

# Evaluation of Response Time in Ethernet-based Automation Systems

Gaëlle Marsal<sup>(1)</sup>, Bruno Denis<sup>(1)</sup>,  
Jean-Marc Faure<sup>(1)</sup>, Georg Frey<sup>(2)</sup>

(1) Ecole Normale Supérieure de Cachan, France

(2) University of Kaiserslautern, Germany

# Outlines

- **Context and approach**
  
- **Model**
  - Delays analysis
  - Structure of Generic Model
  
- **Results**
  - Simulation of a particular architecture
  - Influence of resources sharing
  - Result interpretation
  
- **Conclusions**

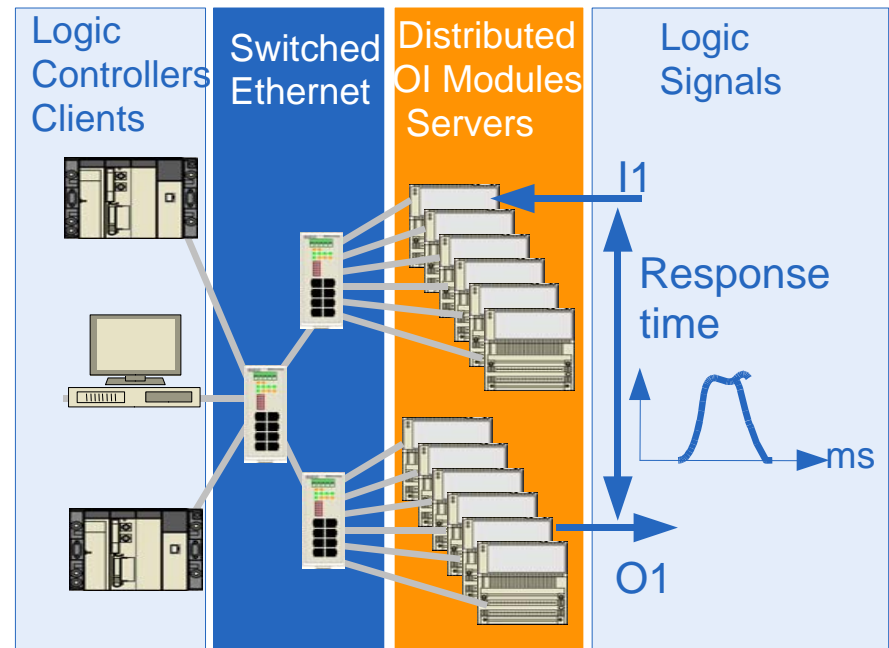
# Context

## ■ Ethernet-based automation system

- Devices: controllers, RIOM
- Protocols: Ethernet, TCP/IP
- Cooperation: Client/Server

## ■ Response time

- Delay between the occurrence of an input event and the occurrence of the corresponding output event

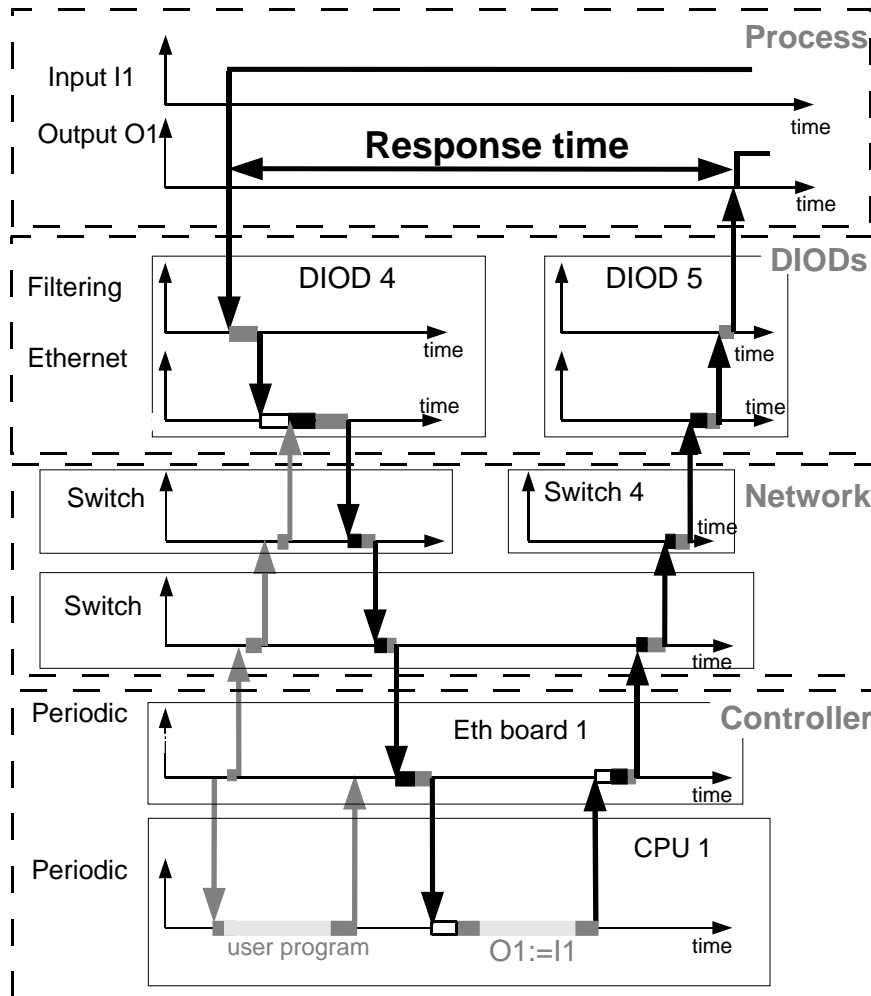


## ■ Evaluation of response time distribution

# Our approach

- **Simulation of Petri Net models of the systems**
  - Main advantages
    - provides a response time distribution while analytic methods yield only boundaries
    - faster than exhaustive state space analysis
  - Limitations
    - non exhaustive analysis
    - possible long simulation time
  
- **Modeling formalism: Hierarchical Colored Timed PNs**
  - Colored PNs allow us to build a generic model
  - Hierarchical PNs ease the model design

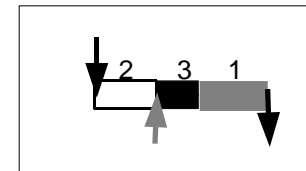
# Delays analysis



## Three delay causes

- data processing
- waiting for synchronization
- waiting for resources

subset of DIOD 4 delay



Caption

- 1: data processing
- 2: waiting for synchronization
- 3: waiting for resource

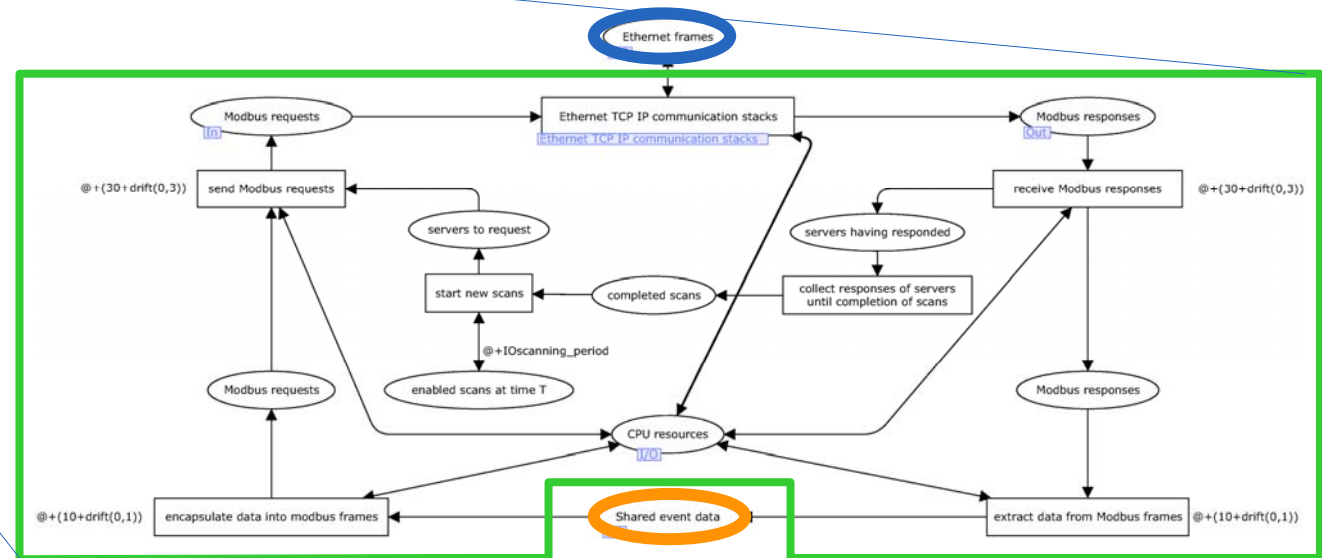
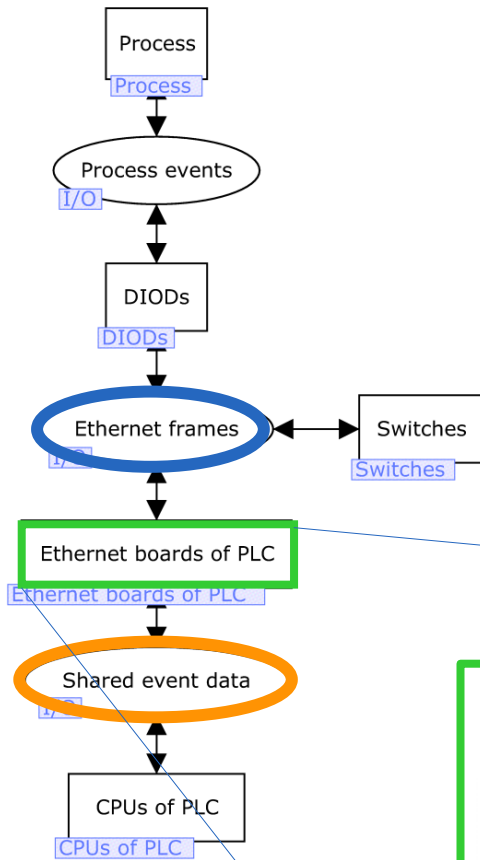
# Structure of Generic Model

- Petri net structure

- is derived from the physical architecture

- Colored tokens

- represent resources or data



# Simulation of a particular architecture

## ■ Feature of this architecture

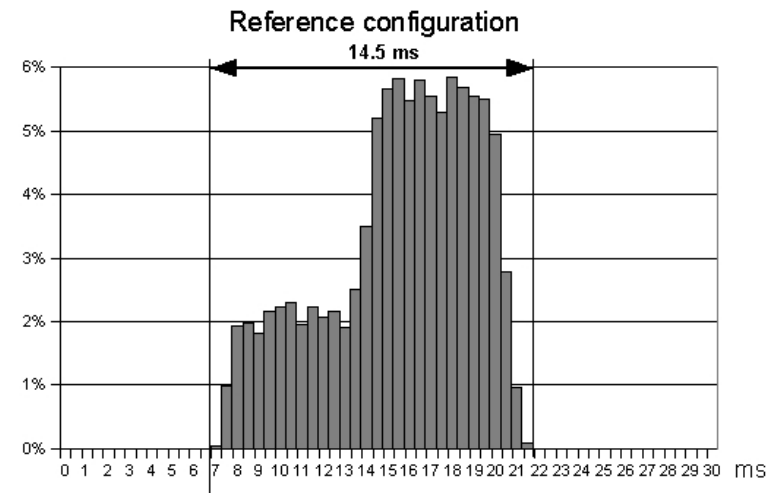
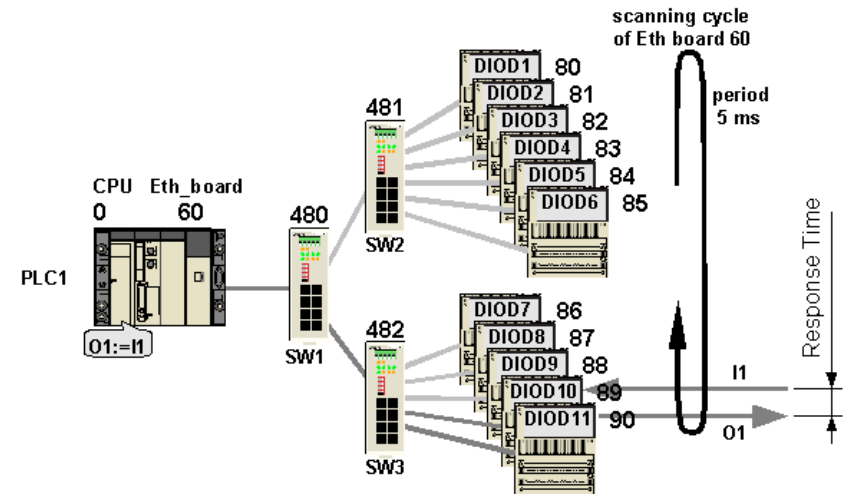
- Only switches are shared

## ■ Simulation

- Software: CPNTools
- Simulation time: 2 hour for computation of 10,000 delays

## ■ Results

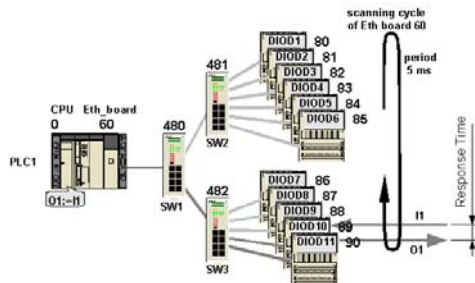
- histogram →
- lower bound = 7.5 ms
- upper bound = 22 ms



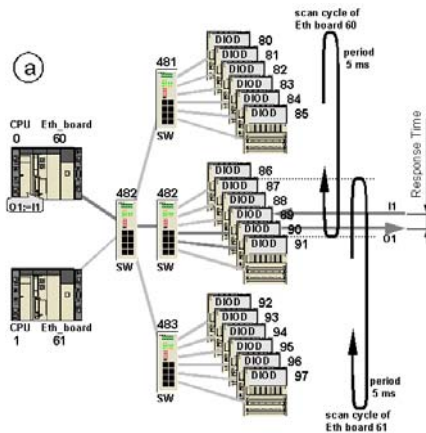
# Influence of resources sharing

## Architecture Features

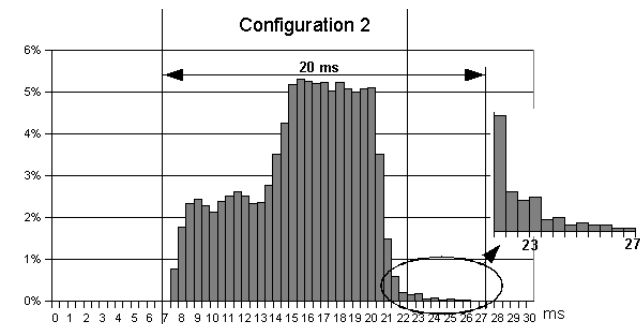
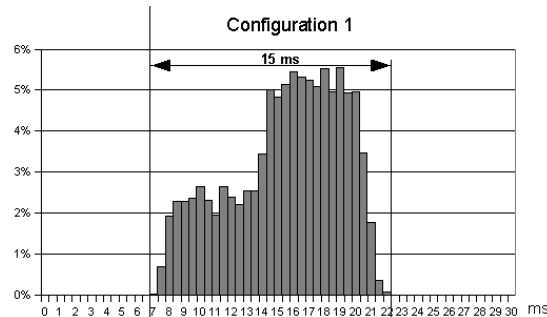
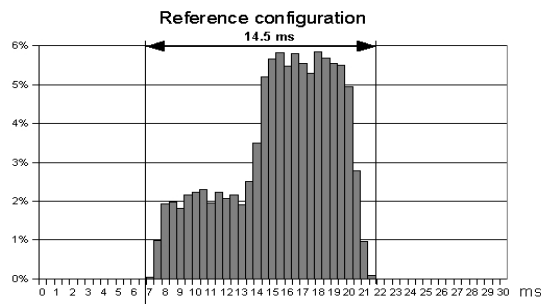
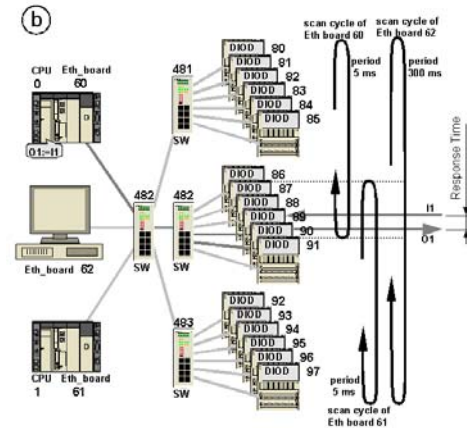
- Only switches are shared



- Switches and 4 DIODs are shared



- Switches and all DIODs are shared





## Result interpretation

- **Small impact of resource sharing on the mean value and the distribution shape of delay**
- **Significant impact of resource sharing on the upper bound of delay**
- **With these results, engineer could decide if resource sharing Ethernet architecture is suitable**

# Conclusions

## ■ This paper has presented

- a Colored Petri Model of Ethernet-based automation system using client/server cooperation
- simulations to evaluation response time distribution of particular architectures

## ■ Main result

- client/server cooperation could be used in Ethernet-based automation system in conjunction with a technique of analysis to guarantee the response times

## ■ Current works

- response time comparison between architectures using client/server cooperation and architectures using master/slave or producer/consumer cooperation
- response time evaluation using exhaustive analysis based on model-checking approach