles.

Num. Vehicles	3	10	15
Latency mean value	0.445 ms	0.448 ms	0.450 ms
Latency std	0.089 ms	0.091 ms	0.101 ms

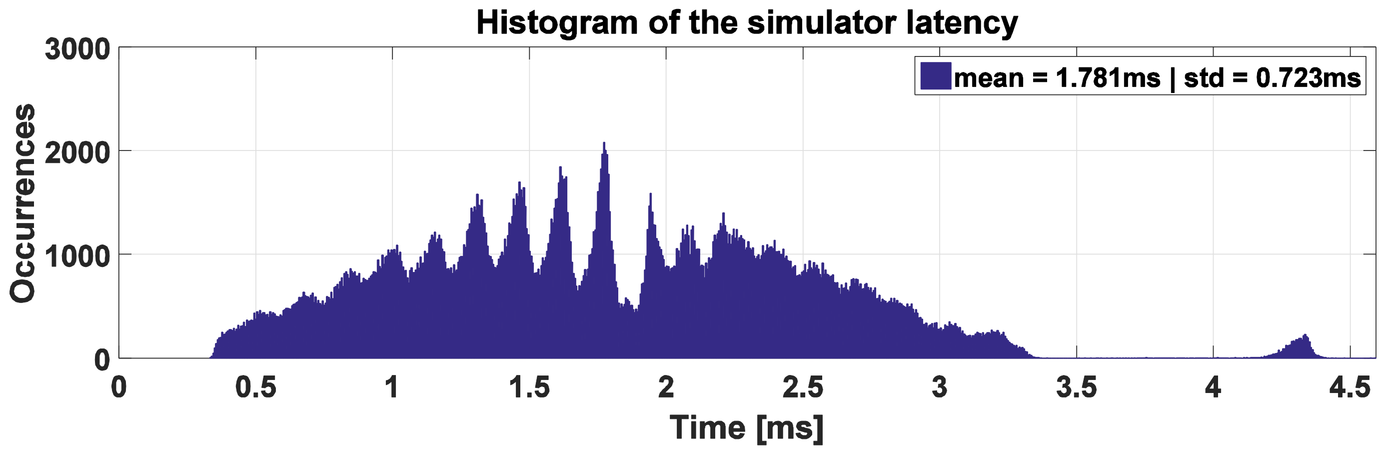
The increase of latency among the case of 3 and 15 vehicles is only **5 µs**

Results

Results with simulation driven synchronization approach:



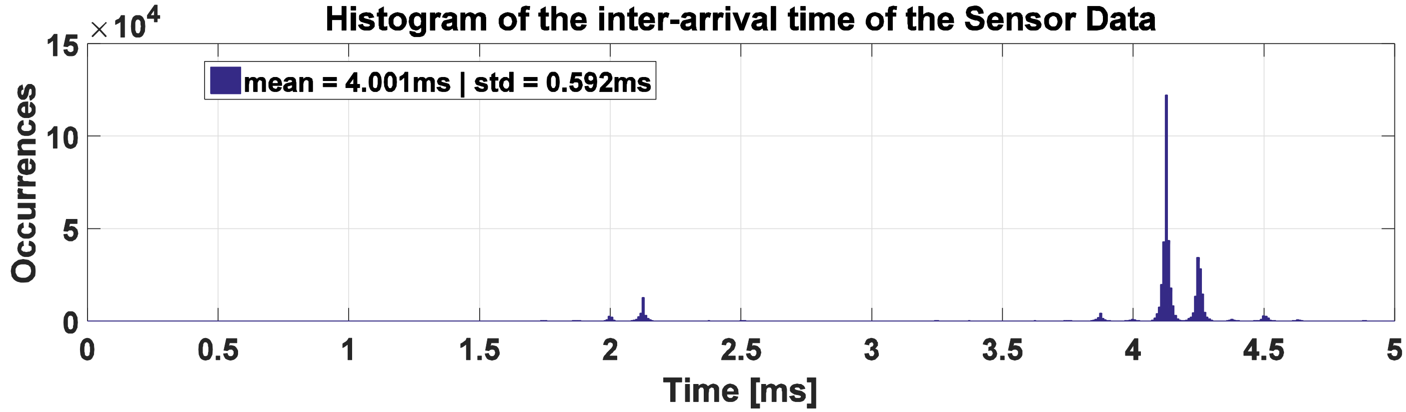
Precise and accurate triggering of the board



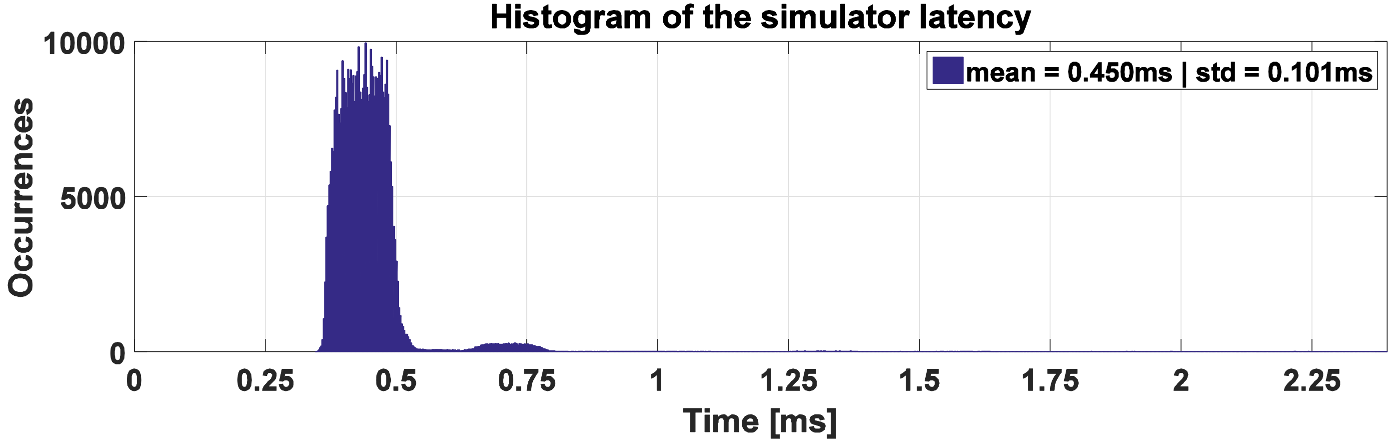
The latency is highly variable

Results

Results with board driven synchronization approach:



The triggering is not precise as in the other approach



The value of the latency is more stable.

Conclusions

- In this work a new structure for a hardware in the loop simulation environment supporting ***multi-vehicle configuration*** has been proposed;

- This solution provides the capability to check the correct execution of the designed algorithms ***directly on the target control board***.

- The carried out tests confirm that it is possible to achieve good ***timing accuracy and precision*** also with several connected vehicles.

Future Works

Future extensions of the proposed framework:

- capability of simulating a realistic communication between vehicles (e.g., packet loss, delays)

- implementation of environment sensors in the synthetic environment

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